A COMPREHENSIVE LOOK AT CUTTING FLUID MAINTENANCE AND WASTE REDUCTION PROGRAM

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ABSTRACT

This paper discusses the development of a cutting fluid management program and a waste reduction program that will allow facilities to extend cutting fluid life, improve performance, and more importantly reduce costs.

The major conclusion derived from this research is that selection of a coolant recovery systems depends on many factors which concerns the facility such as type of coolant being recovered, type of metal chips in the coolant, the existing cutting fluid maintenance program, etc. Hence, there may be several coolant recovery system, which incorporates different technologies, that can be installed and used within a specific industry. Therefore, being a able to work closely with one's coolant supplier and recycling equipment supplier besides having a complete understanding of the in question facility situation are a vital part in purchasing a cutting fluid and recovery system.

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INTRODUCTION

Cutting fluids, also called coolant or metal working fluids, should account for only a insignificant portion of the cost of operating a machine tool. Generally the cost of cutting fluids account for no more than 1% of the total investment in the machine and the operator. However, the importance of the cutting fluid is underrated in proportion to the relatively low cost of it. In contrast, the problems associated with the handling systems and disposal of the coolants can run at a disproportionate high level. However, while coolants are relatively inexpensive, they are one of the most essential ingredients for proper machine-tool operation. Without proper management, handling, and disposal, this innocuous fluid can pose a big problem within a machining environment.

This paper will deal with the development of a comprehensive waste reduction program for metal-working fluids. The intention of this paper will be to develop a user's manual that will consist of two major components. The first half of this paper will deal with the development of a metal-working fluid maintenance program that will involve: choosing the most feasible coolant for the machining operation and development of a fluid management program that will establish guidelines to deal with factors considered when trouble shooting coolant problems. These problems include causes from water quality, coolant concentration, rancid coolant, removal of tramp oil, removal of metal chips, and control of bacterial growth. The latter half of this paper will deal with a metal fluid waste reduction program. This section will include the fluid recovery system itself, such as, the various factors needed in the coolant system to choose the most efficient coolant recovery unit and an in-depth investigation of the types of coolant recovery systems available. Another aspect considered will be how to decide which one of these recycling systems will be the most worthwhile for the investment made.

I. DEVELOPING A CUTTING FLUID MANAGEMENT/ MAINTENANCE PROGRAM

Components of a Fluid Management Program

Any company that works metal must properly manage and monitor cutting fluids in order to realize their full benefits. The key to success of any program is to educate and train the machine operators on proper fluid management procedures. The machine operators should be informed of the purpose of the program, how it affects them, and the benefits to the company as well as themselves. The fluid management program should be developed with the input of the operators as well as the supervisor as this will help overcome worker resistance and allow the program to sustain over time.

The components of a fluid management program will allow the supervisor and the operator to be aware of and establish certain basic rules that will aid in setting up and following a fluid management program. There is not one set program that is appropriate for a machine operation facility. However, the basics steps that are presented below will allow a facility to be informed of the rudiment parts of a program and allow one to tailor the component steps to fit one's own needs [1].

Table 1. Components of a Fluid Management Program

1. Assign responsibility of fluid control to one person.
2. Train machine operators in proper fluid handling procedures.
3. Minimize loss of coolant due to spillage, leaks, carry-out, splashing and evaporation.
4. Properly maintain and inspect all machines.
5. Thoroughly clean out sumps, machines, and fluid-handling equipment before fresh fluid is added.
6. Select a premium performance product.

7. Use dionized water for makeup.
8. Add additives to recovered fluid as needed.
9. Control tramp oil and any emulsification.
10. Remove solids from machine sumps on a regular basis.
11. Establish efficient fluid transfer methods.
12. Aerate fluid.
13. Establish fluid removal criteria or schedule.

Clarification and elaboration on some of the more important areas will be introduced in the following material.

Knowing Your Cutting Fluid

Prior to establishing any type of program for metal working fluids, one must become familiar with the characteristics of the coolant itself.

A coolant has three basic functions: 1) as a lubricant, preventing metal-to-metal contact at the tool/workpiece interface; 2) as a coolant, removing heat generated by a cutting friction; and 3) as a corrosion inhibitor, protecting both the part and machine tool from rust and corrosion [2].

The lubricating function of a cutting fluid can effectively increase the life of the cutting tool if the heat and friction generated by the cutting process are reduced. When cutting fluids are utilized effectively, faster speeds and feeds can be used in the machining process resulting in increased production and reduction of the cost per product.

Reducing cutting-tool temperature is also important to tool life. Even a small reduction in temperature will greatly extend the life of a cutting tool. Water is the most effective agent for reducing heat generated during a machining operation. However, since water by itself causes rusting, soluble oils or chemicals, which prevent rust and provide other essential qualities, are added to make it a good cutting fluid.

As a corrosion inhibitor, coolant used in machining tools should inhibit rust from forming. As mentioned before, water is the best coolant. However, since water causes rusting, a cutting oil is used inconjunction with water to prevent the process of rusting. The ratio of water and cutting oil within the coolant is dependent upon the type of machining operation as well as the part being machined.

There are four basic types of coolant used today. Their advantages and disadvantages along with the factors that affect their performance are examined as follows.

Straight Oils

Straight oils contain 100% petroleum oil or mineral oil blended with additives. Some common additives are sulfurized lards, fats, and chlorinated paraffins. All additions are formulated to provide lubrication required for difficult work. Biocides are not added to straight oils because they contain no water, which supports anaerobic bacterial reproduction [3].

Advantages:
- Easy to recycle
- Excellent lubrication
- Good rust control
- Can be contained in sumps with other machines for both hydraulic and machining lubricant.
- Usually no rancidity problems

Disadvantages:
- Not effective in dissipitating the heat generated by cutting
- In-use cost is higher than water-based fluids
- Can be a safety hazard
- May stain non-ferrous metal

- Can be difficult to remove

Applications:

- Difficult-to-cut metals such as certain stainless steels and many super alloys
- Low machining operations (less than 75 surface feet per minute - 30M/min).
  - < screw machines
  - < cold headers
- severe cutting operations
  - < crush grinding
  - < severe broaching
  - < deep hole drilling
  - < milling
  - < trepanning
  - < tapping

Emulsifiable Oils

Emulsifiable, or soluble, oils permit oil and water to mix and form stable emulsions. The mineral oil and emulsifying agent are the based materials. It is also classified as a water based or water soluble coolant along with the synthetic and semi-synthetic because water is a *major ingredient in all* three of these coolants. A wide variety of additives may be present, depending upon the end application of the fluid. Besides emulsifiers, today's products also may contain extreme pressure (EP) additives, rust preventatives, and anti-bacterial agents. Although they do not match the straight oils in lubricity, they, like water-based fluids in general, are better at cooling. Because of their water content, they are usually formulated with additives for additional workpiece corrosion prevention and resistance to microbial degradation and souring. It should be noted that soluble oils have been replaced in most operations with chemical synthetics [3].

