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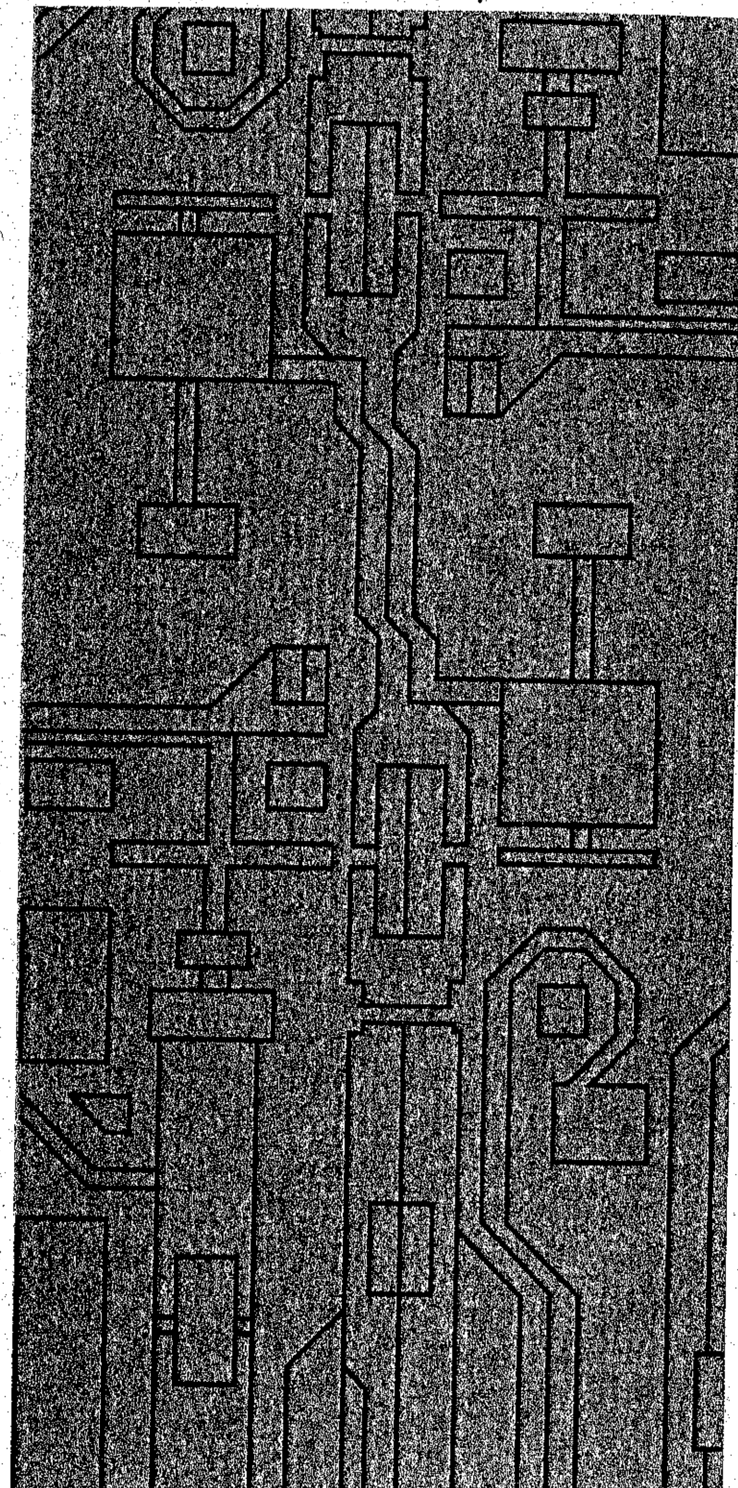


Waste Minimization and Wastewater Treatment of Metalworking Fluids

RSF 0082

Waste Minimization and Wastewater Treatment of Metalworking Fluids

This book is dedicated
to the many people in our industry
who are committed to
improving environmental quality.

Waste Minimization and Wastewater Treatment of Metalworking Fluids

a publication of the
Independent Lubricant Manufacturers Association
Research and Development Committee
651 South Washington Street
Alexandria, Virginia 22314
Phone 703/684- 5574
Fax 703/836-8503

Research & Development Committee Chair
Ralph Kelly, Cincinnati Milacron

Research & Development Committee Vice Chair
Paul Dacko, Ideas, Inc.

Research & Development Project Director
Raymond M. Dick, Cincinnati Milacron

Table of Contents

Preface

The Independent Lubricant Manufacturers Association (ILMA), established in 1948, is a national trade association whose 160 Regular member companies manufacture high quality automotive, industrial and metalworking lubricants and greases. Independent lubricant manufacturers are neither owned nor controlled by the companies that explore for, own, or refine crude oil used to produce lubricant base stocks. Independent lubricant manufacturers blend and compound over a quarter of the total volume of all lubricants sold in the U.S. each year. In the highly specialized area of metalworking lubricants, ILMA members manufacture more than two-thirds of the U.S.'s needs.

In 1986, Dr. Elliot Nachtman, Tower Oil & Technology Co., established an ad hoc Research and Development Committee within ILMA. In 1988 this ad hoc committee was constituted a full standing committee of the association, and Dr. Nachtman was appointed its first chair. The objective of the committee is to promote and support research and development programs that improve and advance the operations of association members, suppliers and customers.

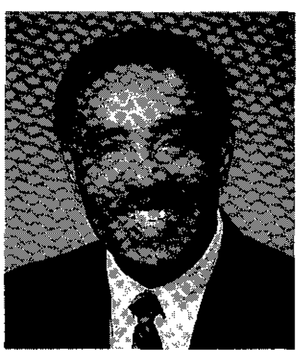
This manual, *Waste Minimization and Wastewater Treatment of Metalworking Fluids,* is one of the first contributions of this committee. These papers provide a single source of information useful in controlling costs, protecting the environment, promoting healthful operating practices as well as complying with federal, state and local laws and regulations. Decisions concerning the choice of clarification, recycling and disposal technology depend upon specific metalworking operating conditions. The papers by experts in the field which comprise the contents of this manual will provide guidance for developing a waste minimization plan with the ultimate goal of "zero discharge."

This publication was conceived, produced and published by the ILMA Research and Development Committee under the leadership of Chair Ralph Kelly, Cincinnati Milacron; Vice Chair Paul Dacko, Ideas; and *Waste Minimization* Project Director Raymond Dick, Cincinnati Milacron. The publication was edited by Messrs. Kelly, Dacko and Dick, with assistance from many industry experts and from the ILMA staff.

The R & D Committee expresses its thanks to the authors for the papers in this book, without whose outstanding efforts this book would not exist; to the industry volunteers who helped with every step of this publication; and to ILMA President Armen Hampar of Lubricating Specialties Company and the ILMA Board of Directors, for their confidence and support.

ILMA Research & Development Committee Chair

Ralph Kelly
Manager, Engineering
& Development
Cincinnati Milacron
Products Division
P.O. Box 9013
Cincinnati, OH 45209
Phone 513/841-8121
Fax 513/841-7256

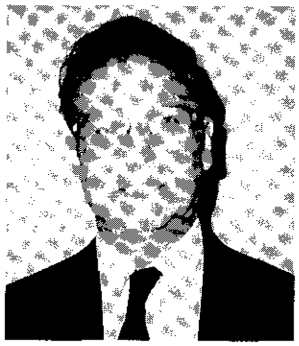


Ralph Kelly joined Cincinnati Milacron as a Senior Microbiologist in 1962. Assuming positions of increasing responsibility, he has served the company as Manager Biochemical Research, Manager Technical Services, Product Manager New Products, and Manager Product Planning, before taking his present position in 1986. Mr. Kelly received a B.S. in Chemistry from Central State Univ. and an M.S. in Microbiology from the Univ. of Cincinnati. In addition to his active role in ILMA, Mr. Kelly's memberships include STLE, Board of Directors of Seven Hills Neighborhood Houses, Inc., Ken-Sil Baseball Assoc., and past member, Cincinnati United Way Board. Mr. Kelly has published ten technical papers and holds 15 patents.

Cincinnati Milacron is a world leader in advanced manufacturing technologies (machinery, computer controls, software, cells and systems) for the metalworking and plastics processing industries; and in robotics, metrology, inspection, controls and information technologies for factory automation in general. The company is also a leading producer of precision grinding wheels and metalworking fluids. Cincinnati Milacron is a Regular Member of the Independent Lubricant Manufacturers Association.

ILMA Research & Development Vice Chair

Paul J. Dacko
Vice President of
Research & Development
Ideas, Inc.
P.O. Box 262
Wood Dale, IL 60191
Phone 708/766-2326
FAX 708/350-3121



Paul J. Dacko heads the research and development programs at Ideas, Inc. Before joining Ideas, Mr. Dacko held several positions in the Chicago area involving R&D and product development. Mr. Dacko received a B.S. in Chemistry from Illinois Institute of Technology.

Ideas, Inc., founded in 1974 by Frank J. Ressa, services the metalworking industry by manufacturing and selling water-, oil- and solvent-based corrosion inhibitors and other specialty chemicals to compounders and blenders. Ideas, Inc. is an Associate Member of the Independent Lubricant Manufacturers Association.

Waste Minimization Project Manager

Raymond M. Dick
Product Manager,
Fluid Management Equipment
Cincinnati Milacron
Products Division
P.O. Box 9013
Cincinnati, OH 45209
Phone 513/841-8088
FAX 513/841-7178

Ray Dick develops and markets metalworking fluid management equipment, designed to recycle or treat used metalworking fluids, and assists customers in their development of fluid management programs. Mr. Dick has worked 13 years for Cincinnati Milacron in the areas of metalworking fluid equipment development, design, manufacturing, marketing and service. Mr. Dick received his B.S. in Environmental Engineering from Syracuse Univ. and his M.B.A. from Xavier Univ. In addition to his active role in ILMA, Mr. Dick is a member of AICHE and has published several technical papers.

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Introduction

Metalworking is a diverse segment of industry involved with the manufacture of a variety of products ranging from automobile, airplane, and farm implement equipment to metal components for products such as engines and appliances.

Metalworking processes include machining, grinding, stamping, drawing, and forming of metal parts. Metalworking fluids are indispensable components of most metalworking processes. In addition, a variety of lubricants such as hydraulic, lube and way oils as well as greases, are used in metalworking machines. It is estimated that more than 90 million gallons of metalworking lubricants are used each year in the United States.[1] The overall cost of the lubricants is estimated at $350 million.[2] Though the costs for machines, tooling, and labor are much higher than for lubricants, the cost of fluid disposal has rapidly increased.

Greater emphasis is now placed on the proper fluid management and disposal of those materials due to the stricter environmental regulations and higher disposal costs. Furthermore, the availability of petroleum oil as well as chemical additives derived from petroleum oil is subject to political as well as economic and technical decisions difficult to anticipate. There is general agreement that the planet contains a diminishing reservoir of oil and that its cost can be expected to increase with time.

This publication was developed to assist the user of metalworking fluids to better select, conserve, control, treat and dispose of metalworking fluids.

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CHAPTER ONE

Definitions of Metalworking Fluids

Many years ago, only straight oil was used for metalworking. Today there are a wide variety of oils, water-based fluids, and lubricants used in the metalworking industry. It is important to understand the basic terminology associated with these fluids for proper understanding, application, control, and disposal. Chapter One gives a broad overview of the various metalworking terms and definitions. As both of the authors emphasize, there are no generally accepted definitions for metalworking fluids.

Definitions of Metalworking Fluids

Greg Foltz
Cincinnati Milacron Products Division

Universally accepted definitions and performance levels do not, as yet, exist in the metalworking fluid industry.

While "metalworking fluids" can be liquid, solid, or gaseous, practically all metalworking fluids in use today are liquid. A large variety of fluids are available to choose from depending on the specific requirements of the metalworking job. Some metalworking fluids are very general purpose while others are designed for specific applications. Metalworking fluids are considered to be metal removal fluids when they are used in operations designed to alter the metal work piece through formation and removal of chips. Metal removal operations include all forms of cutting and grinding. Metalworking fluids are metal forming fluids when they are used in operations designed to alter the shape of the metal work piece without the formation of a chip. Metal forming operations include all forms of stamping, forming, and extruding.

Metalworking fluids are basically divided into four classes: oil, soluble oil, semi-synthetic, and synthetic. The basis for this distinction is the amount of mineral oil contained in the concentrate of each product type. The oil products are used neat (not diluted with water) while the other three categories are all water soluble products. Each product type has distinct advantages and disadvantages.

Metal Removal/Forming Oils

A metal removal or forming oil is a fluid which may be an oil of petroleum, animal, marine, vegetable, or synthetic origin, used singly or in combination, or with additives. These products are not diluted with water for use. They are commonly referred to as cutting or grinding oils.

Extreme pressure (EP) additives, sulfur, chlorine, or phosphorous, are used to improve antiweld properties for heavy-duty applications. Chlorine is more reactive than sulfur and forms the EP lubricant at lower temperatures. Phosphorous is not as effective as either sulfur or chlorine and its use is less common. Generally, chlorine or sulfur are used by themselves or in various combinations, with chlorine preferred for cutting applications and sulfur for grinding.

Cutting oils are classified as active or inactive. An inactive oil will not darken a copper strip immersed in it for three hours at 100C while an active oil will. Straight mineral oils containing sulfurized fatty oils are inactive oils. Active oils are sulfurized or sulfo-chlorinated mineral or fatty oils.

Straight mineral oil is used for light duty machining of ferrous or nonferrous metals. Its major function is as the base fluid for the other blends and additive oils.

Straight fatty oils are very limited in use because of their expense and frequent odor problems. They are used as wetting agents in blends with mineral oils and also to improve lubrication. Examples are palm oil, lard oil, and coconut oil.

A mineral fatty oil blend is a combination of one or more fatty oils blended into mineral oil. These products are nonstaining to ferrous and non-ferrous metals and are used where high surface finish and precision are required.

Sulfurized fatty mineral oil blends contain both fatty oils and sulfur and provide excellent lubricity. They stain less than sulfurized mineral oil since the sulfur is added as a sulfurized fat, in which strong chemical bonding keeps the sulfur from being released until the temperature reaches 265°C. They can be used on both ferrous and nonferrous metals. To increase the antiweld properties at lower temperatures and pressures, chlorine may be added, which will produce a heavy duty fluid for a wide range of applications.

Sulfurized mineral oils contain sulfur which is in the mineral oil. It reacts to form an iron sulfide film in the machining process which will reduce friction and built-up edge and provide antiweld properties. These oils are useful for machining tough, ductile metals. The reactivity of the sulfur makes them unsuitable for copper or copper alloys.

Sulfo-chlorinated mineral oil contains a combination of sulfur and chlorine additives to produce a product with exceptional antiweld properties over a wide temperature range. It is used for machining tough, low carbon steels. These straight oil products will generally provide the excellent lubrication needed in low clearance, low speed operations, especially where a high surface finish is required. They have good rust control. Good sump life is obtained because the bacteria that cause rancidity will not grow in oil unless it is contaminated with water. Since oil dissipates heat only half as fast as water, the straight oils will build up heat. The oil mist that occurs with their use will build up on parts, floors, and machines causing dirty and slippery conditions. In addition to the fire hazards associated with their use, other safety concerns may exist, especially if the machines are not properly shielded or if the work areas are not properly ventilated.

Soluble Oils

Soluble oil (or emulsifiable oil) is a combination of oil and emulsifiers for conventional products and may include other performance additives for premium products. These products are supplied as concentrates which are added to water at typical ratios of one part concentrate to five to 20 parts water. The oil, generally 60% to 90% mineral oil in the concentrate, is made soluble by emulsifying agents, primarily sulfonates. The size of the emulsified particles is large enough to refract light and create a milky, opaque appearance. The EP additives sulfur, chlorine, or phosphorous may be added to form a soluble oil for very heavy-duty operations, including replacement of straight oils in some applications. Premium soluble oils may contain biocide packages, corrosion inhibitors, or other additives to enhance their performance.

Soluble oils are typically general purpose products, capable of being used in a wide variety of operations and on both ferrous and nonferrous metals. They offer good lubrication because of the amount of oil they contain and good cooling because of the heat dissipating effect of the water.

Soluble oils have some disadvantages. When mixed with hard water, some soluble oils may form a precipitate which can build up on parts, machines, and filters. In extreme cases, the emulsion may be split from this hard water. Depending on the operation and the machine set up, mist generated from a soluble oil can cause machines and work areas to become messy and slippery. Rust problems may occur with soluble oils if sufficient rust preventives are not incorporated in the formula. Since the water can support bacterial growth, rancidity problems and short sump life may occur if proper biocides are not present.

Semi-Synthetic Fluids

Semi-synthetic metalworking fluids have much lower mineral oil content than soluble oils, typically between 2% and 30% in the concentrate. Normally, when blended with water they form a translucent emulsion, but this can vary from transparent to opaque.

These fluids have also been called chemical emulsions or preformed chemical emulsions. This is because the concentrate does contain water and the emulsion or dispersion of oil will have already occurred during formulation. This is contrasted with a soluble oil where the emulsion does not form until the product concentrate is diluted with water for use.

Semi-synthetics have a high emulsifier content resulting in smaller oil globule formation and therefore a less opaque mix. These fluids also typically contain additives to provide wetting, corrosion control, cleaning, microbial control, and lubrication. Some may contain the EP additives sulfur, chlorine, or phosphorous to enhance lubrication. In general, semi-synthetics are intermediate between soluble oils and synthetics, offering some of the more desirable properties of each one.

Semi-synthetics generally have sufficient lubricity for moderate to heavy-duty applications. With better cooling and wetting properties than soluble oils, semi-synthetics make possible higher speeds and feed rates. These products also have better settling and cleaning properties than soluble oils, keeping machines cleaner. Good rancidity control contributes to a long and trouble free sump life. The reduced amount of oil contributes to less oil mist and less smoking, providing for a cleaner work environment.

Because they are emulsions, like soluble oils, semi-synthetics may also form a hard water scum if hard water is used in the mix. The cleaning action of these products may cause some to foam.

Synthetic Fluids

Synthetic metalworking fluids are those that contain no mineral oil. They can be classified into three types: simple, complex, and emulsifiable. When diluted with water (typically one to 10%) the simple and complex types form a transparent solution, while the emulsifiable type form an opaque emulsion.

The simple synthetic fluids basically consist of organic and inorganic salts dissolved in water. They function to offer corrosion control and cleaning action along with good heat removal. Simple synthetics are mainly used as grinding fluids for light duty operations.

The complex, in addition to the ingredients of the simple product, will also contain water soluble synthetic chemical lubricants making these products capable of moderate to heavy-duty type operations.

Simple and complex synthetics, because they are transparent solutions, enable the operator to see the work. They keep grinding wheels open and free-cutting, and produce considerably less mist than the other types of fluids. These synthetics usually have excellent microbial control, and their settling and cleaning properties help to extend fluid life. Their excellent cooling capability and the chemical lubrication of the complex type make high speeds and feeds, high production rates, and good size control possible. These synthetic fluids are also stable in hard water.

Because they do not contain oil, simple and complex synthetics do not offer physical lubrication. This may present a problem in certain heavy-duty cutting or grinding operations, or on certain machines where the metalworking fluid must also act as a lubricant. Some synthetic solutions may also foam under conditions of moderate to high agitation.

The newest type of synthetic fluid is the emulsifiable synthetic. It is a synthetic by definition because it does not contain mineral oil, but its opaque appearance and many of its performance properties are similar to a soluble oil. These products usually contain a combination of chemical and physical lubrication systems with the physical lubrication being derived from water soluble organic compounds such as esters, rather than mineral oil. They have the same advantages and disadvantages as other synthetic fluids except for the lack of transparency and the inclusion of a physical lubrication package. Emulsifiable synthetics make possible certain applications, especially aluminum machining, where previously it was difficult to achieve good results. This type of product is also used extensively in the metal stamping and drawing area.

Conclusion

These fluid definitions or classifications are based strictly on composition and mineral oil content. It is also possible to define metal removal and metal stamping fluids in terms of performance levels. Performance may be based on certain industry standard tests or on a particular manufacturer's test and will define a fluid in such terms as lubrication, corrosion control, rancidity control, foaming tendencies, and oil emulsification. Each fluid manufacturer can provide a definition of type and performance level for its products.

Greg Foltz, Manager of
Customer Service
Cincinnati Milacron
Products Division
P.O. Box 9013
Cincinnati, OH 45209
Phone 513/841-8780
Fax 513/841-7256

Greg Foltz has been employed in the customer service areas of metalworking fluids for 12 years. In his current position he is responsible for technical service, products tests, training and product recommendations. Mr. Foltz received a B.A. in Chemistry from Thomas More College and an M.B.A. from Xavier University. Mr. Foltz is a member of STLE and has published and presented papers for SME, STLE and AES.

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Metalworking Lubrication Definitions

Elliot S. Nachtman, Ph.D
Tower Oil & Technology Company

Introduction

Metalworking is a term which describes two different kinds of metal shaping operations:

1. Chip producing - metal removal.
2. Deformation induced shaping - metal moving.

Cutting or grinding are chip producing operations that result in a desired shape through metal removal. Turning, drilling, milling, boring, broaching and shaping are metal cutting operations. Surface grinding, centerless and plunge grinding, cylindrical and internal grinding are some typical grinding operations.

Deformation of metal produces a desired shape by removing metal as a result of plastic deformation. Rolling of sheet, plate, billets or shapes, drawing, blanking or stamping of strip or sheet, wire drawing, tube bending, roll forming, forging, cold heading and extrusion are some typical metal deformation processes.

Lubricants are used to facilitate metalworking operations. They must also satisfy requirements of health, subsequent operations, environmental concerns and disposal. Definition of some of the terms used relative to use of metalworking lubricants is complicated by the absence of generally accepted definitions. However, the following definitions we believe can be useful in communications concerning metalworking lubrication.

Definitions

1. LIQUID OR FLUID LUBRICANTS are of three types: solutions, emulsions and suspensions. The fluid lubricants are frequently called coolants although in many applications cooling is only one of several important characteristics such as lubrication, rust protection, stability, and cleanability required of metalworking lubricants.

a. SOLUTIONS. Fluids whose base may be mineral oil, vegetable oil, water or a synthetic fluid are formulated with additives that are completely soluble in the base fluid. The present practice is to call the oil base solutions "oils," the water base solutions are inappropriately called "synthetics" and the true synthetic fluids used to make metalworking solutions are also called "synthetics." Correct chemical nomenclature suggests use of:

(1) Oil base solutions (OBS)

(2) Water base solutions (WBS)

(3) Synthetic base solutions (SBS)

b. EMULSIONS. When two or more mutually insoluble fluids are mixed together they will separate into separate layers unless surfactants of appropriate ionic character are added to the mixture. Then the surfactant system acts to suspend particles of one fluid in another. This system is called an emulsion. Its color varies depending upon particle size and chemistry, from milky white to almost water clear when the system has a continuous phase consisting of water and a discontinuous phase or particles consisting of oil. Frequently these emulsions are called "soluble oils;" again the nomenclature is misleading since the oil is not soluble in the water, rather it is in the form of particles suspended in the water. Additives which may be soluble in either phase are added to provide desired metalworking lubricant characteristics (rust protection, anti-foam, biostates). "Semi-synthetic" fluids are misnamed and are really emulsions.

c. SUSPENSIONS. Solids such as graphite, sodium carbonate, and molybdenum disulfide are suspended in a fluid carrier such as oil, water or a synthetic fluid. These suspensions depend upon specific gravity, particle size and viscosity relationships to primarily achieve relatively stable suspension.

2. PASTES are formed when water soluble polymers and soaps added to a base fluid thicken the fluid (water or mineral oil). A gel is formed which has good film strength and maintains good viscosity under relatively high pressure and temperature. Pigmented soap pastes are used under more severe metalworking conditions (press work, wire drawing, cold heading). The so called pigments are really solid lubricants (graphite, sodium carbonate, mica, etc.).

3. SOLID LUBRICANTS. Solids such as metallic soaps, graphite, glass and molybdenum disulfide serve as lubricants in wire drawing, hot extrusion, cold heading and bar drawing. These solids are most frequently applied as powders.

Aluminum stearate, calcium stearate and other metallic soaps with or without graphite and/or molybdenum disulfide are frequently the lubricant of choice for wire drawing. Low melting point glasses (850°F and above) successfully lubricate the hot extrusion process for steel (2500°F).

4. COATINGS. A number of coatings, copper plating and phosphate coatings are used on bar, wire or shapes as primary lubrication films prior to deformation designed to achieve further reduction in size or to achieve a formed shape. Lime or borax coatings are frequently applied at the bar or wire mill before deformation as a lubricant film.

Liquid lubricants are almost always used in conjunction with such coatings. Polymers and resin coatings containing lubricity additives are applied to sheet metal at the finishing mill to provide coil stock which may not require any further lubrication at the press shop. The polymer or resin coatings are generally applied by dip coating followed by heating to achieve the desired film properties.

5. ADDITIVES. Some of the most important additives are listed below. In all cases appropriate chemical judgment must be used in combining additives and selecting base stock in order to achieve desired lubricant characteristics. The additives singly or together provide desired operating properties at an acceptable cost.

ADDITIVE	FUNCTION	TYPICAL CHEMISTRY
Surfactant	Emulsification	Sodium sulfonate
Coupler	Stability	Hexylene glycol
Thickener	Viscosity	Acrylic acid esters
Detergents	Cleanability	Overbased sulfonates
Plasticizers	Reduce tackiness	Glycol esters
Anti-misting	Reduce mist	Acrylates
Oiliness agent	Increase film strength	Fatty acid soaps
Dispersants	Prevent fine agglomeration	Polyacrylates
Extreme pressure	Reaction lubricant films	Sulfur, chlorine, phosphorous compounds
Passivators	Prevent staining	Organic diamines
Anti-foam	Prevent foaming	Siloxanes
Alkaline reserve	Control acidity	Overbased sulfonates
Solid lubricants	Film strength	Graphite, mica
Odor mask	Improve odor	Pine oil
Corrosion inhibitors	Prevent rust	Toluyltriazole, amines
Anti-microbial agent	Prevent bacterial infestation	Kathon 886MW, Groton HD2

These additives and their function in metalworking lubricants illustrate some, but certainly not all of the chemicals and their function in the lubricant. Frequently chemicals react to form other chemical species particularly when subjected to the high pressure and increased temperature produced during the metalworking operation.

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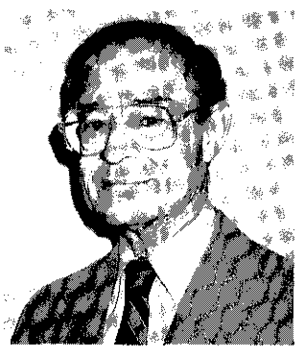
Elliot S. Nachtman, Ph.D.,
Principal
Tower Oil & Technology Company
205 West Randolph Street
Chicago, IL 60606
Phone 312/346-0562
Fax 312/346-6873



Elliot S. Nachtman is a principal of Tower Oil as well as Adjunct Professor in the Systems Engineering Department at the Univ. of Illinois. Initially a chemist on the Manhattan Project at the Univ. of Chicago, he later bacame VP and an officer of LaSalle Steel Co., where he was responsible for research and development. Dr. Nachtman also served as a consultant to the Organization of American States on metal processes and technology transfer; was a member of the Advisory Panel (Metallurgy) for the National Bureau of Standards; and was on the Panel on Application of Deformation Theory to Practice, Materials Advisory Board, National Science Foundation. Dr. Nachtman has published and lectured extensively on various technical and general management subjects, and he holds 31 U.S. patents. Dr. Nachtman has served on the Board of Directors and as the first chair of the Independent Lubricant Manufacturers Association's Government Affairs, Metalworking Lubricants, and Research and Development Committees. In addition, he is a Fellow of the American Society for Metals, a member of STLE and the American Institute of Mining and Metallurgical Engineers. He received the B.A. degree from Wooster College and the M.S. and Ph.D. degrees from the Illinois Institute of Technology.

Tower Oil & Technology Co., founded in 1933, serves customers throughout the continental U.S. Its product lines include metalforming lubricants, cutting and grinding fluids, rust preventives, hydraulic fluids, maintenance lubricants and greases. Tower Oil's regular product line consists of approximately 700 products, with numerous additional experimental products constantly under development and field testing. Tower Oil is a Regular Member of the Independent Lubricant Manufacturers Association.

CHAPTER TWO

Environmental Law

The need to improve the environment was very evident during the late 1960s and early 1970s, when water and air pollution problems were prevalent. Since the early 1970s, the U. S. Congress has enacted a series of environmental regulations to protect the water (surface and ground water), air and land.

As the number of regulations has increased, there is a greater challenge in understanding and complying with the various federal, state, and local laws. Chapter Two provides an overview of the legislation that affects the metalworking fluid and lubricant user.

Environmental Law

Jeffrey L. Leiter, Esq.
and
Robin A. Fastenau, Esq.
Collier, Shannon & Scott

Introduction

Over the past 20 years, Congress has enacted legislation that regulates industrial practices to improve the environment. The Environmental Protection Agency (EPA) was created in the Executive branch, and it has promulgated numerous rules implementing these laws. The various environmental statutes and regulations have direct and indirect effects — economic and otherwise — on all industry, including metalworking fluids manufacturers and users. Accordingly, it is important that an operator of a metalworking fluids facility understand how these environmental requirements affect its operations because the failure to comply may result in severe civil and/or criminal penalties, and, if the violations are not corrected, possible closure of the facility.

This chapter will briefly discuss existing environmental law as it relates to metalworking fluids in the following contexts: 1) solid waste; 2) water; 3) air; 4) toxic substances; and 5) occupational safety and health.

Solid Waste

EPA controls solid waste through two statutes: 1) the Resource Conservation and Recovery Act (RCRA), and 2) the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). RCRA generally regulates the generation, transportation, treatment, storage and disposal of hazardous solid waste. CERCLA generally regulates existing hazardous waste sites, including those created by unauthorized discharges or spills, through the use of statutory enforcement authority.

Under RCRA's "cradle-to-grave" tracking scheme, generators and transporters of hazardous waste are required to register with EPA; comply with labeling and containment requirements; and maintain manifests to document the origin, handling, and ultimate disposition of all hazardous wastes. Facilities which treat, store, or dispose of hazardous waste are required to obtain a RCRA permit that may subject the facility to structural design requirements, as well as operational activities, including monitoring, recordkeeping, reporting and personnel training.

In order to determine whether RCRA's hazardous waste rules apply to a specific metalworking fluids facility, the operator must analyze its process waste "stream" to determine if it generates and manages either a "listed" or "characteristic" hazardous waste. Listed wastes are identified by EPA and can include: 1) hazardous waste from nonspecific sources; 2) hazardous waste from specific sources; and 3) discarded commercial chemical products, and all off-specification products, containers and spill residues.

Characteristic wastes are considered hazardous if they exhibit: ignitability, corrosivity, reactivity or toxicity. Ignitable and reactive wastes were included by Congress because of their respective abilities to cause or exacerbate a fire or to react violently or explode during routine management. Corrosive wastes are capable of corroding metal, thus allowing them to escape or liberate other wastes from their containers. Toxicity, by definition, is a characteristic of hazardous waste because it identifies wastes that are likely to leach hazardous concentrations of specific toxic constituents into groundwater. EPA's regulations under RCRA specifically prescribe tests for determining whether a waste has one of these particular characteristics. If hazardous wastes are present as determined by any of these tests, then the facility operator must comply with the applicable RCRA provisions.

RCRA also prohibits the land disposal of certain hazardous wastes in order to minimize reliance on landfills. Initially, bulk or non-containerized liquid hazardous wastes were banned. EPA also must determine whether to ban disposal of all RCRA hazardous wastes; in doing so, treatment standards for each restricted waste, based on best demonstrated available technology, must be developed. A phased-in land ban program has begun, beginning with dioxins and solvents containing hazardous wastes. EPA published a ranking of all other hazardous wastes based on their intrinsic hazard and volume, and established a schedule for determining whether to ban the land disposal of these other wastes.

Underground storage tanks (USTs) containing petroleum (e.g., petroleum-based metalworking fluids) and substances other than listed hazardous wastes (e.g., chemicals) also are regulated by RCRA if ten percent or more of their volume (including connective piping) is underground. EPA has issued standards for new and existing tanks, use of release detection systems, procedures for reporting and investigating suspected releases, and final closure of tank systems. The Agency also has promulgated financial responsibility requirements for petroleum USTs.

Control of hazardous waste under CERCLA is attained through enforcement and reporting requirements. EPA can order parties responsible for contamination from hazardous substances to clean up the site or to recover funds expended by the Agency in cleaning up the site itself. A hazardous substance is defined in reference to other environmental statutes; accordingly, the list of substances is lengthy. Under CERCLA, owners and operators of hazardous waste sites, as well as generators and transporters of hazardous waste, can be held liable for cleanup costs regardless of fault.

CERCLA also requires that all owners, operators, generators or transporters report all releases of hazardous substances above a "reportable quantity" (RQ) identified in the regulations. For example, a one-pound RQ was established for reporting a nitrosamine release; thus, whenever a release exceeds that amount within a 24-hour period, the operator of the facility must notify the National Response Center in Washington, D.C. of the release. Releases of mixtures (e.g., formulated metalworking fluids) only trigger reporting requirements where a component hazardous substance of the mixture is released in a quantity equal to or greater than its RQ.

Under the Superfund Amendments and Reauthorization Act of 1986 (SARA), which amended CERCLA, Congress enacted the stand-alone Emergency Planning and Community Right-to-Know Act. The law establishes emergency release notification requirements if there is a release of any listed "extremely hazardous substance" in an amount at least equal to its "threshold planning quantity" (TPQ). The TPQs under SARA differ from the RQs under CERCLA.

The community right-to-know provisions also require submission of inventory-related data on hazardous chemicals for which a facility is required to prepare or make available a Material Safety Data Sheet (MSDS) under the Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard. The data must be submitted annually to the local fire department, the appropriate local emergency planning committee, and the state emergency response commission. Reporting is required only for hazardous chemicals in excess of a threshold amount.

The community right-to-know amendments also require facilities to report annually certain chemical releases to both EPA and a designated state official. This requirement applies to facilities in Standard Industrial Classification Codes 20-39 with more than ten employees that manufacture, process, or otherwise use a toxic chemical identified by EPA. Such listed chemicals often found in many metalworking fluids include barium compounds, diethanolamine and sodium hydroxide.

Water

The Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (CWA), limits discharges of pollutants into "navigable waters." It establishes a two-stage system of regulations to impose technology-based effluent limitations on discharges of pollutants into any waters from direct and indirect industrial discharges. Because these limits are not self-implementing, the CWA also creates a permit program, the National Pollutant Discharge Elimination System (NPDES), for all direct dischargers. Specific permit limits are developed by EPA and each state to decrease the volume and nature of pollutants from direct dischargers.

Indirect dischargers are industrial facilities that discharge into publicly-owned treatment works (POTWs). Because POTWs are subject to NPDES permit limits, POTWs place waste limits, in the form of pretreatment standards, on all indirect dischargers using their facility. The metalworking fluid industry generally discharges to POTWs and, thus, will be subject to pretreatment standards as opposed to NPDES permit limitations. Pretreatment standards for indirect dischargers are necessary for two reasons: 1) prevention of pollutants from interfering with the proper operation of the receiving treatment works; and 2) prevention of pollutants that pass through treatment works without receiving adequate treatment.

Recent amendments to the CWA and its implementing regulations require states to ensure that dischargers of pollutants meet applicable water quality-based standards, that such standards be adopted in all new NPDES permits, and that states identify all dischargers of toxic pollutants and bring all water sources into compliance with water quality standards. Currently, states, along with EPA, are modifying all NPDES permits to include these more stringent water quality-based standards. The standards are to be developed based on state decisions regarding the designation of water use (e.g., public water supply use, recreational use or agricultural use). The metalworking fluids industry may be affected by the adoption of water quality-based standards indirectly through changes in pretreatment standards.

The Safe Drinking Water Act (SDWA) regulates public drinking water systems by setting national standards for levels of contaminants, creating a program for the states to regulate underground injection wells, and by protecting sole source aquifers. These standards are designed to bring the nation's drinking water within a level considered safe for human consumption. The SDWA requires EPA to identify contaminants in drinking water which may have an adverse effect on human health and, where feasible, to specify for each contaminant a maximum contaminant level (MCL) or maximum contaminant level goal (MCLG) which may be discharged into the water supply for each chemical. A MCLG is not an enforceable standard, it is only a goal that must be set at a level at which no known or anticipated adverse effects on human health occur and which allows an adequate margin of safety. Some MCLGs for suspected carcinogens are zero.

In general, SDWA standards apply only to "public water systems" which regularly supply water to 15 or more connections or to 25 individuals at least 60 days a year. The definition is intended to apply to facilities which have their own water supply, such as wells. This applies to industries which supply water to employees and/or customers. Exemptions are available if the industry only stores and distributes water or if it obtains water from a regulated public water supply. Moreover, a variance may be obtained if a system cannot meet an MCL despite application of best-treatment technology. However, variances are temporary and will not be granted if the result would be an unreasonable risk to human health. Significant compliance problems may arise if EPA tightens the MCL for lead to .05 parts-per-million.

The second effect of the SDWA is regulation of underground injection of solid waste in order to protect usable aquifers from contamination. State implementation of these regulations prevents underground injection by limiting permits to injection which will not endanger drinking water sources and by requiring maintenance of records, reports, inspection programs and other such provisions. The underground injection control program classifies wells into five categories, some of which have been banned under RCRA.

Finally, the SDWA protects listed aquifers that are the sole or principal drinking water source for an area and which, if contaminated, would create a significant hazard to human health. The effect of such a designation is to bar federal financial assistance to projects which pose a threat to the aquifer.

Air

The Clean Air Act (CAA) sets national air quality standards and creates a regulatory mechanism for attaining those standards by controlling emissions from mobile and stationary sources. EPA has primary responsibility for setting national standards, and state and local governments have the responsibility to implement these standards.

Specifically, EPA must identify and publish a list of pollutants which can reasonably be anticipated to endanger public health or welfare and establish National Ambient Air Quality Standards (NAAQS) for each pollutant. In developing these standards, cost and technical feasibility will not be considered. To date, EPA has promulgated NAAQS for only six pollutants: lead, ozone, carbon monoxide, particulates (less than ten microns in diameter), sulfur dioxide and nitrogen dioxide.

The state implementation plan (SIP) controls emissions from stationary sources to meet NAAQS. If a state fails to devise a SIP adequate to meet NAAQS, then EPA must impose emission limitations. A SIP must include a description of the air quality in each designated area, an emissions inventory of sources that emit the pollutant, emissions limitations and compliance schedules to reduce emissions to a level low enough to achieve NAAQS, a permit program for review of new source construction to ensure new emissions will not cause a violation, monitoring and reporting requirements and enforcement procedures. Any metalworking fluids facility that incinerates waste must examine emissions to determine whether provisions of the CAA apply.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) regulates chemicals that present an "unreasonable risk" of harm to human health or the environment. TSCA regulates such chemicals by obtaining information on the risk prior to their production and by regulating the import, use, labeling and disposal of chemical substances.

Under TSCA, EPA has considered, but has not determined, whether the risk posed by the addition of nitrites in amine-containing metalworking fluids is unreasonable. However, under section 9(a) of TSCA, EPA is negotiating to refer the nitrites issue to OSHA for regulation. To date, OSHA has not regulated nitrite use in metalworking fluids because the Agency is under the belief that such nitrite use is not widespread, particularly with metalworking fluids formulators.

Occupational Safety and Health Act

Congress enacted the Occupational Safety and Health Act to assure safe and healthful working conditions for all working Americans. The Act authorizes OSHA to promulgate both health and safety standards. The health standards include protecting employees from hazardous exposures to chemicals and other toxic substances. These workplace standards are based on medical and scientific evidence showing a relationship between exposure to a toxic substance and adverse health consequences. OSHA has established "permissible exposure limits" (PELs) for hundreds of chemicals and toxic substances, including a number relevant to metalworking fluid operations. For example, barium compounds, butoxyethanol, diethanolamine, oil mist (mineral), and sodium hydroxide are among the substances regulated by OSHA's airborne contaminants standard.

Workplace safety generally is regulated by OSHA's Hazard Communication Standard (HCS), which applies to all employers and is intended to reduce the incidence of chemical illnesses and injuries by establishing uniform requirements for evaluating chemical hazards and transmitting hazard information to affected parties. The HCS does not regulate chemicals and their production. Instead, the standard is designed to convey hazard information by means of container labels, material safety data sheets, and employee training.

Conclusion

Each of these environmental and safety and health statutes may affect the operation of a facility manufacturing or using metalworking fluids. The effect may be in terms of structural requirements, permitting, manifest logging, or reporting requirements. It is important that facility owners and operators understand how these statutes specifically affect them because the failure to conform with the statutory and regulatory requirements could result in severe civil and criminal penalties.

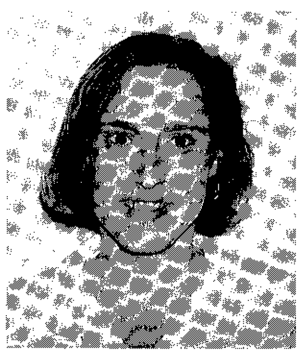
Jeffrey L. Leiter, Partner
Collier, Shannon & Scott
3050 K Street NW, Suite 400
Washington, DC 20007
Phone 202/342-8400
Fax 202/338-5534

Jeffrey L. Leiter is a partner in the Washington DC law firm Collier, Shannon & Scott and is primarily involved with the firm's energy and environmental practice, including representation of the Independent Lubricant Manufacturers Association. Mr. Leiter counsels clients on regulatory compliance issues, environmental considerations in business transactions, and minimizing risks from environmental liabilities.

Mr. Leiter is widely recognized as an expert on underground storage tank issues. He is a member of the American Bar Association and its Sections on Natural Resources, Energy and Environmental Law and Business Law. He is a graduate of Catholic Univ.'s Columbus School of Law and the George Washington Univ.

Collier, Shannon & Scott was established in 1956 and has grown to more than 55 attorneys. Based in Washington DC, the firm's practice areas include antitrust and trade regulation; communications; construction; copyrights, trademarks and patents; employment and labor; energy; environmental law; insurance; international trade; litigation; occupational safety and health; taxation; and transportation. Collier, Shannon & Scott has served as counsel to the Independent Lubricant Manufacturers Association for over 16 years.

Robin A. Fastenau, Associate
Collier, Shannon & Scott
3050 K Street NW, Suite 400
Washington, DC 20007
Phone 202/342-8400
Fax 202/338-5534



Robin A. Fastenau's practice areas include compliance issues under the environmental statutes and litigation of private cost recovery actions under the Comprehensive Environmental Response, Compensation, and Liability Act. Ms. Fastenau is a member of the American Bar Association's Section of Natural Resources, Energy and Environmental Law, and of the DC, VA and PA bar associations. Ms. Fastenau is a graduate of Georgetown Univ. Law Center and the C.W. Post College of Long Island Univ.

SARA Title III
Superfund Amendments and Reauthorization Act
Emergency Planning and Community Right-to-Know

Brenda Pinkelton
Cincinnati Milacron Products Division

"SARA" and "Title III" have become household words to most employers, particularly those of us in the manufacturing sector with ten or more employees. Since 1988, all facilities in SIC Codes 20 to 39 that manufacture, process, or otherwise use certain chemical substances have been immersed in a new kind of accounting. We now are gathering information on chemical weights, uses and releases to complete the Environmental Protection Agency's (EPA) "Form R" or "Toxic Chemical Release Inventory Reporting" forms under SARA Section 313. We must send these forms to EPA annually by July 1.

All facilities — including manufacturing and non-manufacturing ones — that must produce or make available Material Safety Data Sheets (MSDS) for "hazardous substances" under the Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard, must submit these MSDS, or an alternative list, annually to three state and local entities under SARA Section 311. Under SARA Section 312, annual inventories of these hazardous substances must be reported to the same entities. However, these reporting requirements are subject to certain thresholds.

Title III also requires facilities that have "extremely hazardous substances" (EHS) to notify states of the presence of these chemicals and to designate a coordinator to work with state and local entities in planning for response actions in the event of a release of an EHS in excess of its "threshold planning quantity" (TPQ). SARA Section 304 requires a facility to notify the appropriate authority when a release of an EHS in excess of its TPQ will go beyond the facility's boundaries. An EHS is a chemical or a substance that will cause irreversible damage to human health.

Do we really understand what is going on here? We have been provided with three different chemical lists to consider under Title III: "Extremely Hazardous," "Hazardous," and "Toxic" chemicals. Chemicals can be added to or deleted from these lists at almost any time. There are four ways of reporting information under Title III, all with different forms. Further, the rules published in the Federal Register are not clear to many. EPA reported that 95% of the Section 313 forms submitted early under SARA have been completed incorrectly. (TSCA Chemicals-in-Progress Bulletin, June 1988.) The Agency noted that submitters of erroneous reports can be held liable for fines of up to $25,000 per day.

What is SARA? It is the acronym for the Superfund Amendments and Reauthorization Act, passed by Congress and signed into law by President Reagan on October 17, 1986. "Superfund" (CERCLA or the Comprehensive Environmental Response, Compensation, and Liability Act of 1980) involves liability for and cleanup of hazardous waste sites. SARA came about because time was running out on portions of the original Superfund statute, so Congress had to "reauthorize" it. However, under this act, Congress included the stand-alone "Title III," descriptively called the "Emergency Planning and Community Right-to-Know Act."

The purpose of Emergency Planning and Community Right-to-Know, according to its legislative history, is to "get more information from industry" and to provide such information to the surrounding community. This information from industry will be used for the purpose of keeping an eye on hazardous chemicals — their manufacture, their travel, the identities and quantities present in any locale, their use, and their disposal — "from the cradle to the grave." Emergency plans are to be developed so that a community can be prepared in the case of a chemical accident — that is, to prevent a tragedy, such as that which occurred in Bhopal, India. The general public will have access to this information. EPA is charged with the administration of Title III, which includes publishing rules and overseeing compliance. Since implementation of OSHA's Hazard Communication Standard, SARA Title III is the most far-reaching regulation from the federal government to affect manufacturers and users of chemicals.

Just what information will be available to the public? Emergency response plans, material safety data sheets, chemical lists from facilities covered, facility inventory forms, "toxic" chemical release forms, and follow-up emergency notices, all will be available. For lubrication engineers and manufacturers in a competitive marketplace, product formulations and chemical inventories and lists were heretofore kept unavailable. Access to such proprietary information could be a bit disquieting. Nonetheless, there may be some comfort in the fact that all similarly situated facilities must release data as well.

But what about trade secrets? Trade secrets can be claimed, but the data must indeed be a trade secret. An EPA-appointed committee can review a trade secret claim, as submitted, or as requested by petition from any person or group. Within 30 days of the request, this review committee must decide on the validity of the trade secret claim, based on the information submitted. If the Agency determines a trade secret has been claimed "frivolously" under SARA, the penalty can be $25,000. EPA published trade secret rules undr Title III (53 FR 28772, July 29, 1988) noting that "[it] intends to be guided by the Restatement of Torts, section 757, comment b," which has been used consistently in industry and the judicial system for nearly 50 years. EPA, however, has developed some new and specific questions for trade secret determinations, which must be answered and substantiated. Without a trade secrets history under SARA, one can only speculate how often challenges may occur.

How will Title III information be collected? Following the "Title III Statutory Timetable" (Figure 1), we can see how EPA will achieve its purpose:

(a) Chemical lists were published, so that manufacturers, processors, and users (facilities) could identify themselves and report that they are covered.

(b) Rules were published detailing how and to whom facilities will send required chemical information.

(c) State Emergency Response Commissions, and Local Emergency Planning Committees were appointed to receive information.

(d) Facilities send lists, or MSDSs of chemicals they have, their quantities, uses and/or environmental release information to the state and local committees, and to the appropriate fire department.

(e) EPA reviews and reports to Congress on emergency planning systems.

(f) Local emergency plans are completed using the information submitted from facilities.

(g) Federal EPA will collect all state and local data, and work with the National Academy of Sciences to create a Mass Balance study — a "cradle-to-gave" account of chemicals.

All agree that this is indeed a formidable task to accomplish.

Figure 1. SARA Title III Statutory Timetable

Date	Event	Citation
1986 Oct 17	SARA, including Title III, signed into law	Congressional Act
Nov 17	EPA published List of Extremely Hazardous Substances & Threshhold Planning Quantities, under Title III, Secs. 302, 303, 304; EPA also initiated a comprehensive review of emergency systems under Title III, Sec. 305(b)	40 CFR Part 300 (51 FR 41750)
1987 Jan 27	EPA published proposed Emergency & Hazardous Chemical Inventory Form and reporting requirements under Title III, Secs. 311, 312	40 CFR Part 370 (52 FR 2836)
Apr 17	Governors appointed State Emergency Response Commissions (ERC) under Title III, Sec. 301(a)	
May 17	Facilities notified State ERCs that they are subject to the Act under Title III, Sec. 302(c)	
Jul 17	States designated Local Emergency Planning Districts under Title III, Sec. 301(b)	
Aug 17	States appointed Local Emergency PlanningCommittees (EPC) under Title III, Sec. 301(c)	
Sep 17	Facilities notified Local EPC of afacility representative under Title III, Sec. 303(d)(1)	
Oct 17 (& annually thereafter)	Manufacturing facilities submitted MSDSs or lists of MSDS chemicals to the State ERC, Local EPC and local fire department under Title III, Sec 311(d)	
1988 Feb 16	EPA published final Toxic Chemical 40 CFR Part 372 Release Reporting Form, under Title III, Sec. 313(g)	(53 FR 4500)

continued

Figure 1. SARA Title III Statutory Timetable, *continued*

Mar 1 (& annually thereafter)	Facilities submitted their inventory forms to State ERC, Local EPC and local fire department, under Title III, Sec. 312(a)(2)	
Jul 1 (& annually thereafter)	Facilities submitted Toxic Chemical Release Forms to EPA and State ERC under Title III, Sec. 313(a)	
Jul 29	EPA published final rule for Facilities making trade secret claims, under Title III Sec. 322 and 323	40 CFR Part 350 (53 FR 28772)
Sep 24 (& annually thereafter)	Nonmanufacturing Facilities newly covered under OSHA Hazard Communication Standard submitted MSDS or lists of MSDS chemicals to the State ERC, Local EPC and local fire department, under Sec. 311(d)	40 CFR Part 370 (53 FR 29331)
Oct 17	Local EPCs completed local emergency plans, under Title III Sec. 303(a)	
1989 Mar 1 (& annually thereafter)	Nonmanufacturing Facilities submitted hazardous chemical inventory form to State ERC, Local EPC and local fire department under Title III, Sec. 312	
1991 Jun 30	Comptroller General (& EPA) to report to Congress on Sec. 313 Toxic Chemical release information collection, use and availability, under Title III, Sec. 313(k)	
Oct 17	EPA to submit to Congress the National Academy of Science Mass Balance Study, under Title III, Sec. 313(l).	

Brenda H. Pinkelton
Cincinnati Milacron
Products Division
P.O. Box 9013
Cincinnati, OH 45209
Phone 513/841-8121
Fax 513/841-7256

Brenda Pinkelton is Product Safety Administrator, responsible for the Cincinnati Milacron Product Division's MSDS, label information, regulatory information, technical information for customers and the Division newsletter. Since joining Cincinnati Milacron in 1975, Ms. Pinkelton has held positions in corporate analytical chemistry, regulatory affairs, industrial hygiene, and currently in product safety for metalworking fluids and grinding wheels. Ms. Pinkelton has served on committees for several manufacturing organizations and for the Mayor of Cincinnati, developing industry positions on right-to-know issues. Ms. Pinkelton received her B.A. in Biology from Wittenberg Univ., and did graduate work at the Univ. of Cincinnati. She has published several papers on regulatory issues.

Cincinnati Milacron is a world leader in advanced manufacturing technologies (machinery, computer controls, software, cells and systems) for the metalworking and plastics processing industries; and in robotics, metrology, inspection, controls and information technologies for factory automation in general. The company is also a leading producer of precision grinding wheels and metalworking fluids. Cincinnati Milacron is a Regular Member of the Independent Lubricant Manufacturers Association.

CHAPTER THREE

Fluid Management and Waste Minimization

More plants are opting for fluid recycling to reduce their generation of waste. Fluid Management can be implemented in a variety of methods to extend the life of fluids and reduce costs. Each of the following areas needs to be carefully studied to improve the overall use of fluids: water quality; fluid selection; fluid tests and controls; additives such as bactericides; contaminant removal equipment for fluid recycling; and fluid management programs.

Much of the information in this chapter will address these different areas. The goal is to move towards "waste minimization" or "pollution prevention."

It is important to understand the difference in metalworking plants between central systems and individual machines. Each of these has specific requirements for fluid management.

A central system is a large reservoir (typically over 1000 gallons) that supplies fluids to various machines or grinders. These machines typically perform similar operations, enabling one fluid at one concentration to be used by every machine. Advantages of central system management include:

- Single source supply and testing;
- On-line continuous filtration;
- Continuous circulation of fluid; and
- Single source make-up and concentration control.

With good control of a central system fluid, the fluid generally lasts one to three years.

The individual machine plant has self contained sumps for each machine or grinder. These may or may not have contaminant removal systems such as a filter, magnetic particle dragout, or oil skimmer. Advantages of an individual machine for fluid management include:

- More flexible use and selection of fluids; and
- More flexible fluid and sump maintenance.

However, there are disadvantages to controlling fluids in individual machines. Some of these are:

- Non-continuous use of the fluid or machine;
- Variation in concentration control and make-up;
- In many cases, lack of contaminant control equipment; and
- Small sumps mean contamination or concentration variation that deteriorates the fluid quickly.

Because fluid management is more difficult for individual machines, expected fluid life may range from a few weeks to several months.

Fluid management methods available to improve fluid life include:

- Batch treatment recycling systems for individual machines;
- Continuous treatment recycling systems for central systems;
- "On-line" contaminant removal equipment, such as oil skimmers, filters, and centrifuges to improve fluid cleanliness for either individual machines or central systems;
- Fluid recycling services provided by an outside company on a regular schedule; and
- Chemical fluid management contracts with an outside company which manages fluids in the plant.

Chapter Three discusses various approaches to fluid management, to achieve such benefits as reduced waste volume, lower costs, improved fluid performance and metalworking productivity, and improved operator environment. It is important for each individual plant to select the best fluid management program for its particular requirements.

Establishing a Waste Minimization Program at Your Facility

Harry M. Freeman
and
Mary Ann Curran
Pollution Prevention Research Branch
Risk Reduction Engineering Laboratory
Office of Research & Development
U.S. Environmental Protection Agency

Forward

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the nation's land, air and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing the research, development and demonstration of programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

The EPA encourages generators of hazardous and non-hazardous waste to carry out assessments in their facilities to identify opportunities for waste minimization. This paper was prepared by the EPA's Risk Reduction Engineering Laboratory to describe six elements which should be considered when establishing a waste minimization program for a facility. These non-binding guidelines, as suggested by the Agency, have applications across a wide range of industries and manufacturing processes and can assist a waste generator in meeting regulatory requirements.

Introduction

There is underway today in manufacturing facilities in the United States and other industrial countries, a clear movement toward "waste minimization" as a means for reducing environmental problems caused by the generation, treatment, and disposal of hazardous wastes. In many respects this is only a continuation of efforts by industry to increase product yields and profits by reducing wastes. However, as it has become increasingly clear that there is a limit to what can be achieved through "end-of-the-pipe" approaches to solving problems, waste minimization has become increasingly popular. This paper offers several suggestions for implementing an effective waste minimization program. Included is a review of the EPA's recently issued guidance for establishing a waste minimization program.

Background

With the passage of the Hazardous and Solid Waste Amendments (HSWA) of 1984, the U.S. Congress established a national policy declaring the importance of reducing or eliminating the generation of hazardous waste. This policy statement is:

> The Congress hereby declares it to be a national policy of the United States that wherever feasible, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible. Waste that is nevertheless generated should be treated, stored, or disposed of so as to minimize present and future threat to human health and the environment.

In this declaration, Congress established a clear priority for reducing or eliminating the generation of hazardous wastes (a concept referred to as "waste minimization") over managing wastes that were "nevertheless" generated.

EPA believes that hazardous waste minimization means the reduction, to the extent feasible, of hazardous waste that is generated prior to treatment, storage or disposal of the waste. It is defined as any source reduction or recycling activity that results in either: 1) reduction of total volume of hazardous waste; 2) reduction of toxicity of hazardous waste; or 3) both, as long as that reduction is consistent with the general goal of minimizing present and future threats to human health and the environment.[1]

The transfer of hazardous constituents from one environmental medium to another does not constitute waste minimization. Neither would concentration conducted solely for reducing volume unless, for example, concentration of the waste allowed for recovery of useful constituents prior to treatment and disposal. Likewise, dilution as a means of toxicity reduction would not be considered waste minimization, unless later recycling steps were involved.[1]

In a related action, the EPA published in the Federal Register on January 26, 1989, a proposed policy statement on source reduction and recycling. This policy commits the Agency to a preventive strategy to reduce or eliminate the generation of environmentally-harmful pollutants which may be released to the air, land, surface water or ground water. It further proposed to incorporate this preventive strategy into EPA's overall mission to protect human health and the environment by making source reduction a priority for every aspect of Agency decision-making and planning, with environmentally-sound recycling as a second priority over treatment and disposal. The Agency's encouragement of waste minimization is an example of the pollution prevention policy for RCRA hazardous wastes.

Current Federal Regulatory Requirements for Waste Minimization Programs

Besides establishing the national policy, Congress also enacted several provisions in HSWA for implementing hazardous waste minimization. These include a generator certification on hazardous waste manifests and permits for treatment, storage, or disposal of hazardous waste. These certifications (effective September 1, 1985) require generators to certify two conditions: 1) the generator of the hazardous waste has a program in place to reduce the volume or quantity and toxicity of such waste to the degree determined by the generator to be economically practicable; and 2) the proposed method of treatment, storage or disposal is that practicable method currently available to the generator which minimizes the present and future threat to human health and the environment.[1]

In addition, Congress also added a new provision in 1984 that requires hazardous waste generators to identify in their biennial reports to EPA (or the state): 1) the efforts undertaken during the year to reduce the volume and toxicity of waste generated; and 2) the changes in volume and toxicity actually achieved in comparison with previous years, to the extent such information is available prior to 1984.[1]

Waste Minimization Approaches and Techniques

Waste minimization is inevitably site- and plant-specific, but a number of generic approaches and techniques have been used successfully across the country to reduce many kinds of industrial wastes.

Generally, waste minimization techniques can be grouped into four major categories: inventory management and improved operations, modification of equipment, production process changes, and recycling and reuse. Such techniques can have applications across a range of industries and manufacturing processes, and can apply to non-hazardous as well as hazardous waste.

Many of these techniques involve source reduction — the preferred option on EPA's hierarchy of waste management. Others deal with on and off-site recycling. In practice, waste minimization opportunities are limited only by the ingenuity of the generator. In the end, a company looking carefully at bottom-line returns may conclude that the most feasible

Figure 1. Waste Minimization Approaches and Techniques

Inventory Management & Improved Operations

- Inventory and trace all raw materials.
- Purchase fewer toxic and more nontoxic production materials.
- Implement employee training and management feedback.
- Improve material receiving, storage, and handling practices.

Modification of EquipmentInstall equipment that produces minimal or no waste.

- Modify equipment to enhance recovery or recycling options.
- Redesign equipment or production lines to produce less waste
- Improve operating efficiency of equipment.
- Maintain strict preventive maintenance program.

Production Process Changes

- Substitute nonhazardous for hazardous raw materials.
- Segregate wastes by type for recovery.
- Eliminate sources of leaks and spills.
- Separate hazardous from non-hazardous wastes.
- Redesign or reformulate end products to less hazardous.
- Optimize reactions and raw material use.

Recycling and Reuse

- Install closed-loop systems.
- Recycle onsite for reuse.
- Recycle offsite for reuse.
- Exchange wastes.

Source: EPA/530-SW-87-026

strategy would be a combination of source reduction and recycling approaches.[6]

The approaches discussed and illustrated in Figure 1 provide waste minimization examples for generic and specific processes.

Elements of a Waste Minimization Program

So, what is a "waste minimization program?" Understandably, the Agency has been asked this many times since the September 1985 date, after which generators were to have certified that they had one in place.

The generator has a wide latitude in structuring his or her program. Also, since Congress indicated in its accompanying report to HSWA that "economically practicable" is to be determined by the generator and is not subject to subsequent evaluation by the EPA, the generator has even more latitude in defining a program. In a June 12, 1989 Federal Register Notice, EPA issued some non-binding guidelines as to what the elements of an effective waste minimization program might include. These elements are:

- Top Management Support
- Characterization of Waste Generation
- Periodic Waste Minimization Assessments
- A Cost Allocation System
- Encourage Technology Transfer
- Program Evaluation.

Top Management Support

The first step in developing a program is to establish a clear corporate policy. The full commitment from management of time, personnel and financing is extremely important. Lack of this commitment is often one of the most formidable obstacles to waste minimization. The chances for obtaining this commitment are often enhanced by outlining the potential incentives for waste minimization as shown in Table 1.

An appreciation of the necessity for top management support is summed up very well by G. J. Hollod:

> Lack of senior management support will doom a waste minimization program from the start. Many managers in addition to the standard business functions have become occupied with other priorities in the environmental area like land bans, right-to-know and occupational health considerations. Waste minimization is competing with other environmental priorities but management must be convinced that waste minimization is a program that deserves priority and should be part of the "daily diet" for the line organization and not just another environmental headache left to the site's environmental coordinator.[10]

TABLE 1.
WASTE MINIMIZATION INCENTIVES

Economics

- Landfill disposal cost increases.
- Costly alternative treatment technologies.
- Savings in raw material and manufacturing costs.

Regulations

- Certification of a WM program on the hazardous waste manifest.
- Biennial WM program reporting.
- Land disposal restrictions and bans.
- Increasing permitting requirement for waste handling and treatment.

Liability

- Potential reduction in generator liability for environmental problems at both onsite and offsite treatment, storage, and disposal facilities.
- Potential reduction in liability for worker safety.

Public Image and Environmental Concern

- Improved image in the community and from employees.
- Concern for improving the environment.

Source: *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003)

Make waste minimization a company policy.

The objectives of a waste reduction program are best conveyed to a business's employees through a formal policy statement or management directive. A business's upper management is responsible for establishing a formal commitment throughout all levels of the business. An environmental policy statement or the business's operating guidelines might include the following points:

- Environmental protection is a production line responsibility and an important measure of employee performance. In addition, every employee is responsible for environmental protection in the same manner(s) he is for safety;
- Reducing or eliminating the generation of waste has been and continues to be a prime consideration in research, process design, and plant operations,

and is viewed by management like safety, yield, and loss prevention; and

- Reuse and recycling of materials has been and will continue to be given first consideration prior to classification and disposal as a hazardous waste.[11]

As an example of such a policy the 3M Company of St. Paul, Minnesota, includes in its official environmental policy that the company will "prevent pollution at the source wherever and whenever possible." It might be noted that this company also has as part of its policy to "develop products that will have a minimum effect on the environment." While this is somewhat outside the goals of a typical waste minimization program, it is clearly within the goals of an overall pollution prevention program, and should certainly be considered by any company producing products that will ultimately end up in the waste stream.

Set specific goals for reducing the volume or toxicity of waste streams.

Quantitation helps. Some examples of waste minimization goals are:

- The U.S. Department of Defense is committed to reducing its hazardous waste disposal rates by 50 percent by 1992.[3]
- The DuPont Company has stated that its wastes will be reduced by 35 percent by 1990 compared to 1982 values.[4]
- As a benchmark for evaluation of waste minimization goals, a report on waste reduction issued by the Congressional Office of Technology Assessment in 1986 states that "substantially more waste reduction is feasible and more will become feasible. Setting a national voluntary waste reduction goal of perhaps ten percent annually for 5 years would be useful."[5]

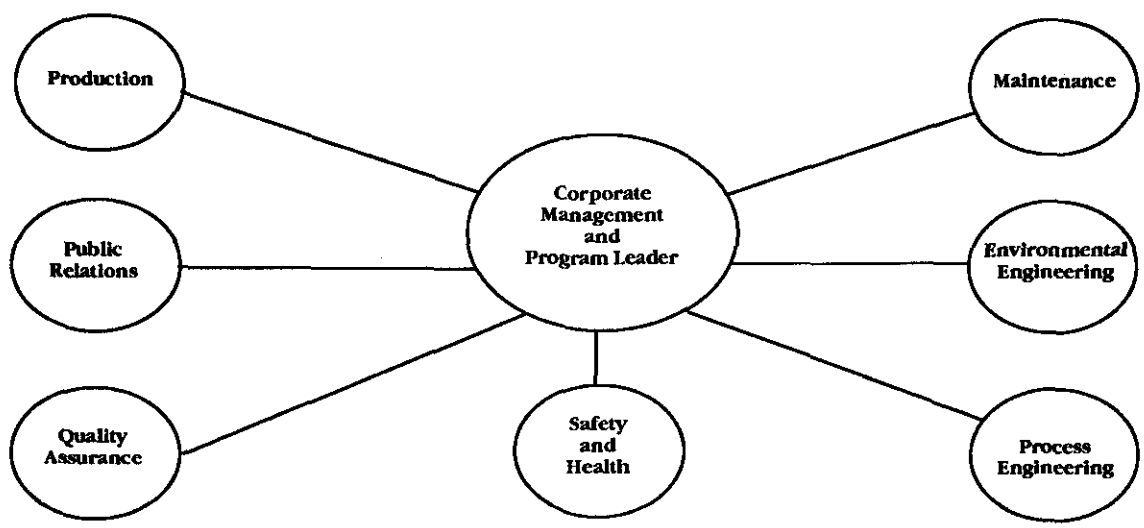
Commit to implementing recommendations identified through assessments, evaluations or other means.

A sure way to undermine a program is to not follow up on recommendations developed by a committed group of employees. Although it may be unreasonable to expect facility management to make wholesale commitments to accept recommendations, it is not unreasonable to expect management to commit to giving a high priority to considering such recommendations and then doing it.

Designate a waste minimization coordinator and select a team at each facility to ensure effective implementation of the program.

For a small facility with only a few waste streams, one person such as a plant manager, plant engineer, or environmental engineer may be responsible for the entire waste minimization program. For larger, highly integrated facilities with many different processes and emission sources, a team or task force might be established. As shown in Figure 2, team members should represent major departments that are involved in waste generation and management and different areas of expertise. A team may include members from production, facilities/maintenance, environmental engineering, process engineering, safety and health, and quality assurance departments. Your appointed minimization "champion" should lead the effort and coordinate all

Figure 2. Suggested Waste Minimization Team Organization



Source: National Association of Manufacturers, 1989.

involved departments. Outside consultants and/or corporate staff should also be considered, depending on the company's nature, the facility's complexity, and available in-house skills.[7]

A summary of functions that might be assigned to the waste minimization team are shown in Table 2.

TABLE 2. FUNCTIONS OF A WASTE MINIMIZATION COORDINATION TEAM

- Define objectives
- Review with site management
- Communicate to site
- Buy-in from generators
- Representation from areas
- Ongoing awareness and training
- Provide resources
- Catalyze
- Coordinate
- Accounting system
- Upgrade projects
- Schedule reviews
- Conduct audits
- Summarize site progress
- Recognize

Source: *Hazardous Waste Minimization* (McGraw Hill, 1989)

Publicize success stories. Reward employees that identify cost- effective waste minimization opportunities; train employees on aspects of waste minimization that relate to their job.

