FLUID LIFE
EQUIPMENT RELIABILITY SERVICES

RELIABILITY SERVICES

THE IMPACT OF WATER CONTAMINATION ON LUBRUCANTS

THE EFFECTS, TESTS, RECOMMENDED ACTIONS AND BEST PRACTICES FOR MINIMIZING CONTAMINATION

WATER CONTAMINATION

Water can be present in lubricants as free, dissolved or emulsified water. Because of the different chemical properties, oil and water do not mix, but separate in two distinct layers. As water has a higher density than oil, free water accumulates at the bottom of the lube system. However, depending on the composition of the base stock and the type of additives, different lubricants can hold very different amounts of water in dissolved phase (note that temperature and pressure also have effects on how much water a fluid can hold).

Beyond the saturation level of the lubricant, water is present as either free water or emulsion. Emulsion is the state where water is sheared and suspended in the oil as tiny droplets by agitation. The presence of emulsifying additive in the oil can also lead to emulsion formation.

Sources of Water Contamination

- Water or moisture ingress through breather, filter, seal or cover into the system
- Leak from cooling systems like heat exchangers, coolers
- Condensation in reservoirs or lube systems
- Equipment washdown
- Water entry during sampling, oil change or top-up (e.g. poor methods, handling practices)

OIL AND WATER DON'T MIX. FREE WATER WILL ACCUMULATE AT THE BOTTOM OF YOUR LUBE SYSTEM.

EFFECTS OF WATER CONTAMINATION

The presence of water in lubricants can have detrimental effects on system components. For example, it is shown in the studies conducted by the Timken Company that water contamination has significant effect on bearing fatigue life.[1]

The following are some of the common effects:

- **Rust and Corrosion** – when metals are exposed to water and oxygen for prolonged period of time, metal oxides are formed. The metal oxides can flake off from the metal surface and contribute to abrasive wear in the system.
- **Vaporous Cavitation** – the vapor bubbles (or cavities) are formed when the pressure of a system (e.g. suction or inlet pressure) is less than the vapor pressure of water. When these bubbles travel to the high pressure zones of the system (e.g. the load zone of a journal bearing), they quickly implode and condense back to the liquid phase. The collapse of the vapor bubbles can generate great force and cause surface fatigue and erosion at the point of collapse.
- **Hydrogen Embrittlement** – water serves as the source of hydrogen during the process of hydrogen embrittlement, in which hydrogen is introduced and diffuses through a metal, causing the metal surface damage. The absorbed hydrogen causes high pressure build-up within metals leading to blistering and cracking.
- **Reduced Lubricating Characteristics** – oil viscosity increases as pressure increases. This property is important for components like rolling element bearings operating under high load conditions (elasto-hydrodynamic lubrication, EHD). In such high pressure regimes, the viscosity of lubricant rises significantly and generates an oil film, which separates the contact surfaces. Water, however, does not increase in viscosity as pressure increases; it will increase contact between metal surfaces and cause fatigue wear.
- **Hydrolysis** – water causes degradation of oil and its additives through hydrolysis, a chemical process in which a molecule of water is added to a substance. For example, ester-based lubricants can be attacked by water and turns into acids and alcohols. This process can be further accelerated by the presence of heat, acid or metal particles.

[1] R.E. Cantley. “The effect of Water in Lubricating Oil on Bearing Fatigue Life.” ASLE Transactions, Vol. 20, 3, 244-248.

EFFECTS OF WATER CONTAMINATION CON'T

- **Diminishing the Effectiveness of Protective Additives** – water can promote oxidation in the presence of heat, oxygen and metal and lead to the formation of oxidants and free radical compounds. These reactive compounds are then neutralized by the oxidation inhibitors in the oil. Therefore, the presence of water contamination in the fluid can quickly deplete the levels of oxidation inhibitors. Because of its polar nature, water can also attach to the hydrophilic metal surfaces or displace the polar additives at the metal surfaces.
- **Foaming in Oil** – water contamination is one of the causes of foaming and air entrainment that can lead to problems like oxidation, reduced lubricating properties and cavitation described above.

