WHITE PAPER

Effectively Eliminating Water Contamination from Hydraulic and Lubricating Fluids

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Effectively Eliminating Water Contamination from Hydraulic and Lubricating Fluids

Water is the most common and damaging contaminant found in hydraulic and lubricating systems. All mechanical systems have a certain tolerance for contamination, but in many cases these tolerances are lost due to ineffective maintenance. Therefore, eliminating this failure pathway by adding an effective water removal program to your lubricant maintenance, is an essential step in achieving reliability targets.

From an equipment perspective, you can easily double the life of your mechanical systems by reducing water levels (Table 1). Doubling equipment life also increases the "trouble-free" operating window and reliability of equipment, and significantly decreases the risk of production losses.

"Water is the most common and damaging contaminant found in hydraulic and lubricating systems."

Table 1—Equipment life extension of a rolling element bearing from reduced water.

	NEW MOISTURE LEVEL				
Moisture	**1000 (0.1%)**	**500 (0.05%)**	**250 (0.025%)**	**100 (0.01%)**	**50 (0.005%)**
5000	2.3x	3.3x	4.8x	7.8x	11.2x
2500	1.6x	2.3x	3.3x	5.4x	7.8x
1000		1.4x	2.0x	3.3x	4.8x
500			1.4x	2.3x	3.3x
250				1.5x	2.3x
100					1.4x

Source: SKF and Oklahoma State University

WATER IS A PRIMARY CAUSE OF LUBRICANT FAILURE

Lubricant breakdown is caused by oxidation and hydrolysis. Any ester-based lubricant is sensitive to hydrolysis, which is the breakdown of the original base stock through reaction with water. Water reverses the chemical process originally used to manufacture the ester, so managing water levels is a key component to the effective maintenance of these lubricants.

While mineral oils are not sensitive to hydrolysis in the same way as ester-based lubricants, water shortens lubricant life by promoting oxidation, acid formation, and may also remove additives. Aside from temperature, the rate of oxidation is based on the amount of water, oxygen, and metal catalysts that are present.

THE BASIS FOR EFFECTIVE WATER REMOVAL

For proactive hydraulic and lubricating fluid maintenance, the program needs to move beyond reactionary measures and actually manage the drivers of oxidation where possible. In doing so, you can significantly reduce the amount of maintenance required and extend lubricant life.

Water can exist in 3 forms: free, dissolved and emulsified. Free water is the excess water above the fluid's saturation point and is visible as a separate layer (Fig. 1). Dissolved water is below the fluid's saturation point and is not visible. Emulsified water is the point in between free and dissolved where water first becomes visible as a "haze" (Fig. 2). The key point is that just because you cannot see water, does not mean it is not there.

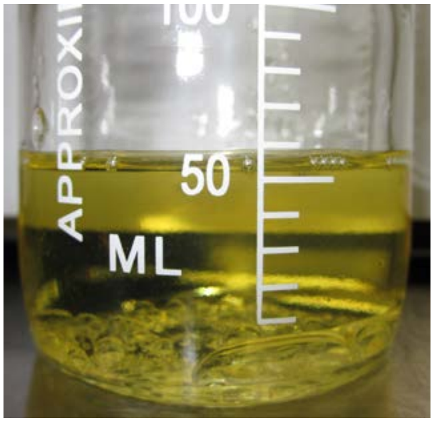

Fig. 1—Free water can be seen forming in the bottom of the beaker as the dissolved water comes out of solution.

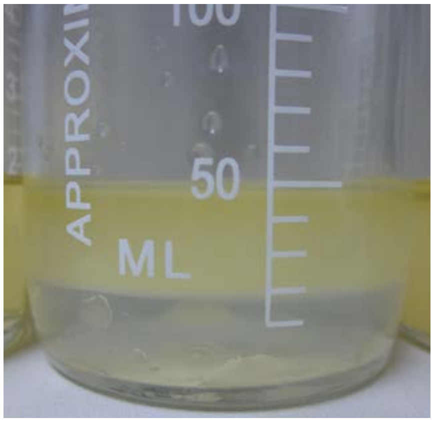

Fig. 2—Emulsified water can be seen throughout the sample with a small amount of free water observed in the bottom of the beaker.

