Cutting Fluids

COMMONLY OBSERVED PRACTICES

The two most common cutting fluids used in the metal manufacturing industry can be broadly categorized as straight or petroleum oils and water-miscible fluids. Water-miscible fluids, including soluble oils, synthetics and semisynthetics, are now used in approximately 80 to 90 percent of all applications. Although cutting, or straight oils, are less popular than they were in the past, they are still the fluid of choice for certain metalworking applications.

Cutting fluid management practices and fluid life vary considerably from facility to facility. In most cases, machine coolant is added to machines in the recommended concentrations but is maintained minimally after this point. The most common reason given for additional coolant attention was odor (rancidity). The response to rancidity was generally the addition of a bactieriacide or dumping and replenishing the coolant with new product. This is a reactive approach that treats symptoms rather than the cause. Premature coolant failure jeopardizes the life of the tool, the quality of the part, and increases raw product usage and waste disposal costs.

Cutting fluids play a significant role in machining operations and impact shop productivity, tool life and quality of work. With time and use, fluid quality degrades and eventually requires disposal once efficiency is lost. Waste management and disposal have become increasingly more complex and expensive. Environmental liability is also a major concern with waste disposal. Many companies are now paying for environmental cleanups or have been fined by regulatory agencies as the result of poor waste disposal practices.

POLLUTION PREVENTION OPTIONS

Fortunately, significant potential exists to extend cutting fluid life through proper fluid selection, maintenance and recycling. A discussion of these topics is presented below.

Product Selection

Choosing the right metalworking fluid can be confusing and time consuming. To select the best fluid for a particular application, advantages and disadvantages of metalworking fluid products should be compared through review of product literature, supplier information, and usage history. Product performance information shared by other facilities is another means of narrowing choices. Ultimately, the best indicator of fluid performance is through actual use in your machining operations.

The following factors should be considered when selecting a fluid:

- Cost and life expectancy;
- Fluid compatibility with work materials and machine components;
- Speed, feed and depth of the cutting operation;
- Type, hardness and microstructure of the metal being machined;
- Ease of fluid maintenance and quality control;
- Ability to separate fluid from the work and cuttings;
- The product's applicable temperature operating range;
- Optimal concentration and pH ranges;
- Storage practices; and
- Ease of fluid recycling or disposal.

One thing that must be remembered when choosing fluids - you generally get what you pay for. Don't choose a fluid just on its initial cost but on the cost per gallon divided by its life expectancy. Although purchase of a premium product is initially more expensive, the long-term cost of the fluid will likely be lower than products of inferior quality.

With significant improvements in fluid formulations, today's fluids are capable of handling a wider variety of machining applications. Machine shops that once required several types of fluids may now find that one or two fluid types meet all needs. Minimizing the number of fluids used in the shop simplifies fluid management. The benefits of a fluid's versatility should be weighed against its performance in a particular metalworking application.

Fluids vary in their suitability for metalworking operations. For example, petroleum based cutting oils are frequently used for drilling and tapping operations because of their excellent lubricity while water-miscible fluids provide the cooling properties required for most turning and grinding operations. Each type of metalworking fluid category, their advantages and disadvantages, and their applications are summarized in the following table.

Cutting Fluid Types - Advantages vs. Disadvantages

STRAIGHT OILS		
	Advantages	Excellent lubricity; good rust protection; good sump life; easy maintenance; rancid resistant
	Disadvantages	Poor heat dissipation; increased risk of fire, smoking and misting; oily film on workpiece; limited to low-speed, severe cutting operations
SOLUBLE OILS		
	Advantages	Good lubrication; improved cooling capabilities; good rust protection; general purpose product for light to heavy duty operations
	Disadvantages	More susceptible to rust problems, bacterial growth, tramp oil contamination and evaporation losses; increased maintenance costs; may form precipitates on machine; misting; oily film on workpiece
SYNTHETICS		
	Advantages	Excellent microbial control and resistance to rancidity; nontoxic; transparent; nonflammable/nonsmoking; good corrosion control; superior cooling qualities; reduced misting/foaming; easily separated from workpiece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications
	Disadvantages	Reduced lubrication; may cause misting, foaming and dermatitis; may emulsify tramp oil, may form residues; easily contaminated by other machine fluids
SEMISYNTHETICS		
	Advantages	Good microbial control and resistance to rancidity; nontoxic; nonflammable/nonsmoking; good corrosion control; good cooling and lubrication; reduced misting/foaming; easily separated from workpiece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications
	Disadvantages	Water hardness affects stability; may cause misting, foaming and dermatitis; may emulsify tramp oil; may form residues; easily contaminated by other machine fluids

Fluid Management

Effective programs can keep metalworking fluid as clean as the initial raw product, significantly prolonging its service life. Components of a successful fluid management program include recordkeeping, fluid monitoring and maintenance.

