POLLUTION PREVENTION GUIDE
TO
USING
METAL REMOVAL FLUIDS
IN
MACHINING OPERATIONS

Developed for the

United States Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
26 W. Martin Luther King Drive
Cincinnati, OH 45268

by the

Institute of Advanced Manufacturing Sciences, Incorporated
Machining Xcellence Division
1111 Edison Drive
Cincinnati, Ohio 45216
800-345-4482
http://www.iams.org
and its

International National Industrial Working Group

TABLE OF CONTENTS

DEDICATION

In November of 1995, the United States Environmental Protection Agency (USEPA) provided a grant to the Institute of Advanced Manufacturing Sciences, Inc (IAMS) of Cincinnati, Ohio to develop this manual. As part of this effort, IAMS formed an industrial working group to provide direction and insure the relevance of this manual to industrial applications. This industrial working group consisted of companies located throughout the United States and Canada. This manual is dedicated to the companies and the individuals who supported the effort to produce this manual and try to apply science to the selection and maintenance of metal removal fluids.

Thomas F. McClure
Manager, Special Projects
Institute of Advanced Manufacturing Sciences, Incorporated
Machining Xcellence Division
Cincinnati, Ohio

The following organizations and individuals are recognized for their efforts and support of this effort.

United States Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Cincinnati, Ohio

John O. Burckle   T. David Ferguson

Institute of Advanced Manufacturing Sciences, Incorporated
Machining Xcellence Division
Cincinnati, Ohio

Michael E. Finn	Michael D. Gugger	Dr. Anil Srivastava
Steven W. Cadigan		Frank W. Gorsler
D. Robert Adams		J. David Layne

Machinability Test Devlopment
Working Group
Chair

Boeing Commercial Airplane Group
Manufacturing Research and Development
Seattle, Washington

Lawrence D. Rissler

Environmental Health and Safety
Working Group
Co – Chairs

Quaker Chemical Corporation
Conshohocken, Pennsylva

Kathryn Strang

Rotex, Incorporated
Cincinnati, Ohio

Eugene Shelton

Selection and Management
Working Group
Co – Chairs

Pollution Prevention Technologies
Incorporated
Plymouth, Minnesota

Ronald Rich

Institute of Advanced Manufacturing
Sciences, Inc
Cincinnati, Ohio

Thomas F. McClure

Working Group Members

A. W. Chesterton Company
Groveland, Massachusetts

Susan Riley
Mark Guenther
Sam Mirza
Machinability Test Development

Castrol
Metalworking Division
Downers Grove, Illinois

James W. Brumgard
Selection and Management

Equilon Enterprises LLC
Houston, Texas

Dr. Robert Profilet
Selection and Management

Hangsterfers' Laboratories
Mantua, New Jersey

Frank Murray
Joseph Gentile
Enironmental, Health, and Safety

Imperial Oil
Exxon Research and Development
Sarnia, Ontario, Canada

Dr. Donald Hewson
Selection and Management

ITW Vortec
Cincinnati, Ohio

Karen Shearwood
Selection and Management

Mag-Chem Incorporated
Mississaugua, Ontario, Canada

Keith Klayh
Selection and Management

Advanced Manufacturing Science and Technology
Rossford, Ohio

Dr. Stuart C. Salmon
Machinability Test Development

Milacron, Incorporated
Products Division
Cincinnati, Ohio

Dr. Charles Yang
Machinability Test Development

Jerry P. Byers
Selection and Management

Enpro
Cincinnati, Ohio

Leonard Ardizzone
Selection and Management

Solutia, Incorporated
Saint Louis, Missouri

Dr. Michael Trehy
Richard Green
Selection and Management

General Motors North American Operations
Research and Development
Warren, Michigan

Dr. Jean M. Dasch
Machinability Test Development

The Lubrizol Company
Wickliffe, Ohio

Bruce Koehler
Machinability Test Development

Houghton International
Valley Forge, Pennsylvania

Thomas F. O'Brien
Machinabilty Test Development

Unist
Grand Rapids, Michigan

Wally Boelkins
Selection and Management

International Lubricants, Incorporated
Seattle, Washington

Blaine Rhodes
James Jones
Selection and Management

Wynn Oil Company
Azusca, California

Joseph DeBlasi
Greg Hewgill
Selection and Management

Kistler, Incorporated
Amherst, New York

David Nowack
Machinability Test Development

Master Chemical Corporation
Perrysburg, Ohio

Milton Hoff
Adrian Fuller
Machinability Test Development

The Timken Company
Canton, Ohio

John W. Fantin
Selection and Management

Pace International
Seattle, Washington

Michael J. Enright
David Sykes
Selection and Management

Wagstaff
Hebron, Kentucky

Carl Wickland
Machinability Test Development

Spartan Chemical Company
Toledo, Ohio

L. C. (Skip) Wolford
Selection and Management

Yuma
Shelbyville, Indiana

Gary T. Farwick
Selection and Management

Members

Aeroquip
Van Wert, Ohio

Steven Goings

Chemtool, Incorporated
Crystal Lake, Illinois

James Athans

CWC Industries, Incorporated
Cleveland, Ohio

Gerald D. Lancaster

Black Clawson
Shartle Division
Middletown, Ohio

Edward Lang

Commonwealth Oil
Harow, Ontario, Canada

Fred Herdmann

Delphi Chasis Systems
Dayton, Ohio

David Yen

Briggs and Stratten
Milwaukee, Wisconsin

John Mourand

Cummins Engine
Lakewood, New York

Terry Mara

ELF Atochem
Corwells Heights, Pennsylvania

Larry Oldfield

Cast- Fab Technologies
Cincinnati, Ohio

SteveTimmons

Cut-Clean Industries
Liverpool, New York

Sam Polimino

ETNA Products
Chagrin Falls, Ohio

Michael T. Bell

Gleason Works Rochester, New York	Osteos Biologies San Antonio, Texas	TES Technologies Cincinnati, Ohio
Stan Moran	Robert Tynmann	Daniel Markiewicz
Glowe, Incorporated Fraser, Michigan	Parker Hannafin Cleveland, Ohio	The Metalworking Group Cincinnati, Ohio
Robert Glowe	Rick Taylor	Michael Kelly
HiLite Industries Carrollton, Texas	Petro Processors, Incorporated South Holland, Michigan	Unichemia International Chicago, Illinois
SamBerry	Richard Siegel	David Wolf
Maine Metal Products Association Portland, Maine	Positrol, Incorporated Cincinnati, Ohio	Wallover Oil Company Strongville, Ohio
Mark Arienti	Richard Weber	Eric Kielts
Meyer Tool, Incorporated Cincinnati, Ohio	Southwest Ratite Cooperative, Incorporated Tuscon, Arizona	Westmont Products Irving, Texas
David A. Johnson	Thomas Collier	Jerry Finn
Michigan Technological University Houghton, Michigan	Speedfam Elk Grove, Illinois	
Dr. John Sutherland	David Deets	

SECTION 1

Introduction and Philosophy

SECTION 1

INTRODUCTION

Let's be honest. The fact that you are reading this manual means you are involved with or are about to be involved with metal removal fluids (also known as metal working fluids (MWF's), coolants, lubricants, etc). You have our sympathy and our support. The journey you are about to begin is not an easy one and is filled with hidden dangers. In the end you will either be a hero or a villain.

If you're in a crisis situation, I suggest you skip the remainder of this section and go directly to Section 2. Section 2 has a listing of common problems associated with metal removal fluids and suggests steps to take to correct these problems.

Those of us who helped put this manual together theoretically know something about metal removal fluids and life in manufacturing operations. We've lived through a great deal of anquish over metal removal fluids and have survived. Sometimes we were the heroes and sometimes we were the villains.

The goal of this manual is simple. We hope to provide you with enough information that we can simplify solving metal removal fluid problems and extend the life of your metal removal fluid. The companion manual to this one, we hope, will provide you with enough information that, if needed, you can select a new metal removal fluid for your organization.

To begin, we have to understand and accept some basic concepts.

1. What does your company make?

If you answered parts, chips, or even scrap, you're not alone. Most people answer exactly the same way. Unfortunately, you're not quite correct. The goal of any manufacturing operation is to make money. Everything else is a means to achieve that goal.[1] While product design, material, manufacturing, quality, and customer service are all important. However, they do not generate revenue. Ultimately someone must buy and pay for your product. Assuming you can sell this product for more than it costs to produce, you will make a profit. Contrary to what others may tell you, there is nothing wrong in making a profit.

2. Metal removal fluids are expensive.

A study conducted by Daimler Benz in Germany in the mid 1980's identified the purchase, maintenance, and disposal of metal removal fluids as contributing 16% of their overall manufacturing costs.[2]

At the beginning of this effort, a survey of small to medium machining organizations located throughout the United States was conducted. This survey showed that an average organization purchases approximately 500 gallons of metal removal fluid concentrate per year. The average cost of the metal removal fluid concentrate is $10 / gallon. The cost of metal removal fluid concentrate for the average organization is $5000. However, the cost of metal removal fluids far

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[1] E. Goldrat and J. Cox, *The Goal; A Process of Ongoing Improvement,* North River Press, Inc., Croton on the Hudson, NY, pp41 (1986)

[2] P. Johanssen, "Null Losung", Mercedes Benz will Kuhlhlscherstoff reuzueren. Industrie Anzeiger

exceeds this price. There are labor costs associated with mixing, maintaining, and fluid change outs. There are also material costs associated with purchasing chemicals and equipment to maintain metal removal fluids. Finally, there are metal removal fluid disposal costs. Due to changing federal, state, and local regulations, metal removal fluid disposal costs are rapidly increasing and are becoming a primary cost driver in the selection and use of metal removal fluids. The survey helped to characterize some of the non metal removal fluid concentrate costs and allows one to estimate the “real” cost of metal removal fluids. Presented in Table 1 is one such estimate.

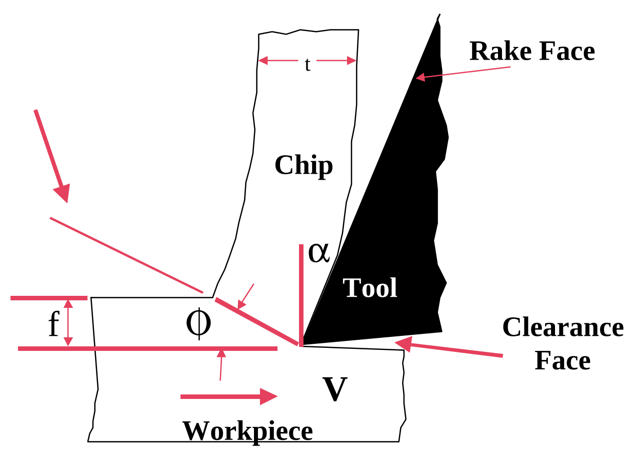
It might be an eye-opening experience for you and your organization to attempt to calculate your own metal removal fluid costs. Presented in Table 2 are suggested points of contact to help you develop the information needed to calculate your costs.

3. Why use metal removal fluids ?

In order to understand the function of the metal removal fluid, one must understand the process of chip formation. A simple two-dimensional representation of idealized chip formation is shown in Figure 1. Chip formation can be approximated by the shearing and sliding of a series of deformed layers of metal. The region where shearing takes place is known as the shear plane. The sheared metal then slides over the rake face of the cutting tool.

In addition to the machined part and chip, one of the primary products of the chip formation process is thermal energy or heat. Temperatures at the cut edge are usually in the range of 260° to 480°C (500° to 800° F) for high speed steel tools and 420° to 650°C (800° to 1200° F) for carbide tools. A metal removal fluid properly applied to the cut zone absorbs the heat and carries it away. During machining, the temperature depends upon the balance between the rate at which heat is generated and the rate the heat is dissipated. As such, it is easy to understand why many on the manufacturing floor refer to metal removal fluids as coolants.

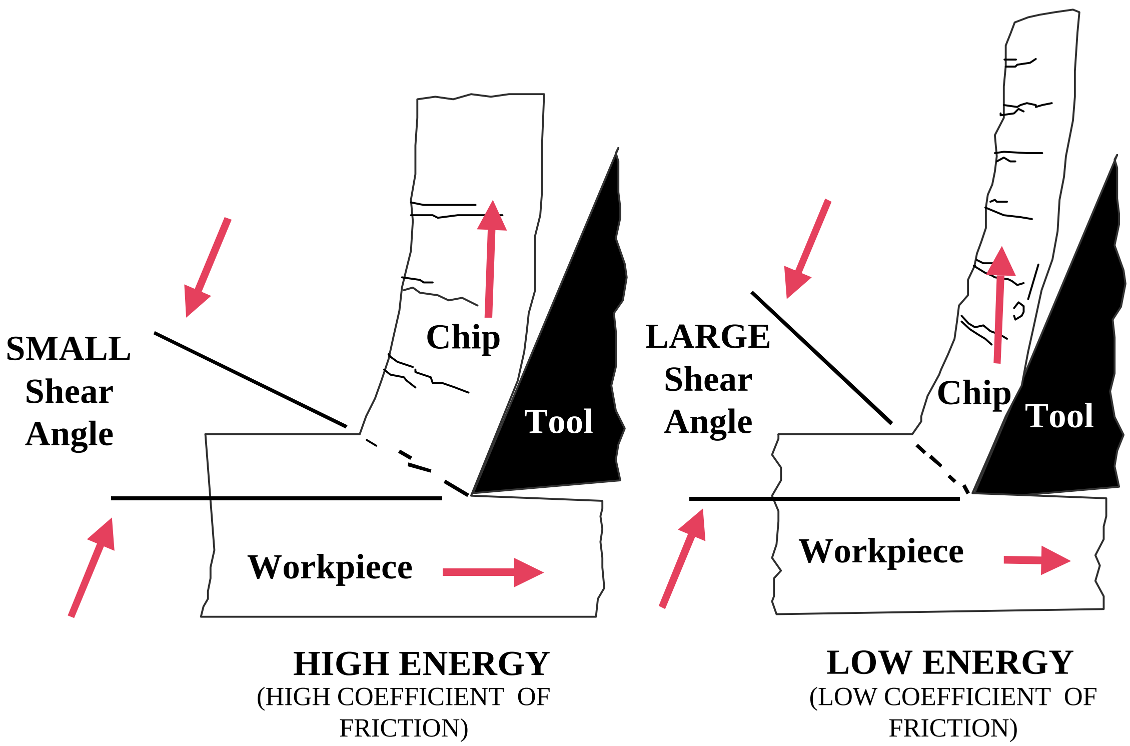
Figure 1. Idealized Chip Formation Process (Turning)



The rubbing action or friction of the chip as it moves across the rake face of the tool also generates heat, although to a lesser degree than the chip formation process. Additional heat is generated as a result of the friction between the tool flank and the cut surface. Reducing friction in these cases results in a reduction of the heat generated. The traditional way of reducing friction is to apply a lubricant to the cut zone.

In addition to lowering the friction at the chip-tool-workpiece interface, the addition of a lubricant affects the amount of heat generated during chip formation process. The amount of heat produced in the shear zone depends on the size of the shear angle. If the shear angle is small, then the plane in which deformation takes place (the shear zone) extends a considerable distance ahead of the tool. The results is a short, thick chip and considerable heat. If the shear angle is large, the shear path is short and the result is a longer, thinner chip. This type of cut generates less heat. Application of a metal removal fluid reduces the friction between the chip and tool effectively increasing the shear angle and reducing heat. This effect is demonstrated in Figure 2.

Figure 2. Effect of Metal Removal Fluid on Chip Formation



By reducing friction and removing heat from the chip-tool-workpiece interface, the operational lifetime of the cutting tool is prolonged. Depending upon what you are trying to accomplish, this means less cutting tool changes or the use of higher machining parameters (speeds and feeds) in the course of producing parts. Now be careful here, many times companies use tool lives as machining process performance indicators. Tool life is a function of the workpiece material, tool material, tool design, machining conditions, and chip-tool-workpiece temperature. Tools, just like metal removal fluids, are expensive. As such, there are many organizations out there who worry a great deal about tool life. Please remember the goal of your organization is to make money. Pushing parts out the door to your customers is the way to do this. You must balance the desire for long tool lives with the reality of the production schedules. Some organizations that demonstrate long tool lives may not be operating at their most productive level.

In addition to their cooling and lubricating properties, metal removal fluids provide additional important functions that enhance overall part quality. The use of metal removal fluid chiller systems delivers metal removal fluid to the cut zone at extremely constant temperatures. This allows one to achieve and maintain very tight tolerances.

In some applications, the ability to remove chips (or grinding swarf) from the cut zone is a primary function. Particularly in drilling applications, this prevents the chip from being re-cut as it travels up the drill flute and helps prevent packing of the drill flute. For this reason, high pressure metal removal fluid application systems are becoming more prevalent in drilling applications.

Perhaps one of the most critical roles that metal removal fluids play actually has little to do with machining. Depending upon the nature of the workpiece material and the final product, the presence of corrosion on machined surfaces is usually unacceptable. Ingredients present in metal removal fluids impart protection from atmospheric corrosion after the workpiece has been removed from the machine tool. Generally, this protection is short lived (less than 3 months) and for longer-term corrosion protection, the part most likely will require cleaning (removal of metal removal fluid) and application of a more traditional corrosion preventative.

So summarizing quickly, we use metal removal fluids to

- **Cool the chip-tool-workpiece interface**
- **Lubricate the chip-tool-workpiece interface**

This allows us to

- **Extend tool life** and/or
- **Operate at higher machine tool speeds and feeds**
- **Enhance part quality (tolerances)**
- **Flush chips or swarf from the cut zone**
- **Temporary corrosion protection**

The problem may not be with the metal removal fluid but with what your organization is doing to it.

A great deal of science goes into the formulation and testing of metal removal fluids prior to their introduction into manufacturing community. The science to maintain and extend the life of metal removal fluids is well known and not necessarily expensive nor difficult but generally is not used. Additionally, many organization fail to recognize that many of their everyday practices abuse metal removal fluids and sooner, much more than later, they experience problems with their metal removal fluid. Upon experiencing these problems, the first inclination is to throw the problem fluid out of the organization and find a new one. Six months to a year later, they run into a similar problem with the new fluid and throw that one out of the organization. As this is written, there are six to eight major metal removal fluid manufacturers in the United States. Each manufacturer makes approximately 200 different fluids. Therefore, there are between 1200-1600 different fluids for you to evaluate. It is highly likely that you would close your operation before you ran out of fluids to test.

So please make a promise:

I will not change metal removal fluids until I understand the problem with the existing one

This may not be easy. Pressures will be brought to bear from various sources such as your management, health and safety, the union, and the workers. Recognize you will need more time to identify and replace the metal removal now used in your organization. Some one, perhaps, you yourself, picked the present metal removal fluid being used. Try to identify the reason this particular fluid was chosen. Once identified write them down for those who follow you.

With this promise and remembering the items addressed above, you can begin to solve your metal removal fluid problems. As previously stated, Section 2 contains a list of common problems associated with metal removal fluids. Hopefully, they will help resolve most of your day to day fluid problems.

TABLE 1

Metal Removal Fluid
“REAL”
Cost Estimate

Metal Removal Fluid Concentrate	
500 gallons/year X $10.00 / gallon =	$ 5,000
Water required to obtain a 5 % concentration	
9500 gallons / year X $0.05 / gallon* =	$ 475
Labor required to mix fluid (Annual)	
208 man hours / year X $35.00 / man hour** =	$ 7,280
Labor required for Fluid Change Outs (Annual)	
208 man hours/year X $35.00 / man hour** =	$ 7,280
Labor Lost while changing out fluid (Annual) (Assuming Machine Operator does not change Fluid)	
208 man hours/year X $35.00 / man hour** =	$ 7,280
Disposal of Waste Metal removal fluid	
10,000 gallons of waste fluid X $3.00 / gallon =	$30,000
TOTAL	**$57,315**

* Cost of 1 gallon of water in Cincinnati, OH.
** Includes employee benefits

TABLE 2

Potential Points of Contact to Develop "Real" Cost of Metal removal fluids

Subject	Contact
Quantity and price / gallon of metal removal fluid(s) / year	Purchasing Department
Concentration of metal removal fluid (s) used in the plant	Maintenance Department/ Machining Department
Cost of Water Publicly Owned Water Works	Purchasing Department/
Labor Involved in mixing metal removal fluid (s) (Burdened Labor rates for plant employees	Maintenance Department/ Machining Department (Human Resources / Finance)
Labor Involved in changing out metal removal fluid(s) (Burdened Labor rates for plant employees	Maintenance Department/ Machining Department (Human Resources / Finance)
Labor lost during fluid(s) change out Machining Department (Burdened Labor rates for plant employees)	Maintenance Department/ (Human Resources / Finance)
Other Fluid Maintenance Costs if appropriate (biocides, filters, lab equipment, fluid management program)	Maintenance Department Machining Department/ Purchasing Department
Labor associated with Fluid Maintenance (Burdened Labor rates for plant employees)	(Human Resources/Finance)
Cost of Fluid Recycling if appropriate (recycling equipment, lab equipment, chemicals)	Maintenance Department/ Machining Department/ Purchasing Department
Labor associated with Recycling (Burdened Labor rates for plant employees)	(Human Resources/Finance)
Cost of Spent Fluid Disposal / Waste Treatment (equipment, chemicals, outside supplier)	Purchasing Department Waste Treatment Maintenance Department
Labor Associated with Disposal (Burdened Labor rates for plant employees	Maintenance Department/ Machining Department (Human Resources/Finance)

SECTION 2

<u>Troubleshooting</u>

SECTION 2

TROUBLESHOOTING

In the next few pages is a list of the common mistakes individuals make when dealing with metal removal fluids. By going through this list and attempting to correct those problems you recognize, you may prevent problems in the future.

Also presented in this section, are the causes and remedies to address the most common problems associated with metal removal fluids. If you are experiencing any of these problems, it is hoped that these pages will provide a basis for resolving the problem or problems.

Feel free to duplicate these pages and bring them out to the shop floor to help you solve the problem.

