Donaldson Company, Inc.
1400 West 94th Street
Bloomington, MN 55431 USA

Mailing Address
PO Box 1299
Minneapolis, MN 55440 USA

SAP (Super Absorbent Polymer) White Paper

Water is prevalent. Water is virtually everywhere. Water is required for life. Yet that same water can be extremely detrimental to hydraulic and lube oil systems. Not until recently has water been acknowledged as a leading fluid system contaminant along with particulates. Water is a frequent and damaging contaminant in hydraulic and lubrication systems. The presence of water contributes to a host of problems, including: increased metal surface wear and corrosion, a decrease in the oil's lubricity and component seizure, additive dumping and accelerated oil oxidation, reduced bearing life, and the promotion and enabling of bacterial and fungal growth and sludge formation.

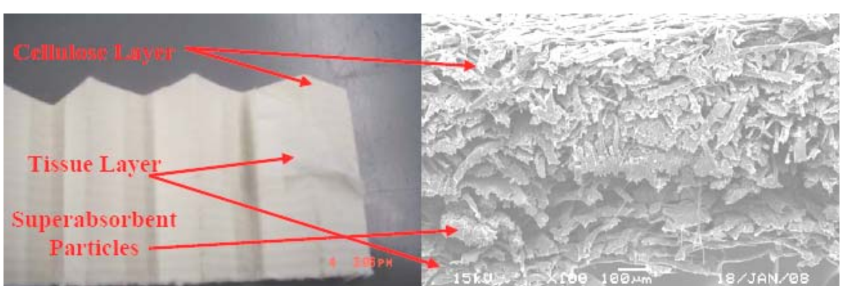
Water Removal

A number of techniques exist to prevent water or moisture ingression or to remove water once it is present in a hydraulic or lube oil system. The best choice of technique for removal is dependant on the whether or not the water exists as a separate phase (dissolved water or free water), and also on the quantity of water present. 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. The chart below provides comparative information on these techniques and their relative capabilities. Care should be taken to apply the best technique to a given situation and its demands for water removal.

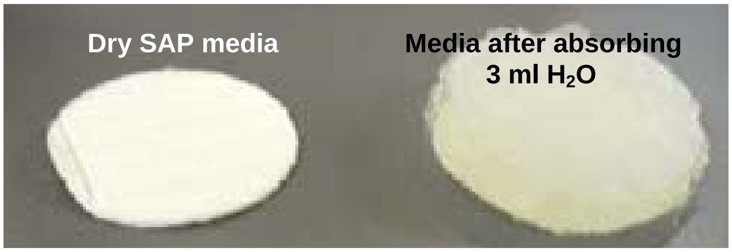
Water Prevention/ Removal Techniques	Usage	Prevents Humidity Ingression	Removes Dissolved Water	Removes Free Water	Removes Large Quantities of Free Water	Limit of Water Removal
Adsorptive Passive Breather	prevention	Y				n/a
Active Venting System	prevention & removal	Y	Y	Y		down to <10% saturation
Water 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

The focus of this paper is water removal via water absorbing cartridges. Perhaps one of the best known, but least understood methods, water absorbing cartridges relay on the absorbing media's ability to draw in to its depth and hold quantities of water. While popular in many "kidney loop" systems, rolled cellulose elements cannot compete on a pound for pound basis with today's superabsorbent particle technology.

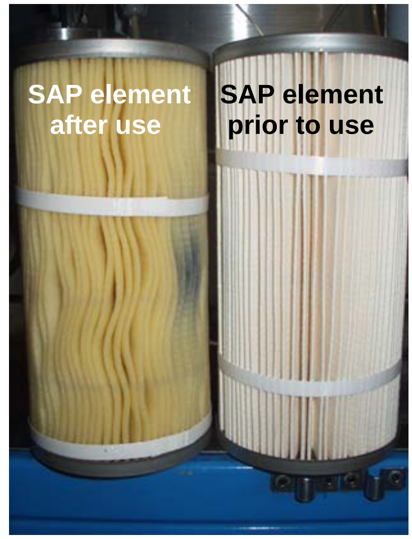
SAP Filter Media



Sodium polyacrylate polymer, a super absorbent polymer (SAP), is today's choice for water absorbing cartridges, holding several hundred times its own mass in water. Even when blended into a cellulose filter media, it readily achieves a capacity of typically 70 times the mass of the entire filter media. That is 70 grams of water per gram of media.



Typically, the SAP is sandwiched between supporting layers, most commonly made of a cellulose fiber media, as shown to the left and on the previous page. As the SAP absorbs water, it expands and eventually turns into a gel-like material with a greatly increased thickness. It is this ‘thickening’ of the filter media that leads to an increased pressure loss in the filter element and that signals the end of the filter’s useful life. The photo to the right indicates the physical appearance changes of the SAP media, in this case after absorbing water to the point of a 25 psid (1.7 bar) differential pressure.



