Preventing Water Contamination Problems

By Dave Webb and Bill Needelman

Although necessary for life, water is a problem for most machines. Problems include corrosion, loss of lubricity, accelerated fatigue cracking, microbial growth, gels, oil oxidation, and acidity. Water creates special trouble in transformers - loss of dielectric strength and deterioration of winding insulation.

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Summary

For minimum protection we recommend keeping water below the saturation level, generally 200-500 ppm for many oils and 10 ppm for transformer oils. For optimum protection we recommend maintaining water levels at or below 30% saturation, generally 75-150 ppm for most machines and 3 ppm for transformers. Maintaining water levels at or below 30% saturation alleviates the problems related to water as well as provides a safety margin against accidental spikes of contamination.

The best cure is prevention. Whenever possible *keep the water out* of the system. This includes good design (such as splash guards), good maintenance (including avoiding water leaks), and good contamination control. Preventing water contamination will preserve the fluid, which reduces costs and insures the integrity of the machinery.

Introduction

We live on a watery planet. Water covers 70% of the Earth's surface: largely in oceans, lakes, and rivers. Water is necessary for life. Before the Industrial Revolution water kept the prime movers going in manufacturing, transportation, and agriculture, from water wheels to beasts of burden. Things have changed. We now rely on high performance machinery. Most of these machines rely on oil for lubrication, heat removal, and power transmission. Modern essential oil-wetted systems include: hydraulics, steam and gas turbines, engines, motors, gearboxes, and electrical transformers.

Paradoxically, as essential as water is for biological life, it is bad for machine life. Along with particles from dirt and wear, water is one of the two most harmful contaminants. Water problems range from corrosion to oil degradation and from plugging gels to the flourishing of microbial colonies. Minimizing water contamination maximizes the performance, fuel efficiency, productivity, and machine life.

Water Problems

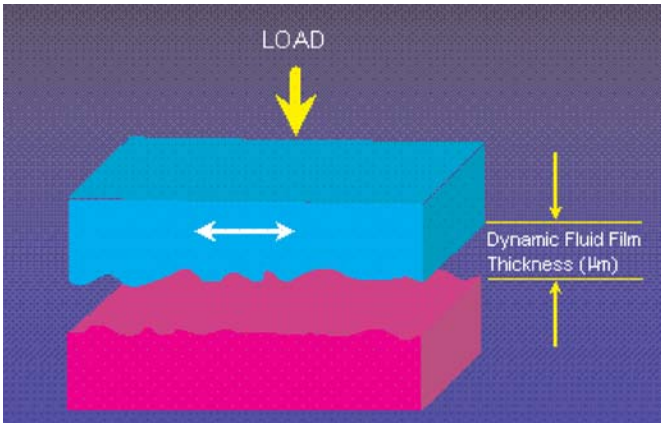
Below is a description of problems caused and/or aggravated by water.

Corrosion: Corrosion is the most obvious problem with free water in oil. It starts with an electromechanical action: pits are formed by the removal of surface metal, resulting in rough surfaces being produced by weaker material and friction. Corrosion also produces abrasive oxides, such as iron rust, that abrade surfaces, occlude clearances, and break off to damage moving parts.

Loss of Lubricity*:* Films of oil separate moving surfaces and when water contaminates these films it displaces the oil. Water cannot keep the surfaces apart, resulting in high friction, adhesive wear, and even seizure.

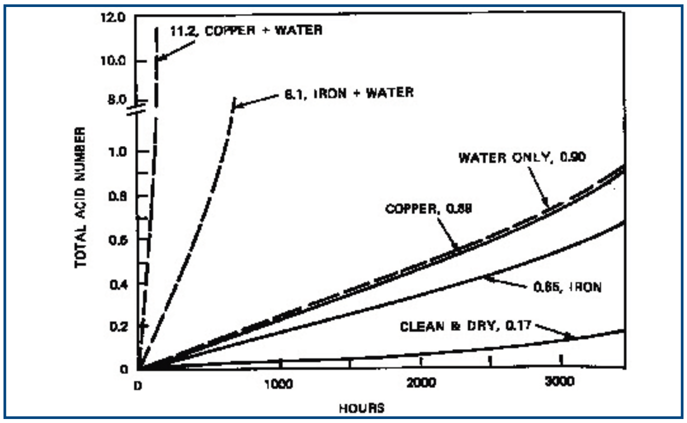
Figure 1: Lubricant Film Supports The Load & Separates Opposing Surfaces

