

COOLANT CONSERVATION through CHOICE and CARE

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October 15, 2005

“Coolants without oil clearly offer the best chance of saving money by conservation along with easier care and recycling. To achieve the maximum dollar value with long term solution life by minimizing disposal and clean out costs the user needs to use and cleanse a single synthetic coolant.”

THE NEED

In many metalworking facilities, water dilutable coolants with oil can generate high costs because of waste treatment and disposal costs. Efforts to reduce this cost by lengthening the coolant's performance life are ongoing and in fact intensifying because of a new fluid's rising prices and stricter environmental regulations. When a new coolant is introduced into many plants, often the first document to be scrutinized is the Material Safety Data Sheet (MSDS) for hazardous components and waste treatment issues. The ideal goal for any metalworking facility is to use a coolant with an effective cleansing system that allows the coolant to last indefinitely and minimize losses due to the drag-out on machined parts.

New technology coolant formulations, modern equipment, and planned maintenance programs for coolant recycling and rejuvenation are experiencing a solid business growth. The economic and operational benefits are certainly strong enough to warrant serious consideration by any plant that generates so much coolant waste that it impacts the company's bottom line. Even small shops frequently can experience serious production losses when they are forced to shut down even a single machining center for a lengthy cleaning of degraded or rancid coolant.

Some major metalworking manufacturers continue to experience large wasteful costs with cheap soluble oils or poor performing semi-synthetics. For example, we recently interviewed a plant that was routinely treating its soluble oil coolants within its facility with chemicals to split the emulsion and then sending out the waste oil for "rejuvenation" back into a soluble oil so that it could be returned to the plant for reuse. The fluid volumes and treatment chemicals costs were staggering. Other plants have resorted to evaporators to drive off the water and reduce the volume to a disposable sludge. Although this method reduces the volume of fluid for disposal, it generates high energy costs and increased coolant consumption. The solution to coolant management problem systems begins with chemical education provided by a competent coolant supplier supported by recycling equipment suppliers.

Coolant manufacturers must face and accept today's cost reduction challenges by producing long life high performance coolants and accepting the market trend of reduced coolant consumption. They must also be able to supply a single product or the minimum number of compatible products for the many different machining requirements within a metalworking facility. Recycling equipment manufacturers need to closely cooperate with coolant suppliers to achieve the most efficient and cost effective contamination removal results.

Two additional trends that exemplify reduced flood coolant consumption are minimum coolant misting and dry machining. While the use of these methods are growing and have some advantages for certain applications, they also exhibit some serious drawbacks. Neat oil usage and recycling typically found in screw machine shops are also important topics that

are not dealt with in this paper. However replacement of oil coolants by new high performance synthetic water based coolants is occurring and should grow.

COOLANT CHEMISTRIES IN RECYCLING

This paper compares the potential of three basic coolant chemistries (soluble oils, semi-synthetics and synthetics) for allowing the coolant to last indefinitely by recycling. Although coolants are not commodity items because of significant differences in composition, quality and pricing, there are some generic properties that can be used to differentiate the three classes when analyzing long-term monitoring, care and longevity.

Companies that have either large or numerous small coolant systems want to not only reduce coolant waste but also monitor and care for the coolant with the minimum amount of effort and time. Those that set up and routinely follow sound basic coolant programs of monitoring, care and maximum coolant reuse can experience many of the following benefits:

- 1.) Reduced new fluid purchases.
- 2.) Reduced fluid disposal costs.
- 3.) Less liability for on-site or off-site environmental issues.
- 4.) Fewer worker complaints concerning odors, dermatitis, coolant mists.
- 5.) Significantly improved tool life, finishes and production quality.
- 6.) Reduced coolant treatment costs, machine downtime and maintenance time.
- 7.) Better and more predictable coolant costs regarding production volumes.

The three basic types of coolants are typically defined as:

- a.) Soluble Oils (consisting of petroleum hydrocarbon oil, emulsifiers and other additives for extreme pressure lubricity, corrosion protection, biological control, wetting, defoaming, etc.).
- b.) Semi-Synthetics (soluble oil and synthetic hybrid typically containing less than 30% mineral oil)
- c.) Synthetics (no oil, chemical lubricity agents and other additives for corrosion protection, biological control, wetting, defoaming, etc.).