Employees often cause the generation of waste and they can contribute to the overall success of the waste reduction program. Just as incentives are used to boost employee productivity, management should provide incentives for the development of useful waste reduction ideas. To utilize this important resource, many businesses give their employees incentives such as:

- Recognition awards for outstanding waste reduction projects and individuals, as well as for resource and energy conservation projects; and
- Bonuses or financial awards for innovative approaches to waste reduction.

Public recognition helps to inform the public of actions taken by the business to reduce and control hazardous waste. Recognition programs can be varied to accommodate each business, its level of involvement, and local attitudes. For instance, public recognition such as an award or certificate may be welcomed by many businesses. Other businesses, however, maintain a "low profile" as a matter of policy. In such cases, a letter from the Board may be preferred. The effectiveness of this program could be increased by combining it with other awards, such as an employee-of-the-month program, or a percentage of the cash savings realized by the suggestion. Regardless of the form of the incentives, employees should realize part of the benefits of their waste reduction ideas and efforts. In some businesses, meeting the waste reduction goals is used as a measure for evaluating the job performance of managers and employees.[11]

The Dow Chemical Company incorporates these elements into its widely recognized and very successful Waste Reduction Always Pays Program; through utilizing company newsletters to publicize waste reduction success stories, and through recognition for teams of employees that propose changes that lead to decreased waste generation. The company also strives to incorporate the principles of waste reduction into all of its training activities.

Characterization of Waste Generation

Maintain a waste accounting system to track the types, amounts and hazardous constituents of wastes and the dates they are generated. It has been our observation, and we might add the observation of many others active in encouraging waste minimization, that most generators do not really know what is in their waste stream, or what possibilities might exist for reducing the volume or toxicity of the streams through relatively simple means. Information about waste streams can come from a variety of sources. Some information on waste quantities is readily available from the completed hazardous waste manifests, which include the description and quantity of hazardous waste shipped to a Treatment Storage and Disposal Facility. The total amount of hazardous waste shipped during a one-year period, for example, is a convenient means of measuring waste generation and waste reduction efforts. However, manifests often lack such information as chemical analysis of the waste, specific source of the waste, and the time period during which the waste was generated. Also, manifests do not cover wastewater effluent, air emissions, or nonhazardous solid wastes. Potential sources of information on waste streams are shown in Table 3.

A useful form for conducting waste stream characterization is shown in Figure 3. This is from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003).

In addition to providing a means for measuring the effectiveness of your program, there are currently three reasons why it is very important to track your progress in this area.

TABLE 3. SOURCES OF WASTE GENERATORS INFORMATION

- Hazardous waste manifests
- Biennial hazardous waste generator reports
- SARA Title III Section 313 environmental release reports
- Environmental audit reports
- Permits, eg. RCRA Part B, National Pollution Discharge Elimination System (NPDES)
- Lab reports/characterization data
- Chemical inventory and usage records
- NPDES monitoring reports
- Material Safety Data Sheets (MSDSs)
- Internal waste tracking system records
- Production records

Source: National Association of Manufacturers, 1989.

1. First, HSWA requires that generators report on the progress of their waste minimization program with the biennial generator report.

2. Also, EPA can make a minimization program and associated reporting a condition of a RCRA permit.

3. Finally, SARA Title III reporting allows for minimization to be addressed, and although this is currently voluntary, it may become mandatory.[7]

The tracking function or record keeping at a minimum should record and identify the generator or "owner" of the waste reduction method being used to reduce that particular waste stream. Table 4 shows a typical printout from a computer tracking program that has been used by the DuPont Company.[10]

One reporting function that would be of particular interest to any program is the tracking of the most successful or most often used waste minimization technique. Table 5 lists the validation codes for the typical waste minimization techniques that are used at DuPont. This information can be used by business managers and technical managers to inform manufacturing facilities in different locations of the country to what might be the most successful waste minimization technique to apply.[10]

Periodic Waste Minimization Assessment

An important element in a waste minimization program is to perform periodic waste minimization assessments, sometimes referred to as "waste reduction audit." Conducted by an in-house assessment team or with an independent outside expert, a waste minimization assessment is simply a structured review of potential opportunities to reduce or recycle waste. Its focus can be broad or narrow. Most find that it is usually more effective to select a few waste streams or processes for intensive assessment rather than to attempt to cover all waste streams and processes at once.

The US EPA has published a manual for conducting waste minimization assessments. This manual, *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003), is available free from the Waste Minimization Branch, US EPA, 26 W. Martin Luther King Dr., Cincinnati, OH 45268. The procedure recommended by the EPA is outlined in Figure 4.[9]

Waste minimization opportunity assessments are an extremely good way to focus attention on potential improvements. The reader is encouraged to obtain a copy of the EPA manual.

TABLE 4.
TYPICAL COLUMN HEADERS IN COMPUTER PRINTOUTS

Production Area	Waste Description	Hazardous Classification	Quantity Generated M lb/yr	Management Disposal Costs $M/yr	Minimization Method
V1023	Organic Acid	Flammable	2	5.5	Recycle
NR126	Polymers	Caustic	50	25	Sale
GA462	Spent Catalyst	Acidic	10	42	Reuse
ME621	Lab Solvent	Ignitable	0.5	1	Fuel
BU215	Acid Catalyst	Corrosive	40	16	Administrative Control

Source: *Hazardous Waste Minimization* (McGraw Hill, 1989)

Figure 3. Form for Conducting Waste Minimization Characterization

Firm ______	Waste Minimization Assessment	Prepared By ______
Site ______	Proc. Unit/Oper. ______	Checked By ______
Date ______	Proj. No. ______	Sheet 1 of 1 Page __ of __

WORKSHEET 10

WASTE STREAM SUMMARY

EPA

Attribute		Stream No. ____		Stream No. ____		Stream No. ____	
Waste ID/Name:							
Source/Origin							
Component/or Property of Concern							
Annual Generation Rate (units ______)							
Overall							
Component(s) of Concern							
Cost of Disposal							
Unit Cost ($ per: ______)							
Overall (per year)							
Method of Management[2]							
Priority Rating Criteria[3]	Relative Wt. (W)	Rating (R)	R x W	Rating (R)	R x W	Rating (R)	R x W
Regulatory Compliance							
Treatment/Disposal Cost							
Potential Liability							
Waste Quantity Generated							
Waste Hazard							
Safety Hazard							
Minimization Potential							
Potential to Remove Bottleneck							
Potential By-product Recovery							
Sum of Priority Rating Scores		Σ(R x W)		Σ(R x W)		Σ(R x W)	
Priority Rank							

Notes: 1. Stream numbers, if applicable, should correspond to those used on process flow diagrams.

2. For example, sanitary landfill, hazardous waste landfill, onsite recycle, incineration, combustion with heat recovery, distillation, dewatering, etc.

3. Rate each stream in each category on a scale from 0 (none) to 10 (high).

TABLE 5. VALIDATION CODES FOR TYPICAL WASTE MINIMIZATION TECHNIQUES

10 :	Process Change
11 :	Modify Operating Procedure
12 :	Advanced Process Control
13 :	Substituted Chemicals
14 :	Use Higher Quality Materials
20 :	Recycle
21 :	Direct Use in the Process
22 :	Direct Use in Another Process
23 :	Regeneration for Reuse
24 :	Use as a Fuel
25 :	Sale
30 :	Improve Waste Treatment
31 :	Waste Filtration
32 :	Waste Decantation
33 :	On-Line Treatment
40 :	Administrative Controls
41 :	Minimizing Washdown
42 :	Reduce Cleaning Frequency
43 :	Longer Turnaround Time
44 :	Improved Spill Control
45 :	Separate Hazardous from Nonhazardous
46 :	Discontinue Manufacture

Source: *Hazardous Waste Minimization* (McGraw Hill 1989)

A Cost Allocation System

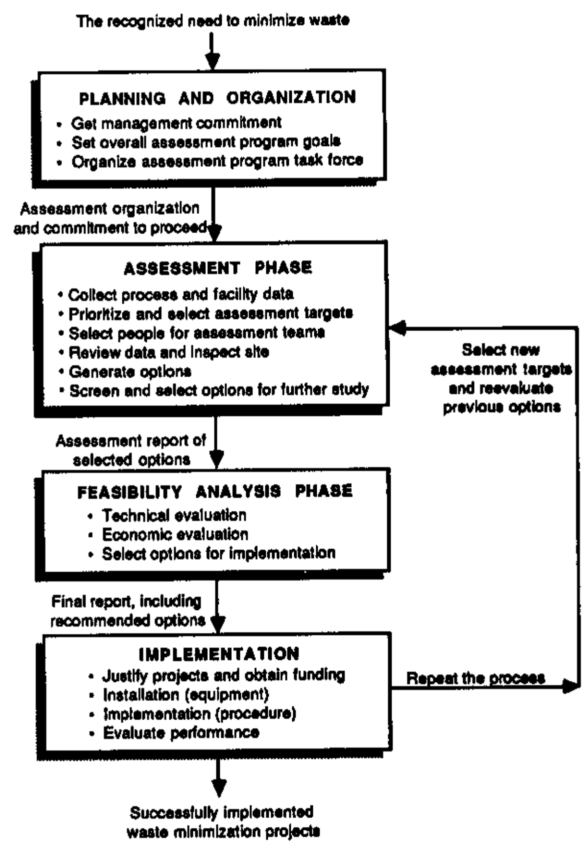
Departments and managers should be charged "fully-loaded" waste management costs for the wastes they generate. In addition to the actual disposal fee for a wastestream of interest, the generator should also consider other cost elements such as:

- Generator Fees/Taxes
- Transportation
- Onsite Storage and Handling
- Pre-disposal Treatment
- Permitting, Reports and Record Keeping
- Emergency Preparedness and Site Cleanup Contingency
- Pollution Liability Insurance
- Raw Materials
- Operating and Maintenance Costs

Encourage Technology Transfer

Seek or exchange technical information on waste minimization from other parts of your company, from other firms, trade associations, state and university technical assistance programs or professional consultants. Many techniques have been evaluated and documented that may be useful in your facility.

Figure 4. The Waste Minimization Assessment Procedure



To facilitate the transfer of technical information EPA was mandated by the Congress to establish a national clearinghouse to provide easily accessible and reliable information on waste minimization/pollution prevention. The clearinghouse is to contain both technical information on how to identify and implement pollution prevention opportunities, and general information conveying the message that, "We, as a society, must begin to integrate pollution prevention into the way we design, build, buy and consume."

EPA's Pollution Prevention Information Clearinghouse (PPIC), which is supported by the Agency's Pollution Prevention Office as well as OR&D, has been created to fulfill this mandate. PPIC (pronounced pea-pick) was pilot-tested by some 300-400 users in 1989 and will be in full operation, accessible to all, in 1990. PPIC collects and disseminates technical and other information on pollution prevention through a telephone hotline and an electronic information exchange network. Indexed bibliographies and abstracts of reports, publications and case studies on pollution prevention will be available. PPIC will also include a calendar of pertinent conferences and seminars, information on federal and state activities and legislation, information on pollution prevention abroad, a directory of waste exchanges and lists of knowledgeable contacts within state organizations, trade associations and the EPA. Copies of various reports will be made available by the clearinghouse either by electronic transfer or through the National Technical Information Service (NTIS) or other sources.

Program Evaluation

Conduct a periodic review of program effectiveness. Use these reviews to provide feedback and identify potential areas for improvement.

Conclusion

We feel that waste minimization provides opportunities to deal more efficiently and effectively with wastes that are hazardous to human health and the environment. The program outlined in this paper is one way a company might pursue establishing a waste minimization program. It reflects the results of Agency analyses conducted over the last several years and extensive interaction with private and public sector waste minimization program managers. However, it is recognized that programs must be tailored to fit various companies. We would leave you with a request, that since nothing happens until somebody does something, do something and incorporate a program that fits your facility.

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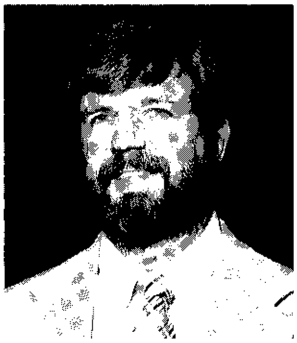
Harry M. Freeman
Chief, Pollution Prevention
Research Branch
Risk Reduction Engineering
Laboratory
Office of Research &
Development
U.S. Environmental
Protection Agency
Cincinnati, OH 45268



Harry M. Freeman is responsible for EPA's research program to encourage the development and demonstration of clean technologies and clean products that result in less pollution being produced. Prior to his present position, Mr. Freeman worked several years in EPA's hazardous waste incineration research program and the Agency's resource recovery from municipal waste program. Other positions held by Mr. Freeman include a two-year assignment with the Toxic Waste Assessment Program in the CA Governor's Office, and a one-year assignment with the U.S. Congress. Mr. Freeman is a Registered Professional Engineer, a member of AICHE, a Diplomate with the AAEE, and a member of the International Juggling Association. In addition to his EPA duties, Mr. Freeman is editor of the books *Standard Handbook for Hazardous Waste Treatment and Disposal*, and *Hazardous Waste Minimization*, published by McGraw Hill Book Co.

Mary Ann Curran
Pollution Prevention
Research Branch
Risk Reduction
Engineering Laboratory
Office of Research
and Development
U.S. Environmental
Protection Agency
Cincinnati, OH 45268

Mary Ann Curran joined EPA's Office of Research and Development after receiving her B.S. in Chemical Engineering from the Univ. of Cincinnati in 1980. She has worked in the areas of energy extraction, hazardous waste land disposal, hazardous waste treatment technologies, and waste reduction assessments. Ms. Curran has coauthored and presented many technical papers. She is chair of the OH Valley Section of the AICHE.

Health and Safety of Metalworking Fluids

Patricia J. Beattie, Ph.D
General Motors Corporation

Metalworking fluids are complex mixtures. They generally contain mineral oil depending on the type of fluid; corrosion inhibitors that may be inorganics or borates, nitrites, nitrates; surfactants such as polyalkyl glycols; lubricants that may be soaps or esters; dyes; often times biocides; and water if it is a soluble oil, semi-synthetic or synthetic fluid. From these data, an evaluation of the potential toxicity of these materials, depending on the extent to which the individual components or the fluids themselves have been tested, may be made. It is essential to have a basic understanding of the type of toxicity testing that is routinely conducted on chemicals and products and the endpoints being measured. This paper will describe some of the standard toxicology test methods, routes of exposure, and summarize current information on the potential health effects of metalworking fluids.

Toxicology Test Methods

There are several kinds of toxicity information that may be available for evaluating a new product. The first is acute information. This involves a single exposure of the material of interest to experimental animals in a controlled study, giving an idea of relative toxicity. In the past, what was most often reported were LD50s, or the lethal dose of the material that killed half of the animals, using various routes of exposure, such as oral, dermal or, possibly, inhalation. In an effort to minimize the use of laboratory animals, the more common trend currently is the use of limit tests. In these tests, the animals are exposed to a single high dose of material. In an oral exposure study, this is typically five grams per kilogram of body weight. If no deaths occur at this level, the product is considered to be relatively nontoxic and an actual LD50 is not further calculated.

The potential for a material to cause irritation to skin and eyes, or sensitization, also falls into the acute type of data and is very important, especially in the area of metalworking fluids, because there typically is potential for skin and eye contact with these products. Results are expressed with numerical scores indicating the degree of severity of irritation or tissue damage.

Another type of toxicology studies is subchronic, or ones where the exposure occurs over a longer period of time and at lower doses. These experiments will generally expose the animals for 90 days and, as much as possible, attempt to mimic the potential exposure in the work place. For example, if inhalation exposure is appropriate, exposure will be for six to eight hours a day, five days a week, over the 90-day period. Subchronic experiments can be quite informative without also incurring exorbitant costs in conducting the experiments. Included here would also be specialty studies to determine target organ toxicity, such as bioassays for evaluating neurotoxicity, reproductive effects, or teratogenicity (effects on the fetus).

Chronic assays expose animals to the material over their lifetime. Examples of these are carcinogenicity studies to determine the potential of exposure to a material to result in cancer or tumor formation. Chronic studies are very unusual for metalworking fluids as a whole and even fairly unusual for the components except for some of the biocides or oils.

Lastly, as a substitute for the chronic studies, short-term bioassays are used as indicators of mutagenicity and potential carcinogenicity. These assays typically use bacterial systems or mammalian cell systems. These can be very useful when they are conducted in a battery of tests that complement one another.

Routes of Exposures

With metalworking fluids, the main routes of exposure are inhalation of mists or vapors and skin contact. Larger, non-respirable particles may be swallowed, so ingestion also contributes to exposure to some extent. Potential for inhalation varies with the type of operation that is occurring, as well as with fluid type and the size of particle that is subsequently generated in a mist. Semi-synthetics and synthetic fluids typically generate smaller particles than the soluble oils or oil materials and are, therefore, more likely to be inhaled into the deep respiratory tract areas. With skin contact, the primary concern is irritation, contact dermatitis, or sensitization. Exposure may also occur by absorption through the skin. Some indication of this potential may be obtained from the results of acute dermal toxicity/lethality assays.

Acute Health Effects of Metalworking Fluids

A number of components that are regularly used in metalworking fluids have been associated with various acute disorders. Skin disorders are fairly common and may be due to either direct contact with the fluid because of alkalinity, or high pH, causing irritation, or due to contact with a specific component within the product. For example, oils may cause an oil-type dermatitis or inflammation of the hair follicles.[1] A number of the other commonly used additives are known to cause contact dermatitis or an inflammation and reddening of the skin and skin cracking. Additives such as amines, petroleum sulfonate, and some of the biocides may have that effect. Skin sensitization has been reported; in other words an allergic response to a chemical or a component in the material. It is often believed that sensitization is due to the biocide. Isothiazalones, formaldehyde, and mercaptobenzothiazoles have been reported to have sensitization potential. Metal allergy dermatitis may also occur. This is believed to be due to the solubilization of metallic ions from the metals and alloys being worked in the system. Nickel, chromium and cobalt are three of the most common metal skin sensitizers.[2]

Adverse respiratory effects have also been reported in areas where metalworking fluids are used. This is generally observed as an upper respiratory tract irritation, bronchitis, alteration of pulmonary function, or nasal irritation.[3,4]

Chronic Health Effects of Metalworking Fluids

Certainly the health effect that has caused the greatest concern in using metalworking fluids is the potential for them to produce cancer. Nitrites or nitrosating agents in combination with amines have been used in metalworking fluids as anti-oxidants and corrosion inhibitors and can give rise to the formation of nitrosamines, liver carcinogens in laboratory animals.[5]

Recently, there has been concern for the potential of mineral oils or petroleum-containing products to cause cancer. Several published literature reviews[6,7,8] evaluating epidemiology studies of metal workers have suggested increases in skin (particularly the scrotum), gastrointestinal, respiratory, and sinonasal cancers.

One of the major difficulties in an evaluation of the literature on mineral oils is the poor definition of the material under study. In the past, the term "mineral oil" has been used to describe oils derived from coal, shale, petroleum crude oil, and even animal and vegetable sources. There has been little recognition of the vast differences in the production, uses, chemical, physical and toxicological characteristics of "mineral oils."

This was the case when, in 1973, the International Agency for Research on Cancer (IARC) cited various reports in the literature and stated that there was sufficient evidence of carcinogenicity of *some* mineral oils in experimental animals and humans.[6] IARC did, however, acknowledge that mineral oils vary in their composition which may also affect their carcinogenicity.

With the promulgation of the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200), with its various information and labeling requirements, it became apparent that a clearer delineation of mineral oils was necessary in order to accurately identify the carcinogenic and non-carcinogenic fractions.

The Hazard Communication Standard requires that chemical manufacturers evaluate the potential hazards of their products and provide this information to their customers. For assessing the carcinogenic potential of a substance, at least three documents must be consulted:

1. The OSHA list of regulated carcinogens;

2. The National Toxicology Program (NTP) Annual Report on Carcinogens; and

3. The IARC Monographs on The Evaluation of the Carcinogenic Risks of Chemicals to Humans.

In order to clarify the mineral oil issue, IARC convened a group of scientists to evaluate the carcinogenicity of mineral oils derived from petroleum crude oils which are then further refined and used as base oils in fuels and lubricants.[8]

The important factors in the production of lubricating oil products are the petroleum crude oil type, the manufacturing or refining process, and the formulation of the final product. Petroleum crude oils are classified as paraffinic or naphthenic. Lubricant refining and product formulations have changed considerably over the years. Until about 1940, processing consisted of acid refining with clay finishing and subsequent dewaxing by chilling. Solvent refining (and solvent dewaxing) was first introduced in the U.S. and Europe in the 1930s. This is an extraction process which, following solubilization of the polycyclic aromatic hydrocarbons (PAHs), selectively removes olefins, naphthenes and then paraffins, depending on the severity of the process. Hydrotreating, as a newer, more severe process than hydrofinishing, was introduced in the sixties. Through a catalytic hydrogenation process, the lubricant base oil is made more paraffinic by the saturation of olefins. The severity of the hydrogenation dictates the degree of conversion of aromatics to naphthenes.

In general, the trend has been toward more highly refined oils with removal of unwanted impurities including PAHs, constituents believed to be major factors in imparting carcinogenic activity to these products. Consequently, animal studies have been conducted on refined mineral oils derived from these newer processing techniques in order to evaluate carcinogenic potential; these are primarily mouse skin painting studies.

Mouse skin painting studies are fairly common in toxicology and considered to be relatively accurate in predicting skin carcinogenic potential in man. The standard protocol in testing mineral oils is as follows: the animals are shaved biweekly and the undiluted test material is applied with a dropper or pipette onto the back of the mice, in the shoulder blade area. The usual dosage is 50 or in some older studies, 100 mg, applied two or three times a week. 50 mg is equivalent to approximately 0.05 ml, so the animals are not being overwhelmed with extremely high doses. The skin of the animals, however, is not washed between applications and these applications continue for essentially the life of the animals - at least 80 weeks or until a papilloma is grossly or visually diagnosed. A papilloma is defined as a horny lesion of one to three mm in size which persists for one week. At this point, the time-to-tumor is recorded and the oil applications stopped.

If the lesion continues to grow, replacing surrounding tissue and becoming ulcerated or necrotic, it is diagnosed as an advanced tumor. Subsequent histopathology usually indicates that these advanced tumors are carcinomas. On the other hand, if a papilloma regresses, oil applications are recommenced.

The following summarizes the results of the data reported in the 1984 IARC Monograph.

There is sufficient evidence of carcinogenicity for:

- Untreated vacuum distillates;
- Acid treated oils (which includes caustic neutralization, dewaxing, or clay treating);
- Aromatic oils;
- Mildly solvent refined oils;
- Mildly hydrotreated oils;

There is no evidence of carcinogenicity for:

- Severely solvent refined oils;
- White oils (when administered by routes other than intraperitoneal injection).

There is inadequate evidence (one study) to evaluate severely hydrotreated oils or oils that have been mildly solvent refined with subsequent mild hydrotreatment; however, the data to date have indicated these are not carcinogenic.

The IARC definition of "sufficient evidence" is "when there is an increased incidence of malignant tumors: a) in multiple species or strains; or b) in multiple experiments; or c) to an unusual degree with regard to incidence, site or type of tumor or age at onset."

Table 1.
Effect of Solvent Refining on the Dermal Carcinogenicity of Lubricating Oils

Oil Type	Tumor Production Advanced	Tumor Production Papilloma	Mean Latency (Weeks)
Dewaxed Distillate (Low Viscosity)	27	0	64.4
Dewaxed Solvent Refined Distillate-Phenol Extracted	0	1	-
Dewaxed Solvent Refined Distillate-NMP-Extracted	0	0	-

Table 1 shows sample data[9] from a study using an oil either dewaxed or solvent refined. The tumorigenicity data are quite striking:

These results are from the same distillate, dewaxed with subsequent solvent refining with either phenol or n-methyl pyrollidone. The solvent used to extract the oil does not appear to significantly affect the carcinogenicity. Fifty C3H mice were used in each group; 50 mg of oil was applied twice weekly for the life of the animal, which was from 98 to 134 weeks.

Table 2.
Effect of Mild Solvent Refining Followed by Mild Hydrotreatment on the Dermal Carcinogenicity of Lubricating Oils

Oil Type	Tumor Production Advanced	Tumor Production Papilloma	Mean Latency (Weeks)
Dewaxed Distillate (Sample A)	22	2	26.4
Sample A - Lightly Solvent Refined	5	1	64.5
Sample A - Lightly Solvent Refined and Hydrotreated	0	0	-

Table 2 shows the effect of mild solvent refining followed by mild hydrotreatment.[9] The protocol of the study was similar to that discussed above.

Again, it is apparent that mild solvent refining reduced the carcinogenic properties of the oils but that this, followed by mild hydrotreatment, appears to eliminate tumor formation.

From this information, a question which then naturally arises is: What is "mild" or "severe" refining? How is this defined? Unfortunately, there is considerable controversy as well as data gaps in defining these terms, and the Chemical Abstract Service Number (CAS Number) indicates only the final refining process, not the severity of earlier processing. Because of this, OSHA published in the Federal Register on December 20, 1985, "Hazard Communication; Interpretation Regarding Lubricating Oils." One of the purposes of this document was to define "mild" hydrotreatment. The critical factors for defining this process are pressure and temperature. OSHA has decided that an oil has been mildly hydrotreated if it has been processed at a pressure of 800 psi or less at temperatures of up to 800°F. Unfortunately, OSHA did not define any of the other refining parameters; however, based on available toxicology literature, the following provides some guidance in this area:

1. Severe hydrotreating at pressures of greater than 3000 psi produces base oils with no evidence of carcinogenicity. Processing at greater than 2000 psi is also probably effec-

tive. Lower pressures might be effective but would require bioassay data for confirmation.

2. For solvent refining, data suggest that 150% furfural at 200°F is usually effective in producing base oils with no evidence of carcinogenicity. However, conditions required may vary depending on crude source and viscosity of the base oils being treated.

In the absence of bioassay data, these guidelines should help to verify that oils have been severely refined, and, therefore, considered to be non-carcinogenic.

Another fairly recent technique for evaluating potential carcinogenicity of oils has been developed by the Mobil Oil Corporation. Modifications have been made to the standard Ames bacterial mutagenicity assay. Mobil has reported this modified Ames assay to have a correlation coefficient of 0.92[10] for oils with median boiling points between 500 and 1070°F when compared with the results of the long-term mouse skin painting studies. A significant correlation has also been observed between the three to seven ring PAH compounds and both mutagenic and carcinogenic potency.[11] The two major advantages to this type of assay versus conducting mouse skin painting tests are time and money. The modified Ames can be run and evaluated in a few days, whereas mouse skin painting takes approximately two years of testing and another year or so to analyze the results, obviously at a much greater cost. In addition, the modified Ames can be used to quickly screen oils of unknown refining history in order to predict potential carcinogenicity.

Another area about which there has been questions is reclaimed, rerefined or used oils. The IARC Monograph does not address reclaimed oils and has only a brief section on "used oils," which is not defined. In the studies reviewed, there are no data that indicate that a non-carcinogenic oil will become positive in carcinogenic bioassays with use or if reclaimed, other than motor oils used in combustion engines and possibly quench oils.

Therefore, with used or reclaimed oils the following should be determined:

- Refining history of the oils indicating they are of a non-carcinogenic class;
- Refining history of contaminants (tramp oils, hydraulic fluids, etc.); and
- Results of toxicology testing for carcinogenicity.

If it can be verified that the starting oils are non-carcinogenic and that they are not subsequently contaminated in-house, they should not need to be labeled and handled as potential carcinogens.

Rerefined oils must meet the same criteria, or have undergone severe solvent rerefining, severe hydrotreating or a combination of both.

Another common family of compounds in metalworking fluids that have of late become a carcinogenic concern are the chlorinated paraffins. These are included in fluids as extreme pressure additives and anti-wear agents.

The NTP recently completed carcinogenicity testing of two of the chlorinated paraffins. The compounds tested were a C_{12}, 58-60% chlorine (Cl) product and a $C_{23/24}$, 40-43% chlorine material. Rats and mice were fed the chemical over their lifetimes. The C_{12}, 58-60% Cl was positive for carcinogenicity in both rats and mice; however, equivocal results were obtained following exposure to the $C_{23/24}$, 40-43% Cl compound.

The NTP report has now been finalized. NTP has published the "Fifth Annual Report on Carcinogens" list of suspect carcinogens. The C_{12} 60% chlorine, chlorinated paraffins are included. This has resulted in many fluid formulators substituting these components in their products.

Conclusions

Based on the available toxicology data, in applications where employee exposure cannot be avoided, it is suggested that the following types of oils be used where possible:

- Severely solvent refined;
- Severely hydrotreated;
- Mildly solvent refined with subsequent mild hydrotreatment; or
- Oils that have been negative for carcinogenicity in toxicology studies.

The complexity of metalworking fluids results in a complex toxicologic profile for these materials. When possible, fluids as a whole should be tested; where this is not possible, the OSHA Hazard Communication Standard requires that a hazard evaluation of the product, based on the toxicity of the components, must be conducted and provided to users of the material.

In all applications where metalworking fluids are used, good industrial hygiene practice must be maintained. Impervious gloves and protective clothing, barrier creams and ventilation, as well as other industrial hygiene control measures should be considered.

In many cases, by controlling for skin irritation and dermatitis, risk of additional chronic effects can be reduced. And, of course, employees must be informed of the potential hazards of these products and trained to minimize exposure as with all chemical materials.

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Patricia J. Beattie, Ph.D.
Toxic Materials Control Activity
General Motors Corporation
General Motors Building
3044 West Grand Boulevard
Detroit, MI 48202
Phone 313/556-1599
Fax 313/974-9546

Patricia J. Beattie joined General Motors in 1978 as corporate industrial toxicologist. She is currently Senior Advisor–Toxicology and director of the Toxic Materials Control Activity for the corporation. Primary responsibilities entail toxicology evaluations and risk assessments on materials being considered for new product/vehicle development, consumer products and potential environmental and occupational problems identified in GM manufacturing facilities. This includes providing toxicology assistance to environmental, legal and regulatory staffs and all GM staffs and facilities worldwide.

Dr. Beattie has a B.S. in Chemistry from the Univ. of Arizona and an M.S. and Ph.D. in Toxicology from the Univ. of Michigan. She is active on ASTM E34.50, is a Diplomate of the American Board of Toxicology, and is a member of the Society of Toxicology, American Chemical Society and American Association for the Advancement of Science. Dr. Beattie is author and coauthor of a dozen scientific papers, and has made numerous scientific presentations. She addressed the Independent Lubricant Manufacturers Association Annual Meetings in 1988 and 1990.

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Microbial Control and Its Impact on Waste Minimization of Metalworking Fluids

Dianne P. Carmody
Andy B. Law
and
Gary L. Willingham, Ph.D.
Rohm and Haas Company

Minimizing Waste Metalworking Fluid Is A High Priority

Public attention has recently been focused on environmental and health problems that may result from mismanaging hazardous waste. This growing national concern for safety, waste minimization and cleaner air and water has resulted in many laws regulating waste. Used coolants are among the types of waste regulated by federal, state and local laws. These laws are making it increasingly difficult and expensive to dispose of waste metalworking fluids.

The two principal federal laws that regulate waste metalworking fluids are the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (Superfund). Both are administered by the Environmental Protection Agency. RCRA is designed to ensure that hazardous chemicals are not discarded in such a way as to cause harm to human health or the environment. RCRA provides for "cradle to grave" management of more than 450 hazardous chemicals.[1] There are several sections of RCRA which are of particular importance to the small quantity (100-1000 kg per month) generators of hazardous waste.[7] Superfund is concerned with cleanup of old waste sites where hazardous chemicals have been abandoned while still potentially dangerous. Through Superfund, the EPA can hold a company liable for the cost of the entire cleanup of an abandoned site, regardless of the amount of waste which that company placed in the site.[1] In addition to RCRA and Superfund, other federal statutes which impact on waste generators are the Clean Water Act, the Safe Drinking Water Act, and the Clean Air Act.[7]

The cleanup, disposal and minimization of hazardous wastes will continue to be driven by government regulations and public concerns. New laws are likely to increase the volume and number of wastes regulated[1] and send disposal costs higher. The simplest way for companies that generate waste to control disposal cost is to minimize the amounts of waste they generate.

Formulation changes in the 1970s, (i.e. conversion from oil-based to water-based metalworking fluids) have increased the difficulty of waste treating these fluids. Synthetic and semi-synthetic fluid may seem easier to dispose of than oil-based fluids, because they contain little or no oil, but in practice, not all synthetics are readily biodegradable nor can they be disposed of acceptably down drains. The inherent stability of semi-synthetics can lead to difficulties in separating water from the other constituents yet the organic components of these fluids must be removed before disposal.[5] Special processes have been and are being developed which are capable of dealing with these fluids. These include incineration, chemical treatment, ultrafiltration, absorption onto granular activated carbon fluidized bed reactors, evaporation and others.[5,10] These processes can be complex and expensive. In fact, many companies spend more to dispose of used coolant than they originally paid for the coolant.[8] These costs may not be obvious however, since they include a variety of charges, fees, and taxes which are likely spread over the budgets of several departments.

With escalating costs and potential liability in waste disposal, minimization of coolant waste is becoming a major priority in the metalworking industry.

Microbial Contamination: A Major Cause of Fluid Spoilage

One way to minimize waste fluid and waste fluid disposal costs is to extend the life of the fluid. To do this, one should be familiar with causes of metalworking fluid failure. Common causes include excessive buildup of oil, dirt, dissolved minerals and metals, coolant splitting, and selective depletion of fluid components.[2] A major cause of metalworking fluid spoilage is microbial contamination. One important way to extend fluid life is to control microbial growth in fluids.

Metalworking fluids spoil because they provide a rich source of nutrients to support microbial growth. Common metalworking fluid constituents which serve as nutrients for microorganisms include mineral oils, fatty acids, emulsifiers, alkanolamines, phosphate esters and waxes.[3,6] Since fluids contain different nutrients the types of microbial contaminants found vary from fluid to fluid.

Waste metal and grinding swarf which are produced during most metalworking applications increase the surface area for microbial attachment.[4]

Poor hygiene and housekeeping contribute greatly to and accelerate microbial problems in the fluids.[9] Excessive tramp oil, debris, cigarettes, food, cleaning solutions, etc. all add to coolant contamination problems.[11]

Bacteria and fungi commonly found in metalworking fluids are given in Table One.[6]

Table 1
Common Microorganisms in Metalworking Fluids

Bacteria	Fungi
Citrobacter freundi	*Candida sp.*
Desulfovibrio sp.	*Cephalosporium sp.*
Enterobacter cloacae	*Fusarium sp.*
Escherichia coli	
Klebsiella pneumoniae	
Proteus mirabilis	
Pseudomonas aeruginosa	

Growth of microorganisms produces a number of undesirable effects. These effects can have a deleterious impact on the worker, the work environment, the coolant and its performance, and the productivity and performance of the machine tool. Overall system problems such as oil separation, clogged equipment and foaming can also occur. Problems associated with microbial spoilage are described in Table Two.[3,6]

Observations of these effects are good indications that a metalworking fluid is contaminated. In addition to observation of problems caused by microbial growth, microorganisms can be detected and measured in metalworking fluids by three different methods:

1) determination of the number of organisms present using dipslides and plate counts;

2) determination of the concentration of cell constituents such as protein, ATP and enzymes;

3) determination of the level of microbial activity (i.e. measuring oxygen demand or carbon dioxide formation).[3]

One should select a procedure or procedures that will provide the most effective, efficient and economical monitoring tool. This tool should be used to monitor systems routinely and alert one to problems early in their development.

How to Control Microbial Growth

The most common method for controlling microbial contamination in metalworking fluids is through the use of biocides. Many biocides are commercially available. Selection of the correct biocide or biocide combination for a given system is extremely important. Many factors influence the performance of biocides in different metalworking coolants. These include solubility, stability, compatibility, speed of kill, biocide concentration, and antimicrobial spectrum. Laboratory evaluations are recommended to determine compatibility, stability, and efficacy of a given biocide treatment in a specific fluid prior to use in the fluid concentrate or for tankside applications. In addition, any time the formulation of a product is modified, it is advisable

Table 2
Problems Associated with Microbial Spoilage in Metalworking Fluids

Worker Effects

- Odor development
- Possible exposure to pathogenic organisms
- Possible contributions to skin and/or respiratory irritation

Coolant Effects

- Splitting of emulsion
- Decreased pH
- Increased corrosion
- Degradation of ingredients
- Loss of lubricity and cooling properties

Machining Effects

- Decreased workpiece quality
- Increased surface blemishes
- Increased down time
- Decreased tool life

System Effects

- Oil separation
- Clogged lines, filters and valves
- Foam formation

to again check the effectiveness of the biocide in that coolant under conditions similar to use conditions.[12]

In addition to proper selection and pre-testing, the effectiveness of a biocide depends on proper use of the product. Proper dose levels, method of addition, and safe handling procedures are important for their optimum use. This information is available from the biocide supplier and can be found on product labels, product literature and material safety data sheets.Controlling microorganisms in metalworking coolants, biocides extend coolant life, thereby reducing waste. Laboratory data provided in Tables Three, Four and Five demonstrate the activity of six commercial biocides in a soluble, synthetic and semi-synthetic fluid

Table 3
FLUID 1
SOLUBLE

Biocide*	Three Days	Four Weeks
None		
Bacteria	F	F
Fungi	F	F
A		
Bacteria	P	P
Fungi	P	F
B		
Bacteria	P	P
Fungi	P	F
C		
Bacteria	P	P
Fungi	F	F
D		
Bacteria	P	P
Fungi	P	P
E		
Bacteria	P	P
Fungi	P	P
F		
Bacteria	P	P
Fungi	F	F

Zero Time Bacteria Level= 10^6
Fungi Level= 10^3

Bacteria $< 10^5$ = Pass (P)
Bacteria $\geq 10^5$ = Fail (F)
Fungi $< 10^3$ = Pass (P)
Fungi $\geq 10^3$ = Fail (F)

*All biocides dosed at upper recommended use level.

Table 4
FLUID 2
SEMI-SYNTHETIC

Biocide*	Three Days	Four Weeks
None		
Bacteria	F	F
Fungi	F	F
A		
Bacteria	P	P
Fungi	P	P
B		
Bacteria	P	P
Fungi	P	P
C		
Bacteria	P	F
Fungi	F	F
D		
Bacteria	P	P
Fungi	P	P
E		
Bacteria	F	F
Fungi	F	F
F		
Bacteria	P	P
Fungi	P	P

Zero Time Bacteria Level = 10^6
Fungi Level = 10^3

Bacteria $< 10^5$ = Pass (P)

Bacteria $\geq 10^5$ = Fail (F)

Fungi $< 10^3$ = Pass (P)

Fungi $\geq 10^3$ = Fail (F)

*All biocides dosed at upper recommended use level.

respectively. In most cases the biocides, at recommended use levels, significantly reduced the level of contamination in the fluids after three days and controlled the level of bacteria and fungi in the metalworking fluids for four weeks. Some differences in performance between different biocides in a given fluid (e.g. Biocide A vs. Biocide C in Fluid 2) and for a given biocide in different fluids (Biocide E in Fluid 1 vs. Fluid 2) are noted.

Table 5
FLUID 3
SYNTHETIC

Biocide*	Three Days	Four Weeks
None		
Bacteria	F	F
Fungi	F	F
A		
Bacteria	P	P
Fungi	P	F
B		
Bacteria	P	P
Fungi	P	F
C		
Bacteria	P	P
Fungi	F	F
D		
Bacteria	P	P
Fungi	P	P
E		
Bacteria	F	F
Fungi	P	F
F		
Bacteria	P	P
Fungi	F	F

Zero Time Bacteria Level = 10^6

Fungi Level = 10^3

Bacteria $< 10^5$ = Pass (P)

Bacteria $\geq 10^5$ = Fail (F)

Fungi $< 10^3$ = Pass (P)

Fungi $\leq 10^3$ = Fail (F)

*All biocides dosed at upper recommended use level.

Waste Minimization Case Study

As was noted earlier, treatment of waste metalworking fluids can be costly. This case study quantifies the annual savings in waste treatment costs, for one central system, which were realized by using a metalworking fluid biocide.

In a recently conducted field trial to evaluate the performance of a broad spectrum fungicide, concentrate metalworking make-up fluid requirements were monitored.

Prior to use of the fungicide in this large central system, make-up fluid concentrate requirements averaged 1800 gallons per month. After biocide treatment for five months, concentrate requirements decreased to an average of 700 gallons per month.

Annualized, approximately 13,200 gallons less metalworking fluid concentrate were required by the system. Assuming a waste disposal cost in the range of $0.50 to $1.00 per gallon, this translates to a savings in waste treatment costs alone of $6,600 to $13,200 per year.

Other savings not accounted for in this case which may be realized include labor costs, burden costs, make-up fluid costs and drum disposal costs.

Conclusion

Biocides offer an economical way to minimize metalworking fluid waste. This saves the user on treatment costs as well as make-up fluid replacement. Biocides also prevent odors, a source of downtime. The properly maintained fluid performs better, yields improved tool lifetime and better quality machined pieces. Proper use of biocides should clearly be a part of any effective strategy to minimize waste for the future.

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Dianne P. Carmody
Biocides Market Manager
Rohm and Haas Company
Independence Mall West
Philadelphia, PA 19105
Phone 215/592-2170
Fax 215/592-3751

Dianne P. Carmody received her B.S. in Chemical Engineering from Lehigh Univ. Before assuming the responsibilities of biocides market manager, Ms. Carmody was market development manager and process engineer with Rohm and Haas.

Gary L. Willingham, Ph.D.
Senior Scientist,
Biocides Formulations
Rohm and Haas Company
Spring House, PA
Phone 215/641-2242

Gary L. Willingham has spent three years in agricultural chemicals formulations and three years in biocides research and development in the areas of metalworking fluids and paints. He has published several papers in the areas of biochemistry, agricultural chemistry and biocides. Dr. Willingham received his B.S. in Chemistry and Biology from the Univ. of Tennessee and his Ph.D. in Chemistry from Johns Hopkins Univ. He is a member of the American Chemical Society.

Rohm and Haas Company is a major manufacturer of specialty chemicals and plastics. Its specialty chemicals are sold to customers in a wide range of industries, who use Rohm and Haas products in the manufacture of numerous goods which are ultimately marketed to the consumer. A Fortune-200 company, Rohm and Haas has 44 manufacturing sites worldwide, and sales offices in more than 30 countries. Rohm and Haas is an industry leader and innovator in polymer acrylic chemistry, biocides, and other specialty chemicals. It is the world's largest producer of acrylate monomers and their derivatives, raw materials used in more than 60% of the company's product portfolio. Rohm and Haas Company is an Associate Member of the Independent Lubricant Manufacturers Association.

Selection of Preservatives for Use in Industrial Lubricants and Metalworking Fluids

Frederick J. Passman, Ph.D.
ANGUS Chemical Company

Introduction

There are three options for controlling rancidity in metalworking fluids: physical treatment, chemical treatment and disposal. Physical treatment involves single point treatment of recirculating coolant with either heat (pasteurization) or irradiation. There is no residual antimicrobial effect from physical treatments. Disposal is a "last option" means for removing rancid coolant from a system. Its effectiveness can be very short-lived if biofilms and accumulated sludges are not removed completely with the bulk fluid. Chemical treatment is the only option which provides a measure of resistance to microbial attack and consequent spoilage throughout the coolant system.

Chemical treatment entails the use of industrial preservatives, the building of "bioresistant" metalworking fluids or a combination of the two. Formulators building bioresistant fluids must take precautions to ensure that at appropriate dilutions, the coolant will biodegrade during waste treatment. The use of multi-functional molecules, which are antimicrobially active and have other benefits in formulations is becoming increasingly popular. Formulators should evaluate the ability of candidate chemicals to meet or exceed each performance criterion for which there is a claim. Often multi-functional molecules partially replace more biologically labile molecules, conferring greater bioresistance to the coolant and reducing (but not eliminating) the requirement for the original chemistry. An example is the use of certain oxazolidines as both biocides and neutralizing amines.

On the following pages, I will discuss non-chemical approaches to rancidity prevention briefly, then focus on considerations for selecting biocides for use in metalworking fluids.

Alternative Approaches to Rancidity Prevention

One key factor in slowing the biodegradation process is keeping the coolant clean. Swarf, turnings, hydraulic oil and debris from the plant environment provide surface area and additional nutrients for bacteria and fungi carried by coolants. Individual sumps (25 to 1000 gallons) should be designed to facilitate sediment blow-out (from sump bottoms) and tramp oil removal. Central systems should be equipped with units for removing cuttings, swarf and tramp oil. There are a variety of filtration and centrifugation technologies available, each with its relative advantages and disadvantages over the others. As formulators, it is important to understand the effect of these mechanical treatment systems on your coolant. Coolant concentrate may be removed with the detritus. Mechanical separation systems may cause foaming or emulsion splitting. This is one of the primary arguments for end users to ensure that coolant formulators and hardware suppliers cooperate.

Physical treatments have several significant disadvantages. Since coolant is treated at only one point in a system, surviving microorganisms can colonize surfaces throughout the rest of the system, where they can continue to cause rancidity in recirculating coolant. Additionally, heat treatment, or oxidation by ultra-violet, radioactive or high-energy irradiation can cause undesirable coolant chemistry changes. Physical treatments are capital intensive, require substantial maintenance and energy cost investments, and are typically out of the control of the formulator.

Chemical additives, whether they are biocides, multi-functional additives or bioresistant molecules, are incorporated into the coolant formulation. They can be tested for compatibility and functionality. They provide the formulator with a degree of flexibility not possible with other rancidity control options. Before the U.S. EPA data call- in, there were approximately 80 chemicals registered for use as metalworking fluid preservatives. It is not yet clear how many of these chemicals are having their registrations supported. It is likely that many of the low volume specialty products will no longer be available for use in metalworking fluids. I will discuss this further under Regulatory Issues.

Using Biocides, Mode of Application

How you choose to introduce one or more biocides into your coolant will depend on a number of considerations. The sensitivities and sophistication of the end user often determine whether tankside additions are possible. Many end users are not interested in handling biocide concentrates within their plant. Under such constraints, biocide must be formulated into coolant concentrates. This is rarely totally adequate, since, over time, most biocides, in coolant concentrate, lose their potency. Moreover, concentrates are often used at different dilutions for different end user applications. It is most challenging to incorporate biocides into coolant concentrates so that they provide adequate protection under "most-dilute" coolant use levels, but do not represent overdosing at "least-dilute" coolant levels.

The alternative is tankside treatment with biocides. Biocides can be added proportionally with either coolant or water make-up. They can be added periodically in accordance with a schedule, or in response to a change in some criterion parameter (for example, bacterial viable titer). It is *inadvisable to add biocide only after rancid odors and slime* accumulation make the plant environment unbearable. Biocide doses required under these acute conditions are generally at the upper threshold of the manufacturer's recommended treatment range, and may result in worker odor or irritation complaints. Also, the slough-off mass produced by shock dose kills may cause filtration systems to be over-taxed. Small diameter piping may become blocked by biomass debris.

Tankside additions provide more flexibility, but they also require more active involvement of end user personnel. The tankside program must meet the formulator's coolant preservation requirements and the end user's safety and scheduling requirements. The end user must be trained to perform routine monitoring, record keeping and biocide addition. Biocide manufacturers can offer a great deal of guidance and assistance in setting up tankside addition programs.

Biocide Types

As mentioned in my introduction, before the 1987 U.S. EPA data call-in, there were approximately 80 biocides registered for use in metalworking fluids. Table 1 provides a representative listing of the most commonly used metalworking fluid biocides. One reason for so many alternatives is that there is no universally suitable product. Any given active ingredient may work superbly in one coolant formulation and be essentially inert in another. I shall discuss this along with other selection issues in a later section.

Biocides can be classified either by their general functionality or by their chemical structure. Bactericides (also spelled bacteriocides) are selectively active against bacteria. Most bactericides used in metalworking fluids are particularly

Table 1. Commonly Used EPA Registered Biocides for Metalworking Fluids*

Manufacturer	Trade Name	Active Ingredients
ANGUS Chemical Co.	BIOBAN GK	*Hexahydro-1,3,5-tris (2-hydroxyethyl)-5-triazine 78%*
	BIOBAN CS-1135	*4,4-dimethyloxazolidine 74.7%; 3,4,4-trimethyl-oxazolidine 2.5%*
	BIOBAN BNPD	*2-bromo-2-nitro-1,3-propanediol 98%*
	BIOBAN P-1487	*4-(2-nitrobutyl)-morpholine 70%; 4,4'-(2-ethyl-2-nitro- methylene)dimorpholine 20%*
	TRIS NITRO	*2-hydroxymethyl-2-nitro-1,3-propanediol 50%*
Buckman Laboratories	BUSAN 77	*Poly[oxyethylene(dimethyl imino)ethylene] dichloride*
	BUSAN 85	*Potassium dimethyldithio-carbamate 50%*
	BUSAN 1030	*2-(thiocyanomethylthio)-benzothiazole 30%*
	BUSAN 1060	*Hexahydro-1,3,5-tris-(2-hydroxyethy1)-s-triazine 78%*
Dow Chemical U.S.A.	Dowcil 75	*1-(3-chloroallyl)-3,4,7-triaza-1-azoniaadamantane chloride 32.5%*
	Dowicide 1	*O-phenylphenol 98%*
	Dowicide A	*Sodium o-phenylphenate 97%*
ICI Americas, Inc.	Proxel CRL	*1,2-benzisothiazolin-3-one 30-33%*
Lehn & Fink (Kodak)	GROTAN	*Hexahydro-1,3,5-tris (2-hydroxyethyl)-s-triazine 78%*
Olin Corp.	Sodium Omidine	*Sodium 2-pyridinethiol-1-oxide, available as powder 90% or aqueous solution 40%*
	Triadine 10	*Hexahydro-1,3,5-tris (2-hydroxyethl)-s-triazine 63.6%; sodium 2-pyridine-thiol-1-oxide 6.4%*
Rohm and Haas Co.	Kathon 886MW	*5-chloro-2-methyl-4-isothiazolin-3-one 8.6%; 2-methyl-4-isothiazolin-3-one 2.6%*
	Kathon 893MW	*2-n-octyl-4-isothiazolin-3-one 45%*
Stepan Chemical Co.	Onyxide 200	*Hexahydro-1,3,5-tris(2-hydroxyethyl)-s-triazine 78%*

*Adapted from Rossmoore, 1981.

active against gram negative bacteria. Fewer are effective against gram positive bacteria. The "gram reaction" refers to the ability of the bacterial cell wall to take up a diagnostic stain and is determined by observing stained smears under a microscope. The difference in the stain reaction, and relative susceptibility to particular biocides, is due to the differences in cell wall chemistry between the two groups of bacteria. The bacteria most commonly recovered from metalworking fluids are all gram negative. These include species from the following genera:

Pseudomonas

Achromobacter

Flavobacterium

Klebsiella

Enterobacter

Escherichia

Proteus

Gram positive representatives of the following anaerobic genera are also recovered commonly, but in fewer numbers:

Desulfovibrio

Clostridium

Hydrogenomonas

Bacillus (a gram positive, aerobic bacterium) isolates from metalworking fluids are not uncommon, but they rarely represent a major proportion of the contaminant population.

Biocides which are selectively effective against fungi are called fungicides. Some products are more effective against the filamentous fungal form, molds. These are called mildewcides. Yeasts are single-celled fungi. *Aspergillus, Candida, Cladosporium, Fusarium, and Saccharomyces* are the most common fungi recovered from metalworking fluids.

Principle chemical classes of biocides include:

alkane derivatives;

formaldehyde condensates;

isothiazolinones;

morpholine compounds;

oxazolidine compounds;

phenols;

pyridine derivatives; and

quaternary ammonium compounds.

Rossmoore (1979) grouped representatives from most of these groups and discusses their properties as heterocyclic compounds. For practical purposes, knowing the basic chemical structure and net molecular charge enables formulating chemists to predict chemical incompatibilities between biocides and other coolant components.

The most diverse group of compounds is the formaldehyde condensate group. In recent years there has been a great deal of controversy over the use of these products in metalworking fluids. Most of the controversy has resulted from a general misunderstanding of the role of formaldehyde in the synthesis and function of these products. Typically, formaldehyde is released only in the immediate environment of the target bacterium, where the pH is substantially lower than in the bulk of the coolant. Formaldehyde concentrations in the air around coolant systems treated with one of four different formaldehyde condensate biocides are no higher than background concentrations (Vysoky, personal communication). Moreover, Rossmoore et al. (paper in press) has demonstrated that many formaldehyde condensate biocides denature endotoxins. Endotoxins are the component of gram negative cell walls that elicit fever reactions in test animals and humans. Non-formaldehyde condensate biocides tested do not denature endotoxins.

The U.S. OSHA has set standards for formaldehyde exposure (29 CFR 1910.1048). Personnel exposed to an eight hour time-weighted average of greater than 0.5 ppm formaldehyde should be monitored routinely for exposure. The permissible exposure limit is 1.0 ppm (eight hour time-weighted average) and the short term exposure limit (15 minute) is 2.0 ppm. To date, we have not seen concentrations greater than 0.5 ppm at distances greater than two feet from any coolant system (Vysoky, personal communication).

Regulatory Issues

The paramount concern regarding the use of biocides in metalworking fluids is safety. All of the biocides registered for use in metalworking fluids have undergone extensive toxicity and mutagenicity testing in accordance with U.S. federal law (40 CFR 162). There are products on the market which are not registered, and for which anti-microbial claims are hinted at but not made openly. Data on the potential health effects of these chemicals are incomplete, so the risk of using them is unknown. Unless you know that the data exist (for example U.S. EPA registration pending), and have had a competent toxicologist review them, you should not use unregistered products.

On March 4, 1987, U.S. EPA issued a data call-in notice for subchronic and chronic toxicological data for antimicrobial pesticide active ingredients. The notice defined three tiers of testing, and listed three exposure categories (low, medium and high). Metalworking fluids were ranked in the high inhalation and dermal exposure categories. This means that biocides registered for use in metalworking fluids will have to undergo Tier three testing; the same as that required for swimming pool and agricultural biocides. The Chemical Manufacturers Association (CMA) has challenged this ranking, and is working with the EPA to show that: a) biocides in metalworking fluids (dermal exposure) represent only one minor component in a very complex matrix of chemical species; chronic biocide data would be meaningless in terms of predicting the potential long-term effect of biocide exposure in metalworking fluids; and b) plant operators are not exposed to significant amounts of biocide through inhalation. At this writing, data are being developed to support the CMA arguments. If these arguments are not persuasive, there will be few biocides whose volume justifies the $2 to $3 million bill for Tier three testing. Biocide selection options will decrease dramatically.

By definition, all biocides are toxic. It is also a given that for any organic compound there are individuals who are allergic to, or sensitized by, that compound. Generally speaking, if an EPA registered biocide is used in accordance with the manufacturer's recommendations, plant workers are not at increased risk. Although some biocides are somewhat more forgiving of mishandling, all registered biocides can be handled safely. The selection of an appropriate biocide should be based on its functional suitability for a particular application.

All states, except Alaska and the District of Columbia, require biocides to have state registrations before they can be sold in their states. (Anonymous, 1987)

Biocide Evaluation

Shennan (1983) reviewed seven alternative bench tests for testing biocide efficacy in metalworking fluids. The objective of any bench test is to obtain an economic, but accurate, prediction of the ability of a biocide treatment regimen to control microbial contamination in coolant in a metalworking system. Short of running trials at each machine or central systems, any testing performed depends on a series of simplifying assumptions. The differences among alternative test methods reflect the relative importance which the method developer placed on specific variables. Thus, different investigators will argue over the relative importance of the composition and frequency of microbial challenges to the test system, composition and frequency of make-up fluid additions, the requirement for iron (or other alloy) chips/filings, requirements for coolant recirculation and the appropriate test duration. Except for tests designed to evaluate biocide efficacy against anaerobic bacteria, all published test protocols call for aeration.

The rationale for selecting a particular protocol depends on the intended use for the data generated. An end user, evaluating relatively few alternative treatments for use in a single coolant in one type of system, is justified in setting up a recirculating system in which the coolant will recirculate over chips or filings of the alloy being worked by the machines which the coolant will service. Recirculation and aeration schedules can be set up to simulate those in the plant. Data generated from this type of test system should provide good predictions of biocide performance in the system to be serviced. However, even under these experimental conditions, variables like personnel throwing refuse into the system, process heat and biofilm activity are not simulated. When several treatment regimens are being compared and several coolants are being tested, space limitations, labor logistics and apparatus costs favor simpler test procedures.

The ASTM procedures (ASTM 1987) for evaluating biocide performance in metalworking fluids and in high water-content hydraulic fluids provide good predictions of the relative efficacy of alternative treatments. These tests require aeration, but not recirculation. ASTM E 686-85, "Evaluation of Antimicrobial Agents in Aqueous Metalworking Fluids," calls for inoculating freshly prepared coolant (at working concentration) with a mixed population of bacteria and fungi. When possible, the inoculum is prepared by culturing a sample of contaminated coolant through several weekly transfers in biocide-free coolant. This then provides data on the efficacy of the treatment against the contaminants encountered in the system to be serviced. Test vessels contain iron filings and are aerated on a five day on, two day off schedule, to simulate industrial conditions. Each week, fluid volumes in the test vessels are brought to original levels with fresh metalworking fluid containing sufficient biocide to maintain "original concentration." Viable titers are determined weekly, and test vessels are rechallenged.

The test has proven to provide reasonably good predictions of biocide performance in the field. However, there are several flaws which warrant discussion. The assumption that coolant concentrate, water and biocide are all lost from the test vessels at the same rate is questionable. Biocides that tend to be transported by the hydrocarbon phase of emulsions will not exhibit the same loss patterns as those which tend to be transported in the water phase. Biocide and coolant concentrate losses due to misting of drag-out are different from those when fluid loss is due primarily to evaporation. These differences are not considered in this procedure. The parameter used to measure biocide performance is the viable count. This may not always be the most appropriate parameter to use. The test duration is given as "six weeks or until failure of the biocide occurs." No definition of "failure" is provided, and with good cause.

There is considerable debate regarding the evaluation of test data. What constitutes biocide failure? Izzat and Bennett (1979) defined failure as greater than or equal to 10^5 colony forming units (CFU)/mL for two consecutive weeks. Rogers et al. (1975) considered 99.9 percent (three log) reduction after 60 days to be acceptable. I consider both maximum log reduction (relative to an untreated, inoculated control) and viable counts of less than or equal to 10^4 CFU bacteria/mL; and less than or equal to 10^3 fungi CFU/mL as pass/fail criteria. Viable counts from an acceptable treatment will have a log value of less than 50 percent of the log of the viable count from the untreated control. For example, if the control yields 2.5×10^9 CFU/mL, log CFU/mL = 9.398. A biocide treatment must reduce the log viable count to less than 4.699, or 5.0×10^4 CFU/mL to be acceptable.

Reduction of viable titers alone may not provide the best indication of biocide efficacy. For more critical metalworking operations, it may be more informative to examine the effect of alternative treatments on the rate of change of important coolant properties. For example, Hill et al. (1976) used particle size distribution to evaluate biocides used to treat aluminum rolling fluids. I often use catalase activity to estimate the biodegradation potential of the contaminating population. Radiotracer-tracked metabolic activity (Mallack, unpublished) and biochemical oxygen demand (Bennett, unpublished) are also used routinely to evaluate biocide efficacy. The essential element of any of these parameters is that they are internally consistent. That is, the results from treated coolants are compared against those from untreated controls, and that over time they prove to provide reasonable predictions of biocide performance in the coolant system itself.

Test duration is another artifact of experimental design. When biocides are used as in-drum preservatives, or when coolant retention time in the system is long (greater than 30 days), then the six week interval is appropriate. Often, high drag-out and evaporation rates translate into retention times of one to two weeks. Under these conditions, speed of kill is often more important than persistence of effect. A modification of ASTM D 3946, "Evaluating the Bioresistance of Water-Soluble Metalworking Fluids," provides good predictability of biocide performance. The test is similar to ASTM E 696, except that it is run for only two weeks. Our laboratory modifies the procedure by sampling for viable counts after 24, 48 and 72 hours in addition to the intervals called for in the ASTM protocol.

When biocides are to be incorporated into a coolant concentrate, parallel test series should be run using concentrate to which biocide has been freshly added and concentrate which has been allowed to age for at least one month after biocide addition. Comparison of these two sets of data will indicate the relative stability of the biocide in the coolant concentrate. Some biocides lose more than 90% of their activity after two weeks storage in a coolant concentrate. This phenomenon may also be formulation specific. A biocide which is stable in one coolant may disappear rapidly in another.

ASTM E 979, "Evaluation of Antimicrobial Agents as Preservatives for Invert Emulsion and Other Water Containing Hydraulic Fluids," depends on both gross observations and viable titers. A conical screen is suspended in a beaker of aerated test fluid. The elaboration of visible slime on the screen simulates filter plugging. This indicates biocide failure, as do viable count recoveries of greater than 10^7 CFU bacteria or greater than 10^2 CFU fungi/mL.

The test procedures described above only estimate anti-microbial efficacy. Once an effective treatment is identified, additional tests should be performed to ensure that the biocide will not affect other fluid properties adversely. Emulsion stability, foaming tendency, lubricity, pH and anti-corrosive properties should be checked. Typically, by the time water is sent to waste treatment, the residual biocide concentration will not affect microbes in the waste treatment system. If there is a question, run biochemical oxygen demand (BOD) and chemical oxygen demand (COD) tests on the aqueous fraction from two coolant preparations; one biocide treated and one untreated. If the BOD:COD ratio is the same for both fluids, or if it is higher in the biocide treated fluid, then there is no problem. Some biocides may require pretreatment before they can be sent to waste treatment. Check with your biocide supplier for this information.

The ASTM recommended practices for safe handling of metalworking fluids (draft in committee) includes recommendations for acute toxicity, eye irritation and skin sensitization tests for the complete coolant package, including biocide. This is generally a sound investment, given the litigious society in which we live.

Biocides rarely function with constant efficacy in perpetuity. Bennett and his students have shown that metal fines affect biocide persistence adversely (Bennett et al., 1981), as do some filtration media (Onyekwelu and Bennett, 1979). At least three mechanisms promote the development of microbial populations which are resistant to a particular treatment regimen. As the biofilm develops, populations are protected from biocides to which the biofilm matrix is impermeable. Slow growing, biocide resistant species gain dominance once their biocide susceptible competitors are eradicated. Selective adaptation through mutation also occurs. Consequently, in the course of any biocide evaluation, treatments should be ranked. The treatment ranked as second best during initial evaluations may become the treatment of choice at some future time. The number of treatment options is unlikely to increase dramatically, given the economic and regulatory barriers to new product development.

Increasingly, combinations of two or more biocides are recommended as part of a treatment program. This may include augmenting the coolant concentrate with multiple biocides or combining an in-drum treatment with a tankside biocide addition program. This approach provides protection against a broader spectrum of microbes and increases treatment flexibility. An added benefit is often prolonged treatment efficacy.

Biocide Application

No biocide evaluation is complete until field performance has been evaluated. If the biocide has been incorporated into the coolant concentrate, the test is relatively simple. Is coolant life prolonged? Are there any new production problems attributable to the presence of the biocide package?

If biocide is to be added tankside, then operators must be trained to handle product safely and to know when to add biocide. Safe handling procedures are listed on the material safety data sheets (MSDS) which accompany biocide shipments. End users should have a master file of MSDS for all products used in their plant.

Operators should be trained to understand the information provided on MSDS and to follow the safe handling procedures as described. Criteria for biocide addition should be defined and promulgated to all personnel responsible for maintaining specified biocide levels. Operators should know how to obtain and interpret the data used to determine biocide requirements. They should be instructed on waste treatment considerations as well. Operators should also be required to maintain a record of all additions as well as the data on which the additions are based. These precautions will ensure that biocides are used in accordance with the manufacturers specifications and that plant employees are not placed at risk through biocide misuse or mishandling. Should a treatment program fail to provide adequate microbial contamination control, the accurate, complete records facilitate diagnostic efforts. Both formulators and their biocide suppliers can assist end users in providing the requisite training to operators.

Summary and Conclusions

Biocides are an integral component of most coolant life extension programs. Except for small machine shops with few, small capacity (less than 100 gallon) sumps, metalworking operations can realize cost savings by extending coolant life. There are many biocides available and registered for use as metalworking fluid preservatives. However relatively few are manufactured by companies that can offer the technical support to evaluate alternative treatments, provide application guidance and diagnostic support in the field. This kind of support is imperative unless the formulator or end user has resident expertise and facilities to perform these functions. Another important consideration in biocide selection is whether the product's reregistration is being supported. I know of several biocides which were previously registered for use in metalworking fluids but are not being supported in the EPA data call-in. These products have already or will shortly lose their registrations for this application, although they may retain registrations for other applications. Check with your biocide supplier to ensure that you are using only currently registered biocides.

The ASTM procedures for evaluating biocide performance have a good track record of predicting biocide performance accurately. When performing a biocide evaluation several treatments should be compared. Different biocides, biocide dose levels and biocide combinations should be compared against untreated controls. Biocide manufacturers are excellent resources for this type of testing. Efficacy testing should be augmented with compatibility testing, to ensure that effective treatments do not affect other coolant properties adversely. All bench tests should be confirmed through field experience.

The EPA registered biocides currently available provide safe, reliable coolant preservation when used as directed and selected in accordance with rationally conceived protocols. Education at the formulator, distributor and end user plant level is required to ensure that biocides are used safely and cost effectively.

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Frederick J. Passman, Ph.D.
Technical Field Service
Manager and Biocides
Business Manager
ANGUS Chemical Company
2211 Sanders Road
Northbrook, IL 60062
Phone 708/498-6700
Fax 708/498-6706

Frederick J. Passman received his A.B. in Microbiology from Indiana Univ. and his Ph.D. in marine microbiology from the Univ. of New Hampshire. Over the past ten years he has consulted and directed laboratory and field research in diverse areas of marine, environmental, industrial and public health microbiology. He has been involved in municipal and industrial sludge composting, microbial enhanced oil recovery, microbially induced corrosion, and the biodegradation of petroleum products; particularly metalworking fluids. Since 1981, Dr. Passman has devoted most of his attention towards solving and preventing rancidity problems in metalworking fluids. In August 1986 he joined ANGUS Chemical Company.

A wholly-owned subsidiary of Alberta Natural Gas Co. Ltd. of Canada, ANGUS Chemical Company is the world's largest manufacturer and worldwide marketer of nitroparaffins and their derivatives. ANGUS products offer application benefits in many industries, including paints and coatings, inks, cosmetics and personal care, metalworking, pharmaceutical, agriculture, petroleum production, fuel, water treatment, biomedical and textile chemicals. The Biocides Division provides a broad line of antimicrobial products for use in metalworking, adhesives, caulks, coatings, emulsion products and fuels.

