Winning the War on Water Contamination

7 Solutions

for Removing Moisture From Oil

By Justin Stover

Executive Summary

Ugly. Torturous. Scourge. Devastating. Catastrophic. Insidious. These are just a few of the words used in papers and presentations to describe the effects of water in oil. You get the picture. For good reason, water has been called the second most destructive contaminant next to hard particles. OEM's and end users are seeking solutions to battle water and looking for suggestions on how it can be controlled. Winning the war on water contamination starts with recognizing it for the threat it is and taking steps to remove it – quickly! This paper outlines methods for water removal. Winning this war will dramatically extend component and lubricant life.

CJC

Clean Oil – Bright Ideas

Introduction

"The presence of water in lubricating oils can **shorten bearing life down to 1 percent or less**, depending upon the quantity present."
- SKF

Water Contamination – A Dangerous Opponent

Water in oil is dangerous because it causes many problems with the machine and the oil itself. Following are some of the effects of water contamination:

- Rust and corrosion
- Film strength loss
- Filter plugging
- Steam damage
- Aeration
- Lower viscosity
- Accelerated oxidation

Many experiments have also shown that water promotes micropitting. Water is always present in oil. All lubricants are susceptible to attack. It is introduced through ingression, condensation, or by oxidation. Sometimes it enters through leaks and faulty seals. It can also be added through improper or careless oil storage and handling.

Once it gets in, the battle with water is on. Water is a formidable foe as it exists in three phases; dissolved, emulsified, and free. In the dissolved state, water molecules are finely dispersed in the oil similar to humidity in the air that surrounds us. Emulsified water is a mixture of oil and water that results in a milky or cloudy appearance. It is similar to fog. Lastly, free water is clearly visible as it settles out much like rain. Water is most dangerous in the free and emulsified states. Most component manufacturers' today state that water content in oil should never exceed 500 ppm if the full life potential is to be realized.

For instance, research has shown that bearing life is adversely affected by water. Reliability and lifetime are a function of reducing water content (see Figure 1).

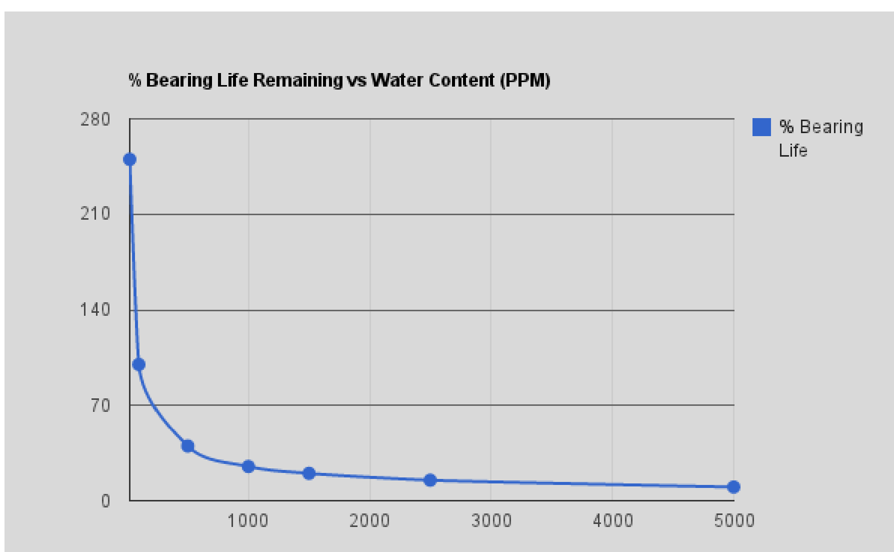


Figure 1
Effect of Water in Oil on Bearing Life (Timken)

Waging war against water is worth the effort. For example, reducing water content from 100 ppm to 25 ppm can extend the life of the bearing by a factor of 2.5. On the flip side, allowing water to increase from 100 ppm to 500 ppm can cut the lifetime in half.

