THE RIGHT WATER CHEMISTRY: UNDERSTANDING THE AQUEOUS INFLUENCE UPON METALWORKING FLUID PERFORMANCE

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INTRODUCTION

When is water not pure H2O? Answer: When it is contains any material that is not water. This is almost always the case in manufacturing plants using water to dilute metalworking fluids. Metalworking fluids need good quality water to operate at maximum effectiveness. When lubricant/chemical suppliers recommend a water soluble product into a customer's plant, they must determine the water quality as well as the fluid's application requirements. Two customers with identical processes can have widely different experiences with the same metalworking fluid because of water quality differences. The impact of water quality can be felt in any type of water soluble fluid application including the following: drawing/forming compounds, coolants, quenching fluids, cleaners, and corrosion inhibitors. Water evaporation from any of these fluids can accelerate any negative effects.

Water analyses are critical for revealing and understanding how the process water used at a customer's facility can impact the performance of a metalworking fluid. It is important to know water chemistry in-depth. Water can constitute from 80 – 95% by volume of the diluted metalworking fluid mixture in individual sumps or central systems.

When developing any metalworking process, it is critical to understand all the variables that will impact upon the metalworking process, including the water utilized for both charging and make-up of systems. Contaminants introduced by extraneous sources from make-up and replenishment water can be as important as other foreign fluids such as tramp oil or grease.

PARAMETERS

Aqueous chemical and physical properties such as pH, conductivity, alkalinity, total hardness (calcium and magnesium levels), other ion and elemental levels, surface tension, turbidity, ECA (electrokinetic charge), foam characteristics and microbiological levels (bacteria, fungi, yeast and algae) can all impact metalworking fluid performance. These properties can affect corrosion protection of the metalworking fluid, residue properties, foam, emulsion stability for semi-synthetics and soluble oils, susceptibility to microbiological attack, charge density of both true solutions and emulsions, filtering properties and wetting. ICP (ion analysis) results should be utilized to monitor process water on a continuing basis to establish a baseline because water characteristics can change dramatically over a year's time. Water quality must be monitored as it can drastically fluctuate as seasonal precipitation patterns change. Parameters that should be evaluated continuously are:

pH of an aqueous system indicates whether it is acidic (pH of 0.0-7.0), neutral (pH of 7.0) or basic or alkaline (pH of 7.0 – 14.0). Most water used commercially in the United States exhibits a pH range from 6.4 to 8.5, depending upon the original source and type of pretreatment conducted by the local water authority. It is important for water used for metalworking fluid systems to exhibit an optimal pH range from 7.0 to 8.5.

Total Hardness exists in water due to the presence of several dissolved minerals and their salts. Predominant ions are calcium and magnesium. Lesser contributing ions would include iron, zinc, aluminum, potassium, and silicon. Total hardness is reported in ppm of calcium carbonate

($CaCO_3$). It can also be reported in units called grains with one grain of hardness equivalent to 17 ppm of calcium carbonate. Water hardness is typically defined using the following scale:

TOTAL HARDNESS (ppm)	**EVALUATION**
0 – 50	Very soft
50 – 125	Soft
125 – 250	Medium
250 – 370	Hard
Over 370	Very hard

Hardness can readily affect metalworking fluid performance. Soft water can impact the performance of all fluids by contributing to foam formation. This is especially true for synthetics in grinding operations and semi-synthetics and soluble oils in both machining and grinding applications. Foam can drastically impact fluid performance by contributing to poor wetting and coverage properties, affecting lubrication, cooling and proper film coverage for in-process corrosion protection. Foam can also hamper fluid detergency contributing to poor swarf handling and filtering. Dense foam formation can lessen filtering capabilities of a system by altering indexing mechanisms and the creation of poor filter beds. Foam can also suspend tramp oils, preventing skimmers and other mechanical devices from effectively removing them. Tramp oils can act as a matrix, becoming finely suspended on a dense bed of foam. This further stabilizes a dense foam layer. Excessive foam can also lead to housekeeping issues, overflowing system barges and return lines such as floor troughs. Foam can also cause pump cavitation, creating excessive wear and premature mechanical failure.