Common Mistakes

Cause	Remedy
• Lack of Training	• **READ MANUAL**
• Contamination of fluids by spilled metal removal fluid, floor cleaners, floor absorbents, etc.	• **READ MANUAL**
	• **READ MANUAL**
• Failure to remove ways and hydraulic lubes	• **READ MANUAL**
• Lack of filtration	• **READ MANUAL**
• Failure to Monitor and Control metal removal fluid Concentration (lack of metal removal fluid management program)	• **READ MANUAL**
• Allow fluid stagnation Can be due to shutdown Can also be due to areas in machine tool that have poor circulation	• Ensure that fluid is always circulated (pump or aeration) install sparging line
• Improper storage conditions–too hot or cold	• Ensure adequate storage conditions
• Cross contamination caused by recycling equipment	• Make sure all fluid is drained back into the machine being cleaned
• Lack of awareness of water quality and its impact on metal removal fluids	• Obtain periodic water quality analysis
• Improper mixing	• Add metal removal fluid to water
• Misapplication of fluid	• Ensure metal removal fluid is where it is supposed to be in adequate quantities
• Fluid selection	• **READ MANUAL**
• Use of bleach as a disinfectant	• Potential generation of hazardous gases
• Use of any non approved sump cleaner	• Can cause foaming, staining, extremely tight emulsions that are difficult to break for disposal
• Indiscriminate mixing of metal removal fluids	• Can cause separation (see separation)

Chip Removal –Hot Chips

Cause	**Remedy**
• Low flow rate in chip return lines	• Ensure adequate metal removal fluid flow rate and velocity to keep lines clean
• Oily residues on chips in bins can cause fires	• If problems have occurred, spray chip bins with inhibitor
• Insufficient dwell time in sump-excessive pumping rate vs. sump size	• Calculate actual turnover rate of the system vs. ideal, and adjust parameters to more acceptable figures Contact manufacturer of machine tool for recommended turnover rates
• Poor machine tool design	• Contact machine tool manufacturer and advise them of the problems you are having with their system

- ***Damp to dry chips seem to have a higher potential to burn than do wet chips***
- ***Dissimilar metals (galvanic corrosion) can exacerbate this problem***

Chips Settling/Fusion and Removal from Cut Area

Cause	Remedy
• High Chloride levels in metal removal fluid	• Get water quality analysis Improve water quality Consult with metal removal fluid manufacturer for metal removal fluid recommendations
• Metal removal fluid concentration (too low)	• Adjust concentration
• Inadequate housekeeping	• Increase cleaning frequency
• Formulation (some fluid types are more likely to have problems with fusion)	• Consult manufacturer for alternate fluid recommendations
• Galvanic Corrosion, dissimilar metals can form cells	• Separate dissimilar metals during machining or thoroughly remove chips and particulate
• Degraded inhibitor in metal removal fluid	• Clean chips from sump ensure metal removal fluid quality in sump over time
• Biological degradation	• Adjust metal removal fluid concentration and biocide
• Turbulent sump conditions	• Install baffles in sump-maintain sump metal removal fluid levels, increase sump size to accommodate swarf levels
• Excessive swarf buildup in sump	• Perform regular swarf removal
• Particle size	• Consider filtration options and sump modificationss if necessary
• Base material (aluminum's, etc.)	• Consult manufacturer for metal removal fluid options, consider swarf removal options
• Low metal removal fluid volume and/or pressure	• Increase metal removal fluid flow and/or pressure
• Misdirected metal removal fluid flow	• Adjust nozzle
• Machine design or process design	• Contact machine tool manufacturer
• Cutting tool design	• Consult tool manufacturer for superior chip breaking design
• Switch to dry or micro lubricated machining without consideration of chip removal	• Incorporate alternate chip removal strategies (compressed air blow off, etc.)

Dermatitis

Cause	**Remedy**
• High Metal removal fluid Concentration	• Adjust to recommended levels
• Sensitivity of employee	• Check hygiene/medical department
• Contaminated metal removal fluid	• Follow maintenance instructions in manual
• Sensitive skin (abraded skin as well)	• Use barrier creams or gloves, protective clothing
• Defatting of skin	• Limit exposure to fluids Check pH of fluids Check detergency of fluids
• Shop rags in pockets, etc.	• Improve employee personal hygiene

Disposal Difficulties

Cause	Remedy
• Regulated ingredients	• Consult supplier msds sheet and waste hauler, local regulatory budies
• Expense	• Check with consultant re: waste stream consolidation, investigate in house treatment possibilities such as evaporation, membrane filtration (refer to expanded section on filtration), chemical treatments, waste hauler
• Solubilized metals	• Check metal removal fluid and sump cleaners for tendency to solubilize metals
• Other contaminants	• Check cleaners to verify if they cause metal removal fluid to be difficult to split

Foaming

Cause	Remedy
• Water quality	• Soft water can cause foam- use blend of hard and soft water-check with supplier
• High concentration	• Adjust concentration to recommended limits
• Water loss via evaporation	• Replenish metal removal fluid at a lower concentration than target operating concentration
• Additive depletion	• Call supplier Make sure that you replenish new metal removal fluid on a regular basis, to replenish additives
• Mechanical problems	• Do scheduled maintenance on machine-check for air leaks
• Contamination	• Cleaner, detergents, soaps accidently added
• Metal removal fluid injection, pressure and flow	• Consult metal removal fluid supplier
• Biological contamination	• Consult supplier for biological remedies

Instability
(Separating in the Sump)

Cause	Remedy
• Mixing incompatible metal removal fluids	• Don't mix products
• Too low concentration	• Adjust to proper concentration
• Biological Contamination	• See biological controls
• Water quality, buildup of Total Dissolved Solids (TDS)	• Check water analysis, improve water conditions
• Tramp oil Consumes emulsifiers Floating layer looks like separated oil	• Remove tramp oil
• Improper mixing	• Add metal removal fluid to water and not water to metal removal fluid
• High pressure metal removal fluid injection	• Consult fluid / equipment manufacturer
• Centrifugation	• Consult fluid / equipment manufacturer
• Temperature	• Consult fluid manufacturer
• Freezing	• Store and ship concentrate in heated environments
• Prolonged storage-some products may separate	• Check manufacturer for shelf life information
• High temperature storage	• Store at temperatures recommended by manufacturer
• Dissolved metal buildup	• Check manufacturer for appropriate metal removal fluid recommendation
• Outside contaminants	• Consult manufacturer for appropriate cleaners, etc. Verify coatings, inhibitors already on parts

Non Ferrous Staining

Cause	Remedy
• High pH	• Consult manufacturer for metal removal fluid selection
• Hard water (poor water quality)	• Get water analysis, improve water quality-check with manufacturer
• Sensitivity of alloy	• Consult manufacturer of metal removal fluids
• Metal removal fluid instability	• See metal removal fluid instability
• Product selection (may contain incompatible ingredients)	• Consult manufacturer
• Machining dissimilar metals	• Better chip removal and particle filtration

Odor

Cause	Remedy
• Particle Buildup (creates bacterial sites)	• Remove particles, filtration, high speed centrifugation (refer to manual)
• Chemical	• Consult manufacturer
• Cleaner formulation may contain phosphates and other additives which encourage Bacterial growth	• Consult manufacturer
• Poor shop hygiene	• Improve general hygiene in the shop
• Improper ventilation	• Improve ventilation
• Biological contamination	• Adjust metal removal fluid concentration, • Identify as bacteria or fungi or both • Consult supplier for treatment recommendation • Dump, clean thoroughly, recharge, and maintain properly from that point on
• Tramp oil: oil itself may be high odor; recycled oils may have troublesome ingredients, tramp oils serve as a food source	• Remove tramp oils. Refer to manual.
• Tramp oil layer causes anaerobic growth	• Remove via skimmer or coalescer.

Paint Stripping

Cause	Remedy
• Inferior paint or inadequate surface preparation	• Clean and prepare surface and repaint (see paint manufacturer for recommendation)
• Fluid selection (some formulations have a greater tendency to strip inferior paints)	• Consult metal removal fluid manufacturer and paint manufacturer for paint selection.

Residues

Cause	Remedy
• High concentration	• Adjust concentration down
• Hard water	• Get water analysis • Improve water quality • Check manufacturer for hard water tolerant formulations
• Biological growth	• Remove masses, adjust concentration up, fungicide, or bactericide as indicated by Biostix test analysis
• Tramp oil	• Remove tramp oil repair source of leaks
• Fluid formulation	• Contact manufacturer for alternatives
• Oxidation of fluids-addition of lime, or oxidizers (bleach)	• Consult manufacturer-partial or complete sump change

Rusting

Cause	Remedy
• Low concentration	• Adjust concentration
• Low pH	• Biological contamination Poor source water quality
• Chemical imbalance	• Consult metal removal fluid manufacturer
• Chemical contamination	• Consult metal removal fluid manufacturer
• Machine maintenance	• Keep machine clean • Coat machine with inhibitor
• Corrosive atmosphere Rusted parts Water quality/sulfates, chlorides Multi metal machining Seasonal atmospheric conditions	• Check sources of corrosives, plating lines, pickling lines
• Stagnant fluid	• Circulate fluid, filter, aerate
• Prolonged storage of finished parts	• Apply corrosion preventive
• Storage conditions	• Separating media (cardboard may be corrosive-change media)

Smoking/Misting

Cause	Remedy
• Cutting tool and part shape	• Tools and parts that cause metal removal fluid misting should be worked on enclosed equipment with ventilation
• Machine process with metal removal fluids	• Consider microlubrication as an alternative
• Process	• Install mist collectors
• Extreme metal removal fluid pressure	• Ensure that metal removal fluid pressure is adequate to cool/remove chips but does not cause stream to explode
• Temperature	• Either increase metal removal fluid flow or adjust machining parameters to generate less heat
• Tramp oil reduces cooling	• Remove tramp oil
• Metal removal fluid nozzle wear	• Worn nozzles cause metal removal fluid break up
• Emulsion instability	• Split emulsions can aggravate misting
• Inadequate or removed shielding	• Ensure that machine is adequately shielded-shields are in place
• Ventilation inadequacies	• Improve or localize ventilation as needed
• Improper metal removal fluid application-positioning	• Too much fluid applied • Fluid hitting chuck instead of tool • Metal removal fluid should be off when machine is not in use
• Formulation	• Investigate shear stable metal removal fluid formulas-consult manufacturer

- ***Microlubrication is often referred to as mist lubrication. This can cause confusion.***

Tool Life
(surface finish, squealing, smoking)

Cause	Remedy
• Low concentration	• Adjust concentration
• High concentration	• Adjust concentration
• Wrong metal removal fluid selection	• Consult manufacturer
• Inadequate application of metal removal fluid	• Ensure nozzles, lines are open and positioned correctly and metal removal fluid flow is adequate
• Metal removal fluid cleanliness	• Remove chips, tramp oil, check filters
• Metal removal fluid separation	• Ensure metal removal fluid integrity, see metal removal fluid instability
• Machine parameters	• Check tool, feed, speed and depth of cut

SECTION 3

Fluid Management

SECTION 3

FLUID MANAGEMENT

At this point, it is assumed that you have solved today's metal removal fluid problem and have some time to contemplate your metal removal fluids before tomorrow's problem . Please recognize that if you had **maintained or managed** that fluid system the metal removal fluid problem you just addressed or may address tomorrow may not have occurred or could have been solved more quickly.

It is also assumed that you have read Section 1 of this manual and recognize that the metal removal fluid(s) you are using can be a major economic factor in your manufacturing operations. The best way to minimize the cost associated with your metal removal fluids is to insure they have **long service lives**. This is true whether you have small sumps or large central systems. By having longer service lives you minimize

- the amount of metal removal fluid you purchase
- the amount of water you have to purchase to dilute the water based metal removal fluids
- the production downtime time associated with cleaning machines during metal removal fluid change outs
- the amount on used metal removal fluid which has to be treated or disposed.

Take a quick look back at Table 1, by reducing these factors you reduce the cost of your metal removal fluid.

The best way to insure long metal removal fluid lives is to **maintain or manage** your metal removal fluids. Now in the next few pages, we are going to devote some time to ways to monitor the condition of your fluids. Even if you don't feel that your company is big enough for this type of program (and no company is too small to try and save money), there are still actions you can take that will prolong the life of your metal removal fluids. These are:

1. Clean system before introducing fresh metal removal fluid.

   We recognize that pumping used metal removal fluid out of the sump and putting new metal removal fluid in the sump minimizes production downtime. However, it's a matter of being penny wise and dollar foolish. By failing to clean the machine tool's metal removal fluid delivery system, you are exposing the new fluid to the exact same conditions that forced you to change the fluid anyway. This is particularly true in the case of bacteria and/or fungi. By draining the sump, you are disposing of the majority of the bacteria/fungi but as long as there is some residual metal removal fluid in the system, there will be some residual bacteria/fungi. These bacteria/fungi consume the organic components (oil and other addtives) present in your metal removal fluid. By allowing them to come in contact with fresh fluid, you are basically providing them with a free lunch. Due to the abundance of food, they will rapidly multiply and within a short period of time, you will find yourself pumping out the machine tool sump again. This indicates a short fluid life meaning you're costing your company money and production time in the long run.

   By cleaning the machine tool fluid delivery system, you are minimizing the exposure of your new metal removal fluid to the factors that caused it to fail in the first place.

This will extend the life of your fluid and prevent production downtime. Your metal removal fluid supplier should be able to provide you with a machine cleaner and instructions on how to use it. The clean out procedure should include circulation of the cleaner through the machine tool fluid delivery system to insure you reach hard to get at locations in the machine tool. This is very easy for machines with individual metal removal fluid sumps but can become complex for individual machines connected to central systems. If cleaning a machine connected to a central system, make sure you take precautions to prevent the machine cleaner from contaminating central metal removal fluid system. The use of dams is highly recommended.

2. Operate system at correct concentration

We have all heard the joke that the three most important things in real estate are Location, Location and Location. In metal removal fluid management there is a Similar phrase but it reads ***Concentration, Concentration and Concentration***.

All water based metal removal fluids are designed to be operated at a given concentration dissolved or emulsified with water. The correct concentration is important to provide the cutting operation with optimal lubricity and cooling, corrosion protection, and resistance to bacteria and fungus. Operating a system at a low concentration may result in decreased tool life, bacteria and/or fungus problems, possible corrosion and eventual downtime. Operating a system at a too high of concentration may result in dermatitis, foaming, heavy residues and excess cost.

There might be some discussion in your plant as to what is the right metal removal fluid concentration. In fact, its highly probable that depending upon plant location, operation, or machinist that the metal removal fluid concentration varies. There are many situations where, if your plant runs multiple shifts, the metal removal fluid concentration in a given machine varies by shift. The operators of this machine all have different opinions as to what is the proper concentration. So they change the concentration at the start their shift. Do you think this might be costing you money?

Proper mixing procedures are critical to the attainment of long metal removal fluid life and economical use of metal removal fluid concentrate, as well as to the elimination of metal removal fluid concentration related problems. Premixing the metal removal fluid concentrate with pure water in accordance with the metal removal fluid manufacturer’s recommendation assures efficient use of the concentrate.

One type of metal removal fluid mixer is the Venturi Type. It has the advantage of being inexpensive. However, the metal removal fluid water concentration it produces can fluctuate with changes in the inlet water pressure, metal removal fluid concentrate level in the drum, and fluid temperatures.

Another type of metal removal fluid mixer is the positive proportioning pump equipped with interconnected water and concentrate cylinders. The metal removal fluid concentration produced with this mixer is not affected by aforementioned variables.

Most metal removal fluid manufacturers recommend that you use a lower concentration of metal removal fluid to maintain the initial concentration. For example, to maintain a 5% concentration of a semi-synthetic metal removal fluid, you would a make-up solution of 2-3%. Remember, that as the metal removal fluid is used, both make-up water and any water present in the product itself evaporates increasing the concentration of chemicals present in the metal removal fluid. Usage of the fluid also causes some of these chemicals to degrade and addition of a low concentration make-up solution replaces these degraded chemicals. Work with your metal removal fluid supplier to develop the correct make-up concentration.

Large systems will suffer from evaporation and metal removal fluid dragout. Therefore, these systems should be monitored carefully and metal removal fluid additions should be made on a regular basis to maintain a constant working concentration.

3. Ensure makeup water is of adequate quality.

The quality of water is of extreme importance to the efficient use of aqueous metal cutting fluids. The life of the system, filter efficiency, foam characteristics, and even tool life and finish, are influenced by the quality of the water. It is essential that the quality of the available water be studied and the proper water miscible metal removal fluid be selected on the basis of the local water characteristics.

Water used for making metal removal fluid mixtures should be made as pure as possible for the most economical and trouble-free use, but even the “cleanest” of shop water is rarely pure. Water throughout the United States is usually contaminated with “hardness” minerals or salts, or both, which have a detrimental effect upon the cutting and grinding fluid mixtures made from them. Rain water is soft, containing no minerals. Water obtained from lakes and rivers may be relatively free of minerals or be heavily contaminated, depending upon whether or not the waters have been able to dissolve minerals during their natural course. Water from wells may be relatively free of contamination but, usually, most well water is heavily contaminated with minerals.

Minerals in metal removal fluid water can cause corrosion of machine tools and machined parts, can aggravate deposition of residues on machine tools, and can increase the rate at which bacteria and fungi grow in the metal removal fluid. The “hardness” of water is calculated on the basis of 17 parts per million of calcium carbonate per U.S. gallon as being equal to one “grain”. Hardness is caused almost entirely by calcium and magnesium ions. Other elements, such as iron and aluminum, are minor sources but can produce undesirable corrosion effects far out of proportion to their concentration. Occasionally, hardness can be increased by zinc which been dissolved from newly galvanized pipes.

Water hardness “uses up” metal removal fluid concentrate and tends to force it out of solution. The net effect is that part of the concentrate does not contribute to cutting efficiency; instead, it may appear as a gummy deposit or residue on the machine and parts. In addition, the lost concentrate can cause parts machines to rust.

Minerals other than hardness “salts,” such as chlorides and sulfates, contribute to rust and, the higher their concentration; the more of the cutting fluid concentrate is require to prevent corrosion. The sulfates are particularly detrimental because they promote the growth of the sulfate-reducing bacteria Desulfovibrio desulfuricans (1) which produce a “rotten egg” odor.

A machine metal removal fluid sump acts as a “still”; the more the fluid is aerated; the more the water evaporates. As this occurs, the minerals in the water increase, causing more residues to form and corrosion to increase. Usually, fluid “makeup”, or additions to the machine sump, are on the order of 5 to 20% per day, depending upon the sump capacity and the severity of the operation. Hence, over the period of a month, solids buildup in the fluid mixture can be three to four times that of the original water. The following are examples of how makeup continually concentrates the solids. A soft water of 3 grains hardness can have a hardness of 12 to 14 grains at the end of one month, and 24 to 27 grains in two months of use. A water of 12 grain hardness would yield water of 48 to 52 grains in one month, or 96 to 104 grains in two months. Therefore, the purer the water for making metal removal fluid mixtures is initially, the longer the fluid can be used before gumming and corrosion problems occur.

A simple test to check for water residue involves filling a 0.50 in. by 2 in (13 by 51 mm) petri dish with the water, placing it into an oven at 220^{o} F (104.4^{o}C), and drying to observe the residue. This procedure can be repeated four times with another petri dish (replenishing water after each evaporation) to ascertain the effects of metal removal fluid water replacement on a monthly basis.

Minerals (hardness and/or salts) are very detrimental to the stability of metal removal fluid mixtures. The more concentrated these minerals are to begin with, the faster they affect the fluids adversely and the more rapidly they build up to cause instability. In fact, minerals can become so troublesome that the concentrate will not mix properly, or that metal removal fluid tanks would have to be dumped and refilled every week to prevent gumming and corrosion problems.

Minerals in water not only cause residues to form and corrosion to occur, but they also help bacteria to grow. These aspects are among the most important considerations in water miscible fluid usage, and the results can be of substantial economic effect. One method of removing “hardness” water is to run it through a zeolite softener. However, this process replaces the “hardness” with ordinary monovalent salt so that residues can build up as before, and corrosion can be even more of a problem. Another method by which minerals are removed from water is reverse osmosis. Reverse osmosis (or R.O.) is a process that uses relatively high pressure (typically 200-800 psi or 1.3 to 5.5 MPa) to force water, containing dissolved minerals and suspended solids, through a semipermeable membrane to produce a high purity water.

Pure water can also be produced by deionization (2), which removes all minerals by chemical absorption so that the effluent is equivalent to distilled water. With this method, no residues are left by evaporation of the water and corrosion effects from minerals are eliminated.

Recommended techniques are the use of reverse osmosis or deionization. Many shops which have plating operations already have deionizer installations so that this water source can easily be used for metal removal fluid mixes. If not, the cost of installing a satisfactory unit, which will produce trouble-free metal removal fluids, is more economical than the cost of rusted machines and workpieces.

Some adjustments can be made in formulating a product to resist the effects of bad water for a period of time. With mineral-free water, however, neglecting other factors, the metal removal fluids could be run indefinitely. Therefore, in bad water areas (water over 8 grains hardness) consult your supplier for recommendations.

4. Minimize and Control Bacteria

Bacteria are of great importance in connection with water miscible fluid usage because bacteria can create a number of problems. Bacteria usually need water in order to grow and they enter the fluid from:

1. Make-up water
2. Parts
3. Air
4. Operator’s Hands
5. Sludge Deposits in the Machine Tool Sump

The majority of bacteria need oxygen for growth, and some types multiply by dividing in two approximately every 20 to 30 minutes. Hence, starting with one bacterium and calculating the numbers resulting from its splitting each 20 minutes, the population that would result in 12 hours (provided none would die during that time) is derived as follows:

Time (hours)	Population of Bacteria
1	8
3	512
6	262,000
9	134,000,000
10	268,000,000
11	516,000,000
12	1,032,000,000

While most bacteria do not survive in the typical water miscible cutting and grinding fluids, the more important of the less than a dozen bacteria which do, are called:

Escherichia coli[2]	Pseudomonas aeruginosa[3]
Klebsiella pneumoniae[2]	Pseudomonas oleovorans[3]
Paracolabactrum species[2]	Salmonella typhosa[1]
Proteus vurlgaris[2]	Staphylococcus aureus[1]

Usually more than one is present at a time. These are known as “facultative” <+> aerobic bacteria. They prefer air (oxygen) for best growth, but can adjust themselves to grow in the absence of oxygen. There is another kind of bacteria, known as anaerobic (Desulfovibrio desulfuricans), which grow in the absence of oxygen, but do not die in the presence of oxygen. These bacteria multiply by dividing in two every four hours. They grow much more slowly than the aerobic, but the results of their growth can be very objectionable. They do not grow in fresh clean fluid, but will usually grow once the fluid has been attacked by the aerobic bacteria. In fact, when makeup is added to a "stinking" metal removal fluid, it will "freshen up" the mix for a few hours until the aerobic bacteria can break it down.

Lubricating and anticorrosion properties are built into cutting fluid concentrates. When they are properly mixed with water, they will perform their functions of lubricating and cooling and leave and anticorrosion film. However, if bacteria feed on the concentrate in the presence of the water, the lubricating effect is reduced so that cutting tool life and grinding wheel life are gradually reduced, and corrosion can be expected to increase. The reason for this is that when bacteria multiply, the faster they will attack the fluid. Therefore, the rate of bacterial growth is important. If fewer bacteria are grown in a given length of time harmful effects can be minimized.

The two most troublesome aerobic bacteria are Pseudomonas oleovorans and Pseudomonas aeruginosa. The bacterium Pseudomonas oleovorans lives in oil, so it multiplies rapidly in those machines which leak lubricating and hydraulic oils. Consequently, all steps should be taken to reduce such oil leakage. If leakage cannot be prevented, the free floating tramp oils should be skimmed from the surface and the partially emulsified and mechanically mixed tramp oil should be removed by centrifugation.

The bacterium Pseudomonas aeruginosa lives on practically anything: minerals in the water, metal removal fluid concentrate, discarded food, oils, etc. Note that Pseudomonas oleovorans and Pseudomonas aeruginosa are both aerobic and facultative and are two species which are present in all water miscible fluids in use because they are difficult to kill.

The main type of anaerobic bacteria which grows in water miscible fluids is Desulfovibrio desulfuricans. It is very difficult to control and is found in almost all metal removal fluids. It produces a very strong odor of rotten eggs (hydrogen sulfide, commonly known as "Monday morning stink"), and can cause severe dark staining of machines and workpieces. In the presence of iron it can eventually make the fluid turn a black color. When this occurs, it is practically impossible for an operator to stand by the machine because of the foul odors.

One of the most important ways of overcoming the problems produced by Desulfovibrio desulfuricans is for the cutting fluid manufacturer to be selective in the raw materials used in the product. Bacteria are very specific in their actions and some materials are better food for them than others. Thus, the raw materials used should be those which are most resistant to bacterial degradation.

Second, the incorporation of effective microbicides is also helpful in preventing or retarding degradation caused by bacterial action. Very few microbicides are effective, however, and they must be used with great care. Some microbicides which function very well in clean products can actually serve as food for the various types of bacteria found in water miscible fluids which are so easily contaminated.