Advantages:

- Reduction of heat; allows higher cutting speeds
- Cleaner working conditions
- More economical to use; dilution with water brings application cost down
- Better operator acceptance; parts are cleaner and cooler
- Improved health and safety benefits; no fire hazard, reduction of oil misting and fogging
- Adequate to good rust protection because of the oily film on the workpiece
- Easier to clean from part
- Better at cooling than straight oils

Disadvantage:

- Maintenance cost to retain characteristics are relatively high; shorter sump life than straight oils
- Oil and water naturally repel each other, making emulsion stability difficult to maintain
- Hard-water, salts, bacteria, and tramp oils will attack the emulsifiers and destabilize the emulsion
- If not properly maintained, could cause rust problems
- May create disposal problems; due to hauling away oil and water
- Does not provide the "hydraulic cushioning" that straight oils provide

Applications:

- Heavy duty soluble oils are suitable for most cutting operations that the straight oils can handle
- Light and medium duty operations

Chemical Cutting Fluids

Chemical cutting fluids, called synthetic or semi-synthetic fluids, were introduced in the mid 1940's. These fluids are stable, preformed emulsions which contain very little oil and are able to mix easily water. Chemical cutting fluids depend on chemical agents for lubrication and friction reduction. At one time it was a common perception that synthetics were primarily for grinding, but heavy-duty synthetics have been introduced in the last few years which can handle most machining operations.

Synthetic Fluids

Synthetic fluids contain 0% petroleum or mineral oil. As such this fluid contain chemical agents to provide the necessary characteristics for an effective cutting fluid. These chemical agents can be the following [3,4]:

a) Glycols to act as blending agents
b) Germicides to control bacteria growth
c) Phosphorus, chlorine, and sulfur compounds for chemical lubrication
d) Soaps and wetting agents for lubrication
e) Phosphates and borates for water softening
f) Nitrates for nitrite stabilization
g) Amines and nitrites for rust prevention

Advantages:
- Rapid heat dissipation; therefore, good cooling
- A high degree of cleanliness which results in clean machine; tool surface and clean cutting fluid troughs
- Good detergent properties which aid in the maintenance of open and fee-cutting grinding wheels
- Excellent workpiece visibility
- Easy to mix; very little agitation is needed
- Excellent resistance to rancidity; therefore, good sump life
- Longer durability than straight or soluble oils
- Nonflammable and nonsmoking (oil-free)
- Generally provide good hard-water stability and can be formulated to perform and remain stable in the hardest water
- Able to rapidly reject tramp oil which can be easily skimmed off the surface
- The higher alkalinity associated with synthetic technology guards against bacterial growth
- Quick setting of grit and fine chips so they are not recirculated in the cooling system

Disadvantages:
- Poor physical lubrication
- May cause foaming problems
- The inherent antibacterial properties can lead to heavy fungal growth
- The high detergent properties tend to dry out the operator's skin and can also wash away bearing and shaft greases, leading to machine failure
- May be less effective on aluminum and other non-ferrous metals

- May form deposits on machines

Applications:
- Can handle most machining operations, however, ideal for metal cutting operations that generate a large amount of heat

Semi-synthetic Fluids

Semi-synthetic fluids can contain 5-45% petroleum or mineral oil. However, this class of working fluids is essentially a combination of an emulsfifiable oil and a chemical solution. Combining the advantages of emulsifiable oils and synthetics fluids, this fluid finds a wide use.

Advantages:
Same as synthetic fluids

Disadvantages:
Same as synthetic fluids

Applications:
- Basically can handle most machining processes

As mentioned earlier, emulsifiable, synthetic, and semi-synthetic are categorized together as water based or water soluble cutting fluids. As such, Table 1 presents a more specific view of the characteristics of these water based coolants [5].

Table 2. Water Soluble Cutting Fluids [5]

CLASS	TYPE	GENERAL CHARACTERISTICS
Emulsifiable Oils	(1) General-Purpose Soluble Oils	Used at dilutions between 1:10 and 1:40 to give a milky emulsion. Used for general purpose machining.
	(2) Clear-Type Soluble Oils	Used at dilutions between 1:50 and 1:100. Their high emulsifier content results in emulsions which vary from translucent to clear. Used for grinding or light-duty machining.
	(3) Fatty Soluble Oils	Used at similiar concentrations to (1) and or similiar appearance. Their fat content makes them particularly good for machining operations and nonferrous metals.
	(4) EP Soluble Oils	Generally contain sulfurized or chlorinated EP additives. Used at dilutions between 1:5 and 1:20 where a higher performance than that given by (1), (2), or (3) is required.
Chemical (Synthetic) Fluids	(1) True Solutions	Essentially solutions of chemical rust inhibitors in water. Used at dilutions between 1:50 and 1:100 for grinding operations on iron and steel.
	(2) Surface-Active Chemical Fluids	Contain mainly water-soluble rust inhibitors and surface-active load carrying additives. Used at dilutions between 1:10 and 1:40 for cutting and at higher dilutions for grinding. Most are suitable for both ferrous and nonferrous metals.
	(3) EP Surface-Active Chemical Fluids	Similiar in characteristics to (2) but containing EP additives to give higher machining performance when used with ferrous metals. Used at dilutions between 1:5 and 1:30.
Semi-chemical (Semi-synthetic) Fluids	-	Essentially a combination of a chemical fluid and a small amount of emulsifiable oil in water forming a translucent, stable emulsion of small droplet size. EP additives are usually included permitting their used for moderate and heavy-duty machining and grinding applications.

Storing

Store cutting fluids in clean and sealable drums when not in used. The drums should be protected from temperature extremes, moisture and direct sunlight. Inert mineral absorbents should be kept on hand to soak up fluid spills. Avoid using sawdust or rags because they tend to combust spontaneously.

Cutting fluids are basically inert. However, as in the case with other organic substances, a reaction can occur if they are mixed with strong oxidizing agents. As such, never store such agents in the same area as cutting fluids.

Mixing

Follow a few simple rules when mixing water-based coolants. First, measure and pour the required volume of water into a clean tank or open drum. Next, add coolant concentrate to the water (never vice versa). Measure out the required volume of soluble concentrate and gradually pour it into the water while mixing. Continue doing this routing until the entire volume of concentrate has been added.

The correct and safest way to mix coolant is with a top-to-bottom turning over action, not a rotary motion. For small quantities, preferably use a flat wooden paddle. For larger volumes, a mechanical agitation is preferable. However, mechanical agitation performed too rapidly can destabilize the mixture and cause components to separate. If the water used for the mixture is hard, it may be necessary to add softening chemicals before blending in the concentrate. The quality of the water used for mixing with the cutting fluid will be discussed more thoroughly in the following section.

Water Quality

Water quality is very important consideration when mixing it with the coolant concentrate. As water can comprise more than 90% of the coolant mixture, it can affect the coolant's performance. Fluid life, tool life, foam characteristics, product residue, corrosion control and stability are all affected by water quality.

Water hardness occurs when inorganic salts dissolve in the water. Typically, these salts are of calcium or magnesium. Water hardness is measured in parts per million (ppm) of calcium carbonate ($CACO_3$) [2]. Water considered soft has fewer than 52 ppm. Water considered moderately hard ranges from 52 to 105 ppm. Greater than 105 ppm is hard water. Furthermore, hard water has more minerals and total dissolved solids than soft water and the higher the initial hardness of the water, the faster the solids will increase in the working fluid. A majority of the water within the United States is classified as hard water.

Hardness is detrimental to coolants because it attacks the emulsifiers and soap portions of the coolant mixture. As water evaporates from a sump, the minerals are left behind and build up increases. To overcome this problem, several hard-water stable fluids have been developed. However, it is best to use softened water in the mixture, even though modern coolant concentrates are designed to perform satisfactorily with moderately hard water. In addition, other fluids may remain sensitive to the hardness of water. For these cases, distillation, dionization, and reverse-osmosis equipment can be used to soften very hard water.

