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WATER IN HYDRAULIC OIL – ITS EFFECT AND CONTROL

In some industries and environments, water is a far more damaging contaminant than solid particles and is often overlooked as a primary cause of component failure. For certain applications, even a small amount of water may have damaging effects on production or equipment. In the field conditions the oil contamination monitoring was accomplished by static extracting samples. The oil servicing and cleaning of the loader were done by the portable filtration system.

Keywords: Water, hydraulic oil, Karl Fischer titration, loader, filtration.

Инж. Зденек КОПЕЦКИ – Ун-т сільського та лісового госп-ва ім. Менделя, Брно, Чеська Республіка

Вода в гідравлічній оливі – її вплив і контроль

У деяких середовищах вода є значно шкідливішим компонентом, ніж тверді частинки і часто – першопричиною складної відмови механізму. В окремих випадках навіть невелика кількість води може шкідливо впливати на створювану продукцію чи обладнання. У робочих умовах контроль забруднення оливи здійснювався за відібраними пробами, а її очищення – мобільною фільтрувальною системою.

Ключові слова: вода, гідравлічна олива, фільтр Карла Фішера, навантажувач, фільтрування.

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Introduction

Water is one of the most abundant substances on Earth. While vital for human life, the effects of water are quite the opposite on machine and lubricant life, resulting in oil degradation, corrosive wear and poor lubrication. Water in hydraulic fluids and lubricating oils has a degrading effect on both the oil and the forest machine. It promotes oxidation of the oil and washes out some additives which are attracted to water. Water coexists with oil in the dissolved, emulsified or a free state. Free and emulsified water pose the greatest risk to the machine and the lubricant, and they should be carefully monitored and controlled. The relationship between the two phases of water (free and dissolved) is represented in Figure 1.

The point at which water changes from a dissolved phase to a free phase is termed the saturation point of the oil. The saturation point of the oil changes with temperature. An example the saturation curve shown in Figure 1, which is typical for hydraulic oil. With no free water at 65°C, 110 ppm (parts per million) of free water will form when the temperature drops to 40°C. This means that for a 300 litre hydraulic system, typical for mobile machine, 0.033 litre of free water will form in the system.

The Effects of Water

Water, in excess of the oil's saturation point, damages a system through accelerated abrasive wear, corrosion and fluid breakdown. A lot of water can effect the system performance much problems including the following:

- Accelerated corrosion
- Reduced bearing life
- Thinner load-bearing oil film
- Material fatigue
- Accelerated oil oxidation
- Change in viscosity
- Deterioration of oil additives
- Bacteria problems

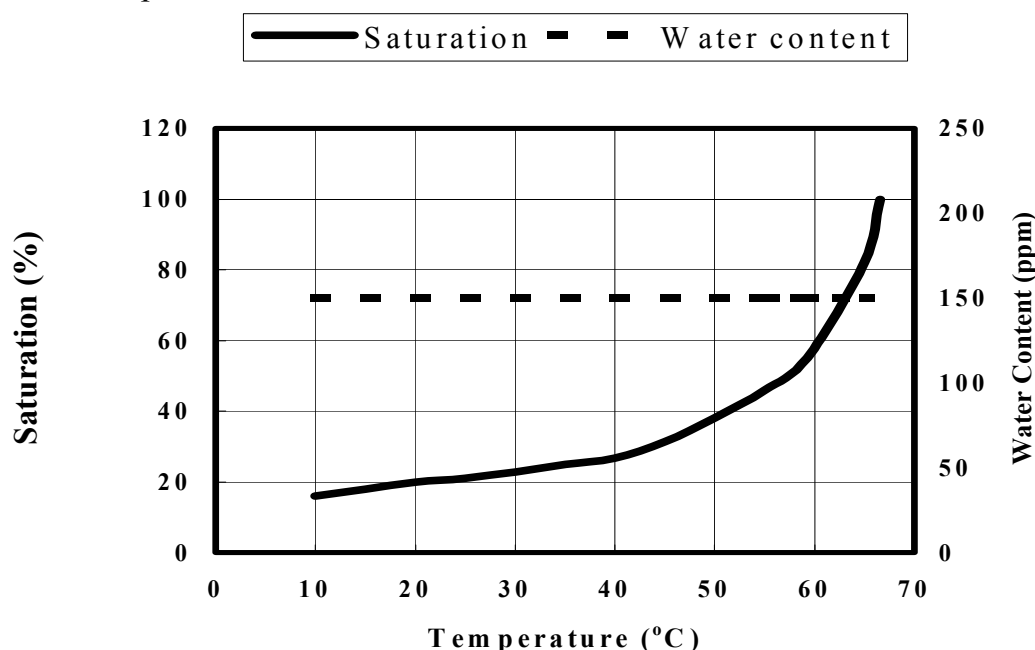


Figure 1. Percent Saturation vs ppm

The Effects of Water in Hydraulic Oil

A moisture in hydraulic oil is a severe contamination. Ineligible effects of water contamination are: Rusts and corrodes metal surfaces, Valves lock with ice crystal, Particle wear increases, Valves and orifices silt more rapidly, Filter life shortens, Destroys antiwear additives (ZDDP) – forms hydrogen sulfide and sulfuric acid, Viscosity decreases during shear.