Third, it is extremely important to maintain good housekeeping; in fact, this is the most important way to control bacterial growth. It does little good to put fresh metal removal fluid into a machine. All this accomplishes is to give fresh food to the bacteria which are in the sump, on machine surfaces, and in metal removal fluid circulating systems. If the machine is thoroughly cleaned with an appropriate cleaner, thoroughly rinsed, and filled with clean, fresh fluid, fluid life will be greatly increased.

On a single machine of approximately 25 gallons (95 liters) capacity, usually from one to five gallons makeup per day is added, based on an average of 5 to 20% makeup per day. Although central systems will generally require three to five times the amount of fluid used by an individual machine, when multiplied by the number of individual machines, much less fresh makeup fluid is required to maintain fluid concentration in a central system. The result is that, if the bacteria in a central system multiply at the usual rate, the smaller ratio of fresh makeup will not act as effectively as a microbicide against them. The net growth will result in more numbers in a given volume of metal removal fluid mix compared with the sump of individual machines.

Further, bacteria tend to settle to the bottom of tanks. Therefore, in any system where the fine metal particles and other silt settles, so do the bacteria. This combination helps the anaerobic bacteria to grow best, i.e., where it is farthest from the air (oxygen). Consequently, it is usually more difficult to control bacterial growth in large central systems than in single machine sumps. However, proper cleaning of central systems sumps between metal removal fluid changes; effective filtration; continuous removal of tramp oils by centrifugation; properly designed, clean metal removal fluid headers (preventing sludge buildup); effective flushing of return flumes; and the judicious use of the proper microbicide can keep bacterial growth under control.

Fungi contamination can also present a problem. In general, there is a natural antagonism between various bacteria and fungi. Therefore, it is necessary that, in keeping bacteria under control, fungi are not permitted to flourish. It is a well known fact that the uncontrolled use of antibiotics to kill bacteria in people will result in taking over and creating problems equal to, if not greater than, the original infection.

Minerals in the water help to feed fungi just as they do bacteria, so that removal of minerals from the water also helps keep fungi under control.

5. Maintain good housekeeping

Having worked your way through the above sections, you should now recognize that maintaining good housekeeping practices will be essential to long metal removal fluid lives.

To avoid problems related to surface finish, a good filtration system needs to be in place. A metal working fluid is subjected to the metal chips and fines of the process, airborne contamination from cascading fluid over a part and the machine, machine leakages, residues left on the part from previous operations, water, operators, etc.. Whenever possible, these contaminants need to be removed. Filtration may just be one part of an extensive system that also includes skimmers, chip conveyors and return troughs. A set of instructions on how to select and size your filtration system was developed by Mr. Leonard Ardizzone of ENPRO, a division of Hydrotech, Inc., for this manual. It is presented in Appendix 4.

Where fine straining ends and coarse filtration begins is a moot question. A porous fabric is fundamental to industrial filtration (as opposed to bed-type). There pore size or opening of the fabric will determine the particle size which may be removed. The fabric may be made from woven fiber or extremely fine wire. Or, it may be matted material such as paper or felt.

For any pore size of filter, any coating of oil on the particles to be filtered can have a decided effect upon drainage of water from the filtered particles or swarf. Hence, leakage of hydraulic or lubricating oils into the metal removal fluid system can alter the filtering rate considerably.

The most common filtering system, where large volumes of fluids are involved, consists of self-advancing rolled fabric. They are actuated by pressure- or vacuum-sensitive devices. This type of area filtration is far more prevalent than fixed-plate or tubular filters.

Filtration may be enhanced in terms of through-put by vacuum or negative pressure. The effectiveness of filtration in terms of minimum particle size removal can be improved by supplemental coatings or filter media. Media such as fuller's or diatomaceous earth, highly surface-active silica particles, and others, add depth or apply the bed principle to area filtration. Filter media are rarely use excepted with fixed plate or tubular areas.

Nonpermeable filtration, sometimes termed "edge filtration," involved discs or stacked plates; thus, it is filtration by clearance. Clearance filtration is readily made self-cleaning by scraper blades. To some extent, this may be regard as ultrafine straining.

The build up of chips and metal fines in the metal removal fluid delivery system provide an excellent "nesting" area for anerobic bacteria. The periodic removal of this debris minimizes the potential for bacteria growth and extends metal removal fluid live.

Many of us accept tramp oil as a way of life. Tramp Oil is defined as oil that is present in the metal removal fluid but is not part of the original concentrate. If enough tramp oil is introduced into the machine tool sump that it can seal off the metal removal fluid to the air promoting the growth of anerobic bacteria. As stated above, the anerobic bacteria cause the infamous "Monday morning odor" problem. Minimizing the amount of tramp oil in the system through the use of skimmers or maintaining circulation in the system even when the machine tool is shut down will help prevent this problem.

Tramp oil is often the result of the machine tool hydraulic system leaking oil into the metal removal fluid. If this is true in your case, fix the leak. This is probably the most difficult task facing industry today. It requires that you shut down the machine which in turn shuts down production on that machine. This, of course, effects the amount of money you can make but what most people fail to realize is that oil leaks are costing you money as well. You pay for the oil leaking into the metal removal fluid. Then you must pay again because the tramp oil shortens the life of the metal removal fluid.. Based on the calculations made in Table 1, you are paying more than twice for not fixing that hydraulic oil leak.

Please recognize that in some cases, you cannot avoid tramp oil. Oil is applied to the ways of the machine tool to insure movement of the workpiece during the machining operation. As the metal removal fluid comes in contact with the ways or the oil drips off the way, tramp oil is introduced into the metal removal fluid. Finding a metal removal fluid that is compatible with your way oil , using an oil skimmer and maintaining constant fluid circulation will help maximize fluid life.

Maintaining good housekeeping also means teaching your company's employees not to use your machine tool sumps as trash receptacles. In many plants, one finds paper cups, banana peels, sandwiches, cigarettes butts, and other trash floating in the metal removal fluid. These not only introduce bacteria into the sump but provide nutrients for bacteria. Trash should go in trash containers even if it means the employee has to walk away from the machine tool.

Just doing these five things willprolong the life of your metal removal fluids and help save some money. However, assuming you want to save your company real money and have more time to address the important company issues your boss says needs your undivided attention, it is strongly recommended that you begin a fluid maintenance program. (By the way, starting a Total Predictive Maintenance program for the manufacturing operation is a good idea, too.)

Starting a Program

First of all you don't need to go out and hire a chemist to run this program. Most likely anyone in your facility is capable of performing these tasks and recording the data required for this program.

The first thing you need to do is to assign the responsibility to an individual. What responsibility you may ask? This individual will be responsible for conducting the fluid management program, posting test results, and addressing problems. This individual will also make decisions as to when metal removal fluid is added to the machine sumps, when additives are added, as well as when sumps are dumped and systems cleaned.

It is suggested that you give this responsibility to someone with people skills as he or she will meet with some initial resistance. Depending upon what type of shop you work in, your machine operators may have the authority or access to metal removal fluid so that they control the concentration they use in their machines. They may not want to give up this control as most likely they feel they know best. Now don't discount this knowledge because in reality they spend much more time machining parts than you or I do and probably know what works best in a given operation. However, people do tend to get stuck in ruts and are resistant to change. You and the individual running this program need some early successes to convince the machine operators this will work. That's why you post charts but we will talk about that later.

If you run more than one shift, you may need more than one individual. Strange things often happen on second and third shift that no one can adequately explain. If you can't have more than one person running the program recognize that the responsible individual may be working cross shift and may not be at work everyday at the same time.

Before you offer up this individual to the company as a human sacrifice, you need to invest in educating him or her. Your metal removal fluid supplier will be happy to provide training to this individual. This provides an opportunity for your designated individual to meet and establish a relationship with the technical staff of the metal removal fluid supplier. These contacts may prove invaluable when trying to solve a tough problem.

Once the individual has finished training, he will know what type of equipment is needed to run the fluid management program. Depending upon the size and level of sophistication you feel you need, it should not prove overly expensive. You should expect to spend a few hundred to a few thousand dollars to equip the program.   This investment is minor in comparison to the potential cost savings associated with your metal removal fluids. Use the information in Table 1 or Table 2 (Section 1) if your boss gives you a hard time.

It is suggested that you focus your efforts and investment on equipment you need to perform the daily or weekly fluid condition tests. The monthly or less frequent tests require more significant investment and most likely will not prove cost effective to your company. You can ask your metal removal supplier to do this tests or contract with an outside laboratory. If you contract with an outside laboratory make sure they've run these tests before.

Fluid Management Team Formation and Operation

Depending upon the size of your organization, you may want to form a fluid management team. This is not just a support group for the individual running the fluid management program but also people who will be assigned tasks and some responsibilities. The team is there to help the fluid indvidual resolve issues he cannot handle on his own. The first thing you need to get is agreement from upper management that you need this team   This will make forming the team easier because you can always name drop when you encounter a reluctant invidual.

It is suggested that you have a representative from manufacturing engineering, engineering, environmental health and safety, maintenance, quality, purchasing, and management. If your plant is unionized, a union representative should also be a member of the team. The management guy is on the team to make sure every one else plays the game.

With the exception of management, you should ask for volunteers. However, remember those who are volunteered by their bosses are just as good.   You should aim as high up the management chain as possible. Maintenance manager is good, Vice President of Manufacturing is better, the Plant Manager or President of the company is even better. After the initial meetings, these individuals can delegate their responsibilities but their presence at the first few meetings and sporadic appearances as the program will make a lasting impression on the team.

Initially, the management guy should call the team meetings. Eventually, the fluid management individual will call the meeting. The meeting place should be convenient to all and not in the ivory tower of management.

Team meetings should be held twice a month initially and eventually transition to once a month. An agenda should be established and minutes kept of the meetings. Responsibilities and report back dates should be established. Recognizing that needs of the company will not allow every team member to attend every meeting, attendance should be taken and recorded on the meeting minutes. While it is important to recognize those who came it is equally important to recognize those who did not attend. The meeting minutes should be sent to each team member as well as to their supervisors.

Okay, enough philosophy. Let's get down to business. In the introduction, the four types of metal removal fluids were discussed. The tests used to check and maintain water based metal removal fluids (soluble oils, semisynthetics, and synthetics) are similar and they will be addressed collectively. Straight oils are unique and require different test than those diluted with water. As such, maintenance of straight oils will be addressed separately.

This manual will not address the specifics of how to do the tests. The training provided by the metal removal fluid supplier will provide detailed test methods. If they fail to do so, there are many manuals and books out there that provide some basic test information. (See Section 6 for a suggested list). As you proceed through the water based metal removal fluid monitoring program, you note that there are some comments concerning the need to conduct certain tests.

Water based Metal Removal Fluid Monitoring Program

Sampling – The sample taken should be representative of the bulk fluid and the analysis should be performed before the sample changes. Bacterial testing should be done immediately and it is recommended that other testing be started within 24 hours of sampling.

Tests to be Performed on a specified schedule (hopefully once a week)

Concentration (Critical)

The concentration of an aqueous metal removal fluid can be measured several ways.

Refractometer – a refractometer is a small hand held device used to measure the refractive index of the water based metal removal fluid. It is perhaps the easiest and quickest way to measure fluid concentration as it can be used at the machine tool.   The reading obtained from the refractometer is compared to against a concentration calibration chart or multiplied by a factor to obtain the concentration of the sample. With time, the individual performing this test immediately knows if the sample is within the required concentration range. The problem arises if you are forced to change metal removal fluids or there is a modification in metal removal fluid concentration that changes the concentration calibration curve or multiplication factor. Make sure the individual performing the test is well aware of this change so they can calculate concentration correctly.

As with many things easy and quick, the refractometer reading is the least accurate method of measuring concentration. As the metal removal fluid ages or becomes contaminated with tramp oil, dirt, etc., it becomes more difficult to read the refractometer increasing the likelihood of error.

Oil Content – if you are using a soluble oil or semisynthetic, you can use oil content as an indicator of fluid concentration. A sample of fluid is placed in a graduated centrifuge tube and sulfuric acid is added. The mixture is then centrifuged for approximately 10 minutes at 1000 rpm. The volume of free oil floating of the top of the mixture is then read from the centrifuge tubes graduation. This volume compared to a concentration calibration chart provides the fluid concentration.

Obviously, since you must use acid and a centrifuge to conduct this test, it cannot be done at the machine tool. Rather, it should be conduct in an area (the laboratory, so to speak) located some distance from the machine tools. Also, just like the refractometer, the presence of tramp oil can give false readings. This method cannot discriminate between oils that should be there and those resulting from contamination.

Chemical Titration – As with oil content, this test must be conducted in the "laboratory". It usually involves adding a known volume of metal removal fluid to a clear container. A water insoluble solvent and a colored indicator is added to the container and then a titrant solution is added slowly until a color change occurs. The volume of titrant solution added is related to the concentration of the metal removal fluid.

Chemical Titration often measures the Alkalinity or Emulsifier Content of the metal removal fluid. These tests provide a more accurate measure of the metal removal fluid concentration than the refractometer or oil content methods. However, contamination and age (particularly the build up of carbonates from water salts) can cause inaccurate readings.

The chemical titration procedure used depends on the metal removal fluid being used. The metal removal fluid supplier is the ***only*** source for obtaining the chemical titration test procedure for their metal removal fluid.

Appearance (Since you're going to be there, you might as well do it anyway)

The appearance and odor of a metal removal fluid is very important and these parameters should be recorded on a daily basis. It may be wise to take a sample of metal removal fluid and store in a glass bottle for reference as a later date to compare the physical appearance of the metal removal fluid at various times. A healthy fluid will be milky (soluble oils), clear (synthetics) or transparent to milky (semisynthetic).

An increasing milky appearance in synthetic or semisynthetic fluids indicates either entrained or emulsified tramp oil. On standing, entrained oil will rise to the surface while emulsified tramp oil will remain emulsified. The presence of free oil indicates the presence of tramp oil or possible destabilization of the metal removal fluid. Cream or free oil present in soluble oil indicates instability.

Gray and black coloration can be due to grinding swarf or metal fines but sometimes this color can be due to microbial contamination. Odor is generally due to bacteria and microorganisms present in the fluid will be aerosolized into the air as part of the mist.

Odor (Same as Appearance)

Aqueous metal removal fluids are typically formulated to have a mild odor. Any metal removal fluid that has a foul odor most likely contains bacteria. A rotten egg odor is due to anaerobic bacteria that will produce H_2S gas.

pH (Extremely Important)

pH determines how acidic or alkaline the metal removal fluid is. Metal removal fluids are formulated to be slightly alkaline with a pH range of 8.5 to 10.0. It is important to record the pH daily to monitor any gradual decreases in the pH of the metal removal fluid. A decrease in pH may result in increased corrosion, foul odors and destabilization of the metal removal fluid. pH can be measured very easily using pH paper but an inexpensive hand held pH meter is preferred. The pH meter should be calibrated with standard buffer solutions each day.

Bacteria/Mold (Extremely Important)

The high water content of aqueous metal removal fluids can be very conducive to biological growth. The level of bacteria or fungus (molds/yeasts) should be monitored regularly to ensure optimum fluid operation. The presence of bacteria can lead to a drop in the pH, emulsion instability, rancid odors, decreased corrosion protection, plugging of filters and eventual downtime. Bacteria and fungal levels can be measured using biological dipslides. These dipslides consist of a plastic paddle coated with agar. Agar is a medium type of microbial growth medium. One side of the plastic paddle is specific for bacteria while the second is specific for fungi.

As the name implies, the dipslide is dipped into the metal removal fluid, withdrawn, and sealed in a clear airtight vial. The vial is then incubated near room temperature for 24 – 36 hours. During this incubation time, bacteria and/or fungi grow on the agar. At the conclusion of the incubation period, the amount of growth that has occurred is compared to a chart that gives an approximate indication of the amount of bacteria present in the fluid.

Bacteria counts should not be allowed to exceed 1×10^5 bacteria/mL and fungal levels should not be allowed to reach 1×10^3

Dissolved Oxygen and Biocide Level are alternate methods of measuring Bacteria/Mold.

> Dissolved Oxygen -An aqueous based metal removal fluid will dissolve a certain level of oxygen. The growth of aerobic bacteria will cause the dissolved oxygen level of a fluid to decrease over time as the bacteria consume the oxygen. A low dissolved oxygen reading (less than 3 ppm) may be indicative of a problem associated with bacteria. Higher levels of dissolved oxygen (6-8 ppm) indicate relatively little bacterial activity. Dissolved oxygen meters are available through scientific laboratory suppliers.
>
> Biocide Level -The level of biocide in some aqueous systems can be determined. The fluid manufacturer should be consulted to determine the method of testing biocide level.

Tests to be Performed less frequently

Tramp Oil (Extremely Important)

Tramp oil is defined as oil that is present in the metal removal fluid but is not part of the original concentrate. Tramp oil will either be free or emulsified. Tramp oil is typically way, hydraulic or spindle oil. Tramp oil will affect the cleanliness of the fluid which can alter the filterability, corrosion protection and resistance to bacteria. Tramp oil can be measured by centrifuging the sample or by splitting a given volume with acid and subtracting the amount of oil that would be present in a clean sample of identical concentration. This test is identical to that described above in Oil Content. Just remember, it's impossible to tell what is tramp oil and what is the oil that is supposed to be there.

Total Suspended Solids (Important)

The amount of dirt or metal fines suspended in a metalworking fluid can result in unacceptable part finishes, dirty machines and eventual bacterial problems. The determination of this parameter essentially measures the effectiveness of the filtration system. This measurement can be done by centrifugation or can be provided by the metal removal fluid supplier. You should work with the metal removal fluid supplier and the manufacturer of the filtration system to address concerns in this area.

Conductivity (Important in areas with Hard Water)

Conductivity can give some information on the quality of a metal removal fluid. The conductivity of a fluid will depend on buildup of water hardness through evaporation, dissolved metals, and other contaminants. Conductivity data should be trended and compared to concentration values to aid in determining contamination. Conductivity is measured µS (micro siemens). Conductivity measuring equipment is available from commercial laboratory equipment suppliers. In some case, inexpensive habd-held conductivity meters are also available. This may be a test you ask an outside laboratory or metal removal fluid supplier to conduct.

Chip Corrosion Test (Important if you've experienced corrosion problems)

There are a few different methods to this test but a popular test is when approximately 2 grams of clean cast iron chips are spread into a Petri dish. The fluid is then pipetted onto the chips for a given time period. The fluid is then drained and the chips are placed on filter paper. The damp chips then cause staining of the paper if the corrosion control of the fluid is insufficient. The filter paper can be saved and used as comparison when the fluid is tested at a later date. ASTM D4627 (Standard Test Method for Iron Chip Corrosion for Water Dilutable Metalworking Fluids) is similar to the test described above. This may also be a test you ask an outside laboratory or metal removal fluid supplier to conduct.

Oil Based Metal Removal Fluid Monitoring Program

The continued success of an oil based metal removal fluid is testing of the used fluid to determine its suitability for continued use. During the course of operation, the fluid may be contaminated or oxidized which may affect its performance as a lubricant. The following parameters should be evaluated on a regular basis to determine the condition of the fluid.

TAN – The Total Acid Number (TAN) is the quantity of base, expressed in terms of the equivalent number of milligrams of potassium hydroxide, that is required to titrate the strong acid constituents present in 1 gram of sample (ASTM D 664 or D 974). The method is used to determine the amount of oxidation products present in a given sample.

Water Content – Mineral oil based lubricants are designed to operate with no water present. The amount of tolerable water in a product will vary but generally levels of 1% are excessive. A hazy or emulsified appearance often indicates the presence of water in the product. This often results in a decrease in corrosion protection and tool life. The water should be removed by on or off site reclamation of the fluid should be replaced. The used oil should be disposed of in accordance to local, state and federal regulations.

Viscosity – The viscosity of a fluid may be very critical depending on the application. Due to high temperatures generated in the cutting zone, certain components of a mineral oil based fluid may become oxidized. Oxidation general causes an increase in viscosity of the fluid. This causes a decrease in the performance of the product. Viscosity changes may also be due to contamination by hydraulic fluids or other machine lubricants. These contaminants may be detrimental to the performance of the product. If the product is considered no longer suitable for use, it should be disposed of in accordance with local, state and federal regulations. In some instances, supplier may provide on site reclaiming thus eliminating the need for disposal of the fluid.

Elemental or Trace Metal Levels – The trace metal level in a fluid provides an indication of additive level or the presence of contamination from other fluids. This data can also provide information on levels of machining debris such as iron (Fe), Copper (Cu) and magnesium (Mg). Trending of this data may indicate the source of contamination and also provide information on the suitability of continued use of the fluid.

IR analysis – Infrared analysis provides a qualitative "chemical fingerprint" of all the components of a metal removal fluid. It provides information concerning additive chemistry, contamination, water content and many other properties.

SECTION 4

Considerations in Selecting Metal removal fluids

Okay, let's be realistic for a moment. Someday, you are going to be forced to select a new metal removal fluid. However, before beginning the selection process, please return to the introduction of this manual and review it. Note that you promised you would not change metal removal fluids unless you understood the problem with the existing one. So what's the problem? If you're changing fluids because of this problem, how will you insure the new fluid solves this problem? What will you do to make sure the new fluid doesn't cause new and different problems.

In the next few sections, a process will be suggested which will help guide you in the selection process. Please note, this process will not be fool proof and will not guarantee that problems with the fluid will not occur but it should help you make a more informed decision about your new metal removal fluid.

Good Luck !

SECTION 4

Considerations in Selecting Metal Removal Fluids

The goal that most shops are looking for is to make an acceptable part as quickly and as cost effectively as possible. Many factors can/will affect those cost, factors such as the machine tool, the tooling selected and the metal removal fluid utilized. The following issues are suggested that may be considered in evaluating a metal removal fluid for your shop.

HEALTH & SAFETY REVIEW:

Without a doubt, this is the top priority associated with selecting a new metal removal fluid. In the ideal world, we would all have assess to a trained industrial hygienist who could review a material safety data sheet (MSDS) and help us determine the safety of a given product. Unfortunately, this is not the case and the review of the MSDS is up to those who select the metal removal fluid. Recognizing this, Section 5 provides an overview of how to read and interpret a MSDS and a EHS Rating System that you can use to rank the safety of metal removal fluid. As a minimum, make sure you compare it to the metal removal fluid you're presently using.

DISPOSAL:

Disposal is rapidly becoming the second most important factor in selecting new metal removal fluids. This is primarily due to the increasing cost and liability associated with these fluids. Whether you have on-site waste treatment and disposal or pay to have used metal removal fluid removed from your site, your waste treater should be able to provide details on product components that may adversely effect the waste treatment process resulting in increased cost to your company.

Prior to starting an metal removal fluid evaluation, a sample of the fluid should be given to the waste treater or disposer . The candidate fluid should be evaluated for compatibility with the waste treatment process used. This is typically done using weak dilutions (0.5% to 1.0%) to account for combination with other wastewater. However, remember that the used metal removal fluid to be disposed may be quite different from a freshly made dilution!

YOUR FACILITY:

Your facility and plant operations are as unique as the people who work with you. As a result, you will need to evaluate your organization and the operations you perform to help select the proper metal removal fluid. Consider:

WATER QUALITY:
As discussed in Section 3, water quality will be critical to the long life and performance of your new water based metal removal. It might be worthwhile to review Section 3 again to refresh your memory as to the importance of good water quality.

Prior to recommending any water based metal removal fluid for consideration to you, the metal removal fluid salesman should ask for a sample of the metal removal fluid make up water for evaluation.

MACHINE TOOLS:

MACHINE TOOL BUILDER:
Can supply seal material data, sump designs, power requirements and so on. Many machine tools are designed to be product specific (straight oil or water based fluids). Machine Tool Builders many times will recommend certain products based on experiences.