Record Keeping

Record keeping is an important aspect of fluid management which begins with the initial preparation of the fluid. Following its preparation, the pH and concentration of the fluid should be measured and recorded. These initial readings should correspond to the acceptable product quality ranges provided by the fluid supplier. They also provide a baseline from which to evaluate the condition of the fluid over time. Concentration and pH measurements for used fluid are compared to "new fluid" values to assess fluid quality.

A detailed log book documenting fluid usage information should be maintained. Fluid management logs for each machine should include the following information:

- Brief description of the machine and sump/reservoir capacities
- Type of fluid used
- Fluid mixing ratios and initial parameter readings
- Water quality data
- Monitoring data including pH readings, biological monitoring data, fluid concentration measurements and inspection observations
- Adjustments made as part of fluid maintenance
- Fluid recycling and/or disposal frequencies including dates of coolant change out and reason for change out
- Equipment cleaning and maintenance activities, dates and comments
- Quantity of coolant added (both change out and periodic additions)
- Documentation of problems that occur.
- General comments

Fluid usage information should be compiled for the entire facility. This allows tracking the quantity of fluid purchased, recycled and disposed on a yearly basis. It also provides a check on the efficiency of the management program and identifies areas of the program that can be improved.

Fluid Monitoring

Monitoring and maintaining fluid quality are the basic components of fluid management. A fluid must be monitored to anticipate problems. Important aspects of fluid monitoring include system inspections and periodic measurements of fluid parameters such as concentration, biological growth, and pH. Changes from optimal fluid quality must be corrected with appropriate adjustments (such as fluid concentration adjustments, biocide addition, tramp oil and metal cuttings removal, and pH adjustment). It is important to know what changes may take place in your system and why they occur. This allows corrective action measures to bring fluid quality back on-line and prevent fluid quality problems from recurring.

Fluid Preparation

Proper fluid preparation is an important step to extend fluid life, achieve the best fluid performance and use fluid concentrate efficiently. Problems associated with high or low fluid concentrations are avoided. Coolant mixtures should be prepared according to manufacturer's directions (as obtained through your fluid supplier and/or product information sheets). Specifications regarding the recommended diluent water quality, concentrate to water dilution ratio, and additive requirements should be used. Information on the product's life expectancy and acceptable operating ranges for parameters such as pH, concentration, and contaminant levels should also be available. These ranges provide future benchmarks for coolant adjustment or recycling.

Water Quality

Since soluble fluids may consist of up to 99% water, the quality of the water used to dilute fluid concentrate is an important consideration in fluid preparation. Dissolved minerals and gases, organic matter, microorganisms or combinations of these impurities can lead to problems. The following water quality characteristics should be monitored to achieve the best fluid performance and extend fluid life.

Hardness

Hardness, a measure of the dissolved calcium, magnesium and iron salts in water, has a significant affect on metalworking fluid performance. "Soft" water generally refers to water with a hardness ranging from 0-100 parts-per-million (ppm) while "hard" water contains concentrations of 200 ppm or more. For metalworking fluids, the ideal hardness for makeup water is generally 80-125 ppm. Foaming may become a problem when concentrate is mixed with water with a hardness below this range, particularly in systems where the fluid is subjected to excessive agitation. A hardness above this range may cause dissolved minerals to react with fluid additives, lowering fluid performance. "Hard" water minerals combine with emulsifiers contained in synthetic or semisynthetic concentrates to form scum deposits on sumps, pipes, filters and even the machine. Hard water can also cause the oil to separate out of suspension.

Dissolved Solids

Hardness is not the only water quality parameter of concern. The total dissolved solid (TDS) concentration in water is an important factor in fluid management. Sulfates promote bacterial growth that cause fluids to become rancid. In many areas, drinking water may have sulfate concentrations of 50 to 100 ppm. Chloride salts and sulfates at concentrations above 80 ppm contribute to corrosion. Chloride levels are generally less than 10 ppm in untreated water but are greatly increased by common water softening. Phosphate concentrations above 30 ppm also react with the fluid to stimulate bacterial growth, irritate the skin and cause rancidity.

During normal fluid use, water evaporation increases the concentration of the working fluid. As new water is introduced to replenish system evaporation losses, additional dissolved minerals may also be added. Consequently, the TDS concentration of a fluid builds up over time. The greater the TDS concentration of the make-up water, the faster these concentrations increase in the working fluid.

In order to maintain the proper fluid chemistry, untreated water with an acceptable mineral content should be used for initial fluid makeup. When replenishing evaporation losses, machine operators should add pre-mixed fluid, not just water, to the system. Demineralized or deionized water should be used for the mix to prevent TDS levels from building up in the fluid. Adding fresh fluid to the system ensures that needed additives such as rust inhibitors and emulsifiers are maintained at desired concentrations.

If fluid life is a problem, it is important to have a water analysis completed. Shops served by a public water supply may contact their local water supplier to obtain the needed data. The fluid manufacturer may recommend some form of water treatment based on the water analysis such as deionized water from an in-line tank, or a reverse-osmosis unit. These types of water purification equipment extract ions. Deionizers produce the purest of waters. Distillation units may also be an option.

