



## Mixing and Maintenance of Neat and Water-Miscible Cutting Fluids

### 1. Requirements of Cutting Fluids

Neat and water-miscible cutting fluids are nearly all based on mineral oils although in recent years, synthetic and vegetable oils have also been used. Cutting fluid solutions do not contain mineral oil and are based on synthetic raw materials.

The most important functions of cutting fluids are to reduce the friction between the material being cut and the tool, to dissipate heat and to transport chips and swarf away from the cutting zone. Additional requirements of neat cutting fluids are low misting, compatibility with metals and plastics and low foaming. For water-miscible fluids, additional requirements are good emulsification, good corrosion protection and resistance to bacteria, yeasts and fungi. These properties are achieved by the use of special additives.

### 2. Storage of Cutting Fluids

Whereas neat cutting oils can be stored for a number of years, water-miscible fluids can be stored for between 6 months and maximum 1 year. Water-miscible products should be stored between +5 °C and + 40 °C. If the ambient storage temperature falls below 0 °C, the concentrate should be stirred (rolling the drum suffices) and heated-up prior to use.

If drums are stored outdoors, they should be placed horizontally to avoid water and/or moisture seeping past the bung when the drum "breathes".

Containers used for the storage of cutting fluids should be clean, sealable and only used for one grade of cutting fluid. Do not use internally-galvanized drums because zinc soaps may be formed, thus negatively influencing the quality of the product.

Storage tanks should be routinely inspected for contamination and cleaned if necessary.

If cutting emulsions are stored in tanks, we advise performing bacteriological examinations once a year. If the result is positive, i.e. the contents are contaminated, the tank and any connected circuitry should be disinfected with the corresponding microbicide.

If a cutting fluid shipment is delivered in brand new containers, we recommend using all the old and previously-opened drums, canisters and containers first.

### 3. Mixing Water-Miscible Cutting Fluids

If the mixing procedure described below is not observed, serious emulsion errors can occur.

Emulsifiable concentrates which form oil-in-water emulsions must be mixed into water. Never reverse this procedure because lumps and gel can form. In the worst case, the mixture will have to be discarded and a fresh emulsion mixed.

No special mixing procedures need be observed for genuine water-based solutions which contain neither mineral oil nor emulsifiers.

The points listed below should be observed when mixing water-miscible cutting fluids. A major factor in an optimum emulsion is the quality of water used.

- The mixing water (preferably drinking water) should have a hardness of 175- 350 ppm  $\text{CaCO}_3$ . The quality of the water should be known in order to avoid problems such as bacteria or extreme pH value. Local water companies can supply further details.
- If necessary, treat the mixing water (softening, demineralizing, filtering, hardening, bacteriological purification etc.) prior to mixing.



906

- The water used for the preparation of cutting fluids should be clean and neutral (with a pH value of approx. 7). River or well water should only be used if it has been tested and, if necessary, treated because such water can be contaminated with microorganisms. These in turn can detrimentally affect the quality of cutting emulsions or solutions.
- The water should not be too hard (precipitation of soaps) or too soft (foaming).
- Soft water can be hardened with calcium acetate.
- Do not store cutting fluids at below 0 °C.
- If drums are exposed to freezing temperatures, allow to thaw indoors. If the concentrate is no longer homogeneous, discard.
- Only use clean, non-galvanized, disinfected and purpose-built containers.
- Do not prepare water-miscible cutting fluids in machine tanks.
- Always mix cutting fluid concentrate into water. Do not add water to the concentrate.
- Prepare emulsions with the assistance of mechanical stirrers, injectors or metering pumps.
- Pay attention to pressure, temperature and viscosity parameters when using injector mixing equipment. These factors do not influence metering pumps.
- Pressure-reducing valves can stabilize variations in tap water pressure.
- Follow mixing ratio recommendations.
- After mixing, check concentration with a refractometer.
- Avoid mixing various water-miscible cutting fluid concentrates.

## 4. Monitoring Cutting Fluids

Ideally, cutting fluids should be constantly monitored. Most importantly, solid and liquid impurities such as chips, abrasion residue and tramp oils should be removed by various centrifuges and/or filters because only clean cutting fluids increase efficiency and reduce scrap. The condition of the emulsion in the tanks should be checked daily. Such measures can significantly increase the life of the cutting fluid.

