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# Active Dry Air Venting for Water Contamination Control

While required for biological life, water can be extremely detrimental to mechanical systems such as hydraulic and lube oil systems. Along with particles, water causes serious problems in oil-wetted machinery.[1],[2] The paths of destruction are many. In dissolved form, water accelerates bearing fatigue and oil oxidation. In free form, emulsified or bulk, it causes corrosion, reduces lubricity, depletes additives, and results in microbial growth.[3]

Water is ubiquitous and enters systems in many ways: through humidity ingressing into the reservoir head space, through rain or wash water entering into unprotected ports and external seals, and through leaks in heat exchangers and system plumbing submerged in water.[5] Humidity deserves special attention. If humid air is allowed to pass into the reservoir head space, the oil readily absorbs water vapor from the air. Solubility of water in oil increases with increasing temperature; therefore, as the system heats up in a humid environment, more water enters the oil. When the system cools, the oil may become over-saturated and free water forms. If this cycle is allowed to repeat, water can cause serious problems, such as corrosion, microbial growth, and additive drop-out.

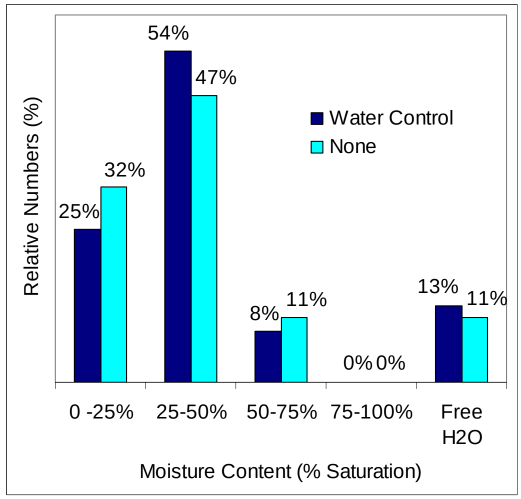



Figure 1 - Summary of water content survey in industrial oil systems.

While the detrimental effects have been known for many years, a recent survey, summarized in Figure 1, reveals the current methods of water contamination control are not sufficient. More than 10% of the systems surveyed had free water. Even worse, the data reveals that more than 10% of those systems protected by water contamination control equipment had free water.[4]

## *Water Prevention & Removal Techniques*

A number of techniques exist to prevent water ingression or to remove water once it is present in a hydraulic or lube oil system. The best choice for removal depends on the water phase, dissolved water or free water, and also on the quantity present. Table A provides comparative information on these techniques and their relative capabilities.

| Water Prevention/ Removal Techniques | Usage | Prevents Humidity Ingression | Removes Dissolved Water | Removes Free Water | Removes Large Quantities of Free Water | Limit of Water Removal |
|---|---|---|---|---|---|---|
| Adsorptive Passive Breather | prevention | Y | | | | n/a |
| Active Dry Air Venting System | prevention & removal | Y | Y | Y | | down to <10% saturation |
| Water Absorbing Cartridge Filter | removal | | | Y | | only to 100% saturation |
| Centrifuge | removal | | | Y | Y | only to 100% saturation |
| Coalescer | removal | | | Y | Y | only to 100% saturation |
| Vacuum Dehydrator | removal | | Y | Y | Y | down to ~20% saturation |

Table A – Water Prevention & Removal Techniques

For example, the presence of water or moisture can be reduced or prevented from entering a fluid reservoir through the use of adsorptive breathers or active venting systems. Once free water is present in small to moderate quantities, water absorbing filters or active venting systems usually provide adequate removal. For large quantities of water; vacuum dehydration, coalescence, and centrifuges are appropriate techniques for its removal. However, as each of these techniques operates on different principles, they have various levels of water removal effectiveness. Care should be taken to apply the best technique to a given situation and its demands for water removal. Also, it is always best to prevent water contamination in the first place. Prevention is the best cure.

The focus of this paper is water prevention and removal via active dry air venting systems. This technique relies on the constant flow of clean and very dry air through the oil reservoir's head space to not only prevent the ingression of humidity, but also remove moisture from the oil by evaporation. This is the only water contamination control technology that can do both prevention and removal.