Any type of coolant could last indefinitely if not for the changes continually occurring while the coolant is use such as: contamination ingress, microbiological activity, water evaporation, and non-uniform depletion of coolant constituents. Often the first components to be depleted are those that impart corrosion protection and lubricity.

CONTAMINATION

Sources of contamination are:

- ✓ Hydrocarbon based lubricants and process oils (tramp oils)
- ✓ Metal and materials from fines and chips (swarf)
- ✓ Dissolved water constituents
- ✓ Biological agents (bacteria and fungi)
- ✓ Dissolved gases from the air entrainment
- ✓ Fluids carried in by metal and material surfaces from previous processing
- ✓ Other foreign matter mistakenly introduced into the coolant such as cleaners, concrete dust, food scraps, paper, cigarettes, etc.

Because coolants are dynamic changing systems, coolant manufacturers must have real world experience and knowledge of complex chemistry and formulations. They must be able to manufacture with exacting skills, utilize quality control measures with repeatable results, and work closely with additive suppliers so that their products can withstand the rigors that coolants face while at the same time be maintained, controlled, and recycled. Thus, modern coolants have become truly high technology products whose ingredients are intricately combined and yet are cost driven to keep prices realistic in the marketplace.

Most manufacturers of recycling equipment are familiar with basic chemistries as well as the effects of contamination and water evaporation that can concentrate contaminants. In designing their equipment, manufacturers understand the contaminants' separation properties that their technical components take advantage of. However, they also need to know how coolant and contamination dynamics interact, and what complexities may work against their separation equipment.

Some contaminants impacting the coolant's life and its continuing effectiveness can be controlled or modified by the user utilizing control measures, additives and high quality separation equipment. Others cannot. These contaminants are summarized in the enclosed table.

Tramp oils may appear in coolants as free floating, mechanically dispersed or emulsified. Primary sources of tramp oil are lubricating oils, grease, or oil residues (process lubes or corrosion inhibitors) on parts coming into the machining operation. Excessive oil can contribute to misting, residue buildup, odors, grinding burn, non-uniform lubricating action and bacterial growth. Tramp oil can be removed by skimmers, centrifuge, coalescing, and sometimes by settling along with fine solid particles. Oil skimmers work quite effectively whether the system is down by allowing tramp oil to float or while running by using gravity as a separation force.

Solid particles such as metal chips, grinding fines, cast iron dust, rust (iron oxides), plastics, loose fungi, coagulated or clumped grease or sludge and foreign material (ex., cigarette butts, paper, candy wrappers, etc.) should routinely be removed by filtering, centrifuge, settling, coalescers, dredging, vacuum/pressure or magnetic systems and other mechanical means. These solid materials can selectively pull out loose emulsified particles. Sometimes special polymers that are being machined can actually "wick" oil out of the coolant.

Bacterial or fungal growth can be reduced with biocides, fungicides, ozone generators, aeration, ultraviolet, chemically treated beads and pasteurization. Fungus is a difficult microbiological issue that can create special mechanical problems because of its bio-mass. Fungus often competes with the same food sources as bacteria. Usually a coolant is not plagued by both bacteria and fungi at the same time. Fungi become evident when they grow on the walls of sumps near the fluid's surface or in coolant feed lines and sometimes produce a "sweaty sock" odor. A bio-mass can turn an oil layer into a mucus-like substance thus sometimes preventing oil from being picked up by a mechanical skimmer. Both mechanical and chemical cleaning is normally required to rid the system of fungal growth.

Extraordinary cleaning agents and methods often need to be employed to effectively and totally remove fungi. Fungi will often go dormant when encountering harsh conditions such as cleaners. When fluid conditions become more favorable, they will reemerge and contaminate the new coolant over again.

After extended use and recycling over a period of time, some coolants experience sufficient selective additive depletion to create serious operational problems such as: corrosion,

reduced lubricity, foaming, odors from microbiological growth products and increasing tool wear. Coolant formulations that use multi-functional components can reduce the probability of selective depletion.