> "Water can exist in 3 forms: free, dissolved and emulsified…just because you cannot see water, does not mean it is not there."

The first water in lubricating fluid will always be in the dissolved form. The amount of water the fluid can hold in the dissolved form is a function of the type and temperature of the lubricant. As temperature increases, more water can be held in the dissolved form as the saturation point increases. The movement of water from one form to another is a physical change.

Understanding which form the water is in is critical when selecting which water removal system to use. Some water removal technologies only remove free water, so using these tools on systems with only dissolved water would be ineffective (Table 2).

Table 2—Water removal system versus type of water removed.

System Type	Dissolved	Emulsified	Free
Centrifuge	Not Removed	Some	Removed
Water Adsorbing Filter	Not Removed	Some	Removed
Coalescing Filter	Not Removed	Some	Removed
Vacuum Dehydration	Removed	Removed	Removed
Air Stripping Technology	Removed	Removed	Removed
Free Flowing N_2 Blanket	Removed	Removed	Removed

Source: Machinery Lubrication

Another important consideration when selecting a water removal system is the water ingression rate and frequency. While these exact numbers may be difficult to pinpoint, what needs to be understood is whether there is a large water ingression problem or a small one, and whether it is happening frequently or infrequently. A large water ingression issue that is happening frequently may require a more robust solution versus what may be required for small, infrequent ingression (Table 3).

Table 3—Water removal system effectiveness.

System Type	>10,000 ppm	>1,000 ppm	>500 ppm
Centrifuge	Yes*	Yes*	Yes*
Water Adsorbing Filter			Yes*
Coalescing Filter	Yes*	Yes*	
Vacuum Dehydration		Yes	Yes
Air Stripping Technology			Yes
Free Flowing N_2 Blanket		Yes**	Yes

*Assuming free water is present and lubricant demulsibility is good

**Rates per day 150-250 ppm

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SOURCES OF WATER CONTAMINATION

Understanding the source of water contamination is equally important to understanding water ingression rates. Water is generally added to hydraulic and lubricating fluids from either a mechanical process or from the atmosphere. While it is desirable to fix all mechanical ingression points, atmospheric contamination is the most common water ingression pathway, but is often overlooked and treated as a fixed constraint that cannot be addressed.

While the use of desiccant breather elements to restrict moisture ingression is common, their usage only reduces relative humidity (RH%); it does not completely dry the air and is insufficient to mitigate atmospheric water ingression. In high humidity environments, desiccant breather elements can be changed weekly and still not isolate the impact of atmospheric water ingression.

All lubricants will move towards equilibrium with the atmosphere contacting them. In most cases, where the moisture content of the atmosphere contacting the lubricant is higher than the moisture content of the lubricant, water will be transferred from the atmosphere into the lubricant. In this situation, the transfer of water from atmosphere to the lubricant occurs via mass transfer.

> "...atmospheric contamination is the most common water ingression pathway, but is often overlooked and treated as a fixed constraint that cannot be addressed."

Atmospheric Breathing Lubricant Reservoirs

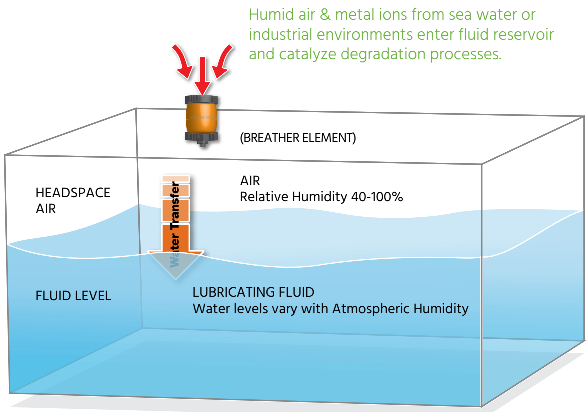

Fig. 3—In atmospheric breathing hydraulic and lubricating fluid reservoirs, the humid air above the lubricant will transfer water into the lubricant via condensation/mass transfer. Although breather elements offer some mitigation, they cannot prevent atmospheric water ingression.