AGE:
The age of the machine tool can be a critical factor in choosing a metal removal fluid. Older machines may have open gear boxes or seal materials that are made of product specific materials designed for water or oil based fluids. Machine tool enclosures can also be a factor in fluid evaluation since mist generation is an area of concern for the workers.

OIL LEAKAGE:
Many machine tools leak lubricating oils, sometimes by design. In the proper filtration, the fluid must be able to perform well in the presence of these non-product contaminants. They affect the fluid performance and can shorten its useful life. Some contain “demulsifiers” that can cause emulsion metal removal fluids to separate. Others can stimulate microbial growth. Every effort should be made to keep these oils from leaking into the metal removal fluid.

SEALS:
Seal materials must be compatible with fluid types. Seal swelling or cracking can cause major machine tool damage. Areas of the machine tool that utilize seals are typically way wipers, O-rings, splash shields and windows. Wire coatings may also be affected by the type of fluid used.

MACHINE COMPONENTS:
Many machine tools are made of many types of metals, ferrous and non-ferrous. Some are painted while others are not. Fluid and machine tool components must be compatible.

SUMPS:
Handling of the fluids is critical. Sump design, sump size, location and contaminant removal can determine what fluid to use.

FLUID PRESSURES:
Some fluids are designed for high speed operations, such as water based where some fluids are designed for slow speed operations such as straight oils.

HORSEPOWER:
The machine tool must be capable of handling the operation from a power requirement, proper fluids and tooling selection can minimize power consumption.

FILTRATION:
Many systems are designed for certain type products-always consult them for product changes.

OPERATION:

WORKPIECE:
The hardness and machinability of the workpiece is critical and will in most cases determine what fluid for fluid type to use. For example a soft cast iron requires difference lubricity than a titanium alloy.

METALLURGY:
Ferrous and non-ferrous metals have different corrosion control chemistries. It is vital that a fluid be used that protects the workpiece from corrosion.

TYPE of OPERATION:
Whether the operation is machining, grinding, or drawing, all types of metalworking operations have various levels of severity. The correct fluid selection can minimize potential problems.

SPEED, FEED and DEPTH of CUT:
The operation itself and how the metal removal or deformation takes place can affect fluid selection. For example a light surface grinding operation may only require a clear synthetic with a rust inhibitor, where a creep feed grinding fluid may require more lubrication and good foam control because this application takes a deeper cut at high machine and fluid pressures.

TOOLS:
Tools are made up of a variety of metallurgy's, such as high speed steels, cemented carbides, carbons, or a variety of metals bonded with a variety of binders such as cobalt. Fluids must be compatible and can prolong tool life. Tool suppliers sometimes have databases on what fluid types perform best with their particular products.

GRINDING WHEELS:
The purpose of the fluid in most grinding operations can be clarity, lubricity or keeping the wheel clean and free of loading. The determination needs to be made as to what function is wanted from the fluid when grinding.

TOOL HOLDER:
Many times the tool and the tool holder are made of non-similar metals. Care in the selection of the fluid should be taken to avoid bi-metallic corrosions.

THROUGH the TOOL FLUID:
Many new tools are now dispensing fluid through the center of the tool to better provide lubrication and cooling at the point of the cut. Because of the high pressure and velocity of this operation, fluids (typically water based) used in these applications need to be low foaming.

LITERATURE/INFORMATION:

It is important to get as much company and product information as possible before deciding on a fluid. The following sources should be able to provide valuable information, to assist in the decision making process:

VENDOR:
The vendor is required by law to submit at your request a Material Safety Data Sheet. They should also be willing to supply Product Brochures, Performance Tests Results and End User Testimonials.

DISTRIBUTORS/AGENTS:
Same as vendors.

INTERNET:
Obviously, the Internet is a great source of company information and products

LOCAL SOCIETY CHAPTERS**:**
The local chapters of the Society of Manufacturing Engineers, the Society of Tribologist and Lubrication Engineers, the National Tooling and Machining Association to highlight a few are excellent sources of networking and information on a vareity of topics including metal removal fluids. You can discuss with individuals in your area what metal removals they have found work best in their local operations.

Technical society meetings and magazines can also be a great source of information.

TESTIMONIALS:
Getting references can be difficult because many customers do not want the hassles involved in calling others. It is important when possible to talk to other users concerning their successes and failures with certain products.

SECTION 5

Selection

(Environmental Health and Safety)

SECTION 5

INTRODUCTION

This section was developed to provide the users of metal removal fluids a user-friendly guide for assessing and minimizing the Environmental, Health and Safety (EHS) impacts in the selection, use and disposal of metal removal fluids. This section will provide you with an overview of regulations under OSHA, EPA and DOT; information on Material Safety Data Sheets and labeling of metal removal fluids; a matrix for rating metal removal fluid; and other issues which impact the use of metal removal fluids. In addition, there is a appendix which lists other reference documents, names of organizations involved with metal removal fluids, and some websites which may provide additional assistance.

REGULATORY OVERVIEW

This section is meant to provide the user with an general awareness of the major federal regulations affecting the use of metal removal fluids. It is not intended to be a complete listing of the regulations nor will it cover any specific state requirements. The user should check with their state OSHA and EPA agency to determine specific state requirements that may affect the storage, use and disposal of metal removal fluids.

Occupational Health & Safety Administration (OSHA)

OSHA's Hazard Communication Standard (29 CFR 1910.1200)
This is the major regulation which covers an employee's right-to-know of potential health and physical hazards in the workplace. This is a performance-oriented standard which went into effect in November of 1985 and requires manufacturers to:

Assess the hazards of materials in the workplace;
Assess the physical hazards of the workplace;
Providing labeling of hazardous materials and processes;
Provide Material Safety Data Sheets (MSDS) on all hazardous materials in the workplace
Develop a written Hazard Communication Program; and
Provide training for all affected employees.

OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) Standard (29 CFR 1910.120)

This is a companion regulation to EPA's requirements for the handling of hazardous waste and for emergency response situations in facilities. This regulation covers the responsibilities of the employer to establish procedures to ensure the safe handling of hazardous waste, the development and implementation of emergency response teams (ERT) to respond to spills, leaks, fires, releases and other emergencies at the facility; and the training of employees involved in both hazardous waste handling and emergency response teams.

In addition, there are several other sections in the OSHA regulations which cover the use of personal protective equipment and respiratory protection. These standards can be found in 29 CFR 1910.132 and 29 CFR 1910.134. These sections require the employer to perform a hazard assessment of the workplace and to determine the necessary protection equipment required to perform the job safely.

Environmental Protection Agency

Resource Conservation and Recovery Act (RCRA) 40 CFR Parts 261-289
This is a series of regulations which covers the disposal of both non-hazardous and hazardous waste. It requires the generator of the waste to characterize the waste stream and determine if it meets the definition of a hazardous waste. Additionally, it sets up requirements for generators, transporters, and treatment, storage and disposal facilities (TSD) for licensing, standards of operations and reporting.

Federal Insecticide, Fungicide, and Rodenticide (FIFRA) 40 CFR
A series of regulations that govern the manufacture, labeling, use and disposal of pesticide products. These regulations covers the use of biocide products used in conjunction with metal removal fluids to prevent the microbial deterioration of the fluid in use.

Toxic Substances Control Act (TSCA) 40 CFR
This regulation requires that all commercially available substances be listed on the TSCA Inventory; provides methods for evaluating the potential hazards of new materials and registering the new substances on the Inventory; procedures for recording and reporting allegations of significant adverse reactions from chemical substances to human health and/or the environment; regulations on PCB's and asbestos, and requirements for the import and export of chemical substances.

This regulation is important for the users of metal removal fluids's to ensure that all of the substances within the metal removal fluids are listed on the TSCA Inventory. There is usually a statement on the MSDS (Section 15) which covers this information. There is requirement that employers using chemical substances record and report any allegations of significant adverse reactions in the workplace. Significant adverse reactions could be such things as cancer, birth defects, other long-term health effects, aquatic toxicity, etc.

Superfund Amendments & Reauthorization Act of 1986 (SARA Title III) 40 CFR
This regulation established community right-to-know requirements. There are three important sections - Section 304, Section 311/312 and Section 313.

Emergency Response Notification

This section currently contains a list of 360 materials deemed to be Extremely Hazardous Substances. A Reportable Quantity (RQ) and Threshold Planning Quantity (TPQ) has been established for each of the substances. Under this section, if a facility stores any of the materials at or above the TPQ, the facility must name an emergency coordinator for the facility. It must notify the State Emergency Response Commission (SERC), the Local Emergency Planning Committee (LEPC) and the local fire department that the facility stores one or more Section 304 substances at or above the Threshold Planning Quantity (TPQ) and supply the name of the emergency coordinator. In addition, the facility must develop and submit emergency response plans to the above agencies for their review. Finally, should there be a release from the facility that exceeds the RQ established for the material, the facility must immediately notify the National Response Center (1-800-424-8802).

Emergency and Hazardous Material Reporting/MSDS

This section requires a facility which stores a hazardous material or an extremely hazardous material (Section 302) to submit Inventory Reporting forms to the SERC, LEPC, and the local fire department.

There are 2 different inventory reporting forms -- Tier I and Tier II. The Tier I form contains information on each hazard category. All the materials are added together to prepare this report. The Tier II form lists each hazardous material. The inventory reporting forms require facilities to submit information on any hazardous material stored at 10,000 lb. or more on one or more days per calendar year or a Section 302 material stored at 500 lb. or more or at or above the Threshold Planning Quantity whichever is less.

USEPA has defined 5 categories of hazardous materials:

1. **Fire Hazard** includes flammable liquids and solids, pyrophoric materials, combustible liquids and oxidizers.
2. **Sudden Release of Pressure** includes compressed gases and explosives.
3. **Reactive** includes water reactive, organic peroxides, and unstable reactive.
4. **Immediate (Acute) Health Hazards** includes highly toxic materials, toxic materials, corrosives, irritants, sensitizers and other hazardous materials which exhibit an adverse effect with short term exposure.
5. **Delayed (Chronic) Health Hazard** includes carcinogens and other hazardous chemicals with an adverse effect with long term exposure.

Information required on the reports include:

- Facility Identification including name of owner or operator and emergency coordinator
- Hazardous Materials with the CAS Number
- Maximum Daily Amount stored at the facility
- Average Daily Amount stored at the facility
- The hazard category or categories for each material
- General location where the material is stored
- Number of days stored on site per calendar year
- Container type and storage conditions (temperature and pressure) Tier II reports only
- Certification Statement

Reports must be filed with the State Emergency Response Commission (SERC), the Local Emergency Planning Committee (LEPC) and the local fire department by march 1 of the following year.

Section 312 requires facilities to submit Material Safety Data Sheets or lists of hazardous chemicals stored at the facility at 10,000 lb. or more or for extremely hazardous substances at 500 lb. or the at or above the TPQ whichever is less. MSDS or lists of MSDS must be submitted within 3 months of exceeding the 10,000 lb. or the TPQ thresholds. Copies of MSDS or list of MSDS must be submitted to the State Emergency Response Commission (SERC), the Local Emergency Planning Committee (LEPC) and the local fire department.

Toxic Chemical Release Inventory Reporting (EPA Form R)

This section requires businesses in SIC Codes 20-39 to submit TRI reports on 317 chemicals and 20 categories of materials. Information on the TRI reports include:

- Facility Identification
- Certification Statement

- Activities and Uses of the Chemical at the facility
- Maximum amount on-site during calendar year
- Releases of the chemical to air, water, land on-site
- Identification of off-site facilities and POTW(Local Sewer Authority)
- Transfers of wastes to off-site facilities
- Transfers of wastewater to POTW
- Pollution Prevention Activities at the site

Reporting is required when the facility exceeds the threshold quantity for the specific toxic material and/or chemical category. There are 3 reporting threshold levels under Section 313:

1. Manufacturer or importer - must file reports if manufactured or imported exceeds 25,000 lb. in the calendar year;
2. Processor of material - must file reports if lb. processed exceeds 25,000 lb. in the calendar year;
3. Otherwise used - used in a process as a manufacturing aid such as a metal removal fluid or cleaner or used in an ancillary process such as waste treatment - must file reports if lb. used exceed 10,000 lb. in a calendar year.

Hazardous Air Pollutants (HAP's) 40 CFR
Under the Clean Air Act Amendments of 1990, EPA established a list of Hazardous Air Pollutants. The emissions of these materials are regulated and may require a facility to obtain an Title V Air Permit. The user of a metal removal fluids may want to avoid the use of any HAP to eliminate the potential need for the air permit and the associated monitoring and reporting requirements and the payment of fees.

Department of Transportation (DOT) 49 CFR Parts 171-180

This a series of regulations governing the transport of hazardous substances by air, water or land. There are requirements for the classification, labeling, and packaging of hazardous substances; for bills of lading (shipping papers); placarding of vehicles. It includes specific requirements for transporters and manufacturers of packaging materials (bottles, boxes, drums, intermediate bulk containers, etc).

One important subsection of the DOT regulations is the requirement referred to as HM-126F. This is a requirement that employers train employees involved in the classification, packaging, labeling, paperwork preparation and transportation be trained in the requirements of the DOT including general safety procedures.

MSDS AND LABELS

MSDS

Material Safety Data Sheets (MSDS) are the corner stone of the Occupational Safety & Health Administration's (OSHA) Hazard Communication Standard (29 CFR 1910.1200). They provide information about the chemical substances within products, safe handling procedures, first aid measures, and procedures to be followed when the product is accidentally spilled or released. They can also save your life. The objective of the MSDS is to concisely inform you about the hazards of the materials you work with so that you can protect yourself and respond to emergency situations.

You should have a MSDS for each metal removal fluid and metalworking fluid purchased by your facility.

Contact your suppliers for copies and maintain a file or notebook that is accessible to all employees. Once you have a copy of the MSDS, the next step is to interpret what it means. The following sections discuss how to understand the information in the MSDS so that you can safely manage your metal removal fluid.

Format and Definitions

The OSHA regulations specify the type of information required on a MSDS but leaves the sequence of the information to the chemical manufacturer who prepares the MSDS. This has led to a wide variation in MSDS formats and often confuses the users of the product. At present, the American National Standards Institute (ANSI) 16-section MSDS (ANSI Z400.1) is becoming the most widely used and accepted format among chemical suppliers and manufacturers. It was recently developed by the Chemical Manufacturers Association as a means to make the MSDS easier to read, understand, and find key sections quickly. The ANSI format incorporates the OSHA requirements and several International Labor Organization requirements. The sections are as follows:

Section 1 - Chemical Product and Company Identification
Section 2 - Composition and Information on Ingredients
Section 3 - Hazards Identification
Section 4 - First Aid Measures
Section 5 - Fire and Explosion Data
Section 6 - Accidental Release Measures
Section 7 - Handling and Storage
Section 8 - Exposure Controls/Personal Protection
Section 9 - Physical and Chemical Properties
Section 10 - Stability and Reactivity Data
Section 11 - Toxicological Information
Section 12 - Ecological Information
Section 13 - Disposal Considerations
Section 14 - Transport Information
Section 15 - Regulatory Information
Section 16 - Other Information

Appendix 1 contains an explanation of each section of the 16-Section ANSI MSDS. It gives you information on what is in each section; the purpose of the section; and who might need the particular information.

Until the ANSI standard is adopted by all chemical manufacturers and suppliers, MSDS's will continue to be found in a variety of formats. The quality and ease of understanding will vary from supplier to supplier. Beware of any sheets with blank spaces or missing information. If you have questions or feel information is missing, contact your supplier.

Acronyms

A typical MSDS may contain acronyms. CAS, PEL, TWA, PPE, and other acronyms can be confusing if you do not understand their meaning. Some suppliers include a glossary terms as part of their printed MSDS. See Appendix 2 for definitions of common acronyms. There is also a very good glossary of terms in the back of the ANSI Standard of Preparation of MSDS (see

Appendix 3 for reference) In addition, there is a MSDS Pocket Dictionary available from Genium Publishing Company (518-377-8854) which defines many of the terms found on the MSDS.

Product Specification Sheets vs. the MSDS

Chemical manufacturers and suppliers, including your metalworking fluid vendors, typically publish Product Specification Sheets to help differentiate the performance characteristics of their various products. Product Specification Sheets, sometimes called Product Data Sheets, contain detailed technical information about the chemical properties and performance expectations of the metalworking fluid as it is used in your operations or processes. This information ensures that you are using the right product for the quality and performance needed from your operation.

Product Specification Sheets often list chemical composition and physical characteristics data that is also found on a MSDS. This includes information like density, boiling point, flashpoint, and volatile content. The Product Specification Sheet does <u>not</u> include the information necessary to make judgments regarding safe handling. Product sheets do not meet the OSHA requirements for communicating chemical hazard information to employees and should never be used in place of a proper MSDS.

Health and Safety Characteristics:
As Purchased vs. As Used

Many metal removal fluids are diluted in water for use. The MSDS supplied by the manufacturer is for the concentrated material. The health and physical hazards are based on the analysis of the concentrated material. However, since the material is diluted in water, the physical and health hazards are generally reduced. Suppliers may be willing to supply an MSDS and/or label for the diluted material. This information can then be used for Hazard Communication training or posted on the particular machine or in the area where the metal removal fluid is used. The use dilution MSDS and/or label more accurately portrays the health and physical hazards to which the employee is exposed.

Labeling and Hazard Ranking Systems

A MSDS is one source of information regarding the chemicals in your facility. The other source is container labels. Chemical manufacturers and suppliers must label all containers, including bags, drums, cans, and bottles. The labels must list information that is also found on the MSDS, such as:

- Name of the product and/or chemical name(s)
- Name and address of the chemical manufacturer or supplier
- Physical hazards (e.g. flammable, explosive, reactive, radioactive)
- Health hazards (e.g. irritant, toxic, carcinogen)

Labels *may* also include instructions for safe storage and handling, protective clothing requirements, and other safety procedures.

Labels come in many formats. Some labels use words to describe the hazards, and some use pictures, colors and numbers to help you quickly identify the kind and degree of hazard. Two commonly used labeling formats with colors and numbers are the NFPA (National Fire Protection Association) system and the HMIS (Hazardous Material Identification System).

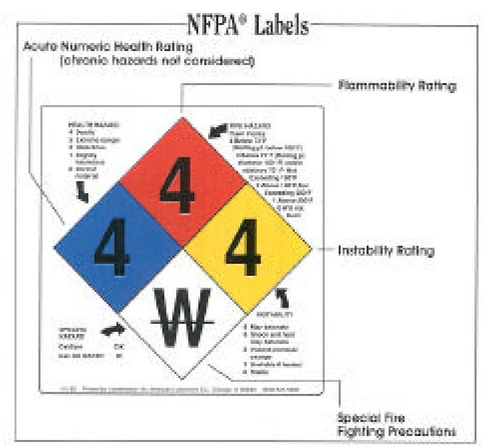
Both the NFPA and HMIS use the same colors and numbers to identify the degree of hazard if the chemical is not handling correctly. Each color on the label stands for a different **type** of hazard as follows:

Blue = health hazard
Red = fire hazard
Yellow = reactivity hazard
White = special hazard (NFPA) or protective equipment recommended (HMIS)

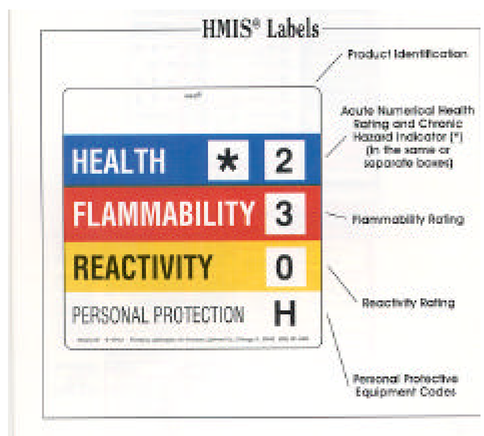
The numbers from "0" to "4" rank the degree or severity of hazard if the chemical is not handled correctly.

0 = Minimum hazard
1 = Slight hazard
2 = Moderate hazard
3 = Serious hazard
4 = Severe hazard

NFPA LABEL



HMIS LABEL



The white section information differs between the NFPA and HMIS label systems. In the NFPA system, the white block displays numbers or pictures indicating the specific hazard as noted above. HMIS displays a code letter associated with the type of personal protective equipment recommended for use. A few examples of the code letter are shown above.

NFPA or HMIS hazard ranking information may also be displayed or listed on the MSDS. It may appear on the MSDS as "NFPA H = 1, F = 4, R = 0" or the entire label/symbol may be shown. A quick reference for understanding the NFPA/HMIS rankings is provided in the table below.

Guide to Hazard Rankings

Health hazard (BLUE) - possibility of injury
 4 = could cause death or irreversible injury
 3 = could cause serious temporary or irreversible injury
 2 = could cause temporary incapacitation
 1 = could cause irritation
 0 = no health hazard

Flammability (RED) - possibility of ignition
 4 = flammable vapor or gas which burns readily
 3 = flammable liquid or solid which can be readily ignited
 2 = must be heated for ignition
 1 = must be preheated before ignition can occur
 0 = no fire hazard

Reactivity (YELLOW) - possibility of reaction (with air or wat
 4 = readily capable of detonation or explosive reaction
 3 = may detonate when exposed to heat or initiating source
 2 = readily capable of non-explosive reaction
 1 = may become unstable at high temperatures
 0 = stable material

EHS Rating System

The Environmental Health and Safety *Metal Working Fluid Evaluation Questionnaire*, was developed to bring some awareness to EH&S issues associated with the end use of metal working fluids, by allowing a wide range of end users to compare one fluid with another. This is accomplished by the having the end user research the question, score the various metal working fluids based on the end users EH&S concerns, and then deciding which metal working fluid best meets the EH&S needs of the end user. All of the information can be found on the MSDS and/or Technical Data Sheet or is based on the user's process. If information is not available, call the supplier and request the data.

If you are scoring more than one metal removal fluid, the lower the number the better the metal removal fluid based on the EH&S concerns.

ENVIRONMENTAL, HEALTH & SAFETY
METALWORKING FLUID EVALUATION QUESTIONNAIRE

Question	Best				Worst	PRODUCT A	B	C	D
What is the HMIS/NFPA health hazard rating of the product? (0 = minimal, 1 = slight, 2 = moderate, 3 = serious, 4 = severe)	1	2	3	4	5				
If the HMIS/NFPA is not given, what is your health hazard evaluation of the product from the MSDS information?	1	2	3	4	5				
What is the HMIS/NFPA flammability rating of the product? (0 = minimal, 1 = slight, 2 = moderate, 3 = serious, 4 = severe)	1	2	3	4	5				
Does the application method/process pose the potential of a misting exposure hazard?	1	2	3	4	5				
Based on the product's flammability and DOT classification, Does the product require special storage/containment precautions?	1	2	3	4	5				
Is the odor of the product objectionable?	1	2	3	4	5				
Is the product classified as RCRA hazardous waste for disposal?	1	2	3	4	5				
Does the product contain SARA 313 reportable chemicals?	1 (no)				5 (yes)				
If the product contains SARA 313 reportable chemicals, will you exceed the facility reporting threshold for those chemicals?	1 (no)				5 (yes)				
Does the product contain HAP's under the Clean Air Act?	1 (no)				5 (yes)				
If the product contains HAP's, will you exceed the regulated quantity for those chemicals?	1 (no)				5 (yes)				
Does the product contain VOC's under the Clean Air Act?	1 (no)				5 (yes)				
If the product contains VOC's, will you exceed the regulated quantity for those chemicals?	1 (no)				5 (yes)				
Based on knowledge of your process and vendor information, is it likely that the product will be biologically stable therefore requiring infrequent usage of biocides?	1 (yes)				5 (no)				
Based on knowledge of your process and vendor information, will the expected life of the product minimize disposal?	1 (yes)				5 (no)				
Based on the MSDS and vendor technical sheets, is recycling a viable option?	1 (yes)				5 (no)				
	PRODUCT TOTALS								

OTHER ISSUES

Recycling vs Disposal

Proper maintenance of the metal removal fluids is essential to preventing spoilage of the metal removal fluid. Recycling is a viable method to maintain the metal removal fluid. It eliminates contaminants such as tramp oil, bacteria, metal fines, etc. This topic is more depth in the maintenance section of the manual.