Waging War on Water

Water Removal Methods

There are several methods to remove water from oil. Some are more rigorous than others. Some are simple and inexpensive while others are more complex and require a significant investment. Every method has advantages and disadvantages so each must be carefully evaluated for the right fit. Here is a look at some of the most commonly used technologies to consider when drawing up a battle plan against water.

1.

The Best Offense is a Good Defense

DESICCANT BREATHERS

Airborne moisture penetrates reservoirs through unguarded passageways. The best way to combat airborne water contamination is to have a solid defense. Use high quality desiccant breathers to restrict ingression. Shielding reservoirs with desiccant breathers not only keeps moisture out but also simultaneously protects against dirt ingression.

NOTE: Changing from old-school bayonet style twist-on caps to a quality desiccant breather will modernize your contamination control army. The change can be made in less than five minutes and will provide a higher level of security (see Figures 2-3).

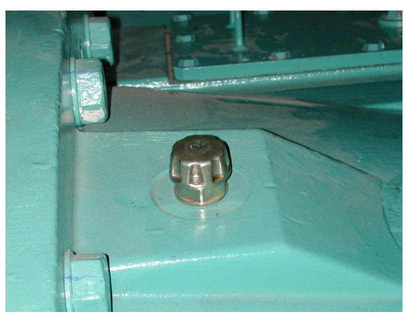


Figure 2
Don't use old school breather caps

Figure 3
Do use high quality desiccant breathers

2.

Let Nature
Take It's Course

GRAVITY SEPARATION

Allow water to settle out of the oil. This natural approach will combat free water only. Gravity acts on moisture, tending to settle at the bottom of the reservoir. This is an inexpensive method but the oil reservoir must be properly designed to promote efficient settling. The oil must have an adequate amount of dwell time. Heating the oil will increase molecular motion, promote coalescence, and reduce viscosity which all together improves the gravity separation process. A cone-shaped tank is also recommended to further aid separation.

NOTE: Gravity separation on its own will not remove emulsified or dissolved moisture.

3.

Soak Up Water
Quickly and Efficiently

DEPTH FILTERS

Superabsorbent depth filters commonly used in offline filter systems are well suited to soak up water like a sponge. The filter media used is cellulose or other water absorbing materials such as polymer. Depth filters feature a thick filter mass that provides low initial pressure drop, high water absorbing capacity, and structural strength. Free and emulsified water is trapped by the depth filter's media (see Figure 4).

Go BIG!
Certain depth filters can provide **1 gallon** of water removal capacity. These filters can be stacked to increase capacity.

Water removal capacity is directly related to the construction and surface area of the depth filter. While many depth filters look similar from the outside, some are built and designed to handle higher water loads while others are more limited. These are details your filter supplier will need to know. Ask your filter supplier. Don't bring a knife to a gun fight. Select a depth filter with a higher water removal capacity to keep operational costs down and effectively control water.

These filters will not remove dissolved moisture. However, in most reservoirs or systems that do not suffer from steady water ingression they will maintain the oil dry and clean. Minor water ingress from condensation will be controlled. Water levels can be maintained at 500 ppm or lower in most cases. If sudden water ingress occurs, they can provide early warning by plugging – a sort of condition monitoring.

Figure 4
Cross section view of water trapped by depth filter media

4.

Spin Your Oil Dry

CENTRIFUGAL SEPARATION

Centrifuges are a traditional solution that will separate free water and some emulsified water. They follow the same principle as gravity separation but greatly speed up the process (6,000 to 10,000 times faster). Water is forced to the outside of the spinning element.

Centrifuges are a proven option for continuous moisture removal. They do not need filter insert replacements. They are best for oil viscosities < ISO VG 150. Consider the operational and maintenance costs when evaluating this solution. Some centrifuges have a reputation for not being user friendly and maintenance intensive.