Distillation

This method utilizes the concept of evaporating water, leaving solids behind. The water vapor is then condensed back to water.

Dionization

Dissolved solids removed by ion exchange. Cations (+) and anions (-) are exchanged for H and OH ions respectively in the ion exchange resin beds.

Reverse Osmosis

A low pressure filtration process in which water passes through a submicron membrane which allows passage of water molecules but not the dissolved solids.

These units which produce nearly pure water, are ideal for systems that lose a lot of liquid through evaporation. Other undesirables such as minerals may also be present in water. Chlorides and sulfates act as catalysts for corrosion. In addition, sulfates provide food for bacteria growth thereby allowing a fluid to become rancid.

Therefore, operating a system with hard water will lead to a progressive increase in the concentration level of hard-water salts and maybe minerals. When in doubt, discuss any proposed water-softening procedure with the cutting fluid supplier.

Delivery

A slow and generous flow of cutting fluid delivered to the work area at low pressure is best for most type of operations. Problems sometimes arise, however, with high pressure systems. The coolant stream can easily be deflected away from the cutting point by tool holders, cutting tools, or the part being machined. As such, the critical tool and workpiece may only receive a fraction of the coolant needed.

A fine coolant spray also may be an ineffective means of coolant delivery because of the lack of coolant reaching the cutting zone. All cutting fluid systems should have adequate splash guards. Without them, the operator may sometimes reduce the flow of the cutting fluid flow rate to avoid being splashed. However, lowering flow rate can result in overheating of the cutting zone can will inadvertently lead to tool and/or workpiece damage.

Most fluids foam under certain conditions. Foaming is usually traceable to any number of items: turbulence caused by excessive pumping, speed, or pressure; feed nozzle being restricted; mixing of incompatible oils which can often occur from either change to or from a straight oil to a soluble oil; or the incorrect application of agitating air during the emulsification of a soluble oil.

pH Acidity and Monitoring

The pH value is the measurement of hydrogen ion concentration. A pH 7 value indicates a neutral solution where lower values being acidic and higher values being alkaline.

Most coolants should be maintained with a limited alkalinity range of 8.5 and 9.5. These levels tend to provide optimum corrosion protection without damaging nonferrous metals while helping to control bacteria.

It should be noted that a sudden drop in the pH level of a cutting fluid is a good indication of increased biological activity or sudden change in coolant concentration due to contamination. If coolant concentration and pH both jump downwards, the sump has been contaminated. If coolant concentration remains fairly constant and pH falls off, biological activity is more than likely increasing.

A coolant's pH or acidity can be measured with litmus papers or pH meters.

<u>Litmus Paper</u>

Litmus Papers are low cost and can give a quick estimate of the pH of the fluid. Test papers are accurate to plus or minus a full pH unit. To only determine the pH of a fluid, simple litmus paper will do.

<u>pH Meters</u>

Medium cost pH meters are accurate to plus or minus 0.2 pH units. Meters that are of higher cost are accurate to plus or minus one-hundreth of a pH unit. pH meter kits can be purchased for one hundred to two hundred dollars. To predict biocide failure, a medium cost pH meter kit will be needed rather than test papers.

Coolant Concentration

Regardless of the type of coolant used, the workpiece material, or method of treating fluids, certain monitoring tests regularly performed will help ensure that the coolant stays in top condition. Weekly monitoring is the minimum; daily monitoring is suggested for small sumps or stand-alone machines. Concentration is important to monitor because it is the measure of the active ingredients present in coolant. Extreme concentrations of coolant can result in increased coolant cost and foam. In addition, if the coolant concentration is too dilute, it can result in shorter tool life, increased bacteria growth, and increased risk of rust on newly machined parts.

The concentration of fluids in water-based coolants can be monitored several ways.

Refractometers

Refractometers work well for clean systems and emulsifiable oils, but their accuracy decreases considerably as solids build up in the coolant. The term refractometer is principally applied to instruments used for determining the index of refraction of a liquid. The index of refraction is a measurement of how much light is bent as it passes through a liquid. The refractometer measures the concentration of the cutting fluid so that water lost in the cooling process can be replaced, maintaining an optimum dilution of the fluid. However, this measuring device is not recommended for synthetics and semi-synthetics, because solids and tramp oils affect their refractive indices, resulting in false readings.

Titration

The best method for checking the concentrations of synthetics and semi-synthetics is titration. This extremely accurate method involves testing how much a specific component the coolant contains. Titration measures a specific chemical or group of chemicals and is less affected by interferences due to tramp oil or water quality.

Metal Chip Removal

Metal chips must also be removed on a routine basis. Not only can metal chips interfere with machining operations, it can also serve as a place for bacteria growth. Chips can be prevented from entering the sump by placing screens over the coolant entrances to the sump or over the exits from the holding tray itself. Chips can also be removed from the sump using raking or vacuuming methods.

Tramp Oil Removal

Cutting fluid from machining processes are collected and recirculated from sumps. During use, the coolant collects hydraulic and lubricating tramp oils from the machining system. Even small amounts of tramp oil can cause problems with water-based cutting fluids. In large enough quantities, tramp oil also affects neat straight oils by diluting their additives. This oil, which can coat the coolant surface, can cause bacterial decomposition, congestion in pipelines, and emulsion overloading.

Growth of anaerobic bacteria can render the cutting fluid unsuitable for disposing through the sewer system. Anaerobic bacteria will shorten coolant life and eventually force disposal of the coolant waste. It may also produce acidic conditions that may dissolve chips making the coolant a hazardous waste.

The latter occurs when emulsifiers in a cutting fluid try to emulsify tramp oil. This action will destroy the equilibrium of soluble and insoluble components and leads to emulsion instability and breakdown. As such, the insoluble metallic soaps will then separate out and build up inside pipes and hoses thereby reducing coolant flow. In extreme cases, the system will need to be flushed with detergent to clear the buildup which leads to costly down time and system recharging.

There are several methods for removing tramp oil. These methods are indicated as follows [4]:

1. Absorbent Blankets, or Fabrics or Pillows
2. Disk Type Oil Wheels
3. Belt Type Skimmers
4. Rope Type Skimmers
5. Porous Media Separators or Coalescers
6. Centrifuges

For small sumps, oil absorbent fabrics or pillows are feasible. When choosing an oil absorbent fabric, select one that will not only repel water but also absorb hydrocarbons.

Belts and disk skimmers are found to be the most common and cost-effective in large and small operations.

A coalescer is a porous media separator where the fluid passes through the coalescer media. The media attracts and separates the tramp oil from the fluid. The media is most usually made of polypropylene which attracts oil to it in preference of water. The coalescer has no moving parts and is generally self cleaning. As the oil separates to the top of the tank, it can be removed by a skimmer. Generally, medium to large shop operations can justify this method of tramp oil removal.

Depending upon the type of maintenance program within the facility, coolant sumps may require oil removal monthly or even weekly. The exact management scheme for waste oil is determined by the type of coolant, level of contamination, presence of metals and organic solvents, and availability of treatment.

Microbial Growth Control

Bacteria are soluble oil's and water-based oils' worst enemy. They feed on fatty components, corrosion inhibitors and other emulsion components. As mentioned earlier in the pH acidity section, the effects of microbial growth in fluids can significantly reduce fluid life. A clean synthetic coolant contains nothing for bacteria to feed on, but any tramp oils in the coolant will nurture bacteria.