In some cases, a water softening unit may be added before the water purification system to reduce water hardness. Although water softeners can be used to obtain the correct water hardness, they are not capable of removing the minerals that contribute to metal corrosion and/or salt deposits. A common home-type water softener is not considered adequate for fluid preparation or fluid make-up water treatment.

Fluid Concentration

Monitoring and maintaining proper fluid concentration is essential in assuring product quality, maximizing tool life, and controlling microbial growth rates. High fluid concentrations may result in increased fluid cost through wasted concentrate, reduced heat dissipation, foaming, reduced lubrication and residue formation. Highly concentrated fluid may also stain the workpiece and/or machine tool and increase the toxicity of the fluid, particularly if the fluid becomes super concentrated from water evaporation. This results in increased skin irritation and an undesirable work environment for the machine operator. Dilute concentrations may result in poor lubricity, shorter tool life, increased biological activity, and an increased risk of rust formation on newly machined surfaces.

Evaporation can lead to a 3 to 10 percent water loss from the fluid per day. Water and concentrate are both lost as a result of splashing, misting and dragout. A total daily fluid loss of 5 to 20 percent may occur from the combination of these processes. As a result of these processes, coolant concentration will normally vary. The concentration of metalworking fluid must be monitored regularly to determine if the fluid is too dilute or too rich. Monitoring provides data for calculating the amount of concentrate and water needed to replenish the system and keep the fluid at its recommended operating concentration. Best monitoring frequencies range from daily monitoring for small sumps or stand-alone machines to weekly monitoring for larger systems. These monitoring frequencies are site specific, however, and are best determined through experience.

Fluid concentration may also be controlled through the installation of closed loop and open loop cooling units on machine sumps or central reservoirs. These cooling units reduce evaporation losses by regulating fluid temperature. This helps tighten tolerances, extend tool life by inhibiting microbial activity and increase the fluid's ability to remove heat from the tool/workpiece interface.

Fluid concentration is measured using a refractometer or by chemical titration. Refractometers are inexpensive tools ($200 to $250) capable of measuring fluid concentration. A refractometer is a portable, hand held optical device that reads a fluid's index of refraction. "Index of refraction" is a measurement of how much light is bent as it passes through a liquid. A fluid's index of refraction changes with the density and chemical composition of the fluid. Refractometer readings for a cutting fluid correspond to its concentration (the higher the reading, the greater the fluid concentration). By measuring a cutting fluid's index of refraction, the optimum fluid concentration can be maintained. Refractometers are typically available though coolant suppliers and provide fast, reliable results. Tramp oils, cleaners, hydraulic fluids and other contaminants reduce their accuracy.

Refractometer methods are fast but are less accurate when the fluid is contaminated with tramp oils. To overcome this problem, vendors of fluids have developed titration kits to determine fluid concentration. The titration measures a specific chemical or group of chemicals and is less affected by interferences from tramp oil or water quality. While titration is more accurate than refractometer readings, the procedure varies by coolant, and excess contaminants can affect accuracy.

The titration is done by taking a measured volume of fluid, adding an indicator, and then adding the titrant drop by drop until a color change is noted. The coolant concentration is determined from the number of drops of titrant added.

Microbial Contamination

Microbial contamination is a major cause of fluid spoilage. All water-miscible fluids are susceptible to microbial deterioration that can significantly reduce fluid life. Fluid manufacturers are constantly developing formulations that are more resistant to microbial degradation. This is accomplished by using high quality ingredients and incorporating biocides in the product.

Tramp oil and other contaminants are food for microorganisms and can make a sump an ideal breeding ground for bacteria. Bacteria populations can double as frequently as every 30 minutes. If allowed to multiply, microorganisms will ruin a fluid, causing odor problems and degrading performance. Successful bacterial control is a must.

Bacteria feed on a variety of substances contained in the fluid including the concentrate, tramp oils (including lubricants and hydraulic oils leaked by machinery), minerals in the water and other contaminants. The greater the bacterial growth rate, the faster the fluid becomes rancid. As bacteria multiply, they produce acids which lower the pH of the fluid, causing increased corrosion and reduced lubricity. The acid produced by the bacteria may also dissolve metal chips and fines, possibly causing the material to meet the definition of a hazardous waste. Bacteria may also darken the fluid significantly, resulting in stained parts.

Most bacteria that cause fluid to become rancid are aerobic. That is, they need oxygen rich environments. Bacteria may also be anaerobic (bacteria which grow in oxygen-poor environments). Anaerobic bacteria grow in systems that are inactive for long periods. Inactivity allows tramp oil to rise to the top of the sump, creating an effective barrier to atmospheric oxygen. Consequently, oxygen in the sump becomes low, aerobic bacteria die and anaerobic bacteria begin to increase. Anaerobic bacteria generate hydrogen sulfide, which produces the rotten-egg odor affectionately referred to as “Monday Morning Stink.”