## *Breather Vents & Blowers Vs Active Dry Air Vents*

### Breather Vents & Blowers

For several years, moisture control breather vents have been used to keep humid air out of reservoirs. These work well in applications where the air relative humidity (RH) is less than 50%, and when other sources of water are not present. However, in hot, humid environments, the life of these devices is limited; and they quickly lose effectiveness. In turn, the oil rapidly becomes wet. Figure 2 shows the humidification of initially dry oil in a reservoir with an open breather port. Simply by contacting humid air, the moisture content in the oil rose to half the ambient humidity level in 8 hours and nearly ambient humidity level in 1 day.

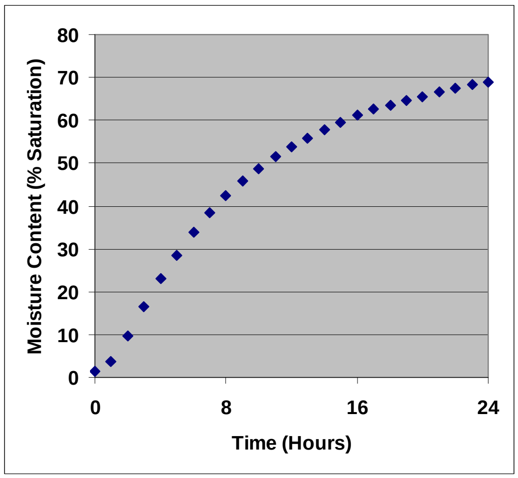



Figure 2 – Oil humidification when not protected from humid air. Ambient air temperature controlled at 90 °F and 80% RH. Oil is Mobil DTE PM 220.

Another common technique to control moisture is the use of a simple blower or fan to continuously blow ambient air through the reservoir head space. This technique can help to prevent condensation in the reservoir and also remove water from the oil if other sources are present. However, the utility is limited because of the use of untreated, humid air. At best, these systems maintain moisture content in the oil equivalent to the surrounding air RH. Another issue often found is lack of air filtration. When not filtered, these systems continuously inject dirty air into the reservoir, causing high particulate contamination of the oil.

### Active Dry Air Vent

A cost effective and virtually maintenance free option is available: active venting of the reservoir head space using a pressure swing adsorption dryer. A schematic of a commercially available system from Donaldson, Active Reservoir Vent™ (ARV™), is shown in Figure 3. Compressed air enters at 1 and is first filtered and then dried by a pressure swing adsorption dryer at 2. The dry air, always at -40$^{o}$C dew point (much less than 1% RH), is then allowed to slowly flow into the oil reservoir, 3, where it blankets the oil surface and flushes the head space with dry air. Air then exits the reservoir at the breather port, 4. In an optimum installation, the breather port is located on the opposite end or corner from the dry air inlet, to provide good mixing in the head space. In addition, systems with continuous turnover of oil will dry more quickly. During operation, the reservoir head space is continuously flushed with extremely dry and particulate free air, providing the optimum condition for moisture prevention and removal.

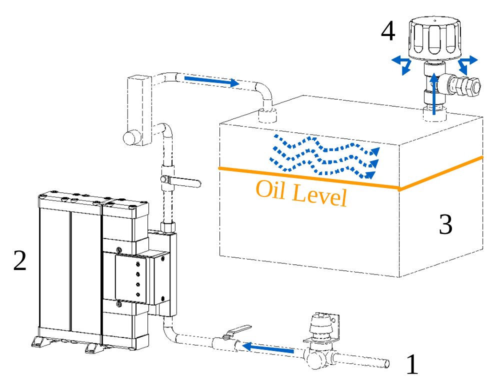



Figure 3 - Schematic of a Donaldson's Active Reservoir Vent™ (ARV™).

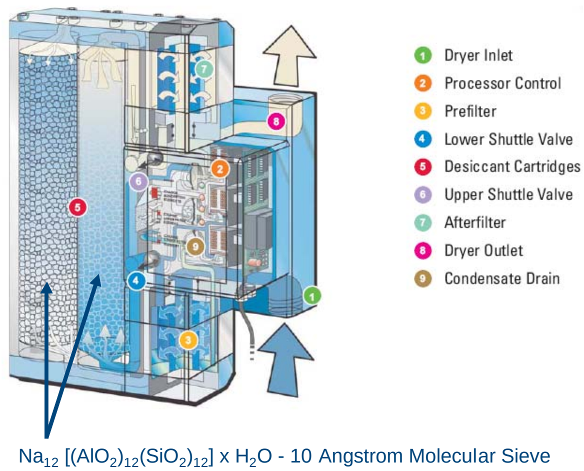



Figure 4 – Donaldson's Ultrapac Pressure Swing Adsorption Dryer.