Biocide Selection for Metalworking Fluids Factors to Consider

Cheryl B. French
Olin Corporation Research Center

Whether you are considering a biocide for inclusion in your concentrate or for tankside addition, the selection of the proper biocide is very important. There are four primary factors to consider prior to making that selection:

1. Biocidal Effectiveness. Do you require a bactericide or fungicide or both? Is it effective at low levels in controlling the organisms in the system? Does it retain its effectiveness over extended periods?

2. Chemical and Physical Properties. Does the biocide alter the chemical properties or performance of the fluid? Is the biocide inactivated by other components in the fluid? Does the biocide adversely affect the physical stability of the fluid?

3. Worker Safety. Does the biocide cause adverse reactions at required dosage levels?

4. Cost Effectiveness. Does the biocide provide the requisite combination of the first three factors, above, at an acceptable use cost?

The importance of each of these factors and how they affect your final decision are discussed below.

Biocidal Effectiveness

The term biocide is used to refer to both bactericides and fungicides. All biocides do not have equal effectiveness against bacteria and fungi nor do they have the same duration of biocidal activity. It is important first to determine if you require a bactericide, fungicide, or both. A sample of coolant from a contaminated system can be analyzed by standard plating techniques or dipslide to both quantify and classify organisms. These techniques are usually satisfactory for the bacterial population. Very often, however, these techniques will not give a representative reading of the fungal contamination. Visual inspection of solid surfaces may reveal the buildup of "slime." It is advisable to take scrapings of the "slime" for additional analysis to determine if it is composed of fungi and/or bacteria or simply a buildup of organic solids. Your biocide supplier can assist with this analysis.

At high enough doses, a biocide can effectively reduce microorganisms to undetectable levels. However, high doses are generally unnecessary, and are often undesirable in a coolant system. At relatively low concentrations, bactericides and/or fungicides can control growth and prevent runaway reproduction. In this way, the proper biocide can prevent the problems associated with too many bacteria or fungi in the fluid, without creating new problems involved in the exposure of workers to high levels of the biocide. Biocides may be harmful, in varying degrees, to humans—a factor which must be taken into consideration in the selection process.

For reasons of cost and worker exposure, a biocide should provide adequate control over a relatively long period of time. There are no universally accepted definitions of these terms, but there are some guidelines.

Adequate control. When added to a fluid, a biocide should effectively reduce microbial populations by a factor of 100 to 1000 times.

Duration of control. For reasons of worker protection and cost, biocides should be replenished only when there is insufficient biocidal activity to control the microbial growth. Ideally, the most desirable biocide would retain sufficient activity between makeup fluid additions or scheduled tankside additions of biocide. Unfortunately, the interaction and subsequent depletion of biocides in most systems is not that predictable. Constant testing and permanent record keeping will enable the formulator to determine use levels and enable the user to establish the best interval for regular tankside additions.

Field Isolate Testing. Compatibility and stability in the concentrate do not completely ensure that the combination of fluid and biocide will have the desired efficacy in the field. Full scale challenge tests should and can be done in the laboratory using field isolates to simulate the working system. Testing can be carried out at various dilutions, with various types and levels of biocides.

There are a number of standard tests which can be performed. Biocide manufacturers should be able to assist with lab support and with procedures for performing challenge testing on your fluid.

Chemical and Physical Properties

Formulated fluids contain a host of components: emulsifiers, pH stabilizers, coupling agents, lubricity agents, defoamers, corrosion inhibitors and extreme pressure additives...and biocides.

Most often, biocides are the last of these to be considered in a fluid formulation. It is important that the biocide does not inactivate the other fluid components and that it is not depleted by the other components in the fluid. Working with biocides that are compatible with the widest range of components vastly simplifies the formulator's job.

The amount and type of biocide needed to control growth is affected by the type of fluid (soluble oil, semi-synthetic, or synthetic) it will be used in, the nature of the contamination, the compatibility of the biocide with the components in the fluid and the conditions under which it must function. The biocide should be stable in the fluid concentrate for the expected shelf life of the concentrate and stable in the dilute fluid under expected operating conditions. Thus the decision as to which biocide to use does not depend totally on efficacy of the biocide, but also on its compatibility with the fluid and its effect on other fluid characteristics: pH, reserve alkalinity, foaming, corrosiveness, lubricity, solubility, emulsifiability, tramp oil rejection, odor and appearance. Even though the formulator knows the individual properties of his other components, the efficacy of the combination cannot be accurately predicted in advance. The formulator should still determine if the combination of the fluid and the biocide retains the desired efficacy and performance characteristics over the expected shelf life, and in use.

Compatibility. The addition of a biocide to a metalworking fluid should not cause any physical changes to the fluid—either while in the concentrate or after dilution. Even the absence of physical changes does not completely ensure compatibility. Compatibility testing or determining if the biocide is chemically degraded by the other components, and to what degree, is recommended in order to estimate the expected shelf life of the biocide in the concentrate. Again your biocide supplier can be of help, either by providing analytical methods or by conducting tests on your fluid.

Solubility. The biocide should be soluble in the fluid concentrate to ensure homogeneous additions of biocide when diluted. For tankside addition, water solubility is necessary to insure even distribution throughout the system and to prevent plate-out.

pH. Fluids are formulated to operate within a specific pH range. (Water-soluble fluids are usually alkaline.) The proper biocide should be active across the entire pH range of the fluid and it should not increase or decrease pH beyond the optimum range of the fluid. In the case of alkaline fluids, biocides which contribute to reserve alkalinity are preferred.

Thermal Stability. When included in a concentrate, a biocide must be stable within a wide range of shipping and storage conditions. After dilution, the biocide should retain effectiveness in the sump, where temperatures range from a few degrees above ambient in the winter to 43°C (110°F) or higher in summer.

Worker Safety

This is one of the most complex and sensitive issues in biocide selection. In addition to meeting all the criteria described above, the ideal biocide would be nontoxic to humans. The "ideal" biocide does not yet exist. So, the task is to find a bactericide and/or fungicide which have the best combination of high effectiveness and low toxicity...without being too expensive.

The toxicological profile and other health-related information pertaining to a biocide can best be found on the Material Safety Data Sheet (MSDS). A biocide with a favorable profile will have certain characteristics including:

- low toxicity from single or multiple exposures;
- lack of potential to cause skin sensitization;
- lack of potential to produce damage to developing offspring and genetic material;
- lack of potential to cause cellular changes, particularly cancer.

Additional information on the use of the biocide can be gained from the registration granted by the U.S. EPA and from the biocide supplier. The legal use of a biocide in metalworking applications in the U.S. requires an EPA registration. To obtain a registration, a biocide must be subjected to an extensive battery of toxicological tests including those referred to above.

A significant step forward in the safe use of biocides is to minimize the potential for exposure. An excellent way to achieve this goal is to use fluid concentrates containing long-lasting biocides which will help reduce otherwise frequent tankside additions.

Cost Effectiveness

Biocide expense or material cost to the metalworking fluid formulator may simply be calculated as the price per pound multiplied by the percent in the formulation. And if the formulator is providing biocide to the end user for tankside treatment as well, this cost would increase to include the price per pound times the tankside dose level times the frequency of addition.

The formulator, who must price his metalworking fluid in a competitive market and who may very often be required to provide tankside additives free of charge, may mistakenly choose a biocide simply by the price per pound in an attempt to minimize the overall use cost. On a price per pound basis, the biocide is usually the most expensive material in a formulation. However, on a use cost basis it can be one of the least expensive additives. Table 1 illustrates the cost breakdown of a typical synthetic formulation. In this analysis, the biocide contributes less than 9% of the total cost of the formulation. Thus, choosing a biocide simply on a price per pound basis may not be advantageous in the long term maintenance of a system. The cost of using either the wrong biocide, or not enough biocide to control microbial contamination, may far exceed the actual use cost of the proper biocide.

The expense of waste disposal and cleaning up a system, including downtime, the expense of premature replacement of machine tools and parts, and the expense of rejected parts is far more important to the end user than a few cents saved on the cost of the biocide. Biocide suppliers can provide efficacy testing to determine the proper level of biocide needed to provide optimum control at minimal cost.

In Summary

- Systems can be efficiently protected from bacteria and fungi by relatively low concentrations of biocide.
- The choice of biocide is determined by a host of interrelated factors, including solubility, pH operating range, chemical compatibility, thermal and physical stability...plus considerations of worker safety and cost effectiveness. The toxicity profile of the biocide is the key to making decisions involving worker safety.
- The properties of a metalworking fluid, and the performance of the biocide in it, cannot be predicted. Laboratory and field tests are required.

Table 1
Cost Analysis of a Typical Synthetic Fluid

Component	Amount(%)	$/lb	Use Cost $	Use Cost %
Corrosion inhibitor	15.00	0.90	0.135	40.1
Ethanolamine	15.00	0.50	0.075	22.2
Polyalkylene glycol	8.00	1.05	0.084	24.9
Fatty acid	2.00	0.65	0.013	3.9
Biocide	0.23	13.00	0.030	8.9
Water	59.77	—	—	—
Total	100.00	—	0.337	100.0

- Neither material cost (price per pound) nor use cost may be significant factors to an end user for whom system maintenance cost—the cost of cleaning up a contaminated system or prematurely replacing machines and tools—far outweighs the cost of using the wrong biocide.

Cheryl B. French,
Senior Applications Specialist,
Industrial Biocides
Olin Corporation
Research Center
350 Knotter Dr., P.O. Box 586
Cheshire, CT 06410-0586
Phone 203/271-4168
Fax 203/271-4351

Cheryl French provides technical support worldwide for sodium OMADINE® and the TRIADINE® antimicrobial product lines in industrial applications, with emphasis on the metalworking fluids industry. Ms. French received her B.A. in Biology from Anna Maria College (MA) and her M.S. in Chemistry/Biology from St. Joseph College (CT).

Olin Corporation's business is primarily chemicals, metals and applied physics, with special emphasis on electronic materials and services and defense/aerospace. The chemicals business segment consists of specialty chemicals including the OMADINE® and TRIADINE® antimicrobials, electronic chemicals, organic chemicals, pool chemicals, urethane chemicals and cleaning products and services. Olin Chemical is an associate member of the Independent Lubricant Manufacturers Association.

Cutting Fluids and Odors

E. O. Bennett and D. L. Bennett
University of Houston

Introduction

The vast majority of cutting fluids available today are quality products which have been carefully formulated to provide the characteristics desired by users. Unlike in the past when coolants were ideal growth media for microorganisms, today many products are reasonably resistant to microbial attack. Unfortunately, these statements can only be made in regards to the unadulterated diluted coolants as they are used in a laboratory.

When the user charges a dirty system with these premium products and then allows them to become contaminated with hydraulic fluids, oils, foreign matter and other filth, then anything can happen even to the best products, and in far too many instances it does.

Management of plants that use cutting fluids who are untrained in microbiology can see slime and they can smell odors. In a plant where there is no slime or odor, microbial counts can be extremely high, but this cannot be detected without using special techniques, and management is happy even though their coolant investment is deteriorating rapidly.

Foul smelling coolants can produce problems for management. Labor unrest can result in requests for OSHA inspections by workers. In at least one instance, a major user was given an air pollution citation because the odors from a circulation system reached nearby homes and the company was reported to air quality control authorities.

Nothing can produce problems between a user and a coolant manufacturer quicker than an odor or slime problem. Even if the coolant has performed for more than a year, coolant manufacturers can lose accounts because odor or slime develops in their products.

Importance of Odor

No matter how good the engineering qualities of a coolant, if it has a tendency to develop odors it often creates the impression of being an inferior product. In many countries, the stability and quality of a product is judged by its tendency to produce odors. Thus, coolants that do not produce odors even though they may have high counts, are considered to be the better products.

Types of Coolants and Odors Related to Them

There is no real relationship between the type of coolant and the odor produced. Under different circumstances, a specific product can develop a number of different odors. Petroleum base products seem to be associated with sulfide odors more often than synthetics; however, synthetic coolants are more likely to develop musty odors than petroleum products.

Most microbial odors in coolants result from the formation of a few types of chemicals. Most odoriferous compounds contain unsaturated bonds, amine groups and sulfur. These include mercaptans, skatoles, indoles and sulfides. Pseudomonads have been shown to produce methyl mercaptan, 3-methyl-1-butanol, butanone and 2-methoxy-3-isopropyl-pyrazine (Miller et al., 1973). Odoriferous compounds found in working coolants have been identified as 2,6-dimethyl-3-methoxypyrazine (Mottram et al., 1984), 2-butene-1-thiol, dimethyl disulfide and dimethyl trisulfide (Yasuhura et al., 1986).

Relationship Between Odor Formation and Microbial Counts

There is no relationship between the development of an odor and microbial counts. Considerable stench has been produced by coolants that have reasonable or even low counts. On the other hand, there are coolants that commonly contain high microbial counts but they rarely produce odors. It has been noted that products that contain considerable amounts of borax, or materials such as oil of pine or oil of sassafras have less tendencies to produce odors.

It is important to remember that not all deteriorated coolants have an offensive odor. There are numerous instances where a coolant loses stability or corrosion control, yet the product does not smell rancid. Odor is an imperfect test of determining the status of a working coolant.

Sometimes the presence of an early morning musty odor is a warning that shortly one will be able to observe slime in the system.

Odor and the Presence of Specific Microorganisms

It has never been demonstrated that one single species of organisms is responsible for an odor problem in cutting fluids. It is believed that odor formation is the result of a number of different organisms attacking a product.

Certain organisms can be associated with specific odors at times. Hydrogen sulfide can be produced by any sulfate-reducing organism including *desulfovibrio*[3], *clostridium*[1], *proteus*[6], *escherichia* and *klebsiella* species.[13] Putrid odors can be produced by *pseudomonads* and *archromobacter* species[7] while musty odors can be produced by *escherichia, aerobacter, proteus* and *klebsiella* organisms.

Testing a Coolant for Odor Problems

Unfortunately, some cutting fluid products do have a tendency to smell bad. In addition, there are other coolants that if contaminated by foreign organic matter, will produce considerable odor.

It is easy to determine if a product has a tendency to generate strong odors. Place a sample of the diluted coolant in a bottle and add a small amount of corn meal and a small amount of used coolant to the container. Cap the bottle and let it stand in a warm dark place for two to three days, and then smell it. This simple test can tell you what the coolant may smell like after use in your plant.

Odor Sources

When odors develop, often the fluid has spoiled and the problem must be corrected by discarding the old coolant, cleaning the system and adding a fresh charge. The problem of rancid coolant usually is obvious.

The most difficult odor problems occur in situations where housekeeping practices are adequate, where reasonable effort is made to keep the system clean and free of foreign matter and the coolants are functioning satisfactorily. Yet, there is a persistent level of off odor which is not overpowering but is noticeable and disconcerting to workers and management. It is an embarrassment to the coolant manufacturer who often tries to control it by biocide treatment. No matter what is done it continues to persist within the plant.

Listed below are some of the practices than can produce odors in working coolants.

Non-Biological Odors

Odors can be formed in coolants as a result of spontaneous chemical reactions. Petroleum base products in contact with iron chips can produce hydrogen sulfide.[7] Sulfur containing coolants can produce significant odors even in the absence of microorganisms. Fatty acids can have disagreeable odors. Some products contain masking chemicals to overcome the real odor of a product. With time, the masking chemical may no longer be effective and the true odor of the product becomes evident. Some preservatives can produce odors in coolants.

The addition of foreign materials, particularly those which contain nitrogen, greatly increases the capacity of coolants to produce odors.

The Ammonia Flush

In recent years, there have been instances when central systems suddenly produce significant amounts of ammonia.[10] This phenomenon has been attributed to the action of microorganisms[8] even though no one has been able to produce an ammonia flush under laboratory conditions using microorganisms from a system where it has occurred.

Several factors seem to be associated with the problem. First, the metal being worked is most often cast iron. Second, the corrosion inhibitor is commonly organic in nature. The coolant often contains boron compounds. Sometimes there has been a major addition of a biocide shortly before it occurs. In many instances, the biocide has been a triazine compound, however, in one case it was Kathon 886.

Usually, an "ammonia flush" occurs once sometime after recharging a system. In one instance it occurred then disappeared and then occurred again about one and a half months later in the same product. The problem lasts from six to 48 hours and then disappears. It is suspected that it is caused by an interaction of nitrogen compounds in the fluid with ferrous particles.[11]

When it occurs there is:

1. A drop in pH of the coolant.
2. Some coolants change from transparent to opaque.
3. Filterability becomes poor, settling of particulates appears hindered and the filter cake mat on the wedge wire filter becomes slushy and loses the ability to entrap fine particles. Examination of the particulate shows an abundance of crystalline material, calcium salts and aluminum oxide, but the majority of the particulates have not been identified.[11]
4. Corrosion control by the coolant does not appear to be adversely affected.

Since chlorine reacts with ammonia to form chloramines,[6] it might be possible to add some chlorine liberator such as chlorine dioxide to a system to remove the problem. At this time, this technique has not been tried in a plant to the authors' knowledge.

System Design

Major fluid drops within a building can be the source of odor problems. A falling fluid tends to release excessive odors that would not be noticeable if this did not happen. Even short drops can lead to only a few hundredths of a ppm.

Pits are major sources of odor when coolants start to turn rancid. Placing pits away from the workers usually greatly reduces complaints. Sometimes, where there is a pit room it is possible to exhaust the odor through the roof without fouling the work areas. When large pits are involved, supervisors must be careful discharging large quantities of off odors when the plant is near residential areas. This is particularly true during times when there is little wind or during a climatic inversion.

Odors are more common in machines with individual sumps and machines that are used only intermittently.[7]

Plant Ventilation

Odor problems can be caused by poor plant ventilation. Almost all coolants have some odor which can be described as being neutral, pleasant or unpleasant. This odor tends to build up within a building when ventilation is poor. Improvement in air movement can solve many odor problems.

Some odor problems are related to energy costs. Most air systems are designed to supply a minimum of replacement air in the interests of energy economy. With so much recirculation of the same air, odors tend to build up more often today in plants where this has not been a problem in the past.

Odors and Flow Rates

It is well known that pumping the coolant at all times can markedly reduce odor problems. Generally, microbial growth in a flowing coolant does not result in the production of odoriferous chemicals. Off odors are most likely to be produced in a coolant that is stagnant; however, this may not be noticeable until the pumps are activated.

Flow rates can be a factor and influence odor buildup within a plant. Low flow rates tend to produce more odor than higher rates. Sometimes increasing flow rates can have a remarkable effect upon reducing odor problems. It should be remembered that in the absence of an effective coolant control program, increased flow rates will often increase the biodeterioration of the fluid even though no odors are produced.

Coolant Temperature

Hot coolants tend to produce more odor than systems working at lower temperatures. One of the most common ways that a coolant can heat up involves loss of volume.[12] Due to sludge buildup in the sump, the volume of flowing coolant is decreased which increases the temperature of the lubricant. A second factor that can influence temperature and odor formation is the adding of more work shifts in a plant. Increasing production by adding a second shift and particularly a third shift can increase the coolant temperature and make odors more noticeable to workers. As a rule, sump temperature should be kept around 20°C whenever possible.[12]

Tramp Oils and Hydraulic Fluids

Tramp oil contamination can produce odor problems. The oil forms a blanket over the coolant and during periods when the system is shut down, foul odors can form in the coolant. Odor problems become apparent as soon as circulation is started.

Sometimes a hydraulic fluid leak into the coolant can produce an oil cap even in a circulating system in any place where there is little or no movement. Even though the coolant is working, odors can form in areas where there is reduced flow.

While no research has been done to support the observation, some hydraulic fluid brands are often associated with odor problems in specific coolants. Certain hydraulic fluids turn up often in situations where coolants develop off odors even though tramp oil is not excessive. This observation may be related to the sulfur or phosphorous content of the hydraulic fluid because it has been noted that these materials increase microbial growth and odor problems[7] in coolants.

Using Biocides

If the problem is caused by microbes, the addition of a biocide will usually require 12 to 24 hours before the organisms are affected. The odor problem is now, and adding a biocide will have no immediate effect upon it. The coolant must be treated for the odor, and then steps can be taken to reduce the microbial population.

Deodorizers

While electronic deodorizers are commonly used in a number of industries where odors can be a problem, very few coolant users have considered this practice for their plants. Most of these units are ozonizers and small generators that produce three to six grams of ozone per hour have been available for many years. It has been claimed that their use reduces energy costs because less outside air is required to keep the environmental air fresh.

Boron Compounds

Boron compounds such as borax have been used for many years to sweeten coolants. The amount required depends on the coolant, the amount of odor, the quality of ventilation and other factors. For these reasons, each plant must develop its own treatment technique. It is wise to consult the coolant manufacturer in order to determine if borax is compatible with the product. Borax should be dissolved in water and then added to the system while it is circulating.

Some formulations have been suggested in the literature concerning the use of boron compounds. It has been claimed that a coolant can be regenerated (deodorized) by the addition of 0.1 percent by weight of a mixture containing 40 parts sodium borate, 40 parts sodium perborate and 20 parts sodium carbonate.[14] A second formulation that has been suggested consists of 45 percent sodium perborate, 50 percent sodium percarbonate, 3 percent EDTA trisodium and 2 percent tetrasodium pyrophosphate.[5] The material is used at a concentration of about 2000 ppm, and the authors are aware of several groups who have found that this is a very satisfactory product for reducing odors in coolants.

It should be remembered that there is at least one report in the literature which indicates that borax can reduce the antimicrobial properties of chemical agents.[4] Therefore, it may be difficult to treat the coolant effectively with a preservative after borax has been added to the product. On the other hand, sodium metaborate increases the antimicrobial properties of alkaline solutions.[4]

TABLE 1
EFFECTS OF BORAX ON THE ANTIMICROBIAL PROPERTIES OF CUTTING FLUID PRESERVATIVES

	Concentration	Percent increase (+) or decrease (-) in inhibitory activity from controls
Borax	1666 ppm	Exhibited no inhibitory activity
Tris Nitro	1000 ppm	-24
Milidin TI-10	1000 ppm	-32
Grotan	1000 ppm	-38
Bioban P-1487	1000 ppm	+71
Ucarcide 250	1000 ppm	*
Grotan HD II	1000 ppm	-22
Triadine 10	1000 ppm	*
Tektamer 38	1000 ppm	-46
Kathon 886	100 ppm	*

Results are calculated from means of duplicate determinations with 5 fluids diluted 1-40.

* No significant difference - less than ± 10%.

Table 1 shows the effects of borax on a number of common cutting fluid preservatives. It may be noted that borax reduces the action of formaldehyde releasers, Grotan HDII and Tektamer 38, but has no significant effect upon the action of Ucarcide 250, Triadine 10 and Kathon 886. The material significantly increases the antimicrobial properties of Bioban P-1487.

Chlorinated Deodorants

Chlorinated deodorants such as anthium dioxide in very low concentrations have a remarkable capacity to produce working coolants with pleasant odors. Chlorinated deodorants should be used carefully and not excessively. They are chemically reactive but do not exert any effect on coolants until the free, uncombined chlorine level exceeds 0.3 ug/ml (Shannon, 1983). Chlorine additives can produce traces of hydrochloric acid in a coolant which may stain tools or machined parts. As far as is known, the use of such products in coolants does not constitute a human health problem (Crow, 1981).

Conclusion

There is no real relationship between the type of coolant and the odor produced. Under different circumstances, a specific product can develop a number of different odors. Petroleum base products seem to be associated with sulfide odors more often than synthetics, while synthetic coolants are more likely to develop musty odors than petroleum products.

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Dr. E. O. Bennett
University of Houston
P.O. Box 42103
Houston, TX 77042
Phone 713/749-3541

Dr. E. O. Bennett is a professor of biology at the Univ. of Houston. His education included degrees from the Univ. of Houston, Univ. of Iowa and Baylor College of Medicine.

Over the past 40 years, he has published a number of papers pertaining to microbial problems encountered in metalworking fluids. Dr. Bennett is a Fellow of the STLE and the American Academy of Microbiology.

Metalworking Fluid Additives for Waste Minimization

Jean C. Childers
Climax Performance Materials Corporation
and
Shu-Jen Huang and Michael Romba
Nalco Chemical Company

Introduction

Waste disposal of metalworking fluids is a major issue confronting the metalworking industry. Rising costs of waste disposal and environmental concerns are forcing fluid users to choose products for their ease of disposal. In addition, metalworking fluids that provide long tank life through product stability and fluid maintenance can reduce the frequency of disposal. For many users, waste disposal is the key criterion for fluid evaluation. The idea is simple: the less waste produced, the less disposal required.

Terms

The requirements on effluent waters are based on ease of separation and degradation of chemical additives in metalworking fluids. The following describes the parameters checked and the significance of each.

Biochemical Oxygen Demand (BOD)

This standard can estimate the degree of contamination in an industrial water supply. BOD is a test that determines the oxygen required for waste waters for biochemical degradation of organic material (carbonaceous) and inorganic materials like sulfides and ferrous iron. It may also measure the oxygen used to oxidize reduced forms of nitrogen unless this is prevented by an inhibitor.[1] BOD is important because high values lead to oxygen depletion which leads to fish kills in rivers and lakes. The BOD value is dependent on time over which a test is run.

Chemical Oxygen Demand (COD)

COD is a measure of the oxygen equivalent from strong chemical oxidants that can degrade organic material.[1] The COD value is independent of time. One sample gives one result. Chromate and sulfuric acid systems are used to oxidize the carbon and hydrogen in organic additives. Nitrogen in alkanolamines and inhibitors are not oxidizable. This value does not correlate with the BOD value since it does not differentiate stable from unstable organic matter.

The ratio of BOD to COD is often used as an index of waste disposability, where a high BOD:COD ratio is desired.

Fats, Oils and Grease (FOG)

For most cities, there should be no floatable grease of any origin. Solid greases can cause obstruction to the flow in sewers. Therefore, all floatable grease should be eliminated. Other oils, fats, or fatty acids whether emulsified or not, in excess of on the average 150 mg. per liter, detected by freon extraction, are prohibited. Mineral oils and other nondegradable hydrocarbons are the source of the problem. Vegetable oils and animal fats are degradable in waste treatment facilities. However, they are regulated because excess amounts could overload the seed-bacteria degradation system, solidify or become viscous, thus interfering with the waste water system. The freon extraction test will solubilize many other organic additives, making low FOG requirements difficult to achieve.

Total Suspended Solids (TSS)

TSS is the solid floating or dispersed material in the effluent which can be filtered. It is not a total chemical solids measure.

Geographical Requirements

Manufacturing facilities that use chemicals such as metalworking fluids, cleaners, cooling water, and paint booth flocculants ultimately discharge these solutions to their local sewer with or without treatment to remove chemicals.

FIG. 1

GEOGRAPHICAL WATER DISCHARGE REQUIREMENTS

CITY	pH	Max PPM FOG (Fats, Oils, Grease)
Chicago	5-10	250
Cincinnati	6-10	50*
Cleveland	5-10	250
Dallas	5.5-10.5	100
Detroit	5-10	2000
Indianapolis	5-10	200
Los Angeles	5.5-11	600
Miami	5.5-9.5	100
Milwaukee	5.5	100*
Minneapolis	5-10	100
Newark	5-10.5	100
New York	5-9.5	50*
Pittsburgh	5-10	200
St. Louis	5.5-10.5	100

*Non-degradable hydrocarbons
vegetable & animal fats higher

Each facility must comply with local ordinances as well as state and federal EPA requirements regarding the quality of water discharged to the sewer. If the user discharges directly to a waterway, the requirements are much stricter. This is necessary to protect the environment as well as the public's health and safety.

The local regulation is to prevent introduction of pollutants into the waste water system which will either interfere with the treatment system (POTW) or pose a hazard to the health and welfare of the public. The municipal requirements vary based on the capabilities of the treatment system and in EPA standards set for the municipality. Figure 1 summarizes the discharge requirements.

Each municipal area has specific requirements for pH and FOG (fats, oils, and grease). Generally, a pH in the range of five to ten units is required while the FOG values average around 150 ppm. Detroit is unusual with its less than 2000 ppm maximum level. However, Detroit has a surcharge for any FOG over 100 ppm. Conversely, a smaller city like Trenton, MI requires less than 25 ppm FOG. There are special requirements for each area. Detroit requires less than 500 ppm phosphorous.

There are no limits on BOD, TSS or COD in many major publicly owned treatment works (POTW). However, through property taxes and surcharges, the user pays a sewerage commission to process his water. The higher the organic and solids loading, the higher the user's surcharge. Users are assessed based on total volume, BOD, TSS and nitrogen content. Other pollutants often limited are various metals, phenols, and halogenated organics. The temperature of the effluent should not exceed 150F for most POTWs. Each user industry may have special requirements and restrictions for disposal of its effluent based on SIC (Standard Industry Classification) code.

Waste Treatability of Additives

The primary emphasis in minimization of waste from metalworking fluids is in formulating fluids with additives that are easy to waste treat by most systems.

This study focused on thirty-one of the most prevalently used additives in the metalworking fluids industry. (See Appendix 1.) Although there are many variations on similar chemistries supplied to compounders, only one of each type was evaluated.

The following emulsifiers, lubricants, and corrosion inhibitors were evaluated by a waste treatment chemical company for their relative waste treatability:

Emulsifiers

Natural Sodium Sulfonate MW-470
Synthetic Sodium Sulfonate MW-475
Sulfonate Base
Alkyl Sulfamido Carboxylic Acid Salt
Octyl Phenol Ethoxylate HLB 10.4
Nonyl Phenol Ethoxylate HLB 13.4
Alkali Fatty Acid Soap
2:1 DEA Tall Oil Fatty Acid Alkanolamide
2:1 DEA Lard Oil Alkanolamide, Soaped
Glycerol Monooleate
Sorbitan Monooleate

Corrosion Inhibitors

Triethanolamine
Alcohol Amines Monoethanolamine Borate Ester
Amine Dicarboxylate Salt
Aryl Sulfamido Carboxylic Acid
Alkyl Amido Carboxylic Acid
Calcium Sulfonate/Additive Blend

Lubricants

Inverse Soluble Ester
Complex Polymeric Fatty Acid
Sulfated Castor Oil
Block Polymer of Ethylene Diamine
Block Polymer of EO & PO
Reverse Block Polymer of PO & EO
Random Polyalkylene Glycol
Acid Grafted Polyalkylene Glycol Salt
Phosphate Ester (Low Phenol)
Phosphate Ester (Ethoxylated Alcohol)
Phosphate Ester (Ethoxylated Phenol)
Amphoteric Carboxylate Salt
Imidazoline

Test Procedure

All additives were tested at a concentration of 1000 ppm in a synthetic oil waste emulsion. This emulsion is a typical representation of the waste stream before treatment in an automotive plant. It is a combination of oils, cleaners, hydraulic fluids, and surfactants diluted to 5000 ppm. Large metalworking fluid users conventionally treat their fluids either by acid/alum split or by charge neutralization with polyelectrolytes. This test program used the polyelectrolyte method because it produces less sludge and is more cost effective.

The chemical treatment consisted of a cationic coagulant, caustic, alum, and an anionic flocculent. (See Appendix 2.) The optimum dosage of the coagulant was determined by jar testing each additive with varying dosages until optimum clarity was obtained. The alum, caustic, and flocculent levels were held constant at typical use levels.

Figure 2 shows the TEA neutralized acid grafted polyalkylene glycol. This additive gave excellent clarity at the same treatment level as the emulsion and has a very wide "window" of effective clarity. This means waste treatment engineers can use a wide range of chemical treatment. There is more tolerance for application variation. The resulting water was then tested for residual chemicals in solution. In this case, although the dosage rating and tur-

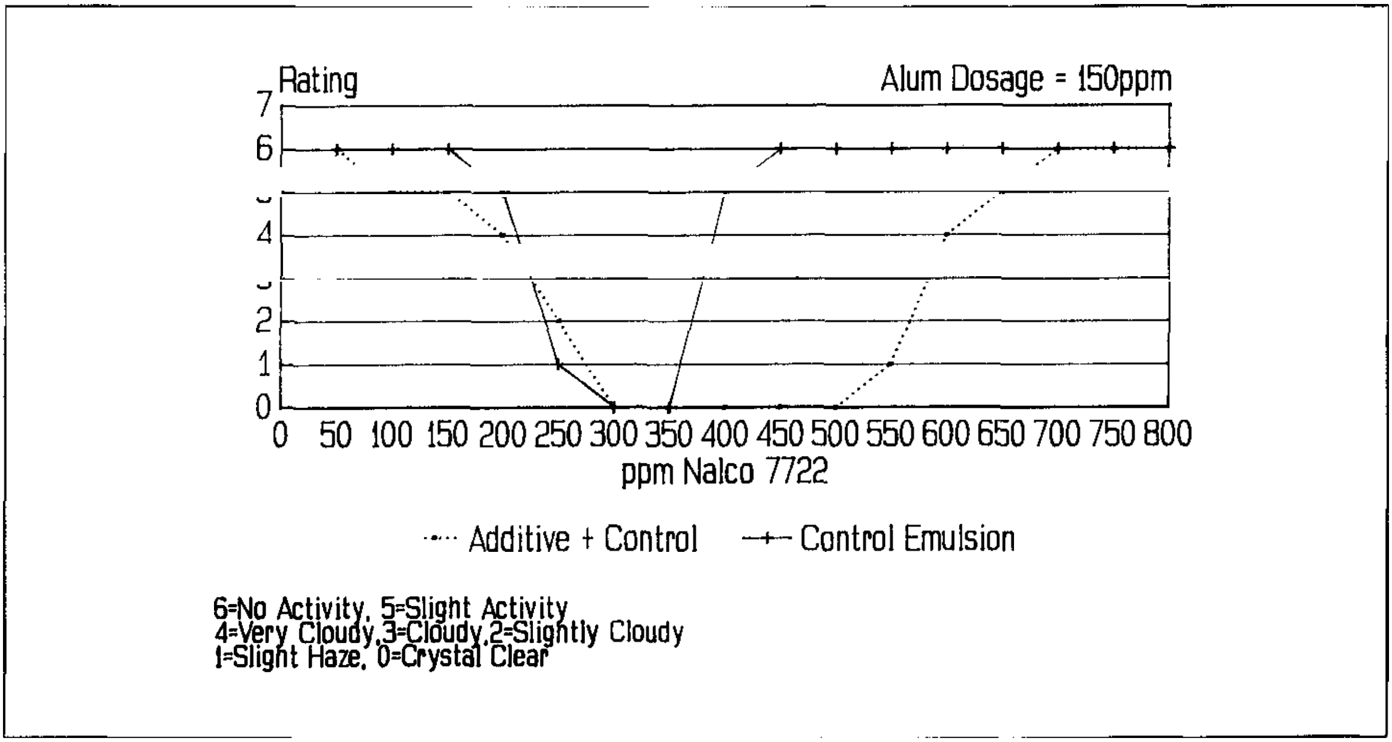

Figure 2. Waste Treatability Study 1000 ppm. TEA/Acid Grafted Polyalkylene Glycol

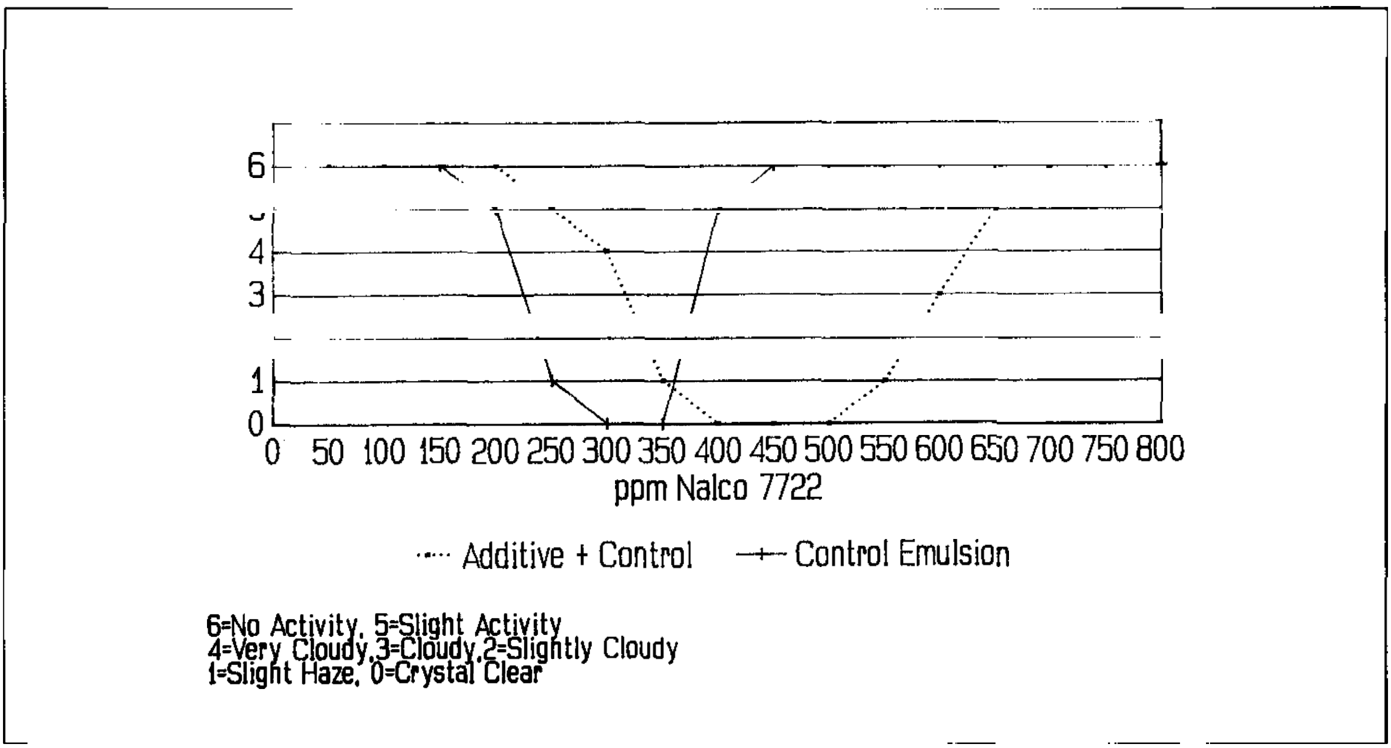

Figure 3. Waste Treatability Study 1000 ppm. Potassium Soap

bidity rating are excellent, the COD tested high because this very water soluble lubricant was not split out of solution. Figure 3 shows an alkali fatty acid soap with good clarity after treatment but at a slightly higher treatment rate requirement of coagulant.

Figure 4 shows the inverse soluble ester. Regardless of the level of coagulant tested, clarity was not good. This indi-

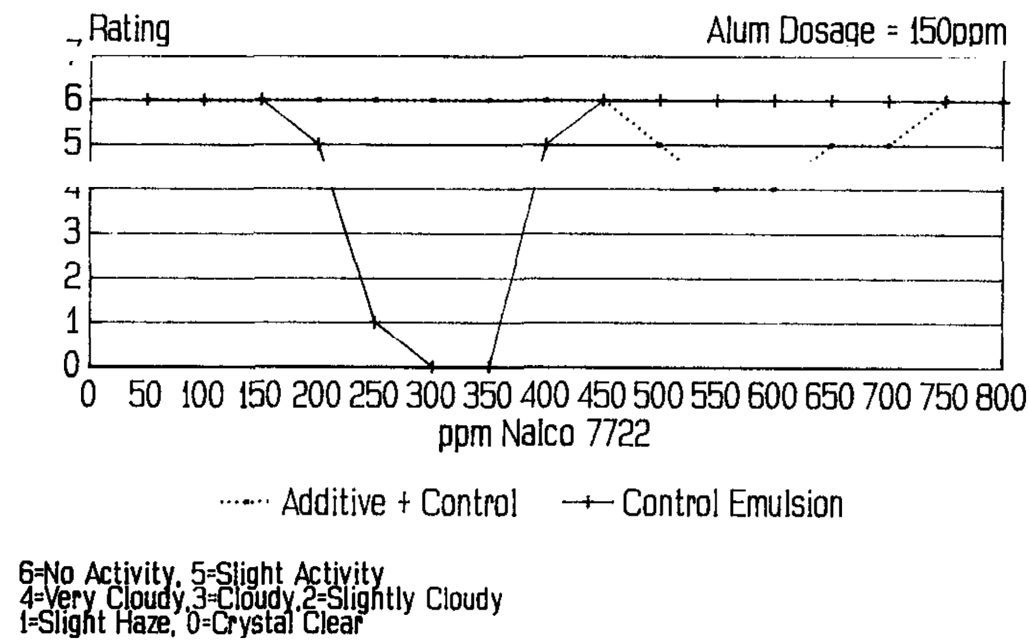

Figure 4. Waste Treatability Study 1000 ppm. Inverse Soluble Ester

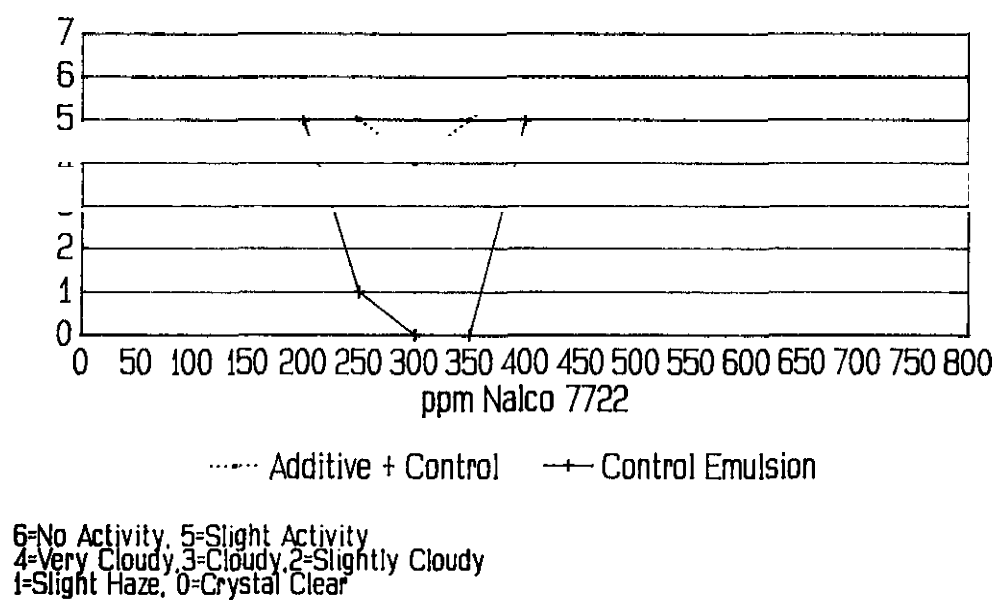

Figure 5. Waste Treatability Study 1000 ppm. Imidazoline

cates the chemicals were not removed by the waste treatment process.

This polyelectrolyte system is a commonly used method for treating automotive chemical effluent. However, because the cationic charge on the coagulant is used to remove additives, the cationic imidazoline additive was most difficult to treat. Figure 5 shows the turbidity after treatment.

The remaining water at the optimal treat rate was then tested for turbidity, COD, and FOG. The COD test analyzes both oxidized and non- oxidized organic matter. The biological oxygen demand (BOD) on the other hand only measures the ability of bacteria to digest some of the organic matter. The COD therefore reveals the total amount of oxidized organic contaminants contained in the water. The absolute turbidity, COD and FOG values are shown in Figure 6.

In general, because emulsifiers have both oil and water solubility, they are the easiest to treat with an average FOG of 81 and COD of 1443 excluding the high HLB ethoxylate coupling agent.

The corrosion inhibitors, most of which are water soluble, showed FOG average of 81 and COD of 2165. These figures were higher because these compounds are more water soluble than the emulsifiers. The amine dicarboxylate was excluded from the average. It was not very treatable in this system, leaving carboxylic acids behind to give an escalated FOG and COD.

The synthetic lubricants were the most difficult to treat. The block polymers are nonionic additives with very high water solubility. Some of the very water soluble additives such as block copolymers did not respond to this treatment process as evidenced by the high COD values. They do vary however in FOG values primarily due to the cloud points of each material. The materials with the higher cloud points were less soluble in the freon extraction. The inverse soluble ester combined with the control emulsion, tying up both additives, and produced high FOG and COD. Conversely,

FIG. 6

ADDITIVES	TREATMENT	AFTER TREATMENT		
1000 ppm	Coagulent ppm	Turbidity N.T.U.	FOG ppm	COD ppm
Control	300	2.75	10	694
Emulsifiers				
Natural Sodium Sulfonate	750	5.20	48	1149
Synthetic Sodium Sulfonate	500	11.00	67	1009
Sulfonate Base	500	3.70	160	1754
Alkyl Sulfamido Carboxylic Salt	700	3.50	55	1243
Octyl Phenol Ethoxylate 10.4	500	4.95	100	1265
Nonyl Phenol Ethoxylate 13.4	350	390.00	256	6115
Alkali Fatty Acid Soap	400	3.50	83	1642
2:1 DEA Fatty Acid Amide	450	14.00	28	1834
2:1 DEA Fatty Amide	550	6.00	93	1922
Glycerol Monooleate	300	5.40	101	1336
Sorbitan Monooleate	350	3.30	72	1279
Corrosion Inhibitors				
Triethanolamine	350	4.70	64	3024
Alcohol Amines	300	7.30	88	2030
Amine Borate	350	3.30	75	2377
Amine Dicarboxylate	300	5.20	1175	2413
Arylsulfamido Carboxylic Acid	300	3.90	99	2408
Alkyl Amido Carboxylic Acid	300	5.60	100	1684
Calcium Sulfonate/Blend	350	5.90	60	1222
Lubricants				
Inverse Soluble Ester	550	260.00	224	4742
Complexed Polymeric Fatty Acid	450	7.20	140	1397
Sulfated Castor Oil	600	3.60	103	1284
BlockCopolymerEthyleneDiamine	300	2.20	104	3039
Block Copolymer	350	2.70	98	3454
Reverse Block Copolymer	350	2.90	532	3434
Random Polyalkylene Glycol	350	4.20	720	3294
TEA/Acid Grafted Poly Glycol	300	2.60	104	3202
Phosphate Ester-Low Phenol	350	5.45	73	2805
Phosphate Ester (Alcohol)	400	20.00	108	2335
Phosphate Ester (Phenol)	300	12.00	68	2782
Amphoteric Carboxylic Salt	450	3.00	66	1248
Imidazoline	300	1000+	2290	5208

the anionic polymeric fatty acid, sulfated castor oil, and the amphoteric carboxylic salt were waste treatable.

Using the following rating scales, these results can be analyzed to determine the relative waste treatability of key metalworking fluid additives.

COAGULANT DOSAGE INCREASE	RATING
0 ppm	10
1 - 50 ppm	9
51 - 100 ppm	8
101 - 150 ppm	7
151 - 200 ppm	6
201 - 250 ppm	5
251 - 300 ppm	4
301 - 350 ppm	3
351 - 400 ppm	2
401 - 450 ppm	1
451+ ppm0	

The rating used for the COD, FOG and the turbidity are as follows:

COD RATING		FOG RATING		TURBIDITY RATING	
0-400 ppm	10	0-25 ppm	10	0- 3.0	10
401-800 ppm	9	26-50 ppm	9	3.1- 5.0	9
801-1200 ppm	8	51-75 ppm	8	5.1-7.0	8
1201-1600 ppm	7	76-100 ppm	7	7.1- 9.0	7
1601-2000 ppm	6	101-125 ppm	6	9.1-11.0	6
2001-2400 ppm	5	126-150 ppm	5	11.1-13.0	5
2401-2800 ppm	4	151-175 ppm	4	13.1-15.0	4
2801-3200 ppm	3	176-200 ppm	3	15.1-20.0	3
3201-3600 ppm	2	201-300 ppm	2	20.1- 50.0	2
3601-4000 ppm	1	301-500 ppm	1	50.1-100.0	1
4001+ ppm	0	501+ ppm	0	100.1+	0

The final rating was based on a weighted formula which takes into account the COD, FOG, turbidity and optimum dosage. The formula used in this analysis is as follows:

(10 percent x dosage rating) + (20 percent x turbidity rating) + (35 percent of COD rating) + (35 percent x FOG rating) = Final Rating.

This formula places a heavy emphasis on the COD and FOG results, since these are the most important factors to a waste treatment facility. However, it is important to note that each user has specific priorities based on a particular system and municipality requirements. Figure 7 shows the additives with their waste treatment values rated. These ratings are not absolute and should be viewed in general terms of (1) easy to treat; (2) moderate treatment; and (3) difficult to treat as shown in Figure 8.

Other additives conventionally used in metalworking fluids exist but were not tested. These include glycol ethers, oil soluble lubricants, biocides, and fungicides.It is common knowledge that glycol ethers used as coupling agents in soluble oils and semi- synthetics are not very waste treatable. Again, their extreme water solubility and capacity for pulling in other additives into the water phase makes them "undesirable" in this waste treatment system.

Oil soluble lubricant additives like chlorinated paraffin and lard oils were also not tested. It was assumed that since they have no water solubility, they would be treatable as long as the emulsifier system is treatable in the metalworking fluid.

Biocides and fungicides hinder the decomposition of a fluid by killing the bacteria that biodegrades the chemicals. Therefore, if the fluid is to be tested for waste treatability, biocides should be removed. In actual use, a biocide usually will be consumed prior to disposal, and, due to the dilution factor in the total effluent of the plant, the efficacy of the biocide is negligible.

The dilution factor of a fluid in the entire waste treatment stream for a plant should be considered when evaluating BOD/FOG values. A FOG value of 100 in a metalworking fluid treated in a lab would decrease after dilution in the total plant's effluent.

Keep in mind that the combination of additives in a particular fluid may act differently than the sum of the individual components of a waste stream. Later, we will combine this waste treatability of metalworking fluid additives with other waste minimization factors.

Disposability by Fluid Type

In general, soluble oils are easier to treat than synthetics or semi- synthetic fluids. Because additives are water insoluble or only dispersable in water, separation is easier by conventional means that were designed to treat emulsions. The more water soluble an additive, the more difficult it is to treat. Therefore, synthetic fluids that contain water soluble and, in many cases, nonionic additives and alkanolamines are more difficult to treat. Chemicals which remain in the water phase contribute to organic loading and resulting high FOG, COD, and BOD levels of the plants' effluent.

Many plants have treatment facilities that are set up to handle only soluble oils and synthetics with anionic chemical additives. These products readily split with acid or polyelectrolyte methods of treatment. Most other synthetics

FIG. 7

Additive	Dosage Increase Rating	Turbidity Rating	FOG Rating	COD Rating	Final Rating
Control	10	10	10	9	9.65
Emulsifiers					
Natural Sodium Sulfonate	1	8	9	8	7.65
Synthetic Sodium Sulfonate	6	6	8	8	7.40
Sulfonate Base	6	9	4	6	5.90
Alkyl Sulfamido Carboxylic Salt	2	9	8	7	7.25
Octyl Phenol Ethoxylate 10.4	6	9	7	7	7.30
Nonyl Phenol Ethoxylate 13.4	9	0	2	0	1.60
Alkali Fatty Acid Soap	8	9	7	6	7.15
2:1 DEA Fatty Acid Amide	7	4	10	6	7.10
2:1 DEA Fatty Amide	5	8	7	6	6.65
Glycerol Monooleate	10	8	6	7	7.15
Sorbitan Monooleate	9	9	8	7	7.95
Corrosion Inhibitors					
Triethanolamine	9	9	8	3	6.55
Alcohol Amines	10	7	7	5	6.60
Amine Borate	9	9	8	5	7.25
Amine Dicarboxylate	10	8	0	4	4.00
Aryl Sulfamido Carboxylic Acid	10	9	7	4	6.65
Alkyl Amido Carboxylic Acid	10	8	7	6	7.15
Calcium Sulfonate/Blend	9	8	8	7	7.75
Lubricants					
Inverse Soluble Ester	5	0	2	0	1.20
Complexed Polymeric Fatty Acid	7	7	5	7	6.30
Sulfated Castor Oil	4	9	6	7	6.75
Block Copolymer (Ethylene Diamine)	10	10	6	3	6.15
Block Copolymer	9	10	3	2	4.65
Reverse Block Copolymer	9	10	0	2	3.60
Random Polyalkylene Glycol	9	9	0	2	3.40
TEA/Acid Grafted Poly Glycol	10	10	6	2	5.80
Phosphate Ester - Low Phenol	9	8	8	3	6.35
Phosphate Ester (Alcohol)	8	3	6	5	5.25
Phosphate Ester (Phenol)	10	5	8	4	6.20
Amphoteric Carboxylic Salt	7	10	8	7	7.95
Imidazoline	10	0	0	0	1.00

can be degraded by bioactivity, but it is very expensive, and users are not willing to invest in a facility change. This situation has been a driving force in the trend to increased soluble oil coolant use. However, synthetics usually offer longer tank life with more resistance to bacterial attack and product instabilities. Longer sump life leads to lower disposal frequency and can thus be cheaper. Ideally, the formulator needs synthetic additives that are waste treatable with long tank life.

Biodegradable Coolants

It is often not enough to simply formulate a metalworking fluid with waste treatable additives. The fluid must also be compatible with the rest of the plant's waste stream. Some additives, when tested alone for treatability look good, but in the waste stream they may emulsify oils or other organic chemicals making a new combination that is not so easy to treat. Likewise a difficult to treat emulsifier already in the waste stream could emulsify components of the coolant causing problems for the waste treatment engineers. For example, five of the additives tested in the control emulsion for residual COD after chemical treatment were tested again by themselves at 1000 ppm with no treatment. COD values of individual additives are not cumulative.

The COD of the difficult to treat additives when combined with the control emulsion were significantly higher than the

FIG. 8

East	Moderate	Difficult
Emulsifiers		
Natural Sodium Sulfonate	Sulfonate Base	Nonyl Phenol Ethoxylate HLB 13.4
Synthetic Sodium Sulfonate	2.1 DEA Fatty Amide	
Octyl Phenol Ethoxylate HLB 10.4		
Alkyl Sulfamido Carboxylic Salt		
Sorbitan Monooleate		
Glycerol Monooleate		
Alkali Fatty Acid Soap		
2:1 DEA Fatty Acid Amide		
Corrosion Inhibitors		
Calcium Sulfonate/Blend	Aryl Sulfamido Carboxylic Acid	Amine Dicarboxylate
Amine Borate	Triethanolamine	
Alkyl Amido Carboxylic Acid	Alcohol Amines	
Lubricants		
Amphoteric	Sulfated Castor Oil	TEA/Acid Grafted Poly Glycol
	Phosphate Ester Low Phenol	Phosphate Ester, Alcohol
	Phosphate Ester Phenol	Inverse Soluble Ester
	Complexed Polymeric Fatty Acid	Random Polyalkylene Glycol
	Block Copolymer	Reverse Block Copolymer
	(Ethylene Diamine)	Block Copolymer
		Imidazoline

FIG. 9

Additive	COD of 1000 ppm Additive Alone Without Treatment	COD of 1000 ppm Additive & Control Emulsion After Treatment
Nonyl phenol ethoxylate HLB 13.4	2334	6115
Inverse soluble ester	2244	4742
Amine dicarboxylate	1506	2413
Imidazoline	2503	5208
Natural Petroleum Sulfonate	2593	1149

COD of the additive by itself before treatment. For example, the COD of the control emulsion after treatment was only 694. By adding 1000 ppm of an additive with a COD before treatment of 2334 as in the nonylphenol ethoxylate, one would assume a COD of no more than 3028. However, in reality it jumps to 6115, after treatment. Conversely, the sodium sulfonate had a lower COD after treatment because it was removed easily from the emulsion without complications. (See Figure 9)

Therefore, a systems approach is required at the end user level which starts at the point of the waste treatability of the fluids additives.

Many compounders of metalworking fluids claim their fluids are biodegradable, meaning they are quickly and easily decomposed by microorganisms or natural environmental factors. Many organic chemical additives used in synthetic fluids have high BOD:COD ratios and are considered biodegradable. Semi-synthetic and soluble oils are not easily biodegraded because of their mineral oil content. In general, linear molecules are more degradable than aromatic molecules.

However, even though a fluid is biodegradable in the drum, it can easily emulsify tramp oil once in use, making it no longer biodegradable. A simple shake test with oil and the synthetic fluid can be misleading. The shear forces in the cycling of fluid through the operations can easily disperse or emulsify tramp oil into the fluid.

FIG. 10

CLEAR	STABLE HAZE	HAZE/SCUM
Emulsifiers		
Octyl phenol ethoxylate HLB 13.4	Alkyl sulfamido carboxylic acid salt	2:1 DEA fatty amide
	Octylphenolethoxylate	Natural petroleum sulfonate
	2:1 DEA fatty acid amide	Synthetic petroleum sulfonate
		Alkali fatty acid soap
		Sulfonate base
Corrosion Inhibitors		
Triethanolamine		
Amine dicarboxylic acid		
Alkyl sulfamido carboxylic acid		
Aryl amido carboxylic acid		
Amine borate		
Alcohol amine		
Lubricants		
Block polymer	Complexed polymerized acid	
Reverse block polymer		
Ethylene diamine block polymer	Sulfonated castor oil	
TEA/acid grafted poly glycol	Amphoteric carboxylate salt	
Random block polymer	Imidazoline	
Phosphate ester low phenol		
Phosphate ester (alcohol)		
Phosphate ester (phenol)		
Inverse soluble ester		

Three additives were insoluble in water. Calcium sulfonate/blend, glycerol monooleate, and sorbitan monooleate, therefore, were not tested for hard water stability.

Also, some hydraulic fluids contain additives that may act as emulsifiers or dispersing agents. In the end, most all metalworking fluids in the waste effluent stream must be treated before disposal to the sewers. The total organic loading, BOD, and FOG are the determinants on the user's cost for disposal.

Maximize Coolant Life

In addition to formulating products with additives that are easy to treat, there are other ways to minimize waste from metalworking fluids. By maximizing the usable life of the fluid, disposal is less frequent resulting in less waste.

From a formulation standpoint, one can look at the hard water stability of metalworking fluid additives. The more stable the additive is to calcium and magnesium salts, the longer the tank life of the fluid. The key metalworking fluid additives were tested for their hard water stability. Each was diluted at 1000 ppm in 500 ppm $CaCl_2$ synthetic hard water and was observed after 24 hours for any haze or separation. The performance is reported in Figure 10.

The additives with the best hard water stability are mostly nonionic emulsifiers and lubricants, and alkanolamine based additives. These additives are more difficult to treat due to their extreme water solubility. The additives with the worst hard water stability were soaps and sulfonates. Conversely, they are easy to waste treat with acid/alum or polymer systems.

The additives that gave a stable haze may be the best middle of the road additives, providing moderate hard water stability with moderate waste treatability.

Some of the additives were hazy because they are emulsifiers with water dispersability only.

Fluid Maintenance

In addition to formulating with additives that are stable in hard water for longer tank life, users can greatly limit disposal with good fluid maintenance. This practice became very popular in the early 1970s with the skyrocketing cost of oil. In addition to lowering coolant costs, good fluid maintenance can lower the costs of downtime and waste disposal. Prudent additions of biocides, fungicides, pH adjusters, and sequestrants can lengthen the fluids' useful life. Biocides and fungicides will control the growth of microorganisms that will deteriorate the chemicals in the fluid. Biodegradable additives for easy waste treatment are

FIG. 11
WASTE TREATABILITY

HARD WATER STABILITY	EASY	MODERATE	DIFFICULT
EXCELLENT	Amine borate Alkyl amido carboxylic acid	Block copolymer-ethylene diamine Aryl sulfamido carboxylic acid Triethanolamine Alcohol amines Phosphate ester (low phenol) Phosphate ester (phenol)	Acid grafted polyglycol salt Random polyalkylene glycol Reverse block copolymer Block copolymer Amine dicarboxylate Phosphate ester (alcohol) Inverse soluble ester
GOOD	Octyl phenol ethoxylate HLB 10.4 Alkyl sulfamido acid salt 2:1 DEA fatty acid amide Amphoteric carboxylate	Sulfated castor oil Complexed polymeric acid	Imidazoline
FAIR	Natural sodium sulfonate Synthetic sodium sulfonate Alkali fatty acid soap	2:1 DEA fatty amide Sulfonate base	

Not included calcium sulfonate/blend, glyceryl monooleate, sorbitan monooleate.

also degradable by bacteria in the systems. By killing the bacteria, one can use waste treatable additives.

pH adjusters like sodium hydroxide and ethanolamines can raise the pH to the preferred 8.8-9.0 range to help hinder bacteria growth, maintain rust protection and emulsion stability. Ethanolamines have better pH buffering capabilities but are more costly.

Sequestrants chelate calcium and magnesium ions that cause water hardness allowing emulsions to reemulsify and synthetic soaps to resolubilize. Care should be used to not exceed the treat level requirement. An excess of sequestrant will cause rust by chelating the metal. More importantly from a waste treatment point of view, excess sequestrant will also tie up metal ions making them difficult to remove in the waste treatment system.Mechanical systems that can recycle the coolants, by removing swarf and tramp oil can also help extend the life expectancy of a metalworking fluid.

By combining waste treatability ratings with hard water stability results, waste minimization results are given in Figure 11.

The best additives tested for both waste treatability and hard water stability were the amine borate and alkyl amido carboxylic acid synthetic corrosion inhibitors. The amine borate is also a known biostat, which further increases its attractiveness. The alkyl amido carboxylic acid was not neutralized before being added to the control emulsion. A neutralization with caustic soda would most likely retain the performance here, but an alkanolamine neutralization will reduce its waste treatability to the moderate to difficult range.

After review of the matrix, the formulator can choose the additives to include in a product based on the customer's needs for waste minimization. Other parameters such as product performance and cost would round out the formulator's evaluation.

Disposal Costs and Risks

Metalworking fluid users have several options in disposal methods. The most expensive method is to have the fluids hauled away for treatment by a waste treatment company. Costs range from $0.30 per gallon in the Midwest up to $1.00 per gallon on the East and West Coasts. Without treatment to remove the chemicals, the total volume of a 10,000 gallon system could cost $10,000 to dispose of. This practice can also be somewhat risky. It could result in a Superfund situation if a disposal site cleanup becomes necessary. Whether you have disposed of a pound or a ton of waste, you can be a potentially responsible party. Choose your waste hauler carefully.

FIG. 12

USER CHARGES 1989

Municipality	BOD $/LB.	TSS $/LB.	FOG $/LB.	TOTAL FLOW $/MM GALS.
Chicago	0.080	0.087		93.*
Cincinnati	0.153	0.089		1123
Cleveland	0.080	0.131		1310
Detroit	0.102	0.116	0.031	782
Indianapolis	0.086	0.097		1188
Newark	0.057	0.038		240

Treating the waste metalworking fluid prior to disposal to the sewers is the most common choice. The sludge from the treatment is the volume which must be disposed, not the total coolant volume. The cost of disposing nonhazardous sludge is about $70 per cubic yard. It is then mixed with garbage in a disposal site. There are small scale processes that can allow even a small user to treat his fluids. Ultrafiltration and centrifuges to separate oil and chemicals can also reduce the organic chemical loading prior to disposal.

Evaporation is another option for waste minimization. If the user has enough property to aerate effluent water in a lined pond, disposal volumes are reduced. Another option is to use the waste heat from plant operations to drive the evaporation of the fluids. These practices may work well for small volume users.

If the user chooses to dispose of his fluids directly to the sewer without treatment, the initial cost may seem low. However, the user may have to pay the POTW surcharges for total flow, BOD, COD, TSS and FOG. Therefore, if the fluids are not treated to remove the chemicals, the user's costs can become significant. Figure 12 shows typical user charges for six major metalworking cities. Increasingly, the costs of disposal are mandating means of waste minimization.

Conclusion

It can be frustrating to the metalworking fluid compounder who strives to make fluids that are easily waste treated by various disposal systems. Conceptually most methods can treat the anionic, sparingly water soluble additives. There are systems available for splitting or treating all the chemistries available. However, not all users have a given system, or will invest in a new system. The fluids must match the disposal system in most cases. By formulating with additives with generally good tank life expectancy that are easily treated in the waste stream, the metalworking fluid compounders can minimize the amount and cost of waste treatment.

References

1. Standard Methods for the Examination of Water and Wastewater, fifteenth edition, p. 485 (1980).

2. Ibid, p. 489.

APPENDIX 1

IDENTIFICATION OF METALWORKING ADDITIVES

Additive	Tradename	Supplier
Natural Sodium Sulfonate MW-470	Actrabase PS-470	Climax/Morco
Synthetic Sodium Sulfonate MW-475	Synacto 406	Exxon Chemicals
Sulfonate Base	Actrabase 31-A	Climax/AMAX
Alkyl Sulfamido Carboxylic Acid Salt	Bohrmittel Hoe	Hoechst Celanese
Octyl Phenol Ethoxylate HLB 10.4	Triton X-45	Rohm & Haas
Nonyl Phenol Ethoxylate HLB 13.4	Triton N-101	Rohm & Haas
Alkali Fatty Acid Soap	Kricinol 35	Climax/AMAX
2:1 DEA Tall Oil Fatty Acid Alkanolamide	Actramide 202	Climax/AMAX
2:1 DEA Lard Oil Alkanolamide, Soaped	Actramide 410	Climax/AMAX
Glycerol Monooleate	Mazol GMO	Mazer/PPG
Sorbitan Monooleate	S-MAZ-80	Mazer/PPG
Triethanolamine	TEA	Texaco Chemical
Alcohol Amines	Inhibitor #3	Oxid
Monoethanolamine Borate Ester	Actracor M	Climax/AMAX
Amine Dicarboxylic Salt	Alox 232	Alox Corp.
Aryl Sulfamido Carboxylic Acid	Hostacor H	Hoechst Celanese
Alkyl Sulfamido Carboxylic Acid	HOE S 2732	Hoechst Celanese
Calcium Sulfonate/Additive Blend	Alox 575	Alox
Inverse Soluble Ester	Inversol 140	Keil/Ferro
Complex Polymeric Fatty Acid	Lube Booster	Keil/Ferro
Sulfated Castor Oil	Actrasol C-75	Climax/AMAX
Block Polymer of Ethylene Diamine	Tetronic 904	BASF
Block Polymer of EO & PO	Pluronic L-43	BASF
Reverse Block Polymer of PO & EO	Pluronic 17R2	BASF
Random Polyalkylene Glycol	UCON ML-1281	Union Carbide
TEA Acid Grafted Polyalkylene Glycol	UCON EPML-X	Union Carbide
Phosphate Ester (Low Phenol)	Maphos 8135	Mazer/PPG
Phosphate Ester (Ethoxylated Alcohol)	Actrafos 110	Climax/AMAX
Phosphate Ester (Ethoxylated Phenol)	Actrafos SP-407	Climax/AMAX
Amphoteric Carboxylate Salt	Miranol LMSF	Miranol
Imidazoline	Miramine OC	Miranol

APPENDIX 2

TEST PROCEDURE CHEMICALS

Cationic coagulant	Nalco 7722	Nalco
Anionic flucculant	Nalco 7768	Nalco

Jean C. Childers
Climax Performance
Materials Corp.
7666 West 63rd Street
Summit, IL 60501
Phone 708/458-8450
Fax 708/458-0286

Jean Childers is the director of sales with Climax, a raw material supplier to metalworking fluid compounders. Using her B.S. in chemistry and M.B.A. in marketing, she has served the industry in the areas of product development, lab management, sales and marketing. In addition to her involvement in ILMA, Ms. Childers is a member of, and frequent speaker for STLE and SME on topics such as industry analysis and trends, and formulation guides for metalworking fluids.