NOTE: Centrifugal separators do not remove dissolved water. Because this is a method of physical separation, there is a risk that additives will be removed.

5.

An Ideal Solution for Most Oils

COALESCING SEPARATION

Looking for a solution that is lower cost and easier to use than a centrifugal separator? Coalescing separators are the answer. They work by attracting water droplets to the coalescing media. As the moisture laden oil passes through the filter, water droplets will impinge upon the media. Smaller droplets will merge together forming larger droplets. Larger droplets have a lower surface area so they will drop out of the oil more easily (see Figure 5).

Coalescers will remove free water and some emulsions. They will not remove dissolve water. However, in most systems they are an ideal solution because the purchase cost and operating costs are lower than other traditional methods of water removal. Well suited for diesel, hydraulic oil, lube oil, and gear oil up to ISO VG 150.

NOTE: Consider Coalescing Separators in applications such as thrusters for marine vessels, pulp and paper machinery, diesel storage tanks, diesel backup generators at data centers, and diesel fuel systems. Typical water results are 50-300 ppm. They will also simultaneously retain hard particles and varnish.

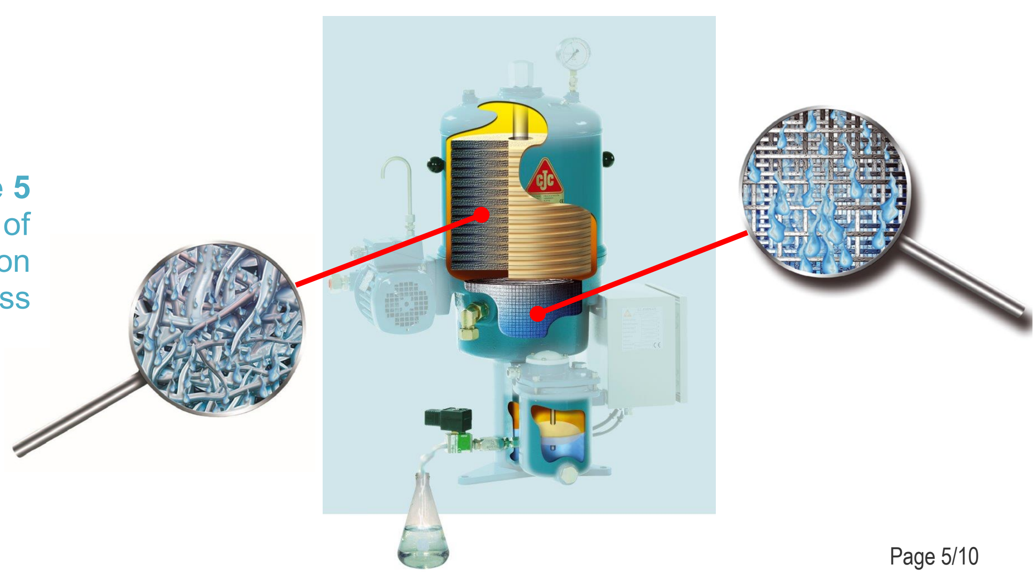


Figure 5
Cut away view of coalescing separation process

6.

High End Solution

VACUUM DEHYDRATION

This solution can remove free, emulsified, and dissolved water. Oil should be filtered prior to passing through the dehydrator to minimize contamination of the elements. It is an effective but costly means of removing water. The dehydration process typically runs at 90°F - 150°F (32°C - 65°C) and vacuum between 23" – 28" Hg. Water will boil under these conditions. At this operating temperature range, it does not cause much damage to the base oil or additive package. However, there is some possibility of additive vaporization.

It is common knowledge that vacuum techniques are not user friendly. If there is a large dose of water ingress (i.e. cooler leakage or sudden water ingress) the vacuum chamber will 'boil over' and create foaming problems. This will cause frequent nuisance tripping.