Two common tests for microbial monitoring include plate counts and dip slide tests. Plate counts involve growing a culture using a sample of the fluid. Microorganism colonies that grow on the sample are later counted and identified. Like plate counts, dipslide tests also involve growing cultures using a sample of the fluid. Dipslides provide a more simple, rapid screening method since cultures are grown overnight and a visual approximation is used to assess microbial contamination. When rancidity is a problem, microbial-growth dip slide monitoring provides a chance to add biocide before problems arise. Reliable microbial-growth dip slides are available from fluid suppliers and laboratory-supply houses. Tests cost less than ten dollars each and are useful in setting up biocide-addition programs.

Weekly or biweekly monitoring is typically recommended for detection of microbial contamination, especially during the early stages of developing a fluid management program. With experience, a less frequent monitoring schedule may be suitable.

Biological growth is controlled by a combination of practices. These include water quality control, routine maintenance, biocides and aeration. Many coolant concentrates contain biocides and pH buffers. Therefore, maintaining proper fluid concentration helps control microorganisms.

Microbial contamination is significantly accelerated by poor housekeeping practices. The best method for controlling biological growth is through routine cleaning of machines, coolant lines and sumps/reservoirs. Machines, exhaust blowers, and hydraulic seals should also be maintained to prevent oil leaks from contaminating the fluid.

Accumulations of chips and fines in a sump also promote bacterial and fungal growth. These particulates increase the available surface area for microbial attachment and prevent biocides from effectively reaching the fluid trapped in these fines. Particulates in the bottom of a sump become septic or rancid if not periodically removed.

Even if the majority of the fluid is free of bacteria, the sludge in the bottom will continue to harbor bacteria and create a septic condition. This can dissolve metals, possibly increasing the toxicity of the fluid to a level at which disposal through a local wastewater plant is no longer permitted.

The addition of biocides inhibits biological degradation of the fluid by controlling bacteria and fungi. Relying strictly on biocides for microbial control is discouraged since these chemicals are expensive and can create hazards for the operator's skin.

Due to the variety of bacteria which may be present in a fluid, use of a single biocide may control certain bacterial species while allowing others to proliferate. Random use of various types of biocides may prove to be more effective. Less frequent doses with higher concentrations of biocide are also more effective than low-level, frequent doses.

Selection of an effective biocide should be based on laboratory tests and actual "real life" performance. Biocides that reduce microorganisms present in the fluid and do not interfere with fluid performance should be selected.

Aeration can be used in conjunction with biocide additives to control anaerobic microbial growth in systems during periods of inactivity. Aeration oxygenates the fluid producing an atmosphere hostile to the odor producing anaerobic bacteria. A small pump can bubble air into machine sumps either continuously or periodically to agitate stagnant areas within the sump.

pH is the measurement of hydrogen ion concentration. A pH of 7 is considered neutral. Higher pH values represent alkaline solutions while pH values below 7 represent acidic solutions. Ideally, the pH for water-miscible metalworking fluids should be kept in the limited range of 8.6 to 9.0. This slightly alkaline range optimizes the cleaning ability of the fluid while preventing corrosion, minimizing the potential for operator dermatitis and controlling biological growth. If the pH of fluid in a sump drops below 8.5, the coolant loses efficiency, can attack ferrous metals (rusting), and biological activity will significantly increase. A pH greater than 9.0 may also cause metal corrosion.

Regular monitoring of a fluid's pH is a simple means of anticipating problems. Coolant pH should be measured and recorded daily after the machine is placed in operation. Steady pH readings give an indication of consistent fluid quality. Swings in pH outside the acceptable range indicate a need for machine cleaning, concentration adjustment or the addition of biocide. Each action taken to adjust the pH to the desired operating range should be documented in the machine log book and evaluated for effectiveness. Any rapid change in pH should be investigated and action taken to prevent damage to the coolant.

The pH of a fluid usually remains constant because of buffers contained in the fluid concentrate. Water evaporation will cause the fluid pH to change after initial mixing. Improper control of microbial growth will also alter the pH of the fluid. By-products of microorganisms produce offensive odors and lower coolant pH. As the fluid becomes rancid or septic, the fluid becomes more acidic. Sudden downshifts in pH usually indicate increased biological activity or a sudden change in coolant concentration due to contamination. If coolant concentration and pH both jump downward, the sump has been contaminated. If coolant concentration remains fairly constant while pH decreases, biological activity has probably increased significantly.