Water Absorbing Filters

Water absorption cartridges are an effective tool to remove free water from hydraulic or lubrication systems, as previously mentioned. By utilizing SAP media technology with its high affinity for water and high absorption, these filters quickly remove free water from a hydraulic or lube oil system. Through fast and efficient free water removal, these filters provides a wide range of benefits, including longer component life, extended fluid change intervals, and greater system uptime and reliability. Such filters are generally available in a range of sizes capable of removing up to ~2 liters of free water.

Generally, these filters offer the following features and benefits.

Features

- Fast, efficient free water removal
- Pressure drop indication of when to change filter
- Low investment cost
- Simple operation

Benefits

- Greater Uptime
- Longer Component Life
- Longer Oil Life
- Fewer Maintenance Hassles
- Lower Energy Consumption
- Greater Machine Efficiency

Typical applications for such SAP filters are:

- Hydraulic System Reservoirs
- Gear boxes
- Lube System Reservoirs
- Small Storage tanks
- Multiple Tanks
- Lube Rooms
- Systems with a “cooler” that leaks
- Systems operating in high humidity
- Marine applications
- Systems without water prevention

Most commonly, these SAP filters are available in the following formats:

- 4” (93 mm) low pressure spin-on
- 5” (127 mm) diameter low pressure spin-on
- 4” (94 mm) medium pressure spin-on
- 5” (117 mm) medium pressure spin-on
- HF4 series, standard 9” length
- HF3 series, standard lengths
- 8310 series, standard lengths
- Standard industrial 6” x 18”

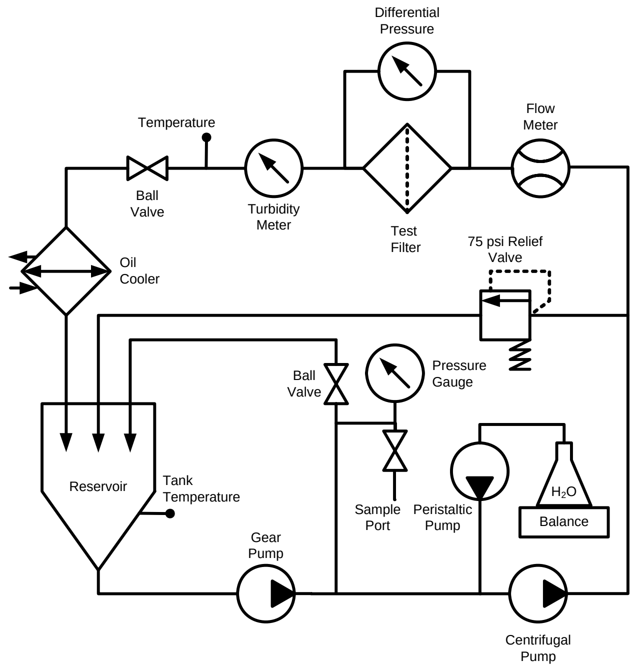
Water Absorbing Filter Performance

There are no current industry test standards to compare various water absorbing filter product. To fill this void Donaldson has developed a reproducible test method based on fuel filter water separation test standards. The test method is based on a multi-pass arrangement.

Multi-pass Absorption Test

- Oil: Viscor 46 R&O (CF46RO) from Rock Valley Oil & Chemical Co.
- Temperature: 100°F (38°C)
- Volume: 36 L
- Flow Rate: 6 lpm
- Element: standard 5” (127mm) diameter by 10.7” (271mm) length low pressure spin-on, with 7.4 ft^2 (0.7 m^2) SAP media
- Terminal Pressure Drop: 25 psid (1.72 bar)

The multi-pass water absorption test schematic appears to the right. In this arrangement, a known quantity of water is fed into the system at a known rate using a peristaltic pump. The water-laden fluid is pumped through a test filter using a gear pump followed by a centrifugal pump to emulsify the water into the oil. Differential pressure is monitored and the filtered fluid is returned to the reservoir.



