Technical Information

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Cutting Fluids – Monitoring and Maintenance

FTI 906, Date: 08/2017

Cutting fluids – Definition

The term cutting fluid describes a medium whose principal functions during machining are cooling and lubrication.
The primary objectives are to reduce friction between the tool and the material being machined as well as dissipating any thus created heat. Another role of the cutting fluid is to flush any chips or swarf away from the cutting zone.
Secondary properties of a cutting fluid include providing effective corrosion protection for machines and components, keeping foaming in check, low evaporation and misting, good skin compatibility, a high flashpoint and high stability.

Classification of Cutting Fluids according to DIN 51385

2	Media for machining operations		
2.1	Cutting fluids	SC	Media for chip-forming machining operations
2.1.1	Neat cutting fluids	SCN	Cutting fluids which are mixed with water prior to use
2.1.2	Water-miscible cutting fluids	SCE	Cutting fluids which can be mixed with water prior to use
2.1.2.1	Emulsifiable cutting fluids	SCEM	Water-miscible cutting fluids which form oil-in-water emulsions when mixed with water
2.1.2.1.1	Cutting fluid emulsions	SCEMW	Emulsifiable cutting fluids mixed with water (ready-to-use oil-in-water emulsions)
2.1.2.2	Water-miscible cutting fluids	SCES	Water-miscible cutting fluids which form a colloidal or real soluti-on when mixed with water
2.1.2.2.1	Cutting fluid solutions	SCESW	Water-soluble cutting fluids (ready-to-use solutions)

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1. Storage of Cutting Fluids

When storing cutting fluids, a differentiation has to be made between water-miscible cutting fluids and neat cutting fluids.

1.1 Neat cutting fluids

Neat cutting fluids can generally be stored for up to two years in sealed original containers provided that the corresponding storage conditions apply.
These storage conditions include, among others, dry, frost-free and in covered spaces, protection against exposure to direct sunlight and heat as well as temperature fluctuations and a maximum storage temperature of 40 °C. After containers have been opened, adequate safeguards must be taken to protect against the ingress of dust, dirt, water, etc. and the contents should be used up as quickly as possible.

1.2 Water-miscible cutting fluids

If correctly stored, water-miscible cutting fluid concentrates can generally be stored for up to six months in sealed, original containers.
Apart from the conditions listed in 1.1, particular attention should be paid to ensuring frost-free storage.

If interim storage tanks are used, make sure that these are routinely and frequently checked for contamination and if necessary, cleaned.

Galvanized pipes and tanks are not suitable for use with water-miscible concentrates.

2. Preparing Water-Miscible Cutting Fluids

2.1 Mixing instructions

As a rule, water-miscible cutting fluids are used as 3 to 20 % dilutions in water. Mixing and determining concentration should be performed in line with the current state-of-the-art and the corresponding information in the technical product information sheets must be noted. As regards mixing, the following should be observed:

2.1.1 Mixing water

The quality of the mixing water is of decisive importance to characteristics of cutting fluid emulsions or solutions.

As stated in the TRGS 611, the mixing and topping-up water must have a nitrate content of less than 50 mg/l. If potable (drinking) water is used, this value is usually met by the local water companies.

The hardness of the water also affects the foaming behaviour of cutting fluid emulsions or solutions. If soft water (water hardness < 8° dH) is used for mixing, foaming problems may occur. If water whose hardness is significantly over 20° dH is used, lime precipitation can occur, corrosion protection suffers, stability is reduced and salt residues can form on machine components after longer use. The optimum and recommended hardness of the mixing water should be between 10 and 15 °dH.

The hardness of mixing water can be adjusted by adding a "hardening agent" such as calcium acetate to water that is too soft and if the water is too hard, fully demineralized water can be added.

The chloride content of the mixing water should not be greater than 30 mg/l because enrichment can occur during the use of emulsions or solutions and this in turn can lead to corrosion on machines and components. Chloride content can also be reduced by the addition of fully demineralized water.

Analytical data on local drinking water supplies can be obtained from the corresponding supplier.

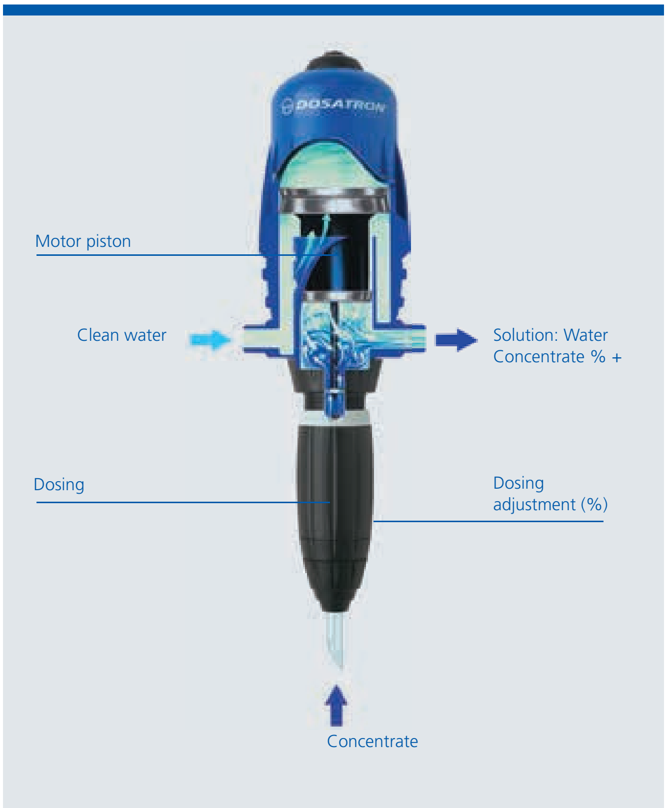
If well water which is not subject to drinking water regulations is used, such water should be tested to make sure that the bacterial count is under 10^3 because otherwise, the emulsion may be subject to increased bacteriological contamination.