NOTE: Initial purchase price can be high. They also tend to take up a significant amount of space. Ask your supplier to provide estimated annual operational costs. Unless it is mission critical to remove dissolved water, a lower cost solution such as Depth Filters or Coalescing Separation is ideal for controlling water.

7.

Whip Water with Desorbers

DESORBERS

These units operate by the "Air Stripping" principle. Desorbers heat the oil slightly before it enters the integrated chamber. Heated oil meets a counter flow of cool air inside the chamber. Air, now heated by the oil, will expand and draw water from the oil. The subsequent air-cooling condenses the water and it is drained out of the system. The cycle continues as the now dry air is recirculated to remove water from incoming oil (see Figure 6). The cycle repeats and the oil gets dry.

Desorbers will remove free, emulsified and dissolved water from all types of oils effectively and reliably. Viscosities up to ISO VG 1000 can be treated with this technique. They are ideal for use in applications where water ingress is a continuous and is a significant problem. Desorbers will not remove additives and are suitable for oil volumes up to 15,000 gallons (57,000 liters).

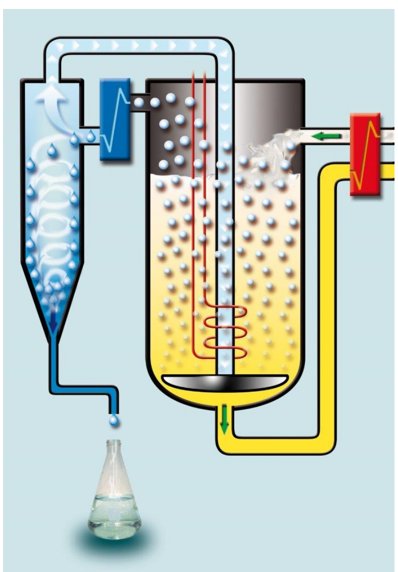


Figure 6
Principle of Desorber operation

For more technical information about Desorbers please click on the following link: http://www.cjc.dk/products/desorbers-water-removal/

Water Removal Summary

7 Solutions – The Big Picture

Leading OEM's and end users are winning the war against water by employing one or a combination of the 7 solutions discussed. Good practice is to set water level targets according to reliability needs (see Appendix - Table 2). Best practice is to remove water below the saturation point so the oil is clear & bright. Following is a table that provides a summary of the 7 solutions including general ratings, advantages, and their tradeoffs.

"Best practice is to remove water below the saturation point so the oil is **clear & bright**"

SOLUTION	WATER TYPE REMOVED	ECONOMY 1. Purchase Cost 2. Operational Cost	ADVANTAGES	TRADEOFFS
DESICCANT BREATHERS	**Free**	1. LOW 2. LOW	Restricts ingression, simple and affordable, also removes solid airborne particles	Will not remove water once it gets in the system
GRAVITY SEPARATION	**Free** **Some Emulsified**	1. LOW 2. LOW	No moving parts required, low cost, no maintenance	May require revised or new reservoir design, requires dwell time
DEPTH FILTERS	**Free** **Emulsified**	1. MEDIUM 2. LOW	High water removal capacity, good operational economy, low maintenance, continuous operation, can provide early warning of leaks/ingress, particle and varnish removal	Lower oil flow, will block off when water removal capacity is reached
CENTRIFUGAL SEPARATION	**Free** **Some Emulsified**	1. HIGH 2. HIGH	No consumables, higher flow rates, particle removal, established technology	Not user friendly, special tools required for maintenance, high energy consumption
COALESCING SEPARATION	**Free** **Some Emulsified**	1. MEDIUM 2. LOW	Water content below 500 ppm with most oils, continuous separation of ingressed water, low maintenance, combines particle and varnish removal	Lower oil flow, may require oil preheaters
VACUUM DEHYDRATION	**Free** **Emulsified** **Dissolved**	1. VERY HIGH 2. HIGH	Removes particles and gas, can be portable, easy installation	Nuisance tripping with sudden water ingress, efficiency decreases with water content >500 ppm, high maintenance
DESORBERS	**Free** **Emulsified** **Dissolved**	1. HIGH 2. LOW	Not affected by viscosity, can handle high water levels, low maintenance, user friendly	No particle and varnish removal, increased energy consumption

Table 1
Water Removal Solutions Performance Overview

Case Studies

Change the Oil?