Climax Performance Materials is part of AMAX, a Fortune 200 company focused in the base metals industry. The Fluids Additives Group manufactures a broad line of functional additives for metalworking fluid compounders, including emulsifiers, rust inhibitors, and lubricant additives.

Shu-jen W. Huang
Nalco Chemical Company
One Nalco Center
Naperville, IL 60563-1198
Phone 708/305-1000

Shu-jen W. Huang received her B.S. degree in Chemical Engineering from Cheng Kung Univ. in Taiwan and a M.S. degree in Organic Chemistry from the Univ. of Rochester. She joined Nalco in 1981 and has worked in several application areas including water clarification, sludge dewatering, general and heavy metal waste treatment, oily waste, waste oil treatment, spray booth water treatment and maintenance. Ms. Huang is currently technical director for the Automotive Chemicals R&D Group at Nalco Chemical Company in Naperville.

Michael A. Romba
Nalco Chemical Company
One Nalco Center
Naperville, IL 60563-1198
Phone 708/305-1000

Michael A. Romba received a B.S. degree in Chemistry from Purdue Univ. in 1985. He joined Nalco in 1988 and has worked in several application areas including heavy metal waste treatment, oily waste, waste oil treatment, and spray booth water treatment. Mr. Romba is currently a chemist for the Automotive Chemicals R&D Group at Nalco.

Nalco Chemical Company, a Fortune 500 company, is one of the world's largest producers of specialty chemicals and services for water and waste treatment, pollution control, petroleum productin and refining, papermaking, mining, steelmaking, metalworking and other industrial processes. Nalco water and process treatments are marketed in nearly 130 countries worldwide. Nalco is an Associate member of the Independent Lubricant Manufacturers Association.

An Overview of Filtration Technology

Jean M. Berger
and
Jill M. Creps
Henry Filters, Inc.

Introduction

Years ago it was common to use machine tool coolants for a short period of time then dispose of them. This did not require any elaborate means of chip removal since the coolant was not used for more than a week. As the cost of coolants increased, it became beneficial to remove the contaminants and prolong the use of the fluid. Recently, the cost of disposal and the environmental concerns have increased, so frequent disposal is no longer an economical option for even those who use small amounts of fluid. The purpose of the following discussion is to acquaint the reader with the various types of equipment available for particle removal from metalworking fluids. A brief discussion of the engineering required to design a unit that will adequately remove chips from a system will follow. The last section describes maintenance practices that should be followed to properly maintain a system once it has been installed.

The term filtration often refers to the process performed by any equipment used for the removal of solid contaminant from metalworking fluids. This usage is incorrect; filtration is the process of filtering, which differs from separation. Those devices involving separation remove the particles by virtue of their physical characteristics, for example, differences in their specific gravity. Filtration requires the use of a barrier to remove particles from the path of coolant flow. Figure 1 lists examples of both types of particle removal devices.

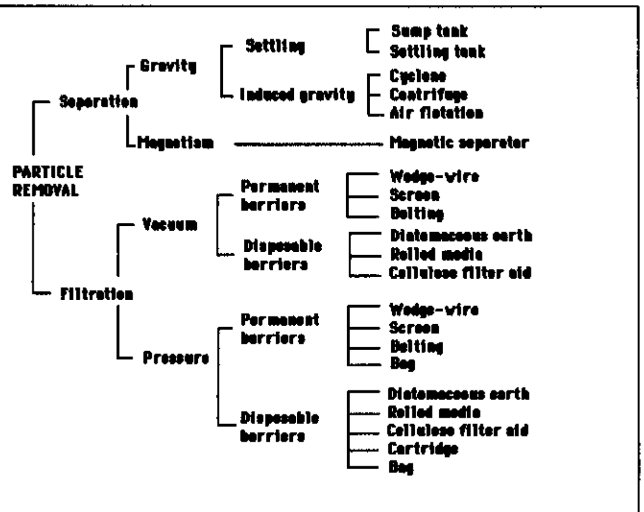

Figure 1. Division of equipment used to remove particles from metalworking fluids. The division is based on the method of particle removal. Separation uses a physical characteristic of particles while filtration uses a barrier to stop the particles. The equipment is further divided by the specific characteristic or barrier used.

Figure 1

No discussion of filtration would be complete without a brief examination of most types of particle removal equipment. Before examining these different types, it is important to understand the difference between separation and filtration, and other terms associated with filtration.

Separation - removes the particles from the fluid using a characteristic of the materials, i.e. density or magnetism. Separators randomly remove particles. A certain size of particle removal cannot be guaranteed.

Filtration - removes particles by passing coolant through a physical barrier (septum). Filtration will remove all particles of a certain size. The filters may be rated by either an absolute or nominal scale.

Absolute - all particles of the size listed will be removed. For example, a filter with a Micron Rating of 50 would remove all particles 50 um or greater.

Nominal - an average of the particle sizes remaining in the fluid under good operating conditions. For example, a filter with a Micron Rating of 50 would remove most particles greater than, and some particles less than 50 um, but the average size of the particles remaining in the fluid would be 50 um.

Micron - non-technical term used for micrometer (um), which is the scientific unit of measurement for 0.001 millimeter (mm). Figure 2 shows the measurement in um of known items.

Examination of the equipment required for particle removal will begin with the simplest types of equipment and progress to the more complex. This will be done by first examining separation equipment, followed by an examination of filtration equipment. This discussion will be restricted to equipment used to remove particulate from metalworking systems and will not describe any other forms of filtration. Throughout this discussion, the term "machine" will be used to refer to any type of machining or grinding center.

Separation Equipment

The simplest systems involve the use of reservoirs, or sump tanks that hold the coolant, allowing some particle settling before the coolant is returned to the machine. These sump

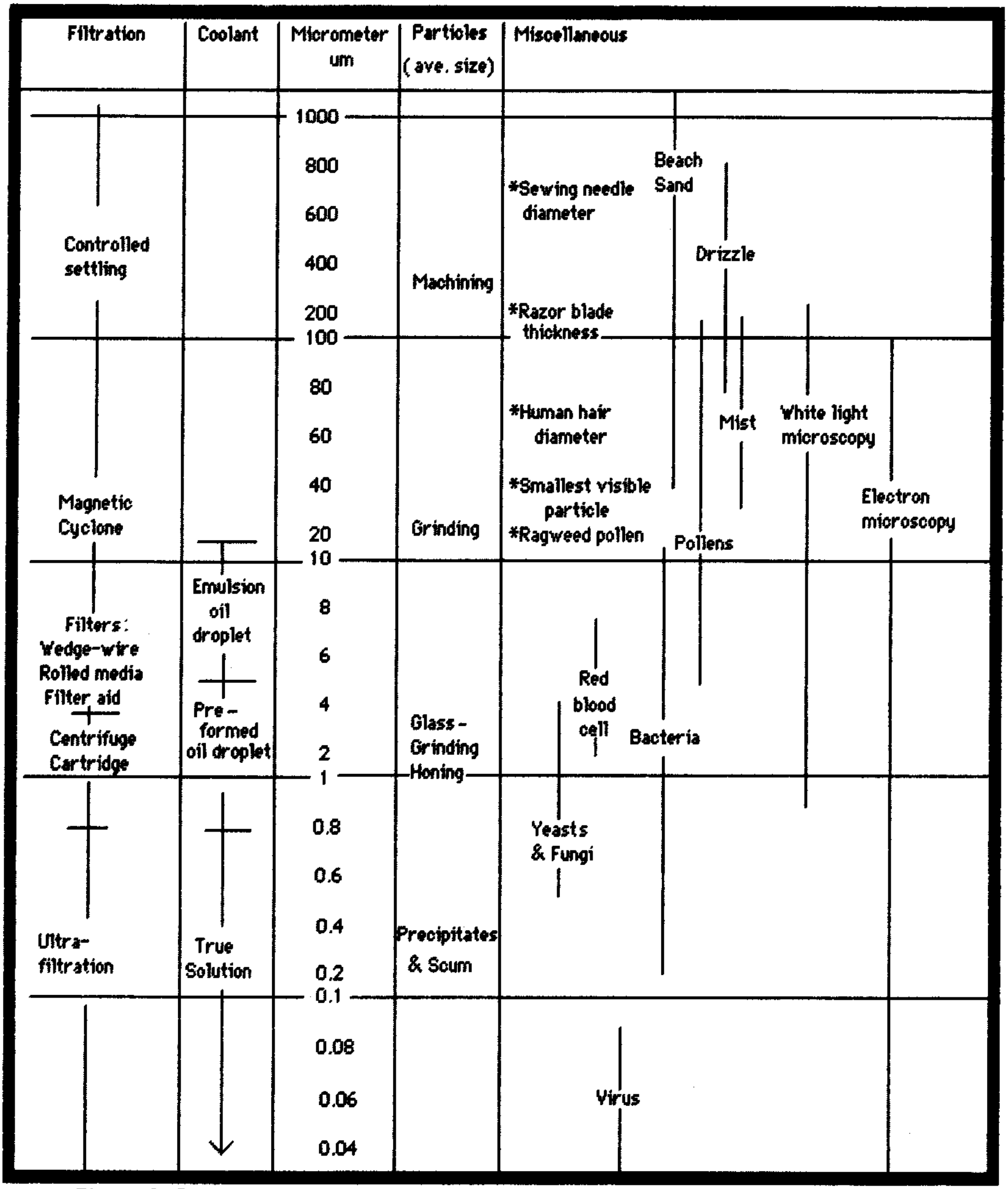

Figure 2. Relative size of particles generated in metalworking processes. When examining these with a light microscope the micrometer (um) scale is used. This figure shows the relative sizes of the particles, emulsified oil droplets and areas where various particle removing equipment is effective. The sizes of various known biological objects are included as a comparison to the particle sizes (5).

tanks generally have no automatic method of removing the chips from the tank, and they must be shovelled out. Chip removal from the tank may include a chip collecting basket that can be lifted from the tank. There are usually some chips that by-pass the basket, remaining in the tank to be shovelled out. Chip removal from a poorly designed system may require that the fluid be drained from the tank and the machine shut down before the chips can be removed. The cost in lost production, whether this is due to an employee removing chips instead of making parts or shutting down the machine, dictates that an improved system be used.

One improvement on this simple sump tank is the addition of the drag chain which automates the chip removal process. The sump tank with a drag chain for chip removal is called a drag tank. This eliminates shutting down production for chip removal since the drag chain will continuously remove the chips. Adding the chain allows the tank size to increase, which enables the tank to accommodate multiple machines. Drag tanks should be constructed of steel to allow for coolant control, as components from concrete may leach into the fluid and microorganism growth can be uncontrollable. The chip drag can only remove particles that fall to the bottom. To enhance the effectiveness of a drag chain unit enhancement of settling is necessary.

An improvement to a drag tank is the addition of baffles or weirs which reduce turbulence in the tank and allow the particles to settle out. This type of system, sometimes called a separator, uses the process called controlled settling. Particles that should settle and the size of the tank needed to allow this settling can be predicted. The baffles and weirs in these units enhance particle settling, allowing two changes to the design. The first could be a reduction in tank size, compared to the drag tank, since the time required for the coolant to remain in the tank is shortened. Another change could be an increase in the number of machines supplied by one separation unit. An example of a separator is shown in Figure 3.

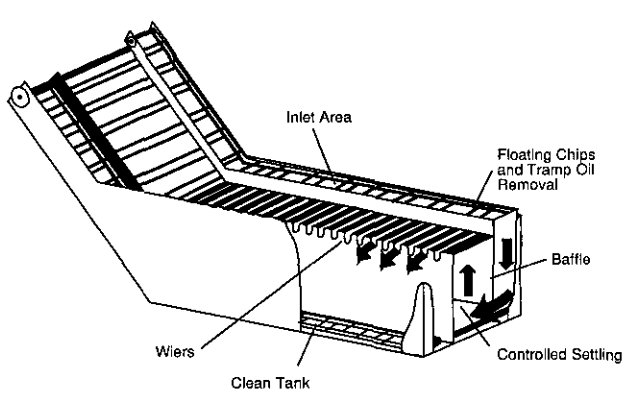

Figure 3. Schematic of a controlled settling separation unit. The baffles and weirs slow the coolant flow through the unit which allows the particles to settle.

Figure 3

A separator with baffles and weirs does have some drawbacks. It requires a physical difference in the density of materials to separate the contaminant from the coolant; materials that have greater differences in density will work better in this type of system. The time required for particles greater than 15 um to settle is a minimum of seven to ten minutes in the best systems. Removal of particles less than 15 um is difficult with most metals because other contaminants, such as air bubbles or oil droplets, will make these chips more buoyant. The tank size can sometimes be prohibitive, since the size of the tank must increase to improve settling of smaller particles. While the baffles and weirs aid in this settling, it is still dependent on the time the coolant remains in the tank. The tank size will increase to allow the coolant to remain in it longer. Regardless of these improvements, it is still possible that particles of all sizes will remain in the coolant and large particles could still plug the line to the machine.

The most common problem with this type of equipment is that the flow through the unit is greater than the capacity for which it was designed, so the particles do not have time to settle. Also, over a period of time, coolant changes occur which may inhibit particle settling. Settling can be affected by contaminating chemicals, some of which destroy the surface tension of the coolant, while other contaminants coat the chips, making them buoyant.

Other methods of separation have been applied to coolant filtration. Most of these "units" require the use of a drag tank for removal of the majority of large contaminant and any fines that are collected the device. These devices include hydrocyclones, centrifuges, magnetic separators and air flotation units.

A cyclone is a device which uses induced gravity to separate materials with a greater density from materials with a lesser density. This process was originally developed for gas/solid separation, but now has been applied to liquid/solid separation. Hydrocyclones use the velocity of the coolant as it enters the unit to produce a vortex which forces metal particles to the outer edge of the unit, while clean fluid moves towards the center of the unit. Figure 4 shows the coolant flow through a hydrocyclone. The large, dense particles are removed from the clean fluid, but those particles of equal or lesser density remain suspended.

In a system utilizing a hydrocyclone, coolant from the machine returns to a reservoir, typically a drag tank, where large particles can be removed. A pump in the reservoir sends the coolant through a nozzle tangentially aligned with the cylindrical upper portion of the cyclone. The nozzle arrangement imparts a centrifugal motion to the liquid[4] creating a vortex. The vortex causes the particles to move toward the outer edge of the cyclone.

The vortex at the outer edge of the cyclone has a downward descent. This pulls the particles toward the bottom of the cyclone. The coolant moves down until it reaches the apex or opening at the bottom. The opening at the bottom of the cone is not large enough to allow total release of all coolant, therefore, the liquid in the center of the cone swells upward and out the top.[2] A portion of the coolant exits the bottom with the larger particles. This discharge is collected in a separation tank where the particles settle out and most of the coolant returns to the reservoir. The speed of the vortex can be varied by varying the velocity of the coolant as it enters the cyclone. Higher velocities enhance particle separation. The particle removal efficiency of the equipment can also be enhanced if flexible hose is used to collect and route the coolant as it leaves the top of the cyclone.[1] Typical system designs have a bank of cyclones piped to a common header. The piping arrangement is often perpendicular to the top discharge of the cyclone, which results in destroying the vortex of the coolant as it leaves, sending shock waves through the liquid in the cyclone. The flexible hose maintains the vortex and flow of the coolant until it enters the clean reservoir eliminating the shock waves.[1]

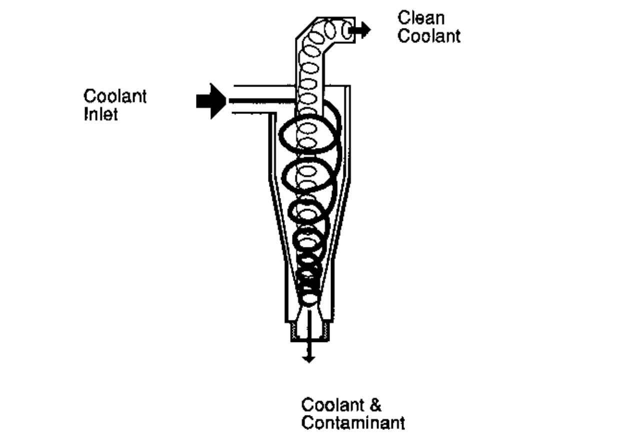

Figure 4. Typical flow through a hydrocyclone. Coolant spirals down toward the bottom, then reverses direction and raises toward the top. The force created by the spiralling coolant moves metal particles to the outer edge and down to the opening where they can leave the unit.

Figure 4

One advantage of this type of system is that there are no moving components in the cyclone. This would indicate that maintenance would be slight, however, prior removal of particles large enough to plug the apex is not always adequate. This creates the need to check the apex daily to ensure it is not plugged. A second maintenance problem that exists is eroding of the apex, which increases the size of the opening and decreases the efficiency of the unit. Replacement of the worn apex is necessary to restore the efficiency of the hydrocyclone. An added advantage of the cyclone is that the forces which exist inside are conducive to emulsification, which helps to stabilize an emulsified coolant. However, this emulsification can cause tramp oils to be emulsified into the coolant.

Another type of gravity separator is the centrifuge, shown in Figures 5 and 6. While the forces used to remove particles are the same as those used in the hydrocyclone, the equipment used to create the gravity forces in the coolant inside the centrifuge differs. Unlike the cyclone, the centrifuge contains moving components. The coolant is pumped into the bowl of the centrifuge which rotates at high speeds. Periodically the bowl and operation are stopped to purge the centrifuge of accumulated particles. The centrifugal force can be the same as that produced by the hydrocyclone, but the fluid can be held at this high gravity for a longer period of time which enhances the separation.[2] Centrifuges are most effective when materials to be separated have great differences in density, such as glass grinding sludge and water based coolant.

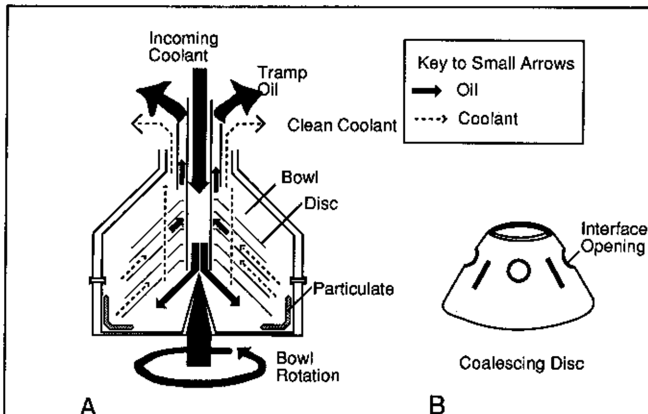

Figure 5. A. Schematic of a centrifuge commonly used for tramp oil removal. This Centrifuge will remove some fine particulate, if it is more dense than the fluid. The arrows show the passage of coolant through the unit.
B. Drawing of a typical coalescing disc used to aid in the separation of the tramp oil from the coolant. The opening in the surface of the disc should be placed at the interface of the tramp oil and coolant where separation occurs.

Figure 5

Unlike the hydrocyclone, the centrifuge has the ability to prevent emulsification, and to remove either tramp oils or particulate from the coolant. Centrifuges commonly used as tramp oil separators, shown in Figure 5, generate enough force that they can separate partially-emulsified oils from the coolant. The centrifuges used for tramp oil removal contain a number of coalescing discs or plates which aid in the separation of the oil and water.

In tramp oil separating centrifuges, excessive amounts of solid contaminant can plug up the discs which the auto-purge cycle cannot remove. This plugging often leads to extensive maintenance time in the removal and cleaning of the discs. Extreme care must be used when cleaning the plates, since damage or misalignment of these discs decreases the efficiency of this type of centrifuge. Addition of a pre-filter which removes all particles, except for the very

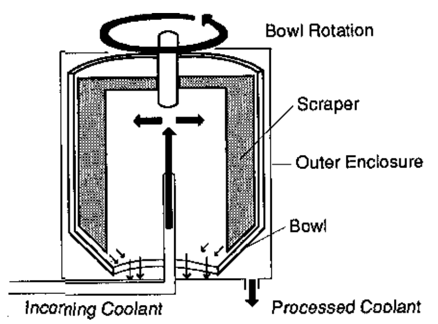

Figure 6. Schematic of a centrifuge used for particle separation. The coolant is pumped into the spinning bowl. Spinning the bowl forces the particulate toward the outer edge. The particulate stays in the bowl while the fluid passes out the bottom.

Figure 6

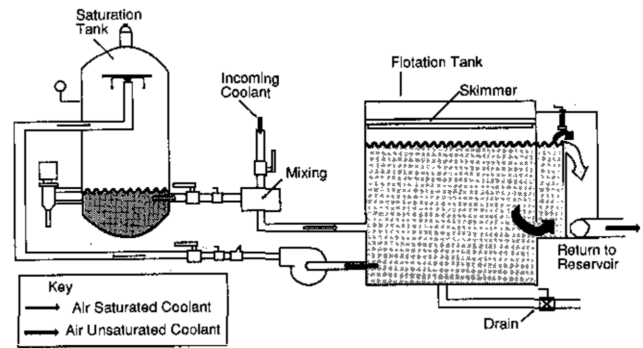

Figure 7. Schematic of a dissolved air flotation unit which introduces fine air bubbles into the coolant for particle separation. In metalworking fluids this unit is generally used as a by-pass system, therefore coolant to be processed is held in a separate reservoir. A portion of the fluid in the unit is saturated with compressed air, this saturated fluid is mixed with fluid to be processed prior to entering the flotation tank.

Figure 7

fine contaminant, in the coolant line prior to the centrifuge prevents this plug-up from occurring.

The design of the centrifuge used to remove solid contaminant from liquid, shown in Figure 6, does not contain the coalescing plates, because the solids adhere to the plates and are not easily removed from the equipment. Equipment designed without these plates allow the dirt to be separated without "plugging" the centrifuge. These centrifuges have a very slow particle removal rate, and are often misapplied to systems which contain too much contaminant. Another method of particle removal is necessary, prior to the centrifuge, in order to remove the excess contaminant. These centrifuges do require a scraping device to remove solid contaminant from the bowl. Problems develop if the scraping mechanism inside the bowl fails.

Flotation, a process that incorporates the reverse of settling, is sometimes used to separate contaminants from fluids. This can be effective for the removal of contaminants less dense than the fluid, since these would naturally float. For particles that are not lighter than water, the creation of air bubbles that adhere to them will give them buoyancy and cause them to float. The particles must then be removed from the surface of the fluid tank instead of the bottom as in the drag tank.

The particles that need to be removed from the coolant are usually more dense, therefore air must be introduced. To date, the biggest problem has been to devise a method to generate air bubbles capable of attaching to all particles. The device used to generate the bubbles must be controllable so that the amount of foam produced can be controlled. The first units agitated the coolant to generate the foam. Newer models use pressurized air to saturate the coolant, then allow the air to dissipate at near zero pressure, forming finer air bubbles. This type of process has been used in waste treatment areas for numerous years, and is referred to as dissolved air flotation. A schematic of a dissolved air flotation unit is seen in Figure 7.

Another type of separator, the magnetic filter, can be extremely efficient in removing ferrous material. Particle removal is dependent on particles falling into the magnetic field, being pulled to the magnet, and removed from the coolant. If particles remain away from this field they will not be removed by the magnet. A high flow rate through the separator is one factor that will prohibit contact between

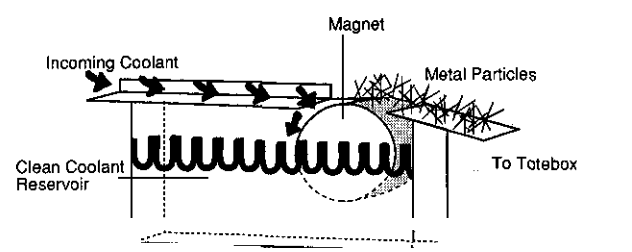

Figure 8. Schematic of a commonly used magnetic separator. Incoming coolant, carrying chips, is passed over the magnet for particle removal. Coolant then collects in the clean reservoir to be pumped out to the machine.

Figure 8

the particle and the magnetic field. These units are usually designed with a large clean reservoir where the particles that are missed by the magnet can settle out. These particles must be removed manually since there is usually no other sludge removing device present in the system. One design used for magnetic separation is shown in Figure 8.

Filtration Equipment

The next step in the progression of particle removal equipment is the addition of a barrier through which the coolant must pass to strip out contaminants. The addition of the barrier changes what might have been a separation device into a filtration device. A barrier will stop particles of a certain size: the absolute rating. To improve the absolute rating of a filter, a change in the barrier must take place.

The principle of filtration depends initially upon a barrier stopping particles larger than the barrier openings. As these larger particles build up on the barrier, the size of the opening decreases, preventing smaller particles from passing through. This effectively removes particles of a much smaller size than the original barrier size; the nominal rating of the filter. Essentially a barrier starts out as a strainer, and, as particles collect on the barrier, "filtration" or removal of smaller particles occurs. The types of barriers used may be permanent or disposable depending on the requirements of the system. Examples of barriers are listed in Table 1.

Barrier	Method of Differentiation
Wedge- wire	Slot size; Permanent
Rolled media	Weight per square yard; Disposable
Pre-coat	Fiber or granual size based on sieve tests; Disposable
Cartridges/ bags	Openings in barrier; May be nominal or absolute um rating; Disposable or Permanent

Table 1. Common barriers used in pressure and vacuum filters. The characteristics used to identify and differentiate each group are listed.

Filtration equipment can be divided into vacuum or pressure filters. Numerous designs of each type of filter exist, some with and some without media or precoat. Both types of filters are effective when applied properly. Most units are designed with a clean reservoir. This clean reservoir must be designed so particles that pass through the filter and settle there can be removed. In the vacuum filtration process, coolant is drawn through the barrier by suction, generally created by a pump. Metal chips are stripped out by the barrier as the coolant passes through. The suction which draws the coolant through the barrier holds the chips onto the surface, regardless of the orientation of the barrier. For example, wedge-wire cylinders suspended vertically or horizontally remain covered with chips as long as the pump suction remains.

As these chips begin to accumulate on the surface of the barrier a chip cake is formed. It is this chip cake that aids in the filtration process by stripping out smaller particles. As this chip cake builds on the barrier so does the resistance to coolant flow. This resistance to flow can be measured as vacuum, if it is measured between the barrier and the pump.

The vacuum builds until a preset point is reached, then the filter automatically indexes. An index is the process used to remove the chip cake that has formed, opening a small portion of the barrier which re-establishes the proper flow rate. This may involve rotating the wedge-wire cylinder, moving the drag chain with or without media below, or shaking off the precoat. Up to ten percent of the filter's surface area is opened during the index. The area opened during an index begins to reestablish the chip cake when flow through that area is restored.

A longer duration between indexes enhances the performance of the filter. When the chip cake is removed, that area of the barrier returns to the conditions that existed prior to cake formation. The area contains large openings which allow particles to pass through that would normally be stopped by a chip cake. For most systems, under normal operating conditions, the amount of time during which this chip passing occurs is short.

The geometry of chips will determine the degree of clarity achieved in any type of filter, since the thickness and density of the chip cake determines the size of the fines removed. A tightly packed chip cake will remove smaller particles while loosely packed chips allow the fines to pass through.

As mentioned previously, numerous types of vacuum filters exist. Two of the most common vacuum filters are rolled media (paper) filters and wedge-wire filters. An example of the rolled media filter is shown in Figure 9. The roll of media is the barrier which lays in the bottom of the tank, supported by a perforated plate or a wedge-wire screen. When the vacuum has reached a point where indexing is necessary, the conveyors move. The conveyors, which rest on top of the paper, pull the contaminated paper out and new paper in to replace it. The advantages and disadvantages of this type of unit are shown in Table 2.

Table 2. Advantages and disadvantages of using Rolled Media Vacuum Filters.

Advantage	Disadvantage
1. lower initial cost 2. contaminant can be permanently removed from the system when taken out with the contaminated paper	1. on-going media cost 2. in larger systems rolled media may tear

Table 2. Advantages and disadvantages of using Rolled Media Vacuum Filters.

Framed, flat wedge-wire panels have been used for many years by numerous companies. The purpose of having wedge-wire for support below the media of a rolled media filter is to allow the chips to accumulate on this barrier if the

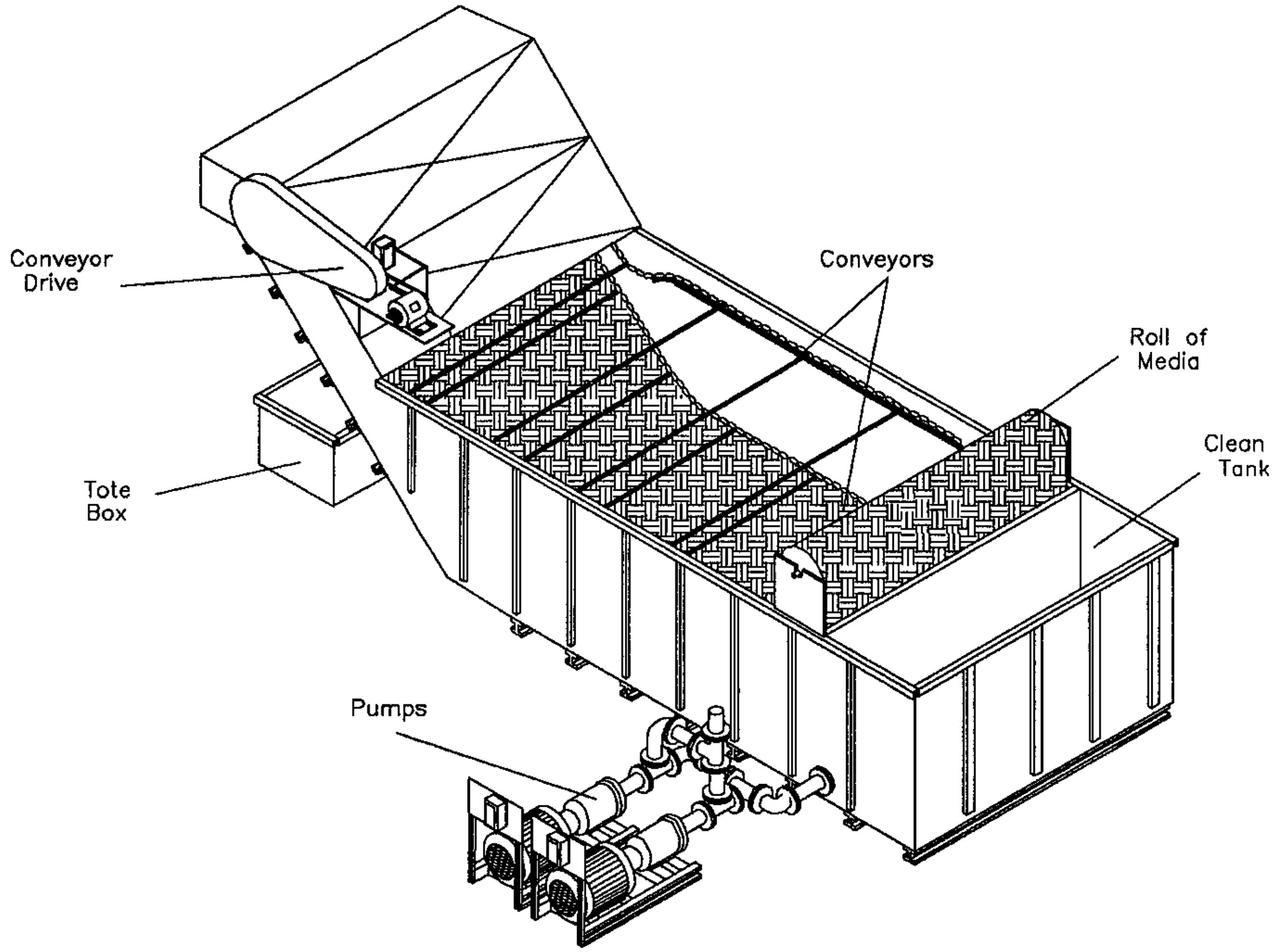

Figure 9. Schematic of a rolled media vacuum filter. The rolled media used is the barrier on which the chip cake is built. The weight of the conveyors hold the media in place and moves it thorugh the unit.

Figure 9

roll of media has been completely expended and not replaced. In other systems, the use of rolled media is eliminated and the wedge-wire screens placed below the conveyors are the only barrier, reducing the expense of media usage. Many older systems incorporating these wedge-wire panels still exist and are functional. If these screens are suspected of being plugged, the tank must be drained for examination, and cleaning the screens is lengthy. Use of the wedge-wire suspended in the tank (discussed below) has decreased the amount of time required for maintenance, but still gives the benefit of using the non-disposable barrier of wedge-wire.

Wedge-wire filters of newer design contain one or more cylindrical wedge-wire filter elements suspended either horizontally or vertically in the center of the tank. The chips are collected on the bare screen until the vacuum reaches the set point, then the filter indexes. The indexing processes differ, but essentially both types rotate to facilitate the removal of chips. An example of a wedge-wire filter is shown in Figure 10. Properly designed wedge-wire systems can be used reliably to remove particles over long periods of time. Table 3 lists the advantages and disadvantages of wedge-wire filters.

A loose precoat can be added to both rolled media and wedge-wire systems to enhance the filtration. Because the use of precoat may reduce flow rates, this must be engineered into the system prior to building the filter, or it will not be able to supply the proper amount of coolant to the machines. It is possible to add the precoat on the weekend while production is off to "clean-up" a system. Consult with

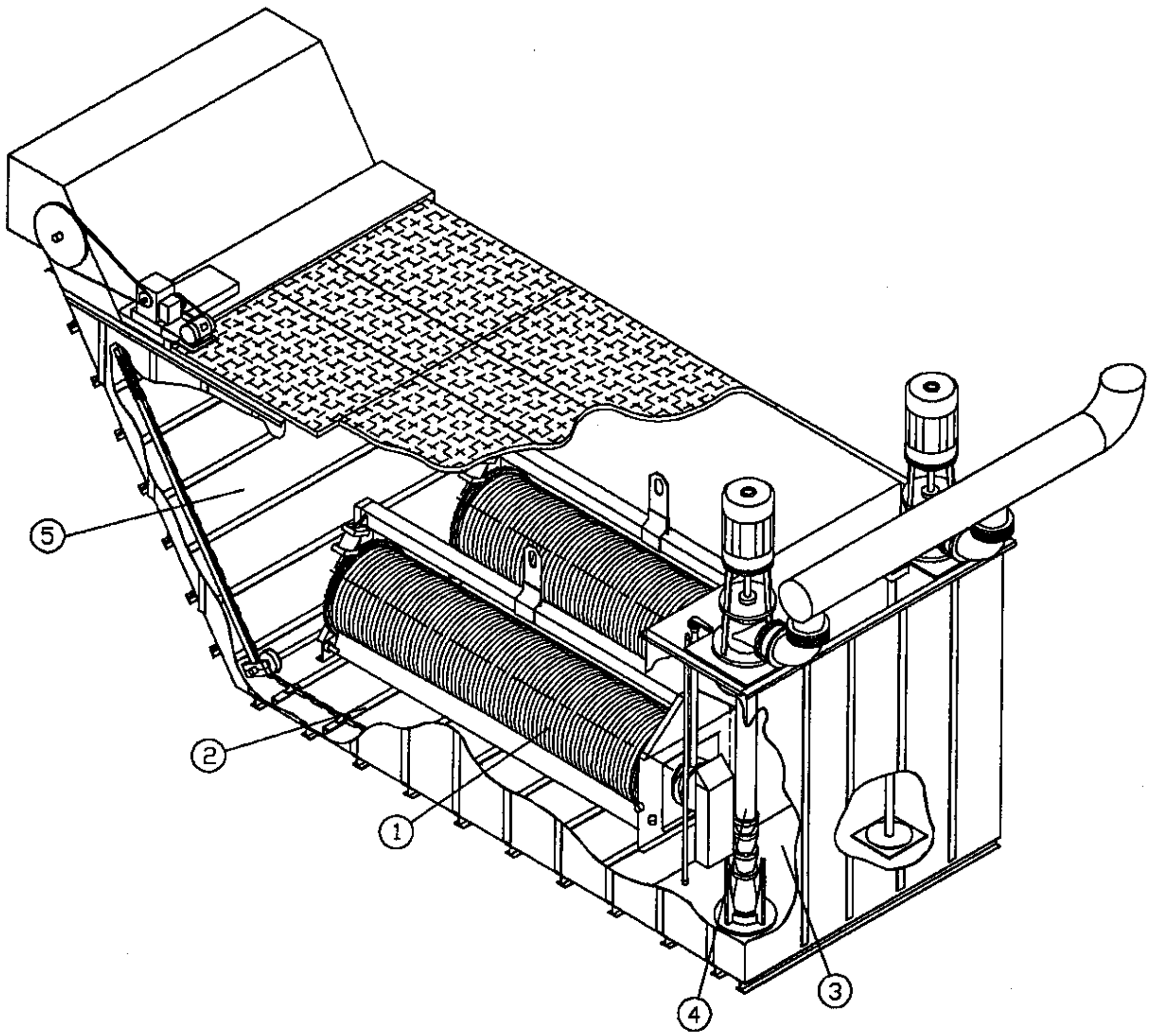

Figure 10. Schematic of a vacuum filter using wedge–wire cylinders as the filter barrier. The cylinders may also be suspended vertically in the tank. Conveyors move below the cylinders to remove the contaminant that settles out of the fluid.

Figure 10

Advantage	Disadvantage
1. permanent barriers, no added cost for operating	1. initial cost may be high
2. movement of conveyors does not affect the filter index in systems using the wedge-wire cylinders	2. contaminant that will not settle remains suspended in the tank.
3. ability to examine cylindrically designed filter barrier without draining tank	
4. may add pre-coat to remove fine contaminants during weekend shutdown	

Table 3. Advantages and disadvantages of using wedge-wire vacuum filters

your filtration engineer for information on using the pre-coat. Table 4 shows the expected clarity from vacuum filtration equipment. The values in the table have been generalized and represent average clarity from a well designed system. These conditions may change as flow rates and coolant conditions change.

In the pressure filtration process the dirty coolant is collected in a reservoir from which a pump draws coolant to supply the filter. This reservoir may be a vacuum filter or separator to remove the large particles. The pump forces the coolant through the barrier. The barrier stops the larger particles but allows the coolant to continue on, and the build-up of larger particles aids in stopping finer particles. After the coolant passes through the barrier it may pass into a clean reservoir or go directly to the machines. Some of these systems are the most complex types of filters that exist.

	Aluminum			Cast Iron		Steel		
	Grinding		Machining	Grinding	Machining	Grinding		Machining
	F	C				F	C	
Cellulose pre-coat	5 - 10	--	---	5 - 10	---	5 - 10	--	---
Wedge-wire	--	20-25	10 - 15	---	15 - 20	--	--	10 - 15
< 1.0 oz m*	--	20-25	10 - 15	---	15 - 20	--	--	10 - 15
1.0 to 1.5 oz m	--	--	---	---	---	--	10 - 15	---
1.5 to 1.9 oz m	--	--	---	---	---	5 - 10	--	---
2.0 oz m	--	--	---	5 -10	---	--	--	---

1) The dashes indicate a non-applicable situation.
2)* m = rolled media
3) F and C in Grinding Columns represent Fine and Course Grinds.

Table 4. Expected size of the contaminant, measured in micrometers (um) remaining in the fluid after vacuum filtration. The amount of particulate, in parts per million (ppm), is expected to be 15 to 20 ppm for each catagory containing the um rating. The effectiveness of a vacuum filter is dependent on the particles in the fluid forming a chip cake.

As the chips pass through the barrier a cake forms. Much like the vacuum filter, as this chip cake builds, the resistance to flow also builds. This resistance to flow increases the pressure required to pump coolant through the barrier. These systems are designed to index from differences in pressure. A differential pressure switch measures the difference in the pressure of the coolant entering the pressure chamber to the pressure after the chamber. When this difference exceeds a predetermined amount, the filter requires indexing. Indexing varies from unit to unit, some require the change to a new pressure chamber and manual removal of the barriers. For example, cartridge cans are usually designed with two cans in parallel arrangement to allow for this type of changing. The index may also involve moving a piece of rolled media or a plastic belt through the unit.

There are many different types of pressure filters. Some use permanent and others use disposable media. These systems may be added to vacuum filters to give a final polishing effect or they may be used independently. Pressure filtration is affected by the geometry of the chips just as vacuum filtration is.

If the chips are coarse, the cake is not as dense and the fine particles get through. The applications that require the use of a pressure filter generally have finer chips, therefore the geometry of the chips is more uniform from system to system. In systems where removal of larger particles occurs before the pressure filter, the chips are very fine, so any cake that is formed is very dense. Usually there are not enough chips in these systems to build a chip cake and particle removal is dependent on barrier opening size. Table 5 describes expected clarity of the various types of pressure filters that will be described below.

Cartridge and bag filters are similar in design and will be treated as one group of pressure filters. Cartridges and bags are held inside a canister that the coolant is pumped through. The bags usually operate with the flow going from the inside out and the cartridges operate with the flow passing from the outside in. Whichever method used, the coolant is pumped through the filter which removes the particles. Cartridge or bag filters, by their design, are not capable of removing large quantities of particles. Large amounts of contaminants require frequent manual removal and replacement of the cartridges or bags. These are best used as polish filters, which are add-ons to other particle removing equipment. The purpose of the polish filter is to remove fine contaminant from a percentage of the coolant, reducing the residual contaminant level in all the coolant.

There are many types of cartridges and bags, and many different micron ratings. The type of bag or cartridge applied to the system depends on the prior method of filtration. A separator, which allows many chips to pass through, would require the use of a filter capable of removing more

Table 5. Expected contaminant remaining in the fluid after pressure filtration. The values in this Table represent the size of the largest particle present in the coolant after it has been filtered. There is no mention of the amount of the contaminant of this size, or smaller, that may remain in the fluid. Pressure filters are generally rated based on their absolute rating.

Filter	Suspended Solids	Basis of Clarity	Testing Method(s)
Flat-bed	Varies from 2 um to 40 um*	Weight of rolled media, which determines opening size.	Measuring suspended solids from known operating systems.
Pressure Tube	1 um to 5 um	Thickness and type of pre-coat used and integrity of tubes.	Measuring suspended solids from known operating systems.
Cartridge / Bag	Varies, depends on manufacturer and rating.	Opening in the barrier. The bags may be in a mesh rating.	Nominal - 95 % to 98 % removal of particles of rated size. Absolute - largest particle able to pass through the barrier. Multi-pass - slurry of contaminant is passed through a barrier, analysis for suspended particles in samples taken before and after the barrier gives the β-ratio. $\beta = \frac{\text{Particles before}}{\text{Particles after}}$

* Flat-bed filter efficiency will be affected by the media that is used. The rating given is a guaranteed value for the largest particle capable of passing through the media. The average size and amount of contaminant lower than the rated value is not mentioned.

Table 5

particles. A bag filter may be applied to this system since it can hold larger quantities of chips than a cartridge, and the particles will be removed when it is lifted out of the canister. A vacuum filter which removes particles with greater efficiency than a separator may be used prior to a cartridge system. The size of the cartridge is dependent on the amount of chips remaining, the size of these chips, amount of flow through the cartridge, and the clarity required.

Other pressure filter designs include flat-bed filters and pressure tube filters. Flat-bed filters consist of a pressure chamber on top of a filter bed. A barrier is placed on top of a support grid. The barrier may be a disposable rolled media or a permanent plastic belting. The top of the pressure chamber closes down on the barrier and "seals" around the edges. The fluid is pumped into the chamber from a reservoir, is and forced through the septum to separate the solids from the coolant. As the pressure differential reaches the pre-set point the unit indexes, removing the contaminant from the surface of the filter barrier. The chamber is drained and the top raises, the barrier is moved through the chamber and is replaced by a clean section of the barrier.

Tube filters consist of long cylindrical tubes suspended in a pressure chamber. A precoat, usually diatomaceous earth (DE), is slurried and pumped onto the tubes first. After the precoat is in place the unit begins to process coolant. The coolant with chips is pumped into the chamber and through the tubes, removing the metal particles. The coolant then proceeds onto a clean reservoir. The chips are removed until the pressure difference indicates time for an index.

During an index, the unit stops processing coolant, the coolant in the chamber and the DE with chips are flushed into a wash-down tank. This tank could be a vacuum filter or a settling tank where the DE and solids are removed. The wash-down tank has until the next wash- down to allow the particles to separate and get the coolant out of the tank. The system is usually designed with a pair of pressure chambers so that another can continue to supply clean fluid to the machines, or with a large enough clean reservoir to provide coolant through the cleaning cycle.

The advantages and disadvantages of pressure filters are listed in Table 6. This table compares pressure filters to vacuum filters, instead of different types of pressure filters. Generally there is little competition between types of pressure filters. Each type has an appropriate use and competition becomes a sales problem for vendors of the different brands. The tube and flat-bed filters compete with rolled media and wedge-wire vacuum filters in numerous applications, therefore considering the advantage of pressure to vacuum filtration is important. Item 3 in the Advantages column requires some discussion. Fluids which are difficult to vacuum filter are those high in viscosity and those that are at elevated temperatures. Vacuum filtration will cause these to vaporize thus starving the pump. Viscous and hot fluids can be forced through the pressure filters without forming vapors. The other items listed in Table 6 are self explanatory.

Advantage	Disadvantage
1. better chip removal than with vacuum filters	1. system design is more complex
2. the coolant is more easily pumped through the cake than it is pulled through	2. dirty coolant is pumped through the media
3. ability to pressure filter solutions which vacuum filter are unable to filter	

Table 6. Advantages and disadvantages of using pressure filters.

Designing the Filter System

Now that most filter types have been discussed, the next issue that must be addressed is: how to choose a system that will work. The term filter system refers to the machine, the coolant, and the filter. Expertise that the filter supplier provides in the engineering of a filter system is in the filter, and all components required to transport the coolant to and from the machine. This section will first focus on the methods used to select the proper filter for the system. A brief discussion on trench design and piping networks will follow.

The variations of equipment design, numerous options, and the particular needs for the system make it a challenge to select the proper filter or filter supplier. In order to ensure that the system being used meets expectations, the selection of a filter supplier is a critical factor. Expertise in the area of filtration, and the availability of technical support are as important to the selection as is good filter hardware. The filter supplier selected should have numerous system designs from which to choose and be able to demonstrate the performance of systems that are in production. It is important to understand limitations of the equipment, which may only be apparent while operating during production, so that the equipment will be purchased and applied properly.

The first issue to be addressed is whether to use a central filter system or an individual filter on each machine. A central system usually uses in-ground trenches and a discharge piping network to tie multiple machines to one filter. This means that there will only be one filter system to maintain.

Individual filters, one per machine, do not require elaborate trenching and piping networks, but each filter does need to be maintained. Even if these multiple machines use the same fluid, the cost of maintaining smaller individual filters will soon exceed the cost of a central system.

While it is not recommended, systems for individual machines can be standardized. The use of a standard filter does reduce the initial purchase cost, although this initial cost should not be the sole criteria used in selecting a filter. When not applied properly these units may not perform as expected, resulting in additional costs to correct the situation. Careful examination of the filter system and study of existing filters will indicate when individual systems must be customized. Central systems, due to their uniqueness, must be engineered specifically for the job.

The engineering of a central filtration system can be very complex. There are no easy reference texts on system designs. Engineering filtration systems is an art, which like any art form requires years of practice to perfect. The actual design, engineering, construction, and method of operation should be left to the filter supplier, since this is where their expertise will surface.[3] The information supplied by the purchaser will be used in engineering of a system specific to the job requiring the filter. Some of the information required to design a filtration system includes type of coolant, level of cleanliness needed in the coolant, size and amount of chips to be removed, type of metal, and total flow of the system.

Selection of the proper filter system is dependent on the particles to be removed, and more important, the amount of chips that can remain in the fluid after filtration has taken place. The cleanliness of the filtered coolant you request will more greatly affect the size and cost of the system than any other single parameter.[3] All filter systems allow some chips to remain in the fluid. The size and amount of these chips varies with the different types of filters. The size or amount of chips that remain in the filtered coolant can be reduced by using multiple filtering processes. As an example, a vacuum filter could be used to remove the bulk of the large particles and then a cartridge filter could be used to remove those particles that pass through the first filter. Care must be used in applying this arrangement to a system to prevent the excessive cost of "over-filtering" all of the coolant. Of those particles less than 30 um, it is not known, accurately, what size is detrimental to any particular machining or grinding application. However, there is much speculation about which particle sizes are detrimental. Study continues today to determine the relationship of coolant cleanliness and part finish, tool life, etc.[3]

Care must be used in determining where the coolant needs to be very clean and where simply straining out the larger particles is adequate. At times it is effective to isolate certain station(s) in a multiple station machining line to receive cleaner fluid than the rest of the line. This will eliminate the need of filtering all the coolant to the high degree of clarity required by the isolated station(s). The vacuum filter followed by the cartridge arrangement described previously might be applied to this situation. The coolant from the cartridge filter may be piped directly to a machine station to provide exceptionally clean fluid to that process. It can be circulated back to the vacuum filter as a by-pass cleaning cycle. The net result of this type of arrangement is to lower the dirt content in a percentage of the fluid thereby increasing the total cleanliness of the system, and, at the same time, to provide very clean fluid to a critical area if needed.

The metal to be worked in the filter system can be an important factor in its design. Common metals, typically seen in metalworking systems, can be divided into three major groups: aluminum, cast iron and steel. Systems to remove glass grinding, titanium, cobalt and tungsten carbide particles are also occasionally required. Each group has particular characteristics that affect particle removal. For example, aluminum machining chips will usually be larger with some curvature, while cast iron machining chips are smaller with less curvature since the cast iron is brittle. Generally, the large aluminum chips are easier to filter out than the cast iron. If the particles are easy to remove the filter unit is less complex.

The three major metal groups can be divided into multiple groups based on other characteristics, such as elemental composition or hardness. Changes in elemental composition can have adverse effects on the filtration process if the change causes the formation of interstitial solutions. An example of this change would be a change in the carbon content in cast iron. At low levels, carbon dissolves into the iron but does not bind, forming the solutions. It can readily move from the iron structure, thereby passing into the coolant during the cut. At higher levels the carbon is unable to move and the formation of interstitial compounds occurs. This carbon is bound in the iron and, during production, remains with the chip. The unbound carbon is much smaller than a cast iron chip, and cannot be filtered out, causing the coolant to become dark in color.

Elemental composition, as well as physical conditions such as heat treating and "working" of the metal, will change its hardness. The hardness of metal can change the shape of the chip produced since softer metals are generally not as brittle. Chips from malleable materials curl and resist breaking apart. As the hardness increases, the metal becomes less malleable so these chips may not curl and may break into small chips.

As mentioned previously the geometry of the chips is one factor that will determine the degree of clarity a filter will attain. The type of chip that is formed in a machining operation is an important design parameter of a filter system. If the hardness of the metal changes after start-up, the filter effectiveness may change. When other metals or new materials (such as composites) are used, testing should be done to determine the chip geometry and the effectiveness of different types of filters. This testing may not be possible initially, but continuing to work with the filter supplier long after the original purchase should be an option the supplier gives.

The type of cutting being done also affects the filter system design. Machining, where a metal cutting tool removes metal, produces different chips than grinding, where a non-metallic material removes the metal. For the purpose of this discussion, metal removed by a machining process will be referred to as chips, and metal removed by grinding will be referred to as swarf. There are numerous machining cuts and each produces chips of different geometry. Fast speeds and shallow depth of cut produce smaller chips while slower speeds and deeper cuts produce longer, larger chips.

The geometry of the part will also affect the chip produced. Small surfaces usually generate smaller chips while large surfaces have more area of contact at any given time, producing larger chips. This is also true of grinding systems. In ID (internal diameter of a part) grinding, the wheel is in contact with the part longer, producing longer swarf than for OD (outer diameter of a part) grinding. Sampling and analyzing a similar system will show the type of chips to be expected and the most effective method of filtration.

Flow rate through the filter is the next criteria used to design systems. Proper flow rate (in gallons per minute per square foot of filter area) will vary depending on the method of filtration chosen, and is critical for clean fluid. The flow rate in a filter is limited by the speed at which the coolant should pass through the barrier. Each barrier has an ideal flow rate for types of chips and conditions. See Table 7 for a listing of typical flow rates for vacuum filters. In vacuum systems that have the barrier suspended in the tank, the flow rate must be great enough to pull the chips onto the barrier. The flow rate affects sizing of the filter tank, since the tank has to be large enough to accommodate the filter area required for proper flow rate.

Material	Flowrate
Steel machining	30 - 40 GPM/SQFT
Steel grinding	8 - 10 GPM/SQFT
Alum. machining	20 - 30 GPM/SQFT
Cast Iron Machining	20 - 30 GPM/SQFT
Filter Aid	
Cellulose powder	5 - 10 GPM/SQFT
Diatomaceous Earth	0.5 - 2 GPM/SQFT

Table 7. Typical flow rates through vacuum filters. The flow rate is dependent on the metal being machined and whether filter aid is used. Filter aid is used in grinding and honing systems. Flow rates are the same for all metals when using filter aid.

Tank sizing is a critical factor in filtration design. The first item that determines the size is the retention time. Retention time is the amount of time each gallon of coolant is held in the tank before it returns to the distribution piping to be cycled through the system again. Sizing of the tank generally requires that most vacuum filters allow a three minute to ten minute retention time, as opposed to gravity separators which require ten to 30 minutes to allow for particle settling. This allows some particles to settle, and prevents the fluid turbulence from washing the chip cake off of the filter barrier. Retention time is not critical in pressure filter reservoirs when settling is not important.

Total flow, the amount of material to be removed, and floor space available for the filter are three other factors that determine the size of the filter tank. The total flow, or gallons required by the machines and flushing, is one factor that determines how large the reservoir must be. Any filter that requires settling of the chips or swarf has to be large enough to allow the chips to settle. The tanks must also be large enough to hold the draw down, which is the coolant needed to fill the header and troughing, that is in transit when the filter is running. Essentially, the filter tank(s) must hold enough fluid to cover the filter barrier, provide enough retention time and keep machines and flushing supplied at all times.

The amount of stock removed from each part and the number of parts run per hour affect the size and design of the filter. If a large amount of stock is removed, the filter has to be designed to remove the heavy chip load. The conveyor must be heavy duty, as well as the chain drive and gear reducer. In rolled media filters the addition of a primary conveyor to remove the bulk of the chips before the filtration process may be needed. If the removal of these chips is not done through the use of a primary conveyor, the rolled media filter may not be the filter of choice, since the filter conveyor motion is related to the chip cake formation. To remove the bulk of the chips the filter conveyor would need to run often, removing the paper media before a good chip cake was established and before the disposal was necessary.

If less contaminant is present, the conveyors do not have to be as heavy, but a precoat or thicker media might be used since there would be fewer chips to form the chip cake. The use of precoat increases the size of most tanks since the flow rate through the barrier must decrease, and the filter area must increase. The use of a cartridge or bag filter as the sole system may be feasible in certain situations where very small chip loads exist, and when conveyors are not needed to remove any contaminant.

The size of a tank is often limited by the floor space available. When floor space is limited, and the filter size is decreased to fit, the filter may not have adequate retention time or filter area and it will not operate as efficiently or cost effectively. By determining the filtration needed before the majority of the engineering has been done on a machine line, proper planning can take place to avoid a space shortage. One major emphasis of research and development for filters is in the reduction of floor space required for the tank. Newer filter designs will require a minimum of floor space.

In part, the success of a filter system is dependent on the pump(s) used. The pumps move the coolant from the filter and fill the distribution piping network which supplies the machines. The pumping capacity must be large enough to supply machine and flushing requirements while maintaining the proper coolant pressure for the machining process. The filter supplier should be able to select the proper size and number of pumps, and work with the customer to select the pump manufacturer and basic design.

Each pump is rated to pump a certain amount of coolant efficiently at a specified pressure. The pump is capable of pumping more or less coolant, but at reduced efficiency; therefore it is desirable to operate the pump at its rated capacity. The higher capacity is often detrimental to the filter system clarity. If the pump is pumping more coolant it must draw the coolant through the filter at a rate faster than design rate. This forces through some contaminant that would normally be stopped by the filter barrier through. When no other method is used to regulate the pressure in the distribution piping, pumping the designed amount of coolant through the pump will provide the correct coolant pressure at the machine.

The piping network that distributes the coolant to the machines may be designed by the filtration supplier or by plant personnel. Critical areas to be engineered are the size and length of the piping required to supply the correct volume and pressure of coolant to the machines. The correct volume includes the amount of coolant required to flood the part for cooling and lubrication, rinse chips away from the part, and flush the trench system. Pressure of the coolant is very critical in lines that contain tooling through which coolant passes. In all machines the pressure must be great enough to wash chips off of the part but not too great that it splashes and over sprays. Pressure losses that occur along the line must be considered so that the coolant which reaches the last stage of a line is at the proper volume and pressure. Careful planning between machine builder, coolant supplier and filter supplier is needed to provide proper coolant distribution to the machine(s).

The trench system is the last area of engineering to be discussed. This is as critical as the first two and is usually designed by filter suppliers, because of their knowledge in the design of the trenches. The trench system must be designed to carry all particles to the filter, regardless of the distance. A trench which allows particles to drop from the flow, before they reach the filter, is poorly designed since these chips create dams that can interrupt the passage of all chips. Coolant and chip movement through the trench system may be by gravity only, or by gravity and coolant velocity.

All trenches require that the proper slope be designed into the system for chip passage. The slope for gravity return must be steeper, therefore the filter level must be lower than for a similar system without gravity return. Velocity trenches can be designed with less slope, since the passage of particles is enhanced by adding flush nozzles to move coolant carrying chips in the trench. The flow through the trench system is critical and specific to the chips generated, as seen in Table 8.

Metal \ Cut	Grinding	Machining
Aluminum	6 f/s	6 f/s
Cast Iron	8 f/s	8 f/s
Steel	8 f/s	12 f/s

Feet per second - f/s

Table 8. Velocity of liquid required to carry metal particles through the trench system to the filter. This is based on a trench slope of ⅛" per foot.

The metals not listed in this table may require testing to design the proper flow rate, or if they are similar to one listed, that flow rate may be used. Some experimentation and flow rate changes can be made in the field, after trench installation. Either type of trench system should be designed to eliminate as much turbulence as possible to minimize misting and foaming of the coolant.

If after the system has been designed, installed and is operating at its peak efficiency, it is determined that critical particles cannot be removed, certain filter parameters may be changed. Care must be used in determining which parameters can be changed and when these changes are not appropriate. For example, it is believed that the thickness of the rolled media can easily be changed to remove fine particles. This is true, unless the change in thickness is too great, because the system still has to be designed to allow for changes in flow, (i.e. one-ounce paper will allow coolant to pass through faster than two-ounce paper). The addition of other types of filtration equipment, or the separation of certain stages in a line for the addition of an identical filter, may be a possibility. Changes to a unit already in existence require extended evaluation of the engineering that went into the initial design, and examination of options that may be advantageous to the system. Selection of a reliable filter partner and careful engineering prior to building the filter can diminish the need to reevaluate the system design after it has been installed, thus saving time and money.

Maintaining a Filter System

Once a filter has been installed it must be maintained to operate properly. There are three major areas that should be examined: hardware maintenance, replacement of consumable media, and coolant control. A filter system in which these areas are controlled should operate reliably for many years.

Preventative maintenance (PM) of the individual filter components is necessary to prevent the occurrence of major mechanical failures. Most PM programs include: examining and replacing worn components; cleaning and checking for proper operation of the pneumatic or electrical components; and lubricating certain sub-components of the filter, per the manufacturer's recommendations. Setting up a procedure to properly maintain the components will prevent the need for disaster maintenance (stopping production to fix the filter). The filter manufacturer should be able to provide recommended PM schedules to follow, as well as information on wear and replacement parts.

Filter maintenance also includes maintaining the filter as a single unit designed to operate within certain parameters. Regardless of the filter used, it has been engineered and designed to remove particles for a specific job. Careful control to maintain the proper filter operation is imperative to clean fluid. A frequent operational problem in filters is flowing more coolant through the unit than it was designed to accommodate. Flow though the filter barrier is limited. If the flow is increased, the filter senses a restriction and attempts to compensate for it by indexing. Increasing the flow through vacuum or pressure filters will decrease the time between indexes, thereby increasing the contaminant that migrates through the filter septum.

Consumable media is the barrier on which certain filter systems rely, and its replacement is necessary for proper operation. The expected consumption of the media may be predicted prior to the purchase of the equipment, although this will be an estimate. Initially the filter should be checked often, to determine when replacement is needed. After the filter has been operating, with production at 100%, a pattern of use should develop that will predict when the media needs to be replaced. This should eliminate operating the filter without media.

The coolant is the next area that must be maintained for peak performance of the system. While coolant representatives, tool engineers and plant personnel are most interested in the lubricity and cooling properties of the fluid, for the filter supplier the fluid must be "filterable" to be of any use. In other words the coolant must be maintained in a condition that enables it to pass through the filter barrier at the rate designed or the filter cannot operate properly. The fluid in the filter can be the most difficult item to control. Slight contamination of the coolant, after a period of time, may affect the performance of the filter. Chemical changes in the coolant, either natural or engineered, can also cause adverse effects on the filter. Monitoring the coolant daily is necessary to ensure that no major changes have occurred. Following the advice of the coolant supplier for proper fluid maintenance practices, and keeping records of additions that were made, will help prevent serious problems.

Control of the fluid involves the control of coolant components and contaminants. The components of the coolant must be measured to determine if they are being removed, while the amount of contaminants must be measured to determine how much is entering the system. Several important checks should be incorporated into a coolant PM program. The method used to measure each item will vary, due to coolant supplier preferences. Duplicating the methods recommended and used by the supplier may prevent discrepancies in the results. Table 9 lists the checks that may be performed and a schedule to follow. The checks, which

DAILY CHECKS	WEEKLY CHECKS	RANDOM CHECKS - as needed
-water level (make-up) -tramp oil -concentration -total oil	-biological growth -dirt load	-rust -foam -filterability -settling/surface tension

Table 9. Checks that should be performed as part of coolant maintenance.

measure conditions that change in the coolant and detrimentally affect the filter, will be described below to aid in understanding the effect on the system.

Extraneous or "tramp" oil is a contaminant that should be controlled in a filter system. Tramp oils may enter into the coolant from leaks in hydraulic components of the machine, from lubrication of the ways on a transfer machine, or from spills that occur as oil is added to the reservoirs for either of these items. Terms used to described the tramp oil as it exists in the coolant are "free," "partially emulsified" and "totally emulsified." Normally free oil does not cause filter problems. However, if it stays suspended in the coolant, it will cover the filter barrier restricting the coolant flow. Free oil may cause stagnation in the coolant when the filter is idle. Partially emulsified tramp oil, also called interface or rag, will cause filter problems as its concentration increases. It always stays suspended but does not cover the barrier unless its concentration is high. Totally emulsified tramp oil does not usually cause filter problems unless the amount is excessively high. The amount of oil that becomes emulsified varies with the coolant. To control tramp oil, the amount that enters must be controlled. There are few devices that will remove tramp oils once they have entered the filter.

Levels of neat product or "concentrate" in the coolant solution must be controlled to allow the filter to operate properly. Some components may be depleted causing filter problems, such as the rust inhibitor, the biocide and the lubrication package. The rust inhibitor prevents rusting of components in the tank, such as the conveyor systems. Also, if particulate in the filter tank rusts, the permanent barriers may become plugged with corroded particles that cannot be removed. Biocide or fungicide concentration may be depleted in a system, allowing biological organisms to grow. The "overgrowth" of biological organisms can be extremely detrimental to the filter operation, since most organisms that grow in coolant systems have a slimy coating. The organinisms with their slimy coating build on the surface of the filter barrier and do not allow coolant to pass through. Depletion of the lubricity in the coolant will create problems with the moving components submersed in coolant which depend on this lubrication.

Because measurement of each of the components from the concentrate is very time consuming, often only one parameter is chosen to be measured. When the concentration is checked, the parameter measured should be a critical component of the coolant. Examples of "critical" components are surfactants, emulsifiers, lubricity agents, or rust inhibitors. A depletion of one of these components could indicate an overall depletion of the components mentioned above and the need for adjustment. The easiest and best way to replenish these components is to add the "balanced" product which will restore every component, even those that are not measured. If excessive additions of concentrate are called for, it may be advantageous to measure one of the other components. This will determine the validity of the initial test results, and may prevent unneeded use of concentrate.

Another check that should be performed is to measure the amount of solid contaminant remaining in the coolant after passing through the filter. This can be used to detect filter malfunctions; early detection of these can prevent major problems. It can also be used to check for different types of contaminant, such as metallic or non- metallic. If much of the contaminant is a non-metallic, crystalline precipitate, the underlying cause should be determined and corrected, because an excessive amount of the precipitate can induce filter problems. Grinding systems are notorious for the amount of wheel grit present. If this grit, which can cause finish problems, is passing through the filter it will be identified through this check.

Coolant foaming is a detriment if it is due to improper surface tension, resulting in the foam remaining on the fluid surface for an unacceptable period of time. Defoamers may be added to change the surface tension and reduce the amount of foam. However, if too much is added, it may not mix well and will remain suspended in the coolant until it is deposited on the barrier. On a permanent barrier the defoamer cover will not allow the coolant to pass through, while on disposable barriers it will be removed from the system. The coolant supplier should be able to recommend the proper defoamer and amount to use.

Other components and conditions may be checked periodically to determine if the fluid is performing adequately in the filter. These checks include filterability, settling and surface tension. The purpose of the filterability measurement is to prove that the coolant is able to pass through the filter barrier restrictions; the coolant must be able to pass through the barrier or the system will not work. The settling capability of a coolant is an important factor in those units that require chip settling. These systems may not function properly or as efficiently if settling characteristics change. The surface tension of a fluid can change the foaming and settling characteristics, causing conditions discussed earlier. Each component of the filter system is affected by changes that occur in any of the other components, whether these occur suddenly or over a long period of time. While most manufacturing plants control the expected changes by controlling the three maintenance areas discussed above, unexpected changes will sometimes occur. Careful observation of the system is required to identify unexpected changes, and a quick response to the observed change is necessary to maintain the system.

Conclusion

The many filter system variations and options that are available have been discussed throughout this paper. In each area, technical experts can help guide the buyer through the necessary steps to acquire the proper equipment. Care should be taken in selecting these manufacturers to ensure receiving a quality product and satisfactory service.

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Jean M. Berger
Supervisor, Chemical Area
Henry Filters, Inc.
1350 Van Camp Rd.,
P.O. Box 859
Bowling Green, OH 43402
Phone 419/352-7501
Fax 419/352-0224

Jean M. Berger joined Henry Filters in 1985 as a chemist. Currently she supervises all chemical troubleshooting and helps customers develop chemical control programs. Ms. Berger received a B.S. in Biology from the State Univ. and College of NY at Fredonia.

Jill M. Creps
Lab Technician
Henry Filters, Inc.
1350 Van Camp Rd.,
P.O. Box 859
Bowling Green, OH 43402
Phone 419/352-7501
Fax 419/352-0224

Jill M. Creps joined Henry Filters in 1985 as a lab technician. She continues to work in this position while attending Owens Technical College majoring in Industrial Marketing. She handles all customer samples and shares in other lab responsibilities.