Potential OSHA Regulation on Metal Removal Fluids

In 1997, the Standards Advisory Committee on Metalworking Fluids (SAC) was chartered for a two year period of time. The group is made up of members from labor organizations, manufacturers, academia, and other third party organizations. The SAC was established under OSHA to investigate the need for and/or recommend, if appropriate, a standard, a guideline, or other appropriate response to the health effects, if any, that result in material impairment to workers occupationally exposed to metalworking fluids. The recommended actions should take into consideration technical and economic feasibility as well as the impact of such recommendations on small business (defined as under 500 employees.) The SAC will review documents and information from NIOSH as well as other pertinent data.

At this point in time, there is still much controversy within the 15 member group. The general direction, however, is fairly clear in that the majority of members are leaning toward the recommendation of an OSHA standard for metalworking fluids. Some major areas of controversy involve health effects, permissible exposure levels (PEL), testing and analysis criteria, and medical surveillance issues. There are, of course, many other areas of discussion and controversy including the recommendation of a standard itself.

Health effects - the origin, significance, validity, impact, and control of adverse health effects; dermatitis; non-malignant respiratory effects (including asthma, and hypersensitivity pneumonitis); cancer issues.
Permissible exposure levels - should a permissible exposure level (with concurrent action level and short term exposure level) be set, and at what that level. Current discussions include the lowering of the PEL for oil mists from the current 5 mg/m^3
Testing and analysis - what is the best (efficacious) method to test for MWF mist, and what laboratory analytical technique should be used for accurate and precise results
Medical surveillance - would this be not only cost-effective but provide occupational protection

The SAC has also been asked by OSHA to recommend ‘best practices’ for the identification, measurement, and control of the metalworking fluid environment. Aside from the standard itself, these recommendations may have the greatest impact on the metalworking fluid environments.

Biocides

Since many metal removal fluids’s are diluted in water, there is the potential for bacterial growth in the use fluid. If the fluid is not properly maintained, bacteria and/or fungi may grow to unacceptable levels. The high levels of bacteria and fungi may cause the pH of the fluid to drop, may cause bio-films on machine surfaces and of the parts. Finally, it may cause the metal removal fluid to have an unpleasant odor.

Biocide, which is the common name for a pesticde, is a material which kills microorganisms such as bacteria and fungi. There are various biocides available from the various metal removal fluids suppliers. These materials are highly regulated by the U.S. Environmental Protection Agency (US EPA). You must carefully follow the directions for use. If not followed properly, you are in violation of federal law and may make the problem worse. In addition, these materials are generally irritants and/or corrosive to the eyes and skin.

Fires with Chips/filters

There have been reports of fires in the hopper/bins that store the chips removed from the process. The cause of the fire is oxidation of the chips. Either the chips have been burned during the process due to inadequate cooling or lack of lubrication. The chips start to rust and the oxidation process creates heat. When companies dispose of both chips and filters in the same bins, the paper or filter media may spontaneously ignite due to the heat. When these items are separate, the oxidation process may cause the chips to ignite or smoke. The chips may ignite if the material on the chips is a straight oil. Water-based metal removal fluids may smoke; although the smoke is typically water vapor from the heating of the metal removal fluid. Many companies now maintain different collection locations for filters and chips to eliminate the fire potential due to oxidation.

SECTION 6

Selection

Chemical and Material Compatability
Testing

Section 6

Chemical and Material Compatibility Testing

This section of the manual remains under development and will be updated at a later date. During the three years the International Industrial Advisory Group met, the group failed to establish and agree upon standard tests that can be used to assess the chemical and material compatibility of metal removal fluids as part of the selection process.

As you may realize from Section 4, there are numerous considerations in selecting metal removal fluids. As a result, companies have developed there own chemical and material compatibility tests based on the material performance characteristics of their products. Boeing Commercial Airplane Group, General Motors, and other companies have developed their own internal tests that they require metal removal fluids proposed for use in their manufacturing operations to pass prior to shop evaluation. IAMS will continue to work with these companies as well as the other IWIG members to develop this section.

In the interest of develop your own chemical and material tests, you are refered to the following references:

J. Byers , ed., *Metalworking Fluids*, Marcel Dekker, New York, pp 191-221 (1994)

J. Silliman, *Cutting and Grinding Fluids, Selection and Application*, Society of Manufacturing Engineers, Dearborn, MI pp 63-96 (1992)

Metalworking Fluids Optimization Guide (NCMS Report 0274RE95). National Center for Manufacturing Sciences, Ann Arbor

SECTION 7

Selection

INTERNATIONAL WORKING INDUSTRIAL GROUP

MACHINABILITY TEST GUIDELINES

SECTION 7

Machinability Test Guidlines

At present, there are no commonly used standard procedures for testing the performance of metal removal fluid while machining. To assess the performance of a particular metal removal fluids during actual machining operations, controlled performance tests where the only variable will be the metal removal fluids to be tested, is the subject of this section.

Four machining processes, specifically, milling, turning (plunging), drilling, and grinding have been chosen for metal removal fluid performance evaluation. During milling and turning (plunging), the cutting forces have been considered as the prime criteria to evaluate the metal removal fluid's performance. During drilling operation, both thrust force and torque are considered as the criteria to study the relative effectiveness of metal removal fluids. During grinding operation, grinding force and grinding ratio (G) are the prime criteria for the relative performance evaluation of various metal removal fluids.

The recommendations contained in this part are applicable in both laboratories and factories. They are intended to unify procedures in order to increase the reliability and comparability of test results when making comparison of Metal removal fluids. In order to achieve as far as possible these aims, recommended reference materials and conditions are included and should be used as far as is practical.

The test conditions recommended in this part have been designed for turning (plunging), end milling, drilling, and surface grinding tests using steel workpieces of normal microstructure. However, with suitable modifications, this part can be applied to other machining tests on, for example, other work materials or with cutting tools developed for specific applications.

The specific accuracy given in these recommendations should be considered as a minimum requirement. Any deviation from the recommendations should be reported in detail in the test report.

NOTE – This part of IAMS' Pollution Prevention Guide does not constitute acceptance tests and should not be used as such.

End-Milling Test Procedure

This part specifies recommended procedure for metal removal fluids performance testing during end milling operation. It can be applied to laboratory as well as to production practice.

The cutting conditions in end milling may fall under two categories as follows;

a) conditions under which predominantly uniform tool wear occurs;

b) conditions under which tool deterioration is due mainly to other phenomena such as edge fracture, chipping or plastic deformation.

This part considers only those recommendations concerned with testing which results predominantly in uniform tool wear.

This part establishes specifications for the following factors of metal removal fluid performance testing with end milling tools in accordance with figure 2.1: workpiece, tool, cutting conditions, metal removal fluid, criteria for the end point of the test, equipment, test procedures, recording, evaluation and presentation of results.

Workpiece

In principle, testing laboratories are free to select the work materials according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of one of the reference materials AISI/SAE 4140 steel (24-26 HRC) is recommended.

Within the specifications, materials may vary with a resulting effect on machinability. To minimize such problems, the provision of work material in compliance with stricter specifications shall be discussed with the supplier. The hardness of the test workpiece shall be determined over the testing zone on the cross section of each test piece at least at five points; one on the center, one near each edge and one on either side of the center point between the center and the edge points

For workpieces, which are cut from larger billets or for which hardness variation might be expected to be significant, additional hardness measurements should be taken to ascertain that the hardness values fall within the prescribed limits. The location of measurement points and the method of measuring should be reported in the test report. The deviation in hardness within one batch of material should be as small as possible. A realistic value for the reference materials is 5% of the arithmetic mean value.

NOTE:
In order to be able to compare results over reasonably long periods of time. It is recommended that testing bodies procure sufficiently large quantities of reference work materials to cover their needs.

Dimensions

In principle, testing laboratories are free to select the dimensions of test workpieces according to their own interest. However, in order to increase the comparability of results between testing bodies, the recommended workpiece for end milling shall be a bar or billet of rectangular cross-section with a length of 12 inch, width of 4 inch and thickness of 0.5 inch. These dimensions should be restricted to ensure adequate stability during machining. The actual dimensions shall be reported.

Tool: End mill

In principle, testing bodies are free to select the end mill cutter according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of R215.44-15T308-AAM (grade SM-30) uncoated carbide inserts and one inch (1”) diameter RA215.44-25MN25-15C cutter body is recommended. Any deviation from the recommended cutter should be reported.

The deviation between individual inserts used in the same testing sequence should be kept to a minimum. The inserts should not have any coating or surface treatment. The presence of any coating or surface treatment shall be reported in detail.

The cutter shall be securely fastened in the chuck and the run-out of the cutter shall be carefully checked at the cutting edges of the insert mounted on the cutter body. The actual run-out shall be measured and recorded.

Cutting conditions

The recommended cutting data have been chosen and combined in order to correspond to and to emphasize the milling principles dealt with in this part. It should be noted that the cutting conditions shall be chosen to be compatible with the cutting tool, the machine tool, and the clamping device, etc., in order to obtain reliable data. The following cutting conditions for metal removal fluid performance evaluation tests are recommended:

- ♦ cutting speed – 400 sfpm;
- ♦ feed per tooth – 0.005 ipt;
- ♦ axial depth of cut – 0.5 inch;
- ♦ radial depth of cut – 0.06 inch
- ♦ length of cut per pass – 4 inch (width of the workpiece).

In cases where the cutting conditions indicated can not be achieved, other values as close as possible to those indicated above may be used.

Metal Removal Fluid

For the assessment of long term reproducibility of these test results, the testing program shall run with a reference fluid having a constant properties. A 2% (by volume) solution of Master Chemical Trim 229 is recommended as the reference fluid. If unobtainable a 2% aqueous solution of Triethanolamine may be substituted. The performance of all metal removal fluids (synthetic, semi-synthetic, straight oil, soluble oil etc.) shall be evaluated with respect to this reference fluid.

Criteria for the end point of the test

Tool life criteria are recommended for the completion of a metal removal fluid performance evaluation test. In practical workshop situations the time at which a tool ceases to produce workpieces of the desired size or surface quality usually determines the end of useful tool life.

The period up to the instant when the tool is incapable of further cutting may also be considered as the useful tool life. To increase reliability and comparability of metal removal fluids performance test results it is essential that tool life be defined as the total cutting time of the tool to reach a specified value of uniform or maximum tool wear. The following criteria for the end point of a test are recommended:

- Uniform flank wear: 0.010 inch averaged over the insert-workpiece contact length

NOTE:
Often the maximum tool wear occurs at a position of the flanks adjacent to the work surface during cutting.

As mentioned earlier, this section of the manual recommends that tool deterioration only in the form of steady wear on the flank shall be used for the end point of the test. Cracks, chipping or any other form of deterioration if occurs, shall be recorded. Flank wear measurement is carried out parallel to the surface of the wear land and in a direction perpendicular to the original cutting edge, e.g. the distance form the original cutting edge to that limit of the wear land which intersects the original flank. Although the flank wear land on a significant portion of the flank may be of uniform size, there will be variations in its value at other portions of the flanks due to tool profile and edge chipping. An average value of flank wear along the tool workpiece contact length shall be measured and recorded.

Equipment

Machine Tool

The milling machine on which the tests are to be conducted shall have sufficient power, rigidity and physical capacity. It should be of stable design and be in such condition that abnormal vibrations or deflections are not observed during the test. The feed speed under load shall be constant. The spindle axle orientation, vertical or horizontal, shall be checked.

Other Equipment

The following table lists equipment, which are necessary and recommended for carrying out the tests specified in Table 7-1

Test procedure

Purpose

The main purpose of the test shall be the performance comparison (or ranking) of the different metal removal fluids (Metal removal fluids) used during milling operation. This comparison or ranking will be accomplished by measuring the cutting force (3-D) exerted on the tool and the tool wear while using a specific metal removal fluids.

Table 7-1: Equipment necessary for measurements in the end milling tests

Clause	Minimum Equipment	Recommended equipment
Workpiece Dimensions Hardness	 Graduated rule Hardness tester	 Sliding calliper Hardness tester
Cutter Dimensions Roughness Defects Runout Hardness	 Sliding calliper Roughness standard Magnifier, having a minimum magnification of 10X Dial indicator	 Micrometer, 0-25 Surface tester Toolmaker's microscope Dial indicator, graduated to 0.001 mm Hardness tester
Metal removal fluid Concentration Flow (pH value) (Temperature)	 Graduated vessel Graduated vessel and stop watch	 Refractometer Graduated vessel and stop watch pH meter Thermometer
Cutting conditions Feed speed Spindle speed Depth and width of cut	 Stop-watch Tachometer Sliding calliper	 Stop-watch Tachometer Sliding calliper
Tool deterioration Flank wear, chipping flaking etc.	 Toolmakers' microscope, dial indicator with a contact point 0.2 mm in diameter	 Toolmakers' microscope profile recorder and special device for mounting the inserts under the microscope
Force measurement Cutting forces in three dimensions	 Piezoelectric (3-D) milling dynamometer, charge amplifier, interfacing board and cables, PC, software to collect and analyze data	 Piezoelectric (3-D) milling dynamometer, charge amplifier, interfacing board and cables, PC, software to collect and analyze data

Planning

It is possible to describe the metal removal fluid performance test procedure in general terms. The method to follow is the same as that used for good machine tool operation, except that great care and observation must be exercised and that certain measurements must be taken. The test matrix should be formulated and used to achieve the purpose of the test.

Before starting the test, the machine shall be thoroughly washed with solvent and then flushed and charged with 10 gallons of test metal removal fluid with a fixed concentration. When using metal removal fluids the flow should ‘flood’ the active part of the tool. The flow rate should be monitored and noted in the test report. Also, ascertain that the milling machine, workpiece and tools fulfill all requirements mentioned earlier. The machine shall be set to the required cutting conditions. If necessary, a preliminary test shall be carried out to check that

- proper interfacing of dynamometer with PC through charge amplifier has been made,
- the dynamometer is properly calibrated, and
- the specified machining parameters have been set on the machine.

The workpiece shall be rigidly fixed in a vice, which is rigidly mounted on the milling dynamometer set on the machine table. The cutting shall be conducted on the 4-inch side of the workpiece. This will provide more rigidity to the system thus helping in avoiding unwanted vibrations during end milling. Climb milling is recommended. The tool flank wear and on line cutting force measurements shall be made at suitable intervals (number of passes). The test shall be stopped when the tool wear reaches the specified maximum limits 0.010 inch uniform flank wear. To evaluate the relative performance of any given metal removal fluids, the end-milling test will be repeated with the base line metal removal fluids under exactly similar conditions using a new insert.

Recording, evaluation and presentation of results

A detailed statistical analysis can be done but is not recommended. The cutting force data shall be analyzed to give average cutting force values during end milling. The tool wear and analyzed cutting force data shall be recorded on the ‘tool wear versus number of passes measurements’ and cutting force (3-D) versus number of passes measurements’ data sheets and plotted on a tool wear (ordinate) versus number of passes (abscissa) and average cutting force (ordinate) versus number of passes (abscissa) diagrams.

Based on the average cutting force and tool wear patterns, the recommendations about the relative performance of different Metal removal fluids shall be made. The trend of tool wear and cutting force patterns reflect on the performance of a given metal removal fluids used during that test. In general, lower values of cutting forces and tool wear rates shall indicate the better performance of the metal removal fluids.

When comparing the performance of a given metal removal fluids, experienced personnel may be able to establish with sufficient accuracy the significance of difference in the test results from a very small number of test runs.

Finally, the evaluation of metal removal fluids performance test results during end milling operation should be properly documented in the form of a report.

Drilling Test Procedure

This part specifies recommended procedure for metal removal fluids performance testing during drilling operation. It can be applied to laboratory as well as to production practice.

The cutting conditions in drilling may fall under two categories as follows;

a) conditions under which predominantly uniform drill wear occurs;

b) conditions under which drill bit deterioration is due mainly to other phenomena such as edge fracture, chipping or plastic deformation.

This part considers only those recommendations concerned with testing which results predominantly in uniform drill wear.

This part establishes specifications for the following factors of metal removal fluid performance testing during drilling in accordance with figure 3.1: workpiece, tool, cutting conditions, metal removal fluid, criteria for the end joint of the test, equipment, test procedures, recording, evaluation and presentation of results.

Workpiece

Work material

In principle, testing laboratories are free to select the work materials according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of one of the reference materials, AISI/SAE 4340 steel (32-34 HRC) is recommended.

Within the specifications, materials may vary with a resulting effect on machinability. To minimize such problems, the provision of work material in compliance with stricter specifications shall be discussed with the supplier. The hardness of the test workpiece shall be determined over the testing zone of each test piece at least at five points; one on the center, one near each edge of the workpiece . It is recommended that additional hardness measurements at several points on the workpiece should be taken to ascertain that the hardness values fall within the prescribed limits. The location of measurement points and the method of measuring should be reported in the test report. The deviation in hardness within one batch of material should be as small as possible. A realistic value for the reference materials is 5% of the arithmetic mean value.

NOTE:
In order to be able to compare results over reasonably long periods of time, it is recommended that testing bodies procure sufficiently large quantities of reference work materials to cover their needs.

Dimensions

In principle, testing laboratories are free to select the dimensions of test workpieces according to their own interest. However, in order to increase the comparability of results between testing bodies, the recommended workpiece for drilling shall be a bar or billet of rectangular cross-section with a length of 6 inch, width of 6 inch and thickness of 1.0 inch. These dimensions should be restricted to ensure adequate stability during machining. The actual dimensions shall be reported.

Tool: Drill Bit

In principle, testing bodies are free to select the drill bit according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of heavy duty, oxide coated, high speed steel, 135 degree split point, 0.5 inch diameter drill bit (NAS 907; Type C) is recommended. Any deviation from the recommended drill bit should be reported.

The deviation between individual drill bits used in the same testing sequence should be kept to a minimum. The drill bits should not have any other coating or surface treatment. The presence of any coating or surface treatment shall be reported in detail.

The drill bit shall be securely fastened in the chuck and the run-out of the drill bit shall be carefully checked. The actual run-out shall be measured and recorded.

Cutting conditions

The recommended cutting data have been chosen and combined in order to correspond to and to emphasize the drilling principles dealt with in this part. It should be noted that the cutting conditions shall be chosen to be compatible with the cutting tool, the machine tool, and the clamping device, etc., in order to obtain reliable data. The following cutting conditions for metal removal fluids performance evaluation tests are recommended:

- speed – 55 sfpm (-420rpm);
- feed rate – 0.007 ipr;
- maximum depth of hole – 1.0 inch;
- radial depth of cut – 0.06 inch;

In cases where the cutting conditions indicated can not be achieved, other values as close as possible to those indicated above may be used.

Metal Removal Fluid

For the assessment of long term reproducibility of these test results, the testing program shall run with a reference fluid (specification…) having a constant properties. The performance of all Metal removal fluids (synthetic, semi-synthetic, straight oil, soluble oil etc.) shall be evaluated with respect to this reference fluid.

Tool wear and criteria for the end point of the test

Similar to end milling test, tool life criteria is recommended for the completion of a metal removal fluids performance evaluation test during drilling operation. To increase reliability and comparability of metal removal fluids performance test results it is essential that drill life be defined as the total drilling time of the drill to reach a specified value of uniform or maximum tool wear. The following criteria for the end point of a test are recommended:

Uniform drill wear: 0.010 inch

As mentioned earlier, this section of the manual recommends that tool deterioration only in the form of steady wear of the drill cutting edge shall be used for the end point of the test. Cracks, chipping or any other form of deterioration, if occurs, shall be recorded. Drill wear measurement is carried out parallel to the surface of the wear land and in a direction perpendicular to the original cutting edge. Although the drill wear on a significant portion of the cutting edge may be of uniform size, there will be variations in its value at other points of the cutting edge due to edge chipping. An average value of wear along the drill cutting edge shall be measured and recorded.

Equipment

Machine tool

The drilling machine or machining center on which the tests are to be conducted shall have sufficient power, rigidity and physical capacity. It should be of stable design and be in such condition that abnormal vibrations or deflections are not observed during the test.

The feed speed under load shall be constant. The spindle axle orientation, vertical or horizontal, shall be checked.

Other equipment

The Table 7.2 lists equipment, which are necessary and recommended for carrying out the tests specified in this section.

Test procedure

Purpose

The main purpose of the test shall be the performance comparison (or ranking) of the different metal removal fluids (Metal removal fluids) used during drilling operation. This comparison or ranking will be accomplished by measuring the thrust force exerted on the drill bit and the torque induced during drilling using a specific metal removal fluids.

Planning

It is possible to describe the metal removal fluids performance test procedure in general terms. The method to follow is the same as that used for good machine tool operation, except that great care and observation must be exercised and that certain measurements must be taken. The test matrix should be formulated and used to achieve the purpose of the test.

Before starting the test, machine shall be thoroughly washed with solvent and then flushed and charged with 10 gallons of test metal removal fluids with a fixed concentration. When using metal removal fluids the flow should ‘flood’ the active part of the drill. The flow rate should be monitored and noted in the test report. Also, ascertain that the drilling machine or machining center, workpiece and drill bits fulfill al requirements mentioned earlier. The machine shall be set to the required cutting conditions. If necessary, a preliminary test shall be carried out to check that

Table 7.2 Equipment necessary for measurements in the drilling tests

Clause	Minimum Equipment	Recommended equipment
Workpiece		
Dimensions	Graduated rule	Sliding calliper
Hardness	Hardness tester	Hardness tester
Cutter		
Dimensions	Sliding calliper	Micrometer, 0-25
Roughness	Roughness standard	Surface tester
Defects	Magnifier, having a minimum magnification of 10X	Toolmaker’s microscope
Runout	Dial indicator	Dial indicator, graduated to 0.001 mm
Hardness		Hardness tester
Metal Removal Fluid		
Concentration	Graduated vessel	Refractometer
Flow	Graduated vessel and stop watch	Graduated vessel and stop watch
(pH value)		pH meter
(Temperature)		Thermometer
Cutting conditions		
Feed speed	Stop-watch	Stop-watch
Spindle speed	Tachometer	Tachometer
Tool deterioration		
Drill wear, chipping, flaking etc.	Toolmakers’ microscope, dial indicator with a contact point 0.2 mm in diameter	Toolmakers’ microscope profile recorder and special device for mounting the inserts under the microscope
Force measurement		
Thrust force and torque	Piezoelectric drilling dynamometer, charge amplifier, interfacing board and cables, PC, software to collect and analyze data	Piezoelectric drilling dynamometer, charge amplifier, interfacing board and cables, PC, software to collect and analyze data

- proper interfacing of dynamometer with PC through charge amplifier has been made,
- the dynamometer is properly calibrated,
- the specified machining parameters have been set on the machine.