If left unchecked, bacteria multiply at a phenomenal rate. Eventually, chemical changes takes place that increase the coolant's acidity, destroying its stability, and causing it to corrode metals.

Another unpleasant by-product of bacterial growth is foul odors. Bacteria known as "sulfur reducers" produce very rancid smelling odors. They can grow in stagnant fluids having low amounts of oxygen. Coolants stagnate after a few days of inactivity, i.e. weekends, holidays, and plant shutdowns. To prevent this from occurring, use of a small air line, pump, or mechanical agitator is used to churn the cutting fluid gently and continuously while in the sump. Such aeration will minimize the sulfate-reducing bacteria's growth rate.

Bacteria can be controlled in various ways. When choosing the most feasible cutting fluid for a particular application, one must be sure it contains an appropriate biocide. One can ask the fluid supplier to recommend a product.

Other Considerations

In some cases, the sump is not accessible and can not be modified, i.e. making oil and chip removal very difficult. An alternative would be to consider a different coolant that might have equivalent properties but provide a longer life in the same environment.

Another consideration would be a centralized sump for several machining operations which may ease maintenance operation and reduce capital costs for maintenance equipment.

However, when looking at purchasing a new machining unit, the access to the coolant sump and ease of performing maintenance should be given considerable priority. Studies have shown that sumps constructed of sheet metal with rounded edges are easier to clean.

Finally, at some point coolant will become spent and will require treatment for disposal. But, if proper preventive maintenance is established, the overall volume of spent coolant could be reduced a considerable amount.

Coolant Trouble Shooting

The first half of this paper has emphasized the important areas that need to be addressed in order to manage and provide proper maintenance of cutting fluids within a small or large machine shop environment. A chart is presented below to summarize the most important aspects of coolant trouble shooting provided that a metal working fluid management and maintenance program has been established [3].

Table 3. Coolant Trouble Shooting [3]

PROBLEM	POSSIBLE CAUSE	REMEDY
Rust, corrosion, staining, etching	pH out of balance	Test and balance as required.
	Bacterial infestation	Add Formalydehyde releasing bactericide.
	Hard water	Test and add hard water additive.
	Concentration too lean	Increase concentration.
	Dissimiliar metals corrosion	Add dissimiliar metals additive per directions.
	Parts stored in paper, wood, or galvanized container	Store parts in plastic or (if iron or steel) in ungalvanized steel container.
	Parts blown off with air line containing water	Filter air
	Parts stacked against each other	Correct. Ventilate.
	Deep tote boxes	Change to shallow tote boxes. Do not fill to top. Ventilate.
	"Mating" parts of machine (lathe tailstock, shanks of turret tooling) not protected	Apply water resistant oil or grease
Surface film	Tramp oils	Skim off. Correct oil leak if possible. Provide tramp oil separator.
	Fungal infestation	Add fungicide as required.
	Hard water	Add hard water additive as required.
Foul odor	Bacterial infestation	Practice good housekeeping. Add formaldehyde releasing bactericide as required. Keep tramp oils skimmed off. Test and balance pH. Test and control hardness. Drain and clean machine prior to vacation and shut-down.
Dermatitis	Hard water	Test and add hard water additive as required.
	pH out of balance	Test and balance as required.
	Operator has sensitive skin	Wash hands frequently. Wear gloves. Apply barrier cream.
Lubricity not adequate	Difficult material or operation	Increase concentration.
	Low pH	Test and balance as required.
	Hard water	Test and add hard water additive as required.
Way oils wash away	Some highly compounded way oils are easily emulsified	Check with supplier for more suitable way oil
	Water soluble way lubricant being used	
Slides or ways sticky	Calcium soap build-up due to hard water	Add hard water additive as required. Clean machine.
Foam	Soft water	Add anti-foam additive as required.
	High agitation machine or pump	Add anti-foam additive as required.
	Coolant recirculating too often due to level tool low or sump too small	Raise level or provide larger tank.
	Air getting into intake side of pump	Correct.
Lines clogging	Hard water	Clean. Add hard water additive.
	Tramp oils	Correct leak if possible. Provide tramp oil separator.
	Evaporation	Test and add water to maintain proper concentration.
	Previous coolant not completely cleaned out	Dump, clean thoroughly, recharge.

III. DEVELOPING A METAL WORKING FLUID WASTE REDUCTION PROGRAM

Obtain Information on Cutting Fluid Waste Generation

Before an effective waste reduction program can be developed and implemented, accurate and current information on waste generation must be a priority. By being aware of the fluid management program that was presented earlier and collecting the necessary information, a successful waste reduction program can become established. The information can be divided and collected into two sections: machine information and facility information. Some of the pertinent information which should be obtained is as follows [1]:

Table 4. Information on Metal-Working Fluid Waste Generation

For each machine:

1. Type of metal-working fluid used.
2. Actual water-to-fluid ratio used.
3. Size of sump.
4. Frequency of sump clean-out.
5. Manual vs. hard-piped fluid addition.
6. Inspection for: hydraulic and lubrication oil leakage; sump and fluid condition; fluid leakage or spillage; effectiveness of machine coolant cleaning system; etc.
7. Reason fluid is dumped.
8. Fluid cleaning devices used.

Facility information:

1. Chemical oxygen demand of each metal-working fluid.
2. How fluid is removed from machines and where taken.
3. Inspect fluid storage area. Examine fluid concentrate handling procedures, note any leaks or spills.
4. Waste hydraulic oil handling procedures.
5. Chip handling procedures.
6. Quantity of fluid used per week.
7. Type of fluids used and where.
8. Cost of waste fluid disposal.
9. Cost of virgin fluid.
10. Current waste management techniques.

A log should be used for each machine concerning the proposed information so that it can keep track of how much fluid is used by each machine. This collection can be monthly, preferably weekly, or daily. Using a log to track oil usage will help identify why cutting fluid is being dumped. Therefore, it may point out areas for better fluid management and maintenance.

Based on the results of the assessment, a waste reduction and/or recycling program for cutting fluid can be developed. However, such a program can and will only be successful once the fluid management program is effectively implemented.

On-Site Coolant Recovery/Recycling Options

There is a wide variety of recycling systems or, sometimes called, coolant recovery systems. For small shops the most effective method to extend fluid life or to recycle fluid for individual machines is the use of batch treatment systems. These systems may be purchased individually or as a complete skid-mounted system. These systems are available with a number of options including automatic coolant concentration addition, deionized water systems for makeup, automatic timers and fill/empty controls, pasteurization for bacteria control, tramp oil removal, etc. However, batch treatment must be done on a frequent basis to minimize the contaminants in the fluid.

These recovery/recycling systems range from $8,000 to well over $15,000 depending upon the options, capacity, and type of equipment used.

Basically, there are three types of coolant contaminant removal methods: filtration or media-based, natural property, and mechanical separation systems. Within these three categories, variation of method of removal can be high.

Pretreatment

In small machine shop operations, providing basic care of the coolant may be the most feasible option rather than making a large capital investment for an elaborate recycling system. Pretreatment methods that can be used for immediate clean-up at the machine itself would be to purchase a sump cleaner/filter [6]. Sump cleaners have been found to the most efficient for extending coolant life. The sump cleaner/filter is able to remove dirty coolants from sump, filter out solids, and be able to pump back coolant in minutes. However, the coolant life would also depend on the change-out practice (no more than once every 3 months) and the proper maintenance of fluids, bacteria addition and inhibitors, and proper dilution practices.