Henry Filters, Inc. is a leading supplier of standard, individually engineered, central coolant filtration systems used primarily by the metalworking industry. Individual, stand-alone filter systems are also designed for applications not requiring large, central systems. In addition to its headquarters in OH, Henry Filters has an office in Litchfield, England, allowing it to market worldwide.

Coolant Management: A Users' Introduction And Guide To Waste Minimization

George L. Hoobler
Master Chemical Corporation

"Something was wrong" at a large midwestern transmission plant. Worried accountants came to the manager of maintenance systems with an "urgent problem." Their "figures" weren't coming out right. Was there computer trouble? Were perishable tools charged to the wrong account? The "trouble" turned out to be that the facility was "significantly under budget on cutting tools ..." We'd all love to have a "problem" like that!

The good news is, any metalworking firm that uses water-based cutting or grinding fluids can indeed enjoy such savings through Coolant Management.

Briefly defined, "Coolant Management" is the maintenance and recycling of coolant fluids for greatly extended use. Its immediate advantages are reducing purchases of costly coolants, and dramatically reducing, even eliminating, expensive disposal of spent coolants. The latter makes it a prime managerial tool for minimizing not only waste but exposure to permanent legal liability for environmental damage under federal and state environmental statutes.

As will be shown, maintaining clean and effective cutting fluids improves performance in virtually every aspect of metalworking. At the same time, it reduces machine and coolant system clean-outs, downtime, and lost production. The net effect can be, and typically is, significant improvement in overall productivity, reduced costs and higher profits. Accordingly, coolants should always be treated as a production rather than a mere maintenance item, and should be controlled by higher-level management. This guide will explain the basic whys and hows of Coolant Management and show you how to put it to work.

Here's how it improved performance at the 1,500,000-square foot plant for making industrial and automotive transmissions. Only three months earlier, management had corrected a costly headache in a machining line by installing a Coolant Management system. (In that short time, the system was already saving enough money to make the accountants jittery about their books!) Consider their previous dilemma — the same situation is all too often the case in metalworking facilities of any size, even those with but a handful of machines:

> The ... facility is a big user of water-soluble cutting and grinding fluids or coolants. Although high tech in most ways, *for years the plant used the cheapest available coolants; no thought was given to recycling them* for indefinite life.
>
> "The coolants we used left gummy, sticky residues on our machines and caused mechanical malfunctions and mislocation of parts, with high machine repair and broken tool replacement costs," said [the maintenance manager]. "We knew lubricating and hydraulic oils which leaked into our coolants reduced tool life and promoted bacterial growth. But all we could do about it was try to skim off whatever floated to the surface of our central system. It wasn't enough. Our maintenance and tool costs kept increasing."[1]

If this sounds too familiar, it is because all of these troubles and many more have afflicted industry from "day one." However, there have been strong incentives in recent years to do it right. These include:

- The rising cost of coolants, labor, machines and cutting tools;
- Sharply increased foreign competition, which should prompt more modernization here;
- Increased concern (and legal liability) for operator safety;
- And perhaps most pressing, the growing insistence on sound environmental practices and waste minimization.

This last concerns us in particularly important ways: not only in meeting ever more stringent environmental regulations and in the soaring costs of legal exposure and of waste disposal, but in recognizing that with today's technology, responsible pollution control is in every way compatible with profit maximization. This is one area where business and the EPA are on the same side. We now have the means, previously unavailable, to prevent coolant failure, hence the dumping of hundreds or thousands of gallons of contaminated fluid per year for every metalworking machine. The same Coolant Management recovers metalworking chips, fines and recyclable tramp oils. This is at once the right and the cost-effective thing to do, and it begins with careful management. It should be planned, not imposed by circumstance. Again, the EPA agrees: waste minimization "is a job best done *when companies set their own goals and objectives.*"[2] Management that fails to employ the new tool of Coolant Management is sure to be at a competitive disadvantage in coming years.

Given the facts, it is very puzzling that so many completely avoidable problems persist. Some of this is due to the age-old but false attitude that "coolants are a necessary nuisance and you can't do anything about them." Yes you can! More important is simply a managerial failure to investigate all avenues of improved productivity. We saw this in the case of the transmission maker: "...for years the plant used the cheapest available coolants; no thought was given to recycling them..." This is equally true in many other plants even today.

It is certainly understandable. Coolants are the lowest-cost item in the metalworking budget: a tiny 0.46% of the overall estimated cost. On a cost basis alone, this appears to be the last place to look for productivity gains. But this is a serious mistake. Management cannot afford to overlook seemingly small details, because they may have major effects in profitability — as is the case here. A sounder view has long been advocated by Dr. W. Edwards Deming, an internationally-known expert on quality control. Managers, he emphasizes, should be "controlling the manufacturing process so thoroughly that one cannot make bad products."[3]

Managers following Dr. Deming's principle have found that coolant fluids, though small in relative cost, have a large effect on productivity; that is, a leveraged effect many times their cost. Thus a dollar invested in Coolant Management may well yield a twenty dollar improvement, or more, in profits. We understand this only if we look at basic metalworking processes and relationships instead of analyzing exclusively in terms of isolated direct cost.

It is at exactly this point that communication seems to break down. Those who are most aware of coolant problems (from machine operators to chemical engineers) have neither accounting nor high-level managerial responsibilities. And top managers in turn too often know little about the technical side: what might be done to improve operations, with what effect on productivity. This guide hopes to shed a little light for both sides, in nontechnical language.

The Characteristics and Functions of Coolants

Dry machining, as a rule, uses too much energy and produces too much heat and metal distortion for efficient work. Therefore it has long been standard practice to bathe the cutting tool, at its point of contact with the workpiece, in a cutting fluid. The primary purposes of the fluid are to lubricate the cut, reducing friction and energy consumed; and to cool it, by drawing off some of the heat produced in cutting, for efficiency and reduced metal distortion. The fluids are commonly called "coolants" because of this.

The bases for coolants range from pure water, which has the best cooling ability but offers no lubrication at all, to oils, which have the best lubricity but inferior cooling. In practice, commercial coolants often lie in between. Plain water would rust the machines and iron alloys, so is never used. Approximately half the cutting fluids sold are straight oils, for applications that need maximum lubrication, at whatever loss in cooling.

The rest of the commercial coolants are water-based, with various chemical agents added to improve lubrication. The generic term for them is "water-miscible," simply meaning mixable in water.[4] Note well that regardless of the application, there is no perfect coolant. This is due to the differing qualities of oil and water in cooling and lubricating. When lubricity goes up, cooling goes down, and vice versa. All commercial coolants are compromises between the strong points of one or the other. But they are very good compromises, with an enormous amount of engineering know-how to back them up, and plenty of choices for the user to meet his particular needs. The coolant supplier can and should analyze the technical requirements of a given machining operation and recommend the best coolant for it. Should problems develop later, the supplier can analyze these also, and adjust the coolant formulation.

High quality coolants serve many other purposes than those directly involved in cutting. They should prevent corrosion or rust in both cutting tools and workpieces. They should be resistant to bacterial degradation of the fluid (this is called "bioresistance"). They should leave a protective residual film on the machined surface, itself easily dissolvable later, be free of gumminess or crystalline residues, and should protect the piece from later rust and corrosion. Coolants should be nonflammable whenever possible (all water-based coolants are). They should be cleanable through filtration. Grinding in particular is highly dependent upon very clean fluids. Perhaps most important, the coolants absolutely must be nontoxic and must promote a healthy and pleasant work environment.

You, as a user of coolants, have a right to expect, and to demand, all of these safeguards in the cutting fluids you buy. You can be sure that you will not get them if you take the cheapest option on your lowest budget item, coolants, not knowing all the headaches and excessive costs that will follow. High quality coolants are more expensive, due to the engineering built into their formulation and the purity of their ingredients. But they alone can best handle the many functions needed in a cutting fluid. As we will see, there could hardly be a better example of false economy than buying an inferior coolant because it seems to cost less in the beginning. In the long run, poor quality coolants cost far more. How important this is, and what can go wrong using less than full-function coolants, is what we will look at next.

How Coolants Fail

Even if you haven't seen it, you can well imagine how easily the cooling fluid circulating through a metalworking machine gets dirty. There is a sump, or reservoir, underneath the machine, from which fluids are pumped back onto the cutting tool, and then are drained off back to the sump. In the process, the fluid may pick up metalworking chips and other residues, leaked or spilled oil, airborne bacteria, shop dirt, food scraps, cigarette butts, spit and other contaminants. Some facilities use local tap water instead of purified water in their coolants, which in most cases adds a heavy (and rapidly increasing) dose of minerals to the coolant. Certain oils can also add minerals such as sulfur or nitrates, and some tramp tapping fluids can add active chlorine or sulfur, creating corrosive acids in the coolant.

The sludge and gunk that accumulate in the process are bad enough, but the worst — and unavoidable[5] — danger is bacteria. There are two kinds, aerobic (which reproduce in the presence of oxygen), and anaerobic (which reproduce where oxygen is absent). Anaerobic bacteria usually do little damage, mainly because their effects are so intolerable that correction is immediate. They produce the horrible "rotten egg" gas that machine operators dread. If they were allowed to persist, they would ruin machines through acidic corrosion. Aerobic bacteria do much more damage without being so vividly noticeable. They are introduced by, or feed on, every one of the contaminants mentioned above. They reproduce like crazy, quadrupling in number every hour! In the process they produce harmful acids and other substances that corrode or gum up the machine, cutting tools and workpieces, and break down the coolant fluid. The fluid turns rancid and "splits out" into an unusable mess. At that point, the coolants must be discarded and trucked to a landfill, at an ever- increasing cost in haulage and disposal fees, not to mention laboratory test costs and penalty rates should the waste contain, for instance, halogens, phenols or BOD/COD substances (hard-to-treat compounds with high Biochemical or Chemical Oxygen Demand).

Just to make matters worse, the two kinds of bacteria work in harmony, neither interfering with the other. The aerobic ones multiply when the fluid is circulating, full of oxygen and food. The anaerobic ones grow when the machine is shut down and the fluid is not circulating, especially in the machine sump, turning the coolant into black slime. Chips and machine waste in the sump are a breeding ground for bacteria, one nearly impossible to penetrate with germicides. Note: Some coolant manufacturers advertise that their cutting fluids are "biodegradable," which sounds like a good thing environmentally. Not so! What they are really saying is that their fluids are susceptible to bacterial attack, which often leads to bigger pollution problems and *always* leads to higher coolant costs.

The end result is the failure of the coolant — and all that it is supposed to do. It is gone for good. There is no way to restore failed coolant. The only medicine here is preventive medicine. Either you prevent coolant failure through Coolant Management, or you lose it. And at that point you have to pump it all out and clean the machine by hand, laboriously, and haul the waste off to a dump that is charging two to five times as much as it did for disposal a few years ago (and in some cases far more).

In the meanwhile, the failing coolant has been wreaking havoc on your machines, cutting tools and workpieces, causing all the problems we saw at the large transmission plant and more, all adding to cost. Cutting tool and wheel life is reduced and is erratic. Machining tolerances also become erratic, with poor finish and size control. Workpieces are subject to rust or corrosion, and if on automatic conveyers, may mislocate before being cut; both factors cause a high fail rate. Machine downtime is high, both for cleaning and repairs. Failing coolants also harm the workplace environment. Tramp oils cause a smoky atmosphere around the machine. Dirty coolant can become irritating both to touch and inhalation resulting in operator discomfort. Such coolant could be deemed "hazardous" under EPA rules, and is that much harder and more expensive to dispose of. Cleaning it all up is labor-intensive, not to mention unpleasant, and costly in both downtime and labor. Finally, the machine must be fully recharged with new coolant, which will start going downhill almost as soon as it is poured in. Then the cycle will repeat.

Every one of these problems is avoidable through ***managerial control*** of fluids. Doesn't it make more sense to you to keep the coolant clean and effective and at work indefinitely, instead of just letting it fail over and over and over?

Doing It Right

Everyone understands that a machine won't work optimally unless its moving parts are correctly lubricated. It is time that all management understood that the same is true of coolants: a metalworking machine cannot work optimally unless it has a clean and correctly formulated cutting fluid. For years, much of the metalworking industry has suffered sub par performance caused by faulty coolants, perhaps thinking it normal or unavoidable. The kinds of problems we detailed above are widespread. This marks a managerial failure: managers are often unaware that they have a problem, or how easily it can be solved. Let us put things simply. If your metalworking facility is not using Coolant Management for its water-based coolants, you do have a problem.

Poor performance is not normal and is not inevitable. For nearly twenty years it has been possible to maintain coolants in a clean and effective condition. Where faulty coolants were causing headaches, Coolant Management restores optimal machine performance. Overall productivity improves, and costs go down. But it won't happen until management makes it happen. That's why we stress that the first step in Coolant Management is ***managerial commitment*** to the program.

The benefits of good Coolant Management are many and represent positive performance in every case that we have seen where good records are kept. Machines stay much cleaner and function correctly, with less maintenance and repair. Cutting tools are more reliable and have a longer life. Machining tolerances improve, so finish and size control are better, and fewer (very expensive) rejects ensue. There is much better in-process corrosion protection. Coolant purchases typically drop to 40% of previous levels, and coolant disposal costs can be cut even more dramatically — savings of 80% are normally achieved, with near total elimination possible. In many applications, undiluted coolant concentrate may be substituted for oil lubricants in gear boxes, hydraulic oils, brush-on tapping or threading compounds or machine way oils, so that when spills or leakage occur, the cutting fluid is enriched rather than contaminated. Little "tricks of the trade" like this lead to big savings later on in waste minimization and quality control.

Such waste minimization wins rave reviews by the EPA, but for our purposes, it's great because it saves a lot of money and bother. The messy chore of hand-cleaning machines and sumps is eliminated (which delights operators!). Indeed, the most noticeable result of Coolant Management is a far cleaner work environment, not least the air. Foul odors are eliminated, as are most dermatitis problems, with the added intangible benefit of improved morale and operator satisfaction. Clean-up costs go down too. In sum, the whole manufacturing process becomes faster, smoother, more efficient and more predictable: a benefit every manager will especially appreciate. Work scheduling can thus be controlled much better. Given the modern understanding that "in-process" inventory is costly, hence the trend to "just-in-time" manufacture, reliable scheduling is a necessity. *Unscheduled interruptions and breakdowns cannot be* tolerated.

Coolant Management is not magic. It is a tool available to managers to improve overall performance. Its track record is astonishingly good if the tool is used correctly. Those who have adopted it are enthusiastic about their results. Those who have not yet examined this option may wish to ponder the following few figures.

It is estimated that for every $1 in coolants, the industry spends $1.10 for abrasives, $4.60 for cutting tools and $214 for labor and overhead. Suppose that while adopting Coolant Management your relative coolant costs rise 50%. A modest and not-unusual 5% gain in productivity would return $10.70. A conservative 10% reduction in tool and abrasive costs would return another 57 cents, for a total return of $11.27 on 50 cents in increased relative coolant costs. Would you spend one dollar to get back $22.54, year after year?

Management at the midwestern transmission plant had no trouble making that decision. The system they adopted is the one we describe next. Moreover, where we picked up the story, they had only adopted it for one machining line. Given the positive results, they quickly installed Coolant Management for the whole plant. Soon, even their nervous accountants were enjoying it.

How to Install a Coolant Management System

The essence of Coolant Management is the introduction and subsequent maintenance of a high quality, stable, bioresistant coolant. The fluid must be correctly formulated for the job at hand, and must be maintained in the correct concentration. Most of all, it must be kept clean through a rigorously scheduled, periodic recycling process. It is up to management to make sure that personnel are trained and that the necessary procedures are carried out without fail.

In keeping the coolant clean, there are only three basic factors to be addressed: impurities in the water supply; tramp oils; and workplace contaminants. Control of these factors will in turn inhibit the growth of coolant-destroying bacteria, which feed on all of them.

At a minimum, an effective Coolant Management system will need the following:

1) A source of chemically pure water. Removal of minerals or impurities is done with a deionizer.

2) Positive-displacement coolant proportioning equipment. In plain English, this is a device for mixing coolant concentrate with pure water in extremely accurate proportions. The device is necessary because the coolant must be kept at the correct and unvarying concentration; otherwise it is vulnerable to bacterial attack and may otherwise become ineffective also.

3) Effective, portable equipment for cleaning and recharging sumps, in batch systems. A well-known mobile suction pump on the market answers this need perfectly. Operators like it because it turns machine clean-up into an easy, 15-minute job instead of the messy one- to-three hour misery it used to be.

4) A high-speed, disc bowl centrifuge to remove tramp oils, bacteria and particulate matter from the coolant. Very desirable also is a skimmer to remove oils that float to the surface. But only the centrifuge can remove machine-emulsified oils. (The tramp oils recovered by either may then be sold to recyclers.) The equipment must be able to reduce tramp oils to 0.5% or less of the coolant.

There is equipment available that combines the deionizer, proportioning device, skimmer, centrifuge and filtration system in one palletized package. This offers a complete and effective recycling center. Whether you use a central coolant system or a batch system of cleaning individual machines, the dirty coolant is pumped out and processed to remove all contaminants, recharged with water and new coolant concentrate, and returned to use. This should be done no less than once a month, sometimes more often.

Coolant recycling equipment costs vary, but the best on the market (and it is penny wise, pound foolish to buy less) has been found, in numerous Coolant Management installations, to typically pay for itself in from four to twelve months, depending on conditions. From then on this equipment contributes a monthly profit to the bottom line. Returns on investment (R.O.I.) of 100% to 200% are not unusual for this type of equipment. However, the equipment capital investment is no longer the only option if Coolant Management is adopted. In many areas, coolant recycling companies now offer mobile services, and they are thriving. These services truck their own recycling equipment to your plant, purify and recharge the coolant in your machines, then go on to their next customer. This is particularly useful to small metalworking shops that cannot afford the capital costs of recycling equipment. Such services are, in a way, a striking proof of the impressive economic benefits of Coolant Management. *They* profit by recycling your coolant and *you* profit in waste minimizaton and improved productivity. The sum of profits, in effect, is the economic gain available from Coolant Management.

Space does not permit giving you here complete instructions for selecting, installing and operating a Coolant Management system. But there is no need to. A reputable coolant supplier can — and should — provide everything you need, from initial analysis of your operations, to cost-savings projections, to day-to-day operating instructions, to advanced technical support on a continuing basis. A single-source supplier of both coolants and recycling equipment is best because, should the system fail, the source of failure and means of correction will be known without doubt or controversy. Such a company has made its own commitment to do things right. It knows that in helping you undertake Coolant Management, it will actually sell you much less of its coolant. But it also knows that minimizing waste is good for its clients' business as well as environmentally right. As you prosper, it prospers.

Coolant Management can upgrade productivity and solve waste disposal problems in your company. Find out who is doing it right, check their references, and inspect systems they have installed. If you like what you see, have them conduct a thorough plant survey for you with projected savings and R.O.I. A reputable supplier should also offer a post audit service a year or so following installation of Coolant Management, to validate those forecasted savings. Then you can be confident that Coolant Management has delivered the benefits you expected.

Notes

1. "How Borg-Warner Recycles Coolants," *Centri-Facts*, Fall, 1986; emphasis added.

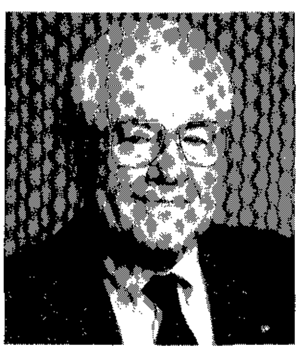
2. "Less is More" video produced by EPA, 1989.

3. "Quality, Productivity, and Competitive Position," W. Edwards Deming, 1982.

4. This term is used whether the mixture is a solution, a colloidal suspension or an emulsion.

5. It is not practical to machine under sterile conditions, so the cutting fluid is continuously inoculated by bacteria from contaminants, including those in the air.

George L. Hoobler
Vice President
Corporate Services
Master Chemical Corporation
501 West Boundary
P.O. Box 220
Perrysburg, OH 43551-0220
Phone 419/874-7902
Fax 419/874-0684



George L. Hoobler joined Master Chemical in June 1977. Before joining Master, he was with Warner & Swasey Co. for ten years, and prior to that he spent nearly twenty years with International Nickel Co. Mr. Hoobler is a graduate of the U.S. Naval Supply Corps School, received his B.S.M.E. from Marquette Univ. and his M.S.M.E. from NJ Institute of Technology.

Master Chemical manufactures metalworking fluids and related equipment for worldwide markets. It markets a complete range of products including water miscible cutting and grinding fluids, specialty cutting oils, washing compounds, rust preventatives, EDM oils, stamping and drawing compounds and tapping fluids under the TRIM® brand name. Its related hardware includes XYBEX® recycling systems, Hydroflow filters and other fluid handling equipment. Master Chemical Corporation is a Regular Member of the Independent Lubricant Manufacturers Association.

CHAPTER FOUR
Treatment Options

Even with the best fluid management, no metalworking fluid will last indefinitely. Typically, two situations will dictate disposal of a fluid: poor appearance and rancid odors. Though these criteria are subjective, most "dump and recharge" decisions are made because the fluid is too oily or dirty, or simply smells too bad. More sophisticated controls can be implemented, where decisions are based on pH, concentration, bacteria or mold counts, oil contamination, particulate contamination, conductivity, or other measurements. Nevertheless, the user must then decide how to treat and dispose of the fluids, once the decision is made to "dump."

Some typical considerations when selecting a waste treatment method include:

- "Hazardous" versus "non-hazardous" regulatory classification of the waste;
- Volume of waste;
- Waste characteristics;
- Availability of sewer disposal;
- Availability and cost of contract hauling service;
- Availability of waste treatment assistance;
- Equipment, labor and chemicals required for on-site treatment;
- Liability; and
- Cost.

Nearly all metalworking fluids require some form of treatment prior to disposal. Once fluids are contaminated with oil, dirt and bacteria, they must be treated to comply with sewer discharge standards. Each plant must then determine whether it can justify on-site treatment or having the fluid treated and disposed of by an outside company.

The primary disposal options for plants are contract hauling, chemical treatment, ultrafiltration and evaporation.

An excellent guide to certified waste haulers is the J. J. Keller and Associates' *Hazardous Waste Services Directory* (see Appendix). Other sources of information include federal and state EPA offices. Finally, the Chamber of Commerce guide or yellow pages will list these types of services or businesses. It is very important to select a certified hauler who is registered with the U.S. EPA.

The economics of contract hauling vary with the volume of waste, characteristics of the waste, geographical location, and availability of disposal facilities. Typical prices range from 35 cents per gallon to several dollars per gallon for a non-hazardous oily wastewater. A fluid classified as hazardous will have a higher disposal cost. Recently the number of disposal sites has decreased, leading to an upward trend in the cost of contract hauling.

The liability issue affects any business that generates, transports, stores, treats or disposes of waste. It is important that each step of the process is completed in an ethical and legal manner. In every case, the most effective methods for treatment and disposal must be used in order to minimize future liability.

Chapter Four discusses these treatment options.

Wastewater Treatment of Metalworking Fluids: Three Options

John M. Burke
Eaton Corporation

Abstract

Proper disposal of spent metalworking fluids is an ever increasing problem. As a result of legislation by federal, state, and local governments, and of the activities of environmental citizen action groups, industries are required to get more involved in on-site waste treatment. Yet even 15 years after passage of the federal Clean Water Act, confusion surrounding the legal aspects, waste treatment system design, performance and appropriate equipment selection for metalworking fluid disposal still prevails. This paper will attempt to assist the user of metalworking fluids in better understanding these complicated issues.

What Is Waste Treatment Of Metalworking Fluids?

For the purpose of this paper we will define WASTE TREATMENT of metalworking fluids to mean the COLLECTION and/or SEGREGATION of fluids for the purpose of reducing the POLLUTANTS in the water phase, and the concentration of POLLUTANTS in a second or sludge phase.

To better define the term, it may be helpful to describe what waste treatment of metalworking fluids is NOT.

The current technology of WASTE TREATMENT of metalworking fluids will not destroy or somehow magically "neutralize" a waste cutting fluid. It is not like waving a magic wand over a solution and having it disappear. That simply does not happen; there will always be some waste or some solid or liquid left over. Also, keep in mind that the water leaving a waste treatment system will still require some form of secondary treatment before this water is released directly to the environment. For example, most discharges from a treatment system are disposed to a publicly owned treatment works (POTW), otherwise known as a sanitary sewer, where further treatment is provided.

COLLECTION and/or SEGREGATION of spent metalworking fluids can be the most challenging portion of this type of project. Removing spent fluids which are flowing into existing pipes and drains, or locating the waste sources, requires just as much planning as the design of the basic treatment system itself.

Furthermore, care must be taken to ensure that you are not simply transferring pollutants from one area to another. For example, incinerating certain types of cutting fluids could eliminate a potential water pollution problem and create an air pollution problem instead.

What Is A Pollutant Or Pollution With Regards To Metalworking Fluids?

A pollutant many be an element, elements, a compound, or selective groups of compounds which is/are undesirable at an established level in the receiving environment (POTW, storm sewer, creek, river, lake, air, groundwater, or landfill).

A key point to understanding the word "pollution" is that a pollutant is locally defined. Just because one company uses a certain metalworking fluid and can legally dispose of this product directly to its local POTW does not mean that you can use this same product and dispose of it directly to a different POTW without violating its regulations. Simply put, when spent metalworking fluids leave your facility either by sewer pipe, air or truck, there is a specific law or laws and a set of regulations which govern this activity. Know your specific laws and avoid a lot of problems later.

When you are getting involved in understanding what waste treatment and pollution are, you are going to be deluged with a whole new terminology. Typically some of these terms which define pollutants in relation to metalworking fluids are:

BOD_5	Biochemical Oxygen Demand 5 Day
COD	Chemical Oxygen Demand
TOC	Total Organic Carbon
pH	Intensity of the Acidic or Basic Character of a Solution
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
O & G	Oil and Grease; can also be called Freon Extractables
TPH	Total Petroleum Hydrocarbons
TTO	Total Toxic Organics
FOG	Fats, Oil and Grease
Influent	Pollution Into a Treatment Plant
Effluent	Treated Wastewater From a Treatment Plant
mg/L	Milligrams per Liter (sometimes called parts per million)
ug/L	Micrograms per Liter (sometimes called parts per billion)

ND	None Detected
<Detected	Less than Detectable (Quantifiably Measurable)
DO	Dissolved Oxygen
MCL	Maximum Contaminant Level
MDL	Minimum Detection Level

If, after reading this you find there are terms or abbreviations which make little sense to you, I strongly recommend you get a copy of the book entitled *Standard Methods For the Examination of Water and Wastewater Wastes*, 16th Edition. This book is an invaluable tool in understanding the terminology of waste treatment. It contains a short text of the significance of each pollutant, and an extremely detailed procedure for the analysis of pollutants.

Another valuable text is *The Condensed Chemical Dictionary*, 10th Edition, published by Van Nostrand Reinhold. Between these two texts, you should easily be able to understand the abbreviations and the significance of pollutants you may be generating.

Establishing Whether You Need To Waste Treat At All

Just because you use metalworking fluids does not necessarily mean that you are a polluter or that you generate pollution. So, you must establish a procedure to determine where you stand relative to your environment. To do this there are several things you must know.

A. Who is regulating you?

Most environmental law originates at the federal level. For example, the federal government passes regulations which it requires states to adopt. The state, in turn, imposes these regulations on cities or sewer districts. These cities or sewer districts, in turn, regulate you, the user. If you dispose directly to state waters, you will be regulated directly by the state. Further, if you are a metal finishing plant such as one that does plating, chemical etching, coloring, phosphating, etc. and you discharge to a city or sewer district, you are directly regulated by the federal pretreatment standards for electroplaters. You are also monitored by the city which reports your pollutant levels to the federal government.

Throughout this paper, we shall refer to your Immediate Regulating Agency as your IRA.

B. When are they measuring you?

Once you have established who is setting your regulations, it is important to determine how frequently your regulator is measuring you. If you are not a suspect polluter, you may audit yourself and report these results to your IRA once per year. If you are being monitored by an IRA, the minimum frequency they would monitor you is quarterly. If you are discharging to a small municipality and they are having problems with industrial polluters, you could expect to be monitored without warning on a daily basis.

C. How are they measuring you?

This issue is very important because if you are a small generator of pollutants, you could be discharging them when the local regulatory agency is obtaining their sole sample. In this case you will not be credited for your normal dilution flows, and their grab samples could erroneously indicate a serious problem.

There are many ways your IRA can sample you, and the process of sampling industrial waste streams, especially those containing oil, can be a science in itself. The fairest way that you could expect to be sampled would be by a composite sampling device. With these devices the IRA can get a reasonable assessment of your discharges to the sanitary sewer.

Our experience has been that, if you feel that the sampling device (be it a grab sampling or a composite sampling) yields an erroneous reading, most IRAs will allow for a resampling, but *all data must be reported.*

D. Where are they measuring you?

There are three distinct ways the IRA can measure you: 1) they can measure you at the point where all your plant's waste, both sanitary and industrial, are combined; 2) they can measure directly from the discharge of your waste treatment system; or 3) they can measure your sanitary discharges and your industrial discharges separately and apply a weighing factor for each flow separately.

If you are measured directly at your industrial waste pretreatment system, you will not be permitted any diluting flows of water from your sanitary sources, in which case your industrial waste treatment system will have to operate at peak efficiency.

E. What is regulated?

As we discussed earlier, the terms of waste treatment are important and the IRA will not only specify the pollutant they want monitored, but also dictate the amount of that pollutant they will allow daily, weekly, etc..

For example: A typical city sanitary sewer ordinance may monitor the following:

BOD_5

COD

Flow
Suspended Solids

Oil and Grease

TTO

Cadmium

Chromium

Copper

Cyanide

Lead

Mercury

Nickel

Silver

Zinc

pH

Your IRA can impose limits on any of these, and exceeding these parameters can result in surcharges and/or fines.

An important point at this part of the paper is a word not found in POTW ordinances or in EPA regulations, and that is the word "biodegradable." Interestingly, some metalworking fluid suppliers still use this word in their literature; however, it is meaningless to the agencies that regulate waste disposal. If a supplier says his product is "biodegradable," ask him for more scientific and meaningful pollution parameters such as his products' levels for BOD_5, COD and TOC, or what may apply to your local regulations.

F. What are the limits?

Typically, the larger the system into which you discharge, the more flexible are the limits on the pollutants. The exception to this would be if there is a concentration of like businesses in a general area. For example, Silicon Valley in California sets very stringent limits on fluorides, because chemicals high in fluorides are common in their industries. It is not good to be the largest discharger in a sanitary sewer or sewer district. The reason for this is that the limits that are imposed on you may be even more restrictive.

G. Are the limits flexible?

If you feel that the limits imposed on you are unrealistic, you can often negotiate those limits to some degree. It doesn't hurt to contact the IRA to discuss how it arrived at these limits. The limits are usually not established arbitrarily, and changing them may not be within the power of the IRA. For example, the city may assign the sewer superintendent as the monitor of the limits. However, in order to obtain an official variance, this procedure may have to go through City Council. If you are having trouble meeting an existing sewer ordinance because of malfunctioning equipment in your facility, the city sewer superintendent may, by his authority, be able to grant you a temporary variance.

H. How do I know if I have a problem?

Now that you have a better understanding of the laws and how they apply to you, you have two things to do to determine whether you have a problem or not.

1. Obtain a representative sample; and
2. Have the sample analyzed.

Obtaining a representative sample can be very difficult, even in a small facility. For example, a number of cutting fluids and washer compounds can be used, all at different mix ratios and volumes; and they can be disposed of at different times of the day. The most reliable method is to use a composite sampling technique. An entire paper can be written just on composite sampling and proper analytical procedures; we will not go into those complex procedures in this paper.

Finally, you must determine the magnitude of the problem. After comparing your results with the IRA's standards, you will determine how serious your problem is. You could be in a surchargeable category, which means that the pollutant which you are discharging to the IRA is acceptable, but the IRA will charge you by some method. The second category into which you may fall is a finable category. Built into any regulating agency's rules is a procedure for fining polluters. Let us say for example, that the IRA has a limit of 100 mg/L for oil and grease, and your analysis shows that you are at 500 mg/L. The first thing that you must do is report your results as soon as possible. Some laws are so structured as to fine the offender not only for the actual violation, but also for each day the violation is not reported. If you are in a surchargeable category, the decision to pay the IRA to treat your waste, or for you to treat your own waste, is purely economic. If you are in a finable category, you will have to present the IRA with a timetable of corrective action. Some portions of this timetable may have to take place within 24 hours if the problem is serious.

If you have determined that you have a problem that you want to correct, waste treatment should be your last choice. Take a look at some common sense ideas, such a fluid management, recycling, or switching from one type of metalworking fluid to another. But if you have already tried all these, then waste treatment or contract hauling are your only options.

Three Common Methods Of Waste Treatment Of Metalworking Fluids

At this point, you have determined that there is a problem, and you have reduced all your fluid volumes as much as possible through fluid management techniques, recycling, and the like. Supposing you still have a problem, you are now ready for waste treatment.

This paper will be limited to three methods of waste treatment or waste management. There are other techniques that I will not be discussing in this paper such as biological treatment, incineration, carbon adsorption, reverse osmosis (RO), and solidification. Each one of these could be the subject of an entire paper.

A. First Method: Evaporation

This is generally considered suitable for low volumes of waste. The primary reason for this limitation to low volumes is due to the enormous amount of energy required (approximately 960 BTUs per pound of water) to evaporate, or essentially to turn water into steam.

Chart 1 shows an example of a simple atmospheric evaporation system. The solution in the tank is heated to boiling, which initially starts at 212°F. In this case, a direct-fired natural gas flame is used as the source of heat. A blower fan on the top of the unit draws in room air through the burner tube and an opening in the lid. Care is taken for this incoming air to be drawn near the surface of the heated liquid, maximizing the efficiency of the evaporation process. This moisture-saturated air passes through the combined stack and mixes with the burner exhaust. The process has a continuous supply of fluids being added into it. The limiting factor is the amount of energy going into the process versus the amount of moisture leaving the system. This concept of evaporation is very straight-forward in the way it works. It could typically cost more than $60.00 per thousand gallons for operating costs alone, based on natural gas as the heat source. The following example shows a method to calculate your evaporation costs using natural gas.

Example 1

Assume 1,000 gallons of a metalworking fluid (MWF) are to be disposed, and this metalworking fluid is an emulsifiable oil mixed at 5% by volume. Further assume this emulsifiable oil contains no water in the concentrate phase and that you expect to concentrate the oil phase to 85% (oil:water). This system will operate on natural gas with an overall heating efficiency of 65%. The cost of this natural gas is $5.50 per thousand cubic feet (MCF), with an average BTU rating of one million BTUs per MCF, and it requires 960 BTUs to evaporate one pound of water. The following equations apply:

1,000 gallons MWF x .05 (mix ratio) = 50 net gallons of oil in 1,000 gallons of solution.

We expect to concentrate to 85% oil:water.

$$\frac{85}{100}\ \frac{oil}{total} = \frac{50 oil}{X} \quad X = 58.8 \text{ total oil/water remaining}$$

58.8 total gallons remaining — 50.0 net oil gallons = 8.83 gallons water not evaporated.

1,000 MWF — 50 gallons oil = 950 gallons water — 8.83 gallons not evaporated = 941.17 total gallons of water to be evaporated.

941.17 gallons water x 8.34 pounds/gallon = 7,849.4 total pounds of water to be evaporated.

7,849.4 pounds water x 960 BTUs/pound water = 7,535,424 net BTUs required at 100% efficiency.

7,535,424 BTUs÷ 0.65 (efficiency factor) = 11,592,960 total BTUs required.

Then using natural gas as a source of heat,

$$\frac{11{,}592{,}960 \text{ BTUs}}{1{,}000{,}000 \text{ BTUs per MCF nat. gas}} = 11.59 \text{ MCF nat. gas req.}$$

11.59 MCF nat. gas x $5.50/MCF = $63.74 to evaporate the volume of metalworking fluid used in this example.

The immediate advantage of the evaporation type process is that it requires very little chemical knowledge, takes up a small amount of floor space, has simple installation, is simple to operate and is not particular to the type of coolant used (synthetic, semi-synthetic, or basic emulsifiable oil).

There are some potential serious disadvantages. In some states an air pollution permit may be required. Fumes emitted from evaporators may be quite noxious, and if you are operating a unit such as this in a residential neighborhood, you may get complaints of foul odors.

Some fluids, such as those which contain high amounts of chlorides (chlorine), can be corrosive at high temperatures. Therefore your tankage may be best made of stainless steel (type 304 minimum).

The most serious problem with an evaporation system is the risk of fire or explosion. If someone dumps a low flash point mineral spirit, gasoline, kerosene, or some other flammable liquid, the risk is high for a fire. So there still must be some fluid management controls, but if you are only generating a couple of drums daily of waste fluids, this may be a good system for you.

B. Second Method: Ultrafiltration

This is a technique whereby waste fluids to be disposed of are pressurized and presented to a semi-permeable membrane where a cleaned phase of waste called the "permeate" passes through the membrane; and the waste stream, called the "feed solution," then becomes the concentrate. In essence, then, an ultrafilter system is nothing more than a supply tank, a pump, and a semi-permeable membrane. A schematic of an ultrafilter waste treatment system is shown on Chart #2.

The flow rate of an ultrafilter is based on the total surface area of the semi-permeable filter. Therefore, the amount of gallons treated per day depends on the total square footage of semi-permeable filter surface available. The capacity of such a unit typically would be sized for a minimum of 400 gallons per day and easily could be built up to treat 80,000 gallons per day or more.

The performance of an ultrafilter can easily reduce the actual oil and grease levels of a metalworking fluid from 30,000 mg/L to less than 100 mg/L in one pass. For metalworking fluids there are three different types of ultrafilters available:

a. Open Channel (½" to 1" internal diameter tube)

b. Hollow Fiber (approximately 0.030" internal diameter tube)

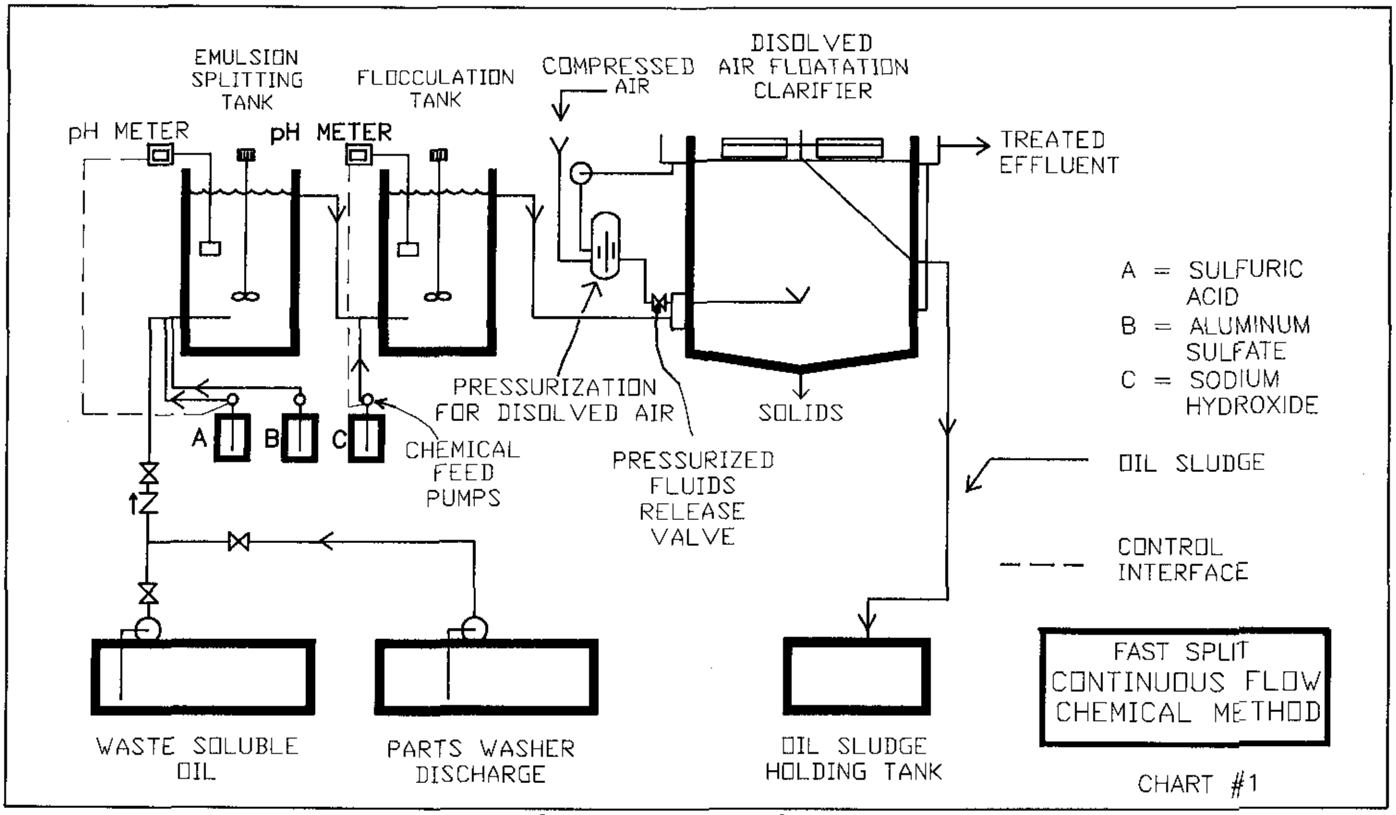


Chart 1. Evaporator Schematic

c. Spiral Wound (approximately 0.030" space between spiral wraps)

The ultrafilter operates by moving the feed stream at high velocities through the center section of the tube or tubes, or between the spaces of the spiral, and the treated solution passes through the membrane at right angles to the main feed stream's direction of flow. This method of filtration is commonly called cross flow filtration. The unfiltered portion of the feed stream is continuously recirculated back to the membranes via a holding tank and pump in a closed loop. Since the fluid in the loop is always recirculated and a portion is removed, the volume in the loop becomes less and less with time. Typically, more waste fluid is added to the loop until the permeate flow decreases to an unacceptable level, due to the concentrating of the feed stream in the loop. Then the waste treatment operator continues to recirculate the feed solution without adding any additional waste solutions and allows the loop to concentrate until the permeate flow drops to a near zero flow rate. The concentrated feed solution then is pumped out of the loop for off-site disposal. The ultrafilter is cleaned with a small volume of detergent and water, rinsed and put back into service, starting the process all over again. See Figures 1 and 2.

When selecting an ultrafilter, several key factors have to be considered:

1. Gallons treated per day (average);

2. Total amount of oil present (both free-floating and emulsified);

3. Amount of solids;

4. Flux rate, which is gallons to be processed per square foot of membrane per day, also called GFD (this is determined by the ultrafilter supplier).

The main advantage in selecting an ultrafilter is its ability to remove emulsified oils, free oils, certain long-chain organic compounds, and suspended solids. Because metalworking fluids encompass such a broad range of emulsifying agents, many different emulsion systems can be present in a waste stream containing these fluids. For the most part, the ultrafilter simply does not care, and it sees these oil compounds as solids and filters them.

The biggest disadvantage to the ultrafilter concept is inherent in the name itself: "ultrafilter" or "ultra tight filter." Small solids or gummy, tacky varnish-like compounds are an ultrafilter's worst enemy. Although the ultrafilter is designed to remove oil, it doesn't like to see too much of it, especially free floating oils. It seems somewhat ironic that the oils the ultrafilter removes best are among the items which it does not like in excess. Further, unlike the evaporator, the ultrafilter can be damaged permanently by some fluids, such as solvents, which can be common in a metalworking plant. Therefore, when operating an ultrafilter, great care and specific administrative controls must be taken to ensure that

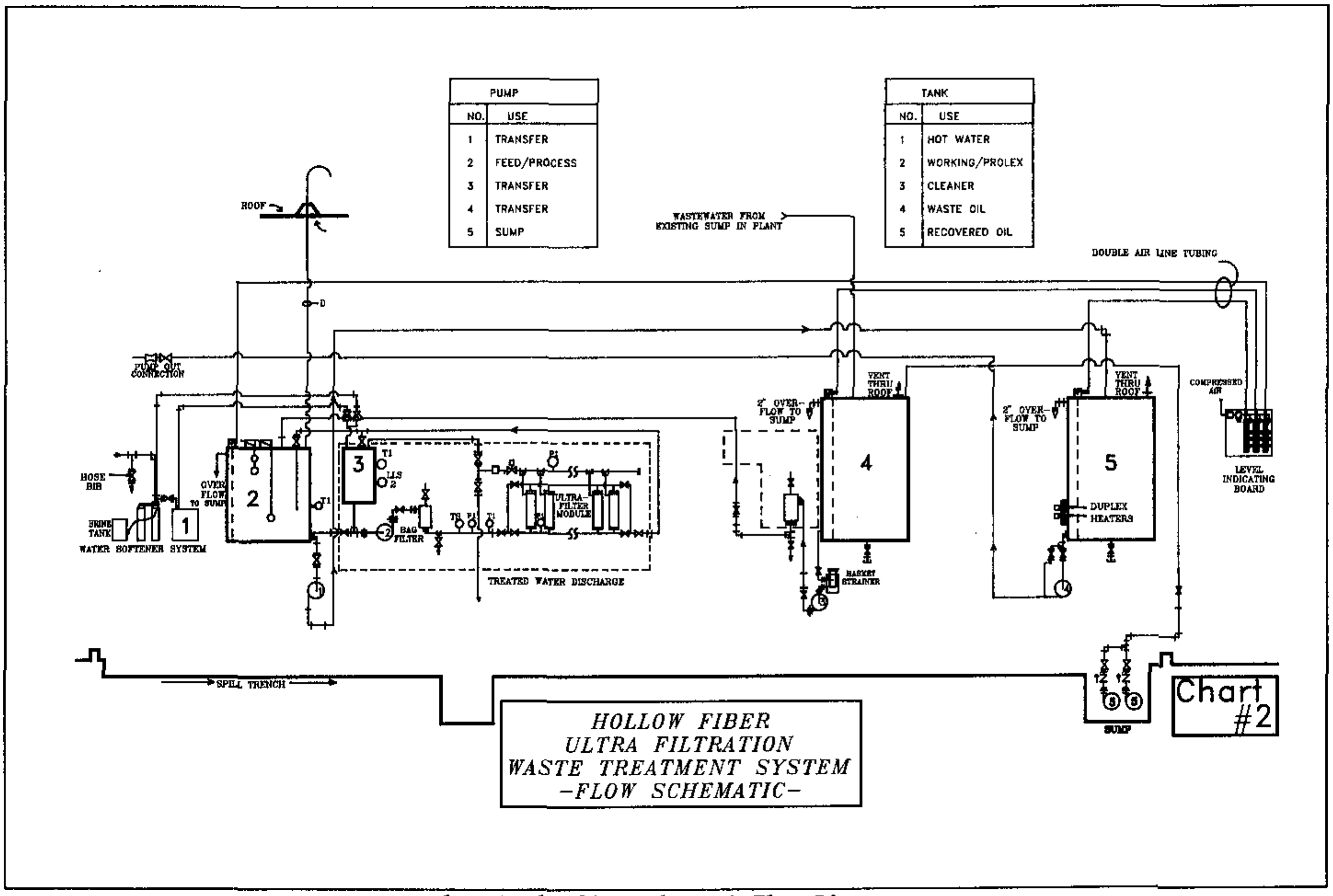


Chart 2. Ultrafilter Schematic Flow Diagram

materials which are used in a manufacturing plant which can damage the ultrafilter membrane be segregated so as to never get into the ultrafilter itself. One mistake on a system could cost multi-thousands of dollars for new membranes.

Another disadvantage is that dissolved metals may pass through the membrane, depending on the pH of the incoming waste stream. This can be a particular disadvantage if you are machining leaded steels, for example, and your IRA has specific limits on lead discharges. If you are operating an ultrafilter and you are treating these types of wastes, you may solve an oil and grease problem but continue to have a metals problem. But don't get me wrong! A properly designed and well administered ultrafilter is an extremely efficient method for solving oil and grease related problems. However, dissolved organic compounds such as those typically found in semi-synthetic and synthetic metalworking fluids pass through the ultrafilter membrane with only minimal reduction in organic content. Therefore an ultrafilter cannot be used to treat these types of fluids. The cost to treat a waste stream using an ultrafilter will run between $5.00 to $7.50 per 1,000 gallons.

C. Third Method: Chemical Treatment

Probably the one method used today to treat spent metalworking fluids more than all other methods combined is some form of chemical treatment. On a small scale, chemical treatment can be used to treat 55 gallons per day, and on a large scale it can be used to treat hundreds of thousands of gallons per day. The chemical treatment of metalworking fluids can be separated into two methods:

1. Acid alum method; and

2. Polymer method.

The basic principal of the chemical method of waste treatment is neutralization of surface charges. Most industrial fluids such as cleaners, soaps, detergents and metalworking fluids (with the exception of synthetics) operate on negative surface chemistry. Various kinds of dirt and oil can be dispersed or emulsified by attaching a strong negative surface charge by different types of chemicals onto the dirt particle or the oil droplet. To "break" this surface charge or emulsifying chemistry, the simple addition of strong positively charged chemical compounds to the solution being treated will begin separation. When sufficient positive chemistry is added to the solution, the contaminants in the solution will phase separate, usually with the oil phase floating and with the treated water underneath. Alum is a common chemical used for this purpose since its key element is aluminum, a trivalent cation; or more simply stated, aluminum has three positive charges associated with itself. Polymers used for this purpose are from a variety of organic compounds with either strong positive or negative charges associated with them, but they function in a waste stream by the same basic principal of surface charge neutralization.

The most common of these chemical approaches is still the acid-alum method. The acid-alum method or acid-inorganic salt method can very effectively handle large volumes of waste; and the real advantage to the chemical method comes when treating large volumes of waste. The chemical cost to treat 1,000 gallons can easily be under $5.00. The acid-alum method on a compatible waste stream can equal,

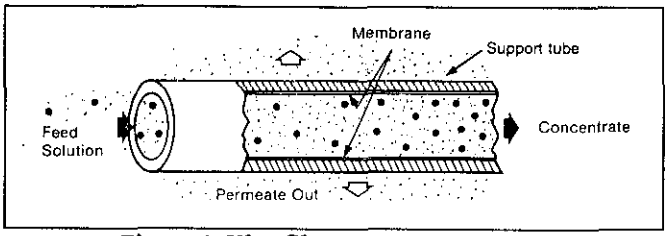


Figure 1. Ultrafiltration Cross Section

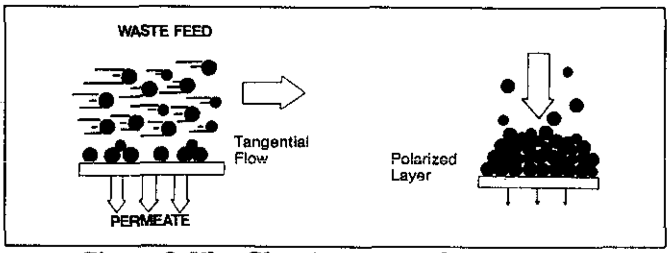


Figure 2. Ultrafiltration Cross Flow Diagram

if not out-perform, an ultrafilter for oil and grease removal; but this happens only with much effort and planning to ensure a waste stream is suitable to this method.

The advantages to the chemical treatment method are that it can handle a variety of wastes, virtually regardless of suspended solids and oil content; and if a large slug of water enters the holding tank (for example if someone left a flowing water source on) and the incoming flows become quite dilute, the flow rate through this chemical method can be doubled to accommodate the dilute incoming flow.

Also, a properly designed chemical method can remove dissolved metals through the action called "co-precipitation." In the example described earlier, machining leaded steels, the chemical method would remove a significant portion of the dissolved lead and collect it in the oil phase.

The disadvantages to the acid-alum chemical method of treatment are becoming ever more apparent. As metalworking fluid chemists learn better ways to make more stable fluids, these fluids seem to be more resistant if not impossible to treat via this method due to emulsifying chemistry that is so powerful that the amount of charge-neutralizing chemistry required is not practical or cost justifiable. Also, two metalworking fluids, when handled separately, can be treated by the acid-alum method, yet when mixed together can be virtually untreatable. The metalworking fluids which chemically waste treat the easiest are the simple basic emulsifiable oils. Ironically, basic emulsifiable oils are easily destabilized by the hard water salts containing calcium and magnesium ions, both of which are divalent cations; that is, they carry two positive charges each. A significant disadvantage of the chemical method is the inability of this technique to properly treat synthetic and many semi-synthetic metalworking fluids.

There are a few advantages of using polymers over the acid alum method.

a. Private chemical companies sell polymers and will offer both laboratory and on-site assistance so that you may use their chemistry. (Since the acid-alum caustic method uses available chemistry from a variety of sources, no assistance is generally given by suppliers.)

b. The precipitates obtained when using polymer chemistry can be much tighter when using the polymer method, so the oily phase will be much more dense.

c. This method can eliminate either the acid or caustic chemicals, so there is some basic simplicity and some safety in using this technique.

However, the polymer method is not without its disadvantages.

a. Polymers are expensive; using them you can easily have costs five times greater than the acid-alum method, without any apparent misuse or over-use of them.

b. If you are recovering the oil phase out of the collected precipitates, the polymer can be a disadvantage, as many polymers tend to knot the oil up into a tightly bound mayonnaise like substance. This tends to make extracting the oil by some other method more difficult.

c. Polymer chemistry can be a very narrow spectrum and may not work well on a widely fluctuating waste stream.

d. Polymer chemistry is proprietary, so understanding the reactions is therefore difficult. When a system gets out of control, how can you bring it under control when you don't fully understand what is happening?

e. Since the chemistry is proprietary, it is difficult to switch from one brand of polymer to another, since

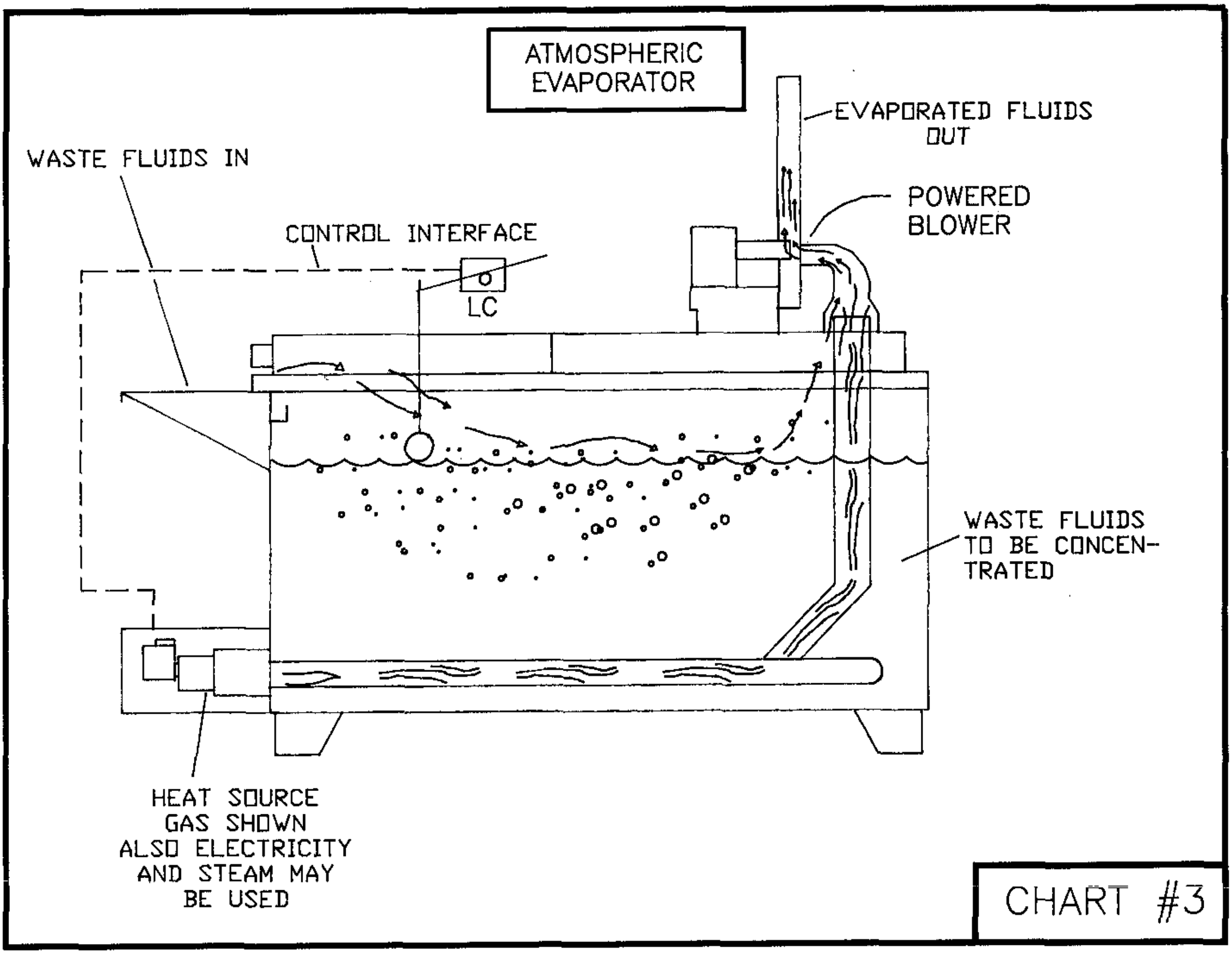


Chart 3. Fast Split Chemical Method Flow Diagram

it is not easy to cross-reference proprietary formulations.

A diagram of a flow schematic of an acid-alum treatment system which Eaton has used in many locations is shown in Chart 3. Referring to this flow schematic, acid and aluminum sulfate (alum) are added to the first reaction tank. In the second tank, a caustic chemical such as sodium hydroxide or calcium hydroxide (lime water) is added to precipitate the alum and also to assist in precipitating the oil and other suspended solids. These precipitates, typically called "floc," are separated in a device called a "dissolved air flotation clarifier." Using sodium or calcium hydroxide speeds up this process considerably, which is why we refer to the acid-alum-caustic method as the "fast split" method. This process can fit into a room roughly 25' x 30' and continuously handle a flow rate of 30 to 50 gallons per minute. The cost for such a system of the aboveground components can run roughly $160,000, including engineering, labor and material, but not including bulk storage tanks or building.

Conclusion

Although I have not covered every method of waste treatment, you can probably figure out which method might be best adapted to your situation. I would like to emphasize our views: waste treatment is a means to an end, and should only be considered when all other avenues have been considered.

If you are going to become involved in waste treatment, make certain the metalworking fluids you select are going to be easily treated and compatible with the process which you select.

Don't rely on promotional claims about products' ease of treatment or how environmentally safe the products are. Have the products tested yourself, and rely on your own data.

Don't give up on recycling; it is really the best method to use in the long run. It not only reduces the volume to waste treat, it also results in a reduction of new product purchases. Finally, we have designed many waste treatment systems. We have done this with detailed instructions, the best safeguards, durable first class equipment, and specific attention to details. The one single most important attribute that you need in order to make a waste treatment system operate successfully for years to come is commitment. If you or your management lack the desire to make it work, there is not a design or a system available that will work. *You* make it happen.

John M. Burke
Program Manager,
Environmental Engineering
Eaton Corporation
Manufacturing Technologies
Center
32500 Chardon Road
Willoughby Hills, OH 44090
Phone 216/523-6775
Fax 216/523-6498

John M. Burke assists all Eaton corporate and manufacturing facilities in engineering compliance with environmental regulations. In addition, Mr. Burke designs waste water treatment systems, fluid recycling systems and processes to eliminate or reduce pollutants at their source. Mr. Burke assists Eaton facilities in selecting specialty lubricants, cleaners and other chemical products which require special disposal considerations. Mr. Burke received his Bachelor of Industrial and Systems Engineering degree from the Univ. of Dayton. He is a member of STLE, has presented more than a dozen technical papers, holds three U.S. patents, and received Tennessee and Ohio Governor's Awards for his design of a fluid recycling system which resulted in significant waste minimization.

Eaton Corporation is a global manufacturer of vehicle powertrain components and a broad variety of controls serving transportation, industrial, commercial, aerospace, and military markets. Principal products include truck transmissions and axles, engine components, electrical equipment and controls. Headquartered in Cleveland, OH, the company has 43,000 employees at 130 facilities in 20 countries.

Treatment and Disposal of Metalworking Fluids

Terrence L. Heller
Mobay Corporation

This paper discusses several issues which plants with metalworking fluid wastes must address. An overview is given of changing environmental laws, general chemical pollutants and treatments with chemical, mechanical and biological programs.

Treatment and disposal of lubricants are governed by laws that regulate their handling. The 1972 Federal Water Pollution Control Act Amendment (FWPCA) mandated the control of water pollution and wastes discharged into navigable waterways. Also mandated was the creation of "pretreatment" systems to control industrial discharge to Publicly Owned Treatment Works (POTW). These facilities, with proper control of effluent, were to be in place by 1977. This major goal was reached by 85% of industry, but by only 30% of POTW, and so amendments were made to the act. Changes included further clarification of toxics, nonconventional and conventional pollutants, clarification of best practical and best available technologies (BPT and BAT), and more control for states to administer NPDES permits and control facility construction.

Congress strengthened the FWPCA in 1977 (including shortening the name to Clean Water Act (CWA), and again in 1987, in ways that have and will impact all industries.

A. POTWs must now impose and enforce concentration based standards on industrial effluents discharged into their collection systems.

B. CWA requires modifying industrial pretreatment programs to comply with pretreatment standards, even if to-date BAT is employed and standards have been exempt because of their discharge to a POTW.

C. CWA regulations prohibit the discharge of used oils to POTWs.

D. BAT and BCT (best conventional technology) effluent limitations for industrial pretreatment must have been met by March 31, 1989.

In 1988 the EPA was active in enforcing strengthened standards. The first federal felony charges, and several misdemeanors, were lodged against pretreatment violators. These laws, along with increasing disposal costs of nearly 15% annually, have heightened interest for industry to evaluate pretreatment, especially BAT, since discharge standards will be tightened for many generated pollutants.

Metalworking fluids contain several specific components which contribute to discharge problems. For convenience, the term "lubricants" will include all those possible components that are of concern, such as cutting fluids, lubricating fluids, drawing compounds, additives, cleaning solutions, and any oil based product that is emulsified in water.

Development of products by specialty lubricant companies to increase cutting tool life and provide greater return on investment has been successful. These products, classified as semi-synthetics and synthetics, are revolutionary for production, but are poorly addressed by current waste treatment practices. These products are creating problems by causing chemical pollutants in effluents to be above recommended discharge standards. Work has been done with high water content products to lessen this problem, but performance limitations do exist.

Industries concerned with treatment and disposal of lubricants will certainly be turning to suppliers for help. With product sophistication and stability improving, the end user is finding new lubricants more difficult and time consuming to treat. The technology burden of treating these lubricants, for this reason, will begin falling on specialty chemical manufacturers and their suppliers.

Many plants faced with pretreatment problems have turned back to lubricants that have good production performance, but yet are treatable. This is necessary to control treatment times, costs, and to prevent surcharges. Surcharges can amount to several thousand dollars per month for major infractions.

Suppliers of specialty lubricants should concentrate on technology for treating their products. If a supplier has a treatment program, it will benefit both him and his customer, reducing the burden on customers who must reevaluate treatment effectiveness if products are changed. It will reduce third parties who provide this service, especially since minimizing multiple suppliers is being emphasized by large corporations. Specialty chemical companies, likewise, will benefit by having supportive water treatment products that may provide a competitive edge. The water treatment market in general is expected to grow from an $8 billion industry in 1989 to $16 billion by 1992.

When developing treatment programs, it is necessary to know the various lubricants and their associated pollutants. Conventional pollutants from lubricants are oils and grease (O&G), suspended solids (SS), soluble constituents that contribute to O&G, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and pH. The basic types of lubricant contributing to these conventional pollutants are straight soluble oils, semi-synthetics, and straight synthetics.

Straight Soluble Oils are composed of mineral oils and emulsifiers. These oils are usually the easiest to treat, result in low residual pollutants in effluent, and good quality oil recovered that can usually be sold.

Semi-Synthetics are composed of fatty acids, alkanolamines, alcohols, polyglycols, amino acids, carboxylic acids, sulfur containing surfactants, chloroalkanes, triazoles, triazines, and mineral oils, among others. These semi-synthetics are more difficult to treat. Also, soluble contaminants remaining in treated waters are moderately high. Recovered sludges can be recycled, but oil content is lower and plants usually must pay for disposal.

Straight Synthetics are similar to semi-synthetics, except without mineral oils. Synthetic wastes are very difficult to treat, produce little sludge, and result in high O&G and COD residuals in treated water.

Other pollutants addressed by the CWA which affect lubricant users are nonconventional and toxic pollutants. Nonconventional pollutants include such items as phosphorous and ammonia. The list of toxics include over 220 items, and may be increased in the future. These nonconventional and toxic pollutants must be addressed only if their concentrations exceed pretreatment standards. Removal of many of these nonconventional and toxic pollutants can be expensive, and there may be special requirements for treatment, handling, and disposal of residuals under RCRA.

To achieve proper removal, different lubricant waste may require different treatment programs. Examples of treatments would be:

Soluble Oils are commonly treated by lowering the pH and using inorganic and/or organic demulsifiers to coagulate emulsified oils.

Semi-Synthetics which consist of nonionic emulsifiers are treated at a neutral pH with organic demulsifiers.

Synthetics are not treatable with coagulating polymer chemistry because of the soluble components. These soluble components must be oxidized chemically or biologically to insoluble and nonpolluting components.

Soluble oils are becoming less common. With improved pretreatment facilities, more semi-synthetics and synthetics are being utilized.

Historically, large facilities have treated lubricant wastes, while smaller facilities generally have paid disposal companies to treat their waste. In the future treating lubricating wastes in-house will become a common practice. These pretreatment practices will achieve effluent compliance, and lower disposal costs (Table 1). Discharge limits will become more refined by state and local agencies, and emphasis will be placed on pretreatment of effluent, and possibly in the future on treatment of pretreatment by-products such as oily sludges. The BCT for pretreatment of water is chemical treatment. A combination of three methods — chemical, mechanical, and biological - - are currently available and eventually, a combination of one or all of these methods will make up the BAT for future pretreatment.

Table 1: Disposal and Treatment Costs, with an Example of Possible Cost Reduction for In-House Pretreatment

Disposal Costs as of 1989	
Oil sludge (<30% oil) hauled by recycler	$0.20/gallon
Oily sludge incinerated	$1.50/gallon
Waste oil (>50% BS&W) may be sold at	$0.06/gallon of recovered oil
Disposal of dried solid sludge is	$55/cubic yard
Hazardous liquids	$2.00/gallon
Hazardous solids	$200/cubic yard
Treatment Costs (Estimated)	
In-house treatment	$0.32 to $7/1,000 gallons
Example	
If 5,000 gallons of 5% oil water is hauled to recycler:	
Cost is	$1,000.00
If this waste is treated and hauled as a 60% oil sludge:	
Chemical treatment at $7/1,000 gallons	$ 35.00
Hauling cost for 416 gallons	0.00
Payback for recovered oil	(15.00)
Net Cost:	$ 20.00
Cost Reduction:	98%
If waste is treated but is only 30% oil:	
Treatment cost	$ 35.00
Hauling cost for 839 gallons	165.00
Net Cost:	$ 200.00
Cost Reduction:	80%

Treatment for lubricants has conventionally been to chemically break the emulsions. This treatment methodology first lowers pH to 2-5 with acid. Inorganic salts such as calcium chloride, alum, or ferric chloride are added to break emulsions. The pH is then raised to 8-9 with caustic, lime or soda ash. Sometimes cationic and anionic polymers are used to help the demulsifying and flocculating process. With development of new effective emulsifying agents, this treatment process has become less effective and expensive.