The pH of a metalworking fluid is readily determined using litmus paper (available through your metalworking fluid supplier) or a handheld pH meter. Litmus paper provides a quick, low cost means of estimating fluid pH. Its accuracy is limited to plus or minus one full pH unit and is not particularly effective in predicting biocide failure.

pH meters are more expensive but provide more accurate readings. Depending on the degree of accuracy and other desired options, pH meter kits may be purchased at a cost ranging from as little as $50 to several hundred dollars. Low to medium cost pH meters are accurate to plus or minus 0.2 pH units, an accuracy sufficient for monitoring biological degradation. Although high-cost meters are accurate to hundredths of a pH unit, this degree of accuracy is of little benefit with regard to fluid management.

System Maintenance

Fluid contaminants must be controlled in order to obtain optimum fluid performance and life. These contaminants can be kept to a minimum with regular system inspections, maintenance and housekeeping practices.

System Inspection

Brief inspections of the fluid and system cleanliness are an important aspect in monitoring fluid quality and avoiding premature fluid failure. Operators and maintenance personnel should be aware of signs which indicate a need for fluid maintenance or recycling. Such observations include excessive tramp oil accumulation, buildup of metal cuttings within the sump, foaming problems and leaky machinery. Machines must also be inspected for stagnant areas, dirt accumulations and bacterial slime accumulations. Observations regarding fluid quality should also be documented in the machine log book. Difficulties in observing and cleaning problem areas often justifies equipment modifications to eliminate the hard to reach or stagnant locations. Retrofitting machines with external sumps often improves accessibility, facilitating routine particulate and tramp oil removal.

Routine Maintenance Practices

Maintaining clean machines, coolant lines and sumps is an integral part of fluid management. Clean machines use metalworking fluids more economically and extend fluid life. Any dirt and oil allowed to remain in the system simply recirculates, resulting in plugged coolant lines, unsightly machine buildup and bacteria breeding sites.

Particulate Removal

Excessive chip accumulation reduces sump volume, depletes coolant ingredients and provides an environment for bacterial growth. Excessive solids buildup can also cause the temperature of the fluid to increase. Machine turnings should be removed as often as possible. Mobile sump cleaners, such as ‘sump suckers’ or high quality drum vacs, are useful for this purpose.

Tramp Oil Control

Tramp oils such as hydraulic oil, lubricating oil or residual oil film from the workpiece are a major cause of premature fluid failure. These oils provide a source of food for bacteria, interfere with the cooling capability of the fluid and contribute to the formation of oil mist and smoke in the workplace. Tramp oils also interfere with fluid filtration and form residues on machining equipment. Tramp oil contamination must be controlled through preventive maintenance and removal.

Ultimately, the best method for control of tramp oil is to prevent it from contaminating the fluid in the first place. Routine preventive maintenance should be performed on machine systems to prevent oil leaks from contaminating the fluid. Some facilities have reportedly substituted undiluted, petroleum based fluid concentrate for gear box oil lubricants, machine way oils and hydraulic oils. Instead of becoming contaminated with leaking oil, the fluid is actually enriched by the concentrate. This should only be done if machines are properly prepared for using a fluid concentrate substitute to ensure this practice does not harm the machine's operation or performance. Machining equipment is also available which has been designed to require less hydraulic oil in its operation, or direct lubricating and hydraulic oil leakage away from the machine sump.

Even with the best preventive maintenance programs, some tramp oil contamination is inevitable and will require removal. Depending on its water miscibility, tramp oil will either "float out" when the fluid is allowed to sit for a period of time or be emulsified by the fluid. Free floating tramp oil should be removed on a regular basis (either continuously or periodically) as a part of fluid maintenance. An oil skimmer, coalescers or oil-absorbent pads can remove floating oils. A centrifuge is needed to remove emulsified tramp oils.

Tramp oil separation and removal can also be improved by purchasing fluids that resist tramp oil emulsification or by using hydraulic and lubricating oils that won't readily emulsify with the fluid. Use of high quality lubricants with ingredients that won't be a food source for bacteria is another alternative.

General Housekeeping

Cutting fluid contaminants such as lubricating oils, greases and metal particulates are an expected part of machining operations. Many of the contaminants that cause fluids to be disposed of prematurely consist of foreign materials such as floor sweepings, cleaners, solvents, dirt, waste oils, tobacco, and food wastes. These contaminants have obvious detrimental effects on coolant quality and should be eliminated by improved housekeeping and revised shop practices. Facility personnel should learn not to dispose of these materials in machine coolant basins.

Annual Cleanout

Machine systems must be thoroughly cleaned out at least once a year in order to keep biological growth in check and maintain proper system operation. During clean-out, each machine should be thoroughly cleaned and disinfected. Simple flushing of cleaning solution through the system does not provide adequate cleaning. To clean a coolant system properly, biocide should be added to the dirty fluid and allowed to circulate before pumping out the reservoir. All chips, swarf and visible deposits should then be removed.

Although accessibility is often an inherent problem due to a machine's design, extra effort should be made to thoroughly clean all hidden areas. If these difficult-to-reach areas are not addressed, they simply become a source of bacteria that rapidly attack the fluid used to refill the sump after cleaning.