DIFFERENTIATING COOLANT TYPES

When considering the three different types of coolants and the effects that usage and contamination play, it becomes obvious that oil containing products are prone to destabilization because of oil's properties of emulsification and distribution of its oil droplet particle size. The more oil in the product, the more difficult it is to remain stable over time due to the contamination onslaught of hard water's constituents, microbiological activity and tramp oil entrainment. Oil and its emulsification components have been the traditional "Achilles Heel" of coolant formulations. Oil has remained popular because of its historically low price and good lubricating quality. But lubrication technology, rapidly rising oil prices, and increasing environmental problems with oil disposal are driving an attitude change in the marketplace.

Oil containing products are often difficult to mix and emulsify into plant water especially if the water is hard. Some oil solubles require special mixing equipment to achieve a decent oil "bloom." In certain cases coolant suppliers need to promote mixing equipment or time consuming techniques in order to achieve a decent dispersion. Mixing through proportioners is a sound practice to control uniform concentration additions and is encouraged, but semi-synthetics and synthetics are much easier to solubilize and disperse in water than oil solubles.

Products containing oil naturally tend to absorb some tramp oil because of the excess emulsifiers built into the product. Some recycling systems that remove tramp oil may also remove some of the product's inherent oil. This means that recycling soluble oils or even semi-synthetics can artificially raise costs by removal and discarding some of the product's oil with the tramp. Even some metal ions can have a negative effect on the emulsifiers and the bond they form with oil. Weak emulsification systems often can entrain metal particles and return them to the metal removal process such that quality can be reduced through shorter tool life or poorer surface finishes. Customers who have switched from soluble products to non-oil containing synthetics sometimes are surprised at the increase in tool life and better finishes. Although some of the cause for this improvement is newer technology in synthetic formulations, there often is an improvement due to the more efficient and quicker removal of solids and tramp oil which previously contributed to non-uniform lubrication.

When soluble oils or semi-synthetics "pull in" foreign oil, they yield higher refractometer readings, thus creating a false indication of higher concentration. The additional emulsified oil can destabilize emulsions, and also serve as additional breeding grounds for bacteria to grow, multiply, lower the pH and create objectionable odors. In addition to oil splitting, oil containing coolants tend to show higher consumption rates due to increased drag out rates.

Oil containing products often cannot be fine treated by micro-filtration methods because the filter will take oil out along with other entrained ingredients. Because oil containing products often have a wide distribution of oil droplet particle sizes and a disparity in electrochemical forces within the fluid, they are more subject to selective depletion of ingredients. This occurs not only in the recycling process but during carry out on parts because of their affinity to certain metal surfaces.

Recently there has been a movement in the coolant industry to promote micro-emulsion solubles and semi-synthetics without petroleum sulfonates. Claims are being made that these products are bio-stable and do not foster foul smelling hydrogen sulfide gas odors resulting from sulfonate degradation caused by bacterial growth. While this claim can be valid in some cases, after prolonged use the micro-emulsion solutions often allow significant bacterial activity that destabilizes the emulsion and reduces rust protection. Although these micro-emulsion chemistries can be recycled and offer longer solution life than traditional formulations, they still can pull in a significant amount of tramp oil thus creating operational problems such as: smoke, oil misting, fine metal particle suspension, oily surfaces, inaccurate refractometer readings and selective depletion of additives (problems already described for macro-emulsion products).

Another innovation in coolant chemistry is to substitute vegetable oils for mineral oils in soluble oil formulations. While vegetable oil imparts a coolant feature of being more rapidly biodegradable in waste treatment systems, this property presents bacteria with prime food sources thus promoting faster bacterial growth in sumps. Although these solubles offer higher lubrication than mineral oils, they do not improve the associated difficulties of tramp oil absorption and separation. Vegetable oils are also harder to emulsify and their emulsions tend to exhibit poor stability. As with mineral oil they can also become destabilized with heat caused oxidation and will yield oily residues and mists. Promoting vegetable oil based coolants can sometimes mislead the user into thinking that once used as machining coolants they can readily be poured down the drain and disposed of without care.