The temperature of the mixing water should in no circumstances be lower than 10 °C because this can lead to miscibility problems. In addition, the recommended temperature of the concentrate should be between 15 and 20 °C.

2.1.2 Mixing water-miscible cutting fluids

When emulsifiable cutting fluids are used, manual mixing must always involve the cutting fluid concentrate being added to the water in the proportions recommended by the fluid's manufacturer. Smaller quantities can be mixed is a separate container. The concentration of the mixture should be checked with a suitable instrument such as a refractometer. It is recommended that mechanical mixing equipment is used for larger systems and/or continuous metering systems.
Such equipment can be either stationary or mobile installations connected to the respective concentrate tanks. If connected to drinking water supplies, care must be taken that non-return valves as specified in DIN EN 1717 or separate systems are used.

Even if automatic mixing equipment can be set to a desired mixing ratio or concentration, we recommend that the finished mixture is checked and, if necessary, adjusted. Any product-specific conversion factors using, for example, refractometers should be taken into consideration.
Such data can be found in the corresponding Product Information sheets.



Source: Dosatron International S.A.S

3. Monitoring of Cutting Fluids

3.1 Water-Miscible Cutting Fluids

A variety of disruptive factors can alter the application engineering characteristics of water-miscible cutting fluids. Routine monitoring of the cutting fluid is therefore necessary to ensure that the fluid is in optimum condition and that the hazard potential for people and the environment is kept as low as possible.
The basis of such monitoring is the German TRGS 611. This contains safety-related information about the composition and application of water-miscible and water-soluble cutting fluids for the machining and forming of components, especially in the metalworking industry. The tests to be performed and the resulting measures to be taken should be discussed and coordinated with the cutting fluid manufacturer or supplier.

To achieve the objectives of economic use and cost reductions when water-miscible cutting fluids are used, it is essential that the properties of the product used are maintained for as long as possible.
Apart from the product's quality and the machining process involved, the service life of a cutting fluid is significantly influenced by the fluid's monitoring and the maintenance substances used along with their scope and continuity. Experience shows that these days it is easier to achieve economic service life with central circulation systems than with individually filled machines. However, it is also true that if cutting fluid manufacturer's or professional association's recommendations are strictly observed and consistently applied, individually filled machines can also achieve very long fluid service lives.

Apart from service life optimization, safety at work also plays an important role. Legislation requires users to fulfil safety at work requirements by keeping cutting fluids in perfect condition. It therefore follows that the monitoring and maintenance measures during a fluid's use in machining processes, i.e. analyzing emulsion condition and the use of maintenance equipment, is immensely important.

For this, users have to comply with a routine monitoring and maintenance plan which documents nominal and actual values. Useful information regarding this is also available in, for example, professional association documentation. Examples of these are the German BGR/GUV-R 143 and the VDI Guideline 3397.

3.1.1 Test methods for water-miscible cutting fluids

Analysis	Test method	Recommended interval, frequency
Appearance and odour	Visually and sensory	Daily
pH value	Electro-chemical (DIN 51369), pH test strips	At least weekly (see TRGS 611)
Cutting fluid concentration	Refractometer, acidic titration “Bohrölprüfer” (DIN 51368)	Daily, at least weekly
Nitrite content	Test strips, photometry	Weekly (see TRGS 611)
Bact. count, bacteria, fungi, yeasts	Dip-Slide method	If necessary weekly
Chloride content	Potentiometric titration; ICP	If necessary
Water hardness	Test strips, Ca & Mg content with ICP	If necessary
Corrosion	Chip-Filter test (DIN 51360-2)	If necessary
Tramp oil, non-emulsified oil	Durability test in line with DIN 51367	If necessary
Solid impurities	Membrane filter method (DIN 51592)	If necessary
Electrolyte content	Conductivity measurement	If necessary

Source: incl. VDI 3397 Sheet 2

3.1.1.1 On-site testing

The following describes a few simple tests which users can perform on site:

a) Visual checks

In the forefront are two important checks which should be performed daily. The first is a basic prerequisite for keeping cutting fluids in good condition and involves checking the cutting fluid level in the tank. In machine tools with insufficient cutting fluid in the tank, the circulation pump can draw air and this can lead to cutting emulsion foaming. This, in turn, can lead to other problems such as inadequate heat dissipation from the tool and component and thus reduced performance such as grinding burns or reduced tool life. The second visual evaluation of the emulsion concerns emulsion colour and degree of dispersion. If optical changes to the cutting fluid occur, this is usually an indication of a change in the condition of the cutting fluid. This requires specific counter-measures which must be accompanied by a comprehensive review of the causes. Normally, an emulsion does not have floating or creamy oil on its surface.

As it is often difficult to perform further evaluations of the cutting fluid in the emulsion tanks, we recommend taking an emulsion sample in a clean and transparent container (glass or transparent plastic) and then examining and evaluating this sample.

There can be a number of reasons why a cutting fluid displays changes and these can be clarified by the monitoring parameters listed below.

b) pH value measurement

A pH value measurement must be performed at least once a week (TRGS 611). The simplest way is to use test strips which show the pH value by colour indication.
These can be used at any time and do not require calibration. However, it should be remembered that such indicator test strips have a use-by date.
If the test strips are too old, inaccuracies can occur due to colour errors.