Fluid Film Lubrication



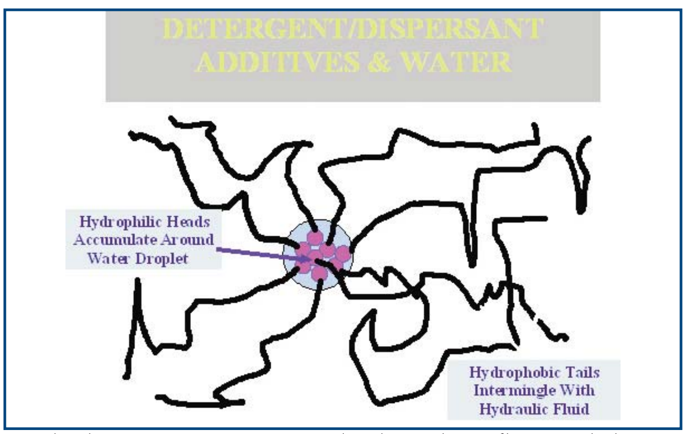
Oil Oxidation: This phenomena produces long-chain polymers that form when oil and water combine. These polymers act as thickeners, increasing oil viscosity. Water accelerates this primary path for oil breakdown. Negative consequences include excessive viscosity, acidity, and insoluble resins.

Figure 2: Water Accelerates Lubricant Oxidation As Measured By TAN



Additive Depletion: Most commercial oil-based fluids contain additives. Water ingression will negatively impact these additives. When additives migrate into free water, the oil concentration of some additives falls below effective levels.

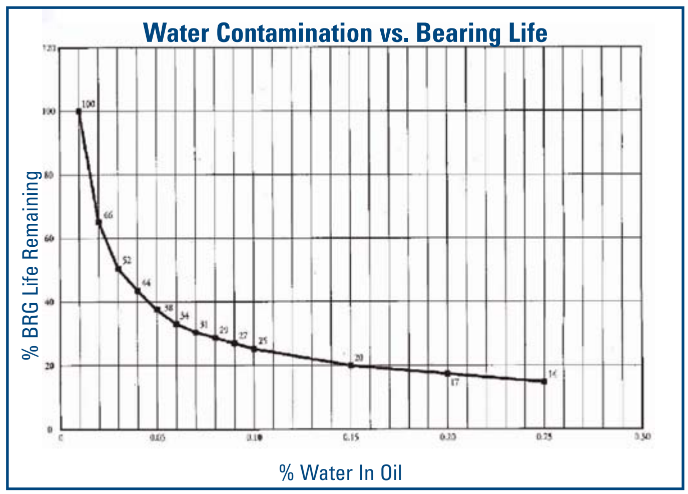
Figure 3



Hydrolysis: Esters are used where low flammability and/or high temperature resistance is important. But the problem is that ester linkage is hydrophilic, or "water-loving." Unfortunately, that feeling is not reciprocated: water reacts with the very same ester linkage and breaks it apart in a process called *hydrolysis*. In the presence of water, ester-based additives and synthetic fluids (such as phosphate esters and polyol esters) decompose into alcohols and acids. Additives are lost and, for ester-based synthetics, oils become acidic. In some cases the acids combine with metals, forming tenacious plugging gels.

Reduced Fatigue Life: Rolling bearings and many types of gears are rated by their contact fatigue life. Contact fatigue life depends on such parameters as bearing steel, load, temperature, and oil viscosity. Contact fatigue life also depends on contamination. As shown in Figure 4, increasing the concentration of water in oil significantly diminishes fatigue life. Dissolved water enters microcracks in rolling contacts, dissociates into hydrogen gas, and weakens steel by hydrogen embrittlement. This process can cut rolling contact fatigue life by seven.