Following cleanout of the sump/reservoir, the system should be charged with water (preferably hot water) and mixed with a machine cleaner. This mixture should then be circulated through the system for several hours in order to loosen and remove any hardened deposits, oily films or gummy residues. The cleaner must be:

- Compatible with the metalworking fluid (in case some cleaner remains in the system after rinsing);
- Low foaming to prevent pump cavitation; and
- Resistant to short-term rusting between cleanout and recharge.

Coolant chemical suppliers often provide instructions for equipment cleaning including information on safe, effective and compatible cleaning materials.

While the cleaning solution is circulating, leaking equipment should be repaired and the outside of the machine cleaned. If possible, troublesome areas should be steam cleaned. Finally, once the machine has been thoroughly cleaned and inspected, any residual cleaning solution must be rinsed from the equipment. Fresh water should be circulated through the system at least twice to rinse off any remaining cleaner. To protect against flash rusting, a small amount of coolant concentrate (0.5 - 1%) should be added to the rinse water. After completely draining the rinse solution, the system can be charged with fresh fluid. The fluid should then be circulated for at least 15 minutes prior to production.

The cleanout procedures described above are provided as general guidance. Each individual facility should develop a cleanout schedule and system suitable for their own operation.

The following is an example of a coolant-change practice found to be most efficient for extending fluid life at one small machine shop.

- Skim all tramp oil from coolant surface.
- Pump coolant from sump.
- Remove sump-access covers.
- Vacuum chips from sump.
- Clean and vacuum sump (repeat until clean).
- Replace sump-access covers.
- Replace original coolant.

The change practice was performed every 2-3 months and required an average of 5 hours to accomplish on a cast sump of 20-100 gallons. Sumps made of sheet metal take less time because corners are generally rounded and more easily cleaned. These system maintenance practices, when combined with improved, ongoing fluid maintenance, can greatly extend fluid life.

Maintenance of Straight Oils

Straight oils are generally easier to maintain than water-based fluids. In fact, straight oils may be the most environmental friendly fluid for certain applications (e.g. honing) due to their extraordinary stability, recyclability and long life. Straight oil maintenance consists of keeping the fluid free of contaminants (such as water or waste oils generated in other areas of the shop), adequate particulate removal through filtration and the addition of antioxidants. The presence of water promotes microbial growth while waste oil contamination dilutes the ingredients added to straight oil for enhanced lubricity and wettability. Waste oil contamination also increases the viscosity of the straight oil, lowering its filterability.

Straight oils that are kept contaminant free and adequately filtered may still require replacement as oxidation increases viscosity, making particulate filtration more difficult. As a result, additives referred to as antioxidants may need to be used to prevent oxidation from occurring.

Summary of Recommended Best Practices for Fluid Maintenance

- **Routinely inspect the fluid and system for cleanliness**
- **Perform regular maintenance on machines and sumps through;**
  - ✓ **Particulate removal;**
  - ✓ **Tramp oil control;**
- **General housekeeping**
- **Annual cleanout of machine systems**
- **Prevent foaming conditions from occurring**

Fluid Recycling

Despite all efforts to extend fluid life, fluid quality will eventually reach a point where routine maintenance is no longer effective. At this stage, the fluid either needs to be recycled or disposed.

The key to effective recycling is knowing when to recycle. Fluid should be recycled well before it becomes significantly degraded. Fluids with excessive bacteria counts or tramp oil concentrations cannot be restored. This is why monitoring microbial activity, concentration, pH and contamination levels are such critical aspects of fluid management.

If the fluid exhibits any of the following characteristics, it should not be recycled. Instead, the fluid should be disposed and the machine thoroughly cleaned before recharging with fresh fluid.

- If the pH is less than 8.0. (Normal pH range is 8.5 to 9.4.)
- If the fluid concentration is less than 2.0%. (Normal is 3.0% to 12.0%.)
- If the fluid appearance is dark gray to black. (Normal is milky white.)
- If the fluid odor is strongly rancid or sour. (Normal is a mild chemical odor.)

Recycling Equipment

A wide variety of recycling equipment is available for contaminant removal and most recycling equipment is generally easy to operate and maintain. The choice of recycling equipment will depend on the needs, objectives and financial resources of the shop. Cutting fluid may be recycled using a variety of equipment including filters, centrifuges, skimmers, flotation and magnetic separators.

Skimmers

Skimmers are specifically designed to remove tramp oils that float to the surface of cutting fluid after it has been allowed to sit still for a period of time. Skimming is most effective when tramp oils have a low water miscibility and the cutting fluids used by the shop reject tramp oil emulsification. Since oil has an affinity for plastic, most skimmers consist of plastic belts or disks that are partially submerged in the fluid. Tramp oil adheres to the skimmer as it passes through the fluid. The tramp oil is then scraped from the skimmer with a blade and collected for recycling or disposal.

