Water In Oil

What's The Big Deal?

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Water represents a real risk to equipment and should be aggressively controlled. Moisture in hydraulic fluids and lubricating oils has a degrading effect on both the lubricant and the machine. Although some additives cling to the water and are removed when the water separates from the oil (known as water washing), others are destroyed by water-induced chemical reactions (oxidation and hydrolysis). Water also promotes oxidation of the oil's base stock, increasing the risk of sludge and varnish formation. Water also causes rust and corrosion of machine surfaces and reduces critical, load-bearing film strength.

Water coexists with oil in a dissolved, emulsified, or free state. Free and emulsified water pose the greatest risk to the machine and the lubricant, and they should be carefully monitored and controlled.

Three Forms of Water

1. ***Dissolved water*** refers to water that has been chemically absorbed into the oil. While dissolved water possesses no direct threat to the component being lubricated, its presence can serve as a catalyst to oxidation. Dissolved water is normally not visible in an oil.

2. ***Emulsified water*** is water that maintains its chemical integrity, but is held in suspension in the oil by additives and contaminants. Emulsified water will severely alter the load handling ability of an oil. When temperature and pressure are applied to a contaminated fluid, the oxidation process is significantly accelerated, leading to premature degradation. Internal corrosion and rust will also result in all areas of the system. When an oil has emulsified water, it will take on a hazy or milky appearance.

3. ***Free water*** describes water that is present in the oil, but not held in suspension. Since oil and water don't mix, an oil's base stock will be constantly trying to separate from water. Without additives or contaminants to bond with the water, it will separate rapidly and settle to the bottom of the oil. Free water will be visible in an oil as a separate phase at the bottom of the oil reservoir.

Effects on Lubrication

In general, water is a poor lubricant. Proper lubrication is dependent on the formation of an oil film to separate opposing friction surfaces. When pressure is applied to an oil film, the oil's viscosity will increase proportionally to maintain protection. Water does not exhibit this tendency and will cause boundary lubrication to occur where full fluid film lubrication would otherwise be present.

Alarm Limits

Water is considered to be among the most detrimental of possible contaminants. Studies have shown that water present at any level can reduce bearing life from 10 to 100 times. While the overall tolerance for water varies from machine to machine, a good general alarm limit for water contamination is 0.05% (500 ppm). Some systems may be more tolerant to water, while others may be more sensitive. Some manufacturers have set limits as low as 30 ppm. Best practice would tend to indicate that it is beneficial to keep water contamination at the lowest level possible.

Controlling Water Contamination

Controlling water contamination requires two individual considerations. First, we must address the issue of keeping water out of the system. Water can contaminate a system by condensation when moist air enters the component and a change in temperature causes the water to condense and drop into the oil. Water can also enter a system through non-drying breathers, faulty hatches and seals, and internally from leaking heat exchangers.

Second, steps must be taken to remove water once it has entered a system. This can be accomplished with physical filtration, vacuum dehydration or centrifuge. For systems prone to contamination, these types of purification can be installed in the system to remove water continuously or on demand.

Systems that are prone to water contamination should use an oil that rapidly separates from water. An oil's ability to separate from water is known as its demulsibility. High detergent oils tend to be poor demulsifiers, while turbine oils and many industrial lubricants have better demulsibility. Circulating systems prone to water influx, such as those found in rolling mills and power generation plants, can simply drain the water from the reservoir to control contamination, provided the oil exhibits good demulsibility. In these situations, the oil's demulsibility should be monitored to ensure that water contamination does not reach the lubricated components.

Screening for Moisture: Crackle Test

One of the easiest ways to measure the presence of free and emulsified water in oil is with the hot-plate crackle test. An emulsion is the stable state of physical coexistence of chemically insoluble substances, like oil and water. Additives and impurities that lower the oil's surface tension can serve as agents to strengthen the emulsion. Water is in a free state when undissolved globules of water are physically suspended in the oil.

For years, oil analysis laboratories have screened samples with the crackle test, performing more detailed analysis, such as the Karl Fischer test, only when the crackle test is positive.

In the crackle test, a drop of oil is placed on a hotplate that has been heated to approximately 400°F. The sample then bubbles, spits, crackles, or pops when moisture is present. If the crackle test is negative, it simply means that the level of water present in the sample is below the detection limit; it doesn't necessarily mean the sample is void of water.

Sometimes the crackle test may not be appropriate and you would need a Karl Fischer test done on all samples from that machine.