Multi-pass Absorption Test Methods

- Water Injection
  - Inject 6 ml/min of H_2O continuously, for standard multi-pass method
  - Inject bulk quantity of H_2O directly into reservoir for dry-down method
- Sampling
  - Samples drawn continuously
  - 10 ml/min for 100 ml total, repeated every 10 minutes
  - Sonicate samples
  - Draw 1 ml for Karl Fischer titration
- Capacity & Efficiency Calculation for continuous multi-pass test

$$C = W_{fed} - W_{remaining}$$

$$E(\%) = \frac{W_{captured}}{W_{fed}} x100 = \frac{W_{fed} - (W_{remaining} - W_{initial})}{W_{fed}} x100$$

Where:

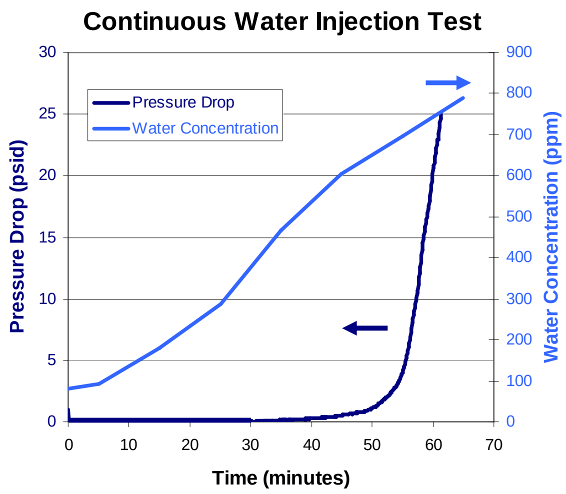
- C = Capacity
- E = Efficiency
- W_{fed} = Mass or volume of water fed
- $W_{remaining}$ = Mass or volume of water remaining
- $W_{initial}$ = Initial mass or volume of water in oil

Continuous Water Injection Test Results

The results of a continuous water injection tests using a typical 5” low pressure spin-on filter, as described above are listed here. The oil is essentially water-free at the start of the test.

Water Summary		
Fed	369	grams
Fed	369	ml
Remaining	18.3	ml
Capacity	350.6	ml
Efficiency	95.03	%

Note that the water concentration in the reservoir gradually increases as the absorbing capability of the filter is consumed. In the process of absorbing water, the filter increases the pressure drop to the 25 psid (1.72 bar) terminal service point, and the reservoir concentration increases from <100 ppm to ~800 ppm



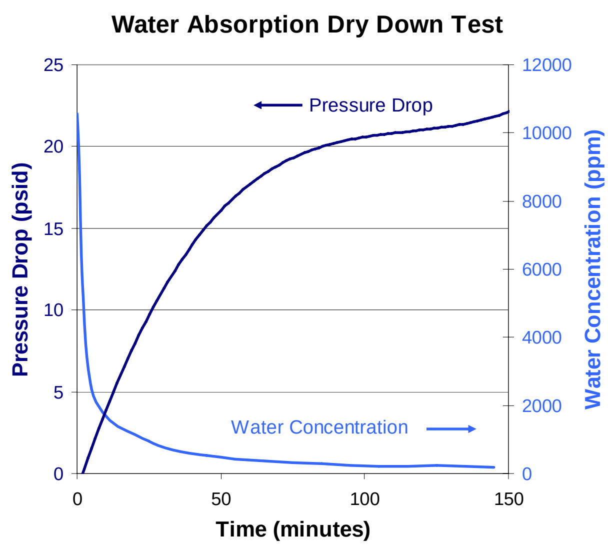
Water Summary		
Fed	350	grams
Fed	350	ml
Remaining	7.14	ml
Capacity	342.9	ml
Efficiency	98.0	%

water. Note that the pressure drop increases rapidly during the final 10% of the filter's life. A rapid increase in pressure loss for the filter element is desired, as this is the key measured parameter to indicate the filter's end of life.

Bulk Water Addition Dry-Down Test Results

For this test the same bench was used, but the entire 350 ml of water was added to the reservoir all at once. Starting from a dry condition, the 350 ml of water was allowed to circulate through the bench using an empty filter housing, until it was well mixed and emulsified. After this an SAP filter element was installed and allowed to absorb water as the fluid flow through it at 6 lpm.

The SAP media rapidly absorbs free water as demonstrated by this test, with >77% water removal within the first reservoir volume change. This increased to 91% water removal in 4 volume changes, and 95% water removal in 7½ volume changes. The test was halted at the same terminal pressure drop of 25 psid (172 kPa).