MEASURING WATER CONTENT IN LUBRICANTS

There are several methods to determine water content in fluids. Some of the techniques that are commonly performed are described below:

- **Crackle Test** – this visual test serves as a quick screening tool for detecting the presence of water contamination (emulsified and free water) in fluids (~250 to >1000 ppm). A drop of oil is placed in the center of a hotplate (temperature set above the boiling point of water) and any moisture present in the oil is reflected in the number of bubbles observed as the water vaporizes. This is a quick and qualitative reference for determining emulsified and free water.
- **FTIR** – FTIR (Fourier Transform Infrared) is another method for screening water contamination in fluids. A used oil sample is compared to a new oil (reference). Infrared radiation is passed through an used oil sample and gets absorbed or transmitted at specific wavelengths based on the types of molecules (especially the chemical functional groups) present in the oil. Because of the spectral features exhibiting among different molecules, the resulting infrared spectrum can be used to identify the presence of common contaminants found in the oil (water, soot, glycol, fuels, oxidation, nitration, sulfation, etc.). By comparing the spectra between the used and reference oil samples, the instrument reports the net difference in the chemical composition. If water is present, a broad peak will appear around 3300 cm^{-1} region. However, this method can only detect water concentrations above 1,000 pm (0.1 %).
- **Karl Fischer Titration** – Karl Fischer (KF) is a quantitative test to detect fluids with water contamination. Unlike crackle or FTIR, KF titration test allows detection of all three states of water (dissolved, emulsified and free water). Two types of KF titrators, volumetric and coulometric titrators, are commonly used in the laboratories. While both methods measure the water concentration based on the consumption of iodine, the coulometric method generates the titrant electrochemically in situ and offers a much lower detection limit as low as 1 ppm.
- **Online Sensors** – the principle of this method is to measure the change of dielectric constant (K) of fluids. Because water has a much greater K than that of hydrocarbon based fluids, the small quantities of water will lead to a measurable change of K value. These devices can monitor the water content below the saturation point and allow corrective action to be taken prior to the formation of emulsified or free water.

CONTROL OF WATER SOURCES

Use of Lubricant Products Formulated With Protective Additives

Different additives are added to the base oil during the formulation process and are specifically designed to provide metal surface protection, lubricant protection or lubricant performance enhancement. Only the additives that are used to minimize the detrimental effects of water contamination are described below

- **Oxidation Inhibitors** – these are used to prevent the formation of oxidative products like varnish, sludge and acids by quenching the reactive oxidative species such as free radicals or hydroperoxides.
- **Rust and Corrosion Inhibitors** – These are used to protect the metal surfaces from water and acidic contaminants. The polar nature of these additives allows the formation of a protective film on metal to prevent attack by oxygen, water and/or acids.
- **Demulsifiers** – these are surface-active agents (surfactants) that release moisture from the lubricant. They prevent the formation of a stable oil-water mixture (emulsion) and promote oil-water separation.

Use of Desiccant Breathers

One of the primary ingression points in which water can enter a system is through the air. The simple solution to avoid this problem is the use of desiccant breathers, which are specifically designed to attach to equipment (e.g. oil reservoir, oil drum) and to protect the fluids from not only moisture but also particle contamination.

When the contaminated air gets through the breathers, the solid particles are first removed by the particulate phase of the breather, which are generally made of synthetic fiber; the moisture in the air is then absorbed by a hygroscopic agent (a bed of silica gel); and the filtered air is further passed through an additional filter to ensure the air is clean before entering the oil tank or reservoir. In addition, most of these breathers have a water-reactive reagent, which changes color as the silica gel adsorbs moisture and to indicate when the breather needs to be replaced. These devices may also be equipped with an activated carbon pad to absorb oil vapors exhaled from the oil tank and protect the devices from oil mist contamination.

