STAY AHEAD OF THE STORM

5 Steps To Control Lubrication Contamination

TESTOIL

REMARKABLE IN EVERY WAY

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ABOUT TESTOIL

TestOil has been in the oil analysis business since 1988.

We started out providing Analytical Ferrography services to power customers and in the early 90's expanded our services. We have focused exclusively on assisting large industrial facilities reduce their maintenance costs and avoid unexpected downtime through oil analysis program implementation.

Our customers rely on us to be their technical experts when it comes to diagnosing oil related issues in equipment such as turbines, hydraulics, gearboxes, pumps, compressors, and diesel generators.

Our state-of-the-art-laboratory has the capacity to process and analyze 2000 samples per day. We employ lean process management to drive excellence and ensure that we maintain our
guarantee of providing same day turn around on all routine testing.

"Management, operations, engineering, and financial personnel should adopt the concept that: Maintenance Doesn't Cost, It Pays."

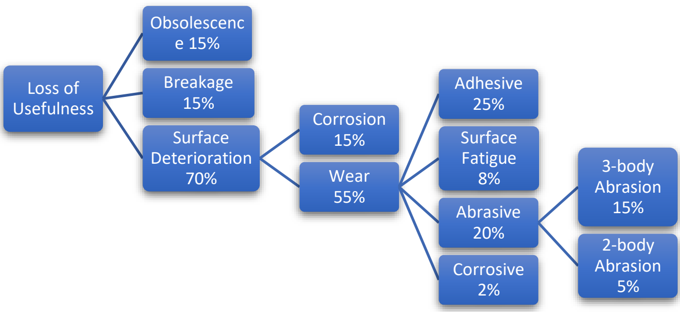
- AISE Steel Technology Magazine –

SECTION 1

AN INTRODUCTION TO LUBRICANT STORAGE & CONTAMINATION

The Issue

When a machine suffers a lubricant-related failure, frequently the root cause is contamination. A study of premature bearing failures identified particulate contamination as one of the greatest contributors.



Ref: Dr. Ernest Rabinowicz, 1981 Bearing Workshop at ASLE Annual Meeting

Another study of estimated annual losses due to various mechanisms of wear across a variety of industries, identified 82% of wear was particle induced.

(*Ref: NRCC No. 26556, "A Strategy for Tribology in Canada: Enhancing Reliability and Efficiency Through Reduction of Wear and Friction", 1986, Table 2.18.*)

Additionally, a Van Dorn Demag study that showed that between 70 and 85 percent of hydraulic system failures and component wear problems can be attributed to solid-particulate contamination within the hydraulic system.

(*Ref: "Primary Cause of Hydraulic System Failure: Dirty Oil" Injection Molding, Volume 6, No. 5, May 1998, p.24-5.)*

The Greatest Cause

With irrefutable proof that particle contamination is the greatest cause of lubricant related failures, the most important follow-up question becomes, "What size particle is the most damaging?" The answer is "clearance-sized", as clearance sized particles will get between surfaces in relative motion and cause wear.

Particles smaller than clearance can pass through lubricated areas unabated. Those larger than the clearance cannot enter areas where they would be the most damaging.

Clearances range anywhere from 0.1-100 µm but are predominantly 22 µm or less. The human eye can detect particles as small as approximately 40 µm, meaning that the most damaging particles are the ones that cannot be seen.

As such, proper storage and handling practices must be aimed at mitigating contamination from microscopic particulates. Doing so can be broken into 5 distinct steps.

5 Steps of Contamination Control

Delivery

- Target cleanliness level should be established for each machine and should be applied to the new oil

Storage

- Lubricants should be stored where the environment can be best controlled

Handling

- Care should be taken to prevent further contamination when dispensing lubricants

Exclusion

- Ensure that the fill cap, breather, hatch, inspection cover and/or dipstick are tightly sealed and in good operating condition

Conditioning

- Proper filtration is key towards defence against contamination

SECTION 2

STEP 1: DELIVERY

The first step in dealing with contamination is admitting that new lubricant is not clean lubricant. Even fresh, new lubricant contains some particulate, and depending on the application, this level may already exceed the recommended cleanliness levels. New lubricant typically achieves an ISO cleanliness of 20/19/16 (give or take one code). This level would be in alarm for most applications except gearboxes and engines.