Figure 4: Reduced Rolling Contact Fatigue With Increasing Water Concentration



Microbe Colonies: Some microbes consider oil to be highly nutritious food. But they also need free water to grow and multiply. Negative consequences of microbial growth include rancid foul odors, human health problems, biomass slimes, foaming, and acidic oil. Preventing the water ingression is a far easier way of treating this problem than treating the symptoms.

Gels: Some additives interact with water to form gels.

These gels foul flow passages, reduce heat rejection, and plug filters. An example is paper machine oils (PMO). Although PMO are now formulated to be more filterable in the presence of water, high water contamination leads to more gel formation, increasing the likelihood of fouling and short filter life. Some oil additives combine with water to form gels that foul oil passageways, flow meters, and filters.

Transformers: Most conductor windings are insulated by cellulose, which deteriorates in the presence of water. Water also diminishes the dielectric strength of transformer oils. Even minute amounts of water contamination will reduce the life and efficiency of the transformer.

Water-in-oil Concentrations

As an experiment, start with completely dry oil and slowly add water. At first, all the water is dissolved and/or solubilized in the oil. As long as the concentration of water remains below saturation, no free water forms. Keep adding water until the saturation level is reached. At that point any additional water added forms free water. Since many water-associated problems start with free water, saturation is of an essential value. However, different oils hold widely differing amounts of water before reaching saturation.

Contamination Control

Unfortunately many contamination control methods assume water has already entered the system and has to be removed after the fact.

Adsorbents: One approach uses filters containing water adsorbing materials. This approach is helpful when controlling relatively small amounts of free water (up to 100 ppm above saturation). It doesn't dry the oil below the saturation level and therefore doesn't alleviate dissolved water problems. In addition, if the oil dries slightly, the adsorbent material releases water back into the oil!

Table B: Keeping Water Out
Oil Fill Caps With Seals
Check for Heat Exchanger & Hose Leaks
Splash Guards
Store Fluid in Dry Areas Sheltered From Rain
Avoid Inlets When Hosing
Check New Oil for High Water Levels (>Saturation)

Vacuum Dehydration: Another method for taking water out of oil is vacuum dehydration. A vacuum reduces the water vapor pressure (the number of water molecules) in the air contacting the oil, so more water molecules hop out of the oil than enter into the oil from the gas phase. The net effect is reduced concentration of water in the oil. This process takes time as water has to first migrate to the surface and then escape. The process is typically accelerated by increasing the *air:oil* surface area and by heating the oil. Unfortunately vacuum dehydration has limitations. The process consumes high amounts of energy, which is costly due to capital equipment and labor. Some tightly bound water is not removed and lighter fractions of the base oil along with volatile additives evaporate with the majority of water. This leads to hydrocarbon emissions and may adversely change the composition of the oil. Basically, vacuum dehydration attempts to fix the water contamination problem after the fact.

Desiccant Breathers: One method that attempts to prevent humid air from entering fluid systems is the desiccant breather. Cartridges are mounted at the breather cap so that ingressing air passes through a bed of desiccant granule (typically silica gel or activated alumina) that removes water vapor from the incoming air stream. This reduces the number of water molecules in the air. Dry air – typically less than 30% RH - continuously contacts the oil surface and over time the water concentration in the oil reaches a similar low level. Since the overall air pressure is not reduced (only the water vapor pressure is reduced) volatile fractions of oil are not lost, as may happen during vacuum de-hydration. Although useful, desiccant breathers have serious drawbacks. Tightly packed granules restrict air flow which can impede fluid movement in and out of the reservoir.

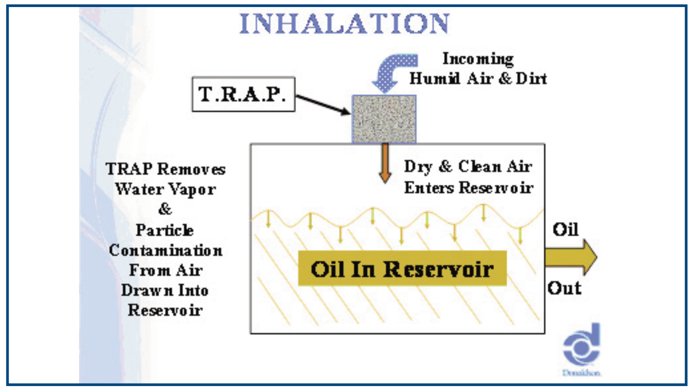
Although effective when new, as desiccant breathers collect water their ability to remove additional water diminishes. They also have limited water holding capacity. When the granules become saturated with water, about 30% by weight, the desiccant is spent and the unit must be replaced (often indicated by a colored dye). Silica gel and alumina cannot be regenerated unless exposed to temperatures in excess of 360°F. Since they are impractical to regenerate, desiccant breathers have restricted service life.