Today waste water treatment is moving away from the radical pH adjustment and inorganics to a greater use of organic polymers. Research and development in this polymer chemistry is helping industry to improve treatment performance, and control operating costs at pretreatment facilities.

These organic treatments remove pollutants by neutralizing emulsifying charges of anionic surfactants, nonionic surfactants, and saponifying soaps so that fine particles coagulate easily. This allows the neutralized coagulated particles to separate from the water by gravitational or mechanical forces. Since minimal inorganics are used, only waste pollutants are removed and a minimum of waste sludge is generated. Studies indicated that costs for disposing of sludges from an organic program will be 60% less than a combined organic and inorganic program, and 80%+ less than a straight inorganic program. If oil sludges recovered from waste treatment are reclassified as hazardous, as the EPA suggests (and as is the case in New Jersey), the benefit for polymer treatment will be significant. This reclassification is an important concern. Currently there is a limitation on heavy metals and halogens in waste oil that classify them hazardous, and other limitations are predicted.

Mechanical treatment of lubricants has been addressed with Microfiltration (MF) and Ultra Filtration (UF), followed, if necessary, by Reverse Osmosis (RO). MF, UF and RO are moderate to expensive for the equipment and maintenance, depending on specific needs. These units will reduce waste volumes but will not eliminate waste. RO units do have problems with sensitivity to charged organic compounds and solvents. Limited chemical treatment will, in most cases, be required when mechanical processing is performed. Chemical pretreating MF and UF filtrate specifically will remove the gross quantity of contaminants, and result in reduced maintenance downtime and cleaning costs. Chemical pretreatment will also increase the life of expensive filter tubes.

Heavy oils and sludges created from pretreatment systems are generally recycled. Recycling facilities will pay for those wastes with moderate oil content. This value will vary between companies. Reclaiming facilities will treat waste sludges with caustic, acid or, if necessary, oleophillic demulsifying materials to separate water, solids and oils. In cases where chemical treatment is not adequate, sludges are mechanically treated. Heavier oil sludges will be mechanically separated with heat, centrifuges, or presses.By-products resulting from chemical and mechanical processing of both the lubricant waste and oil sludges are clean water, clean oil, and solid waste. Clean water which meets local POTW criteria can be either recycled for plant reuse or discharged to the municipality. Solids are landfilled. Waste oils currently are sold for fuel, or recycled as a lubricant base. Proposed laws may eventually require recycled oil to be burned in a certified waste burning facility.

In cases where waste by-products are not being recycled or economically disposed, chemical oxidation and bioremediation are being used. These methods can reduce hazardous waste and soluble organics by as much as 98%. In recent years, use of anaerobic and aerobic bioreduction for industrial pretreatment has been receiving attention. Control of biological environments has been greatly improved lately, especially with aerobic digestion. Aerobic digestion is being used for tertiary treatment of light and medium concentration wastes. This process is documented to be approximately 80-90% efficient at removing organic contaminants, but sometimes requires more than 90 days retention time. This time limitation is a problem specifically with RCRA classified wastes.

The anaerobic process is also efficient at removing organic contaminants that contribute to O&G and COD, but requires larger systems and generates methane gas. This application, however, requires less time for reduction processes than the aerobic process. Conclusion

Industrial facilities working with metalworking fluids are being forced by the CWA of 1987 to monitor effluents discharged to the POTW and sludges hauled from their plants. The strengthened CWA will result in plants having to pretreat waste waters in-house. Also plants may have to pay higher disposal costs or face fines for not complying with the pretreatment laws. Because of these strengthened laws and increasing disposal costs, plants using metalworking fluids will be evaluating new pretreatment processes and fine tuning existing processes. Work on this will require support from the lubricant suppliers who will be encouraged to supply information on chemical, mechanical and biological processes for treating their products. Also, as capital expenditures and operating costs increase at the pretreatment plant, recycling by-products such as water and oil will be needed to help offset treatment costs. In the future, there will be a commitment for users, specialty chemical suppliers, and basic manufacturers to work together with users to meet the treatment and disposal needs of metalworking fluids.

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Terrence L. Heller
Commercial Development Specialist
Specialty Products Department
Dyes, Pigments & Organics Division
Mobay Corporation
1150 Stephenson Highway
Troy, MI 48083
Phone 313/583-9700

Terrence L. Heller is a waste water treatment specialist assigned to Mobay Corporation's Automotive Center in Detroit, MI. His current activities are with products designed for removing new generation coolants and oil emulsions from water, and reducing water and solids from oil sludges. Prior to joining Mobay in 1989, Mr. Heller spent eight years in the water treatment area with the Dearborn division of W.R. Grace. Mr. Heller holds masters and bachelors degrees in environmental biology from Central Michigan Univ.

Mobay Corporation is a Bayer U.S.A. Inc. company headquartered in Pittsburgh. The company is a diversified specialty chemicals manufacturer supplying animal health products; agricultural chemicals; coatings raw materials; engineering thermoplastics; dyestuffs; pigments; inorganic, organic and rubber chemicals; and textile fibers. Mobay's more than 7,000 employees are located primarily at production sites in Baltimore, MD, Baytown, TX, Bushy Park, SC, Kansas City, MO, and New Martinsville, WV.

A Recommended Profile for Determining the Environmental Fate of Metalworking Lubricants

Stan Napier
Keil Division, FERRO Corporation

Abstract

This paper reflects the logic and position which were used successfully to establish the acceptability of new metalworking chemistry to the Environmental Protection Agency concerning environmental fate. It presents an accurate account of today's market and represents the most likely scenarios which exist for addressing the environmental fate of metalworking additives and lubricants. Thorough coverage of the "exception scenarios" is very important in that it greatly helps solidify the fate analysis which is being presented. It is hoped that this sort of specific information and scenarios will be of use to the lubricant compounder and end user as it presents an insight to the approval processes as well as flexibility of the governing agencies towards extending endorsements of acceptability for new lubricant systems or components.

Structure

Structuring an environmental fate analysis for metalworking additives or lubricants is often necessary to fulfill federal registration or municipality guideline requirements. This means that metalworking lubricant effluents are disposed of under controlled conditions while undergoing required waste treatment to remove contaminants and reduce organic loads.

Role of the End User

Metalworking lubricant end users provide a critical step in structuring an environmental fate analysis. These users generally will consist of large facilities in the automotive and aerospace industries. These facilities are primarily located in the Midwest and other sections of the United States where large stamping and machining centers are in the proximity of major producers. As recently as ten years ago, many stamping and machining centers did not treat their effluent before sending it to a local Publicly Owned Treatment Works (POTW).

Today, as a result of governmental regulation and enhanced corporate sensitivity to environmental concerns, these centers have in-house pretreatment systems for cleaning their effluent prior to discharge to the local POTW. Moreover, most major manufacturing centers now have qualified waste treatment engineers, responsible for supervising in-house effluent pretreatment. The treatment methods for these fluids consist of physical, chemical and/or biological systems.

Typical Dilution Factors

Metalworking lubricants are usually diluted at different ratios with water, depending upon their intended application. Draw and stamp lubricants, used to shape metal in automobile fenders, hoods, etc., generally are used at one-to-five to one-to-ten dilution ratios. Coolant lubricants usually must be diluted even more. A recommended ratio of one-to-25 is a typical dilution ratio for use in structuring an environmental schematic.

Removal of Lubricant Residue

The draw and stamp lubricant typically is applied manually with a brush or a roller-coater to the metal. A smaller percentage of draw and stamp lubricant is applied by spraying the metal. Application of the draw and stamp lubricant at the steel mill as a prelube is becoming a fast-growing practice. Draw and stamp lubricants generally are not recirculated or used in central systems. By contrast, coolants are always circulated continuously and applied by flooding the work piece. As the parts are formed and finished, they are removed from the machine.

The finished parts contain concentrations of the lubricant residue which will vary based on the surface area of the metal part. These parts typically are ejected from the machine by blow-off or have a tilt mechanism to drain excess lubricant off before they are conveyed for post-process work. The lubricant residue on the finished parts provide corrosion protection during interim inventory storage, before the part goes on to a post-process or finished stage. The finished metal parts containing the lubricant residue then are conveyed to an acid or alkaline spray industrial washer where the finished part is washed and the residue is removed.

The alkaline spray process provides high impingement pressure at the nozzle and is a replacement technology for vapor degreasers which fell under strict Occupational Safety and Health Administration (OSHA) restrictions for workplace exposure to chlorinated solvents. Water dilutable metalworking lubricants generally leave residues which can be readily removed by conventional acid/alkaline spray systems. Such lubricants help facilitate the transfer to safer industrial spray-wash systems and the elimination of vapor degreasers. Many major automotive and aerospace manufacturers have removed vapor degreasers from their plants. This had a net effect of increasing the demand for water-dilutable metalworking lubricants.

Final Steps in the Fate Analysis

Finished metal parts pass through the industrial spray washer where the residue is washed off and collected as sediment in the spray washers. These washer sediments are periodically removed for proper disposal. The washer emergency overflow represents a slow, gradual bleeding into the in-house effluent stream and therefore is a gradual contributor to the effluent on an ongoing basis. The overflow effluent is usually a mixture of oil and water which then goes to the in-house pretreatment scheme.

Chemical treatment (acid splitting) is the most common pretreatment technique used by the lubricant end users. The acid split process separates the oil and water phases with follow-up neutralization of the water phase and proper skimming off and disposal of the oil phase. This technique became prevalent in the industry because the effluent from oil-based lubricants was in the form of an emulsifiable, soluble oil. Addition of the acid will also cause migration of any fatty constituents into the oil phase. Most organics will be removed during the pretreatment removal of the oil phase. Most larger stamping and machining centers incorporate secondary and even tertiary pretreatment schemes in-house. These systems can include use of primary coagulants, followed by use of polyelectrolytes. Ultrafiltration, reverse osmosis, activated carbon, and biological treatment are also used for treatment of metalworking lubricants. Properly used, these various treatment methods will bring effluent into compliance with POTW discharge standards.

Exceptions to Fate Analysis

Scenario One: Lubricants In Small Job Shops

Small job shops, usually with fewer than 20 employees, occasionally make parts for large metalworking facilities when the volume of such production is too low to justify production by the large facilities. Small shops also perform other metalworking jobs that cannot be done cost-efficiently at large facilities. The use of metalworking lubricants in small shops, however, accounts for less than 20% of the volume of lubricants produced. In the mid 1970s, there were over 10,000 small job shops for the draw and stamp industry. Today, there are only about 2,400 shops. The recession brought on by oil shortages in late 1970s and early 1980s caused a severe shrinkage of this market segment. The small shops could not withstand the financial pressures generated as large producers sought and obtained most contracted jobs to fill capacity and maintain employment levels. While the large producers are fewer in number than the small shops, they comprise the primary machining centers in the United States and are by far the greatest volume users of metalworking lubricants.

Small stamping and drawing shops usually do not generate significant amounts of effluent. Draw and stamp compounds typically are added to flat metal blanks, which are then formed or shaped. The lubricant residue is intentionally left on the resultant part to provide interim corrosion protection. The parts then are shipped to large producers where they are washed by alkaline spray. Any lubricant residue then is discharged to the large producer's pretreatment system. The relatively small amount of effluent generated by the small establishments usually can be pretreated with a simple primary treatment (oil skimming and splitting, solids settling, filtration) before discharge to the POTW. Typically the effluent from small shops is mixed with other plant wastewater (such as sanitary) prior to discharge. Small shops with no more than ten to twenty machines, with the average reservoir on individual machines of approximately twenty-five gallons, are increasingly investigating in-plant recycling and wastewater treatment equipment.

Scenario Two: Sump Dumps of Large Central Systems

Over 80% of the volume of metalworking fluids used in the United States are used by large corporate manufacturing centers employing more than 500 employees. These centers typically use diluted coolant maintained in large reservoirs called central systems, ranging from 1000 gallons to 100,000 gallons in size, to run production. Many large sites contain twenty to twenty-five central systems, each with its own continuous filtration system. The segregation of coolant use at these sites is based on the type of coolant required to do a particular job, i.e. the metal type and machine specifications. In many cases, coolant, when combined with other sources of wastes, can meet standards for disposal. This is often dependent on the concentration of the ingredients involved. Equalization may sometimes be achieved via use of a holding tank to accommodate a controlled flow of the waste stream at low levels to the final effluent.

Discharges of diluted coolant from any central system is performed on a scheduled basis in conjunction with procedures established by the waste treatment department that exists today in all large manufacturing facilities. These facilities typically follow waste treatment guidelines based on state and local requirements that often exceed federal requirements. The amount of metalworking fluid discharges at any given time depends strictly on the facility's capability to treat the waste without impacting negatively on its standard waste treatment procedures. Thus, the general daily profile of the effluent discharged from such machining centers to POTW tends to remain consistent. Many facilities are modifying their waste treatment process to improve treatment of synthetic (aqueous) based fluids. Some of these facilities are devoting substantial attention to the use of aerobic and anaerobic treatment for reducing organic loads typical with synthetic lubricants.

Scenario Three: Accidental Spills

Accidental spills of lubricants may potentially occur (a) while the product is being handled by the compounder; (b) during storage by the user; or (c) in transit between compounder and user. Careful handling, proper storage, and compliance with all Department of Transportation (DOT) regulations, including packaging and paperwork requirements, must be followed to avoid spills. The majority of lubricants will be used by larger facilities, which typically have sophisticated spill prevention and response programs. Information contained in Material Safety Data Sheets and regulations for the handling of chemicals dictate appropriate response procedures when spills do occur.

Scenario Four: Washing Solutions from Compounder's Blend Tanks

Lubricant compounders produce their metalworking lubrication formulations in blending vessels. These blending tanks are periodically washed with high-spray water hoses or by filling the vessels with warm water. The resultant mixture of soapy water will contain some residue of all components in the compounder's formulation. Vessel washing solutions generally are captured in a sump or storage tank by compounders for proper hauling and disposal. Since compounders blend many different products and the resultant washes contain a wide array of chemicals, lubricant compounders use approved waste disposal contractors to haul and dispose of the waste in accordance with the Environmental Protection Agency regulations.

Summary

The size of the metalworking plant, volume of lubricants used, type of lubricants used, mixture of plant wastewaters requiring treatment, and POTW treatment standards will all have an impact on the type of treatment required for environmentally sound disposal of metalworking lubricants. Plants of all sizes must determine effective and economical treatment methods based on these variables.

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Stan Napier
Keil Chemical Division
FERRO Corporation
3000 Sheffield Ave.
Hammond, IN 46320
Phone 219/931-2630
Fax 219/931-6318

Stan Napier is currently Business Manager of the Metalworking Group at Keil, where he has contributed to the development and construction of the FERRO Metalworking Applications Laboratory. He has ten years experience as a formulator of lubricants for metal removal and metal forming applications. Mr. Napier received his B.A. in Biology and Chemistry from the Univ. of Kentucky and his M.S. in Aquatic Ecology from Ohio Univ. Mr. Napier has published several technical papers and is a member of STLE.

Keil Chemical Division of FERRO is a major producer of metalworking additives for both domestic and global markets. Keil is an Associate Member of the Independent Lubricant Manufacturers Association.

CHAPTER FIVE
Chemical Treatment

The most common method of waste treatment today is chemical treatment. Inorganic and organic chemicals are used in industrial wastewater treatment, drinking water treatment, and sewage treatment.

For oily wastewater treatment, various chemicals are used to "break" the metalworking fluid emulsion to provide an effluent that is generally suitable for direct sewer discharge. Chapter Five discusses the chemical treatment of metalworking fluids in detail.

Chemical Treatment of Metalworking Fluids

Jean M. Gucciardi
Betz MetChem
The Metal Chemicals Division of Betz Laboratories, Inc.

Introduction

Metalworking fluids provide lubrication, cooling, cleaning and corrosion protection in the steel and automotive industries. The metalworking fluids can be straight petroleum oils, soluble oils, synthetics or semi-synthetics.

Wastewater resulting from these metalworking operations is variable and requires complex treatment. The intent of this paper is to discuss the chemical treatment and equipment options for wastewater containing metalworking fluids. Specific treatment regimes such as conventional acid/alum/caustic treatment and cationic polymer/inorganic coagulant treatment will be detailed along with the typical equipment used.

Table 1. Classification of Metalworking Fluids

STRAIGHT OILS

- DO NOT CONTAIN WATER
- MINERAL OILS WITH OR WITHOUT ADDITIONAL COMPOUNDING
- COMPOUNDING WITH FATTY OILS, SULFUR, CHLORINE, PHOSPHORUS OR COMBINATIONS OF THE ABOVE

SOLUBLE OILS

- EMULSIFIED SULFONATED MINERAL OILS

SYNTHETICS

- SIMILAR TO SOLUBLE OILS WITHOUT THE OIL
- WATER-DILUTABLE OR WATER DISPERSED
- POLYALPHAOLEFINS (PAO), POLYALKYLENE GLYCOL (POLYGLYCOLS), DIBASIC ACID ESTERS (DIESTERS), POLYOL ESTERS, PHOSPHATE ESTERS, SILICONES, AMINE BORATES, AMINE NITRATES

SEMI-SYNTHETICS

- CONTAIN SMALL DISPERSIONS OF OIL IN ORGANIC WATER-DILUTABLE SYSTEM
- MAY CONTAIN EXTREME PRESSURE (EP) ADDITIVES SUCH AS SULFUR, CHLORINE AND PHOSPHORUS

The first step in treating wastewater containing metalworking fluids is to identify the specific types and general volumes of metalworking fluids used in the plant operations. It is important to determine if the wastewater contains free oil or emulsified oils. Characterization of the wastewater is essential for successful treatment and operation of the treatment facilities. A survey of the plant operations is warranted to determine this information. See Table 1 for a general classification of metalworking fluids.

Emulsion Breaking Technology

Oil/water mixtures may involve two distinct phases or may be present in an emulsified form. The emulsions are further classified as either oil-in-water emulsions where oil droplets are suspended or dispersed in water, which is the continuous phase; or a water-in-oil emulsion where water is dispersed in an oil phase.

If the oil/water mixtures involve two distinct phases, i.e. water and free tramp oil, then gravity separation equipment is suitable for treatment. Typical treatment equipment for separating and skimming free oil includes CPI (Corrugated Plate Interceptors) and API (American Petroleum Institute) separators. The API and CPI units are equipped with skim flights for the removal of float oil. Free oil may be skimmed from holding tanks or basins using a continuous belt or drum skimmers. The oil is squeezed off the skimmer into a trough for recovery. The oil can be further treated or stored for eventual reuse or sale.

Emulsions are stable mixtures of two immiscible fluids, for instance, water and the metalworking fluid. The formation of emulsions is caused by sufficient mixing energy and the presence of emulsifying agents. An emulsifying agent is a surface active agent that alters the characteristics of the oil/water interface. When the interfacial tension between two immiscible fluids is significantly reduced, an emulsion is formed. Examples of emulsifying agents are sulfides, organic acids, metallic salts, clay, silt, surfactants and fatty acids. Emulsifiers are also added to produce the soluble oils and semi-synthetic fluids used in metalworking processes. Other factors affecting emulsion stability include pH, viscosity, specific gravity, temperatures, amount of water in the emulsion, mechanical shear, agitation and retention time.

Emulsion breaking or disruption of the interfacial film stabilizing the emulsion is the goal of oily waste treatment. Consequently heat, chemical treatment, mechanical devices or various combinations thereof are usually required to treat the wastewater emulsions.

Oil-In-Water Emulsion Treatment

Treatment requirements for emulsion breaking include chemical addition to break the emulsions and mechanical equipment to improve the oil/water separation. Various chemical agents are used to destabilize emulsions. Emulsion breakers must be capable of dispersing evenly throughout the emulsion, migrating to the interface quickly and effectively neutralizing the stabilizing effects of the emulsion. Mechanisms include balancing or reversing the interfacial surface tension on each side of the interfacial film, neutralizing the stabilizing electrical charges and precipitating the emulsifying agents.

In the case of oil-in-water emulsions, de-emulsification may be affected by the addition of acid, use of inorganic coagulants such as ferric chloride, calcium chloride or aluminum sulfate or organic polymeric emulsion breakers, particularly cationic polyelectrolytes.

Reactive cations (H^+, Al^{+3}, Fe^{+3}, Ca^{+2}) break emulsions by neutralizing repulsive charges between particles, precipitating or salting out the emulsifying agent and altering the interfacial film so it is readily broken. After the charges are neutralized and the interfacial film broken, the oil droplets are able to coalesce upon collisions with other oil droplets. After neutralization, inorganic coagulants provide a hydroxide floc for adsorption of oil.

Both semi-synthetic and synthetic metalworking fluids may be stabilized by nonionic surfactants. Consequently these fluids would not be amenable to emulsion breaking via cationic charge neutralization mechanisms. Rather they would be more responsive to inorganic coagulant treatment, specifically adsorption by hydroxide floc.

An important variable in breaking wastewater emulsions is pH. Lowering the pH provides H^+ ions for neutralizing the negative charges that stabilize the oil-in-water emulsions. The lower pH can cause chemical reactions between ions in the mixtures and the emulsifying agents that form the interfacial film. A low pH is also effective in destabilizing any chelants present in the wastewater emulsions.

Chemical treatment requirements will depend upon the specific types of metalworking fluids present in the waste stream. Straight mineral oils are amenable to conventional chemical emulsion breaking methods, specifically, cationic polymer charge neutralization. Mineral oils with additional compounding will require cationic polymers and inorganic coagulants such as aluminum sulfate (alum) as well as pH adjustment for successful treatment.

Soluble oils which are defined as emulsified sulfonated mineral oils will be responsive to polymer/alum treatment for emulsion breaking. Because the soluble oils are, by design, emulsions, they respond to classic emulsion breaking technology, cationic polymer charge neutralization.

Synthetic coolants do not contain petroleum oil but contain petrochemicals that are derived from crude oil and natural gas. The synthetic coolants are characterized by high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels. Wastewaters containing synthetic coolants have high residual BOD and COD levels even after conventional polymer and inorganic coagulant or acid, alum and caustic treatment. Metalworking plants have installed biological treatment equipment, such as an Oxitron® fluidized sand bed reactor, to reduce the high BOD and COD content of the industrial wastewater.

Semi-synthetic metalworking fluids contain small dispersions of oil and extreme pressure additives such as sulfur, chlorine and phosphorus. Consequently, semi-synthetics require considerably higher levels of alum for treatment. Polymer demands for treatment of the semi-synthetics are comparable to polymer levels used to treat soluble oils.

If only one type of metalworking fluid was used per plant, chemical treatment would be straightforward, fairly predictable, and possibly consistent. However, all types of metalworking fluids are employed based on the specific machining and manufacturing operations. Wastewater treatment requirements will depend on the different combinations and volumes of metalworking fluids present.

Treatability studies have been conducted on wastewaters containing various amounts of metalworking fluids. One study compared the effects of semi-synthetic and synthetic metalworking fluids on soluble oil treatability. The conclusion was that treatment of wastewater containing semi-synthetic and soluble oils required higher polymer and coagulant dosages than treatment of wastewater containing synthetic and soluble oils. The higher polymer and coagulant demand is due to the strong emulsifier packages in semi-synthetic fluids.

Figure 1: Influent Wastewater Oil and Grease Concentration Versus Chemical Treatment Concentration

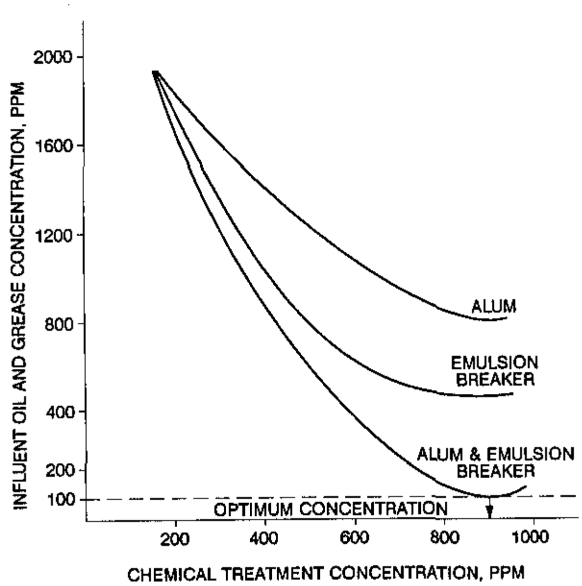


Figure 1

Semi-synthetic fluids contain strong emulsifiers, strong enough to emulsify straight oils or soluble oils.

Laboratory treatability studies can be conducted on samples of the plant wastewater. The wastewater can be spiked with varying concentrations of the metalworking fluids used at the plant. The intent of the laboratory studies is to identify the chemical treatment demand of the metalworking fluids. Figure 1 is a presentation of typical emulsion breaker and coagulant concentrations for treatment of wastewater emulsions.

In addition to chemical treatment of wastewater containing metalworking fluids, specific mechanical equipment can be used to facilitate the treatment of oil-in-water emulsions. For example, either induced air flotation (IAF) or dissolved air flotation (DAF) units are employed for treatment. The fine air bubbles formed by the DAF or IAF process will attach to the oil globules, increasing the rise rate velocity which results in enhanced oil/water separation. The resultant skim float oil can be further treated for recovery and reuse. A schematic of a DAF unit is shown in Figure 2.

Water-In-Oil Emulsion Treatment

Water-in-oil emulsions are often referred to as "slop oil." The sources of slop oil include the free oil skimmings from the CPI, API or gravity separators and the treated oil skimmings from either induced air flotation (IAF) or dissolved air flotation (DAF) equipment.

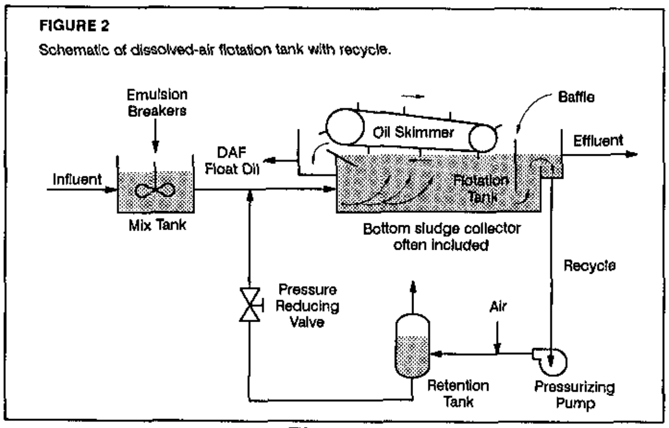


Figure 2

Typical treatment of water-in-oil emulsions includes chemical, heat and mechanical methods. Chemical treatment is required to break the emulsions and will help increase the particle size. Sulfuric acid is used to lower the pH to 1 or 2, which will also assist in reducing the viscosity of the wastewater emulsion. Sodium hydroxide can be added to adjust the pH to 13 or 14 to break the emulsion. However, high pH conditions may render some metalworking fluids into a grease or highly viscous material due to possible saponification. Proprietary chemicals such as nonionic surfactants are also successfully employed for emulsion break-

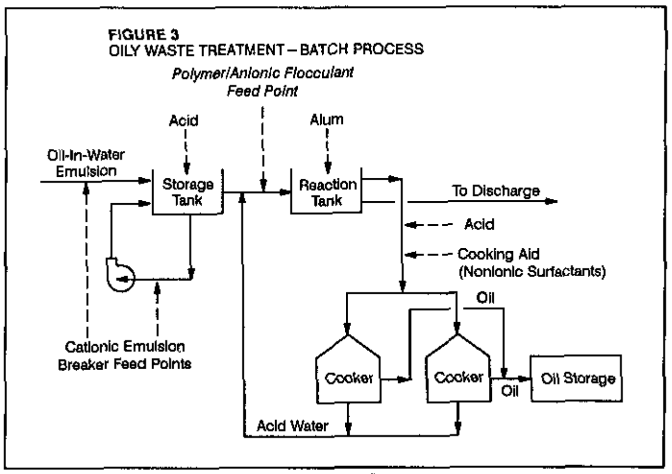


Figure 3

ing. Typical emulsion breaker feed rates range from 1000 ppm (0.1%) to 30,000 ppm (3%).

The water-in-oil emulsion is heated to a temperature of 160°F to 200°F (71°C to 93°C). The heat is applied internally with steam coils or externally by recirculating the emulsion through a heat exchanger. The addition of heat reduces the viscosity and increases the specific gravity differential. Heat also increases the frequency of the droplet collision which, in turn, helps rupture the interfacial film. As soon as the film is broken, the difference in specific gravity allows the separation of the oil from the water.

Another crucial factor in breaking water-in-oil emulsions is mixing. Sufficient mixing energy is required to ensure thorough distribution of the emulsion breaker. Too much mixing will be detrimental and may cause re-emulsification

Mechanical equipment such as disc and solid bowl centrifuges can also be used to treat water-in-oil emulsions. High centrifugal force will accelerate the water and oil separation process. It is also recommended that the water-in-oil emulsions be chemically pretreated with sulfuric acid and/or

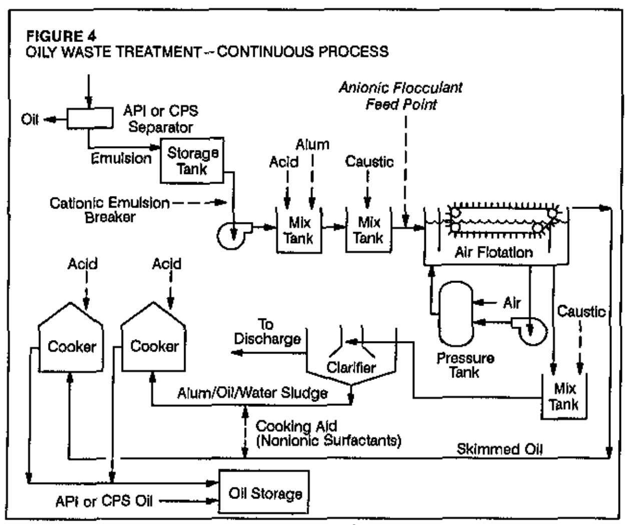


Figure 4

emulsion breakers, and preheated to 200°F (93°C) before centrifugation.

Figures 3 and 4 are flow diagrams for a batch process and a continuous process for treatment of wastewater emulsions.

Jean M. Gucciardi
Project Supervisor
Betz MetChem Division
Betz Laboratories, Inc.
200A Precision Drive
Horsham, PA 19044
Phone 215/957-2460

Jean M. Gucciardi, as Betz MetChem project supervisor in the Utilities Engineering Group, is technical specialist in the areas of water, wastewater and cooling treatment for the automotive and steel industries. Before joining Betz, Ms. Gucciardi was with Wisconsin Electric Power Co., and prior to that was with Donohue & Associates. Ms. Gucciardi received her bachelors degree in chemistry and her M.S. in environmental engineering from the Univ. of Wisconsin-Milwaukee. She is author of a published paper on chlorine decay.

Betz Laboratories' principal business is the engineered chemical treatment of water, wastewater, and process systems operating in a wide variety of industrial and commercial applications, with particular emphasis on the chemical, petroleum refining, paper, automotive, electrical utility, and steel industries. Betz produces and markets a wide range of specialty chemical products, as well as the technical and laboratory services necessary to utilize its products effectively. Chemical treatment programs are applied for use in boilers, cooling towers, heat exchangers, paper and petroleum process streams and both influent and effluent systems.

CHAPTER SIX
Physical Treatment

Various physical treatment methods are used effectively to treat metalworking fluids for disposal. The most common physical treatment method is membrane treatment. Typically, an ultrafiltration (UF) membrane separates the oil, particulates and large molecules from an effluent suitable for direct sewer discharge.

A secondary treatment with UF, such as reverse osmosis (RO) or activated carbon, is capable of providing an effluent for stream discharge or possible reuse. In addition, treatment methods such as incineration and evaporation are being more widely used today for metalworking fluid treatment. This chapter discusses physical treatment options for metalworking fluids.

Recycling Synthetic Fluids Using Ultrafine Filtration: An Effective Approach to Achieving Waste Minimization Goals

Edward E. Heidenreich
EdjeTech Services, Inc.

Introduction

Metalworking fluid manufacturers are being confronted with end users who need high performance metalworking fluids and knowledgeable and responsive technical support. As part of that support, manufacturers are now being asked to furnish technical support to recycle and waste treat their products. A manufacturer's ability to provide this support is becoming a main criteria for product selection. End users have come a long way, and expect the fluid supplier to solve whatever problems may occur, on-site and within a reasonable time.

Synthetic fluids are being used to meet the high performance needs of the end user, but the disposal cost of the fluid is very high in most areas of the country. The end user is searching for a way to extend the useful life of the synthetic fluid and to avoid disposal. One possible answer to this search is using ultrafiltration as a tool to maintain a good working fluid.

This paper addresses three areas:

1. The information-gathering process used to select a recycling system to process synthetic fluids.
2. Using ultrafiltration to clean and reuse synthetic fluids vs. waste treatment.
3. Developing in-plant tests that can be performed by plant personnel to maintain fluid.

The Information-Gathering Process

End users should form an internal coolant/lubricant management team. The team should include:

1. The plant manager;
2. Plant environmental manager;
3. Purchasing agent responsible for purchasing coolants and lubricants;
4. Production manager/supervisor;
5. Maintenance manager/supervisor;
6. Tooling engineer;
7. Machine operators (at least two); and
8. Union representative.

The team's goals are:

1. To improve production;
2. To develop a plant survey opportunity assessment record;
3. To control all coolants/lubricants entering the plant;
4. To obtain optimum results from the coolants/lubricants; and
5. To minimize coolant/lubricant waste.

Problems facing the team are many. Some specific areas of concern are:

1. General housekeeping;
2. Water condition;
3. Emulsion stability;
4. Tool/wheel life;
5. Rancidity;
6. Tramp oil;
7. Oxidation;
8. Contamination;
9. Foam; and
10. Misting.

A plant survey opportunity assessment record work sheet is included as a suggested starting point. The first task of the fluids committee is to gather and record operation data for production and coolants. It is essential to gather this information as early as possible.

When a problem arises this no time to start from ground up building a data file base. In most cases you are facing down time and lost production, and cannot afford delays.

Completing the survey opportunity assessment record is a time consuming task. By adding his input and recording factual data, each party will assist the others to understand what goes into the program to achieve and maintain high production output and minimize rework, scrap, and coolant waste.

The data gathered and recorded will aid you in identifying the real cost for purchasing, storing, using, and recycling coolants and lubricants.

The data gathered will present an existing coolant waste program for everyone to see. Once this present operating procedure is identified, everyone will see how easy it is to change a few operating procedures to minimize waste, improve in-plant working conditions, and recycle the fluids. Once this happens your coolant manufacturer can now supply you with good lubricant management and technical support.

In servicing water soluble fluids, the coolant manufacturer provides an important technical support service. Their technical service becomes very important when you start to recondition coolants and use them for extended periods of time.

It is mandatory that you select a coolant manufacturer that has experience in coolant recycling and waste treatment of its product line. Responsive technical service is mandatory, because the coolant changes with use over time and as a result of contamination. In order to assure continued acceptable product performance in your operation, the coolant manufacturer needs to conduct periodic quality control tests on the coolant while it is in use. This allows the manufacturer to monitor the coolant's condition, identify contaminants, and take appropriate action to insure acceptable product performance.

Once the operating conditions of the coolant are identified, choosing a recycling system becomes relatively easy. Working with the coolant manufacturer, a supplier of recycling systems can design and tailor a system to your plant requirements.

Using Ultrafiltration to Clean and Reuse Synthetic Fluids versus Waste Treatment

Synthetic fluids (no oil in the formula) have been used for several years as a way to increase speeds and feeds on most modern machine tools. These high performance fluids have one major drawback from the user's view point. They have been hard to waste treat with existing treatment facilities.

Off-site disposal has become very expensive in many areas of the country. This added expense has slowed the acceptance of synthetic fluids in manufacturing facilities. This added expense for waste treatment has offset the economics of using them in production.

Some advantages of synthetic fluids are:

1. Extended machine reservoir life;
2. Resistant to bacterial infestation;
3. Stable solution;
4. Good tramp oil rejection;
5. Good cooling; and
6. Good chip separation.

Some disadvantages of synthetic fluids are:

1. Residue build up;
2. Possible skin irritation;
3. Possible foaming; and
4. Difficult to waste treat.

Synthetic fluids, because of their rejection of tramp oils and stable solution, are good candidates for recycling.

These products have shown that they can last ten to 12 weeks in a machine reservoir, where other oil-based fluids last only three to six weeks.

Synthetic fluids have demonstrated that with little care they can last as long as a year or more. However, like all metalworking fluids, they too become so saturated with contaminants from the plant water source and machine tool work areas that they no longer perform the way the user wants.

Synthetic fluids show a tendency to "load up" with contamination that is one micron and less in size. This contamination can be metal fines that are coated with tramp oils that suspend the fines and don't allow them to settle. The suspended contamination reaches a saturation point and settles out on the machine tool, creating a dirty work area. The suspended contamination and mineral salt build up fosters the growth of bacteria, causing a rancid and corrosive condition. Performance declines and the synthetic coolant is flagged for disposal. The machine reservoir is cleaned, and a new charge of coolant is added.

PROBLEM:

What do you do with a fluid that is hard to waste treat on-site and expensive to have hauled away and waste treated off-site?

POSSIBLE SOLUTION:

Ultrafiltration was used to fine filter the synthetic to remove the suspended contamination. The fine filtered synthetic fluid was titrated for the proper ratio. Most synthetic fluids tested required concentrate to be added to the reclaimed fluid to bring it back to the manufacturer's specifications. Once adjusted, the fluid was recycled to the machine reservoir.

RESULTS:

The fine filtered synthetic was used in the machine reservoir and recycled at the normal scheduled period. The fluid performed as well as new fluid. Sump life and corrosion protection seemed unaffected; however, bioresistance of the fine filtered fluid was lacking in some fluids tested.

MACHINE COOLANT RECORD
FILE NAME:

DEPARTMENT NAME: MACHINE NAME:
DEPARTMENT NUMBER: MACHINE IDENT:
COOLANT: RESERVOIR SIZE:

REFRACTOMETER READING: AT CONCENTRATION:
REFRACTOMETER MULTIPLIER IF OTHER THAN 1:
CONCENTRATE NEEDED PER CHARGE: GALLONS:

DATE	TIME	REFRACTOMETER BEFORE	QTY OF COOLANT ADDED	REFRACTOMETER AFTER	pH	BIO STICK READ'G	SUMP CLEANED	OPERATOR SIGNATURE

TEST 1. SYNTHETIC/CLEAN SYSTEM TEST RESULTS

FLUID	RATIO	pH	BACTERIA	FREE% TRAMP OIL	EMULSIFIED TRAMP OIL	CORROSION C.I. TEST
WATER	-	7.1	10	-0-	-0-	SLIGHT
A	1:20	8.5	<10	-0-	-0-	NIL
B	1:20	8.6	<10	-0-	-0-	NIL
C	1:20	8.3	<10	-0-	-0-	-0-
D	1:20	8.8	<10	-0-	-0-	-0-
WEEK SIX						
A	1:20	8.1	10/4	3.5	0.70	SLIGHT
B	1:20	8.2	10/4	2.0	NIL	SLIGHT
C	1:20	8.1	10/2	2.7	0.07	SLIGHT
D	1:20	7.8	10/8	5.0	1.5	HEAVY

TEST 2. SYNTHETIC RECYCLED USING COALESCER SYSTEMS; TEST RESULTS FROM RECONDITIONED SYNTHETIC FROM RECYCLING SYSTEM

The used coolant was removed from the machine reservoirs with a standard sump cleaner/filter unit, and clarified using a slanted plate coalescer, adjusted to the proper fluid ration and reuse in the machine.

FLUID	RATIO	pH	BACTERIA	FREE% TRAMP OIL	EMULSIFIED TRAMP OIL	CORROSION C.I. TEST
WATER[1]	-	8.0	<10	-0-	-0-	LIGHT
A	1:20	8.5	<10	NIL	NIL	NIL
B	1:20	8.5	<10	NIL	NIL	NIL
C	1:20	8.3	<10	0.25	0.03	NIL
D	1:20	8.6	<10	NIL	1.5	SLIGHT
WEEK SIX						
A	1:20	8.2	10/2	3.2	1.0	LIGHT
B	1:20	8.4	10/6	4.1	NIL	MODERATE
C	1:20	7.9	10/4	3.3	1.5	HEAVY
D	1:20	7.4	10/9	5.4	3.5	V.HEAVY

Observations on Test 2:

1. Plant water was filtered through a standard commercial carbon cartridge type filter before being introduced into the coolant system.
2. No additives were added to the recycled coolant other than concentrate to adjust ratio.
3. Machining operations were drilling, tapping, grinding, milling and turning.
4. Materials worked were steel, cast iron and aluminum.

TEST 3. SYNTHETIC RECLAIMED USING ULTRAFINE FILTRATION
FLUID FROM TEST 2, WEEK SIX

FLUID	RATIO	pH	BACTERIA	FREE% TRAMP OIL	EMULSIFIED TRAMP OIL	CORROSION C.I. TEST
A	1:20	8.2	10/2	3.2	1.0	LIGHT
B	1:20	8.4	10/6	4.1	NIL	MODERATE
C	1:20	7.9	10/4	3.3	1.5	HEAVY
D	1:20	7.4	10/9	5.4	3.5	V.HEAVY
FLUID FROM ULTRAFILTER						
A	1:20	8.2	<10	-0-	-0-	SLIGHT
B	1:20	8.3	<10	-0-	-0-	SLIGHT
C	1:20	7.8	<10	-0-	-0-	LIGHT
D	1:20	7.4	<10	-0-	NIL	LIGHT
FLUID AFTER ADJUSTMENT BY ADDING CONCENTRATE						
A	1:20	8.5	<10	-0-	-0-	NIL
B	1:20	8.6	<10	-0-	-0-	NIL
C	1:20	8.3	<10	-0-	-0-	NIL
D	1:20	8.8	<10	-0-	NIL	NIL

Observations on Test 3:

1. Foul odors in fluids C & D were eliminated by fine filtration.

2. Ratio readings, using manufacturer's titration methods, remain a question; they didn't vary 2-5 drops from fine filtered fluid and adjusted fluid after concentrate was added.

3. Fluids A & B required 0.5 gallon of concentrate per 100 gallons of reclaimed fluid to bring pH and ratio to recommended conditions. Fluids C & D required 128 oz. of concentrate per 100 gallons of reclaimed fluid to bring pH and ratio to recommended conditions.

4. After adjustment corrosion protection was reestablished.

5. Bacteria control was reestablished.

TEST 4. SYNTHETIC RECLAIMED USING ULTRAFINE FILTRATION FLUID AFTER TWO WEEKS

FLUID	RATIO	pH	BACTERIA	FREE% TRAMP OIL	EMULSIFIED TRAMP OIL	CORROSION C.I. TEST
A	1:20	8.5	<10	1.6	NIL	NIL
B	1:20	8.6	<10	0.05	NIL	NIL
C	1:20	8.3	<10	1.7	SLIGHT	NIL
D	1:20	8.8	<10	3.0	NIL	NIL
FLUID AFTER SIX WEEKS						
A	1:20	8.3	10/3	2.8	1.0	SLIGHT
B	1:20	8.6	10/2	2.0	0.05	NIL
C	1:20	8.2	10/3	3.5	1.0	SLIGHT
D	1:20	8.6	10/3	4.0	3.0	

Observations on Test 4:

1. Bacteria levels remained constant from week four through week six.
2. Corrosion protection remained constant.
3. pH remained constant.
4. All fluids by week six began to emulsify tramp oils into solution.

Conclusions

1. Ultrafine filtration, properly selected, shows promise as a vehicle to extend the life of water soluble synthetic fluids.
2. Waste volume of the test fluids was reduced by 98%.
3. More in-plant testing under actual production conditions needs to continue with the aid of the coolant manufacturer.
4. These tests showed that both the user and the fluid manufacturer developed a better understanding of the maintenance of synthetic fluids.

Edward E. Heidenreich
EdjeTech Services, Inc.
50121 Bronson Road
Wellington, OH 44090
Phone 216/774-7007

Waste Minimization and Wastewater Treatment of Metalworking Fluids

George W. Skells
Castrol Industrial Central, Inc.
and
Robert H. Brandt
Brandt & Associates, Inc.

All water-based metalworking fluids eventually require disposal, even if the user has selected a good fluid and has practiced proper fluid management. This is true, even if the user has reclamation and/or filtration systems capable of periodic recirculation of the fluid into "as new" condition. At some point, excessive contamination from a variety of sources, such as hydraulic oil, lubricants, floor cleaners, and microorganisms, dictates disposal of the fluid.

When the time for disposal arrives, a manufacturer can contract a waste hauler to remove the spent fluid. However, this is only a short term solution, because hauling costs are increasing and disposal sites are decreasing. In addition, Resource Conservation and Recovery Act (RCRA) "cradle-to-grave" regulations hold manufacturers disposing of fluids responsible, even where licensed waste haulers are involved.

The most economical approach to disposal is to minimize the volume of waste being produced. This can be accomplished by treating the fluid in-house to extract the materials that prevent the fluid from being acceptable to local sewage plants. The offensive materials, generally a small percentage of the total volume, can then be discarded at a cost considerably lower than that for disposal of the total volume.

The standard in-house disposal procedure is based on a two-stage treatment process. The first treatment stage generally includes removal of free oil, or tramp oil, from the system as well as removal of particulate matter such as metal fines, strings, rags, and other debris. Free oil can be removed by centrifugation, ropes, belts, skimmers, and coalescers. The particulates can be removed by settling and/or by positive filtration. The first treatment stage essentially follows the same procedure used in conventional reclamation, repolishing, or recirculation of fluid for reuse.

The second treatment stage necessary for disposal could be accomplished by thermal emulsion splitting, chemical treatment, with or without dissolved air flotation (DAF), or ultrafiltration.

The effectiveness of thermal emulsion splitting depends on the components in the spent fluid. These components may foul heat exchange materials, causing diminished heat transfer. Therefore, thermal emulsion splitting can be expensive because of the high, costly heat consumption required. It takes a given quantity of energy to boil water away from the product, so if you have large quantities of material to process, the cost is high.

Chemical treatment and DAF procedures are well accepted for second stage treatment, particularly by manufacturers producing 50,000 gallons or more of effluent per day. That effluent, of course, contains a variety of different materials, not just the emulsion products or the water miscible materials that are used in the metalworking operation. In general, for the small to medium size manufacturers, chemical treatment can be too costly.

Ultrafiltration provides the most effective secondary stage treatment, if properly applied. Economically, UF fits somewhere between thermal splitting and chemical treatment.

UF is based on membrane technology. This involves a cross flow process in which the metalworking fluid is moved across the surface of a membrane under turbulent conditions and variable pressure. The permeate that passes through the membrane is mostly water. As the fluid is recirculated across the membrane, more permeate collects on the outlet side of the membrane, the fluid on the inlet side becomes increasingly richer in contaminant ingredients. This process does not eliminate waste, but it does concentrate it. The concentrate must be further chemically treated or hauled away.

With the UF process, contaminant volumes are significantly reduced from the original volume of spent fluid. The concentrate may be approximately ten percent of the original volume. For example, 1,000 gallons of fluid waste may result in 900 gallons of permeate, leaving only 100 gallons that need to be further treated or hauled away. This may be sufficient to justify the cost of further treatment or hauling.

Depending on the type and complexity of the original metalworking fluid being used plus constituents related to prolonged use, several water miscible organic and inorganic materials reach the permeate side of the UF membrane. The miscible organics can contribute to unacceptable levels of biochemical oxygen demand (BOD) five day, chemical oxygen demand (COD) and total organic carbon (TOC). Measurements of one or more of these levels are performed on effluent to determine its acceptability for discharge to sewers or streams.

Although second level chemical treatment and ultrafiltration have been very acceptable methods, manufacturers are looking beyond these processes at third level biological digestive processes, activated carbon treatment, and reverse osmosis.

If the UF permeate needs further treatment, several options are available for third stage processing, including processing with activated carbon adsorption, biological digestion, either aerobic or anaerobic, and reverse osmosis (RO). Activated carbon processing has the highest cost per gallon, biological digestion requires a large investment in equipment, and reverse osmosis is relatively slow.

Some large manufacturers that are currently using the second stage chemical treatment methods are discharging effluents that are not meeting standards of their local municipalities. These manufacturers generate 50,000 gallons or more of waste effluent per day, so activated carbon is too expensive and reverse osmosis is too slow. As an alternative, they are exploring biological digestive processes. They are finding that trickling filters that produce biomasses are digestive processes which may be more effective and less costly. They are accomplishing this with either fluidized bed type or an aerobic or anaerobic type of digester.

For small manufacturers that generate less than a 1,000 gallons per week or even a 1,000 gallons per month, activated carbon might be the only practical option for third stage treatment. Medium sized manufacturers may find activated carbon adsorption too expensive and that their discharge volume is not large enough to justify large digestive or biological digestive processes for third stage treatment.

Reverse osmosis (RO) may be the best approach. Reverse osmosis, like ultrafiltration, is a membrane process where the fluid is moved over the surface of a membrane under turbulent conditions and variable pressures. Typically, in reverse osmosis the pressures are higher than those in ultrafiltration. As with ultrafiltration, reverse osmosis concentrates the stream on the inlet side of the membrane, resulting in a concentrate volume of ten to 30 percent of the original volume.

The permeate on the outlet side of the RO membrane may contain a small amount of inorganic salts and some organic materials. However, it is generally acceptable for discharge to sewers.

The manufacturer using RO as its third stage treatment usually begins with the first stage treatment of removing the free oils and the solids. Second stage treatment would be ultrafiltration. The concentrate of the ultrafilter may be recycled through the primary process for additional removal of free oil and particulate to further reduce the waste volume, or it could be hauled away or chemically treated.

The permeate from the ultrafiltration could serve as the feed stream for the reverse osmosis. Then the reverse osmosis permeate could go out to the sewer and the RO concentrate could be either recycled through the first level treatment, chemically treated, or hauled away.

Many manufacturers have used the ultrafiltration process for oily waste water separation for many years. A number of ultrafiltration membranes are available, and their manufacturers promote a variety of different membrane technologies. Field testing and/or laboratory characterization of the waste streams are the only real criteria for selecting and applying a proper membrane. Membrane suppliers may have some general selection parameters, but field trials are generally required to determine the optimum permeation rates or flux rates.

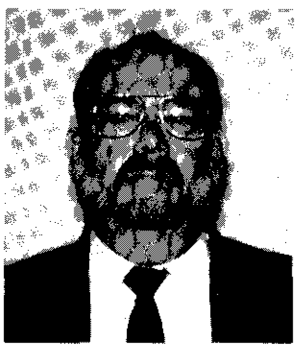
Some manufacturers believe that the permeate from the ultra-filter frequently blocks the reverse osmosis membrane so that it is not practical to apply reverse osmosis. This can happen when the wrong ultrafiltration membrane is selected. If a very coarse ultrafilter membrane is used in an attempt to maximize permeation or flux rates to increase the permeate flow rate and speed the process, the permeate may not be acceptable for further membrane treatments such as RO. An overly coarse ultrafilter would also cause higher use of carbon in activated carbon processing.

Membranes are fabricated from a variety of materials in a wide range of pore sizes. They are classified by different molecular weight cut off levels. These levels determine the size of material that can be retained on the concentrate side versus the size of material that would go through with the water on the permeate side.

With the variety of fluid treatment technologies available to minimize waste, metalworking fluid manufacturers have the responsibility to develop fluids that accomplish more than optimizing machining processes. Fluids also must accommodate the recycling, polishing, and disposal procedures individual manufacturers are using. The fluid producer has to be aware of all the fluid management processes his customers are using. So the fluid producer and the manufacturer have to work very closely to gain maximum performance from the metalworking fluids throughout their entire life. Fluid producers must study and understand each of the stages of technology and the related equipment in use.

Varieties of equipment are available to handle one of the three individual stages of the treatment process, such as first stage equipment to remove tramp oil and particulates. Some equipment manufacturers are cognizant of all three stages of processing and have produced equipment capable of moving fluid through each of the successive stages of treatment. For example, self-contained repolishing/waste treatment equipment is available that remove particulate and free oil, followed by ultrafiltration, followed by reverse osmosis. The tramp oil is automatically removed with an advanced polypropylene coalescing medium and discharge into a drum for disposal or reclamation. Next, a clarifier, consisting of paper medium supported by a wedge wire mesh, provides automatic positive final filtration of suspended dirt and fines. Then the repolished fluid is pumped into a clean fluid tank where it is combined with new coolant which has been automatically premixed with a proportioning pump that is part of the system. If the fluid is no longer reusable, it is automatically pumped to the waste treatment section for ultrafiltration where a special self-cleaning membrane medium removes free oil and particulate. The fluid is then processed in the reverse osmosis section for the final cleaning stage. The volume of waste accumulated in the concentrated form is about ten percent of the original volume.

George W. Skells
Director, International
OEM Development
Castrol Industrial Central Inc.
630 West Washington Blvd.
Chicago, IL 60606
Phone 312/454-1000
FAX 312/454-1143



George Skells has 30 years experience in the metalworking industry, from the plant floor to research and development, application of lubricants, troubleshooting, technical service, and technical marketing. In his current position, Mr. Skells contacts OEMs to gain their approval of Castrol products and supports international information and testing of company products. Mr. Skells received his B.S. in Metallurgical Engineering from IIT. He has published papers, made presentations, and is a member of ASTM where he chairs and is a member of several committees and groups. Mr. Skells is also a member of STLE, SME and ASM International.

Castrol is an international manufacturer and marketer of lubricants and specialty products for the transportation and related industries, including industrial lubricants, process cleaners, corrosion preventives, and metalworking fluids. Castrol Industrial Inc. markets metalworking fluids, industrial lubricants, cleaners and corrosion preventives in the U.S. Castrol is a Regular Member of the Independent Lubricant Manufacturers Association.

Robert H. Brandt
Chairman & CEO
Brandt & Associates, Inc.
504 East Front Street,
P.O. Box 600
Pemberville, OH 43450
Phone 419/287-4909

Robert H. Brandt has been chairman and chief executive officer of his firm since 1979. Prior to that he was with Lamb Technicon's Filtration Division, Henry Filters, and on the Chemistry Department faculty of Capital Univ. Mr. Brandt holds B.S. and M.S. degrees, and is a thesis short of a Ph.D. in Analytical Chemistry. He holds three patents, has published papers, and gives seminars nationwide.

Brandt & Associates provides consulting and manufacturing services in the area of metalworking fluid management, with particular expertise in fluid control, filtration and disposal. Consulting services include analysis of problems, system design, fluids, and quotations; establishing filtration specifications; and developing, testing and installing equipment. In addition, the company provides custom manufactured equipment such as washers, ovens, and dip tanks.

Evaporative Reduction of Waste Coolants and Oily Water

Richard J. Bigda
Technotreat Corporation

Applications for Evaporators

Lubricants containing water can be evaporated to either reduce the volume of an oily or hazardous waste or recover the oil or synthetic base and produce pure water for recycling. Those lubricants most easily evaporated are emulsion coolants, synthetic polymer water-based cooling and hydraulic fluids, or lubricants and oils that have been somehow mixed with water. Depending upon the condition of the wet lubricant, it may be practical to recycle the recovered oil or incinerate it as a fuel. Water resulting from evaporation generally contains less than ten parts-per-million (ppm) of hydrocarbons and is usually in compliance with municipal discharge regulations. The oil can be dried to a point where it will contain only one percent moisture and can be readily burned.

Problems with evaporation occur when the coolants or oils have been mixed with light hydrocarbons such as kerosene or paint thinners, vapor degreasing fluids or chlorinated hydrocarbons. Low boiling contaminants will, to some extent, distill over with the steam and contaminate the condensed water. Depending upon the quality of light materials in the waste coolant, it may be possible to vent the evaporator's steam to the atmosphere and still be in compliance with clean air regulations.

Each case of contamination should be considered individually and, depending upon the analysis of the steam, a decision made as to whether additional steps are necessary. Heavier materials such as dirt, metal fines, heavy organics such as antifreeze and corrosion inhibitors, and viscosity improvers will concentrate in the bottom of the evaporator. The sludge will probably have to be disposed of as hazardous waste. If the fluid is otherwise clean, it might be recycled.

Evaporation is a viable method of separating water from oil and synthetic fluids. It finds particular application when treating something containing a great deal of water, such as the emulsion coolants which often contain only one to two percent oil and additives, the rest being water. In today's environmental climate, oily fluids or water containing oil and various corrosion inhibitors are considered to be hazardous wastes and cannot be dumped down the drain or on the back lot without incurring serious liabilities. Disposal of these watery fluids is becoming increasingly more expensive. In some areas where injection wells are available, the cost may be twenty cents per gallon to have the fluid picked up and injected into a well, while in other areas the cost may be a dollar or more per gallon for getting rid of these wastes. When one considers the cost of evaporation ranges from one half cent to ten cents per gallon, depending upon the method and type of energy used, it begins to make economic sense to reduce the volume of oily waste by 98%, saving a considerable amount of money over the year. In many cases, payout time on evaporators can be less than one year.

Simple Small Volume Evaporation

Evaporators come in a variety of styles and shapes, and different types have differing levels of energy efficiency to effect the separation. Selection of the evaporator, for most businesses, hinges on the quantity and quality of the wet fluids to be processed. The simplest evaporator is usually the best and cheapest for small quantities. For example, waste volumes of 20 to 500 gallons a day dictate the use of the simple application of heat produced from gas, electricity or fuel oil, to directly evaporate the water. In the range of 500 to 1000 gallons a day, the capital cost probably predicts which way the waste generator should go. Above 1000 gallons a day, the larger, more costly evaporators tend to pay for themselves through energy conservation.

Simple atmospheric evaporation is exactly what it says. Heat is applied to the fluid, and when the fluid reaches approximately 212°F, the water vapor separates from the fluid, leaving the oil behind. The water can then either be condensed or allowed to disperse into the atmosphere. Heat for evaporation, which is fundamentally fixed by the latent heat of evaporation (970 BTUs per pound), is added to the fluid. Heat can be applied to the bottom or sides of the evaporator or conducted through the walls of a heat exchanger to boil the water. Heat can be applied internally through the use of electric heating elements. In this way, the entire vessel can be insulated and all the electric heat converted directly into steam with little loss to the outside. If a gas or oil flame is applied, the high temperature flame or hot gases must pass around the evaporator shell or through heating tubes, and some of the heat will be lost up the exhaust stack. The economics of evaporation then depend upon efficiencies of the energy transfer, the cost of the energy or fuel and the associated maintenance cost.

The design of the small waste evaporator should also be considered to ascertain its ease of operation and such maintenance factors as corrosion and fouling of the heat transfer surface. The small waste generator does not wish to take time to carefully tend the evaporator along with the many other things he has to do. The evaporator should be able to operate by itself in an automatic mode and be fail safe, should anything occur which is unusual in its operations.

A good design for a small evaporator will include such features as self priming feed pump, which could either be attached to a drum of fluid or a storage tank. It would automatically go on and off, depending upon the level of liquid in the evaporator chamber. Automatic fail safe shut-off is very important, should the feed run out when the supply drum is empty or the pump quits. To prevent spills, there must be an automatic cutoff valve to stop the flow from an elevated storage tank. Such overflows can cause a terrible mess. An on-off thermostatically controlled heating system to prevent overboiling, with a safety cutoff should the fluid boil down and expose the heating elements, is a necessity. A blower, or some way of utilizing the exhaust flue gases to help move the steam from the evaporation chamber, will facilitate evaporation by keeping the pressure slightly lower than atmospheric and dilute the steam so it will be less likely to condense in the chimney. The evaporator will also be easier to operate and cause less maintenance problems if there is an oil outlet valve to remove oil floating on top of the evaporating liquid and a larger opening in the bottom of the evaporator for safe easy removal of sludge.

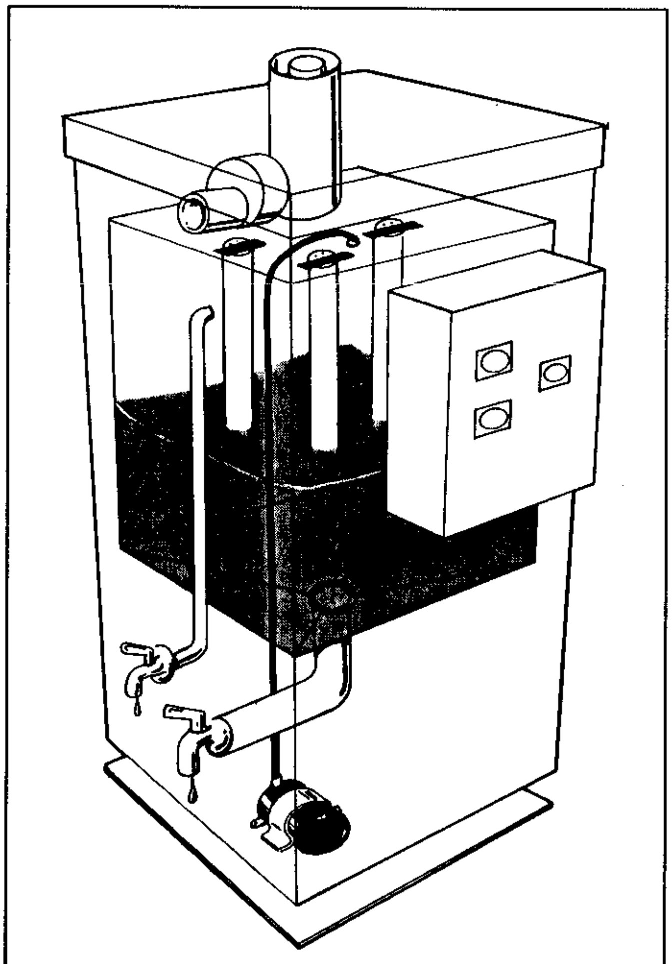


Exhibit 1. Small waste water evaporator, showing vertical heating elements, feed pump, exhaust blower and drain lines.

The heating elements or heating tubes should be placed in such a manner they will not easily foul by collecting sludge or having too high a heat flux, which will cause the heating element to scale, corrode and reduce heat transfer. Though coolants are frequently considered noncorrosive, a variety of chemicals do find their way into the system and tend to cause corrosion. Stainless steel can fight corrosion, especially on heat transfer surfaces, although the metal is becoming increasingly expensive. Costs can be minimized by using resistant coatings in the evaporator to prevent corrosion. The unit should be easy to clean, with ready accessibility to those parts which have a tendency to foul most easily. Several of these features are noted in the accompanying drawing (Exhibit 1) of the small waste evaporator using vertically mounted electric heating elements.

In some localities, steam may be vented directly to the atmosphere without violating air pollution laws. In other cities, such atmospheric venting is illegal. There should be provision on any small evaporator for condensing the steam and either discarding the clean water or using it for makeup water in the plant. In these instances, either a water cooled condenser or a more expensive air cooled condenser could be used. Recognizing that about ten gallons of cooling water will be needed to condense each gallon of evaporated water, when cost or availability of cooling water is a problem, an air-cooled, fin tube condenser can be used, but an electric fan will be needed to drive cooling air across the condensing tubes. If all of the equipment is simple and easily maintained, this type of evaporator will serve most small oily waste generators well.

Some small evaporator manufacturers claim higher efficiencies by using vacuum pumps to aid in evaporation by lowering vapor pressure and temperature of the system. Regardless of the temperature, about the same requirement of 1000 BTUs per pound of water is necessary to evaporate the water. Heat may still have to be added, and the vacuum pump will draw power. It is always easier and usually cheaper, however, to utilize higher temperature differentials to affect these efficiencies. Operating cost for small evaporators is, of course, a function of the cost of the fuel and cost of the electric power. Considering the differences in heat transfer efficiencies and conservation of energy, the energy cost differential narrows with good design, but should slightly favor a direct fired system. The small energy cost advantage must also be balanced with the higher cost of gas fired equipment and problems with fire hazards in areas containing oil. Generally, the cost of direct evaporation is in the range of four to ten cents per gallon of water evaporated.

More Efficient Evaporators for Large Waste Water Generators

With simple evaporation, efficiency is little improved by going to larger equipment. The same amount of BTUs must be put into one pound of water to evaporate it, but when considering larger evaporators, for example in the range of 1000+ gallons per day, energy costs become very significant. If the steam containing the latent heat evaporation can be conserved by condensing this water vapor to heat the incoming wet feed, great cost savings are effected. If two pounds of water can be evaporated by the same 1000 BTUs of energy input, obviously the efficiency is increased by 100%. The trick to the procedure is having high heat transfer efficiencies and multiple use of the same enthalpy of vaporization.

Many large evaporators employ the principle of multiple effects. In this situation, steam coming off the first evaporator pot is condensed to heat the incoming water and vaporize it in the second evaporator. That steam rises and condenses in the third evaporator section, each called an "effect." The driving force is reduced pressures in each successive stage. Essentially, one is using the same heat in cascading evaporators, having lower and lower boiling points. Very clean heat transfer surfaces must be maintained and the units must be very well insulated to achieve this result. Multiple effect evaporators will frequently use the energy three or four times before it is discarded, therefore reducing energy costs by the same factor of three or four.

An even more exciting principle involves vapor recompression evaporation. Here, only a single evaporative chamber is used and as the steam comes overhead, it is drawn into the inlet of a compressor where it is compressed two to three psi and consequently its temperature is increased several degrees. This "high pressure steam" is introduced into the heating side of the evaporator's heat exchanger where the latent heat vaporization is now released to incoming feed water. This steam is condensed by the cooler incoming feed and passes out through another series of heat exchanges to increase the temperature of the raw feed stream. In efficient vapor recompression systems, that same enthalpy can be utilized ten to fourteen times.

Careful engineering design is necessary to achieve this delicate balance and the heat transfer system must be very efficient, otherwise the unit will lose its advantage. The cost of evaporating water can therefore be reduced from the four to ten cents a gallon for direct evaporation to something like one-half to one cent a gallon.

Of course, these more efficient and larger heat transfer surfaces, compressors, pumps and controls cost more money. They are generally about two to three times more costly than a direct evaporation unit. However, when evaporating large volumes of waste water, this capital expenditure can be recouped by the energy savings. A vapor recompression evaporator, for example, which can process 1000 gallons of water a day could cost in the order of $120,000.

Exhibit 2 indicates the flow in the vapor recompression system.