## Pressure Swing Adsorption Technology

Pressure swing adsorption processes rely on the fact that under pressure, gases tend to be attracted to solid surfaces, or adsorbed. The higher the pressure, the more gas or vapor phase molecules are adsorbed; when the pressure is reduced, the gas or vapor phase molecules are desorbed.

When compressed air is passed under pressure through the Ultrapac (Donaldson's pressure swing adsorption dryer shown in Figure 4), the Sodium Alumina Silicate column attracts water vapor more strongly than air. Most of the water vapor remains in the bed, and the air leaving the vessel is dry. When the bed reaches maximum capacity to adsorb water vapor, it is regenerated by reducing the pressure, thereby releasing the adsorbed water vapor. It is then ready for another cycle of producing dry air.

Using two adsorbent vessels with automatic cycling on a timer, allows continuous and nearly maintenance-free production of dry air.

## Active Dry Air Vent Performance

### Lab Performance

Donaldson developed a laboratory test method to validate the dry air vent concept and develop application guidelines. As can be seen in Figure 5, a reservoir was placed inside an environmental chamber. The environmental chamber was used to control the ambient conditions around the reservoir. Typically, a hot and humid condition of 90$^o$F and 80% RH were used for testing.

The reservoir was equipped with a breather, and a mixer was used to simulate typical oil turnover in a recirculating lubrication system. The head space was equipped with an air temperature and RH sensor, and the oil was equipped with an oil temperature and moisture saturation sensor. The dry compressed air was fed directly into the reservoir head space and allowed to exit via a breather.

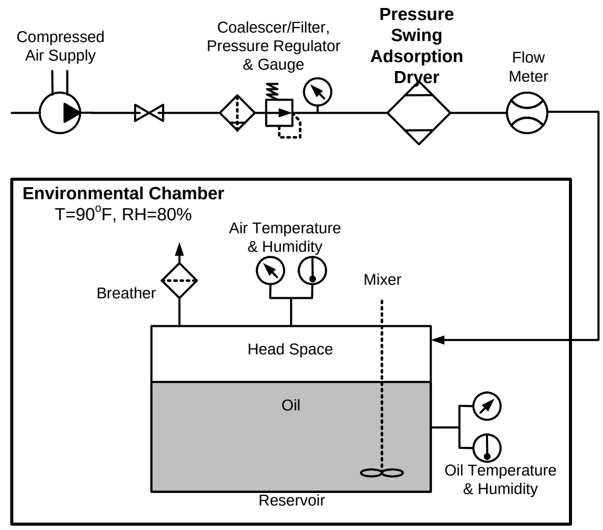
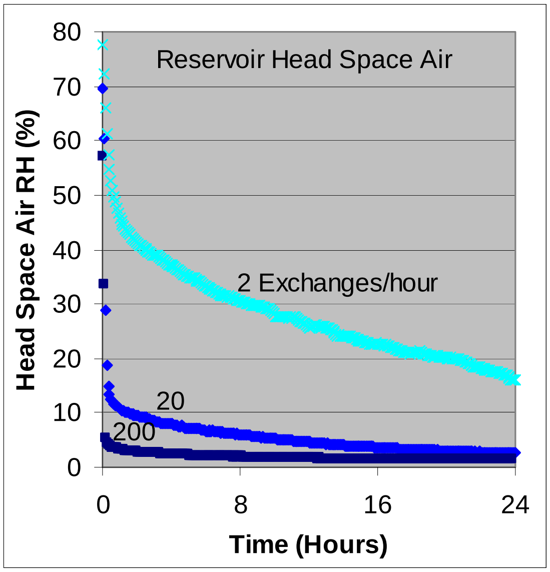



Figure 5 – Donaldson laboratory test system.

For test results reported below, the reservoir was pre-conditioned before each test by opening the breather port, exposing the head space and oil to the hot and humid air from the chamber. This was done for 24 hours. Thus the oil gradually came to equilibrium with the air. Figure 2 shows the resulting humidification of the oil.