### 4.1 Neat Cutting Fluids

In general, neat cutting fluids are simple to monitor because they are less prone to microbiological attack and have a longer service life (longer oil change intervals) than water-miscible cutting fluids. The main parameters which need to be checked are physical contamination, thermal exposure, viscosity and additive level. These fluids are found in central systems as well as individually-filled machines. Systems with less than 300 litres capacity normally generate less maintenance costs than large systems.

### 4.2 Water-miscible Cutting Fluids

Water-miscible cutting fluids require much more monitoring than neat oils. Compared to neat cutting fluids, their change intervals are sometimes very short. The maintenance measures required for small tank capacities are often more complex than for larger central systems.

For both neat and water-miscible fluids, monitoring should not just be restricted to appearance and smell. Complex fluid tests should only be performed by highly-trained personnel. If concentration adjustments which can only be determined by sample analyses become necessary, only about 48 hours should elapse between the taking the sample and determining the result.

906

## 5. The Principal Methods of Testing the Condition of Neat and Water-Miscible Cutting Fluids

### 5.1 Neat Cutting Fluids

Odour, appearance	Optical, sensory testing
Density	DIN 51757
Liquid impurities	Refractive Index DIN 51423 Neutralization number DIN 51558
Solid impurities	DIN 51592 Filtering
Corrosion protection, Nonferrous metals	DIN 51759-1
Steel	DIN 51589
Viscosity	DIN 51562
Water content	Karl Fischer method, DIN 51777
EP properties	Four ball app.; DIN 51350-2/3

### 5.2 Water-Miscible Cutting Fluids

#### Individually-filled machines

Odour, appearance	Optical, sensory testing
pH value	Electrometrically; DIN 51369
Concentration	Hand refractometer
Nitrite content, max.20 ppm	Testing kit, photometric
Nitrate content, max.50 ppm	Testing kit, photometric
Bacteriological contamination, (fungi and yeasts)	Dip-Slide method

These tests should be performed weekly on individually-filled machines (dip-slides; monthly) and results documented on a machine card.

#### Central systems

The same tests and frequency as applicable for individually-filled should also be used for central systems. The tests listed below should only be used if required:

Tramp oil, non-emulsified	Stand test, DIN 51367
Impurities, solid	Filter method DIN 51593
Electrolyte content	Conductivity measurements
Chloride content	Titration methods
Corrosion	Chip-filter test, DIN 51360-2

The amount of nitrite and nitrate in used emulsions and solutions should not exceed 20 mg/litre or 50 mg/litre respectively. If these values are exceeded, a full or partial exchange of the water-miscible cutting fluid may be necessary because these nitrosamine-forming substances (nitrite and nitrate) together with diethanolamines (secondary amines) which may be present, can form carcinogenic N-nitrosodiethanolamines.

### 6. Cutting Fluid Maintenance

Maintaining cutting fluids means taking measures to considerably extend the life of neat and water-miscible cutting fluids while the fluids are in use. Good maintenance will increase cutting performance and lower scrap. In addition, well maintained cutting fluids are less of a burden to machine shop personnel.

#### 6.1 Neat Cutting Fluids

In general, neat cutting fluids are easier to maintain than water-miscible products. Importance points are the removal of solid impurities and the maintenance of the original viscosity. Draggged-in tramp oils such as hydraulic fluids can influence the viscosity and additive level to such a degree that reasonable cutting performance almost disappears.

If this condition occurs, suitable topping-up oils can return the additive level and viscosity of the used oil to that of the fresh oil and thus restore positive cutting performance.



906

## 6.2 Water-Miscible Cutting Fluids

Water-miscible cutting fluids are a natural culture for microorganisms such as bacteria, yeasts and fungi. This means that these emulsions and solutions must be checked more often than neat cutting oils.