A Cautionary Note Regarding Extraction Fans

In some lubricant reservoir designs, extraction fans are used to prevent condensation; however, in humid environments they have the opposite effect as the increased contact between the moist air and the surface of the lubricant contributes water. While extraction fans are common in gas turbines to promote oil return to the reservoir, their usage in hydraulic systems is not recommended as bearing cooling is irrelevant and the approach disregards the deleterious effect of atmospheric water ingression.

WATER REMOVAL SYSTEM SELECTION

Removing water introduced from mechanical processes can be accomplished with a variety of water removal tools that are appropriate for the type and amount of water present. In these situations, high capacity water removal systems may be required.

Atmospheric contamination, on the other hand, presents a fundamental challenge when selecting an appropriate water removal system, as most options only remove water from the lubricant without addressing the source. While most water removal systems appropriate for the type and amount of water present would work, they simply dehydrate the hydraulic or lubricating fluid such that it can accept more water from atmosphere. This creates a counter-productive, energy-intensive cycle that contributes to higher rates of breakdown and results in ineffective and expensive water removal.

Carefully matching the water removal system's capabilities with your application is critical. The water removal system must be able to remove the form of water present in your application and remove it according to the amount of water ingression. Additional considerations include initial cost, consumable cost and energy cost. A brief review of the major types of water removal systems are listed below, followed by a summary in Table 4.

Water Absorbing Filters

Absorbent filters can be used to remove a small amount of free water from lubricants. These filters are normally effective for very small lubricant reservoirs with non-atmospheric water ingression. They have a limited capacity and would be expensive to use in large reservoirs or in cases with ongoing water problems.

Water absorbent filters.

Coalescing Systems

These systems are used to remove large amounts of free water from lubricants in a short period. These units are expensive and ideally suited for extremely high water ingression rates, i.e. >1% water ingress per day. While this water removal technology is essential in situations with high water ingression rates, they cannot remove dissolved water. This can be a problem in cases where the desired water limit is significantly below the saturation point, or with oils that hold high levels of dissolved or emulsified water. Coalescing also requires that lubricants have good water separation (demulsibility).

Coalescing System. Courtesy of Hy-Pro Filtration

Vacuum Dehydrator

These mechanical systems are ideal for removing large amounts of water in a short period of time. These systems remove all forms of water, so they are versatile. The units are expensive and mechanically intensive. When purchasing, make sure the vacuum pump is very high quality and low maintenance as this is the heart of the vacuum dehydrator. Spend the extra money on systems with high-efficiency, maintenance-free designs. If dissolved gas removal is desired, only high-efficiency designs will work.

Using vacuum dehydration equipment continuously on atmospheric breathing lubricant reservoirs with low rates of water ingression is not ideal. While the vacuum dehydrator will maintain the oil significantly below the saturation point for water, the lubricant will start to pull additional water from atmosphere. This counter-productive situation is expensive and can contribute to further breakdown of the lubricant. If you are using these systems in this situation, cycle their usage so they are only operating when needed to reduce energy consumption and decrease fluid stress.

Vacuum Dehydrator. Courtesy of Hy-Pro Filtration

Air Stripping Technology

Air stripping technology injects dry air and heat into a fluid. Moisture is transferred into the air which is then removed under vacuum. These systems are expensive and mechanically intensive and only suitable when water ingression rates are low. The physical introduction of heat and air into the lubricating fluid is also a questionable practice as heat and oxygen are key contributors to oxidation breakdown of the lubricant.

Free Flowing Dry Gas Blankets

Dry gas blankets inject dry air into the headspace above the lubricant level, which is then exhausted out the breather element. This technique is simply a reversal of atmospheric water contamination. While effective at reducing water, the quality, volume and cost of the air used are frequent issues. For this reason, engineered systems are recommended (e.g. TMR™ Air System) that produce a precise amount of clean, and very dry air (-40°C dew point) at the reservoir from a normal compressed air source. For specialized applications including transformers and electro-hydraulic control (EHC) systems, free flowing nitrogen blankets are recommended.