Deliquescent Breathers: Donaldson has developed a new and superior method for preventing the ingression of humid air. It is based on thin film technology and the fact that air leaving a reservoir (exhalation) has lower relative humidity than air entering a reservoir (inhalation).
The T.R.A.P. ™ *(Thermally Reactive Advanced Protection)* is manufactured by uniformly coating the walls of a porous network with a thin film of water-absorbing chemicals. The resulting high surface area of absorbent provides rapid removal of water vapor from air while keeping down size and weight. Unlike desiccant breathers the open porous structure presents minimal air flow restriction, so fluid flow into and out of the reservoir is not impeded. In addition, the proprietary absorbents are not sensitive to oil mists entrained in the air leaving the reservoir.

As a bonus, the T.R.A.P. ™ unit includes a pleated 3 mm filter to protect against ingression of hard abrasive contaminant particles that contribute to the wear of mechanical components. T.R.A.P. ™ is manufactured from materials that can be safely disposed or recycled.

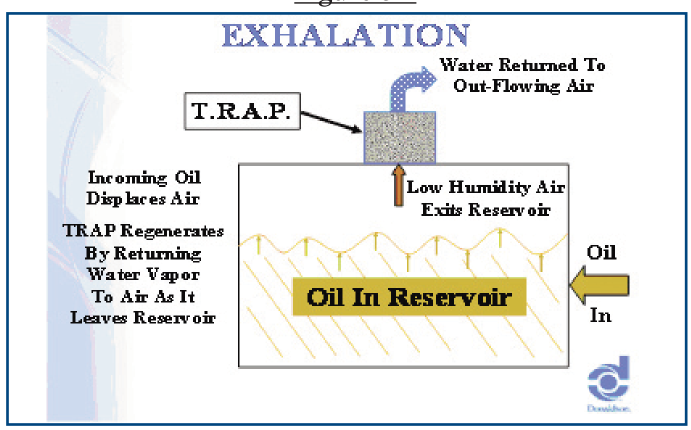
As illustrated in Figure 5A, during "inhalation" humid outside air attempting to enter the system is drawn over a large absorbent surface area inside T.R.A.P. ™. High humidity drives water into the absorbent and most of the water vapor is removed. This dry air maintains the water concentration below 30% saturation. Once inside the system the air contacts warm fluid and metal surfaces, which increases air temperature and further reduces relative humidity.

Figure 5A



During exhalation, Figure 5B, this very low humidity air passes over the same T.R.A.P. ™ absorbent. Low humidity air pulls water out of the thin films of absorbent. The rehumidified air exits the unit and is exhausted into the surroundings.

Figure 5B



It is the difference in relative humidity - high during inhalation and low during exhalation - that drives the T.R.A.P. ™ process. The result is dry oil and regeneration of the T.R.A.P. ™ absorbent during each cycle.

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Figure 6

Conclusion

Water contamination causes major problems in oil-wetted machinery. Water can invade a system in many different ways and it may be present without our knowledge. **Prevention** of water ingression to an oil reservoir **is the best cure.** Conventional water control methods have serious limitations. Absorbent filters may help with free water in small systems, but have low capacity, cannot control dissolved water, and may even re-entrain previously captured water. Vacuum dehydrators are expensive and may adversely change the oil. Desiccant breathers are limited by low water holding capacity and need frequent replacement. An innovative, self-regenerating breather, the T.R.A.P. ™, effectively maintains water in oil well below saturation levels. It is small, lightweight, doesn't harm the oil, and possesses unlimited water removing capacity.

INFORMATION

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