This option may be a treatment method for a small machine shop. But, it can also be used in large operations for preliminary clean up before recycling, for solids separation before disposal, or for mess-free collection and transport of spent coolant.

Filtration or Media-Based Systems

There are several variations of filtration systems. Mainly, these types of systems only remove solids, sludges, metal chips, and dirt. Some of the more familiar systems are as follows [5]:

A. Gravity Filters
   1. Barrier - Bags, paper, wire screen, etc.
   2. Depth - granular beds, thick fiber, etc.
   Advantages:
   - Relatively low initial cost.
   - Easy to operate.
   Disadvantages:
   - Large floor space required.
   - Disposable media adds to operating costs.
   - Requires low foaming fluid.

B. Pressure Filters
   Advantages:
   - Removes small fines efficiently.
   - Large fluid volume with minimal floor space.
   Disadvantages:
   - Required maintenance for high efficiency.
   - Tramp oils can plug media.
   - Disposable media use is high.
   - Hard water soaps can plug media.

C. Vacuum Filters
   Advantages:
   - Removes small fines efficiently (10-25 microns).
   - Relatively low initial cost.
   - Fluid choice is not critical.
   Disadvantages:
   - Required maintenance for high efficiency.
   - Tramp oils can plug media.
   - Disposable media use adds to cost of operation.
   - Hard water soaps can plug media.

<u>Natural Property System</u>

These systems use the cutting fluid's own properties to separate either solids, tramp oil, or both [5].

A. Retention Tanks
   - Machine sump can act as a retention tank if volume is sufficient.
   1. 10 to 30 minute retention time.
   2. Weirs or baffles to speed settling.
   3. Drag out system to remove solids from tank bottom.
   Advantages:
   - Low cost
   - Simplicity (low maintenance)
   - Low operating cost (no replacement filter media)
   Disadvantages:
   - Large floor space requirement.

- ineffective with small (<40 microns) fines

B. Flotation
- Tiny air bubbles form foam that floats solids to top of tank.

Advantages:
- Good aeration.
- No replacement filter media.

Disadvantages:
- Large floor space often requirement.
- Requires low foaming fluid.
- Ineffective with small (<40 microns) fines.
- Relatively high cost per gallon.

C. Surface Skimmers
1. Rags, newspaper, sorbent pads
2. Weirs (overflow, "decanting")
3. Wheels, belts, mops, etc.

Advantages:
- Low initial cost.
- Low operating cost.

Disadvantages:
- Ineffective with small (<40 micron droplets).
- Will only remove surface oil.
- Difficult access in some sumps.

D. Coalescers
- The attraction and separation of tramp oil and other contaminants through the used of a coalescer media. The coalescer media is usually polypropylene, which attracts oil in preference to water.
1. Plate
2. Media Bed

Advantages:
- Relatively low initial cost.
- Simple, low maintenance.
- Low energy/operating costs.
- Continuous operation (non-batch).

Disadvantages:
- Media may plug or get dirty and require cleaning.
- Changing fluids is relatively difficult.

Mechanical Separation Systems

As one can tell by the name, these particular systems uses mechanical means to separate the desired particulates [5].

A. Magnetic Separators.
- Use of magnetic force to separate metal chips from the fluid. Oil and other contaminants must be

separated by other means. Various types are drum, drag out, or conveyor type.

Advantages:
- Low maintenance.
- Low operation cost (no replacement filter media).
- Minimal floor space.

Disadvantages:
- Limited to ferrous or magnetic solids.

B. Centrifuge
- Liquid/Solid separation is accomplished by centrifugal force, which causes contaminants to rapidly settle out of the liquid and form a layer of solids on the inside of the centrifuge. 1 GPM is equivalent to 15 to 25 square feet of settling tank surface area.

1. Bowl type
2. Stacked disk type
3. Manual or automatic clean out

Advantages:
- Minimal floor space.
- Can remove tramp oil.
- No disposable filter media.
- Versatile, can easily change fluids easily.
- Possible tramp oil and solids removal.

Disadvantages:
- May break emulsion of coolant.
- High maintenance cost and time.
- Low maximum flow rate.
- Batch type process.
- High failure rate.

C. Hydroclone
- Utilizes centrifugal force to separate solid contaminants from low viscosity fluids and from water-based fluids. A vortex is formed inside the cone wall where they are eventually discharged through the nozzle. Back pressure causes the clean fluid to reverse direction an it is discharged at the top of the cone. 1 GPM is equivalent to approximately 1.5 square feet of settling tank surface area.

Advantages:
- Simplicity (no moving parts).
- Minimal floor space.
- No disposable filter media.
- Promotes emulsification coolants.

Disadvantages:
- Large particles must be removed first.
- Apex must be inspected daily.
- May cause foaming.
- Ineffective with very small fines.

D. Ultrafiltration

- Ultrafiltration falls between microfiltration and reverse osmosis on the filtration spectrum. Flow is across the surface of a membrane. The membrane acts as a filter, rejecting, suspended solids and emulsifiable oils, allowing water and some low molecular dissolved solids to pass through.

1. Sheet (flat plate, spiral wound).
2. Tube (hollow fiber, tubular)

Advantages:
- Can separate all suspended solids, colloidal materials, and emulsified oils.
- Continuous operation

Disadvantages:
- High maintenance cost.
- High initial cost.

The selection of the type of units which can be used to recover the waste fluid depends upon the level of contaminants the process contains, the fluid specifications that must be met, and the savings associated with the system. As stated earlier, these systems may be purchased individually or as a complete skid-mounted system. These systems are available with a number of options including automatic coolant concentration addition, deionized water systems for makeup, automatic timers and fill/empty controls, pasteurization for bacteria control, tramp oil removal, etc. A summary of these proposed recycling options is presented below in Table 5.

Table 5. Coolant Recovery System Guide

Waste Cutting Fluid Disposal Considerations

Proper care of cutting fluids is important if the maximum benefits of using water-based coolants are to be realized. Extending the cutting fluid life is an economically justifiable policy and certainly should be the first step of any waste management program. However, while prolonging the life of a cutting fluid is possible, extending it indefinitely is not. Eventually, it will have to be treated and disposed of as a waste.

Cutting fluid wastes are various as well as numerous because of the different types of coolant, systems, chemicals, etc. out on the market. Their chemical makeup not only reflects their original makeup, but also the conditions and operations of their used. In some cases, many cutting fluid wastes contain a greater amount of machine tool lubricating oils and/or suspended solids than they do cutting fluid. This is why extreme care should be taken when disposing cutting fluid wastes.

Hazardous Waste Regulations

In 1976, Congress passed the Resource Conservation and Recovery Act (RCRA) which defined the term hazardous waste. The term hazardous waste is a "solid waste, or combination of solid wastes, which because of its quantity, concentration or physical chemical or infection characteristics may:

1. Cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness.

2. Pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed."

Furthermore, it should be noted that hazardous wastes are defined in terms of properties of a solid waste. It should be noted that a solid waste need not be a solid; it can also be a liquid, semi-solid, or a contained gaseous material.

A solid waste is hazardous if it meets one of the three conditions:

1. Exhibits, on analysis, one or more characteristics of a hazardous wastes. The four characteristics have been delineated by the federal Environmental Protection Agency (EPA). Any solid waste that exhibits one or more of them is classified as a hazardous waste. These characteristics are:

   - Ignitability listed as a D001
   - Corrosivity listed as a D002
   - Reactivity listed as a D003
   - Toxicity; 32 metals listed which concentrations greater than their proposed concentration levels.