The crackle is not a scientific test but an estimate that is affected by oil type.

Karl Fischer or Crackle?

Here are some questions to think about to help you decide which test to request:

- What is the detection limit for the test?
- Does the detection limit change depending on the lubricant type?
- Do you know what your limits for water should be?
- How important is it to know any water contamination?
- Are detection limits above my condemnation limits?

The following sections explain the side effects of water in oil and describe a study performed by TestOil analysts to measure the effectiveness of the crackle test.

Check Out The Limitations of The Crackle Test

In an effort to communicate the limitations of the crackle test in detecting water contamination, TestOil embarked on a lab study to uncover crackle detection limits. A total of 493 samples comprised of a variety of lubricant types were run on a 400°F hot plate. The samples were assessed for a positive or negative crackle. These same samples were then analyzed for water contamination using a Karl Fischer titration (ASTM D6304-C). The water results were recorded in parts per million (ppm). The table below summarizes the results of the study. The table lists oil type, the number of samples in the study, the detection limit range, the lowest negative crackle value, and the highest positive crackle value.

The lowest positive values represent those samples that exhibited a positive crackle and the associated Karl Fischer result while the highest negative values represent those samples that clearly had water present according to the Karl Fischer results, yet didn't crackle. Clearly, the study demonstrates that quite a bit of variance exists in the water detection limit of the crackle test. You really need to know your lubricant type before making assumptions on what the crackle can detect. In some cases, your water limits may fall below crackle detection and running the Karl Fischer test on every sample may be worth the cost.

OIL TYPE	Samples Tested	Detection Limit (ppm)	Lowest Positive (ppm)	Highest Negative (ppm)
Turbine	111	**110-610**	110	610
Mineral Gear	62	**240-1190**	240	1190
Synthetic Gear	86	**100-460**	100	460
AW Hydraulic	86	**320-750**	320	750
Polyol Ester	36	**340-1830**	340	1830
Phosphate Ester	37	**450-1140**	450	1140
Engine	40	**320-580**	320	580
Wind Turbine (Optigear)	35	**780-1070**	780	1070
Combined	493	**100-1830**	100	1830

Make sure you understand the detection limits for the crackle test and know your lubricant's tolerance for water.

Quantifying the Amount of Water: Karl Fischer Water Test

If a crackle test (see the preceding section) is positive, further testing is needed in the form of the Karl Fischer Water Test. The Karl Fischer coulometric moisture test is a series of chemical reactions discovered in 1935 by the German chemist Karl Fischer. This method analyzes water in the microgram or part-per-million range. This test is very accurate, to .001%. Water determination by Karl Fischer is defined in ASTM D 6304.

For this test, a sample of oil is introduced into a titration vessel in known mass or volume. Any water present in the sample will react with iodine in the titration vessel. The amount of iodine required to react with the water and the known mass or volume of the sample are used to calculate the amount of water present in the sample. Results can be clearly expressed in percent or parts per million.

An electric current passes through a generator containing a Karl Fischer solution. Iodine is produced at the anode that consumes the water in the introduced sample. When an excess of iodine is detected, the analysis is complete. In choosing this method, make sure that test specimens are compatible with the chosen reagent and that no side reactions occur. This method is typically used to analyze hydrocarbons, alcohols, and ethers. Note: Analysis of ketones must employ a Karl Fischer solution that is specifically formulated for ketone analysis.

Low levels of water (less than 2 percent) are typically the result of condensation. Higher levels can indicate a source of water ingress. Water can enter a system through seals, breathers, hatches, and fill caps. Internal leaks from heat exchangers and water jackets are other potential sources.

Remember This...

When free water is present in oil, it poses a serious threat to the equipment. Water is a very poor lubricant and promotes rust and corrosion to the components. Dissolved water in an oil promotes oil oxidation and reduces the load handling ability of the oil. Water contamination can also cause the oil’s additive package to precipitate. Water in any form causes accelerated wear, increased friction, and high operating temperatures. If left unchecked, water can lead to premature component failure.

About TestOil

TestOil is a full service oil testing laboratory owned by Insight Services. Since 1988 the laboratory has been providing fast and reliable oil analysis results across all industries throughout the Americas.

The firm's comprehensive range of oil analysis services assists reliability engineers with condition monitoring and identification of machine wear.

TestOil employs a sophisticated diagnostic technology that assists their Machine Condition Analysts in making equipment and lubrication condition assessments.

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