Of all the coolant types, synthetics offer the maximum removal potential of oil and solid contamination. They also offer increased resistance to hard water components. Synthetic products should be formulated such that hydraulic, gear, spindle or way lubricants will readily split from the fluid and thus can be easily removed by skimming the top of reservoirs or using gravity separation enhancements. Synthetics offer another distinct filtering advantage of being capable to be fine filtered down to 10 microns or finer and not lose any constituents. In some critical applications ultra-filtration is absolutely necessary to prevent particles from disturbing the cutting or grinding process thus creating unacceptable surface asperities. When fine filtering soluble oils or semis, some of the oil can be pulled out from the emulsion. Thus the coolant can lose some of its lubricating value and show a lower concentration reading using a refractometer. Because they are normally true solutions, synthetic coolants can be filtered down 1 micron thus making metal chips and fine swarf easier to remove. Properly formulated synthetics have fewer food sources for bacteria to thrive on and rarely produce objectionable odors even after long-term recycling or downtimes. Synthetics often show remarkably lower consumption compared to solubles because of the difference in emulsion and solution characteristics.

To achieve the ultimate goal of a zero waste stream or even significantly reduce all disposed fluids, synthetics ought to be coordinated with all water based cleaners and corrosion preventives in a facility. Cleaners and corrosion preventives without the contamination of solubilized oil ought to be recycled as well as the coolants. Synthetics should also be considered when integrating the coordination process backwards to metal forming and drawing applications. When the complete principle of fluid coordination is conceptualized in both the planning and execution stages within a metalworking plant, synthetic based water chemistries become a logical and economical choice.

Although older synthetic coolant formulations exhibited performance drawbacks such as reduced lubrication, paint removal, sticky residues and harshness on worker's skin, newer formulation technologies have overcome these problems. For example, most machine manufacturers are now using more chemically resistant paints such as epoxies. Modern

synthetic chemistry formulations are now able to very adequately lubricate cutting of aluminum and even hard stainless grades. Although synthetics tend to allow slightly more water to evaporate, this is not a serious drawback.

COOLANT CONTROLS

Regardless of the coolant type, coolant concentration control is the single most important maintenance item that must be routinely measured, recorded and acted upon. Using automatic coolant proportioners is a sound practice to ensure uniform ratios. Most coolants should be mixed with water by adding the coolant to the solution, pre-mixing, or mixing with a proportioner. Keeping a record of coolant and water additions is a good idea for tracking costs and keeping solutions at optimum levels.

Typically coolants effectively operate in the range of 3% to 10% by volume. Based on the material composition and the removal operation, coolant suppliers should be consulted for their exact recommendations.

Usually concentration checks are easily performed using an inexpensive and simple instrument called a refractometer (optical scope). The refractometer (see photograph) is a hand held tubular shaped instrument that is portable and measures the refractive index of light passing through an aqueous solution. A refractometer should be a standard quality control instrument that is conveniently on hand and routinely used by coolant managers. The test takes only a few minutes and can prevent problems by keeping the concentration within the recommended operating levels. A new refractometer has a detailed instruction pamphlet packed inside its carrying case that the new user should become familiar with. The concentration measurement is performed using the following steps:

- 1.) Zero the unit by placing a few drops of process water on the slide. An adjustment screw allows the user to make sure that plain water reads zero.
- 2.) After the water is wiped dry, a representative coolant sample is then placed on the slide and the reading taken. Refractometers with a scale from 0-10 are usually used because normally recommended coolant concentrations fall within this refractive index range.
- 3.) The refractometer reading is then multiplied by a factor supplied by the coolant manufacturer to yield the concentration. A control chart or graph should be available from the manufacturer to make the conversion process easier.

A refractometer works best under these conditions:

- Stable fluids
- Uncontaminated systems
- Well maintained and clean running systems
- Systems that use purified process water

Refractometer readings can become fuzzy with oil containing coolants that become destabilized with contamination and its by-products. This is another good reason to consider using a synthetic product. Besides recording the refractometer and concentration results, maintenance personnel should observe the coolant's color, clarity, floating tramp oil, water/coolant additions and any residues present on machinery or parts. Synthetics tend to be clear and often aid operators in seeing the work and its surface finishes.

One common mistake that synthetic or semi-synthetic coolant users make is to interpret the refractometer reading as the percent concentration because of their previous experience with

soluble oils. This has led to using higher concentrations than needed for synthetics and semi-synthetics. Sometimes the higher concentrations have contributed to dermatitis, tacky residues, and machinery paint removal. Coolant control personnel should always check with the coolant supplier to ensure that they are using the correct refractometer factor or a supplier's chart.