Small variations in drill geometry may make significant variations in thrust force and torque values even though they are purchased from the same lot. Therefore, before starting the test, all the drill bits to be used for the metal removal fluid performance test should be calibrated. This calibration can be done by making one hole on the standard test piece using individual drill bit and measuring the thrust force and torque values. The drill bits, which provide approximately same value of, thrust force and torque should be further selected to be used for actual metal removal fluid performance tests.

One workpiece shall be rigidly fixed on the table of the drilling machine/machining center. Another workpiece shall be set on the drilling dynamometer. A fixed number of holes (say 9) will be drilled in this workpiece and then the next hole (10^{th}) will be made in the workpiece which is fixed on the drilling dynamometer. The thrust force and torque shall be measured in real time. This way, the drill wear and cutting force measurements shall be made at suitable intervals (number of holes). The test shall be stopped when the drill wear reaches the specified maximum limits (0.010 inch uniform drill wear). To evaluate the relative performance of any given metal removal fluids, the drilling test will be repeated with the base line metal removal fluid under exactly similar conditions using a new drill bit.

Recording, evaluation and presentation of results

A detailed statistical analysis can be done but is not recommended. The thrust force and torque data shall be analyzed to give average thrust force and torque values during drilling. The drill wear and analyzed thrust force and torque data shall be recorded on the ‘tool wear versus number of holes’, ‘thrust force versus number of holes’, and ‘torque versus number of holes’ measurement data sheets and plotted on a tool wear (ordinate) versus number of holes (abscissa), average thrust force (ordinate) versus number of holes (abscissa), and average torque (ordinate) versus number of holes (abscissa) diagrams.

Based on the average thrust force, torque and drill wear patterns, the recommendations about the relative performance of different Metal removal fluids shall be made. The trend of thrust force, torque, and drill wear patterns reflect on the performance of a given metal removal fluids used during that test. In general, lower values of thrust forces, torque, and drill wear rates shall indicate the better performance of the metal removal fluids.

When comparing the performance of a given metal removal fluids, experienced personnel may be able to establish with sufficient accuracy the significance of difference in the test results from a very small number of test runs.

Finally, the evaluation of metal removal fluids performance test results during drilling operation should be properly documented in the form of a report.

Turning (plunging) Test Procedure

This part specifies recommended procedure for metal removal fluids performance testing during turning (plunging) operation. It can be applied to laboratory as well as to production practice.

The cutting conditions in turning (plunging) may fall under two categories as follows:

a) conditions under which predominantly uniform tool wear occurs;

b) conditions under which tool deterioration is due mainly to other phenomena such as edge fracture, chipping or plastic deformation.

This part considers only those recommendations concerned with testing which results predominantly in uniform tool wear.

This part establishes specification for the following factors of metal removal fluids performance testing with turning tools in accordance with Figure 4.1: workpiece, tool, cutting conditions, metal removal fluid, criteria for the end point of the test, equipment, test procedures, recording, evaluation and presentation of results.

Workpiece

Work material

In principle, testing laboratories are free to select the work materials according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of one of the reference materials, AISI/SAE 4340 steel (24-26 HRC) is recommended.

Within the specifications, materials may vary with a resulting effect on machinability. To minimize such problems, the provision of work material in compliance with stricter specifications shall be discussed with the supplier. The hardness of the test workpiece shall be determined over the testing zone on the cross section of each test piece at least at five points; one on the center, one near each edge and one on either side of the center point between the center and the edge points.

For workpieces, which are cut from larger billets or for which hardness variation might be expected to be significant, additional hardness measurements should be taken to ascertain that the hardness values fall within the prescribed limits. The location of measurement points and the method of measuring should be reported in the test report. The deviation in hardness within one batch of material should be as small as possible. A realistic value for the reference materials is 5% of the arithmetic mean value.

NOTE:
In order to be able to compare results over reasonably long periods of time, it is recommended that testing bodies procure sufficiently large quantities of reference work materials to cover their needs.

Dimensions

In principle, testing laboratories are free to select the dimensions of test workpieces according to their own interest. However, in order to increase the comparability of results between testing bodies, the recommended workpiece for turning (plunging) shall be a bar of circular cross-section with a diameter of one-inch (1") and length of 6 ft. These dimensions should be restricted to ensure adequate stability during plunging. The actual dimensions shall be reported.

Tool: Turning inserts

In principle, testing bodies are free to select the turning inserts according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of uncoated carbide inserts (Type TPG-322; Grade K313) is recommended. Any deviation from the recommended inserts should be reported.

The deviation between individual inserts used in the same testing sequence should be kept to a minimum. The inserts should not have any coating or surface treatment. The presence of any coating or surface treatment shall be reported in detail.

Cutting conditions

The recommended cutting data have been chosen and combined in order to correspond to and to emphasize the turning (plunging) principles dealt with in this part. It should be noted that the cutting conditions shall be chosen to be compatible with the cutting tool, the machine tool, and the clamping device, etc., in order to obtain reliable data. The following cutting conditions for metal removal fluids performance evaluation tests are recommended:

- ♦ Cutting speed – 150 sfpm (574 rpm);
- ♦ Plunging rate – 0.001 ipr;
- ♦ Plunging width – 0.1 inch;

In cases where the cutting conditions indicated can not be achieved, other values as close as possible to those indicated above may be used.

Metal Removal Fluid

For the assessment of long term reproducibility of these test results, the testing program shall run with a reference fluid having a constant properties. The performance of all metal removal fluids (synthetic, semi-synthetic, straight oil, soluble oil etc.) shall be evaluated with respect to this reference fluid.

Criteria for the end point of the test

To increase the reliability and comparability of metal removal fluid performance test results it is essential that criterion be defined for completion of the tests. The recommended criterion for the end point of a test shall be:

- 620 cycles (plunges) for each test

As mentioned earlier, this section of the manual recommends that tool deterioration only in the form of steady wear on the flank shall be used for the metal removal fluid performance evaluation. Cracks, chipping or any other form of deterioration, if occurs, shall be recorded. Flank wear measurement is carried out parallel to the surface of the wear land and in a direction perpendicular to the original cutting edge, e.g. the distance from the original cutting edge to that limit of the wear land which intersects the original flank. Although the flank wear land on a significant portion of the flank may be of uniform size, there may be variations in its value at other portions of the flanks due to edge chipping etc. An average value of tool flank wear shall be measured and recorded.

Equipment

Machine Tool

The turning center on which the tests are to be conducted shall have sufficient power, rigidity and physical capacity. It should be of stable design and be in such condition that abnormal vibrations or deflections are not observed during the test. It is recommended that the turning center be interfaced with the hydraulic bar feeder (1 to 1-11/2 inch bar dia. Capacity). The bar feeder assists in enhancing the consistency and efficiency for running the plunge test in place of cutting the bars and chucking them. The feed speed under load shall be constant. The spindle axle orientation shall be checked.

Other equipment

Table 7.3 lists equipment, which are necessary and recommended for carrying out the tests specified in this section.

Test Procedure

Purpose

The main purpose of the test shall be the performance comparison (or ranking) of the different metal removal fluids used during turning operation. This comparison or ranking will be accomplished by measuring the cutting force (2-D) exerted on the tool and the tool wear while using a specific metal removal fluid.

Planning

It is possible to describe the metal removal fluids performance test procedure in general terms. The method to follow is the same as that used for good machine tool operation, except that great care and observation must be exercised and that certain measurements must be taken. The test matrix should be formulated and used to achieve the purpose of the test.

Before starting the test, the machine shall be thoroughly washed with solvent and then flushed and charged with 10 gallons of test metal removal fluids with a fixed concentration. When using metal removal fluids the flow should 'flood' the active part of the tool. The flow rate should be monitored and noted in the test report. Also, ascertain that the turning center, workpiece and tools fulfill all requirements mentioned earlier. The machine shall be set to the required cutting conditions. If necessary, a preliminary test shall be carried out to check that

- proper interfacing of dynamometer with PC through charge amplifier has been made,
- the turning dynamometer is properly calibrated,
- the position of the plunging tool is properly centered, and
- the specified machining parameters have been set on the machine.

The test bar in the turning center will be fed through the bar feeder and shall be rigidly fixed in the chuck while plunging. The plunging tool shall be mounted on the turning dynamometer fixed on the tool post. The dynamometer shall be properly interfaced with PC to collect force data. The plunging into the surface of the test bar shall be conducted while being flooded with metal removal fluid to make five full-depth plunges and the cutting force exerted on the insert will be collected. The cycles shall be repeated after indexing the bar forward in the bar feeder. The testing campaign shall be continued until 620 cycles are completed. The cutting forces and tool wear shall be measured at regular intervals after each cycle (e.g. 50, 100, 200, 300, 400, 500, and 620 plunges). To evaluate the relative performance of any given metal removal fluid, the turning (plunge) test will be repeated with the base line metal removal fluid under exactly similar conditions using a new insert.

Test procedure

Purpose

The main purpose of the test shall be the performance comparison (or ranking) of the different metal removal fluids (Metal removal fluids) used during turning operation. This comparison or ranking will be accomplished by measuring the cutting force (2-D) exerted on the tool and the tool wear while using a specific metal removal fluid.

Planning

It is possible to describe the metal removal fluid performance test procedure in general terms. The method to follow is the same as that used for good machine tool operation, except that great care and observation must be exercised and that certain measurements must be taken. The test matrix should be formulated and used to achieve the purpose of the test.

Before starting the test, the machine shall be thoroughly washed with solvent and then flushed and charged with 10 gallons of test metal removal fluid with a fixed concentration. When using metal removal fluids the flow should ‘flood’ the active part of the tool. The flow rate should be monitored and noted in the test report. Also, ascertain that the turning center, workpiece and tools fulfill all requirements mentioned earlier. The machine shall be set to the required cutting conditions. If necessary, a preliminary test shall be carried out to check that

- proper interfacing of dynamometer with PC through charge amplifier has been made,
- the turning dynamometer is properly calibrated,
- the position of the plunging tool is properly centered, and
- the specified machining parameters have been set on the machine.

The test bar in the turning center will be fed through the bar feeder and shall be rigidly fixed in the chuck while plunging. The plunging tool shall be mounted on the turning dynamometer fixed on the tool post. The dynamometer shall be properly interfaced with PC to collect force data. The plunging into the surface of the test bar shall be conducted while being flooded with metal removal fluid to make five full-depth plunges and the cutting force exerted on the insert will be collected. The cycles shall be repeated after indexing the bar forward in the bar feeder. The testing campaign shall be continued until 620 cycles are completed. The cutting forces and tool wear shall be measured at regular intervals after each cycle (e.g. 50, 100, 200, 300, 400, 500, and 620 plunges). To evaluate the relative performance of any given metal removal fluid, the

Table 7.3: Equipment necessary for measurements in the turning (plunging) tests

Clause	Minimum Equipment	Recommended equipment
Workpiece Dimensions Hardness	 Graduated rule Hardness tester	 Sliding calliper Hardness tester
Inserts Defects Runout	 Dial indicator	 Toolmakers' microscope Dial indicator, graduated to 0.001 mm
Metal Removal Fluid Concentration Flow (pH value) (Temperature)	 Graduated vessel Graduated vessel and stop Watch	 Refractometer Graduated vessel and stop Watch pH meter Thermometer
Cutting conditions Feed rate Spindle speed Width of cut	 Stop-watch Tachometer Sliding calliper	 Stop-watch Tachometer Sliding calliper
Tool deterioration Flank wear, chipping, flaking etc.	 Toolmaker's microscope, Dial indicator with a contact point 0.2 mm in diameter	 Toolmaker's microscope, Profile recorder and special device for mounting the inserts under the microscope
Force measurement Cutting forces in two Directions	 Piezoelectric (3-D) turning Dynamometer, charge amplifier, interfacing board, and cables, PC, software to collect and analyze data	 Piezoelectric (3-D) turning dynamometer, charge amplifier, interfacing board and cables, PC, software to collect and analyze data

turning (plunge) test will be repeated with the base line metal removal fluid under exactly similar conditions using a new insert.

Recording, evaluation and presentation of results

The cutting forces acting on the inserts shall be the primary response variable for comparing the performance of any given metal removal fluid. The cutting force data shall be analyzed to give average cutting force values during turning (plunging). The flank wear shall be another response variable and the data for flank wear shall be collected. The tool wear and analyzed cutting force data shall be recorded on the “tool wear versus number of plunges measurements” and “cutting force versus number of plunges measurements” data sheets and plotted on a tool wear (ordinate) versus number of plunges (abscissa) and average cutting force (ordinate) versus number of plunges (abscissa) diagrams.

Based on the average cutting force and tool wear patterns, the recommendations about the relative performance of different metal removal fluids shall be made. The trend of tool wear and cutting force patterns reflect on the performance of a given metal removal fluid used during that test. In general, lower values of cutting forces and tool wear rates shall indicate the better performance of the metal removal fluid.

A detailed statistical analysis can be done but is not recommended. When comparing the performance of a given metal removal fluid, experienced personnel may be able to establish with sufficient accuracy the significance of difference in the test results from a very small number of test runs.

Finally, the evaluation of metal removal fluid performance test results during end milling operation should be properly documented in the form of a report.

Grinding Test Procedure

This part specifies recommended procedure for metal removal fluid performance testing during surface grinding operation. It can be applied to laboratory as well as to production practice.

The cutting conditions in grinding may fall under two categories as follows;

a) conditions under which predominantly wheel wear occurs due to attrition;

b) conditions under which wheel deterioration is due mainly to grain/bond fracture or wheel loading

This part considers only those recommendations concerned with testing which results predominantly in uniform attritious wear of the wheel.

This part establishes specifications for the following factors of metal removal fluids performance testing during surface grinding in accordance with figure 1: workpiece, tool, cutting conditions, metal removal fluid, criteria for the end point of the test, equipment, test procedures, recording, evaluation and presentation of results.

Workpiece

Work material

In principle, testing laboratories are free to select the work materials according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of reference material (a) AISI/SAE 4140 steel (32-34 HRC) and (b) AISI/SAE 4140 steel (56-58 HRC) is recommended.

Within the specifications, materials may vary with a resulting effect on machinability. To minimize such problems, the provision of work material in compliance with stricter specifications shall be discussed with the supplier. The hardness of the test workpiece shall be determined over the testing zone of each test piece at least at five points on the center line of the workpiece, one at the center, one near each edge and one on either side of the center point between the center and the edge points.

For workpieces, which are cut from larger billets or for which hardness variation might be expected to be significant, additional hardness measurements should be taken to ascertain that the hardness values fall within the prescribed limits. The location of measurement points and the method of measuring should be reported in the test report. The deviation in hardness within one batch of material should be as small as possible. A realistic value for the reference materials is 5% of the arithmetic mean value.

NOTE:
In order to be able to compare results over reasonably long periods of time, it is recommended that testing bodies procure sufficiently large quantities of reference work materials to cover their needs.

Dimensions

In principle, testing laboratories are free to select the dimensions of test workpieces according to their own interest. However, in order to increase the comparability of results between testing bodies, the recommended workpiece for grinding shall be a bar or billet of rectangular cross-section with a length of 6 inch, width of 2.5 inch and thickness of 0.5 inch. These dimensions should be restricted to ensure adequate stability during machining. The actual dimensions shall be reported.

Tool: Grinding wheel

In principle, testing bodies are free to select the grinding wheel according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of grinding wheel with specification 32A60-IVBE is recommended. Any deviation from the recommended grinding wheel should be reported.

The deviation between grinding wheel conditions used in the testing sequence should be kept to a minimum. Therefore, single point dressing of the wheel ‘2 overlay method’ is recommended. The grinding wheel shall be properly balanced before mounting on the surface-grinding machine. The actual run-out, if any shall be measured and recorded.

Grinding conditions

The recommended surface grinding data have been chosen and combined in order to correspond to and to emphasize the grinding principles dealt with in this part. It should be noted that the grinding conditions shall be chosen to be compatible with the grinding wheel, the surface grinding machine, the clamping device, etc., in order to obtain reliable data. The following grinding conditions for metal removal fluid performance evaluation tests are recommended:

- Grinding speed – 6000rpm;
- Depth of cut – 0.0005 inch (for workpiece with 32-34 HRC);
- Depth of cut – 0.001 inch (for workpiece with 56-58 HRC);
- Metal Removal Fluid impingement velocity – matching with wheel speed

In cases where the above grinding conditions indicated can not be achieved, other values as close as possible to those indicated above may be used.

Metal Removal Fluid

For the assessment of long term reproducibility of these test results, the testing program shall run with a reference base line fluid (specification….) having a constant properties. The performance of all metal removal fluids (synthetic, semi-synthetic, straight oil, soluble oil etc.) shall be evaluated with respect to this reference fluid.

Criteria for the end point of the test

In practical workshop situations the time at which the grinding wheel ceases to remove material from the workpieces due to dullness of the grinding wheel usually determines the end of useful wheel life. To increase reliability and comparability of metal removal fluids performance test results during grinding, grinding ratio shall be considered as the primary criteria for evaluating the metal removal fluids performance shall be determined(G) which is defined as the ratio of the total amount of material removed to the total amount of wheel wear. The grinding forces will also be considered as the criteria for the evaluation of a metal removal fluid performance during surface grinding. The following criteria for the end point of a test are recommended:

- No further metal removal due to dullness of the wheel
- Accelerated wheel wear starts occurring due to grain/bond fracture of the grinding wheel.

As mentioned earlier, this section of the manual recommends that wheel deterioration only in the form of attrition wear shall be considered. Once, large amount of grain/bond fracture starts occurring, the grinding shall be stopped. This phenomenon shall be monitored through the grinding force measurement in real time. Wheel deterioration due to grain/bond fracture, however, shall be recorded.

Equipment

Machine tool

The surface-grinding machine on which the tests are to be conducted shall have sufficient power, rigidity and physical capacity. It should be of stable design and be in such condition that abnormal vibrations or deflections are not observed during the test. The feed speed under load shall be constant. The spindle axle orientation, vertical or horizontal, shall be checked.

Other equipment

Table 7.4 lists equipment, which are necessary and recommended for carrying out the tests specified in this section.

Test Procedure

Purpose

The main purpose of the test shall be the performance (or ranking) of the different metal removal fluids (Metal removal fluids) used during grinding operation. This comparison or ranking will be accomplished by measuring the cutting force (2-D) during surface grinding and the grinding ratio (G) using a specific metal removal fluid.

Planning

It is possible to describe the metal removal fluid performance test procedure in general terms. The method to follow is the same as that used for good machine tool operation, except that great care and observation must be exercised and that certain measurements must be taken. The test matrix should be formulated and used to achieve the purpose of the test.

Before starting the test, the machine shall be thoroughly washed with solvent and then flushed and charged with 10 gallons of test metal removal fluid with a fixed concentration. When using metal removal fluids, the flow through the nozzle should impinge directly on the active part of the wheel workpiece contact. The flow rate should be monitored and noted in the test report. Also, ascertain that the grinding machine, wheel, and workpiece fulfill all requirements mentioned earlier. The machine shall be set to the required grinding conditions. If necessary, a preliminary test shall be carried out to check that

- proper interfacing of dynamometer with PC through charge amplifier has been made,
- the dynamometer is properly calibrated, and
- the specified grinding parameters have been set on the machine.

The workpiece shall be rigidly mounted on the grinding dynamometer set on the machine table. The plunge grinding shall be conducted on the 0.5 inch side of the workpiece, which is the thickness of the workpiece. This will develop a 0.5 inch wedge shaped profile on the periphery of the grinding wheel. The grinding will be continued for several number of passes and the forces during each pass will be collected in real time. The test shall be stopped when (i) the wheel becomes dull and glazed after which no much metal removal takes place or (ii) more grain/bond fracture occurs in place of wheel wear due to attrition.

Recording, evaluation and presentation of results

The collected data shall be analyzed to give average grinding force values during grinding. The grinding ratio (G) will be calculated after measuring the amount of wheel wear and the total amount of metal removed tool. The grinding ratio (G) and grinding force data shall be recorded on the ‘grinding ratio (G) versus number of passes measurements’ data sheets and plotted on a grinding ratio (G) (ordinate) versus number of passes (abscissa) and average grinding force (ordinate) versus number of passes (abscissa) diagrams.

Based on the average grinding force and grinding ratio (G) values, the recommendations about the relative performance of different Metal removal fluids shall be made. In general, lower values of cutting forces and higher values of grinding ratio (G) shall indicate the better

Table 7.4 Equipment Necessary for Measurements in the Surface Grinding Tests

Clause	Minimum Equipment	Recommended equipment
Workpiece Dimensions Hardness	 Graduated rule Hardness tester	 Sliding calliper Hardness tester
Grinding wheel Dimensions Runout	 Sliding calliper Dial indicator	 Micrometer, 0-25 Dial indicator
Metal Removal Fluid Concentration Flow (pH value) (Temperature)	 Graduated vessel Graduated vessel and stop Watch	 Refractometer Graduated vessel and stop watch pH meter Thermometer
Cutting conditions Spindle speed Depth and width of cut	 Tachometer Sliding calliper	 Tachometer Sliding calliper
Wheel wear Attrition wear, grain/bond fracture	 Toolmakers' microscope, dial indicator	 Toolmakers' microscope, profile recorder
Force measurement Cutting forces in two Directions	 Piezoelectric (2-D) grinding Dynamometer, charge amplifier, interfacing board and cables, PC, software to collect and analyze data	 Piezoelectric (2-D) grinding dynamometer, charge amplifier interfacing board and cables, PC, software to collect and analyze data

performance of the metal removal fluid.

A detailed statistical analysis can be done but is not recommended. When comparing the performance of a given metal removal fluid, experienced personnel may be able to establish with sufficient accuracy the significance of difference in the test results from a very small number of test runs.

Finally, the evaluation of metal removal fluid performance test results during grinding operation should be properly documented in the form of a report.

APPENDIX I

Environmental Health and Safety

APPENDIX 1

Environmental Health and Safety

Section A

<u>Explanation of 16-Section MSDS</u>

SECTION 1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

In this section, you will find the name, address, phone number, emergency phone number for the manufacturer/importer/distributor of the product. You will find the product name. This is the section that links the name of the product and the name of the manufacturer/importer/distributor on the label to the MSDS. You may find other synonyms for the product name; general application and/or product description information. This section may also include the date of preparation/date of revision and the preparer's name (may also be found in Section 16). This section is essential for all users of the MSDS.

SECTION 2 COMPOSITION, INFORMATION ON INGREDIENTS

Typically you will find the hazardous ingredients listed. You may find the percent or percentage range for that ingredient (if in a mixture), the CAS Registry Number for any ingredients listed and the PEL, TLV or other exposure limits. Some of this information may also be found in Section 8. This section is useful for all users of the MSDS

Sometimes the supplier will claim the identity of the hazardous ingredient as confidential. The specific chemical name and CAS # will not be supplied. However, the supplier must supply all known health and physical hazards associated with the ingredient. There are provisions under OSHA's Hazard Communication Standard where the confidential information must be supplied to a qualified medical person in the event of an emergency.

There is an additional provision under OSHA's Hazard Communication Standard where the chemical identity may be kept confidential or trade secret. If the supplier has tested the product using internationally accepted test protocols <u>and</u> the results indicate that the product is non-hazardous, they may eliminate the listing of any ingredients.

SECTION 3 HAZARDS IDENTIFICATON

In this section, you will find important information about the physical and health hazards associated with the product. The section will list the potential acute health hazards and the potential chronic health hazards associated with the product. It may include the exposure limits (PEL, TLV, etc.); medical conditions aggravated by exposure to the product. You may also find a general "Emergency Overview" for the product including information about the physical and health hazards; label statement and DOT regulations. This section is important for emergency response personnel but is useful for all users of the MSDS.

SECTION 4 FIRST AID MEAUSRES

This section will include first aid measures to treat typical exposures to the chemical product. May also include information for a treating physician. This section is important for all users of the MSDS especially emergency response personnel.