For example, a typical cleanliness target for some machines might be 18/16/13. To put this into perspective, a study by Caterpillar estimated that it would only take ½ teaspoon of particulates to contaminate a 55-gallon drum of fluid to 18/16/13. This means that a drum of new lubricant with a cleanliness of 20/19/16 contains at least 2 teaspoons of particulates. Therefore, a target cleanliness level should be established for each machine and should be applied to the new lubricant upon delivery.

The following table, from Hypro Filtration, provides guidance for setting target cleanliness codes and provides specifications for the filters needed to achieve those levels. The target cleanliness is based off the lowest (cleanest) recommended level of all the components within the machine.

Target ISO Cleanliness Codes

Recommended* Target ISO Cleanliness Codes and media selection for systems using petroleum based fluids per ISO4406:1999 for particle sizes $4\mu_{[c]}$ / $6\mu_{[c]}$ / $14\mu_{[c]}$

Pumps	Pressure < 138 bar < 2000 psi	Media $\beta x_{[c]} = 1000$ ($\beta x = 200$)	Pressure 138-207 bar 2000 - 3000 psi	Media $\beta x_{[c]} = 1000$ ($\beta x = 200$)	Pressure > 207 bar > 3000 psi	Media $\beta x_{[c]} = 1000$ ($\beta x = 200$)
Fixed Gear	20/18/15	$22\mu_{[c]}$ (25μ)	19/17/15	$12\mu_{[c]}$ (12μ)	-	-
Fixed Piston	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)	17/15/12	$7\mu_{[c]}$ (6μ)
Fixed Vane	20/18/15	$22\mu_{[c]}$ (25μ)	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)
Variable Piston	18/16/13	$7\mu_{[c]}$ (6μ)	17/15/13	$7\mu_{[c]}$ (6μ)	16/14/12	$5\mu_{[c]}$ (3μ)
Variable Vane	18/16/13	$7\mu_{[c]}$ (6μ)	17/15/12	$5\mu_{[c]}$ (3μ)	-	-
Valves						
Cartridge	18/16/13	$12\mu_{[c]}$ (12μ)	17/15/12	$7\mu_{[c]}$ (6μ)	17/15/12	$7\mu_{[c]}$ (6μ)
Check Valve	20/18/15	$22\mu_{[c]}$ (25μ)	20/18/15	$22\mu_{[c]}$ (25μ)	19/17/14	$12\mu_{[c]}$ (12μ)
Directional (solenoid)	20/18/15	$22\mu_{[c]}$ (25μ)	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)
Flow Control	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)
Pressure Control (modulating)	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)	17/15/12	$7\mu_{[c]}$ (6μ)
Proportional Cartridge Valve	17/15/12	$7\mu_{[c]}$ (6μ)	17/15/12	$7\mu_{[c]}$ (6μ)	16/14/11	$5\mu_{[c]}$ (3μ)
Proportional Directional	17/15/12	$7\mu_{[c]}$ (6μ)	17/15/12	$7\mu_{[c]}$ (6μ)	16/14/11	$5\mu_{[c]}$ (3μ)
Proportional Flow Control	17/15/12	$7\mu_{[c]}$ (6μ)	17/15/12	$7\mu_{[c]}$ (6μ)	16/14/11	$5\mu_{[c]}$ (3μ)
Proportional Pressure Control	17/15/12	$7\mu_{[c]}$ (6μ)	17/15/12	$7\mu_{[c]}$ (6μ)	16/14/11	$5\mu_{[c]}$ (3μ)
Servo Valve	16/14/11	$7\mu_{[c]}$ (6μ)	16/14/11	$5\mu_{[c]}$ (3μ)	15/13/10	$5\mu_{[c]}$ (3μ)
Bearings						
Ball Bearing	15/13/10	$5\mu_{[c]}$ (3μ)	-	-	-	-
Gearbox (industrial)	17/16/13	$12\mu_{[c]}$ (12μ)	-	-	-	-
Journal Bearing (high speed)	17/15/12	$7\mu_{[c]}$ (6μ)	-	-	-	-
Journal Bearing (low speed)	17/15/12	$7\mu_{[c]}$ (6μ)	-	-	-	-
Roller Bearing	16/14/11	$7\mu_{[c]}$ (6μ)	-	-	-	-
Actuators						
Cylinders	17/15/12	$7\mu_{[c]}$ (6μ)	16/14/11	$5\mu_{[c]}$ (3μ)	15/13/10	$5\mu_{[c]}$ (3μ)
Vane Motors	20/18/15	$22\mu_{[c]}$ (25μ)	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)
Axial Piston Motors	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)	17/15/12	$7\mu_{[c]}$ (6μ)
Gear Motors	20/18/14	$22\mu_{[c]}$ (25μ)	19/17/13	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)
Radial Piston Motors	20/18/15	$22\mu_{[c]}$ (25μ)	19/17/14	$12\mu_{[c]}$ (12μ)	18/16/13	$12\mu_{[c]}$ (12μ)
Test Stands, Hydrostatic						
Test Stands	15/13/10	$5\mu_{[c]}$ (3μ)	15/13/10	$5\mu_{[c]}$ (3μ)	15/13/10	$5\mu_{[c]}$ (3μ)
Hydrostatic Transmissions	17/15/13	$7\mu_{[c]}$ (6μ)	16/14/11	$5\mu_{[c]}$ (3μ)	16/14/11	$5\mu_{[c]}$ (3μ)