A very important consideration when using all test strip methods is the correct handling of the strips. This includes the dipping of the test strip into clean emulsion which does not have tramp oil floating on top. Furthermore, time is important, i.e. how much time should elapse before the test strip is evaluated.
The advantages of the test strip method are its speed and simplicity without the need for additional reagents. The method is thus relatively immune to erroneous readings caused by handling errors.

A somewhat more accurate but more costly alternative to pH measurements with test strips is to use an electrical pH value measurement instrument. Regardless of whether a battery operated pocket instrument or a laboratory instrument, it is important that operators know how to handle the pH electrode as regards cleanliness and the necessity of routine recalibration prior to measurements. In addition, it is necessary to ensure that the measurement head (diaphragm) is clean so that no tramp oil can interfere with the measurements which inevitably lead to false readings.

Source: Hanna Instruments

An important point for pH value measurements and the corresponding documentation is the development of the pH value over the course of the emulsion's service life. The continuous monitoring of pH values allows countermeasures to be taken in good time.

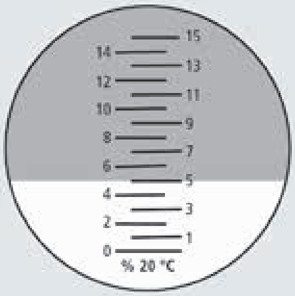
c) Concentration measurement

It is recommended that the concentration of the emulsion is tested at least once a week and even daily if the emulsion volume is small and/or it is used in highly-stressed machining centers with high drag-out. For this, there are simple and cost-effective methods available. One possible concentration measurement tool which should be available in all metalworking workshops is the hand-held refractometer.

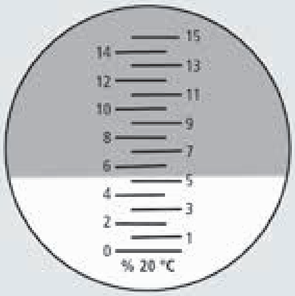
Hand-held refractometer

This instrument is used to optically determine concentration along with the cutting fluid-specific refractometer factor which can be found in the respective Product Information by measuring the refraction of light (refractive index) through the medium. The value seen on the measurement scale which corresponds to the clear, boundary between the colours is then multiplied by the cutting fluid-specific factor to generate the emulsion concentration value.

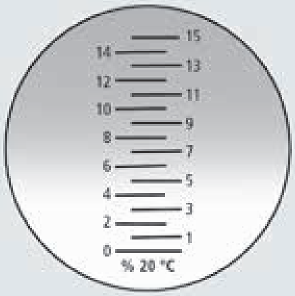
When using a hand-held refractometer, it is important to set the zero point adjustment with pure water prior to any concentration measurements. A heavily contaminated or less than stable emulsion or one which has excessive tramp oil can lead to the dividing line being diffused which, in turn, caused inaccurate or unsafe concentration measurements.
Normally, concentration measurements with hand-held refractometers generate almost identical values both immediately after the sample has been taken and after many hours. However, if the emulsion is not stable, the values may differ significantly.



Sharp dividing line:
Reading x Factor*,
e.g. 5 x 1.4 = 7%



Unclear dividing line:
Reading x (Factor* - 0.2),
e.g. 5 x 1.2 = 6%



Blurred dividing line:
Reading x (Factor* - 0.4),
e.g. 5 x 1.0 = 5%

*e.g. Refractometer factor 1.4

Titration

Another way of determining concentration is titration. This is a quantitative method. A corresponding colour indicator is added to the emulsion sample of unknown concentration. Using a burette, a titrant (for example, 0.1 mol/l HCl) is added drop by drop to a defined volume of the sample until the colour changes at the equivalence point. The concentration of the emulsion can then be determined with the titrant consumption and the product-specific titration factor of the cutting fluid.

Some cutting fluid manufacturers offer titration sets with which it is possible to determine concentration directly at the machine with the help of a titration curve. Information about other titration methods can be obtained from the cutting fluid manufacturers.

d) Nitrite content

Another parameter which is required to monitor cutting fluids is nitrite content.

Against the background of avoiding hazards to employees caused by nitrosamine contamination, the nitrite content of cutting fluids should be determined weekly. Nitrite is a reaction component which together with secondary amines can lead to the creation of carcinogenic nitrosamines. Nitrite can be formed by the nitrate in the mixing water but is not a substance contained in cutting fluids. Because cutting fluids containing secondary amines are banned, this second reagent (for example diethanolamine) which can lead to the creation of nitrosamines is largely excluded. However, contamination through the drag-in of other media cannot be completely excluded. (TRGS 611)

As measurements show, limiting nitrite concentration to less than 20 ppm provides sufficient guarantee that the permissible MAK value of 5 ppm nitrosodiethanolamine in the emulsion is not exceeded. If these values are higher than 20 ppm, it is essential that the source of the nitrite is found. If such a source, such as quenching salts, is found, this must be eliminated or excluded.
Further measures to reduce nitrite could include partial replacement or the use of fresh cutting fluid. (BGR/GUV-R-143)

e) Nitrate content

As already mentioned, nitrite can originate from the nitrate in the mixing water and this should therefore be regularly checked.

Test strips are also available for this purpose. According to drinking water regulations, a maximum of 50 ppm nitrate is allowed. As a rule, nitrate concentrations are between 10 and 20 ppm. However, significantly higher concentrations than 20 ppm may be found in regions of intensive agricultural activity.

Nitrate monitoring does not have to happen on a weekly basis. Nevertheless, we recommend that this value is routinely checked or, at least, have the nitrate value confirmed by the local water supplier and documented.