The moisture can be in three states of coexistence:

- Dissolved water [Saturation point is 200-300 ppm (1 %=10 000 ppm)],
- Emulsified water [Oil is milky (water over 1 %)],
- Free water [Water settles to tank bottom when circulation stops].

Table 1. Unwanted Effects of Water Contamination

On the Hydraulic System	On the Hydraulic Oil
Corrodes metal surfaces Valves lock with ice crystal Particle wear increases Valves and orifices silt more rapidly Filter life shortens	Destroys antiwear additives (ZDDP) – forms hydrogen sulfide and sulfuric acid Viscosity decreases during shear

There are tables or graphs, where extended machine life is shown [1]. Figure 2 shows the relation between extended life of hydraulic system with varying levels of moisture contamination. It was determined by Fitch and recommended by USA Navy [4]. Note, that the critical region is less than 500 ppm for mobile machine with the medium-pressure system.

Current Moisture Level (2500 ppm)

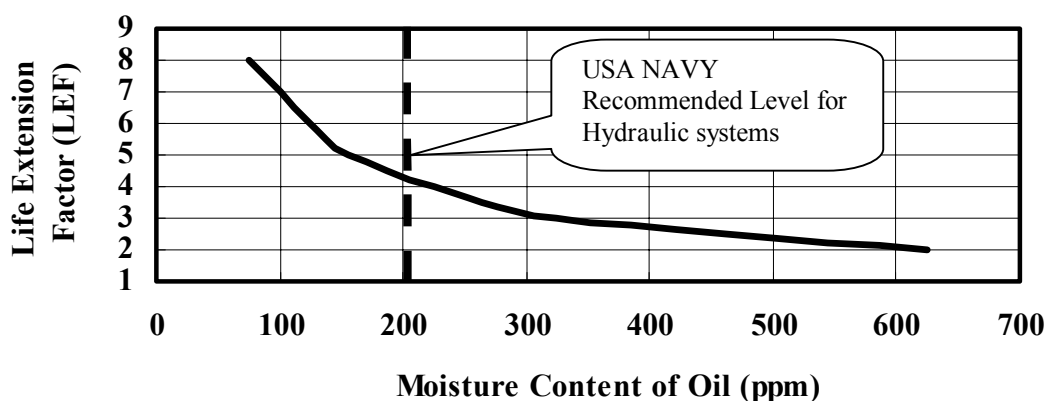


Figure 2. Life Extension Factor vs Moisture Content of Oil for Mobile Machines

The ways to measure the presence of water in oil

There are a number of ways to measure the presence of water in oil. However, most of them are complicated, expensive or difficult to use in the field because they employ wet chemistry. One easy way of detecting the presence of free and emulsified water in oil is with the hot-plate crackle test. This simple, tried-and-true method alerts the user to the presence of any free water.

Several methods are available to determine the water contamination level in fluids. Current methods for determining absolute water concentrations in lubricating oils include FTIR, Karl Fischer titration, dielectric measurements, calcium hydride test kits. Despite the importance of accurately determining water concentrations in oil, no one method can claim to be the ideal solution for all situations, as the table suggests.