For small sumps, oil absorbent fabrics or pillows (treated to repel water and absorb hydrocarbons) may suffice for tramp oil removal. The fabric can be drawn across the sump pit for tramp oil removal or pillows may be allowed to float in the sump to absorb oils. The disadvantage of using absorbents is the subsequent need for disposal.

Coalescers

Coalescers are often used in conjunction with skimmers to enhance tramp oil removal. Coalescers are porous-media separators which use oleophilic (oil attracting) media beds (typically constructed out of polypropylene) to attract oil in preference to water. These media beds often consist of inclined corrugated plates or vertical tubes. As cutting fluid is passed through the coalescer unit at a low, nonturbulent flow rate, dispersed tramp oil droplets attach to the media and coalesce to form larger and larger droplets. Eventually these droplets reach a size at which they rise to the top of the coalescing unit for removal with a skimmer. Coalescer units have no moving parts, are generally self cleaning and may be purchased for $1,000 to $5,000.

Like skimmers, coalescers are ineffective for removing emulsified tramp oils. They may also accumulate fine particulate matter during their operation. If these units are not cleaned periodically, the dirty media will provide a breeding ground for microorganisms.

Separation Equipment

Separation equipment includes settling tanks, magnetic separators, hydrocyclones and centrifuges. The primary function of this equipment is particulate removal. Settling tanks and centrifuges may also be used for tramp oil removal.

The simplest separation system consists of settling tanks. Settling tanks use baffles and weirs designed to promote settling of heavy particulates to the bottom of the tank while allowing tramp oil and light particulates to float to the surface of the fluid. Settling tanks are equipped with skimmers to remove the floating oil and light particulates. Chips and other particles that settle to the bottom are removed using baskets or automatic chip conveyors.

Magnetic separation tanks use cylindrical magnets to remove ferrous particulates. Contaminated fluid flows over the slowly rotating magnetic cylinders that extract the ferrous particulates from the fluid. The ferrous particles are then scraped from the magnetic cylinder into a tote bin for disposal. Nonferrous metals that pass by the magnetic cylinder are removed with another separation process, typically settling.

Hydrocyclones and centrifuges create artificial gravity for contaminant separation. Density differences between the cutting fluid and contaminants cause their separation. In a hydrocyclone, cutting fluid rapidly enters a cone-like vessel, producing a vortex that forces denser solids down and out. The disadvantage of hydrocyclones is that they tend to emulsify tramp oils.

Centrifuges use a spinning bowl to develop the centrifugal force needed for contaminant removal, exerting a force up to 6,000 times gravity (6,000 Gs) on the cutting fluid. However, unlike hydrocyclones, some centrifuge units can remove free, dispersed and emulsified tramp oil. High speed centrifuges also offer the extra benefit of bacterial removal. Removal of emulsified tramp oils requires a centrifugal force of 4,000 to 6,000 Gs. These units often use several coalescing disks to aid tramp oil separation. The disadvantage of centrifuges is the intensive maintenance required for the system and cost. In addition, under certain conditions, centrifuges used for removal of emulsified tramp oils may also separate fluid concentrate from the working solution. Your fluid supplier should be consulted beforehand to ensure centrifuging will not have a detrimental impact on fluid quality.

Filtration Equipment

Filtration involves passing cutting fluid through a permeable material for particulate removal. Filters may be permanent or disposable and are rated on an absolute or nominal scale. The absolute rating of a filter refers to smallest size particle that will be removed during filtration while nominal ratings refer to the average particle size that will remain in the fluid after filtration. Filters are typically made from materials such as wedge wire, microscreens, paper, cloth and manmade fibers such as nylon, polypropylene or polyester. In some applications it may be necessary to use a series of progressively finer filters in order to achieve the desired level of particulate removal.

Filtration systems used for recycling cutting fluid include vacuum, pressure and gravity filtration. Vacuum filtration pulls cutting fluid through the filter for particulate removal while pressure filtration uses a pump to force the fluid through the filter. The filtered fluid then enters the reservoir for redistribution. As chips and other contaminants build a cake on the filter media, resistance to flow increases. At a preset limit, the filter medium (usually rolled paper and wedge wire filters) indexes to expose a clean surface.

Gravity filtration systems involve cutting fluid flowing onto a blanket of filter media suspended over a reservoir tank. Particulates are then removed as the fluid passes through the filter into the reservoir for redistribution.

Flotation

Flotation is a process in which cutting fluid is aerated to achieve contaminant separation. During aeration, oil and particulate matter adhere to the air bubbles and are carried to the surface where they are mechanically skimmed off. This contaminant removal process is typically used after larger and heavier particulates have already been removed by settling.

Recycling System Selection

A wide variety of recycling systems are available for purchase. Such systems incorporate the above recycling equipment in their designs in order to remove contaminants such as tramp oil, particulates and bacteria. They are also capable of readjusting the fluid's concentration before it is returned to the individual machine. The following factors should be considered when selecting a recycling system in order to ensure it meets the needs of the shop:

- The volume of fluid which will require recycling (e.g. the number and volume of sumps);
- Particulate and tramp oil removal requirements;
- Type of material machined at the shop and hours of operation;
- Type of metalworking operations performed at the shop;
- Types of cutting fluids used by the shop and their optimal concentrations;
- What additives will be needed.