Apart from simply evaluating the test strips visually, there is also the possibility automatically reading the strips with a so-called "Reflectoquant system". This option may be of interest if a large number of individually filled machines have to be monitored.

f) Water hardness

Another check which can be of benefit but is not mandatory, particularly in the case of individually filled machines with high replenishment volumes, is testing water hardness.

This is often the case if the mixing water contains well water. Here again, there is the possibility of using economical and simple-to-use test strips to test for any increase in hardness. Very high levels of water hardness can result from high evaporation losses.

The influence of water hardness on emulsion stability is judged to be non-critical for the large majority of today's cutting fluids. A greater problem is the water hardness-related deposits and gumming which can affect metalworking machines along with the associated high cleaning costs. But such burdens add up and excess hardness can certainly negatively affect emulsion service life which ceases to be optimum and too hard water can necessitate costly rust-related rectification work.

If checking water hardness and possible correction by adding demineralized water eliminates a burden to the emulsion, service life can be significantly increased.

3.1.1.2 Monitoring plan / Documentation

According to German BGR/GUV-R 143, when water-miscible cutting fluids are used, a monitoring plan must be created and maintained which allows nominal and actual comparisons to be made at any time. Such plans must include the parameters, the test methods used, the test intervals, the corresponding measures taken and possibly, cutting fluid-specific information.

Documentation and monitoring data obligations are most easily and simply fulfilled with so-called on-site machine registers. With these, developments of the measured values and emulsion condition tendencies can be identified at a glance.

There is also the possibility of monitoring, administrating and presenting such data with corresponding software. Such programs are usually offered as a service by the cutting fluid supplier.

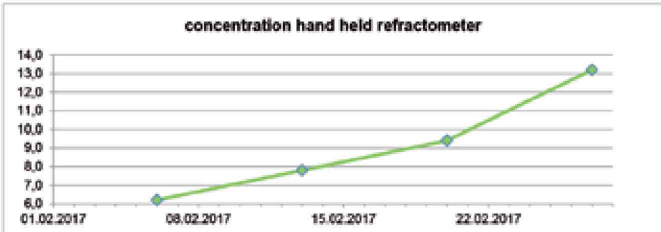
It is the user company’s duty to document and store test results and any resulting measures taken for at least three years.

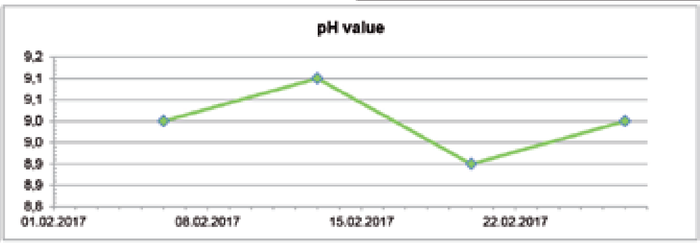
FUCHS CUSAR System

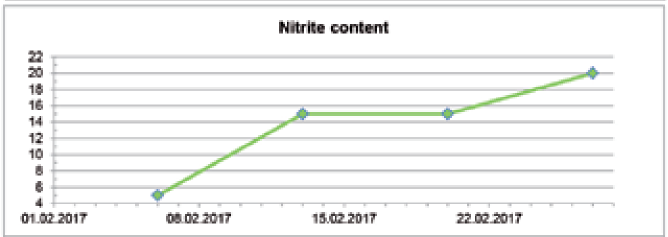
CUstomerSample Analysis and Reporting System

Customer: xxx **Machine:** xxx
Location: xxx **Component:** xxx
Contact person: xxx **product:** ECOCOOL XXX
Customer EquiNo: xxx **Machine No.:** xxx **Component No.:** xxx

Date of sample		report No.	Appear-ance	concentr. Hand held refracto-meter	concentr. Titration	concentr. Bohröl-prüfer	pH value	Nitrite content	Bacteria count	Chloride	water hardness calc.	tramp oil	Chip-Filter test	Calcium	Magnesium
				FLV-T-05	FLV-K-21	DIN 51368	DIN 51369	Teststreifen	FLV-G-04	FLV-C-08		FLV-F-11	DIN 51360-2	ICP	ICP
			-	%	%	%	-	mg/l	10^/ml	mg/l	°dH		KorrGr	mg/kg	mg/kg
06.02.2017		12345678	ok	6,2	5,3	6,9	9,0	5	<10^3	<30	20	traces	0	143	91
13.02.2017		23456789	ok	7,8	8,8	8,7	9,1	15	<10^3	<30	22	2	0	158	98
20.02.2017		34567890	ok	9,4	9,2	9,7	8,9	15	<10^3	33	24	traces	0	174	112
27.02.2017		45678901	ok	13,2	13,0	13,4	9,0	20	<10^3	37	22	traces	0	161	96







Diagnosis for the current laboratory value		concentration slightly above the target range (7,0-13,0%); 27.02.2017 xxx

date: 27.02.2017 **created by** xxx

he analysis report was compiled with the utmost care, to the best of our judgement, and according to the current state of knowledge. Fuchs Schmierstoffe GmbH will assume no liability for damage to property resulting from the use of the test results, unless the damage is the result of an intentional or grossly negligent conduct on the part of Fuchs Schmierstoffe GmbH. In the event that the report has additionally been commented, this comment is based on a technical expert report by the signatories and constitutes a recommendation. Please be advised that the test result refers exclusively to the tested samples and therefore represents an individual assessment. The test results, or extracts thereof, must not be published without the written consent of Fuchs Schmierstoffe GmbH.