After pre-conditioning the reservoir, we initiated testing with the ARV™. The flow of dry air was controlled using a variable area flow meter with an integrated needle valve. The temperature and RH of the head space air and the temperature and the moisture content of the oil were continuously monitored.

Test results demonstrate ARV™ is not only an effective water prevention tool; it is also a user-friendly water removal system. Because the oil surface is continuously flushed with dry air, moisture is continuously removed, and the oil dries to beneficially low levels. Figure 6 shows head space RH (left) and moisture content in oil (right) versus time. The ambient condition around the reservoir was controlled to 90$^o$F and 80% RH. For the conditions of these tests, the highest flow rate was equivalent to 200 air exchanges per hour; while the lowest flow rate was equivalent to a scant 2 air exchanges per hour, requiring very little compressed air. The number of air exchanges per hour is equivalent to the volume flow rate divided by the head space volume.



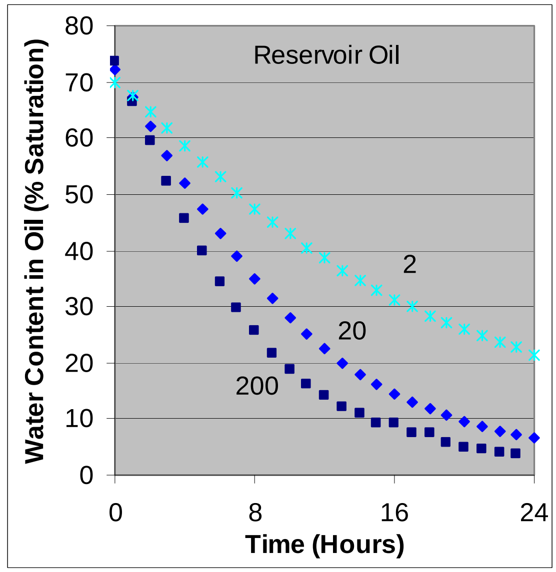




Figure 6 – Reservoir head space air RH (left) and resulting moisture content in oil (right) versus time for range of dry air exchanges per hour. Ambient temperature controlled at 90°F and air RH controlled at 80%. Study oil is Mobil DTE PM 220.

The headspace air dries very quickly, causing a large gradient in the RH of the air versus the moisture content of the oil. This gradient drives desorption (evaporation) of water from the oil, which is then carried out of the reservoir by the air flow. Through these lab experiments and careful study of the physics involved in this process, we have found the rate of oil drying can be characterized by its half-life and is dependant on the oil surface area to volume ratio. The half-life is the time needed to reach one-half of the starting value. For systems with no additional water sources, the times required to reach this level are summarized for three typical systems in Table B.

Table B – Time to dry oil from 100% RH for different area to volume ratios.

| | Large Area/Volume Ratio | Model System<br>Medium Area/Volume Ratio | Small Area/Volume Ratio |
|---|---|---|---|
| Time to Dry From 100% RH to <15% RH | 16 Hours | 24 Hours | 36 Hours |

## Field Performance

A large hydraulic press at a central Wisconsin manufacturer has been plagued by moisture problems. The press uses large quantities of water based coolant during a stamping process. The water based coolant evaporates and rises up and around the overhead reservoir. As a result, the overhead reservoir is constantly surrounded by hot, humid air and the hydraulic oil becomes moist. Over time, the press reservoir has suffered from corrosion and many valve failures have resulted.

A solution was found using Donaldson's new ARV™ product. The press has a large reservoir holding 3000 gallons of hydraulic oil with another 100 cubic feet of head space. Large hydraulic cylinders result in substantial volume changes inside the tank; therefore, a 10 cubic feet per minute (cfm) system was specified, providing up to 6 air changes per hour. For the purposes of this field test the reservoir was instrumented with an air temperature and RH sensor in the head space and an oil temperature and moisture saturation sensor in the oil.

After installing the unit, turning it on, and adjusting the flow to 7 cfm (resulting in ~4 air changes per hour); the head space RH immediately reduced from over 40% to about 5%. Figure 7 summarizes the data generated to date. Although the oil temperature and oil moisture sensor failed to record during the first half of the test, the manual readings found the oil quickly dried from about 12% saturation to around 5% saturation. In spite of the oil having been recently dried with a vacuum dehydrator, ARV™ drove moisture levels down to more beneficial levels. Note that during the trial period there were many weekend shutdowns when plant compressed air also shut down, which explains the periodic increases and decreases in the head space air temperature and RH. Most importantly, ARV maintained water levels in the oil at about 5% saturation, which for this hydraulic fluid is about 100 ppm.