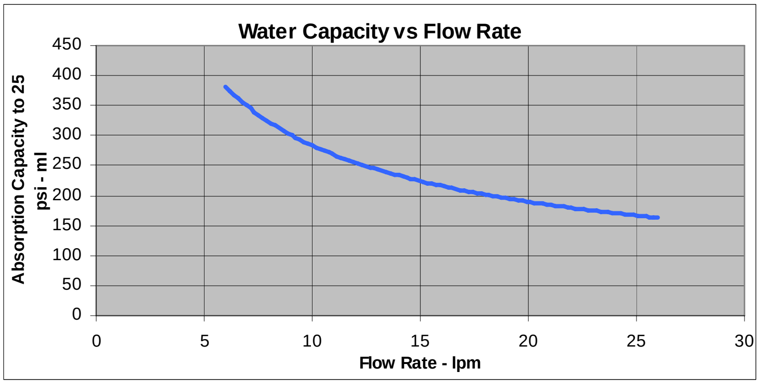


These results are reflected on the plot to the left. The rapid drop in water concentration is evident in the first 10 minutes of the clean down test. The tabular data for the clean down test are listed below. Included are calculations of the number of volume changes of the fluid in the reservoir versus the water removal efficiency.

	res volume	36	l	
	flow rate	6	lpm	
	exchange rate	0.17	chg/min	
Time-min	Water-ppm	DP-psid	Efficiency	Volume Changes
0	10564	0	0.0%	0.0
5	2462	0.8	76.7%	0.8
25	947	4.2	91.0%	4.2
45	539	7.5	94.9%	7.5
65	363	10.8	96.6%	10.8
85	279	14.2	97.4%	14.2
105	220	17.5	97.9%	17.5
125	230	20.8	97.8%	20.8
145	195	24.2	98.2%	24.2

Water Holding Capacity vs Flow Rate

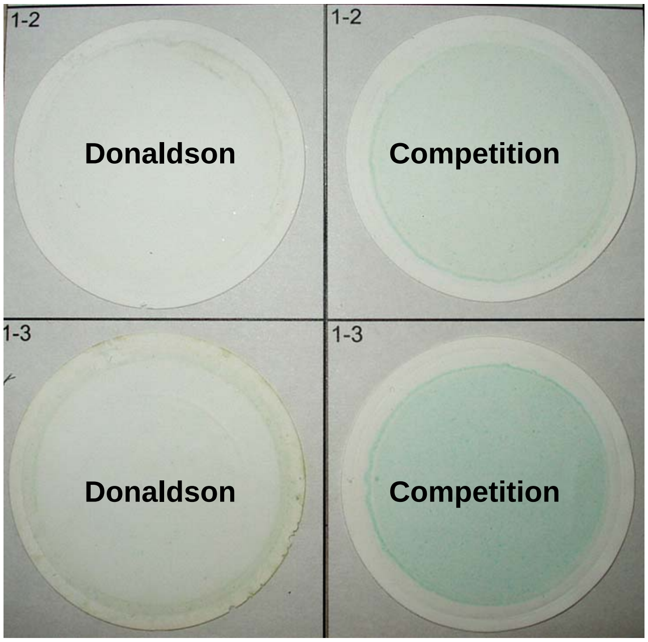
Additional tests were conducted at various flow rates up to >4 times higher than the previous tests. All tests were terminated at the same pressure drop. The absorbing water capacity therefore falls as the initial pressure loss increases proportionally with increased velocity. Capacities fell from about 380 ml to 160 ml as the flow rate increased from 6 to 26 lpm.



SAP Migration Analysis

One final performance parameter to consider is that of SAP migration through the filter. Certain designs and configurations of SAP filter media allow a portion of the SAP, as it becomes 'gel-like' upon saturation with water, to become free from the filter media matrix and to migrate downstream. This has the potentially adverse affect of hydraulic or lube oil system plugging and blocking of passageways.

A test method was developed to determine if and how much SAP migration occurs during the use of an SAP filter element. This technique includes drawing a 100 ml sample from the reservoir through a 0.45 µm membrane. This membrane is then rinsed with petroleum ether, and then covered with a 0.5% Copper Sulfate solution for 2 minutes. The solution is then drawn through the membrane, allowing for its examination for blue spots or staining. The SAP material is such that it absorbs the Copper Sulfate solution. Therefore, any such staining is indicative of the presence of SAP. As the source of the samples is the reservoir, blue staining means that a portion of the SAP was released downstream of the filter. The bluer the staining, the more SAP released. An ideal SAP filter would have its SAP integrally bonded and therefore not show signs of staining of downstream water samples.



Conclusions

When selecting an SAP water absorbing filter, there are a number of important performance considerations. One should seek the appropriate filter size consistent with:

- Higher possible water holding capacity at 25 psid (1.72 bar)
- Highest possible efficiency
- Negligible to no SAP migration

All else being equal, a lower flow rate will mean a higher water holding capacity, but of course a longer clean up time as well. Plan to run the filter system for at least 7 reservoir volume changes to assure an approximate 95% water removal level, depending on the filter design selected. Remember that SAP filters only remove free water. If additional water removal is required, then other previously-mentioned techniques must be employed.

Authors

Marty Barris Donaldson Company, Industrial Hydraulics Engineering Director
Greg LaVallee Donaldson Company, Industrial Hydraulics Principal Engineer
June 23, 2009