   Further elaboration of these listings can be found in the Code of Federal Regulations, Volume 40, Part 261, Section 261.2, Subpart C.

2. Has been named as a hazardous waste and listed.

3. Is a mixture containing a listed hazardous waste and non hazardous solid waste (unless the mixture is specifically excluded or no longer exhibits any of the characteristics of hazardous waste).

Heavy Metals Consideration

Heavy metals are hazardous due to their toxic effect on various body systems. Most of these materials will not break down readily in the body which thus can accumulate over time. Small and large operations of machining operations can produce a fluid containing heavy metals. These fluids and wastes are considered a hazardous waste according to the toxicity testing procedures. Generators are responsible for determining if a particular solid waste is hazardous. They must either test the waste material using standard methods or have sufficient knowledge about the waste to assess whether it exhibits any of the characteristics of a hazardous waste.

On/Off-Site Disposal Options

Once the machine shop have recycled or recovered their coolant as much as feasible, the disposal of the waste cutting fluids is the next priority. There are several options that can be considered: evaporators, ultrafiltration, wastewater disposal, chemical treatment, and contract hauling and disposal services.

Evaporators

Evaporators are generally considered suitable for low volumes of waste due to the large amount of energy required from labor-intensive activities required to evaporate a small volume of material.

Normally, spent coolants contain 90 to 95% water. As such, evaporators are used to remove the water from the waste liquids, thereby reducing the volume of waste needing to be disposed. The advantages of utilizing evaporators are:

- little chemical knowledge to operate
- use very little space
- simple to operate
- type of coolant used (synthetic, semi-synthetic, or soluble oil) is not critical.

However, evaporators do not eliminate waste, only reduce the volume. Also, evaporators, as mentioned earlier, are very labor intensive when it comes to cleaning the units. As such, evaporators should be considered when other treatment systems do not meet a shop's needs and waste must be disposed by contract.

Ultrafiltration

Ultrafiltation systems can provide effective treatment of the wastewater by separating the water from the oily waste. The quality of water is then appropriate for sewer disposal. The concentrate from ultrafiltration may be processed from oil recovery, if only the tramp oil is recovered, or incinerated if classified as hazardous material.

Wastewater Disposal

Small amounts of spent cutting fluid can be disposed of as a wastewater if it is not a hazardous waste. Some requirements that will allow for disposal of spent cutting fluids in a municipal sewer system are as follows [2].

1. Are water soluble
2. Receive regular biocide additions
3. Have not become septic
4. Have had the chips and fines removed
5. Have had the tramp oil absorbed to less than 100 mg/l
6. Have a pH between 6.0 and 9.0
7. Do not contain toxic concentrations of heavy metal ions

However, it is of the upmost importance that the wastewater treatment plant, POTW, or municipal sewer of your district be contacted for specific regulatory limits and subsequently approval of any disposal.

Chemical Treatment

Chemical treatment is the addition of chemicals which change the nature of the liquid waste. Most firms rely on chemical-splitting technologies due to the complexity of the treatment process. Chemical treatment beyond pH control is generally not an option for most facilities.

Contract Hauling and Disposal Services

Contract hauling and disposal service costs are generally very high; therefore, many shops opt for in-plant treatment. However, for small volumes of waste which are extremely complex and toxic, it may be cheaper to have it hauled away for chemical treatment or incineration.

IV. HEALTH CONCERNS

The machining of metals involves the risk of human exposure to many chemicals. The biggest concerns of cutting fluids are dermatitis, infections, and respiratory problems. However, most of these problems stem from the contaminants within the coolant and not the coolant itself. Because human contact is unavoidable in the workplace, chemicals, ingredients, and potential health effects should be considered when selecting such items.

Under the Hazardous Communication (Right-To-Know) Standard, material safety data sheets (MSDS) are required and should be readily available from the vendor on all fluids purchased. By using MSDSs, important health and safety information can be obtained when workers are exposed to these fluids.

V. SUMMARY

In order to assure success with any type of fluid management/maintenance and waste reduction program, there are several major items that need to be addressed and dealt with upon beginning such programs.

Management Commitment - Without the support from upper management, the programs that have been presented will not and cannot be completely successful.

A Complete Understanding of Your Particular Situation - A complete plant survey and evaluation of your coolant's conditions are essential to the success of your program.

A Lubricant Supplier - A good rapport with the coolant supplier who is willing to work with you to get the most out of his product is essential.

A Recycling Equipment Supplier - A supplier who has experience and is willing to work closely with you and your coolant supplier to select the most feasible recovery system and options for your facility's needs.

As everything else, fluid economics is rapidly changing. As such, continuous involvement and awareness is needed because of the emerging issues that involve fluid productivity, health and safety, and as environmental concerns are exposed. However, by obtaining and maintaining a steady state condition of your cutting fluid, facilities will be able to address their coolant problems and will be able to efficiently and effectively handle the particular problem. Thus, through careful fluid management, metal working facilities can substantially improve fluid life performance which will ultimately reduce overall costs.

VI. APPENDICES

Appendix A. Supplier Address List

Note: Most of these companies stock more than one type of coolant recovery technology.

System Type	Supplier
Media-Based (Filtration)	CECOR Incorporated 102 Lincoln Street Verona, Wisconsin 53593 (608) 845-6771
	COMO Industrial Equipment, Inc. P.O. Box 1671 Janesville, Wisconsin 53547 (608) 756-3838
	Dynamic Process Industries 1900 W. Northwest Hwy Dallas, Texas 75220 (214) 556-0010
	The Harvard Corporation P.O. Box 108, US Highway 14 North Evansville, Wisconsin 53536 (608) 882-6330
	Sanborn 25 Commercial Drive Wrentham, Massachusetts 02093 (508) 384-5346
	Hyde Products, Inc. 28045 Ranney Parkway Cleveland, Ohio 44145 (216) 871-4885
Natural Property System	
	Hyde Products, Inc. 28045 Ranney Parkway Cleveland, Ohio 44145 (216) 871-4885
	Cincinnati Milacron Marketing, Co Products Division, P.O. Box 9013 Cincinnati, Ohio 45209
	Dynamic Process Industries 1900 W. Northwest Hwy Dallas, Texas 75220 (214) 556-0010

ALMCO
902 East Main Street
Albert Lea, Minnisota 56007
(507) 377-2102

Mechanical Separation

Centrifuge	Balcon, Inc. 502 E. Vermont Street Indianapolis, Indiana 46202 (317) 788-4411 (800) 241-9712
	Hyde Products, Inc. 28045 Ranney Parkway Cleveland, Ohio 44145 (216) 871-4885
	Sanborn 25 Commercial Drive Wrentham, Massachusetts 02093 (508) 384-5346
Hydroclone	ALMCO 902 East Main Street Albert Lea, Minnisota 56007 (507) 377-2102
	Hyde Products, Inc. 28045 Ranney Parkway Cleveland, Ohio 44145 (216) 871-4885
Ultrafiltration	Hyde Products, Inc. 28045 Ranney Parkway Cleveland, Ohio 44145 (216) 871-4885
	Sanborn 25 Commercial Drive Wrentham, Massachusetts 02093 (508) 384-5346
Pasteurization	Dynamic Process Industries 1900 W. Northwest Hwy Dallas, Texas 75220 (214) 556-0010
	Sanborn 25 Commercial Drive Wrentham, Massachusetts 02093 (508) 384-5346

Appendix B. Case Studies on Coolant Recovery

Case Study #1

RECYCLE WATER-SOLUBLE COOLANT

The purpose of recycling coolant is to extend coolant life, improve performance, and reduce costs. A coolant recycling module would provide an efficient process for removing oil - and other contaminants, controlling bacteria, and adjusting the mix concentration of the coolant. This facility uses three types of water-soluble coolant for certain machinery within the facility. Fourteen multi-spindle machines use a soluble oil with an extreme high pressure additive; six forging machines use Waylube 460; and six end-finishing machine use Waylube 68. However, calculations will only involve the multi-spindle machines because of the greater quantities involved. Thus, the savings within this recommendations will be somewhat conservative because the savings from the Waylube lubricants.