*Depending upon system volume and severity of operating conditions a combination of filters with varying degrees of filtration efficiency might be required (I.e. pressure, return, and off-line filters) to achieve and maintain the desired fluid cleanliness.

STEP 2: STORAGE

Fluctuating temperatures cause a condition known as breathing, in which air moves in and out of the container's head space and the atmosphere — even in sealed containers. Moisture and airborne particles travel with the air, resulting in contamination and degradation of the oil. Extreme hot or cold temperatures can lead to chemical degradation as well.

Once the lubricants have been received, they must be stored in a manner that prevents further contamination. Use the following checklist to ensure you are practicing proper storage techniques with your lubricants.

Proper Storage Checklist

- [x] If lubricant is stored indoors, it is stored in a clean, dry environment kept at a stable, moderate temperature.

- [x] If lubricant is stored outdoors, lubricant is sheltered as much as possible from environmental conditions that may degrade them and placed in containers on blocks or racks to help protect them from ground moisture.

- All storage containers are sealed (no open caps or bungs), and First In, First Out inventory control is employed to ensure proper stock rotation.

- Opened containers that have been opened for dispensing, are protected with a suitable breather to prevent further ingression of moisture and particulates.
  - Dispensing can be done through quick-connect fittings to further reduce the contamination of open containers.

- To reduce the already-existing contamination, the use of kidney-loop filtration, to pre-filter the lubricant during delivery, storage and/or dispensing, should be considered.

SECTION 4

STEP 3: HANDLING

The use of sealed transfer containers prevents additional contamination, but the use of rack-mounted filtration or a filter cart to fill the containers, should be considered. This provides a single pass through of at least one filter, which will reduce the level of particulates, and possibly moisture, in the oil.

Once lubricants are ready for dispensing into the machine, care should be taken to prevent further contamination. Use the following checklist to ensure you are practicing proper handling techniques with your lubricants.

Proper Handling Checklist

- Transfer containers are labelled clearly; color-coded, (particularly with corresponding shapes) to help ensure the right lubricant is applied.
  - Use of an incorrect lubricant could cause equipment damage or failure, health and safety issues, and a host of other problems

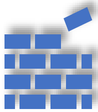
- Transfer containers are equipped with quick-connect fittings to prevent further contamination from filling machines.

When transferring a greater volume of fluid than can easily be carried, filtered dispensing pumps are used to ensure no further contamination takes place

- May even assist in reduction of contamination
- Filter carts, or even filtered barrel pumps, are good examples, and can be equipped with quick-connect fittings to prevent further contamination

SECTION 5

STEP 4: EXCLUSION



The cost of proper exclusion is a mere fraction of the cost of filtration to remedy contamination.

Once the lubricant is in the machine, the greatest source of contamination becomes the machine's fill cap, breather, hatch, inspection cover and/or dipstick. Use the following checklist to ensure you are practicing proper exclusion techniques with your lubricants.