Table 2. Methods for Determining Water in Oil

Method	Test Summary	Advantages	Disadvantages
FTIR	A scanning infrared spectrometer is used to measure the characteristic infrared water absorption peak around 3400 cm^{-1} . Water concentrations are determined by the amount of absorbed light using a predefined calibration constant.	It is a fast, cost-efficient method for determining water concentration in oil.	Depending on oil type and condition, FTIR is only able to detect water to 500- 1 ppm. It is also sensitive to interference effects from molecular species that have absorption peaks around 3400 cm^{-1} .
Karl Fischer Titration	The sample is titrated against Karl Fischer reagent using either coulometric or volumetric titration.	It is an accurate, reliable method of determining water concentration down to 10 ppm.	Because the test method requires a wet chemistry procedure and specialized lab equipment, it is not generally applicable to onsite analysis.
Dielectric Tester	The addition of polar contaminants such as water to an oil increases the dielectric can be related to the amount of water contamination in the oil.	It is adapted for use in onsite, using pre-pack-aged test kits.	Interference effects caused by the presence of polar contaminants such as dirt and wear debris can lead to difficulties quantifying water concentrations.
Calcium Hydride Testers	The sample reacts with solid calcium hydride (CaH). Any free or emulsified water present will react with the CaH liberating hydrogen gas, which increases pressure in the test vessel. The amount of water present is proportional to the pressure change.	The test provides a simple, quantitative way of determining water-in-oil concentrations onsite, using test kits	The test is limited to free and emulsified water only. The lowest detection limit cannot be less than the oil's saturation point, typically 200 – 600 ppm, depending on oil type.
The Visual Crackle Test	An easy way to detect the presence of free and emulsified water, the most dangerous forms of water in oil, is with the hot-plate crackle test.	This simple, tried and true method alerts the user to the presence of any free water.	For years, oil analysis laboratories have screened samples with the crackle-test, performing more expensive analysis only when the crackle test is positive.

Methods of Water Removal

The best way to manage water contamination is to keep water out of the oil in the first place. Water enters the sump or reservoir at those points where the machine interfaces with its environment. Following are tips for water exclusion:

- Manage new oil properly.
- Use desiccant breathers or other tank headspace protection.
- Use and maintain high quality shaft and wiper seals.
- Avoid shafts, fill ports and breathers when washing down machines. Avoid high-pressure sprays in the areas of seals if possible.
- Maintain steam and heating/cooling water system seals.

Following is a description of the most common water decontamination techniques. Table 1 provides a general rating of the ability of each technology to remove free (unstable suspension), emulsified (stable suspension) and dissolved (incorporated into the oil's molecular chemistry) water.

Table 3. Water Removal Techniques

Separator Type	Water Type Removed		
	Free	Emulsified	Dissolved
Gravity	Yes	Some	No
Centrifuge	Yes	Some	No
Absorbing Elements	Yes	Yes	No
Vacuum Dehydration	Yes	Yes	Yes

Gravity Separation – Because water generally has a higher specific gravity than hydraulic fluid, water tends to settle at the bottom of the reservoir. Gravity separation alone does not remove tightly emulsified or dissolved water.

Centrifugal Separation – By spinning the fluid, the difference in specific gravity between the fluid and the water is magnified. Centrifugal separators remove free water faster than gravity separators. They also remove some emulsified water depending upon the relative strength of the emulsion vs. the centrifugal force of the separator. Centrifugal separators do not remove dissolved water.

Absorbent Polymer Separation – Free and emulsified water is collected by super absorbent polymers impregnated in the media of certain filters. These look like conventional spin-on or cartridge type filters. The water causes the polymer to swell and remain trapped in the filter's media. Superabsorbent filters can remove only a limited volume of water before causing the filter to go into pressure-drop induced bypass. This method is suitable for hydraulic system mobile machines. These filters do not remove dissolved water.

Vacuum Dehydration – This technique effectively removes free, emulsified and dissolved water. Vacuum dehydration units operate by distributing oil over a large surface area and effectively boiling the water by increasing the temperature to approximately 66 °C to 71 °C. These devices effectively remove water at a temperature that does not cause much damage to the base oil or additives. Vacuum dehydration will achieve reductions of 100 percent of free water and gases and at least 80 percent of total dissolved water and gases.

Proactive "Life Extension" Maintenance

Mobile machines, including forest machines, for example the harvesters, multifarmers, loaders are large and expensive systems and we have to apply special maintenance. Suitable maintenance are the Predictive (On-condition) maintenance and especially the Proactive maintenance. The Proactive maintenance is based on monitoring of the machine's conditions. It directs to achieve improved fluid cleanliness, dryness, and coolness levels and provides an on-site monitoring activity to insure stability of these conditions. Proactive maintenance, by definition, involves continuous monitoring and controlling of machine failure root causes. In oil analysis, root causes of the greatest importance relate to fluid contamination (particles, moisture, heat, coolant, etc.) and additive degradation.

The Proactive maintenance of the loader KN 251 were done by the off-line filtration. It's open hydraulic system operates with medium-pressure system. In the field conditions the particle contaminant monitoring was accomplished by dynamic extracting samples and water contaminant monitoring by static extracting samples. There were used portable particle counter – called digital Contam-Alert (dCA), the Visual Crackle Test and the Karl Fischer Titration for monitoring.

The Visual Crackle Test were used to presence of any free water. The Karl Fischer Coulometric Titration is one of the most accurate methods. In coulometric Karl Fischer titration, iodine (I_2) is generated electrochemically from iodide (I^-). When iodine (I_2) comes in contact with the water in the sample, water is titrated. Once all of the water available has reacted, the reaction is complete. The amount of water in the sample is calculated by measuring the current needed for the electrochemical generation of iodine (I_2) from iodide (I^-).