Problem: Water in Gearbox Oil (ISO VG 320)
Solution: Depth Filters

"**4x** Life Extension"

A gearbox with 90 gallons (340 liters) of synthetic gear oil became contaminated with water and corrosion. Water and particle contamination were out of control, despite an expensive inline filter installed in the oil cooling circuit. It was recommended to change the oil and flush the gearbox, at a minimum cost of $15,000. As an alternative solution, at a fraction of the cost, a depth filter with 1 gallon of water absorption capacity was installed. In just 2 weeks of processing the water content was reduced from 390 ppm to 40 ppm (see Figures 7-9). The resulting life extension was a factor of 4 (see Appendix - Table 1).

390 ppm

40 ppm

Figure 7 [Left]
Oil sample *before* adding Depth Filter

Figure 8 [Center]
Depth Filter saturated with water contamination

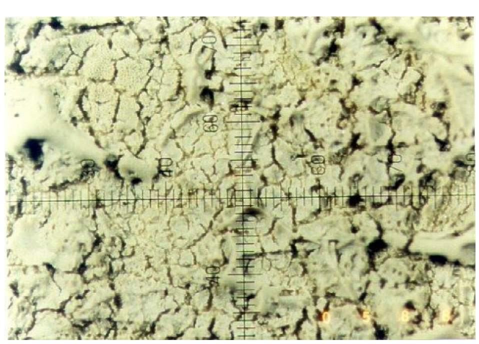
Figure 9 [Right]
Oil sample *after* adding Depth Filter

Trouble was Brewing

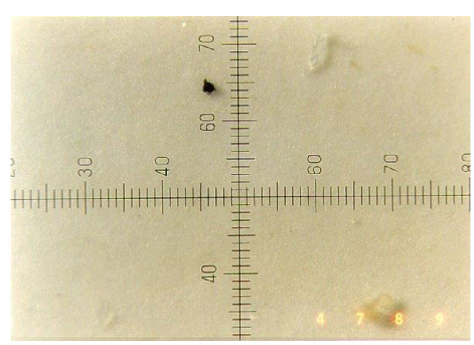
Problem: Water in Bottle Labelling Machine Oil (ISO VG 220)
Solution: Coalescing Separation

"**10x** Life Extension"

The machines at a major brewery were under attack from water. Wash-down procedures introduced significant amounts of water. Monthly oil changes and costly rebuilds had been carried out for years until a Coalescing Separation solution was installed. Water content dropped from 40,000 ppm to 172 ppm (see Figures 10-11). The resulting life extension was a factor of 10 (see Appendix - Table 1).



40,000 ppm



172 ppm

100X 0.8 Micron Patch

Figure 10 [Left]
Oil sample *before* adding Coalescer

Figure 11 [Right]
Oil sample *after* adding Coalescer

Case Studies

Pulp Mill in Peril
Problem: Water in 250 Gal of Vacuum Blower Lubricating Oil
Solution: Desorber

”**$350,000** in Savings”

An alert operator noticed that the sight glass turned milky and hazy due to water contamination. Further investigation revealed that the water-over-oil cooler had failed. A Desorber was immediately installed to combat this threat. In 1 week nearly 7 gallons (26 liters) of water was removed. Pulp Mill staff calculated a cost savings of $350,000 (see Figure 12-13).