Chemical titrations and pH testing can be used in addition to refractometer readings and fluid observations. For large systems, more in-depth analysis is often performed by the coolant supplier. These tests can include bacteria and fungi levels, sediment, floating tramp oil, conductivity, alkalinity, and emulsion quality evaluations such as particle size measurements. While these tests can be helpful, it often takes several days to receive a supplier's report results and the fluid may have further degraded. A good maintenance program should be able to spot trouble early enough to identify problems and implement corrective action. Supplier's results can then be used to confirm and back up the routine tests and observations performed by plant personnel.

BASIC CONSIDERATIONS FOR MACHINE SHOPS

Shops that have as few as 5 machines or a total coolant volume of 500 gallons or more should consider recycling. Smaller volume usage shops may have to recycle even on a single machine basis because of local zero discharge requirements, small volume high disposal costs, or very expensive downtime. Factors that are paramount are the amount of fluid involved, the number and type of coolants and nature and quantity of contamination. To simplify the process, the first step is to find one coolant that can do all the jobs in the shop from tool grinding to production CNC machining. This one effective coolant should provide reasonably extended bath life even without extensive recycling equipment. This one product would provide the shop manager a head start in bringing his fluid management program on line and with some degree of control.

Coolants are frequently dumped because they reach such a point that their continued service is unacceptable because such operational conditions as:

- a.) Excessive contamination that cannot be removed.
- b.) Emulsion instability sometimes caused by hard water build up or tramp oil contamination.
- c.) Poor quality production.
- d.) Rusting of machinery components.
- e.) Odors that can no longer be tolerated controlled or minimized.
- f.) Worker complaints of mist, dermatitis, or other serious complaints that cannot be overcome by treatment with additives.
- g.) Total color or appearance changes that management recognizes from previous experiences.
- h.) Recommendation of the coolant supplier based on laboratory analysis service work.

A plant with a number of individual machines is a good candidate for a recycling system that is set up off-line. The coolant is routinely collected and delivered to a recycling system where it is cleaned up by settling, filtering and tramp oil skimming. It is often checked for the concentration levels and if necessary brought back to recommended levels. Then the recycled coolant is brought back to the machining centers. Portable units are often employed to clean up the coolant at each machine and then moved to the next unit as required.

When changing a machine from one coolant to another, complete cleaning of an individual machine may be required and performed both mechanically and chemically. The specific method is often chosen based on the degree of contamination and the condition of the coolant. Even new machines should be inspected for corrosion preventive coatings and may need to be thoroughly cleaned before charging the coolant. Effective cleaning chemicals are usually available from coolant suppliers. These water dilutable cleaners have detergency to remove light oil films, loosen chips and swarf, and biologically disinfect the system. They should be circulated in all lines and tanks where coolant is or has been to ensure a thorough clean out. Concentrations and times should be followed using the manufacturer's recommendations. Cleaning recycling systems may be necessary to remove bacterial contamination, oil residues and clumped metal fines.

There are many good recycling systems available to the metalworking industry that come in a wide variety of sizes and complexities. From simple skimmers and filters to centrifuges and coalescers, these systems work effectively under basic mechanical principles that allow coolants to be separated from their contaminants with time, physical, and chemical principles. Understanding the nature of the contamination and how it can be readily separated is the key to selecting the best and most cost effective system.

RECYCLING CONSIDERATIONS

Regardless of the type of coolant being used by a machining company or a captive shop, cleansing and recycling should be investigated and implemented after coolant cost savings and other cost considerations such as downtime and waste disposal are analyzed.

Setting up a recycling system should be done after in-depth consultation with operational/maintenance management, the fluid supplier, and equipment supplier. The key points to keep in mind as plant personnel plan and execute a program are:

- 1.) Keep it as simple as possible and not burdensome to shop personnel.
- 2.) Make sure everyone understands the objectives and how the program is going to be implemented and function. Although returning the coolant to its original condition is not practical, refreshing it back to an earlier state is.
- 3.) Responsibilities and duties of each party should be spelled out and made part of the quality program.
- 4.) Clear communications between the plant, chemical and equipment personnel are essential.
- 5.) Do a thorough survey of the coolant systems, their locations, products used, and space considerations so that if necessary the coolant can be moved by mobile transport or a pumping and piping system.
- 6.) Analyze make up and addition methods to assure that convenience and safety issues are covered.
- 7.) Make sure that the suppliers are quality driven, competent, experienced and fully supportive during the planning and execution phases.
- 8.) Use survey data supplied by manufacturers to determine the optimum coolant for all machining systems.
- 9.) Review documentation of coolant practices, experiences, and control results, especially any biological activity.
- 10.) Have the coolant supplier analyze the make up process water.
- 11.) Recycling equipment should have low maintenance requirements and be compatible with all coolants if there are more than one.