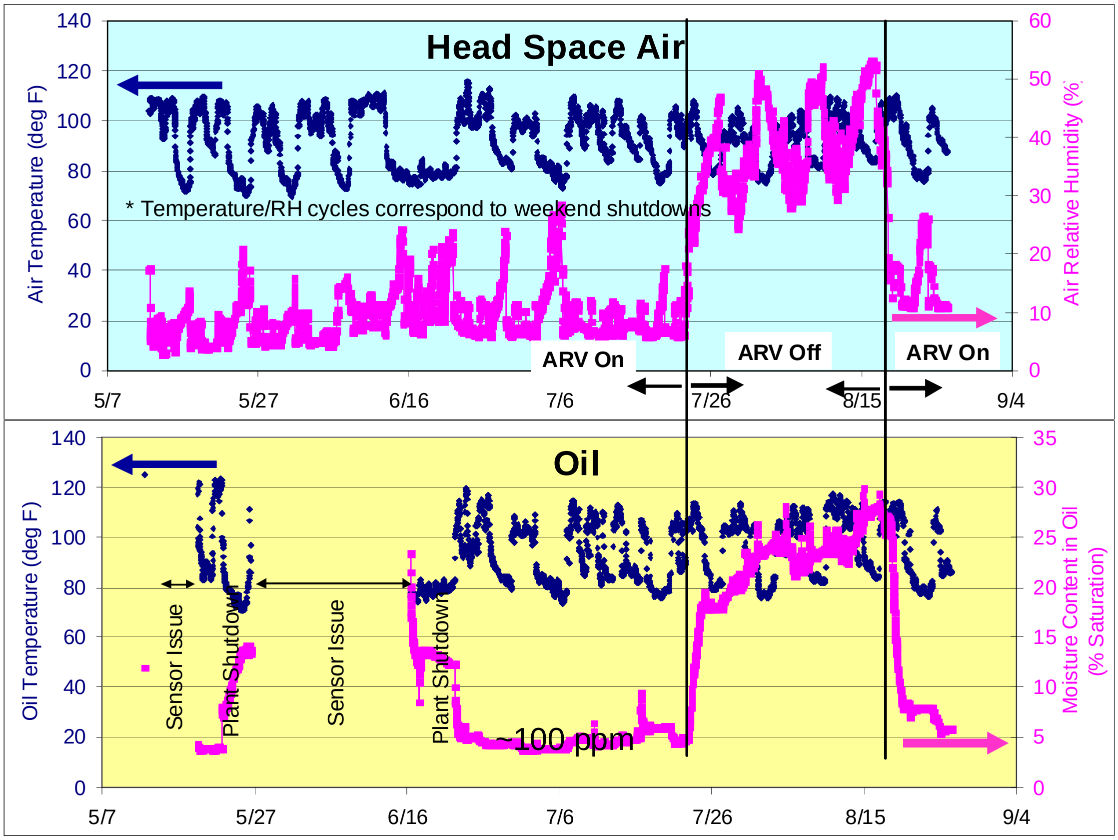



Figure 7 – Results from Active Reservoir Vent™ use on large hydraulic press.

Perhaps the most revealing data is when we turned off the ARV™ on July 24th. Both air and oil RH immediately started climbing to harmful levels. Finally, we turned ARV™ back on August 18th and both the air and oil RH quickly returned to beneficially low levels. This clearly demonstrated the benefits of the active dry air venting technique. The customer has purchased an ARV system and is planning on splitting the flow from one 10 cfm unit and feeding half of the air into a second twin hydraulic press.

## Conclusions & Recommendations

1. Water is a serious contamination issue for oil wetted machinery, causes many issues, and ingresses into systems through several paths.
2. Although the performance of most water removal equipment depends on the type of water in oil (dissolved, emulsified, micelles, bulk, etc.), a blanket of very dry air removes all forms of water contamination.
3. Active dry air venting is a proven technology to both prevent humidity ingression into the reservoir, and to remove water from the oil to extremely low moisture levels.

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