3.2 Neat Cutting Fluids

Neat and water-miscible cutting fluids are formulated from low-aromatic mineral oils, white oils, synthetic oils or renewable synthetic esters. Selected additives such as corrosion protection agents, anti-misting agents, EP and AW additives, emulsifiers or wetting agents are used to improve the fluid's characteristics in use.

As opposed to water-miscible cutting fluids, neat cutting fluids have almost unlimited service life if well maintained. Bacteriological contamination cannot occur because no water is present.

The recommended tank temperatures for neat cutting fluids is under 30 °C and should never exceed 40 °C.

Solid contaminants should be continuously filtered out of the fluid. A disadvantage of neat cutting fluids is the possibility of the irreversible mixing with hydraulic oils, spindle oils and slideway oils resulting from, for example, leakages. To combat this problem, it is always recommended to use fluid families or multifunctional oils.

3.2.1 Test methods for neat cutting fluids

Analysis	Test method	Recommended interval	Information about
Appearance and Odour	Visually and sensory	Daily	Contamination, drag-in
Viscosity	DIN 51562	Every three months	Dragged-in tramp oil, ageing
Water traces	Karl-Fischer titration (DIN 51777)	In case of abnormalities	Dragged-in emulsions, cleaners or water
Impurities	Particle counter (incl. ISO 4406) or gravimetric measurement (ISO 4405)	Depending on dragged-in dirt during machining	Degree of contamination
Fluid contamination	IR spectroscopy or with Neutralization number	If necessary, as a rule every three months	Dragged-in tramp oils
Saponification number	DIN 51559		Additive condition, dragged-in tramp oils
Neutralization number	DIN 51558	If necessary, as a rule every three months	Ageing, additives
Density	DIN 51757	If necessary	Dragged-in tramp oils
Air separation	DIN ISO 9120	If necessary	Cooling capacity, dragged-in tramp oils
Four Ball welding load	DIN 51350	If necessary	EP additives
Reichert wear test	FLV-R 3*	If necessary	AW additives
Foaming	FLV-S 12* ASTM D 892	If necessary	Foaming, additives
Brugger value	DIN 51347-2	If necessary	EP /AW additives
Metal content	Emission spectrometry (ICP), x-ray fluorescence spectroscopy (RFA), Atomic absorption spectrometry (AAS)	If necessary	Additive levels, solid or soluble impurities
Flash point	DIN EN ISO 2592	If necessary	Dragged-in solvents
Corrosion protection	Copper corrosion (DIN EN ISO 2160)	If necessary	Determining corrosion protection additives and dragged-in contaminants
Evaporation losses	DIN 51581-1	If necessary	Evaporation losses
Oil mist index	FLV-O 02*	If necessary	Misting characteristics
Colour	DIN ISO 2049	If necessary	Aging, contamination, dragged-in tramp oils

* FUCHS SCHMIERSTOFFE GMBH Laboratory procedure

4. Maintenance of Cutting Fluids

4.1 System cleaners for water-miscible cutting fluids

The service life of a water-miscible cutting fluid can be decisively influenced by the thorough cleaning and disinfection of the cutting fluid system.
Acceptably good service life can only be achieved if systems are properly cleaned and disinfected prior to initial filling.

While cutting fluid tanks and chip conveyors can be cleaned with high-pressure or steam cleaners, mechanically cleaning pipes and other fluid circuitry is very complicated. Any such mechanical cleaning must be followed by disinfection.

System cleaners are used to clean and disinfect difficult-to-reach and inaccessible parts of the cutting fluid system. In these products, special agents ensure that such areas are wetted. They dislodge deposits, fungal infestations and bacterial colonies. The built in emulsifiers dissipate floating creamy oil and transport impurities in the system. The microbiocides in system cleaners serve to "disinfect" the whole system.

When using system cleaners, it is important to use the correct concentration and to observe the recommended application time. Always follow the recommendations of the cleaner's manufacturer.

The following procedure has proven to be successful:

- Add system cleaner to the cutting fluid prior to draining
- Allow to circulate for 8 to 24 hours
- Drain the tank
- Mechanical cleaning of the tank, conveyor, etc.
- Flush cutting fluid system with fresh emulsion
- Drain the tank
- Refill cutting fluid system

The fungi problem should be mentioned here. These are sometimes still in fluids after treatment with system cleaners. One problem could be fungicidal films which are not fully dislodged by system cleaners and whose fungi spores can re-infect fresh cutting fluid batches.
In such cases, it is recommended that in consultation with the cutting fluid supplier, the fresh fluid is subjected to further repeated treatment with fungicides.

4.2 Preservatives for water-miscible cutting fluids

Water-miscible cutting fluids mainly consist of nitrogen, carbon, oxygen as well as sulphur and phosphorous compounds which are a nutritional basis of biological growth. Excessive bacterial counts can permanently impair cutting fluids, reduce their life and thus harm the environment. Bactericides (substances which destroy bacteria) and fungicides (substances which destroy fungi) are used to conserve water-miscible cutting fluids.
Without such conservation, bacterial and fungal growth would soon render cutting fluids unusable, which would endanger not just the environment but also the health of workshop personnel who work with cutting fluids. Further information on this can be found in the VDI Guideline 3397, Part 4 and BGI / GUV–I 762.

Bactericides: Combat bacterial attack
Fungicides: Combat fungal growth

The EU Biocide guidelines (BPR, Guideline (EU) No. 528/2012) have serious consequences on the availability of biocides for cutting fluids. All biocides for the Product Group 13 (cutting fluids) must be thoroughly tested for their danger to people and the environment. Many biocide manufacturers have been scared off because of these cost-intensive tests. As of March 2017, only 25 substances (from over 1,000) remain available, including 13 formaldehyde-splitters (FAD), some of the most important bactericides for cutting fluids. The controversial classification of fomaldehyde (not to be confused with FAD) in "Carcinogenic Catergory 1B", has also led to critism of formaldehyde-releasing agents.