Figure 3. Monitoring of the loader KN-251 by dCA

The first contamination monitoring was accomplished by static and dynamic extracting samples, Table 4.

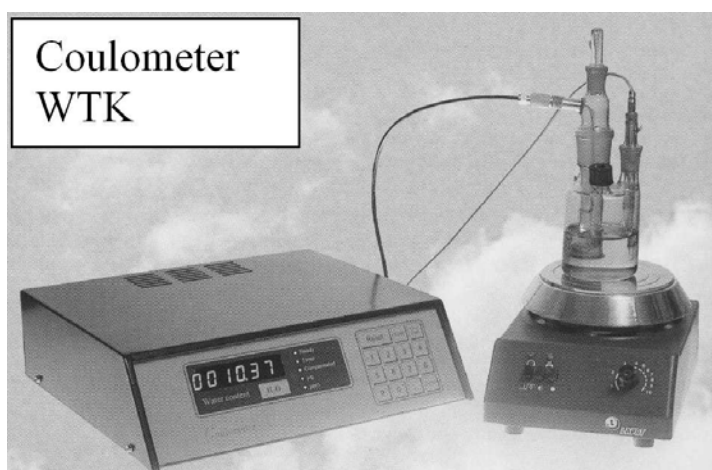


Figure 4. The Coulometer WTK



Figure 5. The Portable Filtration System FA 2-3

Table 4. First contamination monitoring of hydraulic system KN-251

Tested parameter	Extracting Sampling
ISO Code	22/19
Number of Particles >5 μm	25450
Number of Particles >10 μm	8125
Number of Particles >15 μm	3147
Number of Particles >25 μm	796
Number of Particles >30 μm	389
Number of Particles >40 μm	158
Number of Particles >50 μm	45
Number of Ferro-particles	0
All water	1310 ppm

The Portable Filtration System FA 2-3 were used for cleaning. This system was modified with filter element SDFC 1888 (Super Duty Filter Cartridge). The element can absorb water (max. 0,56 litre) and it removes of particle ($> 3 \mu\text{m}$, $\beta_3=100$) from hydraulic oil HM32.

Experimental results of off-line filtration are shown in Figure 6.

Conclusion

Controlling water is like controlling cholesterol: it is not something you can attempt occasionally and expect good results. It requires a change in lifestyle, which may require some major procedural revisions and some minor machine

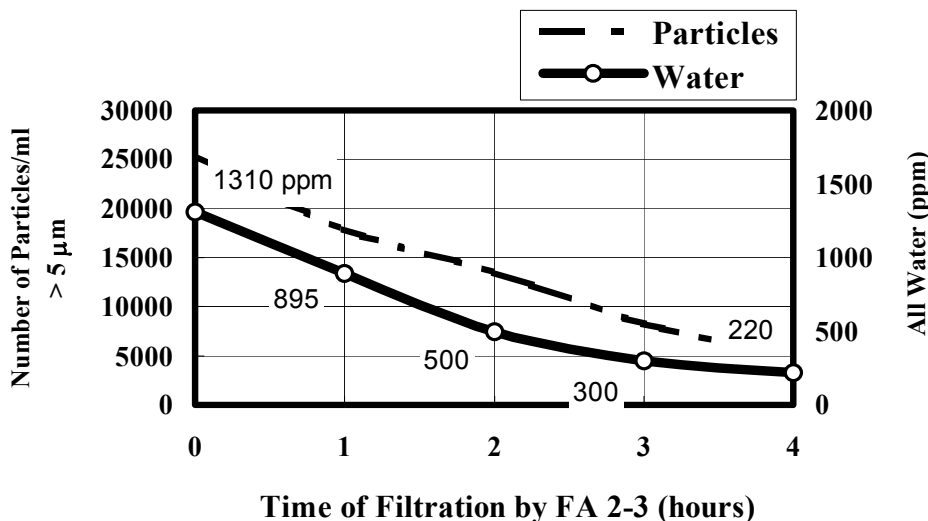


Figure 6. Oil servicing and cleaning of hydraulic system KN-251

modifications. However, given the damage water can cause, the change is well worth the effort. The Proactive maintenance is presented as an important means to cure failure root causes and extend machine life. We have to realise it periodically. The water contaminant monitoring and cleaning provides "the first defence" against corrosion, degradation of oil and mechanical failure.

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EVALUATION OF TIMBER EXTRACTION MACHINES IN TURKEY

In forestry, like every kind of production, production works require a productive power. This productive power can be provided by both human power or animal and machines

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