The coolant that is used within the facility is removed and disposed as necessary. The main reason it is disposed is due to solids that collect in the coolant and from the odor caused by the bacteria that becomes trapped within the coolant. Currently the spent coolant is taken to a concrete pit where the oil is skimmed from the top and the coolant itself is allowed to evaporate. This waste stream is not considered hazardous.

We recommend purchasing a coolant recycling unit to recycle the water-soluble coolant onsite (Refer to Appendix A). However, selection of a coolant recovery system depends on many factors such as the type of coolant being recovered (ie synthetic, semi-synthetic), the type of metal chips in the coolant, etc. Therefore, close contact with a coolant recovery vendor is a vital part to purchasing a system that is feasible for your facility.

Through purchase of a recycling system, we estimate an annual savings of $17,746. Should the waste stream be determined to be hazardous, there is a 20% state income tax credit available for the purchase and installation costs of equipment used to recycle hazardous waste. The payback for this recommendation is calculated to be 1.6 years.

DATA

* Amount of Concentrated Coolant Purchased
  Soluble Oil (Extreme High Pressure) .... 5,390 gal/yr
* Amount of Water/Coolant Mixture Used
  Soluble Oil (EP)
  - 15 gal (oil):260 gal (water) .... 98,817 gal/yr [1]
  - Cost of Soluble Oil (EHP) $5.36/gal
* Estimated Loss of Coolant due to
  Evaporation and Spillage .... 1,500 gal/yr
* Cost of Electricity (Including Demand) ... $0.09/kWh [2]
* Cost of Water .... $3.00/1000 gal[2]
* Labor Rate .... $20 /labor hour

* Coolant Recovery Unit

    Batch Quantity Capacity (can handle up to) .... 300 gal
    kW Rating of Coolant Recovery Unit .... 15 Kw
    Load Factor .... 0.7% [3]
    Fraction of Coolant Recovered 95%
    Treatment Rate .... 1 gpm [4]
    Handling Time per Batch .... 1.0 hrs [3]
    Purchase Cost of Coolant Recovery Unit .... $23,500 [4]
    Purchase Cost of Split Sump Cart .... $3,500 [5]
    Purchase Cost of Makeup Fluid Module Option ... $1,800 [6]

1 Obtained from client.
2 Average cost for electricity and water.
3 Estimated.
4 Information obtained from vendor.
5 The split sump cart is used to transport the dirty coolant from the machines to the coolant recovery unit which will be in a centralized area.
6 A concentration monitor gives a digital indication of the coolant concentration in the clean tank. Water or coolant concentrate is automatically added as required to maintain the desired water/concentrate ration.

CALCULATIONS

Current Annual Cost

A. Purchase Cost

= [(quantity of coolant used)(purchase cost)]
= [(5,390 gal)($5.36/gal)
= $28,890/year

B. Estimated Water Cost

= [(quantity of coolant concentrate)(water/coolant mixture quantity)(coversion factor)](water cost)
= [(5,390 gal)(260 gal/15 gal)($3/1,000 gal)
= $280/year

C. Estimated Total Cost

= (purchase cost) + (estimated water cost)
= ($28,890/yr) + ($280/yr)
= $29,170/yr

Proposed Annual Cost (using a coolant recovery unit)

Batch Processing Time (treatment rate)

= (machine sump capacity)(treatment rate)(conversion factor)
= (275 gallons)(1 gpm)(60 min/hour)
= 4.6 hours/day

Note: This is the time to treat the spent coolant from one multi-spindle machine sump. However, this time does not represent the actual man hours required to process the coolant because the recycling unit for the most part is automated. It is assumed that one batch will be run every working day when the coolant in the machine sumps need to be cleaned.

Annual Quantity of Batches

= (coolant/water mixture disposal)/(sump capacity)
= (98,817 gal/year)/(275 gal/sump)
= 359 batches/year

Note: Since there are approximately 200 annual working days for the one-ten hour shift, 1.5 batches can be run per each working day. Furthermore, this assumes that 100% of the coolant will be recycled and does not consider the loss of coolant once the chips are removed from the machines.

A. Operating cost of Coolant Recovery Unit

= Electricity cost + labor cost
= [(kW rating of recovery unit)(operating time per batch)(number of batches per year)(cost of electricity)] +[(handling time per batch)(batches per year)(labor rate)]
= [(15 kW)(4.6 hrs/batch)(359 batches/yr)($0.09/kWh)] + [(1.0 hrs/batch)(359 batches/yr)($20/hr)]
= $9,409/year

B. Coolant Replacement Cost

Coolant Replacement from Recycling

Based on the 95% recovery capability of the recycling unit, approximately 275 gallons x 0.95 = 261 gallons can be recovered per batch. Therefore, 14 gallons from each batch will be charged with new coolant.

Total Gallons/Batch	:	275
Gallons Reusable	:	261
Quantity Lost	:	14

Therefore, the cost of coolant is as follows:

= [(new coolant needed per batch)(batches per year)(coolant cost)(15:260 mixture ratio) + (estimated amount of coolant lost due to evaporation and spillage)(15:260 mixture ratio)(coolant cost)
= (14 gal/batch)(359 batches/yr)($5.36 /gal)(5.76%) + (1,500 gal)(5.76%)($5.36/gal)
= $2,015 /year

Total Proposed Cost

= (operating cost of coolant recovery unit) + (coolant replacement cost)
= ($9,409/year) + ($2,015/year)
= $11,424/year

Annual Dollar Savings

= (current annual cost) - (proposed annual cost)
= ($29,170 /year) - ($11,424 /year)
= $17,746/year

Annual Waste Reduction

= (total quantity of coolant recovered per batch)(number of batches per year)
= (224 gallons/batch)(359 batches /year)
= 80,416 gallons of coolant mixture /year

Note: 4,632 gallons of this coolant mixture is the concentrated soluble oil. i.e. (80,416 gal)x(15:260 mixture ratio)

Implementation Cost

= [(recovery unit cost includes installation cost) + (split sump cart cost) + (makeup fluid module option)]
= [($23,800) + ($3,500) + ($1,800)]
= $29,100

Note: PPTAP and OSDH do not recommend or endorse any specific vendor or system. The particular type of equipment and its options presented were used merely as an example and to provide an economic analysis.

Simple Payback

= (implementation cost)/(annual savings)
= ($29,100)/($17,746/year)
= 1.6 years

Note: Useful life of the coolant may be extended by using high quality make-up water. For example, dissolved solids may react with chemicals in coolant, enhance bacterial growth, create foaming problems, and affect product quality.

Coolant quality may also be improved by good housekeeping which will prevent and minimize contamination of coolants by dirt, oil, etc. There should be no disposal of paper, cigarette butts or other debris in coolant sumps.