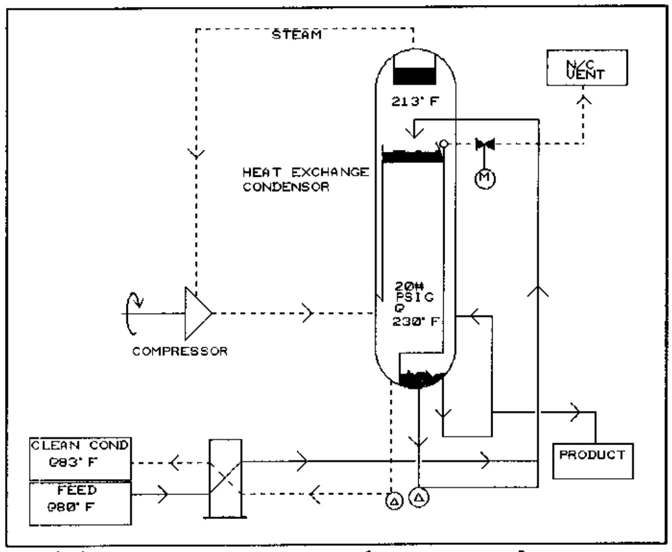


Exhibit 2. Vapor recompression evaporation system.

Since these sophisticated systems are sensitive to heat transfer fouling, very dirty fluids may need some pre-treatment before they can be put into the evaporator. This may mean filtration or chemical treatment to remove chemicals which may foul the evaporator. All these factors should be explored before selecting an evaporative system.

In summary, evaporation, whether it be simple or complex is an excellent way to reduce the volume of watery waste streams which may contain oils or heavy organic material commonly associated with water- based metalworking fluids. In simple evaporators, emulsions or wet oils can easily be handled and dirty sludge removed along with the oil and water to yield both clean water and dry, burnable oil. In general, evaporation may cut disposal costs by 80-90%. In some cases, you may completely eliminate the hazardous waste problems in machine shops and industrial organizations. Evaporators can also tolerate other wet fluids such as floor wash, paint wash, various oily rinses and wash waters from parts washers. Plating, circuit board or photographic wastes and other watery materials and solutions can also be evaporated to reduce their disposal volume. Each of these should be looked at separately, however, as in some cases it may not be advisable to mix all wastes together for processing at the same time. Evaporation does offer a simple and easy method for the reduction of watery fluid waste and particularly in comparison to other methods such as ultrafiltration, reverse osmosis, and ion exchange, and it should be considered near the top of the list for any plant having such waste fluids. Great savings in disposal costs can be made with only a small investment in equipment, energy and time.

Richard J. Bigda
President
Technotreat Corporation
6216 S. Lewis
Tulsa, OK 74136
Phone 918/742-5052
Fax 918/742-5585

Richard J. Bigda, a chemical engineer, currently serves as president of both Technotreat Corporation and of Richard J. Bigda & Associates, a chemical and petroleum engineering consulting firm. Before undertaking the design and manufacturing of high-performance skid-mounted waste water treatment systems, Mr. Bigda was an engineering consultant for the Corps of Engineers, and spent many years with several diversified oil and chemical companies. Mr. Bigda, who received degrees from Wayne State Univ. and the Univ. of Michigan, has written several books and numerous articles on energy and waste oil.

Technotreat specializes in industrial waste treatment, detoxification, volume reduction and recycling. It manufactures all types of process equipment, including evaporative systems, code pressure vessels, skids, tanks and reactors. Instrumentation consists of computer driven process controls, control panels, pH, ORP, temperature and pressure controls. The company specializes in analyzing its customers' problems and developing economical solutions to waste management.

Evaporation: Evaporate the Water Portion of Coolants/Water-Based Wastes

Gary Dixon
Samsco, Inc.

When a single capital investment can generate a payback of less than one year and, at the same time, meet the disposal objectives of both industry and the nation — that's news. An evaporative methodology has the ability to do just that.

Evaporation, as a method to reduce or concentrate liquids, of course, is not revolutionary. However, using evaporation to solve the unique disposal problems of the metalworking industry, particularly its oily process waste waters, is relatively new and exciting.

Evaporation provides today's generator of metalworking coolants and of a variety of other water-based wastes with a simple and inexpensive method of accomplishing everyone's goal—waste minimization. The approach eliminates entirely any sewer discharge, while also reducing dramatically the costs and liabilities associated with off-site shipping.

Typically, the waste streams are reduced to a mere two to ten percent of their original volume. While the water phase of the waste is virtually eliminated, the remaining oils (water-free) and/or solids are concurrently segregated for final disposal. The water is eliminated at an approximate operating cost of \$.03 to \$.08 per evaporated gallon. This, of course, compares favorably with a typical cost of \$.40 to \$3.00/gallon for off-site shipping.

The Appeal of Evaporation is Broad

- IT IS EXTREMELY SIMPLE TO INSTALL, OPERATE, AND MAINTAIN.
- THE CAPITAL INVESTMENT IS LOW, AS ARE THE OPERATING COSTS.
- ADDITIONAL LABOR OR SKILLED LABOR IS DEFINITELY NOT REQUIRED.
- NEITHER ADDITIONAL CHEMICALS NOR MONITORING DEVICES ARE REQUIRED.
- NO EXPENSIVE REPLACEMENT OR CONSUMABLE ITEMS ARE REQUIRED.
- IT HANDLES A WIDE VARIETY OF STREAMS SIMULTANEOUSLY.
- IT ELIMINATES HAVING TO MAKE PRODUCTION DECISIONS BASED UPON DISPOSAL PROBLEMS.
- *IT IS A LONG-TERM ANSWER, NOT A SHORT-TERM BANDAID.* THE GENERATOR FREES HIMSELF FOREVER FROM THE EVER-TIGHTENING RESTRICTIONS OF THE SEWER AUTHORITY. HE REDUCES DRAMATICALLY HIS OFF-SITE SHIPPING VOLUME AND THE ASSOCIATED COSTS AND LIABILITIES.

General Background: Why Evaporation?

The evaporative equipment specifically designed for metalworking waste streams originated as a response to a changing marketplace. This marketplace was created by new federal and state environmental regulations, coupled with ever-tightening sewer discharge limits. Rapidly escalating disposal costs were the overall effect.

Waste streams that historically could go "to drain" were being restricted. The streams were also smaller volumes than those that traditional disposal methods had previously addressed. These new problems created a major dilemma for the newly regulated generator. With only old (and often times impractical) answers available for solving them, many generators simply opted for not making a decision.

Consequently, a whole new group of regulated generators was created that was not being served well by the conventional approaches of recycling, ultrafiltration, chemical splitting, and water treatment.

These standard alternatives seemed impractical because of the limitations they imposed. They were technically complex, labor intensive, waste-stream specific, capital intensive, required consumables or a combination of these.

Of even greater concern, most of the methodologies left the generator with a large volume of water. This water might or might not meet current sewer discharge limits. Even if it did, the discharge would still require continuous monitoring/lab fees and still run the risk of not meeting ever-lowering discharge limits.

Clearly these methodologies had been designed for larger-volume generators with more lenient sewer requirements. In contrast, the new evaporative equipment was designed specifically to solve the disposal problems for this newly defined generator.

Case Study Problems

A look at a typical case study illustrates best how the evaporative methodology fills the gap between today's disposal problems and the available answers. It demonstrates how evaporation provides a preferable answer, both functionally and financially.

This manufacturer generates a variety of water-based waste streams, but metalworking coolants (oil based and synthetic) are a large percentage of the total volume. The other streams are comprised of alkaline cleaners, floor-scrubber waters, tumbling solutions, some rinse waters and oily compressor waters. With some pre-treatment, the generator is able to discharge most of these wastes to sewer.

Unexpectedly, the generator receives a letter from the local sewer authority, restricting his discharge. None of the generator's streams meet the new discharge levels. Allowable oil discharge levels have been dropped to 15 ppm (a neighboring town is at zero ppm). The generator cannot meet it. His copper content is also too high, and the BOD/COD level is borderline.

The total volume of these multiple streams is 57,000 gallon per year. After the compliance notice, the generator is forced to begin using an available underground holding

CASE STUDY - PAYBACK ANALYSIS		
CURRENT OFF-SITE DISPOSAL COST		$34,200
57,000 gal/yr at $.60/gal		
EVAPORATIVE EQUIPMENT	$14,385	
Stainless Steel Automatic Fill-Level Controls		
OPERATING COSTS	$ 2,850	
57,000 gal/yr at $.05/gal		
TOTAL EVAPORATIVE COSTS		-$17,235
RESIDUAL STRAIGHT OIL-DISPOSAL COST		-$ 570
2,280 gal/yr at $.25/gal		
1st YEAR COST SAVINGS		$16,395
2nd YEAR COST SAVINGS		$30,780
PAYBACK - 6.25 MONTHS		

Figure 1. Case study payback analysis.

tank. From the holding tank a disposal firm pumps the waste waters into a tank truck, and the manufacturer begins paying to haul the waste streams off-site. See Payback Analysis, Figure 1.

The generator explores the known alternatives and for various reasons does not feel comfortable enough to commit to one. He has minimal space available, entry level personnel for operating and maintaining any equipment, a management that is reluctant to spend large sums of money and a warranted apprehension about future sewer restraints.

Case Study Answer

Subsequently, the manufacturer learns that a sister plant has already solved a similar disposal situation. It is using an evaporator exclusively to evaporate more than 200,000 gallons of coolant per year.

These managers had chosen evaporation because they knew that they could not make the coolant-chemistry management portion of recycling work in their facility. In addition, production used three coolant products, and they did not want to consolidate further in order to make recycling practical. Other disposal methods left them with continuing sewer discharge problems.

The generator contacted the evaporative organization that had worked with its sister plant. Together they developed a needs analysis that assessed the following: waste stream composition, disposal constraints, facility and personnel considerations, manufacturing needs, short and long term goals, liability concerns, specific regulatory compliance aspects, and payback consideration.

After comparing the evaporative approach to the conventional disposal methodologies (recycling, ultrafiltration, chemical splitting), they decided on evaporation. As a result, management accomplished positive results in a variety of major areas.

Positive Results

[1] Because the generator would be evaporating its waste stream on a daily basis, the plant was able to remove its 6,000 gallon underground holding tank and replace it with a small inside tank. This enabled them to eliminate tank monitoring costs and the potential liabilities of an underground tank.

[2] The new operation necessitated no change in worker duties. The waste waters were now simply pumped into a different holding tank and were automatically fed into the evaporator as needed. Periodic discharge of the small amounts of segregated water-free oils and/or solids was easily scheduled into their other maintenance duties.

[3] No additional chemicals would be required, thereby avoiding their associated safety, storage, and disposal entanglements.

[4] There were no sensitive and costly filtration membranes that would require replacement.

[5] The processes also allowed manufacturing engineers the flexibility of selecting any process chemicals they desired. No longer were their manufacturing decisions based upon the disposal restrictions of their chemicals. (Example:

reducing the numbers/types of coolants used, so as to make recycling/disposal processes practical.)

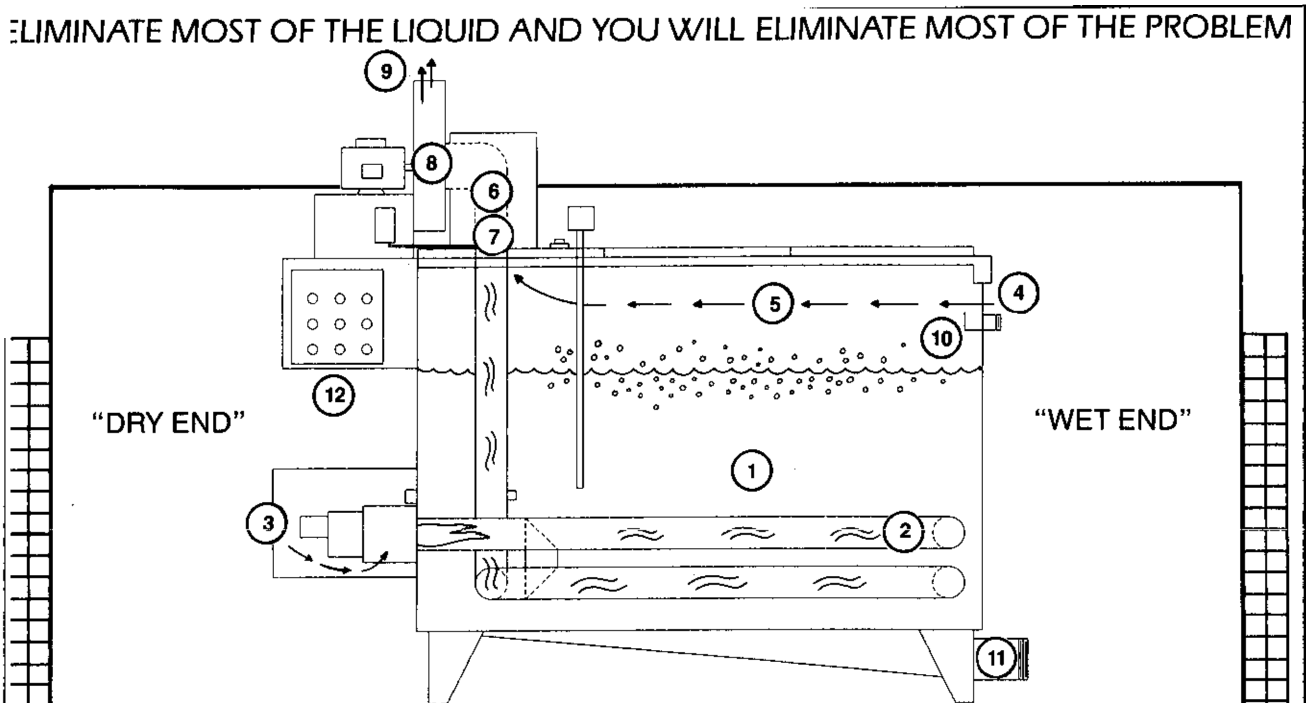
[6] This evaporative design was an "equal opportunity piece of equipment" that could simultaneously handle a variety of aqueous waste streams, with a variety of soil loads. They had found ONE answer for a multitude of disposal problems.

[7] Only approximately 14 square feet of valuable floor space were consumed by the equipment. Installation required no more than 110 V, a gas line, venting, and simple plumbing to the holding tank.

[8] With this approach, the generator had evaporated the water phase of his streams and therefore had eliminated any discharge being sent "to drain." Furthermore, as local sewer restrictions continue to tighten, the facility would no longer be affected. The generator had not made a "band-aid" decision. His answer was flexible and long term.

[9] The oil portion of the waste streams was returned as a water-free oil and consequently was handled inexpensively through a waste-oil dealer.

[10] Any remaining small amounts of chips/fines/solids were simply disposed of along with other similar plant solids.



PRINCIPLES OF OPERATION

- Solution is fed to the tank[1] in either a batch or continuous mode (automatic fill).
- Solution is heated in the tank to boiling (212°F) by a serpentine gas-fired heat exchanger.[2]
- Blower[8] draws in ambient air through both the burner[3] and a sized opening in the tank.[4]
- Air is drawn across the surface[5] of the heated liquid, sweeping away water vapor as it breaks the surface.
- This moisture-saturated air and the flue gases leave the tank via separate passageways[6,7] and are joined together at the blower entrance.
- The two air streams, environmentally safe, are mixed in the blower[8] and are released up the stack.[9]
- Free oils and oils whose emulsions have been thermally broken float to the surface. They are then removed, either automatically or by actuating a simple switch. These oils exit via an overflow trough[10] into an external waste receptacle.
- Precipitated solids settle to a sloping trough and are easily removed via a convenient clean-out port.[11]
- A full-function Control Panel[12] indicates various operating conditions (normal, shutdown, etc).

Figure 2. Principles of operation of a typical evaporator.

[11] The financial considerations were very favorable, with a payback period falling significantly under one year. (See Payback Analysis, Figure 1.)

How It Works

Practicality, dependability, and durability are considered high priorities by most facility and maintenance groups. Facility managers must have equipment that they can make work in their shop. Therefore the evaporative equipment's design has to perform its function, but not at the expense of becoming a maintenance headache.

Because such maintenance equipment is often placed in low-traffic areas, operated by entry-level personnel and is frequently left unattended, it is important that the unit's design address these anticipated conditions. The equipment must operate automatically, it must operate simply, and safety shutdown conditions must be designed into its operation.

Operation of a typical evaporator is explained in Figure 2.

Various heat sources can be used, but gas (natural or propane) is preferred, because gas burns cleanly and is extremely economical. The design of the heat exchanger should consider the natural dropping out of stream solids and their accumulation in the tank bottom. The equipment design, therefore, should avoid heating through a transfer surface in the tank bottom, where the settled, accumulated solids can bake on and insulate the transfer surface.

There are typical safety burner shut-downs that should be considered standard features on a unit. They are as follows:

[1] An airflow detector and switch lockout to insure that the vapor exhaust fan is on while water vapors are being generated.

[2] A low-level sensor to shut down an unattended unit if the liquid level evaporates down to a preset minimum.

[3] A high temperature sensor to shut off the burner if the liquid temperature rises above 212°F (caused by either inappropriate materials or inattention).

In moving liquid wastes to an evaporative unit, one of two basic approaches can be selected. The waste can be fed in a batch mode or automatically from a holding tank. An automatic mode fills the unit continuously and maintains a constant operating level, thereby eliminating the labor of manual filling and providing a 24-hour operation. A properly designed evaporator will offer wide flexibility in complementing any existing facility's logistics and requirements, whether waste is fed by batch or automatically.

A well-engineered evaporator will also consider the chemical composition and the solids/oil content of the current streams, as well as any future streams. As a consequence, the equipment design will offer alternatives on such variables as tank configuration and tank material.

The actual removal of residual oils and solids can be achieved in various ways (manually or automatically), requiring only an initial decision on simple tank positioning and/or plumbing.

By assessing a client's own set of disposal circumstances and objectives, the evaporation equipment manufacturer can assist a facility in planning for the most beneficial use of its evaporative equipment. Together, they will consider such variables as generated volume, stream composition, characteristics of residuals, locations of waste streams, and facility logistics.

Summary

Evaporation is a proven technology. Units placed in facilities over the last five to six years continue to provide the benefits that were originally projected. Water is being eliminated efficiently in diverse industries in almost every state. These installations range from small shops to a healthy list of large, well known Fortune 500 manufacturers.

The expertise that the pioneers of this approach have developed over the last few years have established this methodology. Their efforts and field results have earned the support of both the regulatory and consulting world, as well as the metalworking world which they serve.

Potential users of any equipment are generally concerned about three things:

- Will it do what is promised?
- Will it do it as inexpensively and as simply as claimed?
- Will my state allow me to use it?

The author's solid six years of experience with clients all across the country show that their use of evaporation has elicited a "Yes" to all three questions.

Gary Dixon
Samsco, Inc.
18 Cote Avenue
Goffstown, NH 03045
Phone 603/668-7111
Fax 603/647-0537

Gary Dixon is part of the application engineering group at Samsco, Inc. Prior to joining Samsco, Mr. Dixon was the director of product/market development for a division of United Technologies. With a degree in engineering physics/mathematics, Mr. Dixon has had a diverse career in both direct engineering and marketing management within industry and in private consulting.

Samsco, Inc. was founded in early 1985, and has since established itself as a market leader in evaporative technology designed for the metalworking industry's oily water wastes and the alkaline cleaners that remove them. Samsco provides comprehensive application engineering and environmental regulatory assistance as well as a full line of evaporative equipment.

Introduction to Ultrafiltration and Reverse Osmosis

David B. Rubin
Sanborn Inc.

Ultrafiltration (UF) has been an accepted and highly successful method of treating metalworking fluids for over 15 years. As discharge requirements become more stringent, ultrafiltration may not be adequate. More restrictive COD (chemical oxygen demand) and oil and grease limits will dictate further treatment and reverse osmosis (R/O) or other methods will be required to polish UF permeate, thus permitting its safe and legal discharge.

Ultrafiltration and reverse osmosis are membrane-based technologies which reduce the volume of industrial waste fluids. Despite their complex membrane technologies, UF and R/O systems are surprisingly simple to understand, operate and maintain. They are safe for both their operators and the environment. In today's world of cradle-to-grave responsibility, hazardous waste manifests, generator licenses, and stringent regulations and enforcement, UF and R/O reduce liability and minimize waste.

Membrane Filtration

Filtration is a method of separating substances of varying sizes. Shower drains and y-strainers are common examples of filters. Membranes also separate substances; however, these substances are frequently microscopic. Membrane pores are so fine that in addition to separating solids from liquids, they also separate larger molecules from smaller molecules.

The major difference between traditional filters and a membrane is the orientation of the fluid flow to the filter surface. In a traditional filter, the dirty stream flows perpendicular to the filtering media. Ultrafiltration membranes utilize cross-flow filtration in which the feed stream is introduced parallel to the membrane surface. Cross- flow filtration is advantageous because it induces membrane self- cleaning.

To better understand cross-flow filtration, picture what happens to an ordinary garden hose when the water valve is opened. Even though the flow is forced lengthwise through the hose, the hose hardens as water is forced against the hose wall due to hydrostatic pressure. Similarly, as dirty feed is pumped from a process tank through a membrane system, hydrostatic pressure forces water and aqueous substances through the membrane's pores. The rejects, that portion of the feed that is not passed through the membrane, are returned to the process tank.

Water is continuously pumped from the process tank through the membrane in a turbulent flow condition. The turbulence prevents contaminants from building up on the membrane surface. Therefore, membranes only require periodic flushing and/or chemical cleaning. A traditional filter clean-out is not necessary.

The periodic cleaning consists of recirculating a mild detergent solution from a cleaning tank through the membranes. A 30 to 60 minute flush with a detergent usually is all that is required to maintain system flow rates and extend membrane life. Occasionally, if particularly severe contaminants are being processed, an acid cleaning and/or a "sponge ball" treatment in the case of tubular membranes may be required.

Membrane life is dependent on a number of factors, including:

- attention to cleaning;
- concentration of contaminants in the feed;
- total usage time;
- frequency of concentration dumps; and
- pH of fluid.

Typically, membranes will last two years under normal operating and cleaning conditions.

What happens to the solids, and the oil and grease which can not pass through the membrane? All the rejected material is returned to the process tank. However, the concentration of these contaminants is increased as some of the water has been removed from the system. During any given pass through the system only a small fraction of the water passes through the membrane. Most of the water is returned to the process tank. As the circulation continues, much of the water is removed and the contaminant concentration increases. Eventually, the contaminant concentration will reach 45-50%. At this point, the process tank is drained and the concentrated waste solution is hauled away as manifested waste. If the original oil concentration was 5% (as would be the case with a water soluble coolant mixed at a 20:1 ratio), the total volume will be reduced by 90%. Similarly, disposal costs will also be reduced by 90%. The great appeal of membrane systems are these substantial cost savings.

Ultrafiltration

Ultrafiltration removes suspended and colloidal particles from a wastewater using a semi-permeable membrane. Pore size varies from membrane to membrane; typically, all particles, emulsions or solids, with a molecular weight greater than 8000 are rejected by a UF membrane. Consequently, oil and grease, and water soluble coolant concentrate will be separated from water by ultrafiltration. The water which passes through the membrane will usually contain less than 100 ppm (parts per million) of oil and grease (O&G). Therefore, a plant with an O&G limit of 100 ppm, a common limit, will be able to safely and legally discharge the effluent from an ultrafiltration system directly into a sewer drain.

UF membranes are manufactured in three basic configurations: tubular, hollow fiber, and spiral. The membranes employed in the configurations possess like physical characteristics (i.e., pore size and structure); however, they are assembled differently which allows for various applications. For example, a waste stream high in solids is best suited for a tubular membrane which allows the particles to easily pass across the membrane as reject. If these solids were introduced into a spiral configured membrane which only has 1250ug channels between membrane surfaces, these channels would quickly become clogged and necessitate a thorough membrane cleaning.

The tubular design is the most common configuration. Several tubelets (long tubes whose inner surface is impregnated with the membrane) are housed within a larger plastic tube. Rejected fluid flows through the tubelets and is returned to the process tank. Clean water which has passed through the membrane exits the larger tube through a permeate carrier.

Spiral UF membranes somewhat resemble jelly rolls. The membrane and spacer are tightly wrapped around a permeate carrier several times. This configuration is more compact and thus requires little area.

Hollow fiber membranes have a tremendous surface area. In this configuration, hundreds of membrane fibers are contained in a large tubular housing. The hollow fiber membrane can be flushed and back-flushed to enable a very effective and thorough membrane cleaning.

UF systems have several common and practical applications in today's metalworking shop. Any process which generates oily waste water is a prime candidate. Common applications include:

- wash waters;
- floor scrubbings;
- steam cleaning condensate;
- air compressor condensate (blowdown); and
- metalworking coolants.

Many UF system suppliers offer application and feasibility tests either on site or in laboratories. Recently, some firms have introduced portable systems which can be used both for demonstration and testing, and also by smaller metalworking shops for primary waste treatment. These portable systems make ultrafiltration available to everyone.

Reverse Osmosis

Reverse osmosis is also a membrane process which separates substances via cross flow filtration. R/O, although similar to UF in theory, operates under higher pressures (500 psi and above). The principle of osmosis is demonstrated when water passes from the less concentrated side of a semi-permeable membrane to the more concentrated side until equilibrium is reached. However, when enough pressure is applied to the more concentrated side, the water will pass through the membrane and enter the less concentrated side. This is the theory behind Reverse Osmosis and the reason for the high operating pressure.

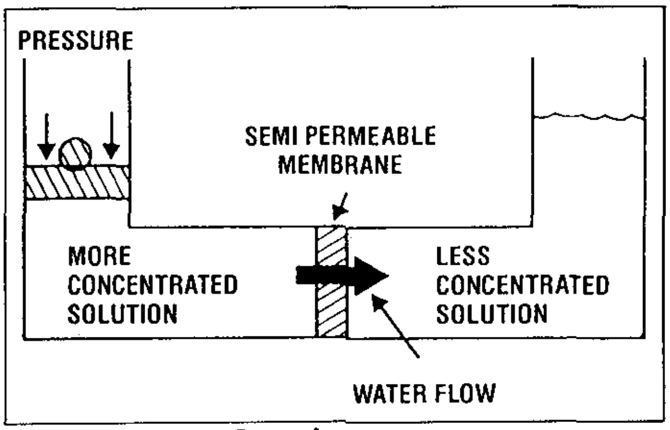


Figure 1. Reverse Osmosis

Pore sizes in R/O membranes are in the five to 20 angstrom range. With such small openings, these membranes can be susceptible to fouling. For this reason, the feed to an R/O system is usually UF permeate which contains only trace amounts of hydrocarbons and aqueous salts and metals, substances which pass through a UF membrane. Any substance with a molecular weight greater than 100 will be rejected by an R/O membrane. Therefore, plants that face particularly stringent discharge limits for COD, BOD and O&G will employ R/O as a final polishing step for their UF permeate. After R/O processing, a metalworking waste stream will contain only trace amounts of contaminants. R/O permeate can be safely and legally discharged to the sewer.

The R/O system, like a UF system, includes three basic components: a process tank, a pump, and the membranes. As feed (UF permeate) is pumped through the membranes, dissolved metals, salts, and any remaining hydrocarbons are rejected and return to the process tank as concentrate. The clean R/O permeate can be safely discharged to the sewer. R/O membrane configurations and cleaning requirements are very similar to those of UF membranes. Warm water, detergent and/or acid flushes as needed will increase membrane performance and lifetime.

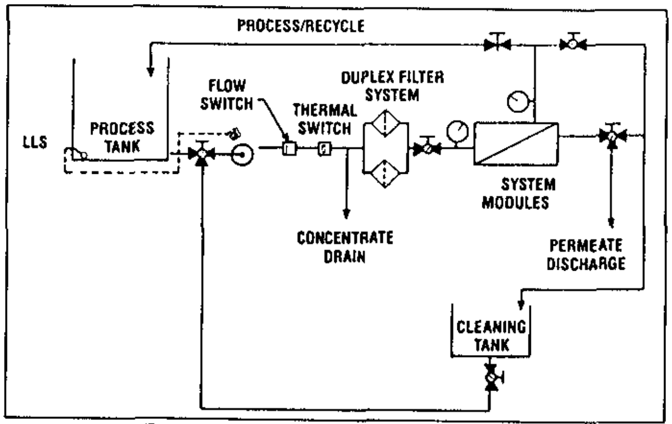


Figure 2. The reverse osmosis system.

Conclusion

UF and R/O are integral parts of waste minimization programs in hundreds of metalworking shops. These technologies can reduce waste volumes by as much as 90%. Membranes are a positive barrier which provide consistently good effluent quality. Oily wastewater flows on one side, and a treated effluent suitable for sewer discharge is produced. For several years, UF has been successfully employed to reduce waste volume and cost. As discharge limits become more stringent, UF followed by R/O may be the best method to provide needed effluent quality.

David B. Rubin
Sanborn, Inc.
25 Commercial Drive
Wrentham, MA 02093
Phone 508/384-3181
Fax 508/384-5346

David Rubin is a sales/applications engineer in the environmental systems division of Sanborn, where he performs on-site engineering and applications studies for customers. Before joining Sanborn, Mr. Rubin was a plant engineer with Union Carbide Corp. Mr. Rubin received a BSChE with Distinction from Worcester Polytechnic Institute.

Sanborn has been a leader in separation technology for over ten years. Sanborn supplies custom engineered and designed systems to recycle industrial lubricants, machine tool coolants and petroleum based oils, as well as ultrafiltration equipment to dispose of oily wastewater.

CHAPTER SEVEN
Biological Treatment

Due to the high organic content of most metalworking fluids, they are good candidates for degradation by bacteria for waste treatment. However, the high oil content of these fluids typically eliminates using biological treatment as the primary treatment method; either a chemical or physical treatment process precedes the use of biological treatment with metalworking fluids.

With stricter standards for sewer discharge, many plants find that primary treatment is no longer adequate to meet the effluent standards. This is particularly true with Chemical Oxygen Demand (COD) or Biochemical Oxygen Demand (BOD) standards.

As a secondary treatment process, aerobic or anaerobic biological processes are effective in reducing the COD and BOD of the waste. These processes are typically more effective with continuous flow and large volume wastewater plants.

Today, there is more interest in biological treatment for larger metalworking plants, and eventually we may see more and more plants using biological treatment as a secondary treatment for their fluids.

Biological Wastewater Treatment of Metalworking Fluids

Terry M. Williams, Ph.D.
and
Ann M. Potcher
Rohm and Haas Company

Background

The disposal of metalworking or cutting fluid wastes is a complex process and the selection of a given treatment method depends upon the specific type of fluid used. A variety of soluble oil, synthetic, and semi-synthetic fluids are available for use in metalworking processes to provide cooling and lubrication.

The treatment of soluble oil metalworking fluids has been accomplished in the past largely by physical-chemical separation techniques.[4] These methods have been effective because the oil fraction is readily separated from the aqueous phase. The recovered oil is typically discarded or may be recycled. The liquid portion of the waste stream is then released to a municipal sewer system or discharged directly to a receiving stream, if specific effluent restrictions are met.

Physical-chemical processes, however, have proven inadequate for treating wastewaters containing synthetic and semi-synthetic cutting fluids.[9,10,13,16] Portions of the soluble organic components of these metalworking fluids are not removed by conventional treatment schemes and subsequently pass through the system untreated. The organics which remain in solution increase the pollution load of the effluent, as measured by the chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5).[12] Depending on the strength of the waste and specific discharge limitations, alternative treatment techniques may be required to permit discharge of the wastewater to a stream or municipal sewer system.

The BOD_5 test determines the amount of oxygen used by microorganisms to oxidize a substrate over a five day period. The COD test is a measure of the oxygen required for strictly chemical oxidation. The BOD_5/COD ratio is an indicator of the relative biodegradability of a given waste. Low ratios indicate that the microorganisms are unable to oxidize the components of the waste.

Water-miscible coolants contain a variety of biodegradable carbon compounds.[6,7] As a result, there has been recent interest in the application of biological systems for the treatment of water-miscible cutting fluid wastes. In this paper, a description of biological treatment processes (aerobic and anaerobic) will be provided and specific case histories which have been reported will be discussed.

Biological Treatment Strategies

A variety of biological treatment systems are available to provide for the degradation of organic compounds in liquid waste streams.[12,17] These systems rely on the ability of microorganisms, primarily bacteria, to utilize the available sources of carbon, nitrogen, and phosphorus in the wastewater for growth. Most systems operate by providing a continuous or semi-continuous input of wastewater to a high density of microorganisms. As the organisms metabolize the nutrients in the influent waste stream, the BOD_5 of the waste is reduced. The level of BOD_5 reduction which can be achieved is a function of the type of organic compounds present, the method of treatment, and the types of organisms present in the microbial biomass.

Metalworking fluids in general are susceptible to microbial contamination and degradation by a variety of bacteria and fungi.[1,3,5,7,8,11,14,15] This is evident in the widespread use of biocides to maintain control over the microbial counts in the systems. The major source of nutrients in the fluids is the soluble organic compounds which serve as a source of carbon for the mixed populations of microorganisms. A variety of nitrogen and phosphorus compounds is also present in the fluids. Many of the common components in metalworking fluids, including fatty acids, petroleum hydrocarbons, and glycols, have been shown to support the growth of bacteria.[7]

Conventional methods for treating municipal wastes, including both domestic and light industrial sources, involve biological processes to reduce the BOD_5 content to a level suitable to meet discharge limits. Another wastewater parameter which is typically monitored is the suspended solids (dry weight) content of the microbial solids.[12] A typical biological treatment design includes a primary sedimentation of the wastewater to remove excess solids followed by a biological process in which the microbial activity takes place. The wastewater is then clarified by settling and the effluent is ready for discharge. Depending on effluent restrictions, chlorination may be required to reduce the level of coliform bacteria.

Biological treatment plants are designed to utilize the microorganisms in either a suspended or attached growth mode.[12,17] In the suspended- growth systems, the microbial community develops in compact aggregates, termed "flocs," which are freely suspended in the liquid medium. In the attached-growth systems, the microorganisms develop in biofilms on solid surfaces, including plastic, stones, sand, or activated carbon. Both of these unit process designs operate by providing a sufficient residence or contact time to allow for complete degradation of the wastewater nutrients by the microbial biomass. Several variations on these techniques are available and are capable of effectively treating liquid wastes. Specific examples related to metalworking fluid treatment are given in the following sections on aerobic and anaerobic processes.

Aerobic Processes

Biological treatment systems employing aerobic processes operate by providing a continuous supply of oxygen to achieve complete oxidation of the organic compounds (BOD_5) in the influent waste. Many of the systems require relatively short residence times, but have the added energy requirement and cost associated with providing mechanical aeration.

Suspended-growth systems may include activated sludge, extended aeration, or oxidation pond designs.[12,17] The activated sludge process is the most commonly used treatment design for domestic wastes. In this system, oxygen is provided to the microorganisms (flocs) in an aeration basin where the BOD_5 reduction occurs. The biomass (suspended solids) is maintained at a desired level by recycling a portion of the settled sludge from the final clarifier back to the aeration tank. The following examples illustrate the potential for using activated sludge designs for biodegradation of spent cutting fluids.

Biological treatability of synthetic and semi-synthetic metalworking fluids from an automotive machining plant was investigated by Kang *et al.*[9] Chemical treatment of the wastewater had been practiced, but often proved inadequate resulting in low efficiency of BOD_5 and COD removal. Benchscale activated sludge units were operated to test the treatability of four fluids at three concentrations. Three of the lubricants (containing glycol, alcohol-amine, and fatty acid components) were shown to be easily degraded yielding low COD values, whereas one fluid (containing a different alcohol-amine) was more resistant to biological treatment. The lowest effluent BOD_5 values were obtained with the fluid containing fatty acids as the major component.

Another study using the activated sludge process for biological treatment of machine tool coolants was reported by Polak.[13] In this system, wastewater from the metalworking facility was being discharged directly to a waterway. The chemical treatment process periodically failed to satisfy the limits for BOD_5 in the plant effluent. Benchscale activated sludge tests were conducted using pretreated wastewater containing three different cutting fluids. The system was operated at pH 7.5 to 8.5 and a dissolved oxygen level of two to four mg/l. Two alkanolamine-based synthetic fluids, tested at three concentrations, were readily degraded yielding effluents between five to 34 mg/l BOD_5. Biological treatment of an emulsified oil coolant waste in the activated sludge model system resulted in effluent BOD_5 values of eight to 22 mg/1. The authors noted that chemical pretreatment was most effective in reducing the level of COD in the emulsified oil waste relative to the synthetic fluids.

A study was conducted by Baker *et al.*[2] to define the predominant types of bacteria present in an activated sludge reactor treating water-based cutting fluids. The treatment system was designed specifically for the biological degradation of the spent metalworking fluid from a machining operation. After an initial adaptation period, the activated sludge system achieved over 95 percent efficiency in removing BOD_5. Fifteen different genera of bacteria were isolated and identified from the samples. Certain organisms were common contaminants of cutting fluids, whereas several groups of bacteria had not been reported previously in metalworking fluids.

Attached-growth systems offer an alternative method for biological wastewater treatment. They may be stationary with the liquid passing over the biofilm, as in trickling filters or fluidized-bed reactors, or they may involve direct movement of the surface through the liquid, as in rotating biological contactors. The trickling filter design is the most commonly used method of this type for domestic waste treatment. Fixed-film technology has shown numerous applications in treating a wide variety of industrial wastes.[17]

An aerobic upflow fluidized bed reactor was evaluated by Sutton *et al.*[16] for treating synthetic metalworking fluids in an automotive parts manufacturing plant. In the upflow mode the wastewater flow is recycled upwards through a bed of silica sand at a velocity sufficient to expand the support medium. Microorganisms attach to the sand particles and metabolize the nutrient in the influent waste. Oxygen is added to keep the system aerobic to provide for complete oxidation of the organic matter. In this study, the wastewater from the machining operations was required to meet specific BOD_5 limits prior to its discharge to the local municipal sewer. With the increase in use of synthetic and semi-synthetic fluids in the plant, conventional physical-chemical treatment methods were unable to meet the desired effluent discharge standards. A two-stage biological reactor was used to treat the wastewater and achieved 81 and 98 percent reduction in the COD and BOD_5 of the wastewater, respectively. The performance of this system was not adversely affected by changes in the rate of addition or concentration of the feed.

Anaerobic Processes

Anaerobic biological treatment systems function by the breakdown of organic compounds in the waste in the absence of oxygen. Organic compounds are degraded by fermentation and anaerobic respiration processes. Sludge digesters are typically operated anaerobically to reduce the organic content of the settled solids from most municipal wastewater treatment systems. Conventional activated sludge designs may be modified by alternating between aerobic and anaerobic conditions in the aeration basins to improve the performance under certain operating conditions. Fixed-film (biofilm) systems, including rotating biological contactors and fluidized bed reactors, have also been operated under anaerobic conditions for biological treatment of specific types of wastes.[17]

Anaerobic treatment systems for metalworking fluids have not been investigated to the same extent as aerobic systems. Kim *et al.*[10] examined the use of a granular activated carbon (GAC) fluidized bed reactor to anaerobically degrade a mixture of eight water soluble cutting fluids. The authors noted that the organic components were initially adsorbed onto the GAC, but the adsorption capacity decreased over time. The COD of the effluent was reduced by 64 percent following anaerobic treatment. The residual organics which passed through the anaerobic process were shown to be aerobically biodegradable. The authors suggested that anaerobic treatment systems should be followed by aerobic units or frequent replacement of the GAC filter medium to improve overall effluent quality. Methane gas, a common byproduct of anaerobic degradation, was also generated during the biological treatment of metalworking fluids in this study.

Summary

Biological treatment processes can be considered a suitable method for improving the overall level of treatment of metalworking or cutting fluid wastes. The case studies demonstrated that conventional physical-chemical treatment of wastewaters containing synthetic and semi-synthetic cutting fluids fail to remove large quantities of soluble organics. The addition of a biological treatment process in the overall waste disposal program was effective in reducing the BOD_5 and COD of the wastewaters.

The aerobic treatment systems provided for more complete oxidation of the organic components in the wastewaters relative to the anaerobic systems, although a few studies are available with the latter. The biodegradability of cutting fluids will be influenced by a number of factors, including the composition of the fluid, the type of microorganisms present, and environmental conditions.[1,2,4,7] Additional studies are needed to evaluate other types of biological systems for the disposal of metalworking fluid wastes and to determine the effect of process variables on treatment performance.

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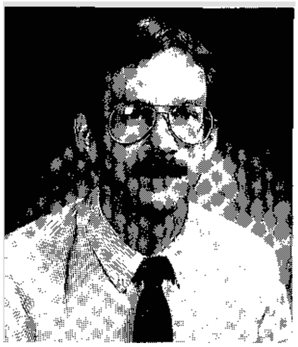
Terry M. Williams, Ph.D.
Senior Microbiologist,
Biocides Research
Rohm and Haas Co.
Independence Mall West
Philadelphia, PA 19105
Phone: 215/592-3000
Fax: 215/592-2178



Terry Williams has held the position of senior microbiologist, biocides research, at Rohm and Haas Co. for three years. In his current position, he is team leader for systems protection research in the areas of metalworking fluids, water treatment, pulp and paper, and oil fields. Dr. Williams previous experience includes 12 years in environmental microbiology. Dr. Williams received a B.S. in Biology from Gettysburg College, an M.S. in Environmental Pollution Control from Pennsylvania State Univ. and a Ph.D. in Microbiology/Ecology from Pennsylvania State Univ. He is a member of STLE and ASME, and has published numerous abstracts and articles.

Rohm and Haas Company is a major manufacturer of specialty chemicals and plastics. Its specialty chemicals are sold to customers in a wide range of industries, who use Rohm and Haas products in the manufacture of numerous goods which are ultimately marketed to the consumer. A Fortune-200 company, Rohm and Haas has 44 manufacturing sites worldwide, and sales offices in more than 30 countries. Rohm and Haas is an industry leader and innovator in polymer acrylic chemistry, biocides, and other specialty chemicals. It is the world's largest producer of acrylate monomers and their derivatives, raw materials used in more than 60% of the company's product portfolio. Rohm and Haas is an Associate Member of the Independent Lubricant Manufacturers Association.

CHAPTER EIGHT
Recycling and Disposal of Oils

As opposed to "water-based" metalworking fluids, there are many "straight oil" metalworking products used in industry. These oil products can be broadly classified as industrial lubricants or processing compounds. The U.S. EPA was directed by Congress to develop regulatory management standards for recycled oil and to determine whether to list "used oil" as hazardous.

Recovery and Conservation of Oil-Based Metalworking and Industrial Lubricants Through Reclamation

Ike Tripp, Jr.
Etna Products, Inc.

Introduction

Most manufacturers in the metalworking industry use a wide variety of metalworking compounds and industrial lubricants in their equipment. With the passage of the Resource Conservation and Recovery Act (RCRA) in 1976, the government of the United States served notice on the metalworking industry that industrial waste will be regulated from "cradle to grave." Subsequent regulations under RCRA, the first of which was published in the Federal Register on May 19, 1980, have now begun controlling the generation, treatment, storage and transportation of hazardous waste. The Environmental Protection Agency (EPA) is charged with managing RCRA, and it has issued numerous criteria over the years for the identification and treatment of waste.

Used metalworking fluids and industrial lubricants contain a wide variety of contaminants. Metals such as copper, brass, lead and other metals are a by-product from application and use. A variety of other contaminants such as solvent or cleaning compounds may be mixed into used metalworking fluids and industrial lubricants.

Public and governmental concerns with used oil have increased greatly in recent years. There are a multitude of statutes, in addition to RCRA, such as the Clean Air Act, the Clean Water Act, the Toxic Substance Control Act (TOSCA), among others that affect end users of oil and generators of used oil.

The impact of many different EPA regulations has been to force the users of all types of metalworking compounds and industrial lubricants to consider the following points:

1. Increased disposal cost for "waste" generated.
2. Increased paperwork.
3. Increased liability exposure.
4. Petroleum must be viewed as a non-renewable, valuable resource.

If the "waste oil" is properly managed, potential problems can be alleviated. Historically, used oils have not always been responsibly managed. For example, used oil contaminated with dioxin was used as a dust suppressant; used oil contaminated with high levels of lead has been mixed with fuel oil and consumed as boiler fuel in apartment buildings; and it has been improperly dumped into sewers and landfills in numerous sites in the United States.

In response to these problems, Congress in 1980 passed the Used Oil Recycling Act (UORA, Public Law 96-463), as an amendment to the 1976 RCRA law. Congress added to RCRA definitions of "used oil" and "recycled oil." Congress also directed the EPA to develop regulatory management standards for recycled oil by October 15, 1981. The Agency was also to report to Congress as to whether to list "waste oils" as hazardous under RCRA.

The determination of the hazard designation has been very difficult. The EPA finally decided in November 1986 that it would be environmentally counterproductive to list all "used oil" as a hazardous waste. This ruling was overturned in an October 1988 ruling by a federal appeals court. The court held that the EPA could not take "stigmatic effects" into account in making its listing determination, but rather the Agency was required to base its decision solely upon technical criteria for listing specified in the statute.

Now Congress has begun the process of reauthorizing RCRA and several bills relating to the "waste oil" issue are pending on Capitol Hill. It is too early to determine the scope of the final bill, but each bill includes strict management standards, imposes strict liabilities upon improper disposal, and at the same time each bill includes provisions to encourage reclamation to avoid these liabilities.

Scope of the Problem of Waste Oil

In 1988, it has been tabulated that slightly more than 2.4 billion gallons of petroleum lubricant and automotive lubricant were purchased. Based on currently available data, over one billion gallons of that fluid became a waste oil. It is estimated that only about ten percent was recycled by various reclamation techniques. The massive quantity of waste oil that was disposed of in 1988 and in preceding years points to a staggeringly expensive environmental burden that should awaken the industrial community to the fact that it must consider the merits of reclamation. We can no longer ignore the ecological impact of disposing of waste oil, much less continue wasting a valuable non-renewable resource.

On another note, one must consider that the petroleum supply/demand balance will undergo fundamental changes during the decade ahead. These changes are going to have significant impact on the oil import dependence of the United States and the industrialized nations of the world, as well as on the petroleum refining industry. It is projected that oil production of non-members of OPEC (Organization of Petroleum Exporting Countries) will peak in the early 1990s, and at the same time production from the North Sea and the United States will begin to decline. While Mexico and several non-OPEC nations have been able to expand their production capacity through the 1980s, these gains have been offset by losses in the other non-OPEC producing countries. This projected decline in production from non-OPEC countries is alarming, as this will change the supply of crude oil needed to meet growing free world oil requirements. It is projected by the year 2000 that international petroleum demand will increase by more than one percent per year with total demand expected to grow by nearly ten million barrels per day. This means that OPEC will become more important in the world markets, and the dependence of the United States on foreign imports of oil will become a more critical factor. We all remember what happened in 1974 and 1979 due to excessive dependence of the United States on foreign oil. In these time periods, the U.S. experienced rapid price increases for petroleum products and, correspondingly, high inflation. These projected long term changes in the supply/demand ratio are going to intensify the need to find and to develop new maintenance and reclamation techniques so the waste oil that we currently discard can become a valuable source of supply in the years to come.

Oil waste can be broadly classified as either industrial lubricants or processing compounds. Industrial lubricants would include such products as motor oil, greases, rolling stock journal lubricants, and all materials which reduce friction. Conversely, processing fluids include compounds such as metalworking fluids, quenching compounds, solvents and fluids that have other functions, such as rust prevention, heat reduction, or friction reduction.

This paper has been written to address the reclamation of oil-based industrial lubricants and metalworking compounds. These compounds can be broadly classified into the following areas.

1. Straight mineral oils - These are non-emulsifiable straight oils. These oils are either paraffinic or naphthenic and they find widespread use in the compounding of oils for a wide variety of metalworking operations and industrial oil applications.

2. Chlorinated oils - These products are primarily chlorinated paraffins, fats or olefins which find widespread use as extreme pressure lubricity additives in industrial metalworking compounds.

3. Sulfurized-chlorinated oils - These oils are combinations of sulfurized oils or fats combined with chlorinated paraffins or olefins. These mixtures find widespread usage as extreme pressure lubricity additives in industrial metalworking compounds.

Costs and Contaminants in Waste Oil

The problem of waste oil is complicated. RCRA, combined with increasing competition for oil in the long term, produces a significant set of problems which must be addressed. In addition there are significant costs that are incurred relative to "waste oil." One must consider the cost of the pollution of our air and waterways, the cost of the excess purchases necessary to replace oil which has been lost and, finally, the cost of the equipment and the labor for catching leaks and disposal of a product once it has been used.

The major contaminants that are found in most oil lubrication reservoirs takes two forms, particulate matter and chemical.

1. Particulate contamination. The solids that form the majority of contaminants found in lubrication reservoirs include oxides, fines, splinters that are pulled off the workpiece, and floor sweepings. In general, these solid particles have a size equal or greater than the thickness of the lubricating film and adversely affect the load carrying capacity of the lubricant.

2. Chemical contamination of a lubricating system can result from the influx of water, solvents or light hydrocarbons, such as gasolines, alcohols or fuels. Water is the primary contaminant found in many reservoirs, and it can enter a lubrication system in many ways, including:

a. Contaminated make-up oil;

b. Leaking water-cooled heat exchangers;

c. Condensation from the air;

d. Leakage of miscellaneous water-based emulsions or alkaline cleaners utilized within the plant through the reservoir covers and access panels.

In addition, chemical contamination can consist of oil oxidation products and reaction by-products by the heat of the metal deformation process reacting with the lubricant used at the interface of the material and work tool.

Water contamination takes two basic forms:

1. Dissolved water. In this case, water can exist in dissolved form up to a certain point, after which the oil is said to be saturated. Any increase in water content above the saturation point results in free water droplets being suspended in the oil.

2. Free water. These droplets of free water tend to collect in low points in the reservoir and can also plate out on other components within the system. It has been found that as little as one tenth of one percent of water can cause problems in a reservoir of straight oil. The water turns to steam at the workpiece to tool interface and this steam displaces the oil. This, of course, minimizes lubrication and causes subsequent galling, pick-up and tool failure. Another problem associated with water is corrosion. Corrosion is caused by the reaction of the free water and the build-up of acids in the oil.

Figure 1 illustrates the balance between the amount of contaminants entering a lubrication systems and new material being utilized in the system. The solid line indicates a reservoir where no filtration is being utilized to maintain the quality of the lubricant over the long term. The contaminant level rises over time until it finally reaches a maximum acceptable level of contamination. At that point, tool life, productivity and product quality become unacceptable, and it is necessary to shut down the system, clean it out and recharge with new oil prior to starting a new cycle.

On the other hand, the dotted line shows the experience gained from the use of a reclamation system to remove the particulate and water contamination so that the level of contaminants reaches a steady state equilibrium. In this case, approximately half of the oil is removed from a reservoir, and is replaced with a batch of reclaimed product. This is repeated over time, so we see that the level of contaminants rises and falls again with time. One notices that the contaminant level is higher with each peak, and eventually these peaks reach the maximum acceptable level of contamination. Then the whole system will have to be cleaned out. The peaks keep rising as only half of the material was treated at a time so the reclaim technique can never "get ahead" of the level of contaminants entering the system. The only way to "get ahead" of the contaminants entering the system is to utilize a system of filtration that will continually remove fines from the entire reservoir, rather than just removing half of the oil and recharging reclaimed material to a reservoir already contaminated with fines.

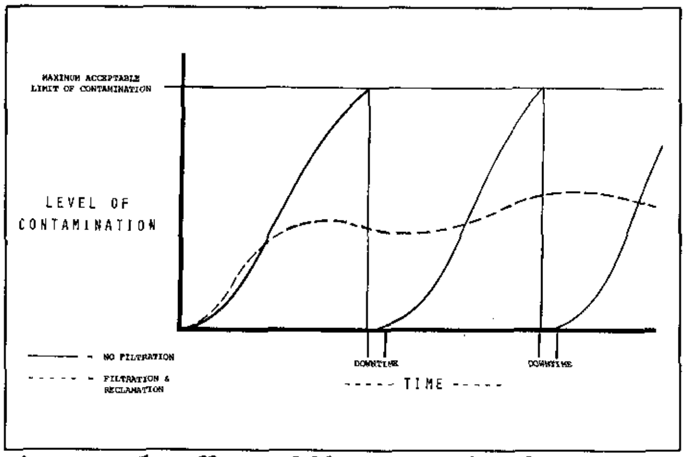


Figure 1. The effects of filtration and reclamation on contamination level over time.

Methods and Benefits of Waste Oil Reclamation

It is important to define the term reclamation. Reclamation is the use of a mechanical or chemical means to remove solid impurities, water and other degradation products, such as acid, that have entered the oil. Furthermore, reclamation normally requires the addition of additives to restore the oil so as to meet the original specifications. This reconstitution of additives is the most important point of the reclamation process.

The most common methods for reclaiming would include settling, centrifuging, heating and holding, or filtration. Conversely, rerefining is used where one wishes to produce a base stock for a lubricant or other petroleum product. Rerefining includes such processes as vacuum distillation, hydrotreating and/or other treatments that would employ acid, clay or other chemicals. This paper is primarily concerned with reclaiming, but it is important to keep rerefining in mind.

There are a number of advantages to using improved maintenance and reclamation techniques:

1. As RCRA regulations become better defined, it will become increasingly expensive to dispose of "oily" waste products. Reclamation represents a way to reduce those costs.

2. With projected changes in supply and demand, oil prices are expected to rise over the coming years. Reclamation represents a way to extend the useful life of an oil and to reduce make-up costs. An active preventative maintenance program combined with reclamation of a product lost due to leakage will reduce the cost of make-up.

3. The use of a reclamation program allows the conservation of petroleum, which is a valuable non-renewable resource.

4. Reclamation has been shown to yield excellent increases in tool life and productivity. It is a known fact that a clean system of oil runs longer and more efficiently than a tankful of dirty oil. The use of a reclamation system can reduce the overall waste treatment cost.

5. The use of reclaimed oil reduces disposal costs and subsequent possible liability costs that occur when the disposal of an item is not handled correctly.

6. The use of reclaimed oil allows for an assured source of supply.

7. Numerous field tests have shown that the use of reclaimed oil can allow an improvement in the effectiveness of secondary operations such as cleaning and annealing. These secondary operations are sensitive to the surface cleanliness of the workpiece and the use of a clean, reclaimed oil has been found to improve productivity on the secondary operations as contaminant levels due to excess impurities in the lubricant are minimized.

8. As a corollary to that advantage, scrap loss is reduced on secondary operations.

9. One field test indicated the use of reclaimed oil seemed to dissipate heat better and allow the manufacturer to operate the equipment at higher speeds. Given the fact that oil is not an efficient heat sink, it is postulated that the

reclaimed oil is providing more effective lubrication, and, therefore, less heat is generated during the course of the metalworking process. It is postulated that the reclaimed oil allows for superior lubrication as the additive package is at full strength versus a system that is operating on contaminated oil where the components of the oil have been depleted due to oxidation, heat and drag-out.

Physical Methods Used to Separate Oil and Contaminants

There are four primary physical methods utilized to separate oil and solid contaminants. These are gravity separation, centrifuging, heat and hold, and filtration.

1. Gravity separation. The function of gravity separation depends on the difference in specific gravity of the oil, suspended contaminants and water. Most gravity systems are large tanks or ponds which allow the suspended solids to settle to the bottom where they can be removed by a drag chain or through a drain valve, if the material is in a large tank.

2. Centrifuging is a process where materials of different densities are separated by means of centrifugal force which impels the heavier material outward from the center of rotation. The method works faster than a gravity type settling system and takes up much less space. There are two basic types of centrifuges:

   a. Automatic self-dumping centrifuge, which continually discharges solids.

   b. Manual centrifuge, which must be shutdown for cleaning.

Although a centrifuge works faster than a gravity tank and takes up very little floor space, both the automatic self-dumping and manual centrifuges are expensive to purchase and to maintain. Another point to be considered when one is evaluating a centrifuge on something such as an aluminum drawing oil is that the contaminants to be removed are finely divided. These contaminants have approximately the same specific gravity as the oil, and this, of course, negates any effectiveness on the part of a centrifuge.

3. Heat and Hold. In this case, to physically separate oil and contaminants one heats the material to between 65°C to 85°C and holds it in a quiescent tank or reservoir. This heat lowers the viscosity of the oil and allows many of the fines and solids to settle out and to be pulled off the bottom of the reservoir.

4. Filtration. In this case, the lubricant is forced through a filter element under pressure. The filter element removes a majority of solids from the oil. Filters can be divided into two broad categories, surface filters and precoat filters.

Surface filters are cartridge type filters which are generally micro screen containers of either paper or steel in cartridge form. Conventional cartridge systems can remove particles as small as three microns. It is best to use a series of different size cartridges in line rather than one "fine" filter. The method of using a series of filters will reduce the need to change cartridges at frequent intervals and therefore reduce overall costs.

Precoat filters use diatomaceous earth or clay as the media to remove solids. These filters operate either under pressure or vacuum and operate in two basic stages. In the first stage a slurry of diatomaceous earth and clean oil is pumped through a filter to apply a thin precoat layer of diatomaceous earth over the filter element. In the second stage, after the precoat layer has been applied, dirty oil is pumped into the filter while more diatomaceous earth is slowly added to the dirty "feed". In this way, the diatomaceous earth will maintain the porosity of the filter cake on the filter, the element. After cleaning the filter, the cycle would begin again.

There are a number of different types of precoat filters.

1. The flat bed advancing paper filter is a horizontal carrier belt upon which rests a filter paper. Dirty oil is collected in a pool over this paper and horizontal carrier belt, and a vacuum is pulled from underneath. The vacuum pulls the oil through the filter paper leaving the contaminants on the filter paper. The filter paper becomes coated and eventually the smaller particles blind the filter paper. At this point, a sensor notes the decrease in oil flow and the paper is advanced exposing a clean section. The dirty paper and sludge is collected at one end of this system for disposal.

2. The rotary vacuum filter consists of a cylindrical drum covered with a fabric to which a layer of precoat composed of diatomaceous earth is applied. The drum rotates into the dirty oil and a vacuum maintained in the drum pulls the dirty oil through the filtering media to be discharged as clean oil. The cake of precoat is continuously scraped off the drum so the media does not blind.

3. Pressure filters: there are a number of different pressure filters that use precoats. The most common include:

   a. Plate and frame filter, the most common and least expensive precoat-type filter. The plates are vertically oriented in a horizontal frame.

   b. The vertical tank, vertical leaf type filter depends on a pressure differential across the element to hold the filter cake in place. This type of filter has the advantage of quick and easy removal of the filter cake.

   c. In the horizontal leaf, vertical tank filter, the filter cake is held in place by gravity and these filters are often times used where a filtering operation is intermittent.

Precoat type filters produce a highly polished oil, but they have several disadvantages. The dirty filter cake must be disposed of in accordance with RCRA regulations, and these filters are expensive to purchase and to operate.

Case Histories

This section of the paper is a review of the cost savings generated by utilizing a reclamation program with several different types of oil. Figure 2 details the cost analysis of reclaimed oil versus new oil for four different oils. In every case, the freight is prepaid on lubricant shipped to the off-site reclaimer and freight is charged on reclaimed material shipped back to the customer. Conversely, freight is only paid one way on new material. That fact notwithstanding, the use of reclaimed oil still represents a significant savings over purchasing new oil.

1. The first case is the reclamation of a copper tube drawing oil. The use of reclaimed oil yielded a cost savings of 52.8%.

2. The next case is a chlorinated oil used to produce cold drawn stainless steel tube. Inlet sizes ranged from 1/8" to 2". The reclaimed oil allowed a 22.3% cost savings.

3. The next oil is a sulfurized-chlorinated oil for drawing carbon steel bar and shapes. The reclaimed oil allowed for a 24.4% cost savings.

4. The final illustration is a hydraulic oil. The reclaimed oil yielded a 40.7% savings.

The direct cost savings yielded through the use of reclaimed oil versus new oil are, in and of themselves, attractive. When one adds in the benefits of such things as reduced liabilities and disposal costs, the process becomes an attractive alternative to disposal.

Conclusion

This paper has presented several of the methods that can be utilized to reclaim and to reuse metalworking compounds and industrial lubricants. There are a number of steps that should be followed in order to successfully implement a reclamation program. These steps would include the following points:

1. Top management commitment must be obtained. Support for a reclamation program must come from upper level management so that arguments among purchasing, engineering, plant operation and maintenance over the cost and merits of an oil reclamation program are alleviated.

2. A plant survey should be conducted by an internal group within the plant or by the lubricant supplier. The purpose of this survey would be to analyze the source of each "waste" oil within the plant and to establish the degree of clarification or reclamation required.

3. The next step is to establish a preventative maintenance program to cut down on leaks and spills. A program of this nature will reduce the amount of oil required for make-up and the amount of waste oil generated.

1. Case History - Reclamation of Copper Tube Drawing Oil	
Cost-New Oil	
$0.90 x 390 lbs/Drum x 80 Drums	$28,080.00
Freight (One Way) (500 miles)	700.00
Total	**$28,780.00**
Cost-Reclaimed Oil	
$0.39 x 390 lbs/Drum x 80 Drums	$12,168.00
Freight (Both Ways)	1,400.00
Total	**$13,568.00**
Savings (per 80 drum lot)	**$15,212.00 or 52.8%**
2. Case History - Reclamation of Chlorinated Tube Drawing Oil	
Product: Stainless Steel Tube Drawing Lubricant	
Cost - New Oil	
$0.782/lb x 550 lbs/Drum x 80 Drums	$34,408.00
Freight (One Way) (500 Miles)	700.00
Total	**$35,108.00**
Cost - Reclaimed Oil	
$0.588/lb x 550 lbs/Drum x 80 Drums	$25,872.00
Freight (Two Ways)	1,400.00
Total	**$27,272.00**
Savings (per 80 drum lot)	**$ 7,836.00 or 22.3%**
3. Case History - Reclamation of Sulfurized-Chlorinated Carbon Steel Bar Drawing Oil	
Product: Carbon Steel Draw Lube	
Cost - New Oil	
$0.543/lb x 425 lbs/Drum x 80 Drums	$18,462.00
Freight (One Way)	700.00
Total	**$19,162.00**
Cost - Reclaimed Oil	
$0.385/lb x 425 lbs/Drum in 80 Drums	$13,090.00
Freight (Two Ways)	$ 1,400.00
Total	**$14,490.00**
Savings (Per 80 drum lot)	**$ 4,672.00 or 24.4%**
4. Case History - Reclamation of Hydraulic Oil	
Product: ISO 68 AW Hydraulic Oil	
Cost - New Oil	
$2.30/Gallon x 6,000 Gallons	$13,800.00
Freight (One Way)	$ 700.00
Total	**$14,500.00**
Cost - Reclaimed Oil	
$1.20/Gallon x 6,000 Gallons	$ 7,200.00
Freight (Two Ways)	$ 1,400.00
Total	**$ 8,600.00**
Savings (per 6,000 gallon lots)	**$ 5,900.00 or 40.7%**

Figure 2. Four Case Histories

4. A program to segregate the waste must be instituted so the oils can be reclaimed with greater expediency. Used oils should not be mixed with solvents or other chemical wastes. In many cases, these impurities are impossible to remove and they lower the yield of good reclaimed oil from a waste stream.

5. Select lubricants with the properties that provide maximum results on the metalworking application, but, at the same time, these compounds should be easy to reclaim and to re-use so that lower overall treatment costs can be achieved.

6. Select the best treatment method for the given waste stream whether it be a reclamation system that is installed within the plant or whether the services of an outside contractor are utilized.

7. If a contractor outside the plant is going to be handling the material, one should give serious consideration to the following points:

a. Does the facility have the appropriate RCRA and state permits for a reclamation facility?

b. Is the facility clean and are the tank farms, loading areas and unloading areas environmentally secure?

c. Does the contractor have adequate oil reclamation equipment to carry out the treatment and reclamation of the waste stream that you are producing?

d. Does the facility have an adequate laboratory and quality control system so as to insure the overall quality of the reclaimed oil that will be yielded by the process?

The process of reclamation has advanced significantly in recent years. Hopefully in the not too distant future when reclamation and improved maintenance programs are successfully instituted, we will all be able to reap the benefits of the improved availability of oil, improved operations, and an improved non-polluted environment. Maybe then we will have the courage to consider other types of conservation techniques and find that they are not as painful as we had originally envisioned.

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Ike Tripp, Jr.
Etna Products, Inc.
16824 Park Circle Dr.
P.O. Box 630
Chagrin Falls, OH 44022-0630
Phone 216/543- 9845
Fax 216/543-1789

Ike Tripp, Jr. is President of Etna Products, Inc. He joined the firm in 1974 and has held numerous positions including Research & Development Chemist, Sales Engineer, Plant Manager, Product Manager, and most recently Executive Vice President/General Manager. Mr. Tripp received a bachelors degree in geology from Allegheny College. He is author of numerous papers. Mr. Tripp chairs the Government Affairs Committee of the Independent Lubricant Manufacturers Association and is a member of its Board of Directors. In addition to his active role in ILMA, Mr. Tripp is a member of STLE, the Wire Association, and SME.

Etna Products manufactures specialized metalworking compounds for the automotive, steel and general metalworking industries. The company also manufactures specialty polymers used by the paint, coatings, ink and adhesives industries. Etna Products is a Regular Member of the Independent Lubricant Manufacturers Association.

Treatment and Disposal of Oils

Derek Wilkinson
and
David Peel
BresLube Division of Safety- Kleen Canada, Inc.

Introduction

Oil is a unique natural resource, and like many natural resources, our reserves of this valuable commodity are being quickly depleted. However, unlike most other resources, oil can be effectively reclaimed and reused. It is a material that most of us use or depend upon every day, but it can create an environmental headache for us, particularly in its crude (unrefined) form or in its "used" state. It can pollute our beaches and waterways and decimate our wildlife. For these reasons governments have wrestled with regulating the disposal of used oil for a long time. Most people now realize the environmental and economic significance of correct disposal or reclamation of used oil, but because of the complex and sometimes conflicting state and federal laws, and lengthy debates about hazardous and non-hazardous declarations, people are confused about used oil, especially with regard to the disposal of used oil. In this article, we will look at the characteristics of used oil and explain some of the more acceptable methods of disposal.

Is Used Oil Hazardous?

The regulation by the US EPA of used oil is governed by its original generation and analytical characteristics, and the intended method of disposal. This is probably the single most relevant reason for lack of understanding of the rules regarding disposal. To explain the regulation, let us look first at the issues of waste generation and characteristics, and then at the method of disposal and how the two relate. Here individual state regulations may differ from federal regulations, and for these reasons you should consult the Code of Federal Regulations and with state officials before developing your own disposal procedures.

Used Oil Generation and Characteristics

One of the most important factors in classifying waste oils is the size of the waste generator. Persons who generate less than one kg of acutely hazardous waste, and less than 100 kg (approximately 25 gallons) of hazardous waste per month are conditionally exempt small quantity generators (CESQGs). CESQGs are largely exempt from federal regulations (see 40 CFR Part 261.5) and must identify their hazardous wastes, not accumulate more than 1000 kg of this waste, and dispose of this waste at a hazardous waste facility or a facility approved by the state for municipal or industrial wastes.

Small Quantity Generators (SQGs) generate between 100 and 1000 kg of hazardous waste each month and no more than one kg of acutely hazardous waste. These generators must comply with the 1986 rules on the management of hazardous waste. These include standards for the accumulation, storage, treatment, and disposal of these wastes. All other generators except SQGs and CESQGs are large quantity generators (LQGs), and must comply with all hazardous waste management regulations.

Hazardous wastes are defined in 40 CFR Part 261. Hazardous wastes fall in two categories: listed hazardous waste and characteristic hazardous waste. Many states utilize these federal definitions, however some states have additional requirements or exemptions specific to used oil. Other regulations also apply to used oils which contain PCBs or pesticides.