As hardness increases, it can readily and negatively affect the emulsion stability of semi-synthetics and soluble oils. The formation of hard water soaps between calcium and magnesium ions and anionic components (typically fatty acid based emulsifiers) can radically alter emulsion particle size. This will rapidly lead to visible signs such as scum formation and lose emulsions (cream and free oil present). Both semi-synthetics and soluble oils are impacted by calcium soaps. Semi-synthetics are especially hampered by high magnesium levels. Hardness levels can build up in water stored for use as well in metalworking fluid systems due to aqueous evaporation. Many systems can loose from 5 – 25% of their water on a daily basis, depending upon system size, openness to plant environment, time of year, geographical location, plant conditions (air temperature and circulation patterns) and metalworking fluid temperatures as the water circulates. Continual aqueous makeup with hard water will contribute to rapidly escalating levels of hardness in the system. Resulting emulsion instability in semi-synthetic and soluble oils will lead to corrosion problems, susceptibility to emulsification of tramp oils and microbiological attack, poor tool life, improper surface finish, foam and filtering problems. Hardness levels must be regulated and there must be the proper blend of water types utilized to maintain system hardness values at reasonable levels for proper metalworking fluid performance.

WATER TERMS

Alkalinity is another indication of the overall health of both the water and metalworking fluid in use. Two types of aqueous alkalinity are measured.

P Alkalinity is referred to as permanent alkalinity. It is expressed as ppm of calcium carbonate and is a measure of the carbonate ion level (CO_3^{-2}).

M Alkalinity is referred to as total alkalinity. It represents the combined alkalinity of P Alkalinity (carbonate ion level) and the bicarbonate ion level (HCO^-_3). M Alkalinity is also expressed as ppm of calcium carbonate.

Conductivity is a quantification of the ability of water to conduct an electrical current. It is an indication of the total level of dissolved minerals and salts present in the water. As conductivity increases, water quality decreases. Conductivity measurements do not differentiate between minerals or salts and can be used to detect both the presence of contaminants in the system and the build up of hard water soaps. Conductivity is expressed in micro mhos or micro siemens.

Several other parameters should also be monitored and quantified in an aqueous database.

ECA (electrokinetic charge) is an indication of the charge strength of the water (degree of anionic or cationic charge).

Surface tension expressed in dynes per centimeter reveals how water and aqueous solutions wet out and covers all substrates including the tooling and work piece. Metalworking fluid chemistries can lower surface tension so aqueous and fluid films offer better coverage and performance.

Turbidity is a measure of the degree of opaqueness or clarity of the water source. Usually expressed in ntu (nephroletic turbidity units), it is determined on a turbidity unit utilizing transmitted light. It can be used to determine the level of suspended solids in the water or aqueous solutions.

ICP (total ion analyses) track the level of cations and anions in ppm in the operating aqueous solution. It can be utilized for a variety of purposes including the tracking of initial harmful ion levels in water, presence of contaminants or formulation components and for selective depletion analyses. Important ions that should be tracked in the incoming water include chlorides, sulfates, and phosphates. Chloride levels (Cl^-) can contribute to corrosion problems, especially at levels above 25 – 40 ppm. Sufficient levels (SO_4^{-2}) can contribute to corrosion problems and support the growth of specific bacterial species. Phosphates (PO_4^{-2} and others) can lead to foam problems, alkalinity issues and also support microbiological degradation of fluid systems by supporting bacterial growth.

Finally, Microbiological contamination, bacterial and fungal growth can significantly impact on the performance life of both the water and metalworking fluid, leading to lubrication, corrosion and fluid stability problems. Microbiological contamination can also lead to health problems such as respiratory irritation or dermatitis among plant personnel exposed to the contaminated fluid. This growth can be monitored via a number of methods including biostrips, plate counts and dissolved gas methods such as HMB. It is very important to monitor this parameter as a quick response such as controlling incoming water quality, adjusting coolant concentration or the appropriate and correct additive/biocide addition can often prevent a serious crisis.