4.3 Defoamers

The use of defoamers is only recommended if the cause of the foaming is either unkown or is known but cannot be eliminated in the short-term, for example, if water quality fluctuates, contaminants are dragged-in through alterations in machining sequences, cutting fluids changes, etc. Defoamers should only be added if good mixing can be guaranteed. Additions up-stream from filters should be avoided because they may be filtered-out.
The supplier's recommended usage concentration must be observed. Excessive doses of defoamers can detrimentally affect air release properties and the foam may even become more stable.
Before adding defoamers to cutting fluids, they should first be diluted with water. This allows the optimum effect to be generated because the defoamer mixes more rapidly.

4.4 Other service products

This category includes all special products whose use is benefical to users and which can be used in line with cutting fluid manufacturer's recommendations, such as products to boost cutting performance, increase pH value or improving corrosion protection.

4.5 Preventative measures

To reduce the cost and complexity of cutting fluid maintenance, preemptive measures can be taken in advance, for example, when new machines are ordered.

These are usually simple, mechanical solutions which generate very little or no extra costs but which can significantly reduce the time and effort necessary for monitoring when machine tools are in use.

a) Type of cutting fluid

First of all, there should be clarity regarding the type of cutting fluid to be used. This does not mean that operators have to know whether their cutting fluid will be manufactured by company A or B, but whether a water-miscible or neat cutting fluid will be used. This decision alone can cut subsequent monitoring and maintenance costs.

b) Location of the cutting fluid tank

When operators order machines, attention should be paid to whether cutting fluid supply and return tanks and and anciliary machinery are easily accessible for later maintenance and cleaning measures.

c) Size of the cutting fluid circulation system

A sufficiently large cutting fluid circulation tank volume is a decisive criterium for the later, foam-free operation of machine tools. We advise consulting and following the recommendations in VDI Guideline 3035.

d) Resting zones in cutting fluid tanks

If water-miscible cutting fluid maintenance equipment is used, it may be worthwhile constructing so-called resing zones inside the various tanks so that any tramp oils can rise up and be removed.

e) Interior walls of the cutting fluid tank

Interior surfaces of tanks should not be painted, galvanized or coated in any other way as such coatings may be attacked and become detached which, in turn, can cause filter problems.

5. Maintenance Equipment for Cutting Fluid Systems

The VDI Guideline 3397, Part 2 offers an overview of all the maintenance equipment available for separating solid and fluid contaminants and impurities. The suitability of the respective technology depends largely on the machining process involved and should always be clarified.

5.1 Removal of solids

This is an overview of the most commonly used equipment to separate solid impurities:

Equipment	Effect / Degree of separation	Complexity
Band filters	Medium / High	Low
Precoat filters (mainly for mineral oil-free emulsions and oils)	High	High
Magnetic separators	Medium	Low
Sedimentation tanks	Medium	Low
Drum or gap filters	High	Medium
Hydro cyclones	Medium	Low

Filtration is the most commonly used mechanical separation method. The large majority of machining centers are already designed to be fitted with filtering systems. Depending on which filter mesh sizes are used, all types of solid impurities can be removed.

The filtering method is mainly influenced by the type of cutting fluid (water-miscible or neat), the required degree of cutting fluid purity dictated with the machining process and the quantity of solids which need to be removed.

5.1.1 Band filters

Because of increasing disposal costs, filtation systems in which the actual filter can be cleaned and reused are becoming more popular. Such systems naturally slash disposal costs for used filter materials. Examples of these are endless nonwoven band filters from which the metal particles are removed by scrapers or by various flushing techniques.

When filtering water-miscible cutting fluids, it must be remembered that too fine mesh sizes not only remove solid particles from the fluid but can also separate out fluid components. This can mean that defoamers, i.e. foam-reducing, finely dispersed soaps which are formed by the hardness in the water, can also be removed. This can, in turn, significantly change the behaviour of cutting fluids.

5.1.2 Precoat filters
Precoat filters use an additional medium such as diatomaceous earth (Kieselgur) or cellulose to initiate the filtering process. These media form a filter cake whose pores are very fine. However, it should be remembered that some very fine pore media can absorb or filter-out certain components of the cutting fluid itself. Such filters are best suited to cutting fluid solutions and not water-miscible fluids. As a result of the high investment costs and complex systems involved, Precoat filters are mainly used in central systems where high demands are made on the cleanliness of the cutting fluid. A disadvantage of this filtering method is the additional disposal costs of the filter additives.

5.1.3 Magnetic separators
Compared to the other filtering methods, these systems are limited to ferro-magnetic contamination and can operate in continuous and non-continuous modes. A non-continuous method could be a permantent magnet in the fluid which is cleaned during machine down times. Continuous systems are more efficient than band or magnetic drum separators. In these, the trapped dirt particles are continuously removed by band scrapers or from the drum.

5.1.4 Drum or Gap filters
Filtration is achieved by a permanently installed cellulose or gap system, whereby the filtering effect is mainly generated by the built-up filter cake. Their suitability therefore needs to be examined on a case-by-case basis. One advantage of this system is that the sludge is free of additives but may still contain a large amount of moisture which then may have to be de-watered.

5.1.5 Hydro cyclones
The fluid is rapidly rotated or spun. The particles in the cutting fluid are pressed against the cyclone's wall by centrifugal force where they gather and are then drained as a thin slurry. These slurries are very wet and have to be correspondingly treated prior to disposal. This method is only used for water-miscible cutting fluids.