Recycling systems consist of both batch and continuous in-line systems. For small shops, the most effective method to recycle fluid for individual machines is the use of a batch-treatment system. Batch-treatment systems are portable or nonportable fluid recycling units. Fluid from individual machine sumps is treated in batches for contaminant removal. A recycle system for a small shop can cost from $7,500 to over $15,000 depending on the equipment options selected.

Typically, contaminated fluid is removed from the machine sump using a mobile sump cleaner (i.e. a sump sucker or high quality drum vac) and placed in the batch-treatment recycling unit for contaminant removal. To keep fluid clean, batch treatment must be done on a frequent basis. Many shops find that batch treatment must be done two to three times as often as the fluid's life expectancy. Thus, if a fluid lasts three months before it needs disposal, it will need to be batch treated monthly. If the fluid only lasts two or three weeks, it will need to be batch treated weekly.

Recycling Schedules

How often a fluid must be recycled depends on the following conditions:

- Fluid Type
- Water Quality
- Fluid Contamination
- Machine Usage
- Machine Filtration
- Fluid Control
- Fluid Age

A fluid that is stable and resists biological contamination will be able to withstand repeated recycling and will require less recycling. Poor water quality (water that is too hard or too soft) will cause excess dissolved minerals to accumulate in the fluid and may require more frequent recycling.

The level of productivity of a shop will also affect the frequency of recycling. Large shops that operate at maximum capacity around the clock will need to recycle fluids more frequently than smaller shops whose work schedule is less demanding. It is generally recommended that coolants be recycled every two or three weeks on average to keep coolants fresh and usable for extended periods of time. Some manufactures of recycling equipment recommend a 30 day recycling schedule for each machine.

COST/BENEFITS

An ideal machine coolant management program involves both proper management of the coolant in the machine sump and on-site recycling. The Figures 5-1 and 5-2 can be used to calculate the costs/benefits provided by a comprehensive coolant management program. A company should enter its own data and perform the corresponding calculations.

Figure 5-1
Machine Coolant Management Alternatives
Cost/Benefit Worksheet
Existing Conditions

ITEM	VARIABLE	EXAMPLE	YOUR FACILITY
A	Number of machine sumps	20	
B	Average sump capacity in gallons	100	
C	Facility coolant capacity in gallons = A x B	2000	
D	Coolant cost per gallon (Concentrate)	$10.00	
E	Dilution ratio (Concentrate to Water)	1 to 20	
F	Cost of coolant in the sump per gallon = D x E	$0.50	
G	Sump change outs per year	4	
H	Daily coolant makeup requirements (10%) in gallons per day	200	
I	Annual coolant usage in gallons = (C x G) + (H x 260 days)	60,000	
J	Annual coolant purchase cost = I x F	$30,000	
K	Annual amount of coolant generated as waste in gallons	8,000	
L	Coolant disposal costs per gallon	$0.60	
M	Annual coolant disposal cost = L x M	$4,800.00	
	Total annual coolant management costs = J + N	$34,800.00	

Figure 5-2
Machine Coolant Management Alternatives
Cost/Benefit Worksheet
Coolant Management and On-Site Recycling

ITEM	VARIABLE	EXAMPLE	YOUR FACILITY
A	Coolant recycling equipment cost	$50,000	
B	Number of machine sumps	20	
C	Average sump capacity in gallons	100	
D	Facility coolant capacity in gallons = B x C	2000	
E	Coolant cost per gallon (Concentrate)	$10.00	
F	Dilution ratio (Concentrate to Water)	1 to 20	
G	Cost of coolant in the sump per gallon = D x E	$0.50	
H	Sump change outs per year	12	
I	Daily coolant makeup requirements (5%) in gallons per day[a]	100	
J	Annual coolant usage in gallons = D + (I x 260 days)	28,000	
K	Annual coolant purchase cost = G x J	$14,000	
L	Annual amount of coolant generated as waste in gallons	0	
M	Coolant disposal costs per gallon	$0.60	
N	Annual coolant disposal cost = L x M	$0	
	Total annual coolant management costs = J + N	$14,000.00	

[a] Less makeup coolant is required due to proper maintenance of coolant concentration and sump cleaning (i.e. No shock treatments are necessary for pH or biocide control)

As calculated above, annual coolant purchase and disposal costs were $34,800 per year. By installing a $50,000 recycling system and maintaining the coolant properly in the sump, coolant disposal was eliminated and significantly less new product was used. These reductions brought the annual coolant purchase/disposal cost to $14,000 per year or a $20,800 annual savings. Based on this situation, a payback on the recycling equipment can obtained in less than 2.5 years.