CONTROL OF WATER SOURCES CON'T

Desiccant Breathers - Considerations & Recommendations

The following are some of the considerations and recommendations for desiccant breather selection

- Breathers are available in one of two major types.
  - Particulate filter only (minimum standard is 3mm absolute)
  - Particulate filter plus moisture trap (i.e desiccant breather)
- Desiccant shall be selected based on the environment in which the equipment operates (i.e. indoor vs outdoor). Different products are designed to perform in extreme environments (e.g. high humidity/dust, high vibration, limited space).
- The air volume exchange for the equipment should be taken into consideration to ensure the volumetric flow rate is within the breather capacity. It must be sized to match or exceed the amount of air exchanged (the required cubic feet per minute) for each application.
- Desiccant breathers are suggested for the following equipment:
  - Stationary and mobile hydraulic systems
  - Gearbox drive systems
  - CompressorsStorage tanks
  - Circulating oil systems
  - All dispensing systems (e.g. barrel pumps)
- Breathers should be inspected as part of the standard routine inspection task.
- All plant equipment should be periodically reviewed to determine if existing breathers are adequate or need to be upgraded.

PROPER STORAGE AND HANDLING OF LUBRICANTS

As mentioned above, all storage tanks (including dispensing systems) should be protected with a minimum 3mm (micron) desiccant breather. Water contamination can be further minimized by implementing the following practices:

- Lubrication storage buildings and areas shall be located when possible away from areas where high water contamination sources are present.
- Water may be drawn into the oil containers in response to temperature fluctuations.
  - Lube rooms shall be properly heated and ventilated to maintain a storage temperature between 10 to 30 degrees
  - All opened drums and pails must be stored indoors at all times.
  - All new or unopened oil drums shall be stored indoors if and wherever possible.
  - All bulk storage tanks shall be sampled quarterly to confirm oil quality.
- All oil storage and dispensing containers are kept tightly closed or sealed from the atmosphere when not in use.

Use of Oil Analysis

Depending on the criticality of an application, the water content in a system should be determined periodically or tracked in real-time. By monitoring the water content in fluids using some of the common methods described above, corrective actions can be taken early to eliminate the contamination path and prevent premature equipment failures when the water content is above the alarming limits.

Routine Inspection and Other Preventive Measures

- Inspect breathers, joints and seals as part of the preventive maintenance service, and perform repair or replacement as necessary.
- Repair leaks from cooling systems like heat exchangers and coolers as soon as practical. It will likely cost more down the road by deferring the repair.
- As free water accumulates at the bottom of the lube systems, periodically drain water from low points.
- Minimize water ingress through shafts, fill ports, breathers, seals, etc. when performing equipment washdown.
- Water can be introduced during sampling, oil change or top-up. Ensure proper sampling and oil handling techniques are employed.
- Use lubricants containing demulsifiers to shed water (e.g. turbine, hydraulic)

REMOVAL OF WATER

There are several methods to efficiently remove water from the lube systems. Some of the techniques that are discussed below:

- **Gravity Separation** – water generally has higher density (or specific gravity) than most of the lubricants. Free water settles at the bottom of the reservoir and can be easily removed by regular draining. The effectiveness of oil and water separation can be improved by larger reservoir size (allows sufficient resident time to promote separation) and higher fluid temperature. Note that some fluids (e.g. some phosphate esters) have higher specific gravities than water; water contaminant will float on top and won't be removed by this method.
- **Centrifugal Separation** – similar to the gravity separation, the centrifugal method is also based on the different specific gravities of fluids. The fluid separation however is significantly magnified by the centrifugal force; free water and some emulsified water (depending on the relative stability of the emulsion) can be efficiently removed from the oils.
- **Coalescing Separation** – this type of separator traps the small water droplets on or near the surface of a filter or screen and allows the formation of larger droplets, which is favorable due to the lower interfacial tension (larger water droplets have less surface contact with the fluid). However, this method cannot remove dissolved water from oil.
- **Absorbent Separation** – this method requires the use of absorbent polymers impregnated in the filter media. Upon absorbing emulsified or free water in fluids, these polymers swell and get trapped in the filter media. However, these types of separators can only be used in applications with limited exposure to wet environment as large amounts of water will lead to clogging the filter and causing the filter to go on bypass.
- **Vacuum Dehydration** – this separation method can be used to effectively remove all phases of water. As the boiling point of water drops under reduced pressure, the exposure of fluids to a vacuum system allows water to be distilled/ removed from fluid at a lower temperature and minimize degradation of the base oil or additives.

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