5.2 Separating fluid contamination
The market these days offers users a wide range of equipment which is either permanently installed or can be used as a mobile system. Apart from the investment costs and the later maintenance costs, when such apparatus is selected it must be remembered that their use may lead to depletion of the emulsion and that emulsion is carried-out with any tramp oil.
To avoid unpleasant surprises later on, it is recommended that tests are performed on the machine in advance in practical conditions. The following summary shows the most commonly used equipment:

Tramp oil separation table

Equipment	Costs	Depletion hazards
Oil skimmers	Low	Very low
Coalescence separators	Neutral	Very low
Separators	Neutral	Low

5.2.1 Oil skimmers
There are a number of techniques which can be used to remove tramp oils. Relatively simple and economical are band, disc or hose skimmers.
In the case of disc skimmers, the floating oil adheres to a rotating disc in the emulsion (disc skimmer) and is thus transported to a scraper and then removed. If such systems are used, it is important that there is a resting zone in the cutting fluid tank so that any tramp oil has the chance of floating to the top of the emulsion. Excessive turbulence in the fluid allows the tramp oil to mix back into the emulsion and then the disc only removes emulsion. Alternatively, such skimmers could be used when the machine and circulation system is stationary.

5.2.2 Coalescence separators
This method is designed to be used in by-pass mode. A part of the cutting fluid is removed from the tank and de-oiled in a coalescence separator where the fluid comes to rest and the non-emulsified tramp oil droplets join to form larger puddles (coalescence) which are then drawn off.
There are a great many designs available on the market both in permanently fixed and mobile versions whereby the mobile versions are ideally suited for individualy filled machines.

5.2.3 2-phase separators / Centrifuges
In 2-phase separators, the cutting fluids are spun at high speeds. The high centrifugal forces create different emulsion and oil phases or densities so that the tramp oil can be removed. With coarsely-dispersed emulsions, there

is a danger of depletion, i.e. apart from tramp oils, certain integral components of the cutting fluid may also be removed. As a result, prior on-site trials are recommended.

The relatively high initial costs are only worthwhile if the mobile machinery can be used for a larger machine park or as a by-pass separator for central cutting fluid systems.

5.3 Simultaneous removal of tramp oils and solid particles

The above-listed methods for removing solid and fluid impurities can, if necessary, be combined. Examples are listed below.

5.3.1 3-phase separators / Centrifuges

3-phase separators are a further development of the above-described 2-phase separators. In the third phase, solid particles are removed. The separated particles which gather on the walls of the separator have to be manually removed in the case of non self-cleaning separators or are automatically thrown-off in the case of self-cleaning separators.

5.3.2 Sedimentation tanks with oil skimmers

This is a combination of the above-mentioned methods. Such equipment can be either permanently installed or mobile and is primarily used for individually filled machines.

5.3.3 Flotation plants

The cutting fluid is pumped into a separate tank and aerated with a series of fine air jets. The air bubbles rise to the top of the fluid whereby they transport tramp oils and very fine solid impurities such as graphite. The upper layer of the tank is then drawn-off. Coarser particles must be removed with an upstream filter.

5.3.4 Inclined filters (3-phase separators)

After the contaminated emulsion in the inlet manifold of the inclined filter has been drawn-off, the emulsion is fed through the inclined metal slats in the tank.

By using the gravitational and coalescence effects, the tramp oils droplets formed rise up the lower surface of the slats and are skimmed-off at the top. Solid particles sink down into the sludge areas where they are drained-off.

The degree of emulsion cleaning is dependent on the correct design of the equipment and the maintenance of the optimum fluid flow rate. The removed sludge is normally very wet and has to be dewatered.

5.4 Maintenance wagons / Cleaning wagons

For a large number of individually filled machines, it may also be economical to use so-called maintenance wagons. In princple, these are flexible maintenance units which can be used for all machines and are fitted with band and cartridge filters along with some form of centrifugal separation technology.

They can be used continuously in by-pass mode or in non-continuously during, for example, machine down times. Whenever such systems are used, a certain degree of hygiene should be observed. The emulsion maintenance wagons should be regularly cleaned. Especially if they are used non-continuously, unchecked bacterial and fungal growth can occur while the wagons are not being used.

Is maintenance worthwhile?

The monitoring and maintenance of cutting fluids prolongs their service life and reduces consumption and waste.
Positive effects also include longer tool life, better component quality (surface finishes and accuracy) and improved health and safety for employees working with cutting fluids.

All these cost reductions make a significant contribution to the competiveness of metalworking companies and thus securing their future.