Proper Exclusion Checklist

- [x] The machine's fill cap, breather, hatch, inspection cover and/or dipstick are all tightly sealed and in good operating condition.
- [x] The breather is of high-quality and capable of excluding particulate down to 1 µm.
- [x] If the ambient environment has fluctuating or high humidity, moisture ingression is prevented with a desiccant breather

SECTION 5

STEP 5: CONDITIONING

The last line of defense against contamination in any machine is filtration, whether full-flow, on-board filtration, or supplemental slipstream (kidney-loop) filtration. Proper filter selection is the key factor towards the ultimate outcome.

There are two types of filtration media:

Filtration Media

Celulose (paper)	Synthetic Filters
• lower denisty of pores • larger pores • higher fluid restriction	• Higher density of pores • smaller pores • lower fluid restriction and the ability to be tapered (variety of pores)

There are two types of filters, both can be made with either type of filtration media:

Types of Filters

Surface Filters

- lubricant passes through only one layer of filter media, but across a relativly large surface area acheived by pleating the media

Depth Media Filters

- lubricant passes through the media edge-wise, achieving greater efficiency at the expense of a significantly reduced surface area and increased back-pressure or flow resistance

Regardless of the media or filter type, all filters can be rated according to a common factor referred to as the Beta Ratio. The Beta Ratio is simply the ratio of the number of particles, of a given size, upstream of the filter, to the number of particles, of a given size, downstream of the filter. The ratio is always reduced to a factor achieving 1 particle downstream of the filter so that the expression remains a single value.

- Multipass Method for Evaluating Filtration Performance of a Fine Filter Element (ISO 16889:1999)

- $\beta_x = \dfrac{\text{Number of particles greater than } x \text{ microns upstream}}{\text{Number of particles greater than } x \text{ microns downstream}}$

- So, $\beta_5 = 20$. For every 20, >5 micron particulates upstream, only 1 would be downstream from filter.

Beta Ratio of 2

- *Definition* - for every 2 particles upstream, only 1 particle would be downstream
- Nominal
- 50% Efficiency

Beta Ratio of 75

- *Definition* - for every 75 particles upstream, only 1 particle would be downstream
- Absolute
- 98.7% Efficiency

However, any Beta Ratio in between can also be considered Nominal, and there are at least three Beta Ratios higher than Absolute (Beta 100, Beta 200 and Beta 1000). It is best to refer to the actual Beta Ratio, and not these terms (Nominal and Absolute), when specifying or selecting a filter.

When evaluating the difference between filters of the same micron rating, but differing Beta Ratios, consider the following table showing the particle reduction after as few as four passes, starting with a fluid containing 1,000,000 particles >5µm per ml.

Filter Rating	First Pass	Second Pass	Third Pass	Fourth Pass
$ß_5$ = 75	13,333	178	2.370	0.031605
$ß_5$ = 100	10,000	100	1.000	0.01000
$ß_5$ = 200	5,000	25	0.125	0.000625
$ß_5$ = 1000	1,000	1	0.001	0.000001

The ultimate outcome of all four filters is a reduction from 1,000,000 particles/ml to less than one particle/ml after just four passes. The point is that a decrease in efficiency becomes less of an issue with multiple passes through the filter.

For a fluid transfer, meaning the fluid will only have one pass through a filter, it may be advisable to use a high Beta Ratio filter. In circulating conditions, the Beta Ratio becomes less of a consideration, so long as speed is not a concern.

It should be noted that over-filtration is not an issue, as is sometimes thought. “Filtration studies on new and used lubricants prepared with several base stocks show that no additives are removed from these lubricants after they were filtered several hundred times.”
(*Ref: Canter, Neil. "Lubricant Additives: What Degree Are They Removed by Filtration Systems?" TLT Dec. 2013: 26-34.)*

As for moisture filtration, it must be understood that water can appear in up to three phases: dissolved, emulsified or free. Different filtration technologies address different phases, as outlined in the following table:

Separator Type	Water Phase Removed		
	Free	Emulsified	Dissolved
Gravity	Yes	Some	No
Centrifuge	Yes	Some	No
Coalescing	Yes	Some	No
Absorbent Polymer / Desiccant	Yes	Yes	No
Vacuum Dehydration	Yes	Yes	Yes
Headspace Dehumidification	Yes	Yes	Yes

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