- 12.) Any electrical components should be well protected from the coolant's water and the associated vapors. Some separators avoid this problem by operating off normal compressed air systems already available in the shop.
- 13.) Management must make the commitment to do it right from the beginning and not be driven only by pricing, but rather view this recycling program as a cost reduction program. The commitment must also allocate enough funds for capital investments and manpower to effectively carry out the program so that the full savings of coolant reduction, improved quality, time, etc. will be realized.

CONCLUSION

The coolant's chemistry, especially the product's stability under the ever changing conditions and ingress of contamination, is one of the key elements in developing a sound recycling system. The equipment chosen is critically important to ensure efficient contamination removal without selectively removing any coolant components. Some recycling systems are built so that they will minimize oil pull out from weak emulsion systems by using a "gentle" approach. However, as the emulsion further weakens, even that system may begin to experience oil "plate out." Newer soluble oils and semis are very capable of being successfully recycled. However synthetics offer the best possibility of maximum long-term recycling and indefinite sump life along with their lower consumption costs, cleaner parts and machinery, and reduced biological activity.

No discussion of coolant choices can complete without the mention of price per gallon. However, in today's environment within most metalworking plants the focus has dramatically shifted from price to cost. Synthetics have become very cost effective because of their lower consumption rates, improved productivity and more efficient recycling. The full set of promises that lubricant companies offered with their synthetics in the 1970s have now arrived because of new technology and the need to conserve and recycle coolants.

Photographs:

- a) Different coolants and their emulsion characteristics
- b) A destabilized soluble oil
- c) Tr amp oil accumulated on top of a synthetic

Contributions from equipment companies are recognized and information about those companies including photographs of their equipment will be made available.

JFM

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10-15-05

TABLE OF CONTAMINATION EFFECTS ON DIFFERENT COOLANTS

CONTAMINANTS	SYNTHETIC	SEMI-SYNTHETIC	SOLUBLE OIL	COMMENTS
Water: Hardness Ions (Chlorides, and Sulfates)	Minimal to no effect on solution but can help create tacky residues and increase rust potential	Moderate influence on the emulsion and creation of tacky residues and rust potential	Strong negative influence in destabilizing emulsion and increasing rust potential	Water evaporation increases problem; using deionized or distilled water may be necessary
Lubrication Oils (Tramp Oils)	Should readily split from solution	Some splitting and some absorption into coolant promotes bacterial activity	Little splitting and heavy absorption into coolant can replace coolant's oil, strongly destabilize emulsions and promotes bacterial activity	Prevent oil entering coolant and remove by skimming, coalescing, centrifuging as necessary
Chips, Fines, Abrasives (Swarf)	Can be readily separated by filtering, settling, magnets, centrifuges etc.	Can be separated by filtering, settling, magnets, centrifuges etc. Very fine swarf can attach to oil particles	Can be separated by filtering, settling, magnets centrifuges etc. Small particles can attach to oil particles	The finer the particles and the looser the emulsion, the more likely that metal removal becomes more difficult
Organic Matter, Biological Agents from Various Sources	Usually most components are not attractive food sources and higher alkalinity tends to decrease bio agents' capacity to thrive	Oil, emulsifiers, fatty substances can be good food sources; alkalinity tends to discourage growth of bio agents	Oil, emulsifiers, fatty substances can be excellent food sources; bacteria lowers pH and tends to destabilize emulsion and promotes rust	Biocides, fungicides and alkalinity boosters may have to be added into the coolants raising costs and dermatitis potential
Fluids from Previous Operations	Water dilutable products will mix, oil products will tend to split	Water dilutable products will mix, oil products will tend to split, but some may emulsify	Water dilutable products will mix, oil products will tend to emulsify with some splitting	Fluid entering coolants should be analyzed and coordinated to minimize negative results