Plant Services
SPECIAL REPORT

7 ways contaminants get in your machines, and how to avoid them

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I. HOW DO MACHINES FAIL?

Particle Contamination

Professor Ernest Rabinowicz spent much of his time at MIT researching machine wear and what he referred to as loss of usefulness. Rabinowicz found that approximately 50% of lost equipment usefulness is due to mechanical wear and another 20% is due to corrosive wear. The National Research Council of Canada furthered the understanding of the cause of mechanical wear by concluding that although several wear mechanisms exist, 82% of mechanical wear is caused by particle contamination.

It stands to reason that if particles are the root cause of most of the wear occurring in machines, organizations should work to control particle ingression and have a method for removal when necessary.

Moisture Contamination

Depending on base oil type, additive content, and temperature, all oils will adsorb a certain amount of water. But when the water content increases beyond an oil's saturation point, water comes out of solution and either forms an emulsion or settles on the bottom of the oil sump. Either way, water is a problem. Mixed with the lubricant, water causes rust and corrosion, promotes oil oxidation, contributes to sludge and varnish formation, and destroys the lubricant's film strength.

PRIMARY WEAR MECHANISMS

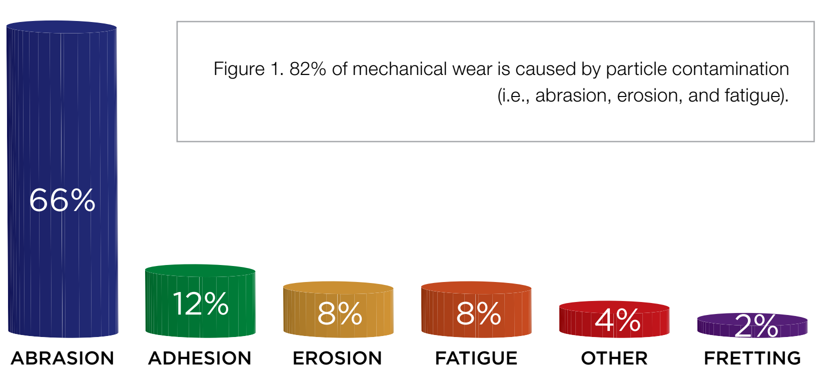

Figure 1. 82% of mechanical wear is caused by particle contamination (i.e., abrasion, erosion, and fatigue).

II. WHERE DOES CONTAMINATION COME FROM?

The two routes of contamination are ingested (i.e., from the outside), and built-in or internally generated (i.e., from the inside). Furthermore, studies show it costs about 10 times as much to remove contaminants than it does to exclude it.

1. Ingested – Lack of Initial Oil Filtering

Most new oils are not very clean, containing up to 8-16 times the levels of particle contamination and twice the moisture content recommended for critical applications.

Perhaps one of the most common misconceptions in maintenance and reliability is that the new oil we buy is clean enough for immediate use. The reality is that a new drum of lubricating oil will typically have a particle count of approximately 19/16/14 or higher (see Table 1). That means that every cubic centimeter of oil in the drum contains between 2,500 and 5,000 particles that are at least 4 microns in diameter – about 1 billion particles for the whole drum.

A Cleanliness Code is great, but why do these numbers really matter? It seems like a lot of contaminant, so surely this should be visible in the oil? The reality is that 4-, 6-, and 14-micron particles simply cannot be seen with the naked eye. In fact, it's not until particles get as large as 40-50 microns that we can see them without a microscope. By comparison, a red blood cell is around 8 microns. To put that into perspective, the life expectancy of your equipment is being compromised by red-blood cell sized particles!

Cleanliness requirements for improved reliability and extending component life range from an ISO Particle Count of 15/13/10 to 18/16/13 depending on the component type. Very few new oil particle counts meet that criteria.

The first step in ensuring the cleanliness of new oil is to filter the oil to an acceptable level. Best practice is to pass the oil through particle and water removing filter elements 5-7 times prior to transferring to critical equipment. The technique used to filter the new oil depends on the oil's method of delivery. If it comes in drums, each drum can be filtered using portable compact filtration units (see Figure 2). If the volume is sufficiently large, the oil can be filtered as it is transferred.

Figure 2. Portable filtration units can be used to filter oil that is delivered in drums.

Another popular technique, which covers a wider range of storage and handling issues, involves the use of a comprehensive lubricant management system (see Figure 3). These systems can be configured with a wide range of options, including separate pumps and filters for each lubricant; high-quality desiccant breathers to prevent subsequent contamination to the fluid; fittings and spigots that minimize contamination.

Figure 3. A comprehensive lubricant management system can include separate pumps and filters or each lubricant as well as options such as desiccant breathers.