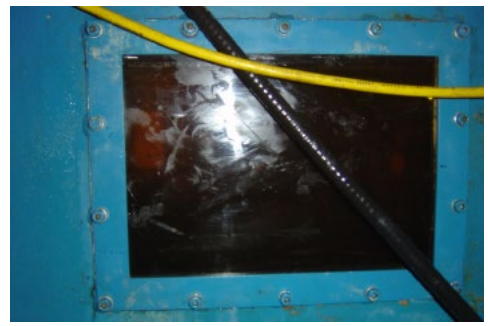


Figure 12 [Left]
Sight Glass *before* adding Desorber

Figure 13 [Right]
Sight Glass *after* adding Desorber

Conclusion

Defeat Water For Good
Fighting the war against water contamination is a challenge. But the battle can be won. It may require some investment, procedural changes, and modifications to maintenance programs. But it is do-able. Contamination control programs often encounter internal barriers to secure the funding required to deploy initiatives. A well-planned water removal program can dramatically extend component life and yield savings in the hundreds of thousands of dollars.

Considering the damage that water can cause, waging this war is well worth the effort. Water removal successes can also help a company to reduce environmental impact, outperform competitors, improve margin, and decrease overall resource consumption. Clean and dry oil is good for the machine – and good for business! Don’t wait for water contamination to destroy your machines. Use 1, or a combination of the 7 solutions suggested in this paper to remove water contamination promptly.

About the Author

Justin Stover serves as Sales Manager at C.C. Jensen. He brings over 17 years of experience working closely with OEM’s and end users to achieve clean and dry oil in their machines. Justin focuses on developing contamination control strategies, reliability, condition monitoring, oil analysis interpretation and cost savings. He can be reached at justin@ccjensen.com

APPENDIX

Table 1 – Life Extension Factor for Water Removal

LEM - MOISTURE Level

Source: *Noria Corp.*

Current Moisture Level, ppm	Life Extension Factor								
	2	3	4	5	6	7	8	9	10
50,000	12,500	6,500	4,500	3,125	2,500	2,000	1,500	1,000	782
25,000	6,250	3,250	2,250	1,563	1,250	1,000	750	500	391
10,000	2,500	1,300	900	625	500	400	300	200	156
5,000	1,250	650	450	313	250	200	150	100	78
2,500	625	325	225	156	125	100	75	50	39
1,000	250	130	90	63	50	40	30	20	16
500	125	65	45	31	25	20	15	10	8
260	63	33	23	16	13	10	8	5	4
100	25	13	9	6	5	4	3	2	2

1% water = 10,000 ppm. • Estimated life extension for mechanical systems utilizing mineral-based fluids

Example: By reducing average fluid moisture levels from 2500 ppm to 156 ppm, machine life (MTBF) is extended by a factor of 5

Table 2 –How Low Should Water Levels Be?

Target Dryness Table

Machine or Fluid Type	Reliability Penalty Factor									
	1	2	3	4	5	6	7	8	9	10
Steam Turbine – Bearing Oil	2000	1500	1000	750	500	400	300	200	100	50
Steam Turbine – EHC Fluid	2000	1500	1250	1000	750	600	500	400	325	250
Mobile Hydraulics – Mineral Oil	10000	5000	3000	2000	1000	750	500	400	300	200
Diesel Engine Oil	20000	10000	5000	3000	2000	1000	500	400	300	200
Air Compressor Lube – Mineral Oil	4000	3500	3000	2000	1000	500	400	300	200	100
Industrial Gearbox	3000	2000	1500	1250	1000	750	600	500	400	300
Transmission / Differential	10000	5000	3000	2000	1000	750	500	400	300	200
Paper Machine Oil	4000	3500	3000	2000	1000	500	400	300	200	100
Motor or Pump Bearing Oil	2000	1500	1000	750	500	400	300	200	100	50
Industrial Hydraulics – Mineral Oil	4000	3500	3000	2000	1000	500	400	300	200	100
Phosphate Ester Hydraulic Fluid	2000	1000	1250	1000	750	600	500	400	325	250
Diesters or Polyol Esters	3000	2000	1500	1250	1000	750	600	500	400	300

10000 ppm = 1%

REF: NORIA