Of particular importance is the efficient removal of solids and tramp oils via filters or centrifuges. Maintaining the prescribed concentration is also very important because insufficient concentration promotes microbiological growth, lowers emulsion stability, lowers machining performance and accelerates corrosion problems on machines and workpieces. On the other hand, excess concentration can cause foaming and thus poor component quality as well as less efficient cooling and therefore less efficient machining.

A crucial factor for these fluids is pH value. At low concentrations (5 %), the pH value should not drop below 8.8 and at higher concentrations (10 %), the pH value should not exceed 9.3 if the emulsion is fresh. In this pH span, emulsions are considered "non-irritating". Depending on their age, the pH value of used emulsions can rise or fall. pH value increases are normally due to the presence of alkaline machine or system cleaners. A fall in pH value is normally caused by bacteriological attack.

This in turn can cause corrosion on machines and workpieces. Unpleasant odours can also be created and the emulsion may also become unstable.

We recommend using Dip Slides to determine the level of microbiological (bacteria, yeasts, fungi) contamination. If a microorganism content of more than one million bacteria, yeasts or fungi per ml fluid is established, you should urgently contact your cutting fluid supplier to discuss biocide treatment.

Another worthwhile maintenance measure is to remove all floating contaminants (tramp oils and abrasive residues). Apart from potential blockage problems, these contaminants can weaken the sta-

bility of the emulsion as well as making it more prone to bacteriological attack.

Emulsion instability can also be caused by salts such as chlorides or sulphates dissolved in the water. This is why excessively hard water (>440 ppm CaCO<sub>3</sub>) should be avoided. Such water can also cause the formation of soaps. As too soft water (<175 ppm CaCO<sub>3</sub>) can result in heavy foaming, such water may have to be artificially hardened.

Another contributory factor to emulsion instability is high temperature. Large amounts of water can evaporate. This can result in higher salt concentrations (electrolyte) and ultimately lead to the emulsion splitting. Remedial measures include a partial exchange of the emulsion or topping-up with fully demineralized water.

A further maintenance measure is the aeration of the emulsion. Bacteria have been found to multiply rapidly in emulsions which are cut-off from air supplies or if the emulsion remains stationary for too long. Sulphonates may also be reduced to H<sub>2</sub>S.

This leads to highly unpleasant odours. If machining operations are shut-down, it is worthwhile simply turning on the circulation pumps to allow a degree of gas-exchange to take place.

Maintaining a constant (cool) temperature also increases the stability and performance of a water-miscible cutting fluid. Only in very rare cases is it necessary to heat an emulsion.

Cooling a cutting fluid usually improves tool life apart from reducing vapours. Another bonus of cooling is that microorganisms grow less quickly.

## 7. Corrective Maintenance for Neat and Water-Miscible Cutting Fluids

Both types of cutting fluids are required for metalworking operations and both occasionally generate problems which need to be solved.

906

## 7.1 Neat Cutting Fluids

Problem	Corrective measure
Fluid level in tank too low	Top-up; check for leaks
Excess solid impurities	Fit suitable filtering systems, centrifuges or exchange the fluid
Liquid impurities (water or solvents)	Heat fluid, fit separators
Viscosity too high or too low	Top-up with an oil containing the same additives, determine causes, check for leaks, replacement
Corrosion (steel, nonferrous metals) Tramp oils	Remove water, add corrosion inhibitors, replacement Stop leaks of slideway, hydraulic and lubricating oils, replacement
Foaming	Check pumps for air leaks, check fluid levels, add de-foamers, replacement
Oil mist, oil vapours	Use low-misting oils, add anti-mist agents, fit extraction to machines, improve cutting fluid feed to the cutting zone

## 7.2 Water-Miscible Cutting Fluids

Problem	Corrective measure
Fluid level too low	Add pre-mixed cutting fluid, check evaporation potential, check for leaks
Microbiological level greater than 1 million/ ml fluid (unpleasant odour)	Add pre-mixed cutting fluid and biocides, set at alkaline or neutral pH value
Fungal or yeast attack	Add biocides, test bacteriological contamination with Dip Slides

## 8. Changing Cutting Fluids

Even if a cutting fluid is optimally maintained, there is a point at which it may nevertheless need changing. The life of a new fluid batch largely depends on the cleanliness and disinfection of the system, particularly in the case of water-miscible cutting fluids.