Machine Type		Particle Level Target
Hydraulics (1500-2500 psi)	With servo valves	15/13/11
	With proportional valves	16/14/12
	Variable volume piston pump	17/15/12
	With cartridge valves or fixed piston pump	17/16/13
	With vane pump	19/16/13
Gearbox		19/16/13
Paper machine		18/14/11
Steam turbine		18/14/11
Pumps		17/14/12

Table 1. At an ISO code of 19/16/14 or higher, new oil is too dirty for most critical applications.

Systems like these allow staff to easily clean new oil, keep it clean, prevent cross-contamination, and track lubricant consumption by product type without having to engineer the process from scratch.

2. Ingested – Improper Storage Techniques

Once your oil is filtered to the correct level, the battle to keep it that way begins immediately. When it comes to a quality Lubrication Program, how you store and handle your lubricants can have detrimental effects down the road. Quality practices are not just about keeping lubricants clean, but also ensuring the appropriate amounts of appropriate lubricants are maintained in a manner that promotes the lubricant's health while it is in storage.

A custom designed Lubrication Storage & Handling Room is the lubricant's sanctuary from a harsh plant environment (see Figure 4). The "Lube Room" provides a dedicated storage area where lubricants can be adequately prepared and maintained for service. This includes a place to pre-filter, store, and kit for routine preventive maintenance tasks. It also provides a method for usage control. Keeping oil clean is not difficult if you use the right tools. It certainly helps to have an enclosed storage area with climate control, but this setup isn't always feasible. Common-sense measures like good housekeeping, wiping fittings, using dust covers, and installing desiccant breathers on tanks and drums (Figure 5) can go a long way toward keeping dirt out of stored lubricants.

Figure 5. Desiccant breather installed on a drum.

3. Ingested – Exposure to Ambient Environment During Transfer

One of the major sources of contamination ingress is when the oil is being transferred from the oil container into the machine reservoir. Since by definition this is occurring out in the plant, opening the oil transfer container or machine to the ambient operating environment can cause oil cleanliness levels to exceed your target.

Figure 4. An example of a Lube Room.

For large reservoirs the best transfer method is to use fixed plumbing to pipe the machine reservoirs to the storage tanks. However, this is only feasible for very large systems as it is very expensive and impractical for small equipment. For other large systems, or those with a moderate size reservoir, the best method is usually to pump oil directly into the sump from a drum or tote tank using a filter cart. Portable filter carts are one of the most versatile and effective tools available to lubricant transfers and decontamination.

For applications with very small sumps or those that are located such that a filter or top-off cart is impractical, oil transfer containers (see Figure 6) are also an option as long as they meet certain criteria. A good quality oil transfer container should be plastic, sealable, color-coded or marked for product type, and it must be cleaned on a regular basis. It is critical to isolate your oil and equipment with a transfer container that is equipped with quick connects so they can be filled without exposing the container to the outside environment. The trigger should also be self-closing so that the container is always sealed when not in use.

4. Ingested – Incorrect Lubricant Added to Machine

Some of the key properties of a lubricant can be expected to be altered when mixing incompatible lubricants (see Table 2). These alterations to the lubricant properties may come from incompatibility from base stock to base stock, or from issues with the compatibility of the many different additives found in today's lubricants. The severity of the conditions can range widely, from a slight reduction of oil service life all the way to sudden catastrophic failure.

Contaminant Type	Damage to Lubricant	Damage to Machinery
Cross-contamination of lubricants	• Oxidation • Additive loss • Viscosity changes • Loss of demulsibility of water • Increase in air entrainment	• Varnish/deposits • Potentially exacerbates all wear mechanisms due to loss of film strength and changes in additive concentration • Premature filter plugging

Table 2. The effects of lubricant cross-contamination.

To avoid cross-contamination of fluids, make sure there is a dedicated filter cart for each type of lubricant in use and avoid the labor intensive process of flushing carts to switch products. Some manufacturers allow you to color code your filtration unit to help identify which cart should be used with a particular lubricant.

Color-coded lubricant ID tags are an essential practice for avoiding cross-contamination and are an OSHA requirement for all liquid containers. An ID system should be applied to all filtration units, tanks, oil transfer containers, grease guns, and application points. Ideally, these labels should be shape and color coded. Just like how you can recognize the label of your favorite soft drink from across the room, oil labels should be clear and concise so there's no mistaking what is contained within the container or unit.