Case Study #2

SEGREGATE AND RECYCLE WATER BASED COOLANT

The purpose of recycling coolant is to extend coolant life, improve performance, and reduce costs. A coolant recycling module would provide an efficient process for removing oil, and other contaminants, controlling bacteria, and adjusting the mix concentration of the coolant.

This facility uses water-based coolant for certain machinery within the facility. This coolant is removed and disposed periodically because of the odor caused by bacterial growth that begins to build up in the coolant, with use. The bacteria are attracted by the tramp oils in the coolant. Currently the waste coolant is collected in drums along with the other waste streams, and disposed of through a fuels burning operation. The hauling and disposal are handled by an outside agency.

We recommend that you consider, collecting the waste coolant in separate drums, and purchasing a coolant recycling unit to recycle the water based coolant on site. Selection of a coolant recovery system depends on many factors such as the type of coolant being recovered (i.e., synthetic, semi-synthetic), the type of metal chips in the coolant, etc. Through purchase of a recycling system, we estimate an annual savings of $21,088. This unit would not qualify for the 20% state income tax credit available for equipment that recycles hazardous wastes since this waste stream has not been established to be hazardous. The payback for this recommendation is calculated to be 1.1 years.

DATA

* Amount of concentrated coolant purchased 325 gal/yr
* Amount of water/coolant mixture used .....3,250 gal/yr[1]
* Amount of water/coolant mixture disposed..3,111.5 gal/yr
* Amount of water/coolant mixture lost due to splashing and evaporation..........295 gal/yr[4]
* Purchase Cost of Concentrated Coolant ....$9.28 /gal[2]
* Estimated Disposal Cost ....$6.36 /gal[2]
* Cost of Electricity......................$0.0661 /kWh
* Labor Rate ....$10.00 /hour
* **Coolant Recovery Unit**
*   Batch Quantity ....60 gal[3]
*   kW Rating of Coolant Recovery Unit ....13.5 Kw
*   Load Factor ....0.7%[4]
*   Fraction of Coolant Recovered ....95%[5]
*   Treatment Rate ....60 gph
*   Handling Time per Batch ....0.50 hrs[4]

DATA CONTINUED

* Purchase Cost of the Coolant Recovery Unit.... $25,300[5]
* Purchase Cost of the Sump Cart................ $4,225[5]

1 This quantity includes the ten to one ratio with water
2 Approximate cost based on total disposal cost
3 Based on sump cart size. We are considering the use of a 60 gallon sump cart.
4 Estimated
5 Vendor quote

CALCULATIONS

Current annual cost

A. Purchase cost

= (quantity of coolant used)(purchase cost)
= (325 gal/yr)($9.28 /gal)
= $3,016 /yr

B. Estimated disposal cost

= (total quantity disposed)(disposal cost)
= (3,111.5 gallons/yr)($6.36 /gal)
= $19,789 /year

C. Estimated total cost

= (annual purchase cost) + (estimated annual disposal cost)
= ($3,016 /yr) + ($19,789 /yr)
= $22,805 /year

Proposed annual cost (using a coolant recovery unit)

Number of batches per year

= (coolant disposal quantity)/(batch size)
= (3,111.5 gallons/yr)/(60 gallons/batch)
= 52 batches/year

Batch processing time (treatment rate)

= (batch size)/(treatement rate)
= (60 gallons)/(60 gallons/hr)
= 1.0 hours

A. Operating cost of coolant recovery unit

= Electricity cost + Labor cost
= [(kW rating of recovery unit)(operating time per batch)(number of batches per year)(cost of electricity)] +[(handling time per batch)(batches per year)(labor rate)]
= [(13.5 kW)(1 hrs/batch)(52 batches/yr)($0.0661/kWh)] + [(0.50 hrs/batch)(52 batches/yr) x ($10.00/hour)]
= $ 306 /year

B. Coolant replacement cost

Based on the 95% recovery capability of the recycling unit, approximately 60 gallons x 0.95 = 57 gallons can be recovered per batch. Therefore, 3 gallons of spent coolant from each batch needs to be disposed. Further some fresh coolant would have to be added to replace the coolant lost through evaporation and splashing. Therefore, the cost of coolant is as follows:

= [(new coolant needed per batch)(batches per year) + (new coolant needed to replace lost coolant)] x Cost of coolant /(10-1 ratio of coolant and water)
= [(3 gal/batch)(52 batches/yr) + (295 gal/yr)] x ($9.28/gal)/(10)
= $419 /year

C. Disposal costs

Disposal cost of spent coolant

= (total quantity of spent coolant disposed)(estimated disposal cost)
= (3 gal/batch)(52 batches/yr)($6.36 /gal)
= $992 /year

D. Total proposed cost

= (operating cost of coolant recovery unit) + (coolant cost) + (disposal costs)
= ($306 /year + $419 /year + $992 /year)
= $1,717 /year

Annual dollar savings

= (current annual cost) - (proposed annual cost)
= ($22,805 /year) - ($1,717 /year)
= $21,088 /year

Annual waste reduction

= (quantity of coolant recovered per batch)(number of batches per year)
= (57 gallons/batch)(52 batches/year)
= 2,964 gallons of coolant/year

Implementation cost

= (cost of recycling unit + cost of sump cart)
= ($25,300 + $4,225)
= $29,525

Available tax credit

None

Note : Since this waste stream has not been established to be hazardous, the equipment purchased to recycle it does not qualify for the state income tax credit. It would be advisable to determine if this waste is really hazardous. Also, if this waste stream is determined to be non hazardous, disposal costs would be greatly reduced.

Simple payback

= (implementation cost)/(annual savings)
= ($29,525) / ($21,088 /year)
= 1.4 years

VII. REFERENCES

1. Gary Hunt, "Metal Working Fluid Waste Reduction Program," Focus: Waste Minimization, Fall 1988, pg. 4-5.

2. Timothy Cole, "Know Your Coolants," Cutting Tool Engineering, October 1990, pg. 59-62.

3. Westmont Products, "Lubrication Seminar."

4. Iowa Waste Reduction Center, "Cutting Fluid Management in Small Machine Shop Operations," University of Northern Iowa, 1990, pg. 10.

5. James P. Mackey, "Metal Working Fluid Recycling: Approaches That Work," Hyde Products Inc., Presented as part of Templex Metal Fluids Seminar, 19 April 1988.

6. Cecor Inc, "SumpCleaner/Filter-Air."

VIII. BIBLIOGRAPHY

"Lubrication Seminar." Westmont Products.

"SumpCleaner/Filter-Air." Cecor, Inc.

Cole, Timothy. "Know Your Coolants." Cutting Tool Engineering, October 1990, pg. 59-62.

Hunt, Gary. "Metal Working Fluid Waste Reduction Program." Focus: Waste Minimization, Fall 1988, pg. 4-5.

Hyde Products Inc. "Metal Fluid Seminar." Presented as part of Templex Metal Fluids Seminar.

Iowa Waste Reduction Center. "Cutting Fluid Management in Small Machine Shop Operations." University of Northern Iowa, 1990, pg. 10.

Mackey, James P. "Metal Working Fluid Recycling: Approaches That Work." Hyde Products Inc., Presented as part of Templex Metal Fluids Seminar, 19 April 1988.

Schaffer, George. "Recycling Coolant Reduces Cost." American Machinist, February 1978.

Skells, George. "Fluid Management Skills." Cutting Tool Engineering, October 1990, pg. 52-57.

Threadgill, James A. "Care and Control of Coolant Sumps." Plant Engineering, January 1961.