SECTION 5 FIRE FIGHTING MEASURES

You will find the following information listed: flash point (if applicable), basic fire fighting instructions, extinguishing media, fire and explosive properties and products of combustion. You may find information about the fire point and flammable limits where available. This section is important for trained fire fighters.

SECTION 6 ACCIDENTIAL RELEASE MEASURES

This section will give you information on handling spills or releases of the product. May break down this information into handling for small and large spills or releases. This section is typically used by emergency responders and EHS professionals.

SECTON 7 HANDLING AND STORAGE

The handling section will typically have the same general statements from the label about physical contact, fire and explosion and personal hygiene. The storage section will have general information on storage such as temperatures and unusual storage requirements. This section is important for all users of the MSDS.

SECTION 8 EXPOSURE CONTROLS, PERSONAL PROTECTION

Will included Personal Protective Equipment (PPE) and ventilation recommendations. PPE may include eye, skin or respiratory protection. In addition, may list specific ingredients with up-to-date exposure limits (information may be found in Section 3 or 4). This section is important for employers and EHS professionals but should be reviewed by all users of the MSDS.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Will list various physical and chemical properties* such as:

Appearance/Odor
Physical State
Odor Threshold
Boiling/Melting/Freezing Point
Specific Gravity or Density
Bulk Density
pH (for neat material or a use dilution)
Solubility of material in water
VOC Determination
Evaporation Rate
Percent Volatile
Percent Solids
Vapor Pressure
Vapor Density
Viscosity
Water/Octanol Partition Coeffecient
Flash Point (may also be found in section 5)
Autoignition Temperature
Fire Point (may also be found in section 5)
Flammable Limits (may also be found in section 5)
Molecular Weight

If the information is not available, the supplier must indicate it. Indications may include Not Available or Not Applicable (NA) or Not Determined (ND). All users of the MSDS any use some or all of this information.

*Not all inclusive

SECTION 10 STABILITYAND REACTIVITY

Will list potential reactivity hazards. Will list the stability of the material, conditions to avoid; materials incompatible with the chemical, hazardous decomposition products, and hazardous polymerization. This section is intended for employees and EHS professionals; may also be used by emergency responders.

SECTION 11 TOXICOLOGICAL INFORMATION

This section will list the results of specific animal and/or human testing where available. May include such things as LD_{50}, LC_{50}, Draize Eye Irritation Index (or other indices) and the Primary Irritation Index(PPI) for skin irritation. May include information about the potential to cause cancer, reproductive hazards, and target organ effects. May include information about potential mutagenicity or teratogenicity of the material. May include information from Section 3 and may further explain items found in Section 3.
While this section is generally intended for EHS or medical professionals, it has important information for all users of the MSDS.

SECTION 12 ECOLOGICAL INFORMATION

Will list information to evaluate the potential environmental impact of the material such as COD data, BOD data, test data on effects of the material on animals, fish or other living species. This section typically used by EHS professionals.

SECTION 13 DISPOSAL CONSIDERATIONS

Will include information on the proper disposal of the material. Will indicate if a hazardous waste and include the EPA Hazardous Waste ID#. May include information on recycling. This section typically contains general statements about disposal. This section typically used by technical or EHS professionals responsible for waste management.

SECTION 14 TRANSPORT INFORMATION

If regulated under DOT, will include the proper shipping name, hazard class, UN/NA Number, and Packaging Group. May include the Emergency Response Guide Number and International Air and Water regulations. This information is typically used by technical personnel involved in shipping departments, emergency responders and EHS professionals.

SECTION 15 REGULATORY INFORMATION

Includes information on the regulatory status of the product. May include SARA Title III, Section 311/312 Tier I or Tier II, SARA Title III, Section 313, Toxic Substances Control Act Inventory status, Comprehensive Environmental Response Cleanup and Liability Act (CERCLA), state RTK or disclosure requirements (CA, MI, PA, MA, NJ) and international regulations. Typically used by EHS professionals.

SECTION 16 OTHER

Typically will include the date of approval of the MSDS or the date of most recent revision; reason for revision; preparer’s name and title. May include HMIS/NFPA ratings for the product; special considerations, reference material and a disclaimer.

Section B

Acronyms

Acute Exposure **-** Short term exposure

CAA/CAAA - Clean Air Act/Clean Air Act Amendments of 1990

Carcinogen **-** material which either causes cancer in humans or because it causes cancer in animals is considered to be capable of causing cancer in humans.

CAS Number - A unique identifying number for chemical substances. Assigned by Chemical Abstract Service in Columbus, Ohio.

CERCLA **-** The Comprehensive Environmental Response, Compensation, and Liability Act. Created the Superfund to finance the cleanup of abandoned hazardous waste dumpsites.
CHEMTREC **-** Center in Washington, DC to provide emergency information on materials involved in transportation accidents. 24-hour number is 800-424-9300.

Chronic Exposure **-** Long term exposure

CNS - Central Nervous System

CNS Depression **-** Drowsiness, dizziness and/or headache caused by a chemical exposure. Extreme symptoms may include unconsciousness, coma or death.

CO - Carbon Monoxide

CO_2 - Carbon Dioxide

COC **-** Cleveland Open Cup Test. One test method for determining flash points.

Combustible Liquid **-** under DOT, a liquid with a flash point above 141 F. but below 200 F.

CFR - Code of Federal Regulations. The printed forum for all federal regulations. Each agency or groups of agencies are found under a different code. For example, EPA is found in Title 40; OSHA under Title 29; and DOT under Title 49.

CWA - Clean Water Act

Dermatitis **-** Skin rash; inflammation of skin

DOT **-** The Department of Transportation

DOT ID #s - four-digit numbers used to identify particular materials for purposes of transportation. UN is for both domestic and international transportation; NA is for domestic transportation only.

EINECS **-** The European Inventory of Existing Chemical Substances. A list of chemical substances that were marketed in the European Community between 1/1/71 and 9/18/81.
Rules for inclusion of substances were different that US TSCA regulations.

EPA **-** The Environmental Protection Agency

FIFRA **-** The Federal Insecticide, Fungicide and Rodenticide Act . Regulation of pesticides including biocides

Flammable Liquid **-** under RCRA and DOT, a liquid with a flash point at or below 141 F.

HAP - Hazardous Air Pollutant under Clean Air Act Amendments of 1990

HMIS **-** Hazardous Material Identification System

IARC - International Agency for Research on Cancer. One of the sources of data on a material's carcinogenicity.

Mutagen - material that induces genetic changes in the DNA

LC_{50} - The amount necessary to kill half the test animal population in an inhalation study.

LD_{50} - The amount necessary to kill half the test animal population in an oral ingestion study.

NFPA - National Fire Protection Association

NIOSH - The National Institute for Occupation Safety and Health

NO_x - Nitrous Oxides

NTP - National Toxicology Program. One of the sources for information on a material's carcinogenicity.

OSHA - The Occupational Safety and Health Administration

PAH - Polyaromatic Hydrocarbons. Also called PNAs (polynuclear aromatics) or PCAs (polycyclic aromatics). Cyclic hydrocarbons of which many of these materials are carcinogenic or are converted to carcinogens when metabolized by animals or humans.
In Europe, the level of PAHs in mineral oil determines whether these oils are labeled as carcinogenic.

PEL - Permissible Exposure Limit. An eight hour time weighted average level at which the majority of employees may be exposed to without undue health effects. Established by OSHA and listed in 29 CFR 1910.1000.

PMCC - Pensky-Martens Closed Cup Tester. One test method for determining flash points.

POTW - Publicly Owned Treatment Works (Sewer Authority)

ppb - parts per billion

ppm - parts per million

RCRA - The Resource Conservation and Recovery Act. Covers hazardous waste disposal

SARA - Superfund Amendments of Reauthorization Act of 1986. Reauthorized the Superfund regulations and created the Community Right-to-Know regulations.

SO_x - Sulfur Oxides

STEL - Short-term exposure limit - usually 15 minutes.

TCC - Tag Closed Cup Tester. One test method for determining flash points.

Teratogen - material capable of causing physical defects in a developing embryo.

TLV - Threshold Limit Value.   An eight hour time weighted average level at which the majority of employees may be exposed to without undue health effects. Established by the ACGIH.

TSCA - The Toxic Substances Control Act

TSCA Inventory - Inventory of chemical substances in commerce in the United States between 1973 and 1975 and those materials for which PMNs have been issued.

VOCs - Volatile Organic Compounds

Section C

Additional Resources

This section will include publications of interest and websites where you can obtain additional information. It will also contain agency names and addresses.

Publications

American National Standard for Hazardous Industrial Chemicals - Material Safety Data Sheets – Preparation(NASIZ400.1-1993). American National Standards Institute 11 West 42nd Street, New York, New York 10036

Criteria for a Recommended Standard – Occupational Exposure to Metalworking Fluids - US Department of Health & Human Services, National Institute for Occupational Safety & Health, Cincinnati, OH. January 1998

Metal Removal Fluids: A Guide to Their Management and Control. Organization Resources Counselors, Inc. August 1997.

Metalworking Fluids Optimization Guide (NCMS Report 0274RE95). National Center for Manufacturing Sciences, Ann Arbor, Mi. 1997

What you need to know about occupational exposure to metalworking fluids. (DHHS 98-116) US Department of Health & Human Services, National Institute for Occupational Safety & Health, Cincinnati, OH. March 1998

Symposium Proceedings - The Industrial Metalworking Environment: Assessment and Control. November 13-16, 1995. American Automobile Manufacturers Association March 1996

Symposium Proceedings - The Industrial Metalworking Environment: Assessment and Control of Metal Removal Fluids. September 15-18, 1997. American Automobile Manufacturers Association. September 1998.

IAMS publication : Waste Reduction of Cutting Fluids and Lubricants (Tom, Please put it specific reference.)

Websites

www.epa.gov/ US Environmental Protection Agency

www.osha.gov/ US Occupational Safety & Health Administration

www.dot.gov/ US Department of Transportation

www.cdc.gov/niosh National Institute for Occupational Safety & Health Administration

www.iams.org Institute for Advanced Manufacturing Sciences

www.ncms.org National Center for Manufacturing Sciences

www.ilma.org Independent Lubricant Manufacturers' Association

www.aama.com American Automobile Manufacturers' Association

www.astm.org American Society for Testing and Materials

www.ansi.org   American National Standards Institute

www.metalworkingfluid.com Metal Working Fluid Magazine

Agencies

United States Environmental Protection Agency (EPA) 401 M Street, SW, Washington, DC 20460-0003. Phone: 202-260-2090

Occupational Safety and Health Administration (OSHA) 200 Constitution Avenue, NW, Washington, DC 20210. Phone:1-800-321-6742

U.S. Department of Transportation, Research & Special Programs Administration., Office of hazardous Materials Standards, 400 Seventh Street, SW, Washington, DC 20590. Phone: 202-366-4900

National Institutes for Occupational Safety & Health, 4676 Columbia Parkway, Cinncinati, OH. 45226-1998 Phone: 1-513-533-8328

APPENDIX II

Filtration Fundamentals

APPENDIX II

Filtration Fundamentals

The following section was developed by Mr. Leonard Ardizonne of ENPRO, a Division of Hydrotech, Inc. It is perhaps, the best primer I've read on filtration and filtration systems. It seemed unfair to break it into smaller sections and attempt to incorporate it into the main body of the manual so Mr. Ardizonne's efforts are presented as he wrote them.

Introduction

The set-up of your cooling system project went very well and projections of savings are significant. Then you entered into production. All went well in the first few weeks. One day, just a few weeks into the program, you come into the shop on a Monday morning and you notice the fluid is a completely different color from when you started. The operators are unable to maintain surface finish and the whole shop is starting to smell! You run into your office to hide and find e-mails and phone messages from maintenance, asking where to go to get replacement nozzles and hoses and pumps! Then your boss bursts in….!!!!

So what happened? If the following symptoms have appeared in the system, then perhaps you didn't pay enough attention to filtration or worse yet, you didn't put a system in!

- High particulate count and discolored fluid
- Short fluid life (<8 weeks)
- Short tool life as compared to past experience or manufacturer's estimates
- Frequent sump cleaning caused by excessive dirt deposits
- Short system component life (pumps, valves, connections, hoses, etc.)
- Frequent nozzle plugging/block
- Frequent leaks and excessive maintenance

The proper selection, location and maintenance of a filtration system can greatly reduce the problems listed above. In turn allowing economical operation of the machine(s) to achieve increased production rates. Projections of savings will be met.

Filtration Definitions

The following definitions will aid in the discussion of a filtration system. Use this section as a reference when dealing with filtration issues.

Filtration - A process of removing particles from a fluid by forcing them through a porous medium (a cartridge, bag, sheet or other filter). Typically the medium is disposable, manually cleaned or back-flushed (automatically cleaned).

Filter System - The combination of a filter and associated hardware required for the filtration process.

Centrifuge Filtration - A filtration system that uses centrifugal force to separate particles of different densities.

Particulate - A contamination found in Metal Removal Fluid. They are defined by size.

a. Large Chips – particulate that is greater then 150 microns in size. Typically removed from the filtration stream by the machine tool conveyor system.

b. Small Chips – particulate between 25 and 150 microns. These typically settle into the sump of the machine tool. If allowed to amass they will eventually begin to circulate through the metal removal fluid system

		causing wear, damage and eventually failure of components
	c. Silt Particulate –	greater then 2 microns less the 25 microns. These particulate remain suspended in the metal removal fluid and will grow in population if the filtration system is incorrectly sized or inefficient. Degradation of the fluid resulting in shortened fluid life, shortened tool life and increased maintenance and costs are the results of this type of contamination.

Pressure Vessel - A filtration system that uses a filter element(s), cartridge(s) or bag.

Filter Element - Sometimes referred to as the filter cartridge. They are most times resin-impregnated cellulose or resin impregnated synthetic fibers, often times with a wire support mesh.

Cartridge - A multi-layer material design that includes the filter element. It is designed for quick change out and/or cleaning.

Bag Filters - A sock type design, often with multi-layers of synthetic fibers

Flow Path - The direction of the fluid flow through a filter or through the system. Typically the filter element is “outside in”, bags are “inside out” and cartridges can be in either direction depending on the design.

Mesh - The rating of the filtration ability of the filter/system. The finer the mesh the “better” the filtration ability of the system.

Micron Chart

159 microns = 100 mesh screen
100 microns = table salt
90 microns = smog
70 microns = human hair
60 microns = pollen
50 microns = fog
40 microns = lower limit of human visibility
7 microns = red blood cell
2 microns = bacteria

Efficiency of Filtration Products

Elements and Cartridges are extremely efficient filtration products because the manufacturers, in most cases, meet a list of Industry Standard and Testing[i] in their quality control procedures. The following is a sample list of these standards:

ISO 2942 Fabrication Integrity

ISO 2941	Collapse Burst
ISO 2943	Material Compatibility

These standards form the ANSI Standard called the Multi-Pass Method for Evaluation of Filtration Performance. This is the only widely used test for determining the particle separation characteristics of a filter element or cartridge. It is generally considered the most important of all filter-testing methods.

The contamination media used for this test is Air Cleaner Fine Test Dust (ACFTD). This is readily available and internationally accepted as a material with particle shape and size distribution consistent from batch to batch. This consistency is known from 1 micron upward.

It is recommended that filter elements/cartridges that uses the Beta absolute ratings from the Multi-Pass test be selected. This provides the best assurance of consistent filter efficiency. It should be noted that this test was developed for straight oils or water. Metal removal fluid (oil/water based, synthetic or semi-synthetic) creates an emulsion, which may cause the Multi-Pass test to be inconsistent.

In the nominal filtration test, a given amount of ACFTD (selected by the manufacturer) is fed through the system. The containment and subsequent removal of the contaminant by the filter over a one-hour period is what is measured. There are two ratings that are presented:

1. less then 50% of the particles that are greater then the given micron rating
2. 90-95% of the particles are greater then the given micron rating

The problems associated with the nominal rating systems are the absence of reproducibility/uniformity and the lack of comparative test data. There is no way with this technique to compare one filter to another. The nominal rating is an arbitrary value indicated by the filter manufacturers and has been depreciated.

The Beta Ratio rating is a better indicator of performance. Using the Multi-Pass test, the Beta Ratio defines the number of particles (using the ACFTD), greater then a given size (x) in the influent upstream of the filter, to the number of particles greater then the given size (x) in the effluent on the downstream side of the filter. This ratio is defined as

$$B_{(x)} = \frac{\text{Number of upstream particles} >(x)\text{M}}{\text{Number of downstream particles} >(x)\text{M}}$$

Where $B_{(x)}$ is defined as the Filtration Ratio. Consider the example given below….

Example:

A filter element has a Beta Rating of $B_{(10)} = 75$. This indicates that all particles > 10 microns are being captured by the filter element at a ratio of 75:1. Because Beta Ratios deal with efficiency, they can be expressed as the percentage of the particles greater then size (x) removed. Or….

$$E_{(x)} = \frac{B - 1}{B} \times 100 =$$

$$= \frac{75 - 1}{75} \times 100 = 98.7\%$$

Note that Beta Ratings are established on a upstream/downstream Ä P. Also, the Beta Ratio efficiency should remain consistent through the terminal life of the filter element.

Beta Ratio and Efficiency		
	Beta Ratio	% Efficient
ANSI B93.91 1973 mean	1	0
	2	50
	5	80
	10	90
	20	95
	50	98
ANSI B93.31 1973 absolute	75	98.7
	100	99

In addition to the Beta Ratio, the Multi-Pass test can also be used to evaluate two other parameters; Apparent Dirt Capacity and Retained Dirt Capacity. The Apparent Dirt Capacity is a measurement of the total ACFTD fed in to the filter system up to the point where a terminal pressure drop of the element occurs. This term is useful in comparing filter life of the same size Beta value. However, it is not a measurement of the contaminant the filter has captured. That measure is the Retained Dirt Capacity. When all contaminant is captured, the Retained Dirt Capacity is equal to the Apparent Dirt Capacity.

Bag filters, in most cases, are rated using the nominal rating approach, not the Beta Ratio test. It is difficult to determine the true efficiency of bag filters. Unless upstream and downstream counts are analyzed in a lab where particle counts can be taken frequently, Beta Ratio's are too difficult to capture. Most filter testing labs can do this. However, in the field at the user level, particle counts are nearly impossible to perform when using metal removal fluids that are synthetic, semi-synthetic or oil/water based. Other techniques are discussed below.

The major factors restricting the use of commercially available particle counting devices are the following:

- Air bubbles generated when fluid passes through the sensor
- High fluid opaqueness which prevents light transmission
- Existence of foreign liquid droplets in the fluid stream
- Poor electrical conductivity characteristic of the fluid
- Difficulty in obtaining compatible dilution fluid

Depending on the technology used to count the particles, any one of these can be the issue.

For metal removal fluid applications and especially when cast iron is in the effluent, clean-able wire mesh pleated, stainless steel filter elements are a good solution when the dirt ingestion rate is high. This is also true when particle size is high, in the > 25 micron range. A 200 mesh (74 micron, absolute) stainless steel pleated element should have the structure and integrity that is capable of filtering the larger particles, building a “cake” up on it’s surface, which would in turn filter smaller particles, perhaps down to as much as 10 micron in size.

This type of filter element is easily cleaned, requiring no special tools or solutions. It can usually be cleaned in less than five minutes. These elements may not use the Beta Ratio test or rating. They do however, if constructed properly, provide an absolute rating. As stated above, a 200-wire mesh is a 74-micron absolute rating. This means that there are no porous holes that can be detected above that rating. Currently, there is additional study underway in “cleanable and back-flush” filtration technology. This approach may, in the near future, be the best solution for Metal Removal Fluid filtration.

In addition to filter type systems another particle separation technique incorporated into these systems uses the principals of centrifugal force.

Economics of Filtration Products

Filter vessels utilizing elements, cartridges or bags are competitively priced for a given pressure size. A vessel is not a consumable item and can therefore be amortized. The elements, cartridges and bags are consumables and are an issue that needs to be considered.

Bag type filters are the least expensive to replace at between $2 and $20 dollars depending on size and quality. The efficiency of the bag filtering technique must be questioned. A 5 micron or 15 micron bag may only be 10% efficient or less at a given micron level. Though particulate may start accumulating, this does not mean that the desired filtration level is being accomplished. If not, other issues will arise that may be more costly then an efficient filtration system would have been.

The use of the Beta Ratio for elements and cartridges is efficient. However, replacement costs are high. In addition, the particulate holding capacity of these devices is relatively low and they must be changed more often, again increasing their cost. The average price per change-out in a vessel ranges from $25 to $250.

When deciding which type of filtration system to install, it is misleading to only compare cost. Frequency of change-out, cost of elements, risk of failure, down time etc. all must be taken into consideration. The following example will illustrate.

Example

Machine “A”, “B” and “C” are in production, side by side, producing the same parts.

Machine A

Total Yearly Maintenance Costs = $8000
(includes: new metal removal fluid, labor, component replacement, and tool replacement)
Filtration Element: Bag Type.
Replacement Cost: $250 yearly (included)

Machine B

Total Yearly Maintenance Costs = $5000
(includes: new metal removal fluid, labor, component replacement, and tool replacement)
Filtration Element: High efficiency Beta Absolute Filter
Replacement Cost: $2500 yearly (included)

Machine C

Total Yearly Maintenance Costs = $10000
(no filtration used)

As can be seen from this example, though the element change-out cost of machine B is the highest of the three, it also has the lowest overall maintenance costs. The efficiency of the filtering system is such that it overcomes the initial element cost.

The filtration vessels utilizing elements, cartridges or bags can be used at individual machines or in centralized systems that accommodate numerous machines throughout a plant.

Also, as stated in the previous section, when particulate ingression rates are high, as in metal removal fluid application, stainless steel filter elements may be most economical. Though initial cost is high ($280-$500), the cleaning time is only approximately 5 minutes for a 200 mesh (74 micron, absolute) and a single element can last up to three years before replacement, depending on the application. These are recommended for most metal removal fluid applications.

For centralized systems, a centrifuge with automatic back-flush cleaning is highly recommended. Though the initial cost of these systems is high ($8000 +, depending on size and filtration capacity), the low maintenance and long life of the system offset the initial investment. In addition, the high quality of the effluent returning into production helps to offset the costs even further through higher production rates, reduced replacement costs and reduced disposal costs.

Selection of Cleanliness Level: Choosing the Micron Size

Review the Introduction of this document. Determine if the problems in the system are related to particulate contamination. Once that determination has been made, some initial issues must be eliminated as a source of contamination. Most machine manufacturers install a filtration system on their machines. Check this system. Inspect the filter unit, pumps, lines etc. for signs of wear and proper maintenance. Correct any maintenance problems or filter issues before adding or replacing the existing system.

Once these problems have been addressed, if issues still remain with the system, sampling of the fluid in the system must be conducted to determine a baseline of contamination. The purpose of withdrawing samples from different places in the system is to compare particulate weights for accuracy and dirt settling. For an individual machine sump, a minimum of two (2) sets of samples, are recommended. The first should be done immediately after clean fluid is installed. The second sample set is withdrawn near the end of the fluid life. However, additional samples withdrawn through this time frame will aid in the accuracy of the evaluation. Each and every sample should be documented with dates, times, withdrawal location, along with any fluid maintenance done in the time frame; i.e. water added, additional fluid added etc.
In large central systems where the fluid is changed out at longer intervals (yearly for example), a minimum of six (6) samples should be taken at evenly spaced times throughout the year.