6. Common practical problems – causes and solutions

6.1 Water-miscible cutting fluids

Problem	Cause	Remedy
Foam	Water too soft	Harden water
	Poor air release	Add anti-foaming agents
	Aeration	Check, and if necessary fill, fluid tanks, their volumes, flow rates and pumps
	Microbiological reaction products	Vent and circulate fluid regularly, check concentration and pH values, if necessary, replace or partially replace cutting fluid
	Defoamer drag-out	Add defoamers
	Dragged-in tramp oils	Remove tramp oils regularly
	Excessive concentration	Add 0.5 % emulsion to dilute to the correct concentration
Odour	Heavily polluted emulsion	Optimize cleaning concept
	Longer periods of machine down time	Circulate and vent the fluid
	Insufficient venting of the circulation system	
	Contamination with foreign objects	Train personnel
	Insufficient concentration	Check and correct concentration
	pH value too low	Correct pH value with suitable agents
Emulsion instability	Incorrect emulsion mixing	Check, correct and/or optimize mixing procedures
	pH value too low	Adjust pH value and possibly use bactericides
	Dragged-in salts, water too hard	Add demineralized water
	Dragged-in fluid contaminants	Avoid and, if necessary, remove dragged-in contaminants
Corrosion	pH value too low	Add pH value boosters
	Concentration too low	Check and adjust concentration
	Chloride content too high	Add demineralized water, replace or partially replace fluid
	Conductivity too high	
Skin problems	pH value too high	Check concentration and reduce by adding 0.5 % emulsions
	Concentration too high	
	Bacterial count too high	Use suitable bactericide Observe and apply skin protection plan
Deposits	Dragged-in tramp oils	Remove tramp oils, effectively combat the causes, replace or partially replace fluid
	Dragged-in fluid contaminants such as cleaners or corrosion preventives	Replace or partially replace fluid
	Ageing	Adjust system temperature to <30 °C
	Inadequate cleaning	Remove deposits, optimize filtration
	Microbiological decomposition products	Use bactericides, clean and disinfect prior to replacement
	Concentration too high or too low	Adjust concentration by diluting or adding emulsion
	Machine lubricant incompatibility	Use lubricant family concepts
Quality problems / short tool life	Concentration too low	Add concentrate
	Excessive tramp oils	Remove tramp oils regularly, avoid contamination
	Cutting fluid feed	Check fluid feed lines, avoid blockages, Select suitable nozzle layout and fluid jets
	If necessary, select a more suitable cutting fluid	Consult cutting fluid supplier
Filtration problems	Poor filter cake formation	Add wetting agents; check water hardness
	Fungal blockages	Protect the system with biocides, cleaning and disinfection
	Lime soaps	Adjust fluid with demineralized water
	Tramp oil	Remove tramp oils, check compatibility

6.2 Neat cutting fluids

Problem	Cause	Remedy
Filtration problems	Viscosity too high, flow rate falls	Eliminate dragged-in tramp oils, use fluid families
	Gumming of the filter resulting from dragged-in water-miscible cutting fluids	Eliminate drag-in or dry components
Poor component quality / short tool life	Excessive contamination	Install or test and optimize filtration
	Excessive tramp oil drag-in	Use fluid families Use additives after analysis and consultation with the cutting fluid manufacturer
	Dragged-in water	Find and eliminate causes, separate water with suitable equipment
Foam	Dragged-in aqueous media	Avoid foreign object contamination, replace or partially replace fluid
	Temperature too high	Check flow rates and, if necessary, optimize tank volumes or install coolers
	Flow rate (circulation) too high	Increase tank volumes
	Mixing with tramp oils	Avoid contamination, use compatible multifunctional oils
	Incorrect application	Optimize cutting fluid feed and return
High emissions	Process-specific misting and evaporation	Use suitable oils, use anti-misting additives
	Incorrect application	Extraction, encapsulation; optimize cutting fluid feed
	Increased temperature	Install cooling, check fluid volumes
	Drag-in of low boiling point substances (e.g. cleaning emulsions or hydrocarbon degreasers	Eliminate foreign object contamination
Skin problems	Fine abrasion	Observe and apply skin protection plan
	Dragged-in machine cleaners or maintenance products	Avoid contamination if possible
		Make available and use suitable personal protection equipment
Turbidity/ Colour and odour changes	Thermal loads	Examine the influence of temperature on storage and the process
	Dragged-in foreign objects	Replace or partially replace fluid

7. CPM – Chemical Process Mangement

Based on its high technical qualification, FUCHS is going one step further by implementing its CPM (Chemical Process Management) at customer's premises to manage the fluids used.

Lubricants, whether they are industrial oils, corrosion preventives or metalworking fluids, directly or indirectly influence the efficiency of manufacturing. The correct selection but also the matching of individual process components as well as the correct handling of products are, as this FTI illustrates, all topics which play an important role. As these tasks are not part of manufacturers' core business, they are often neglected and possible optimization measures are not always fully implemented.

The CPM team acts as an on-site specialist and focuses on all questions concerning the use of lubricants. Its flexible technical services are tailored to the needs of the respective customer. The modular concept is principally based on three main areas:

Procurement management (System supplier),
Warehouse management and
Fluid management.

The CPM service is complemented by diverse additional options such as laboratory analyses or the implementation of recycling concepts.

The most important element of CPM is fluid management with the service team looking after customers's machines on a daily basis. This includes topping-up lubricant systems, documenting consumption as well as monitoring and maintaining products. The gathered service data, i.e. consumption at every lubrication point, both on-site and laboratory measurements as well as all activities and the warehouse administration are all archived in the CPM Navigator. This database was specially developed for fluid management. Measurements are taken on machines and in the warehouse with barcode scanners. Using our expertise and experience as lubricant specialists, we perform structured analyses and evaluations to identify and exploit process optimization and savings potential. In this way, customers benefit from the full performance of the lubricants.

As the system supplier, the FUCHS CPM back-office looks after the entire procurement chain, the planning and the supervision of deliveries. This module is complemented by warehouse management in which FUCHS personnel look after the whole warehouse administration. A company's entire lubricant needs are thus provided for in the highest quality and the complete process is fully auditable.

The benefits of CPM are underscored by many long-term projects with outstanding customer satisfaction and many successful technical and organizational cost savings concepts.

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Notes

Innovative lubricants need experienced application engineers

Every lubricant change should be preceded by expert consultation on the application in question. Only then can the best lubricant system be selected. Experienced FUCHS engineers will be glad to advise on products for the application in question and also on our full range of lubricants.

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