Used oil, by itself, is not a listed hazardous waste under RCRA, although it is listed in some states (e.g., New Jersey, California, Massachusetts). Used oil will become listed hazardous waste if it has been mixed with other listed hazardous waste such as halogenated or flammable solvents, unless the generator is a CESQG (40 CFR Part 261.5 (h)). Halogenated solvents are solvents which contain fluorine, chlorine, iodine or bromine, and include many degreasing solvents. Listed flammable solvents include many oxygenated and hydrocarbon solvents, including benzene, methanol, and gasoline.

Characteristic hazardous wastes are those wastes which exhibit any of the following characteristics: corrosiveness, ignitability, reactivity or EP toxicity, but which do not contain a listed hazardous waste component. Used oils can become characteristic hazardous wastes as a result of:

a) EP Toxicity - heavy metal contamination - this usually applies to used crankcase oil which may contain excessive amounts of metals from either wear or residue from the

Metal	Maximum Concentration*
Arsenic	5 ppm
Cadmium	1 ppm
Chromium	5 ppm
Lead	5 ppm

*As tested by EP Toxicity Extraction Procedures combustion chamber. These metals and their maximum concentrations (before the material is declared hazardous) are identified below:

b) Ignitability - low flash materials with a flash point lower than 140F are ignitable hazardous wastes. A low flash is usually a result of blending used oil with a flammable material such as gasoline or a solvent. This would be the case if a common drum, vessel, or container were used for the storage of all liquid wastes. To avoid generating ignitable waste, generators should be careful to segregate their liquid waste streams and arrange for suitable disposal of each.

Disposal Methods

Used oils which are being "discarded," "abandoned," "recycled," or which are "inherently waste like," are solid wastes, and are therefore regulated by the US EPA. The definition of solid waste encompasses most common disposal options, including road oiling and landfills/sewers, burning and incineration, reclamation, and reprocessing (see 40 CFR Section 261.2 (a), (b), (c), and (d)). However, used oils which are to be rerefined may be exempt from regulation under RCRA, unless they are from small or large quantity generators, and contain listed hazardous waste.

a) Land Disposal

Most states do not allow used oils to be used as road oil, nor can most used oils be disposed of in landfills or sewers due to land disposal restrictions (see 51 Federal Register p. 40, 572.(1986)). Used oils which contain organic solvents, halogenated organics (including halogenated paraffins), and heavy metals are banned from land disposal, effective November 8, 1988. There are exemptions from this ban for some generators, however if you intend to dispose of your waste via land disposal you should consult the regulations and local authorities. Used oils which are disposed of by land disposal should be tested for solvent contamination and the presence of any "California List" materials prior to being sent for disposal.

b) Burning or Incineration

Used oils which are being burned or incinerated may be regulated under 40 CFR Part 266, or under the full RCRA regulations. This includes raw used oils and used oils which are being reprocessed to form used oil fuels and then being marketed by the reprocessor. Part 266 places special restrictions on used oils which are intended to be disposed of by burning. Depending on the size of the generator and the level of contamination within the oil, this oil will then be regulated as hazardous or non-hazardous fuel, with corresponding restrictions on how this material may be handled, and where it may be burned. The regulation of used oils from a SQG or LQG which is destined for disposal by burning is shown in Figure 1. Because of the obligations which these regulations may impose on the generator, it is important that generators be aware of how their oil is classified.

Used oil from CESQGs is regulated under 40 CFR Part 266 subpart E, regardless of how this oil would normally be classified. For SQGs and LQGs, waste oils are regulated under 40 CFR Part 266 subpart D if the oil contains RCRA listed hazardous wastes, otherwise it is regulated by subpart E of Part 266.

Used oils from SQGs and LQGs are considered to contain listed hazardous waste if listed hazardous wastes have been knowingly added to the used oil (Part 261.3(6)(2)). Also under the Part 266.40(c) "rebuttable presumption," used oil containing more than 1000 ppm of total halogens is presumed to be a hazardous waste, unless it can be rebutted by demonstrating that the used oil does not contain "significant quantities" of listed halogenated hazardous wastes. While there is no definition of "significant quantities" in the regulations, the documentation that was published along with the Part 266 rules suggests that levels on the order of 100 ppm of any individual listed halogenated solvent would be considered significant.

If the oil is considered hazardous, it is regulated under 40 CFR Part 266 subpart D. In this case the SQG or LQG is subject to the normal RCRA requirements set out in Part 262. These include having to identify your hazardous waste and register with the US EPA. The waste must be manifested to the disposal site, and shipped in accordance with US DOT regulations. The regulations also impose storage and accumulation standards, and require record keeping and reporting of the waste handling. Additional requirements are specified in Part 266.32 if the generator markets this used oil directly to some other burner, or burns this material himself.

Generators of non-hazardous used oil are subject to Part 266.42, which only imposes requirements on generators who burn their own oil or market this oil directly to other burners. Non-hazardous used oil can be classified as on-specification or off-specification depending on the concentration of various contaminants, and this will affect the handling and pricing of this material.

c) Rerefining

Used oils which are recycled by rerefining are exempt from regulation under RCRA if they are generated by a CESQG, or if they have not been mixed with a listed hazardous waste. If the used oils generated by a SQG or LQG have been mixed with listed hazardous waste, then the generators are regulated under 40 CFR Part 262. In the rerefining process, waste oils are reprocessed and purified back into lubricating oils, and these rerefined oils are then blended with additive packages to produce various commercial types of oil. The rerefining process involves the removal of both the physical and chemical impurities from the waste oil, and produces a very good quality product. These products meet or exceed industry standards, and are often

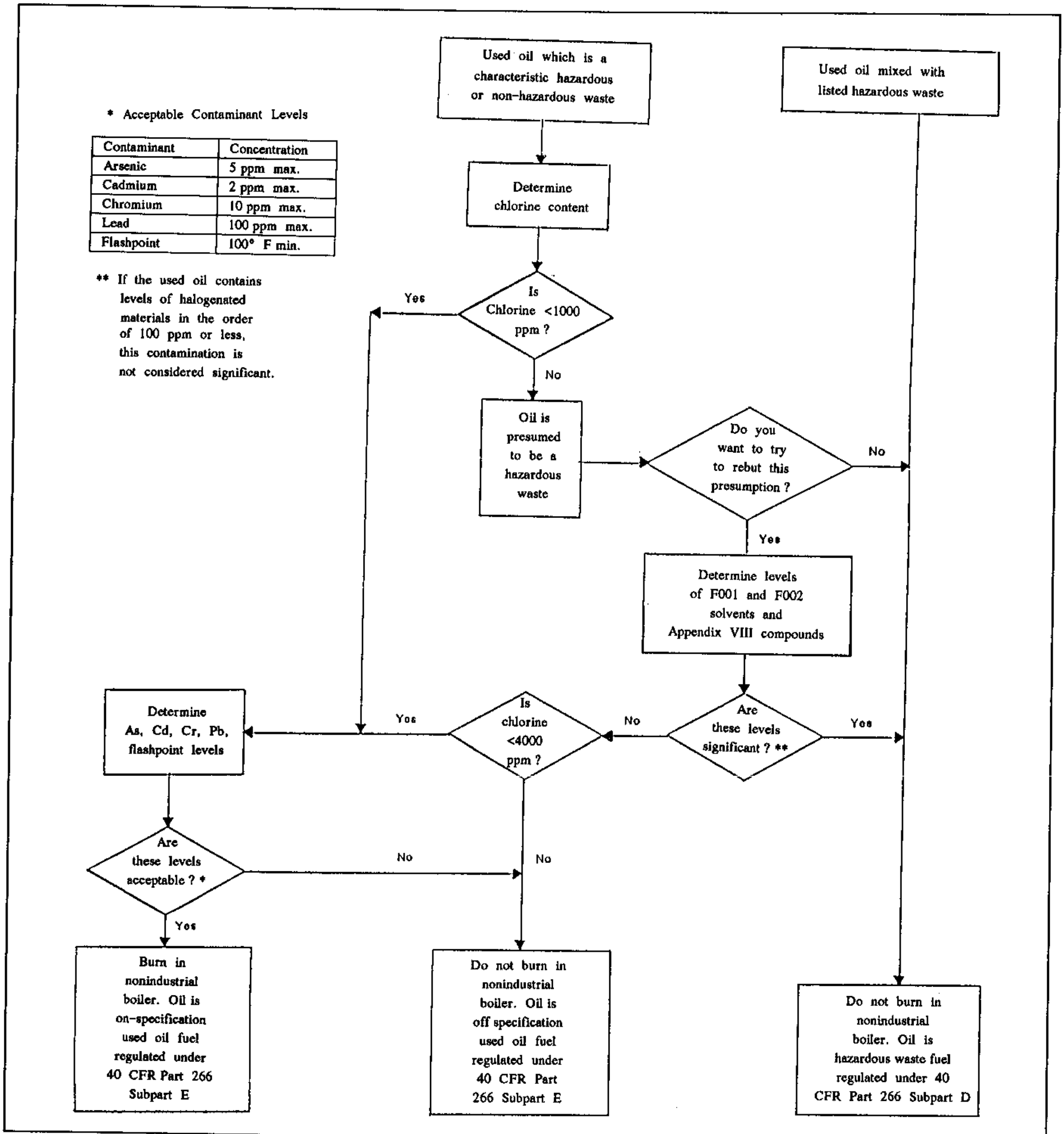


Figure 1. Regulation of used oil destined for disposal by burning

attractively priced, particularly for companies which generate very large volumes of waste oil, since the same refining company can both supply them with and dispose of their oils.

d) On-site reclamation

One final common disposal option is on-site reclamation, usually by a dehydration/filtration type process. These types of processes are not regulated under RCRA; however the reclaimed oil will degrade as the base oil and additives break down, and this reclaimed oil still contains chemical contaminants that could damage equipment or represent health hazards to workers. In addition the sludge from these processes can be very difficult and expensive to dispose of, as it may be a hazardous waste sludge. Due to the land disposal restrictions, this material will likely be unsuitable for any disposal method except incineration.

Choosing a Disposal Facility

It is obvious from the above that, in order to safely dispose of used oil, it is important to be knowledgeable about the oil. This includes knowing how the oil was generated, how the oil was stored, and the characteristics of the original oil and the used oil. It is difficult for most generators to obtain this information easily and effectively. However, the generator still has a responsibility to ensure the safe disposal of his used oil. The best insurance for a generator is to deal with a reputable used oil collection and disposal company.

A good company will freely disclose how the oil is stored, tested, and how the used oil is ultimately disposed. Ask for information about the company: what permits does it have? what is the extent of its insurance? what is its environmental performance? Better still, visit or audit the used oil collection and recycle facility to see for yourself how your oil will be managed.

It is important for the generator or the used oil disposal facility to test the used oil periodically to ensure that it is consistent in quality. Also if the process generating the used oil changes significantly, then the oil should be retested. The price of this testing is usually modest, and should be regarded as good insurance by the generator. With this testing program, the generator can demonstrate that his used oil has been tested and characterized, and with this information the correct disposal method can then be determined.

The generator should also serve his own interest by storing used oil separately from other waste streams, particularly spent solvents and other hazardous wastes. This makes characterizing these wastes much simpler and facilitates the appropriate disposal for each waste stream.

Summary

Most used oil disposal options are regulated under the hazardous waste provisions of RCRA, and testing should be carried out on this material in order to ensure that it is receiving appropriate disposal. This should include testing for flash point, heavy metals, solvents, halogenated materials, and PCB materials. The generator should also be knowledgeable about how its waste is being handled and disposed, as this affects how this material is regulated. Finally, the generator should also evaluate the waste disposal company it is using, in order to ensure that the disposal firm is properly testing and handling this waste.

Most used oils are disposed of through land disposal or burning, or recycled by rerefining or reclamation. Of these options, recycling used oil by rerefining is normally regarded the most environmentally- sound choice. Like most environmental problems, when the disposal of used oil is viewed from a recycling angle, it becomes a "win-win" situation. The generators can be assured of an environmentally-sound use of this material, while the recycler contributes to the conservation of this non-renewable resource. The rerefiner produces a quality product at prices often below that of virgin materials, and can both supply and dispose of this material for his customers. It is a solution we believe can serve us all well as we enter the twenty first century.

Derek Wilkinson
BresLube Division of
Safety-Kleen
Canada Inc.
300 Woolwich St.
P.O. Box 130
Breslau, Ontario N0B-1M0
Canada
Phone 519/648-2291
Fax 519/648-2658

Derek Wilkinson is an Environmental Engineer with the Oil Recovery Division of Safety-Kleen Corp. and has worked at the BresLube rerefinery site for five years. During this time he has been responsible for environmental compliance for both the Canadian and U.S. used oil collection and rerefining operations of the company. This includes nearly 200 vehicles and four processing facilities. Mr. Wilkinson is a professional engineer with a degree in Chemical Engineering from the Univ. of Waterloo, where he specialized in pollution control and biotechnology.

BresLube Division of Safety-Kleen Corp. collects and recycles approximately 150 million gallons of used oil annually, producing rerefined lubricating oils and used oil fuels. Safety-Kleen Oil Services collects used oil in 24 U.S. states and three Canadian provinces, and delivers this oil to three reprocessing plants and the BresLube rerefinery. The company is currently upgrading its East Chicago reprocessing plant into a rerefinery and plans to build a third rerefinery on the northeastern seaboard of the U.S. The company's recycled products include a wide variety of lubricating and other petroleum products, used oil fuels and asphalt extender. BresLube Division of Safety-Kleen Corp. is an Associate member of the Independent Lubricant Manufacturers Association.

David Peel
BresLube Division of
Safety-Kleen Canada Inc.
300 Woolwich Street
P.O. Box 130
Breslau, Ontario N0B-1M0
Canada
Phone 519/648-2291
Fax 519/648-2658

David Peel is Vice President of Manufacturing for the Oil Recovery Division of Safety-Kleen Corp. and has worked for BresLube for six years. Before joining BresLube he spent 12 years as a project engineer in refineries and in the oil fields. Mr. Peel is in charge of all the oil recovery processing facilities at BresLube, and he played a key role in the rerefinery's recent construction and environmental upgrades. Mr. Peel graduated from Manchester Polytechnic with a degree in Mechanical and Production Engineering and is a Chartered Engineer in Great Britain.

CHAPTER NINE
Recycling and Disposal of Solvents

Organic solvents have been widely used in metalworking plants to clean parts, machines and tools. Typically, the cleaning step removes oils, greases, or water-based metalworking fluids from the metal. The cleaning step may be prior to an assembly or painting process.

In recent years, the emphasis for solvent use has been to segregate and recycle these materials to eliminate any improper land or sewer discharge. Chapter Nine discusses equipment and services available to recycle these solvents.

Handling and Disposal of Spent Organic Parts Cleaner Solvents

Paul Dittmar
Safety-Kleen Corporation

Introduction

Organic solvents have been used for years in automotive, metalworking, and other industrial shops to clean tools, machine parts, and work pieces. A common practice up until recent times was to simply dispose of the spent fluid by pouring it down the drain, dumping it onto the ground, including it with ordinary trash, or including it with other waste fluids, such as spent lube oil or metalworking fluids. Awareness of the cost to human health and the environment led to the advent of safety and environmental regulations. Shop owners bear the responsibility of compliance with these regulations.

A reputable parts cleaner service company that recycles solvent offers a total solution. This paper describes the proper handling and disposal of spent organic parts cleaner solvent and the cost and benefits of the total service to the shop owner.

The Need

The need of the shop owner is two-fold. First, he needs to provide a system for effective cleaning of tools, machine parts, and sometimes even work pieces, that is efficient, cost-effective, and safe. As an employer, he must provide training of his workers in proper use of solvents in the work place to comply with OSHA "right-to-know" regulations.

Second, the shop owner must handle and properly dispose of hazardous waste solvents. As a small quantity hazardous waste generator (SQG), he must be aware of a complex set of rules embodied in the Resource Conservation and Recovery Act (RCRA) of 1976 (reauthorized in 1984), which regulates these wastes from "cradle to grave."

A Small Quantity Generator's Responsibilities

Specifically, SQG's who generate between 220 and 2200 pounds per month (100-1,000 kg per month) of hazardous waste must:

1. Be sure that the waste material is transported by a carrier who has an EPA identification number, and that it is stored, treated or disposed of at an EPA-permitted hazardous waste facility.

2. Fill out a multi-part, "round-trip" manifest for waste leaving the premises. This manifest must accompany the waste shipment to its final destination, and copies of the manifest must be retained by the generator for three years.

3. Not store the hazardous waste on-site for more than 180 days (270 days if waste must be shipped more than 200 miles) without applying for, and receiving, a storage permit.

4. Obtain a US EPA identification number as a generator of hazardous waste.

5. Use Department of Transportation (DOT) acceptable storage containers and labels.

6. Accept the fact that he is responsible for the proper handling and disposal of the waste he generates at all times, even after disposal. If a generator's waste is found, in the future, to have contributed to contamination, and clean-up is required, the burden of this expensive procedure rests at least in part with the generator.

RCRA regulations should be taken seriously, because non-compliance can result in severe penalties from the EPA:

1. A civil penalty may be imposed which requires that the violation be corrected. In addition, a fine may be imposed, up to $25,000 per day for each day the generator or handler is not complying with the corrective action required.

2. A criminal fine up to $50,000 per day, or imprisonment up to five years, or both, may be imposed on the person or persons who knowingly transport, or cause to be transported, hazardous waste to a facility not having a permit to handle it. It may also be imposed if the person or persons knowingly dispose of hazardous wastes without having a permit.

3. A criminal penalty up to $50,000 per day, or imprisonment up to two years, may be imposed on the person or persons who knowingly ship waste without a manifest, or falsify documentation for the shipment of waste.

Disposal Alternatives

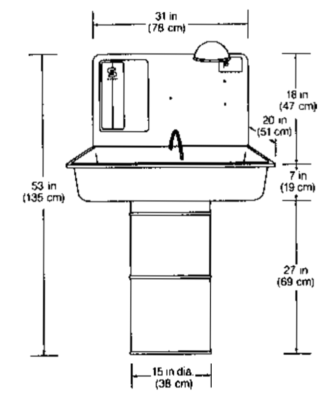
Alternatives for disposal of hazardous spent fluids include:

1. POURING IT DOWN THE DRAIN. *This is not a viable alternative*, since it is illegal to dispose of a hazardous waste in this manner. Also, it imposes a burden on municipal waste treatment plants.

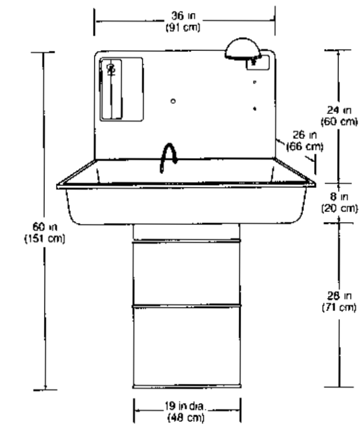
2. DUMPING IT ONTO THE GROUND OR ONTO SOLID WASTE DISPOSAL SITES. This is also non-viable, from the standpoint of EPA's land ban restriction regarding solvents and other hazardous wastes.

3. DRUM THE FLUID AND HAVE IT HAULED AWAY. Although legal if done by a licensed hauler and disposal

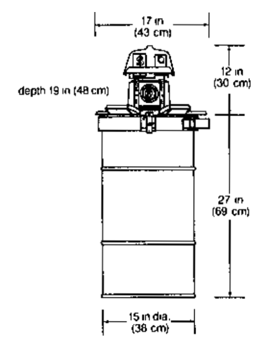
FEATURES AND SPECIFICATIONS



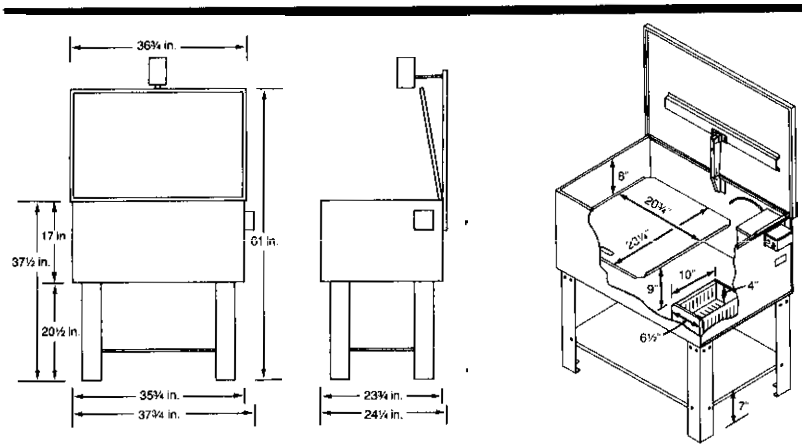
Parts Cleaner:
Model 16
Sink Dimensions: 31 in. (78 cm), 20 in. (51 cm).
7 in. (19 cm)
Solvent Capacity: 10 U.S. gallons (38 liters)
Power: 115 volt, AC, 60 hz.



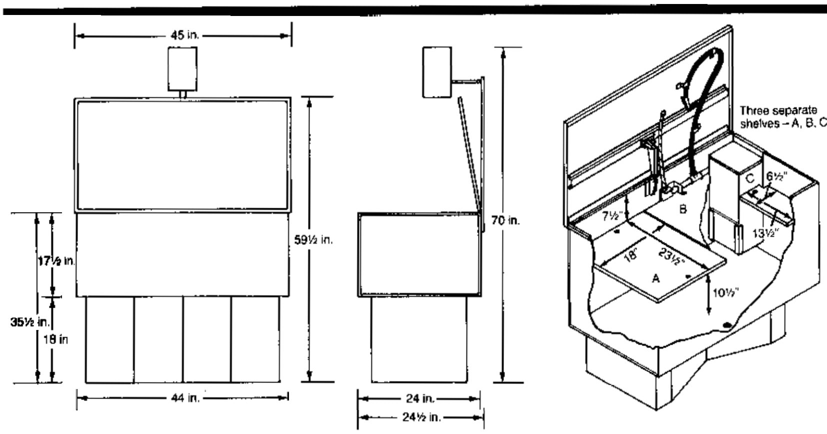
Parts Cleaner:
Model 30
Sink Dimensions: 36 in. (91 cm), 26 in. (66 cm).
8 in. (20 cm)
Solvent Capacity: 20 U.S. gallons (76 liters)
Power: 115 volt, AC, 60 hz.



Immersion Cleaner:
Model 11—Air Powered
Basket: 6 in. (15 cm), 11 in. (29 cm)
Solvent Capacity: 6 U.S. gallons (23 liters)
Power: Air minimum 80 PSI



Parts Cleaner:
Model 34
Tank Dimensions: 35¾ in. (90 cm), 23¾ in. (60 cm), 17 in. (43 cm)
Small Parts Basket: 10" x 6½" x 4"
Solvent Capacity: 30 U.S. gallons (114 liters)
Power: 115 volt, AC, 60 hz.



Parts Cleaner:
Model 44
Tank Dimensions: 44 in. (112 cm), 24 in. (61 cm), 17½ in. (44 cm)
Small Parts Tray: 16¾" x 12" x 2⅝"
Solvent Capacity: 40 U.S. gallons (151 liters)
Power: 115 volt, AC, 60 hz.

Exhibit 1. Parts Cleaner Devices

companies, this approach is expensive. It can cost as much as $200 per drum for stand-alone off-site recycling or $1000 per drum for incineration (a method of "last resort"). Furthermore, the load must first be sampled and the fluid analyzed, which can cost $200 to $1000 per sample.

4. ON-SITE RECYCLING. On-site evaporation or distillation can purify the solvent for re-use. However, it still leaves a residue, which is a hazardous waste that must be disposed of. Also, it is prohibitively expensive, especially for smaller businesses. On-site distillation equipment costs over $10,000, and maintenance and operating requirements are significant. Furthermore, the equipment requires some technical expertise to operate effectively.

5. ON-SITE FILTRATION EQUIPMENT. This offers the possibility of prolonging fluid life, but, as in the case of on-site recycling, it does not address ultimate disposal and is generally prohibitively expensive.

6. FULL SERVICE. A full parts cleaner service that recycles solvents offers a cost-effective, total solution and is widely used throughout industry.

Parts Cleaner Service Description

Parts Cleaning Device

Typical parts cleaner devices are depicted in Exhibit 1. They come in different configurations and sizes, depending on specific needs. Components include:

1. Work basin of rugged steel construction.

2. Solvent containment, such as a drum underneath the work basin.

3. Electric or air-driven pump to circulate the fluid.

4. Filters to keep the solvent as clean as possible while in use.

5. Automatic basin closure in case of fire.

For hard-to-clean parts, where high temperatures have turned oil into varnish, an immersion cleaner unit is available, which is equipped with an air-driven device to agitate the part auto-matically.

Solvent

The solvent used in parts cleaning is typically mineral spirits, a mixture of primarily single-chain, aliphatic hydrocarbons of a narrow boiling range. Properties are shown in Exhibit 2.

On use, the solvent becomes contaminated with dirt, metal parts, metallic and carbonaceous fines, gasoline, grease, oil, and water. It may also become abnormally contaminated with other organic and inorganic hazardous fluids. Typical spent solvent properties are shown in Exhibit 3.

Specific Gravity	0.78
Boiling Range, °F	310-400
Flash Point, °F	105 MIN
Composition, %	
Paraffins	75
Naphthenes	24
C8+ Aromatics	1

Exhibit 2. Typical Clean Mineral Spirits Solvent Properties

Flash Point, °F	105+
Oil and Grease, V%	5
Bottom Sludge and Water, V%	5

Exhibit 3. Typical Dirty Solvent Properties

Service Steps

Overall, the parts cleaner service consists of the following steps:

1. Provide a parts cleaner device, if not already owned.

2. Provide fresh, on-specification cleaning solvent.

3. Provide information on safe use of the solvent and parts cleaner device.

4. Return to the shop on a regular schedule to clean the parts cleaner, regardless of the source of the device. Replace spent solvent with fresh solvent.

5. Remove the spent solvent from the site.

6. Provide proper manifesting paperwork to ensure regulatory compliance.

7. Supply related products, such as parts cleaning brushes, etc.

Behind the Scenes: Recycling and Disposal

Although the shop owner has removed the hazardous waste from his shop when the service company hauls away the spent solvent, this does not eliminate his liability. The shop owner must be assured that the service company is legally transporting, storing and treating the waste. Therefore, it is of interest to the shop owner to be aware of what happens to his spent fluid behind the scenes.

A service company that conducts recycling will have a totally "closed loop" on the solvent handling. This is depicted in Exhibit 4. To start the loop, clean solvent is delivered to the shop owner by the service representative.

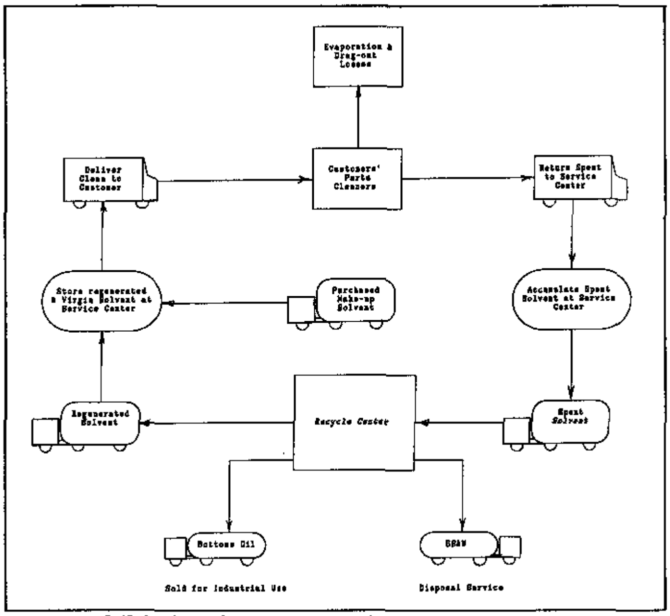


Exhibit 4. Solvent Use and Regeneration Loop

During use, the solvent becomes contaminated, and some of it is lost through evaporation and drag-out with the parts that are cleaned. Next, the spent solvent is hauled away by the service representative to a service center, where it is temporarily stored and consolidated into tanker loads.

Tankers then deliver the bulked fluid to a recycle center for reclamation. Concentrated waste solids and bottoms oil are then treated and disposed of in accordance with state and federal regulations.

The purified mineral spirits, augmented by virgin solvent purchased to replenish losses in the loop, is shipped back to the service center for storage.

Exhibit 5 shows how spent mineral spirits is purified in the recycle center. When a tanker truck containing dirty solvent arrives at the recycle center, the flash point is first checked before unloading. If it is too low, the load cannot be accepted for processing, and it must instead be processed as hazardous waste fuel. Dirty solvent from the service center is pumped into one of several large tanks, where bottom sediment and water (BS&W) are removed by gravity settling. The clarified mineral spirits is preheated by exchange and pumped to a multiple-stage evaporator unit, where clean mineral spirits distills overhead. The cleaned mineral spirits is sent to a salt tower for dehydration, and finally to storage tanks.

Cost

A total parts cleaner service that employs fluid recycling is very cost effective. Although such companies vary somewhat, the total cost of the service typically ranges from $50 per month for nine gallons of mineral spirits to about $175 per month for 55 gallons. This includes the equipment lease, service call, machine cleaning, fresh solvent, and removal of spent solvent.

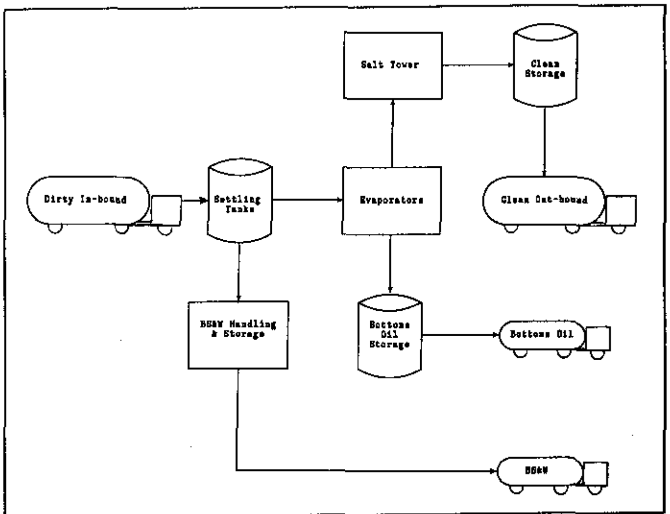


Exhibit 5. Recycle Center Process Flow

By comparison, use of a licensed hauler and disposal company is much more expensive. First, a parts cleaner device must be purchased. Second, fresh solvent must be purchased at about $2 per gallon or $110 per drum. Third, analysis of a drum sample at $200 to $1000 per sample may be required. Finally, the drum of solvent must be hauled away and disposed of at a cost of $100 to $200 per drum. Thus, the total cost can be as high as $310 per 55-gallon drum without analysis and $1310 with analysis, not including the parts cleaner.

Benefits

The benefits provided by a total parts cleaner service include the following:

1. A tough, dirty parts cleaning job is made easy.

2. Information on proper procedures for safely handling solvents in the work place is provided, thereby assisting the employer in complying with OSHA "right-to-know" regulations.

3. It is much faster than other approaches.

4. Machines are well maintained.

5. It is not necessary to purchase fresh solvent.

6. The shop is kept cleaner.

7. This results in higher productivity, morale, employee satisfaction, and customer satisfaction.

8. The shop owner need not directly dispose of the hazardous waste. The parts cleaner service assists the shop owner in regulatory document preparation.

9. There is no need for expensive analytical work.

10. The shop owner's liability, while not eliminated, is greatly reduced through proper management.

11. The shop owner simultaneously serves society through conservation of natural resources and waste minimization.

How to Choose a Parts Cleaner Service Company

Whom should you pick to provide a total parts cleaner service? Some key questions to ask the candidate company are:

"Are you operating with proper federal and state environmental permits?"

"Have there been any actions taken against you by state or federal regulatory agencies regarding your permits?"

"Does your company have 'deep pockets'? In other words, are your financial resources great enough to protect your customers in the event of accidents, clean-up operations, or legal proceedings stemming from these or other environmental matters?"

Summary

We live in a new age in which our society has become aware of the need to protect the worker and the environment while operating profitable businesses. A cornerstone of industry today and for the foreseeable future is environmental waste minimization and recycling. A parts cleaner service from a reputable firm backed by large assets offers a total solution to the shop owner's need for a system to clean parts and handle hazardous waste fluids in a safe, efficient, cost-effective way that fully complies with applicable local, state and federal regulations. This translates to a well maintained shop, lower operating costs, higher worker and customer satisfaction, and peace of mind.

Paul Dittmar
Safety-Kleen Corporation
P.O. Box 92050
Elk Grove Village, IL 60009-2050
Phone 312/694-2700
Fax 312/694-2733

Paul Dittmar is Manager of Process and Product Development at Safety-Kleen's Technical Center, where his responsibilities include technical development of new recovery processes and improvement of existing recycle operations. He also supports chemical product development of new products and improvement of existing products. Before joining Safety-Kleen, Mr. Dittmar was Supervisor of Engineering Research with Atlantic Richfield Co. and Quality Assurance and Testing Superintendent with Katalco/ICI Americas. Mr. Dittmar has a B.S. in Chemistry and an M.S. in Chemical Engineering from Michigan State Univ. as well as an M.B.A. from the Univ. of Chicago. Mr. Dittmar is a member of AIChE and STLE, and he is a Registered Professional Engineer of IL.

Safety-Kleen Corp. provides parts cleaning and specialty services to almost 425,000 businesses that generate hazardous waste fluids, with a primary focus on small quantity generators. Safety-Kleen is the world's largest provider of parts cleaning services, with company owned, licensed or joint venture operations on almost every continent. The company's specialty services for generators of other hazardous waste fluids include providing equipment, reclamation, recycling and disposal.

Safe Recovery of Solvents By Conductivity Heat Transfer

Peter B. Scantlebury
Finish Company, Inc.

Abstract

Solvents can be distilled in-house safely and efficiently by manufacturers using a few hundred gallons or only a few gallons per hour.

Such solvents are not just the low-boilers (i.e. degreasing solvents), but also the high-boilers (i.e. ketones, aromatics, alcohols).

Economics remains the primary advantage of in-house solvent recovery. Yields and repetitive recovery rate are 85% to 95%. Imagine reprocessing a 55-gallon drum of contaminated solvent and reclaiming 50 gallons into excellent, pure solvent for immediate reuse.

Second, the hazardous discharge liability is reduced dramatically with in-house reclaiming.

Batch and continuous feed distillation equipment is now conventionally available and in use in hundreds of industrial applications.

Introduction

This paper discusses today's batch distillation process of recycling contaminated solvents as it has evolved from earlier methods. Explanation of the process and equipment as well as case studies are included. This paper illustrates the necessity for in-house recycling of contaminated solvents and the viability of this alternative to hazardous waste disposal.

Safe Recovery of Solvents by Indirect Heat Transfer

Prices of solvents have increased since the early 1980s, and will continue to increase dramatically. Legislation by federal and state governments has given "cradle to grave" responsibility to users of industrial solvents, thereby causing the cost of disposal to skyrocket. Solvents are essential to industrial processes, so solvents' price rise results in ever-higher costs of goods sold.

In order to cope with these increasing purchase costs, and with the expense and liability of disposal, hundreds of companies have opted to reclaim their contaminated solvents in-house.

True solvent reclamation is achieved by distillation, not by mere filtering. Filtration alone may extend a solvent's life for a limited time. By removing particles such as metal shavings, dirt, etc., it can produce a reusable although not pure solvent. Typically, parts washers come with a built-in filtering system to allow multiple uses of the solvent before a change is necessary. But filtration cannot extend its life indefinitely.

Distillation can return cleaning solvents to their original performance by removing all contamination, both suspended and dissolved. However, fractional distillation systems for breaking down solvents into their original components are expensive and not normally practical or necessary for reclaiming solvent for cleaning purposes.

Simple distillation units can reclaim both single and multiple component solvents. With multiple component solvents, composition may change due to evaporation during use. Normally, this will have little or no effect on utility of the distilled solvent because all properties necessary for cleaning are retained.

This article discusses solvent recovery with simple batch, package units. Equipment of varying capacities is readily available from several manufacturers, allowing the convenience of an in-house operation while substantially reducing both cost and hazardous waste disposal.

Distillation systems have not always been economically feasible for a business generating small quantities of waste solvent. One reason was that it was very expensive to design and manufacture a "safe" unit.

Underwriter's Laboratories states, "The maximum acceptable temperature for external surface of the heater for Class I, Group D shall be 365°F" (Book UL823). This is by far the most important safety design aspect of a small distillation unit. Prior techniques used bayonet-type heaters immersed into a heat transfer fluid that in misoperation could be disastrous and ultimately result in degradation of the fluid.

With small package batch distillation systems now available, electric heaters are cast into a heavy aluminum disc in the bottom of the distillation pot whose wall is also aluminum. Thus, the vessel is essentially a single piece of aluminum. The aluminum conducts the heat throughout the very thick bottom and up the walls surrounding the contaminated solvent, transferring heat from almost all directions. The very thick cast bottom of this vessel and the cast-in thermowells with redundant temperature controllers prevent the temperature from exceeding 350°F. Also, it is absolutely necessary that the remainder of the unit be explosion-proof. This means full compliance with Class I, Division 1, Group D of the National Electric Code. This adds some strict, difficult and costly requirements such as rigid conduits, special heavy electrical boxes, potted fittings, etc.

Many common and relatively inexpensive solvents such as mineral spirits boil at temperatures in excess of 365°F. Thus, they cannot be reclaimed "safely" (in compliance with UL) with a conventional unit of this type. To satisfy this need, a vacuum system attachment can be provided to allow distillation to occur at less than 365°F.

Small-scale solvent recovery systems have evolved from conventional batch stills which required considerable effort in removing sludge and still bottoms. The evolution to a plastic disposable liner bag system was a clear step forward. In this process, a bag of high-temperature stabilized nylon film is inserted into the still to contain all solvent and residue. Solid, paste or liquid residues can then be removed simply by lifting out the bag.

An alternative to the liner bag feature is available with the introduction of small batch solvent recovery units with a Teflon- coated boiling vessel. The residue remains behind in the pan and is easily removed by lifting out the pan.

For small batch distillation (15 to 55 gallons per shift), the boiling vessel is heated via electric heating coils encapsulated in the cast floor of the all-aluminum vessel. For large batch (or continuous) distillation (30 to 80 gallons per hour), a steam-heated jacket surrounds the distillation chamber. In either case, vaporized solvent is condensed in a water-cooled heat exchanger and collected in a receiving drum.

In-house solvent recovery by batch distillation is rapidly gaining favor. Not only have prices of solvents increased dramatically, but disposal costs have accelerated as well. In some states, it is almost impossible to dispose of used solvents due to the lack of hazardous waste disposal sites.

Equipment available for less than $8,500 can recover about 15 gallons per shift. Such operations typically require a half hour of semi- skilled labor per shift and use seven to ten cents of electricity per gallon processed. When solvent cost plus disposal cost is considered, payback can be less than one year, even for single shift operations.

Case Studies

1. Degreasing Solvents

Following punching, welding and grinding of sheet and reinforcing steel in the manufacture of custom-built luminaries, a Pennsylvania company employed a degreaser for removal of surface oil.

Solvent prices were rising, and disposal of dirty solvent as hazardous material cost $90 per drum. The once-through system for solvent use was proving too expensive.

Handcrafted workmanship was of a high order and use of dirty solvents in the degreaser, which leave a residue on the product, would not be tolerated. The company decided to find an alternate to adding new solvent to the degreaser every time a recharge was necessary.

Opting for in-house reclaiming, it installed a 15-gallon batch still, which separates the volatile solvent from the oil picked up in the degreaser. Distilled solvent is collected in a drum for reuse, and the oil is retained as residue.

In the first year of operation, this Pennsylvania company experienced a reduction of more than 90% in new solvent purchase and also found reuse for the residual oil. Payback time also was approximately one year.

A one-shift, 15-gallon batch daily distillation permits emptying the 160-gallon degreaser as often as once every two weeks. With light contamination, this may be extended to once every 30 days.

2. Coating Manufacturers

Solvent recovery has been a necessary part of operations at a varnish company in Indiana. The plant needs to recover about 500 gallons per day of a mixture of virtually all types of organic solvents:

- Ketone, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), and acetone comprise roughly half the total.
- Aliphatic and aromatic solvents such as toluene, xylene, heptane, and naphtha account for about 35% of the solvent mixture.
- Glycol, ethers, and alcohols represent the remaining solvent load.

This mixture of solvents has been calculated to cost approximately $2.16 per gallon.

The spent solvent needs to be treated primarily to remove accumulated water, and also to extract small amounts of pigment and other high boiling impurities. The company had employed an extraction/recovery still that could process up to 30 gallons per hour; however, it required too high a level of operator skill for the still to be economical.

Because the solvent was both too costly and too hazardous to discard, the plant contracted to have the spent solvent treated and returned. The cost of this service was high, and the purified solvent that was returned was of lower quality because the contractor would mix it with other solvent wastes before treatment. After investigating possible alternatives, a sample of the contaminated solvent was presented to a recovery still manufacturer for a feasibility determination. The results were favorable and warranted installation of an automated 500 gallons per shift solvent distillation and recovery unit.

The solvent recovery equipment employs differential heat transfer technology. This is achieved by indirect heating through a jacket having bands of steam coils. By controlling the fluid level, temperature and viscosity, the solvent is separated by vaporization and is subsequently recondensed for recovery.

Contaminated solvents are collected in drums and unloaded into a holding tank prior to treatment. The solvent distillation unit automatically feeds from the tank. Continuous internal mixing and scraping in the distillation boiler keeps the feed in suspension and prevents residue buildup. The purified solvent is gravity discharged into a collection tank.

The automatic operation was an important deciding factor for the plant. Not only does it circumvent the problem of insufficient operator skill, but it allows the person responsible for the unit's operation to do other functions; he performs the necessary material handling operations such as collection of contaminated solvent drums.

The recovery still was installed in January 1982 and has been operating with no major difficulties.

The unit is operated during one shift each day, reclaiming about 400 to 500 gallons of solvent and producing about one drum of still bottoms. According to daily logs, the cost of recovery has been 30 to 50 cents per gallon compared to $1.05 per gallon charged for contract work. The payback period, based on these figures and including equipment and labor considerations, is estimated to be under two years.

Maintenance and operator requirements have been minimal. When the recorded solvent output level drops, the unit is washed (to clean heat transfer surfaces) and the scrapers are replaced.

The distillation unit has satisfactorily processed the spent solvents to an acceptable purity level. Analytical testing of the recovered solvents by gas chromatography has shown that the water content is less than 1% (no water peak detected).

3. Silk Screen Decorators

Early in 1982, a New England company saw a need to improve its screen cleaning process.

The existing system utilized a totally exhausted booth into which a hose washed down the contaminated silk screens. This not only created a liquid waste, but also vented thousands of dollars a year into the atmosphere. Their first step to improve the process and save money was to install an automatic screen washer. This washer is totally enclosed, allowing no vapors to escape to the atmosphere during the cleaning process. The equipment saves 200 gallons per day of an extremely volatile MEK while extending the solvent's life up to five times before it needs changing.

Having improved its washing process, the company next purchased a solvent still to rescue the waste solvent. Fifteen gallons are processed in a batch, and the still is operated on one or two shifts daily.

The purchase price for new MEK is $2.27 per gallon and the yield for the still is between 13 and 14 gallons per batch.

The distillation unit paid for itself within six months and has been updated to incorporate new technology.

Conclusion

In order to continue using necessary solvents in their processes, manufacturers and their suppliers must reprocess them to reduce costs and eliminate wastes. The preferred method from a quality and cost standpoint is indirect heat transfer solvent distillation.

Peter B. Scantlebury
Finish Company, Inc.
921 Greengarden Road
Erie, PA 16501-1591
Phone 814/455-4478
Fax 814/455-8518

Peter Scantlebury, a thirteen-year employee of Finish Company, has been a Distillation Sales Engineer for over six years. In this capacity, he assists customers in the proper application and use of atmospheric and vacuum distillation systems.

Finish Company, Inc. is a leader in research and products for solvent and coolant distillation equipment capable of processing five to 500 gallons per day for solvents with boiling temperature from 100° to 500°F. In its thermal distillation process of solvent and coolant recovery, waste is subjected to controlled gradual temperature increases. After a few hours, the solvents and coolant solutions boil and turn into vapor, escaping from the contaminants. Vapors are then condensed, while contaminants remain behind for disposal. Over 3,000 installations are successfully distilling and recovering solvents and coolants using Finish Company equipment and technology.

CHAPTER TEN
Container Management

The majority of metalworking fluids (concentrates or oils) are manufactured and shipped in 55-gallon steel drums. While the majority of these drums are not recycled, more and more plants are investigating the use of bulk shipments or the use of returnable "totes," or larger storage tanks with capacities of approximately 300-600 gallons.

Residues left in drums can cause the used drum to be designated as a hazardous waste under RCRA. Therefore, the availability and cost of landfill disposal for drums is a concern. Chapter Ten discusses container management issues in depth.

Responsible Container Management

Daniel W. Barber
Daniel W. Barber, Inc.

Source reduction and waste minimization are twin goals that mirror the growing need for U.S. industry to become more efficient and productive. These concepts harken back to days when maximum use was made of all raw materials, and nothing was thrown away until the very last possible use had been wrung from it.

Business has returned to this concept, recognizing that beyond the cost effectiveness of source reduction, society will not tolerate wastefulness. Much of today's legislation is aimed at preventing and punishing it. "Use it up, wear it out," is a growing cry when it comes to resources. There also is great economic impact. Each time a product is thrown away before yielding its fullest measure of usefulness, the owner pays twice: once to buy it, and then to replace what was wasted.

Getting to the "bottom of the barrel" — literally — can be a major help with these efforts. Steel drums, which can be re-used over and over and then finally reclaimed as steel scrap, are an age-old solution to the burgeoning crisis we face in packaging disposal. Best of all, their use pays off not only in the fight for source and waste control, but also in the serious area of liability.

Two facts of life for business today — protecting the environment and conserving resources — mean that manufacturers of substances have "cradle to grave" responsibility not just for the products they make but also for the containers used to ship these products. These manufacturers must track the entire life cycle of their packaging, from when they first ship it out, to when it finally is disposed of in a safe manner.

Because of this liability, shippers are learning to look more carefully at their packaging. Even before the package is filled, they must consider where it will end up.

Many shippers of hazardous materials are startled to find that they suddenly cannot find a way to dispose of their drums — steel, fiber or plastic. Their traditional methods of disposition — landfills, scrap dealers, and even drum reconditioners — were refusing to take them.

Sanitary landfills, crowded with solid wastes of all kinds, began to single out drums as unacceptable. Uncrushed, a drum requires 9 cubic feet of space in a landfill. Crushing can help, but even so, landfill operators began to fear that the presence of residues inside the drums would make them liable under Superfund regulations.

That same fear struck scrap metal dealers. They announced they would not accept any drums, rather than risk liability under Superfund for waste the drums might or might not contain.

What all this meant was that companies which had taken the steel drum for granted were forced to examine their use more closely. Giving industry the tools needed to do this became the goal of the "Responsible Container Management" process.

The Responsible Container Management (RCM) process was developed even before general industry realized there was a need for it. Steel drum manufacturers and reconditioners saw the impact that regulations were having on their customers' businesses, and knew they had an obligation to provide a solution.

This solution is available and proven successful after several years of implementation by manufacturers of chemicals, inks and paints, petroleum products and others.

RCM is a process that follows the entire lifecycle of a drum. Along the way, it addresses the economic, legal and regulatory concerns associated with container use.

Industry today lives under new standards of environmental protection and conservation of natural resources. All forms of packaging are being examined to enhance reuse and recyclability. Environmental damage from improper disposal of used packages and their residues is no longer tolerated. Increasingly, it is packaging producers and users who are expected to see that these standards are met.

The RCM process encompasses several major elements:

SELECTION. The selection of steel drum specifications by the container filler is the first step in RCM. Here, a variety of needs must be accommodated. The drum must meet applicable regulatory and shipping mode requirements; lading protection must be ensured; and the drum must be compatible with the anticipated distribution environment, all with an eye to handling, transportation and safety concerns.

Drum emptiers also need to know which specifications can enhance the used container's value and desirability to drum reconditioners. For example, DOT spec drums are usually preferred by reconditioners, as are 18-gauge steel drums without linings. Drum buyers should inquire about specifications which influence used drum value; local reconditioners and dealers are a good source of this information.

DISPOSITION. When handled properly, this need not be a headache. But personnel in charge of used container disposition now have crucial responsibilities that begin when the drum status changes from full to empty. They must manage drum emptying; maintenance of labels; proper preparation for shipment; control procedures; and selection of qualified reconditioner or dealer to accept empty containers.

EMPTY DRUM CERTIFICATION. This is the single most important aspect of RCM. It is a written documentation, executed by the drum emptier and the container reconditioner or dealer. It confirms that the drums being transferred are actually empty, in accordance with the Environmental Protection Agency's definition of empty containers (40 CFR 261.7), and that they have been properly prepared for transportation.

For most products, only drums meeting EPA's definition of "empty" and sent to a drum reconditioner escape classification as hazardous wastes. Used drums which are classed as hazardous wastes face staggering costs of legal disposal, far more than through disposition when empty to drum reconditioners and dealers.

EPA considers a drum empty if (1) "all wastes have been removed that can be removed using the practices commonly employed to remove materials from that type of container, e.g., pouring, pumping, and aspirating," and (2) no critically hazardous "P-list" products, such as pesticides, (listed by name in 40 CFR 261.33e), are involved. EPA says the container is empty only if it "has been triple-rinsed using a solvent capable of removing" the product, or has been cleaned by another method shown to achieve equivalent removal.

Finally, DOT requires that all openings on the empty container be closed and that all original markings and labels be in place as if the drum were full of its original contents.

Members of NABADA-the National Association of Container Reconditioners require that the drum emptier sign off on all these items, usually each time there is a drum pick up. This certification is vital because it is a drum user's principal guarantee of compliance with two of the nation's most important environmental laws: the Resource Conservation and Recovery Act of 1976 (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund). Among enlightened drum using companies, this documentation has not just been accepted, but enthusiastically welcomed.

Proper emptying makes sense from a cost standpoint as well, because the avoidable residues of costly materials left in drums can represent enormous lost profits. This is virgin product that has been paid for, but discarded unused. Proper emptying complements industry's goals of source reduction and waste minimization. And certification reinforces in the responsible employees the need to comply with strict environmental regulations covering the disposition of all used materials.

AUDIT. Drum users need to review the essential aspects of container selection, use and management within their own organizations. A variety of operational areas must be consulted: purchasing, sales, engineering, plant operations, and property disposal. Through an audit, drum users can identify which regulatory requirements apply, and spot management practices which may affect exposure to liability.

They can also see where improvements are needed in container management in order to meet legal and regulatory requirements, especially in the recycling and disposition of used containers. NABADA can help companies to set up such an audit, which covers the lifecycle of the drum, from container selection through use to disposition.

PLANT REVIEW. The RCM process ends with a review of the drum reconditioning plant where used containers are to be handled. Several areas of plant operations should be consulted to confirm regulatory compliance. Buyers of reconditioned drums for use with hazardous materials should also review plant operations for compliance with DOT requirements.

The steel drum reconditioning industry has the equipment and the know-how to guide business through this task. Working with drum users under the RCM program, both the producers and users of this time-tested, economic and versatile package can ensure compliance with today's high standards.

Using the RCM process, drum users can maximize value for their used containers, ensure environmental and regulatory compliance, and minimize serious liability exposures.

RCM incorporates new approaches to the long-standing concerns of used container disposition, and it meets the challenge of today's strict new regulations and heightened standards of environmental responsibility.

ONE KEY STEP in RCM is learning about the drum reconditioning plant where your used containers will be cleaned and either reconditioned for reuse or recycled as scrap steel. Careful evaluation of prospective reconditioners begins with a visit to the reconditioner's plant.

The reconditioner should be evaluated for its "environmental awareness and responsibility." This means discussing the recycler's specific pollution control programs.

Look at the reconditioner's waste management program. Ask to see its documentation of areas such as employee training and waste treatment program. And if the reconditioning firm treats or stores hazardous waste more than 90 days after it was generated, the firm needs to have federal or state approval to function as a hazardous waste treatment, storage or disposal facility.

Ask how residues are handled, including nonhazardous ones. Are they treated and discharged to sewers in accordance with local authorities' regulations? How good is the recycler at meeting his water quality discharge limitations?

Look at how the reconditioner completes and stores its Uniform Hazardous Waste Manifests. When hazardous waste needs to be shipped offsite, how is this handled? Are they transported by a properly identified hazardous waste transporter to a permitted hazardous waste treatment, storage or disposal facility?

How are the company's housekeeping practices? Are there broken or junked drums rusting in the yard? Are drums processed quickly enough so they don't rust through? Are unprocessed drums periodically inspected to eliminate leakers? See if work stations are clean and free from wastes and debris.

"The extent to which the reconditioner is willing to commit resources to maintain a clean plant is an indicator of the overall emphasis on pollution control," many experts say.

Take time to look also at the drums being produced for re-use, even if you won't be buying them yourself. Quality of these drums is another good sign of the company's systems. Does the reconditioner produce drums for use in transporting hazardous materials? Does the firm have a Department of Transportation registration number?

Knowing the right questions to ask can be vital, especially when maneuvering through the complex realm of environmental compliance. More in-depth information on what to look for in this area is contained in a brochure by NABADA, as part of its Responsible Container Management program. Copies of the brochure are available from NABADA - The Association of Container Reconditioners, 8401 Corporate Drive, Suite 425, Landover, MD, 20785-2224. Phone: 301/577-3786; Fax: 301/577-6476.

Daniel W. Barber
Daniel W. Barber, Inc.
P.O. Box 11244
Wilmington, DE 19850-1244
Phone 302/737-6485
Fax 302/737-7189

Daniel W. Barber, former president of NABADA-The Association of Container Reconditioners, participated in the development of RCM and has presented the program widely. Mr. Barber has been in the chemical packaging industry for nearly thirty years, 25 of them with the Plastics Division of Container Corporation, in sales and marketing. During this period he served three terms as chair of the Society of the Plastics Industries, Plastic Drum Institute. Mr. Barber served as president of NABADA until 1989, when he devoted full time to his consulting company. In 1985, Mr. Barber established Daniel W. Barber, Inc. to provide support services to organizations involved in the distribution of hazardous materials through the "Responsible Container Management" program.

Glossary

Aerobic organism: An organism that requires oxygen for its respiration.

Agglomerate: To gather fine particles together into a larger mass.

Anaerobic organism: An organism that lives in the absence of oxygen.

Anion: A negatively charged ion resulting from dissociation of salts, acids, or alkalies in aqueous solution.

BOD: Biochemical oxygen demand of a water; a measure of the oxygen required by bacteria for oxidation of the soluble organic matter under controlled test conditions.

Cation: A positively charged ion resulting from dissociation of molecules in solution.

CERCLA: Comprehensive Environmental Response, Compensation and Liability Act. Regulates existing hazardous waste sites and those created by unauthorized discharges or spills.

Chelating agents: Organic compounds having the ability to withdraw ions from their water solutions into soluble complexes.

Coagulation: The neutralization of the charges of colloidal matter.

COD: Chemical oxygen demand; a measure of organic matter and other reducing substances in water.

Colloids: Matter of very fine particle size, usually in the range of 10^{-5} to 10^{-7} cm in diameter.

Coalescence: The gathering together of coagulated colloidal liquid particles into a single continuous phase.

Electrolyte: A substance that dissociates into two or more ions when it dissolves in water.

Emulsion: A colloidal dispersion of one liquid into another.

Equalization: Minimization of variations in flow and composition by means of a storage reservoir.

Facultative organisms: Microbes capable of adapting to either aerobic or anaerobic environments.

Filtrate: The liquid remaining after removal of solids as a cake in a filter. Filtration: The process of separating solids from a liquid by means of a porous substance through which only the liquid passes.

Flocculation: The process of gathering coagulated particles into settleable flocs.

Ion exchange: A process by which certain ions of given charge are absorbed from solution within an ion-permeable absorbant, being replaced in the solution by other ions of similar charge from the absorbent.

Membrane: A barrier, usually thin, that permits the passage only of particles up to a certain size.

NPDES permit: The National Pollution Discharge Elimination System permit required by and issued by EPA.

OSHA: Occupational Safety and Health Administration. Regulates health and safety standards in the work place.

Oxidation: A chemical reaction in which an element or ion is increased in positive valence, losing electrons to an oxidizing agent.

Pasteurization: A process for killing pathogenic organisms by heat applied for a critical period of time.

pH: A means of expressing hydrogen ion concentration in terms of the powers of 10; the negative logarithm of the hydrogen ion concentration.

Pollutant: A contaminant at a concentration high enough to endanger the environment or public health.

Polyelectrolyte: A polymer material having ion exchange sites on its structure.

POTW: Publicly Owned Treatment Works.

Precipitate: An insoluble reaction product in an aqueous chemical reaction, usually a crystalline compound that grows in size to become settleable.

Rag: Debris that accumulates at an oil-water interface.

RCRA: Resource Conservation and Recovery Act. Regulates the generation, transportation, treatment, storage and disposal of hazardous solid waste.

Reverse osmosis: A process that reverses (by the application of pressure) the flow of water in the natural process of osmosis so that it passes from the more concentrated to the more dilute solution.

SARA: Superfund Amendments and Reauthorization Act. Contains the Emergency Planning and Community Right-to-Know Act.

Sedimentation: Gravitational settling of solid particles in a liquid system.

Surfactant: A surface active agent; usually an organic compound whose molecules contain a hydrophilic (having an affinity for water) group at one end and a lipophilic (having an affinity for oil) group at the other.

TSCA: Toxic Substances Control Act. Regulates chemicals that present unreasonable risk of harm to human health or the environment.

Ultrafiltration: A physical molecular separation process which operates at moderate pressure (30 psi) through a semi-permeable membrane.

APPENDIX
For Further Information

Chapter One: Definitions

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R. K. Springborn, ed., *Cutting & Grinding Fluids: Selection & Application, (Dearborn, MI: ASTM, 1967), pp 102-104.*

Chapter Two: Environmental Law

Environmental Law Handbook, 10th Ed., Government Institutes, Inc. (Rockville, MD 1989).

Law of Environmental Protection, Sheldon M. Novick, Ed., Environmental Law Institute (New York, 1987).

Underground Storage Tank Guide, Jeffrey L. Leiter, Ed., Thompson Publishing Group (Washington DC, 1988).

Chapter Three: Fluid Management & Waste Minimization

Russell W. Phifer and William R. McTigue, Jr., *Handbook of Hazardous Waste Management for Small Quantity Generators. (Chelsea, MI: Lewis Publishers, 1989).*

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J. J. Keller & Associates, *Hazardous Waste Management Guide (Neenah, WI: John J. Keller, 1987).*

Chapter Ten: Container Management

J. J. Keller & Associates, *Hazardous Materials Guide (Neenah, WI: John J. Keller, 1987).*

State Waste Minimization Programs

Alabama
Hazardous Material Management Resource Recovery Program
University of Alabama
P. O. Box 6373
Tuscaloosa, AL 35487-6373
(205) 348-8401

Alaska
Alaska Health Project
Waste Reduction Assistance Program
431 West Seventh Avenue
Anchorage, AK 99501
(907) 276-2864

Arkansas
Arkansas Industrial Development Commission
One State Capitol Mall
Little Rock, AR 72201
(501) 371-1370

California
Alternative Technology Section
Toxic Substances Control Division
California Department of Health Services
714/744 P Street
Sacramento, CA 94234-7320
(916) 322-5347

Connecticut
Connecticut Hazardous Waste Management Service
Suite 360
900 Asylum Avenue
Hartford, CT 06105
(203) 244-2007

Connecticut Department of Economic Development
210 Washington Street
Hartford, CT 06106
(203) 566-7196

Georgia
Hazardous Waste Technical Assistance Program
Georgia Institute of Technology
Georgia Technical Research Institute
Environmental Health and Safety Division
O'Keefe Building, Room 027
Atlanta, GA 30332
(404) 894-3806

Environmental Protection Div.
Georgia Department of Natural Resources
Floyd Towers East, Suite 1154
205 Butler Street
Atlanta, GA 30334
(404) 656-2833

Illinois
Hazardous Waste Research and Information Center
Illinois Dept. of Energy and Natural Resources
1808 Woodfield Drive
Savoy, IL 61874
(217) 333-8940

Indiana
Environmental Management and Education Program
Young Graduate House, Room 120
Purdue University
West Lafayette, IN 47907
(317) 494-5036

Indiana Department of Environmental Management
Office of Technical Assistance
P. O. Box 6015
105 South Meridian Street
Indianapolis, IN 46206-6015
(317) 232-8172

Iowa
Iowa Department of Natural Resources Air Quality & Solid Waste Protection Bureau
Wallace State Office Building
900 East Grand Avenue
Des Moines, IA 50319-0034
(515) 281-8690

Center for Industrial Research and Service
205 Engineering Annex
Iowa State University
Ames, IA 50011
(515) 294-3420

Kansas
Bureau of Waste Management
Department of Health & Environment
Forbes Field, Building 730
Topeka, KS 66620
(913) 296-1607

Kentucky
Division of Waste Management
Natural Resources & Environmental Protection Cabinet
18 Reilly Road
Frankfort, KY 40601
(502) 564-6716

Maryland
Maryland Hazardous Waste Facilities Siting Board
60 West St., Suite 200A
Annapolis, MD 21401
(301) 974-3432

Maryland Environmental Service
2020 Industrial Drive
Annapolis, MD 21401
(301) 269-3291
(800) 492-9188 (in MD)

Massachusetts

Office of Safe Waste Management
Department of Environmental Management
100 Cambridge St., Room 1904
Boston, MA 02202
(617) 727-3260

Source Reduction Program
Massachusetts Department of Environmental Quality Engineering
1 Winter Street
Boston, MA 02108
(617) 292-5982

Michigan

Resource Recovery Section
Department of Natural Resources
P. O. Box 30028
Lansing, MI 48909
(517) 373-0540

Minnesota

Minnesota Pollution Control Agency
Solid and Hazardous Waste Division
520 Lafayette Road
St. Paul, MN 55155
(612) 296-6300

Minnesota Technical Assistance Program
W-140 Boynton Health Service
University of Minnesota
Minneapolis, MN 55455
(612) 625-9677
(800) 247-0015 (in MN)

Minnesota Waste Management Board
123 Thorson Center
7323 Fifty- Eighth Avenue North
Crystal, MN 55428
(612) 536-0816

Missouri

State Environmental Improvement and Energy Resources AuthorityP. O. Box 744Jefferson City, MO 65102(314) 751-4919

New Jersey

New Jersey Hazardous Waste Facilities Siting Commission
Room 614
28 West State Street
Trenton, NJ 08608
(609) 292-1459 or
(609) 292-1026

Hazardous Waste Advisement Program
Bureau of Regulation and Classification
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625
(609) 292-8341

Risk Reduction Unit
Office of Science and Research
New Jesey Department of Environmental Protection
40 East State Street
Trenton, NJ 08625
(609) 633-1378

New York

New York State Environmental Facilities Corporation
50 Wolf Road
Albany, NY 12205
(518) 457-4139

Division of Solid and Hazardous Waste
New York Department of Environmental Conservation
50 Wolf Road
Albany, NY 12233
(518) 457-3273

North Carolina

Pollution Prevention Pays Program
Department of Natural Resources and Community Development
P. O. Box 27687
512 North Salisbury Street
Raleigh, NC 27611
(919) 733-7015

Governor's Waste Management Board
325 North Salisbury Street
Raleigh, NC 27611
(919) 733-9020

Technical Assistance Unit
Solid and Hazardous Waste Management Branch
North Carolina Department of Human Resources
P. O. Box 2091
306 North Wilmington Street
Raleigh, NC 27602
(919) 733-2178

Ohio

Division of Solid and Hazardous Waste Management
Ohio Environmental Protection Agency
P. O. Box 1049
1800 WaterMark Drive
Columbus, OH 43266-1049
(614) 481-7200

Ohio Technology Transfer Organization
Suite 200
65 East State Street
Columbus, OH 43266-0330
(614) 466-4286

Oklahoma
Industrial Waste Elimination Program
Oklahoma State Department of Health
P. O. Box 53551
Oklahoma City, OK 73152
(405) 271-7353

Oregon
Oregon Hazardous Waste Reduction Program
Department of Environmental Quality
811 Southwest Sixth Avenue
Portland, OR 97204
(503) 229-5913

Pennsylvania
Pennsylvania Technical Assistance Program
501 F. Orvis Keller Building
University Park, PA 16802
(814) 865-0427

Bureau of Waste Management
Pennsylvania Department of Environmental Resources
P. O. Box 2063
Fulton Building
3rd and Locust Streets
Harrisburg, PA 17120
(717) 787-6239

Center for Hazardous Materials Research
320 William Pitt Way
Pittsburgh, PA 15238
(412) 826-5320

Rhode Island
Ocean State Cleanup and Recycling Program
Rhode Island Department of Environmental Management
9 Hayes Street
Providence, RI 02908-5003
(401) 277-3434
(800) 253-2674 (in RI)

Center for Environmental Studies
Brown University
P. O. Box 1943
135 Angell Street
Providence, RI 02912
(401) 863-3449

Tennessee
Center for Industrial Services
Suite 401
226 Capitol Boulevard Building
University of Tennessee
Nashville, TN 37219-1804
(615) 242-2456

Virginia
Office of Policy and Planning
Virginia Department of Waste Management
11th Floor, Monroe Building
101 North 14th Street
Richmond, VA 23219
(804) 225-2667

Washington
Hazardous Waste Section
Mail Stop PV- 11
Washington Department of Ecology
Olympia, WA 98504- 8711
(206) 459-6322

Wisconsin
Bureau of Solid Waste Management
Wisconsin Department of Natural Resources
P. O. Box 7921
101 South Webster Street
Madison, WI 53707
(608) 266-2699

Wyoming
Solid Waste Management Program
Wyoming Department of Environmental Quality
Herschler Building, 4th Floor, West Wing
122 West 25th Street
Cheyenne, WY 82002
(307) 777-7752

U. S. EPA REGIONAL OFFICES

Region 1
John F. Kennedy Federal Building
Boston, MA 02203
(617) 565-3715

Region 2

26 Federal Plaza
New York, NY 10278
(212) 264-2525

Region 3

841 Chestnut Street
Philadelphia, PA 19107
(215 597-9800

Region 4

345 Courtland Street, NE
Atlanta, GA 30365
(404) 347-4727

Region 5

230 South Dearborn Street
Chicago, IL 60604
(312) 35302000

Region 6

1445 Ross Avenue
Dallas, TX 75202
(214) 655-6444

Region 7

726 Minneapolis Avenue
Kansas City, KS 66101
(913) 236-2800

Region 8

999 18th Street
Denver, CO 80202-2405
(303) 293-1603

Region 9

215 Freemont Street
San Francisco, CA 94105
(415) 974-8071

Region 10

1200 Sixth Avenue
Seattle, WA 90101

U. S. EPA
Office of Solid Waste
401 M Street, SW
Washington, DC 20460

RCRA/Superfund
Hotline
(800) 424-9346
(In Washington, DC: 382- 3000)