WATER TYPES AND TREATMENT REGIMES

Good water chemistry is essential for the proper long-term utilization and performance of metalworking fluids. Sufficient volumes of proper water must be available on-demand for both charging of systems and solution make-up. It may be necessary to install storage tanks to maintain proper water quantities to meet all production requirements. Types of water and treatment programs are summarized below:

Tap Water is readily available in many parts of the country and comes from a variety of sources. It is often used as the initial source for metalworking fluid systems. Tap water chemistry can vary widely depending upon original source, geographical location and pretreatment conducted on-site or by the local water authority

Softened Water processes treat water by passing it through exchange resin systems. Calcium and magnesium ions are exchanged for non-hardening sodium ions. This process results only in a change of ions and no change in the total quantity of dissolved minerals. The sodium ions do not promote the formation of insoluble soaps. Softening agents used do not remove corrosive ions such as chlorides. Softened water is not a recommended source for regular use of metalworking fluids.

Demineralized Water processes represent the most efficient methods of treatment of hard water. Demineralization methods actually remove the dissolved minerals. Two most common and cost effective methods are deionization and reverse osmosis. Deionization removes minerals by passing the water through a mixed resin bed. Two ion exchange resins selectively remove both cations and anions. Cations removed are replaced by hydronium ions and anions are replaced by hydroxyl ions. Mixed bed unit are extremely effective at reducing hardness levels to essentially zero ppm. Water essentially exhibits a zero ECA value (neutral ionic charge). Resin beds need to be flushed or backwashed on a regular basis to remove all contaminants and to prevent microbiological interference. Beds also need to be regenerated on a regular basis. Reverse osmosis forces water through a semi-permeable membrane under high pressure and varying flow conditions. The RO process can effectively remove up to 95% of dissolved minerals. Often reverse osmosis units are used in conjunction with a water softener pretreatment stage. Filters need to be flushed and replaced as necessary. Microbiological contamination also needs to be regularly monitored.

NEW DEVELOPMENTS

Water quality has always been important, however there two recent developments that have made water quality even more important:

1.) Coolant formulators are often presented with changes in raw materials driven by economics and sources of supply. For example, the recent closing of a U.S. sulfonate (emulsifier and corrosion inhibitor chemical) plant has forced metalworking manufacturers to reformulate many products. The new formulas may not be as effective in all water quality conditions.

2.) Regulatory compliance issues and waste treatment costs have driven users to make metalworking fluids last longer and extend dumping time frames giving water contaminants more time to build up and create problems.

This means that formulators must enhance their products with higher levels of stability and use newer technology additives. They must communicate regularly with their customers to observe performance and meet the demand for better fluid economics.

SUMMARY

Good water quality is essential for the proper performance, biostability, and sump life of metalworking fluids. Aqueous databases should be maintained and major parameters monitored for all water sources. A variety of treatment methods are available for producing safe and effective water for both charging and make-up for any metalworking fluid system need. Regardless of treatment methods or fluid system capacities, the following aqueous guidelines should be practiced and strictly enforced:

Appearance:	Clear and water-white, free of all debris
Odor:	None
pH:	7.0 – 8.5
Hardness:	125 – 200 ppm
Total Alkalinity:	25 – 100 ppm
Turbidity:	< 5 ntu
Bacteria:	None
Fungi (both yeasts & molds):	None
Chlorides:	< 20 ppm
Sulfates:	< 40 ppm
Phosphates:	< 40 ppm

A balanced treatment program is crucial for effective water utilization. Users should contact their manufacturer for help in determining their water quality and system recommendations for treatment options. Tap water often can be utilized for charging systems and treated water (preferably deionized or revere osmosis) used for regular make-up. Aqueous databases should be maintained and reviewed on a regular basis. Water chemistry should always be reviewed and product compatibility evaluated if required.

When it comes to water soluble metalworking fluids, water should not be taken for granted. Knowing and monitoring water quality can prevent problems and improve any plant's productivity.

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PICO Chemical Corporation has been in business since 1976 and is an ISO 9001:2000 certified manufacturer of value-enhanced specialty chemicals and lubricants to clean, condition, lubricate and protect metalworking, metal forming and related processes.