A cutting fluid should be changed if specific values cannot be reached in spite of corrective maintenance. It is always worthwhile to perform a fluid change if system or machine cleaning operations are being undertaken.

### 8.1 Neat Cutting Fluids

In general, neat cutting fluids are very long-lasting. However, sometimes small-capacity circuits have to be changed more often than large central systems.

A neat fluid should be changed if:

- Solid and fluid impurities cannot be removed
- Tool life drops
- Filtering becomes difficult
- The fluid ages excessively
- Machining finishes deteriorate



906

- Odour problems arise
- Skin compatibility deteriorates

Old fluids should be re-conditioned or correctly disposed-of. All pipework, tanks valves, nozzles etc. should be thoroughly cleaned.

## 8.2 Water-Miscible Cutting Fluids

As a rule, water-miscible cutting fluids are changed more frequently than neat oils.

A water-miscible cutting fluid should be changed if:

- The fluid has an unpleasant odour
- It causes gumming
- There are heavy deposits on the machine
- Thick foam floats to the top of tanks
- pH value drops or rises
- Electrolyte levels increase
- Water is too hard
- If soaps are formed
- The fluid thickens
- The fluids becomes unstable
- Cutting performance declines
- Excess solid or liquid impurities are found
- Tool life falls
- Microorganisms flourish
- Fluid circuitry clogs
- Filterability deteriorates

- Surface finish deteriorates.

A water-miscible fluid is changed in a similar way to neat oils. however, a system cleaner must be added before the system is drained.

This ensures that bacteria, yeasts and fungi in pipework are eliminated. Depending on the degree of contamination, the system cleaner should be added to the system 8- 24 hours before draining. After the old fluid and cleaner are drained, the whole system should be disinfected again. Such thoroughness is necessary to ensure that the fresh fluid is not contaminated with residual microorganisms.

Used water-miscible cutting fluids can be reconditioned or disposed-of.

## 9. Handling Cutting Fluids

The function of cutting fluids in machining operations is to minimize tool wear, maximize machine performance and to increase the quality of the components manufactured.

In many cases, machine personnel make unavoidable contact with cutting fluids. Without doubt, even dermatologically-tested cutting fluids can cause skin irritation. In addition, bronchial passages and mucus membranes can be affected.

A major problem is allergies. It is therefore absolutely necessary to take protective measures to minimize the hazards to people and the environment. The following precautions should therefore be taken:

- Avoid contact with cutting fluids
- Wear oil-resistant protective clothing
- Wear eye protection
- Encapsulate machines



906

- Ensure adequate ventilation in machine shops
- Fit oil mist and oil vapour extraction to machines
- Offer skin protection advice
- Apply a barrier cream on the hands and arms repeatedly throughout the day. If working with oils, use a water-soluble cream. If working with emulsions, use an oil-soluble cream
- Do not use abrasive hand cleaners
- Only use pH-neutral soaps
- Do not clean oily hands in cutting fluids
- Dry hands with clean, soft paper towels
- Change soiled clothing
- Do not wipe hands with dirty rags
- Safety instructions should always be readily available
- Only use cutting fluids which are free of nitrite, chlorine and diethanolamines
- Observe safety-at-work regulations
- Be aware of fire hazards when machining magnesium or magnesium alloys
- Use suitable binders (granulate) on soiled or oily floors.

cutting fluids. This highlights the absolute necessity of selecting the best cutting fluid for the job in hand and of maintaining it properly in order to minimize the amount of cutting fluid which has to be disposed of.

#### FUCHS Cutting Fluids

ECOCOOL	emulsifiable products
ECOCOOL S	synthetic, water-miscible products
ECOCUT	cutting oils
PLANTOCUT	biodegradable cutting oils

Contact FUCHS for the very best in cutting oils and fluids. We are global suppliers of carefully-matched and compatible metalworking fluids. And we provide global solutions.

#### 10. Disposal of Cutting Fluids

Observe local waste regulations when disposing of used cutting fluids. Every operator is naturally interested in reducing the disposal costs for used