TMR™ Air System

Free Flowing Nitrogen Blankets

Free flowing dry nitrogen blankets (e.g. TMR™ N_2 System) generate and inject a small amount of high purity nitrogen into the headspace above the lubricant level, which is then exhausted out the breather element. Free flowing nitrogen blankets exploit the natural principle of equilibrium by keeping the atmosphere on top of the lubricant <0.01% RH, which will always be much drier than the lubricant. The free flowing dry nitrogen on top of the lubricant has an extremely high capacity to remove water and dissolved oxygen (Fig. 4).

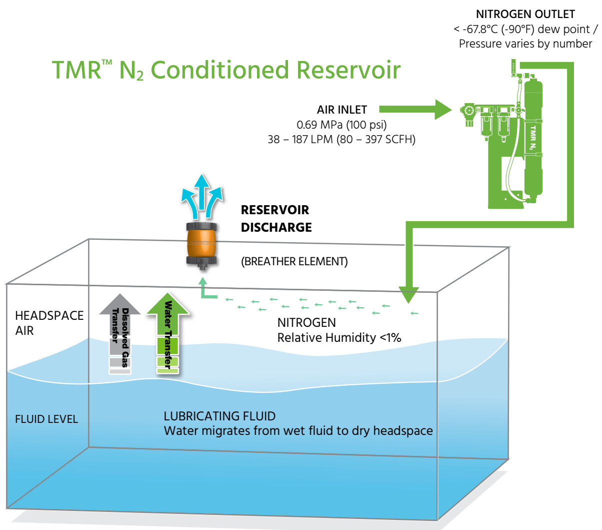

Fig. 4—With free flowing N_2 blankets, the lubricating or hydraulic fluid is always protected with high purity N_2 at <0.01% RH. Water in the fluid will convert into water vapor and be vented out the breather element.

TMR™ N_2 System

This highly effective technique reverses atmospheric water ingression. Free flowing nitrogen blankets also offer the important benefit of eliminating fluid contact with oxygen, which reduces oxidation breakdown. Over time, harmful breakdown gases including hydrogen and carbon monoxide are also removed.

Free flowing nitrogen blankets like the TMR™ N_2 system, produce a precise amount of extremely high quality nitrogen (99%) directly at the reservoir from a normal compressed air source. With a typical life of 10 years, no moving parts or electrical requirements, TMR™ N_2 systems are extremely cost effective (Table 4), and ideally suited to atmospheric breathing reservoirs or systems with low to moderate water ingression rates.

Table 4—Water removal system versus capital cost and cost of consumables.

System Type	Capital Cost	Consumable Cost	Energy Cost
Centrifuge	High	Low	Moderate
Water Removal Filter	Low	Highest	Low
Coalescing Filter	High	Moderate	Moderate
Vacuum Dehydration	High	Low	High
Air Stripping Technology	High	Low	Highest
Free Flowing N_2 Blanket	Low	Lowest	Low

SUMMARY

Reducing water levels has been proven to extend equipment life and trouble-free operating windows by a minimum of 1.4x to as high as 11x. Carefully selecting water removal equipment so that it is matched to your application requirements can avoid costly mistakes and the need to repurchase the correct water removal system. In applications where the primary ingression pathway is mechanical in nature and cannot be eliminated, selecting the correct water removal system is essential for cost effective operation. When the primary ingression pathway is atmosphere, choosing a water removal system that eliminates the underlying source will not only reduce maintenance requirements, but also reduce rates of breakdown extending fluid life.

ADDITIONAL RESOURCES

1. TMR™ Air System Product Information
2. TMR™ N_2 System Product Information
3. Turbine Oil Coalescing Skids, www.hyprofiltration.com
4. Vacuum Dehydration Systems, www.hyprofiltration.com

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