Sampling should be done as follows:

1. Sump samples should be withdrawn with a syringe that has been thoroughly pre-cleaned and validated to assure a minimum amount of contamination.
2. Take the fluid sample from two areas.
   A. The sump – middle of the sump at about the half depth level.
   B. The pressure line – at least downstream from the supply pump and upstream from the machine. In addition, if a filter is already present in the system, take samples upstream and downstream from it.
3. Sample bottles should be obtained from a lab supply house and should be carefully selected to be as easily cleaned as possible. Fluid samples should be emptied into these bottles.
4. Every sample should be documented with dates, times, withdrawal location along with any fluid maintenance done in the time frame; i.e. water added, additional fluid added etc.

Since the Multi-Pass – particle count method is limited in the field (see Efficiency of Filtration Products, above); either of two particulate contamination analysis methods can be used.

- Particle Re-suspension Method (PRM)
- Gravimetric Method

PRM utilizes the principle of particle re-suspension from one fluid (the metal removal fluid) to another (straight oil). Using this method, filtering the contaminated fluid through an ultra-fine membrane filter, particles are re-suspended into the oil, which is compatible with the particular particle counter being used.

The results from this sampling and testing will help determine the solid population that needs to be controlled in the subject fluid. If eighty percent (80%) of the particulate population ranges from 15 to 25 microns, then an efficient 15-micron absolute filter is required.

For further information on this subject and others regarding Fluid Contamination Control check this reference:

Dr. E.C. Fitch or Dr. R.K. Tessman
FES Inc.
5111 N. Parkins Rd.
Stillwater, OK 74075
PH: (405) 743-4337
FX: (405) 743-2012

Filtration System Methods

When dealing with individual machines (sumps up to 500 gal.), there are three basic filtration approaches to consider for removal of particulate contamination:

- In-Line Filtration
- Portable/Stationary Filtration Systems that circulate the metal removal fluid in the sump
- Centralized Filtration Systems

Each has their advantages and disadvantages. Selection is on a per sight \ per application basis.

The In-Line Filtration method is the most efficient because it is continuous and non-bypassing. The in-line filter must be oversized due to the high ingression dirt levels in the Metal Removal Fluid (METAL REMOVAL FLUIDS). When sizing a filter system, the flow rate of the filter, gallons per minute (gpm), should be equal to or greater then the sump volume.

$$Q(\text{gpm}) = V(\text{gal})$$

For example, if a metal removal fluid sump contains 150 gallons, the in-line filter should have the capability to flow 150 gpm with a clean ΔP of 2 psi, regardless of the micron size of the element. The filter vessels should be equipped with upstream and down stream pressure gauges and sample ports. A differential indicator switch is also an option.

A filter element/cartridge capable of this flow rate will measure approximately 6" OD x 36" long. A comparable bag filter would be approximately 30" x 36".

The operating pressure of the filter vessel should be a minimum of 50 psi above the pressure of the system. Filter vessels utilizing element/cartridges (disposable or wire mesh cleanable) or bags can be sized for the system. The filter vessel should be maintenance friendly, where few or no tools are required to change out the element/cartridges or bags.

One of the three systems was the Portable Filtration System. It consists of a circulating metal removal fluid pump and a portable sump. It should be sized as mentioned above, except for the operating pressure. Since this method is independent of the machine specification, the filter vessel can be rated separately. The filter system pump should be sized to circulate the sump metal removal fluid at least 20 times per day. This system can be move from machine to machine. However, to achieve the 20 turnover rate, the flow rate must increase. Based on a 12-hour shift and machine sumps of 150 gallons, the flow rate must increase by 5 gpm for every machine sump per day.

Example: to clean three (3) machines per day – in a 12-hour shift

15 gpm or 900 gph x 12 hr shift = 10,800 gallons per day
10,800 gallons per day / 150 gallons per sump = 72 turnovers
72 turnovers / 3 machines = 24 turnovers per machine per day

Another of the three systems was the stationary system. This generally accommodates only one machine. It to must be sized accordingly. Given a typical sump of 150 gallons the following is a sizing example.

Example:

Sump size	=	150 gallons
Filter flow capability	=	150 gpm
Circulating pump flow rate	=	5 gpm
Operating pressure of filter	=	100 psi

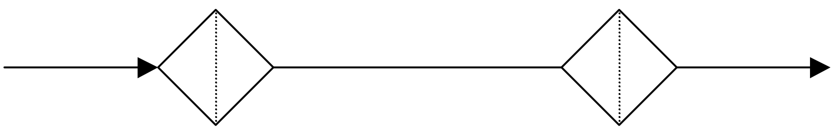
Turn over rate = 5 gpm or 300 gph x 12 hr = 3600 gallons/shift

3600 / 150 gallon sump = 24 sump turnovers/shift

The last of the three systems is the Centralized Filtration System. This is a system that is remotely located to the machines. The dirty metal removal fluid is either manually or automatically by pump and a piping system, delivered to the filtration system. Some systems are specifically designed for this technique. They filter entire shops. Volumes of contaminated metal removal fluid ranging from 500 to 1000 gallons weekly will require two filter vessels capable of 100 – 150 gpm flows, each. A pleated filter element/cartridge that measures approximately 6” x 36” should be capable of this flow rate. The flow rate is based on a clean $\Delta P < 2$ psi and 5 microns absolute.

In all three methods above, additional filter life and more surface area is required. To accomplish this, the filter vessels can be oriented in parallel and/or in duplex arrangements. If dirt ingression varies and if plugging of the filter elements/cartridges is a concern, arranging the vessels in series can be a possible solution. An example is given.

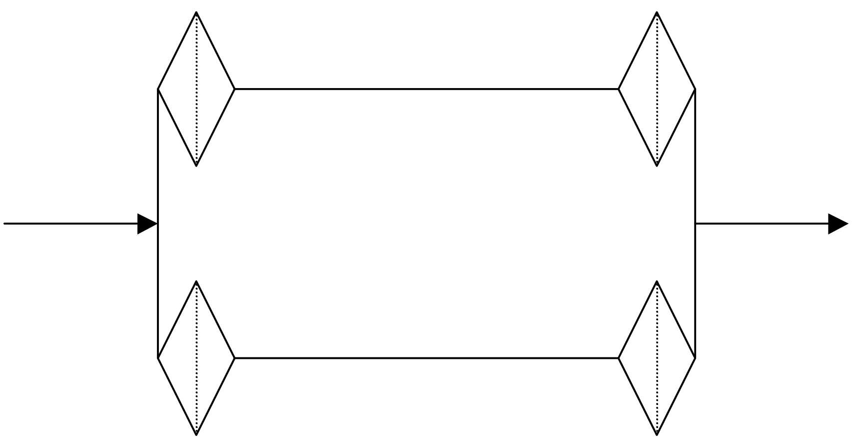
Example:
A bag type filter vessel with a nominal rating of 5 to 10 microns is clogging. Following that filter in line with another Element type, at a rating of 15 to 25 microns will aid in the clogging issue.



5 or 10 Micron Nominal
Bag Type Filter

Element Type Absolute
15 – 25 Microns

These can also be set up in parallel to further increase the efficiency of the system as follows:



5 or 10 Micron Nominal
Bag Type Filter – two
stage

Element Type Absolute
15 to 25 Microns – two
stage

This system will increase filtration surface area and increase life.

The filter element/cartridge type 15 – 25 microns absolute, is downstream of the bag filter type 5-10 microns nominal. The efficiency of the filter element/cartridge is greater then that of the filter bags. It is also more expensive to replace. Therefore, the use of the filter bags up stream from the element will increase the life of the element and reduce the cost of operation.

Tramp Oil

Tramp Oil is a contaminant that is generated by the leaking of the machine lubrications and hydraulic oils into the metal removal fluid sump(s). When it enters the metal removal fluid system it is in a free state. It is not emulsified in the metal removal fluid. As it mixes with the metal removal fluid and circulates in the system, the tramp oil breaks down into droplets as small as 20 microns. Tramp oil will encapsulate metal particulate (fines), and coat the walls of the sump, piping and components.

Tramp oils also diminish the ability of the metal removal fluid to remove heat from the work piece. This causes the metal removal fluid and the material to increase in temperature, to the point where it can effect dimensional quality. In addition, this temperature rise will enhance the environment for bacteria growth. Bacteria feed on the fatty acids in the tramp oil. The heat accelerates this activity. As the bacteria slime grows and manifests itself in the machine metal removal fluid, it causes the deterioration of the metal removal fluid, accelerates tool wear, diminishes quality, both dimensionally and surface finish, and results in health problems for the operator with rashes and allergies.

Maintaining the tramp oil levels can control bacteria. Tramp oil is considered to be a more serious metal removal fluid contamination problem then that of particulate. Sometimes it is difficult to determine if the contamination problem is the result of particulate or tramp oil, or both. The tramp oil contaminant problem should be addressed first.

Maintenance

If tramp oil is a concern, maintenance should be done to minimize or eliminate the source. Some oil will leak into the metal removal fluid stream on almost any machine. Maintenance should be done to find and correct any excess leakage. Once complete oil separators can be installed.

Types of Tramp Oil Metal removal fluid Separators

Enhanced Gravity Flow Separators – these utilize coalescing polypropylene plates with maximum plate surface area per cubic foot of space occupied and no consumables. These can be designed for both low and high flow rates and can be used in individual machine sumps or in a centralized system. This system can separate free tramp oil droplets as small as 20 microns when the surface area is above 90 ft^2 per cubic foot of fluid. The cost and maintenance of this type of system is low.

Centrifuge System – this system uses centrifugal force for separating the tramp oil from the metal removal fluid. In general, metal removal fluid has a density or specific gravity of approximately one (1). Tramp oil, is generally around 0.85 – 0.90 for its density or specific gravity. This difference is what allows this system to separate the two. Centrifuge Systems are usually designed for large, central systems with low flow rates. One drawback is that it can drive some contamination into emulsion droplets. The initial cost of this equipment is high.

Coalescing Cartridges – these membrane systems known as ultrafiltration cartridges, are a thin, permeable, inert, polymeric material. These are cast in such a way so that the size and shape (tortuosity) of the pores is controlled. These are widely used in bacterial filtration and solution sterilizing. Designed for low flow rates, there is a high equipment cost associated with this system. In addition, these cartridges can occasionally remove metal removal fluid additives used in centralized systems.

Tramp Oil/Metal removal fluid Separation Methods

There are basically two methods, Bulk System Tramp Oil/Metal removal fluid Separators and Individual Machine Sump Tramp Oil/Metal removal fluid Separators. With Bulk separation the metal removal fluid is removed from the sump on a scheduled basis before it reaches terminal life. It is then treated using Bulk System Filtration/Separation Equipment.

Bulk filtration/separation equipment can be purchased and designed to meet requirements and needs of any shop. The system should consist of a tramp oil metal removal fluid separator, a filtration system and a clean tank. The size of the system will depend on the volume and the flow rates required.

The Individual Machine sump method is more complicated. The process is the cleaning of the metal removal fluid, removing the tramp oil and circulating the metal removal fluid through a separator, all done at the machine while still in operation. The equipment to do this can be designed to be stationary at the machine, or portable, where it can service a number of machines. The portable system must be designed with the shop layout in mind. It will need to get into narrow, tight places. Either way, it should incorporate a floating skinner, a pump, hose, and a separating tank, using coalescing plates. The process should remove the floating solids, the interface level (or "rag layer" that contains emulsion droplets and bacteria) and contaminated metal removal fluid down to about ½" below the fluid level.

Once the tramp oil and rag layer have been removed, the separator will continue to circulate the metal removal fluid that contains many small tramp oil droplets that are about to coalesce to the surface. The separator must be able to effectively capture these tramp oil droplets before they exit the unit. To do so, the separator must contain sufficient surface area. Coalescing plates can be spaced and stacked ¼" apart. They are designed in such a way as to enhance the efficiency of the separator utilizing Stoke's Law. The rise velocity of the droplets can be calculated using Stoke's Law.

Mathematically stated Stoke's Law is:

$$V_R = \frac{g\,(c - o)\,D_o^{\,2}}{18\,\eta}$$

Where:

V_R	=	Rise velocity of tramp oil
g	=	Gravimetrical constant
η	=	Viscosity of Metal removal fluid
o	=	Density of Tramp oil
c	=	density of metal removal fluid
D_o	=	Diameter of tramp oil droplet

In addition to the rise velocity described by Stoke's Law, the residence time through the separator must also be calculated. Below are the math and an example.

R_t = V / Q

Where:

R_t = Residence time – the time required for the metal removal fluid to pass through the separator

V = Volume of the separator

Q = Flow rate through the separator

Example:

Given -

Metal removal fluid Density	=	1
Tramp Oil Density	=	0.85
Temperature	=	68° F
Tramp Oil Droplet Diameter	=	20 *u*m
Size of Separator	=	20 gal
Flow of Separator	=	5 gpm
Plate Spacing	=	.025"

then

$$V_R \text{ @ } 68° \text{ F} = \frac{g\,(c - o)\,D_o^2}{18\,\eta} = \frac{g\,(1 - 0.85)\,20^2}{18\eta}$$

$$= 0.07 \text{ in/min}$$

$$= 14 \text{ min/in} \times .025 \text{ in (plate spacing)}$$

$$= 3.5 \text{ min}$$

therefore

$$R_t = 20/5 = 4 \text{ min} \quad \text{or} \quad R_t > R_R$$

Check this example and calculation

The above example proves that under given conditions a 20 micron droplet of tramp oil can be captured in a separator using coalescing plates at a staking of 0.25" apart in a separator vessel that contains a volume of 20 gallons and flows at 50 gpm. The example also demonstrates that the more surface area per volume (ft^2/ft^3) inside the vessel, the more compact the separator vessel can be at maximum flow rate.

Bulk Separation

Simply defined this means to remove the metal removal fluid from the sumps on a scheduled basis, before the metal removal fluid reaches it terminal life. The metal removal fluid is then treated using Bulk System filtration/Separation Equipment.

Bulk filtration/separation equipment can be purchased and designed to meet requirements and needs. The system should consist of a tramp oil metal removal fluid separator, filtration system and a clean tank. The size of the system will depend on the volume and the flow rates of the manufacturing equipment involved.

Sizing a Tramp Oil Metal removal fluid Separator

In individual machine sumps the tramp oil separator is designed to circulate the metal removal fluid in the sump. Therefore the volume turnover rate per day is the most important factor to consider. The minimum turn over rate per machine sump recommended is 15 times.

As example, a circulation rate of 5 gal/min through the tramp oil metal removal fluid separator equals 300 gph or 4,800 gal/day (assuming 16 production hours in a day). So 4800gdp/15turns/day = 320 gallon sump per day or two (2) sumps at 160 gallons or 4 at 80 etc. can be serviced by this separator.

The most important elements to consider are the volume turnover rate, the tramp oil metal removal fluid separator efficiency and the price. These will be used to determine your best value.

<u>Example:</u>

Compare Tramp Oil Separator “A” and “B” below.

TOCS “A”	-	Flow:	2 gpm
	-	Surface Area/ft^3:	45 ft^2/ft^3
	-	Price:	\$3,000.00
TOCS “B”	-	Flow:	5 gpm
	-	Surface Area/ft^3:	90 ft^2/ft^3
	-	Price:	\$3,000.00

TOCS “A” flow rate is 2 gpm with 45 ft^2/ft^3 of surface area efficiency.

TOCS “B” flow rate is 5 gpm with 90 ft^2/ft^3 of surface area efficiency.

In this example, the surface area efficiency (sae) determines the best value because the price is the same. TOCS “B” has twice the square feet per cubic feet with a flow rate of 5 gpm. This gives a volume turnover rate of 2.5x.

On Site Wastewater Treatment and Discharge

Purpose and Scope

To identify and recommend on-site industrial wastewater treatment methods for machine metal removal fluids in a safe and environmentally sound manner.

Methods of On-site Wastewater Treatment

There are many technologies available to remove hazardous contaminants from individual wastewater. They allow it to be discharge into publicly owned treatment works (POTW), sewer systems, surface waters or into refuse. Most technologies use multiple steps to remove suspended solids, oils and metal ions from wastewater/metal removal fluid. This requires extensive treatment equipment and labor. The sludge generated from these wastewater/metal removal fluid streams are also sometimes classified as hazardous waste.

The following four methods will be discussed briefly:

A. Chemical Treatment Technology
B. Packaged Chemical Treatment Technology
C. Membrane Technology
D. Evaporation Technology

The recommended method is the Packaged Chemical Treatment Technology. This approach accomplishes wastewater/metal removal fluid treatment suitable for discharge into POTW in a very short period of time – usually minutes as opposed to hours or days – and treatment is usually accomplished in one step, in a single vessel.

Chemical Treatment Technology

Chemical Treatment Technology has greatly improved over the years for wastewater that contains suspended solids, oil, metal and metal ions, including disposing of rancid metal removal fluid. The question is how to get rid of the spent metal removal fluid in a manner that is both economically and environmentally responsible? The Environmental Protection Agency (EPA) had declared that unless certain standards are met for metal, oil and grease, suspended solids and other contaminants, wastewater/metal removal fluid cannot be discharged to sewer or surface water. This leaves two primary options to be considered….

1) Haul and treat the wastewater and/or metal removal fluid off-site
2) Purchase a treatment system capable of removing enough contaminant to allow the stream to be discharged to sewer or storm water.

In the long run it would most likely be more cost effective to control this in house. To do this using Chemical Treatment options there are two treatment systems available:

A) the conventional Multi-Tank System
B) Packaged Treatment Systems (see above)

If the Multi-tank or Multi-step system is chosen, pH adjustment chemicals and polymers to treat the stream in multiple steps are used. This System will require large amounts of floor space, labor and skill for its operation. A typical treatment system contains as many as six treatment tanks described below.

A. Spent metal removal fluid is pumped to tank #1 where pH is adjusted to an acid condition in order to break the oil emulsions.

B. The spent metal removal fluid is flowed to tank #2 where a cationic or positively charged polymer is added to attract oil droplets and create a floc.

C. The spent metal removal fluid then flows to tank #3 where the floc is allowed to settle out.

D. The floc solids are sent to a filter press while the overflow water is sent to tank #4 where pH is adjusted to an alkaline condition (pH of apx. 10) to precipitate soluble metals.

E. Wastewater is then flowed to tank #5 where anionic, or negatively charged polymer is added to attract and coagulate precipitated metals into the floc.

F. The wastewater stream is flowed to tank #6 where the floc is settled out of the water and again floc solids are sent to a filter press.

The Multi-tank System, in most cases, is too cumbersome and requires considerable floor space. In addition, it also requires the full time attention of a skilled operator. Another problem is that the sludge developed is often leach-able and requires either further treatment or disposal into a hazardous waste landfill.

Package Treatment Systems

An alternative to the Multi-tank System for flow of less then 50 gpm or about 10 to 15 thousand gallons per day is a pre-manufactured or packaged treatment system. In contrast to the Multi-tank System, the Package Treatment Systems are designed to focus on a broad range of wastewater or metal removal fluids of similar composition and are based on adding the equivalent of a “one size fits all” chemical dry powder treatment in a single step. The treatment takes place in minutes (apx. 90 seconds) as opposed to hours. All of the contaminants settle to the bottom of the vessel as a floc that is easily de-watered. The sludge left behind is non-leachable and can be disposed of as a non-hazardous waste.

The chemicals are a series of dry powders composed of minerals, in-organic and organic acids, in-organic and organic bases and polymers. These chemicals are blended into complex and carefully controlled formulations. The process occurs quickly and sequentially without the need for extra holding tanks or constant supervision. The procedure of the chemical process is as follows:

1) The acidic compounds cause the oily contaminants to coalesce and separate

2) The polymeric cationic portion of the formulation attracts any remaining oil and larger more highly charged anions such as phosphates and sulfates.

3) The basic component comes into play helping to precipitate metallic hydroxides. This drives the system to a fully flocculated condition where the cationic polymer molecules (with any absorbed oil), metallic ions and positively charged material are all attracted to the clay. Any unappreciated heavy metals cations still remaining in solution, exchange ions with the sodium on the clay and become strongly bound to the clay structure. The resulting mass is a complex mixture of encapsulated contaminants and waste solids held

together by van der Waals forces as well as electrostatic forces. The clay particles begin to stick together, entrapping the other components and surrounding them completely. This is called a pozzolanic reaction. At this point, the flocculated and solidified waste mass is non-reachable.

Packaged Treatment Systems can be set up for ongoing, automatic wastewater/metal removal fluid treatment or they can be used in situations where the generator wants to accumulate wastewater/spent metal removal fluid for a full day's generation and treat the entire flow in a single batch.

Packaged Treatment Systems have a relatively low equipment start-up cost. The treatment cost (powder) is in the $0.02 to $0.05 per gallon of spent metal removal fluid. This is a significant savings over hauling waste or other methods.

Membrane Technology

Reverse Osmosis (hyper-filtration), Nano-filtration, Ultra-filtration and Micro-filtration processes all operate on the principle of separating suspended or dissolved solids in solutions by use of a membrane surface.

The passage of liquid (called permeate) and the blocking of solids is a function of the size of the openings in the membrane, the size of the impurities and the magnitude of the pressure applied.

In Micro-filtration (MF) the membrane removes particles in the range of 0.05 micron to 2 micron in diameter. The fluid passes directly through the MF membrane in normal flow or in two separate effluent streams in a longer lasting cross flow mode. The trans-membrane pressure can range from 1 to 25 psig.

The Ultra-filtration (UF) membrane removes particles in the molecular and macro-molecular range - .0015 to 0.1 microns. This includes colloids, viruses and bacteria. The trans-membrane pressure applied ranges from 10-200 psig.

In Nano-filtration (NF), the membrane removes particles in the 300 – 1000 molecular weight range, NF softens the water without salt regeneration systems and provides unique organic desalting capabilities. The trans-membrane pressure applied ranges from 50-250 psig.

The process of Reverse Osmosis (RO), which is also known as hyper-filtration, is the highest filtration level possible. RO includes separating dissolved salts, removing bacteria, pyrogen and organics from water. The filtration level is from 1 – 200 angstrom units (1 angstrom = 10^{-4} micron). The trans-membrane pressure applied ranges from 200-1000 psig. This to will retain ions and most orgaincs over 100 molecular weight.

In general, membrane separation is a process which feed water flows along (cross flow) the membrane surface under pressure. The purified water permeates the membrane and is collected. The concentrated water, containing dissolved and un-dissolved material that does not flow through the membrane, is discharged into the drain. Depending on the type of system (UF, NF or RO) and the characteristics of the contaminated solution being processed, permeates may be used.

These types of membrane filtration for contaminated metal removal fluids will require pre-filtration and tramp oil separation, upstream of the membrane, to prevent plugging of system equipment. The cost of pre-filtration, tramp oil separation and membrane system equipment, along with the rejected waste costs, need to be calculated when evaluating this method.

Evaporation Technology

This technology is based on physical evaporation of water from dissolved solids. Water is evaporated from the collected fluid (metal removal fluid) to allow the chemical concentrate to be returned in the process bath. The water vapor may be condensed and reused in the rinse system. Evaporation units are operated either at atmospheric pressure or under vacuum. Atmospheric evaporation is more commonly used then vacuum due to its lower capital cost. These units are useful in deducing the volume of a liquid waste for treatment or disposal.

The evaporation method for contaminated metal removal fluids will require the capture of free oils whose emulsions have been thermally broken and float to the surface. The precipitated solids that settle in the trough of the evaporator system must be removed and disposed of properly. The cost of the evaporator system, the free oil and sludge disposal must be calculated when evaluating this method.

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[i] Multi-Pass (Beta ratio) Method for Evaluation of Filtration Performance – ANSI/(NFPA) T3.10.8.8R1

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