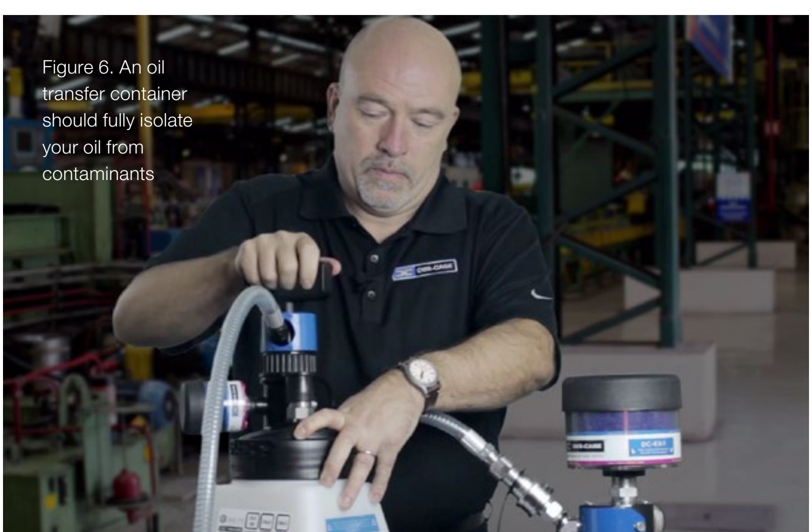

Figure 6. An oil transfer container should fully isolate your oil from contaminants

5. Ingested – Unprotected Vent Ports

Today's options for restricting the ingression of contaminants are a far cry from yesterday's open tube turndown pipes that did little more than keep the birds out. Conventional vent ports or breather caps provide little or no protection. They are typically rated at 40 microns and offer no means of capturing moisture. Retrofitting these ports

WHAT IS A DESICCANT BREATHER?

Desiccant breathers combine a drying media with a combination of filters to prohibit the entry of water and microscopic particulates from entering the system and remove water contained within a reservoir to prevent condensation. A large variety of sizes, desiccants and options allow you to select the right solution for your application.

with desiccant breathers will provide 24/7 protection against uninvited contaminants, both dirt and water.

As nearly all gearboxes, reservoirs, and storage tanks are designed to breathe, allowing only clean, dry air to enter the system is essential to extending the life of your equipment. Replacing standard breather/filter caps with a desiccant breather immediately prevents moisture and moves particle filtration from 40 microns to 3 microns or less.

6. Built-In or Internally Generated – Original Fabrication or Repair Residue

Companies often make a false assumption that the reservoirs in the new or repaired equipment they receive is clean. Unfortunately, that is often not the case. Paint chips, core sand from castings, rubber fragments from hoses and seals, lint from shop towels, rust, and weld splatter are examples of the types of built-in contamination that can end up in your reservoir. Contaminants can also invade new and repaired systems during transport and storage to your plant or through using dirty oil during testing.

Because the amount of particle contamination that can be built into a system or added during repair activities can be significant, it is best practice to flush the reservoir prior to initial operation. Filter carts can be effective tools for flushing systems in situations where only mechanical separation is required (see Figure 7). A new hydraulic system or one that has had components such as pumps, motors, or piping replaced is an excellent candidate for flushing.

Hydraulic valve failures upon start-up are common when proper flushing procedures are not followed. Although hydraulics, as a machine category, are very sensitive to contamination and require initial

Figure 7. Filter carts are an extremely versatile filtration solution.

TIPS FOR SYSTEM FLUSHING

- Maximum flowrates do not really apply here — the more turbulence in the fluid the better.
- Although filter carts are not typically capable of circulating oil through the piping in hydraulic or lube oil systems, they can be effectively utilized at the reservoir while using system pumps to circulate oil through piping.
- When flushing new hydraulic systems, it is recommended to isolate valves and other sensitive components with jumpers.
- When flushing a new or repaired system it is helpful to use the minimum allowable oil viscosity to maximize turbulence.

flushing, you should not overlook other lubricated machines, such as pumps and gearboxes. Any sealed, lubricated component should be flushed before or shortly after start-up. In fact, offline filtration can be much more effective at eliminating run-in debris than changing the oil at the first scheduled interval.

7. Built-In or Internally Generated – Internally Generated Particles

As machines and oil age they will inevitably begin to wear and degrade. Whenever oil-wetted components wear, the debris that is shed from the machine surfaces enters the oil and becomes a contaminant. This wear debris can lead to enhanced machine wear unless it's removed by aggressive filtration, which is why most experts recognize that contamination causes 80% of active wear. Over time a machine will make its own particles, causing erosion, abrasion, and fatigue directly to the machine, and oxidation, particle scrubbing, and viscosity increase to the lubricant. Although age is inevitable, life can be significantly extended by keeping your lubricants clean and dry through a combination of exclusion and extraction practices.

III. THE BOTTOM LINE

Don't Forget to Test!

Testing the oil in your machines can tell you whether your maintenance plan is working as intended. Another benefit is that a sudden rise in particle levels can be a sign of mechanical failures (such as misalignment or a broken gear) that haven't shown up yet in vibration analysis, providing you with an early warning.

Although the cost of lubricants typically represents 1-3% of a maintenance budget, it would be incorrect to make the assumption your lubrication program has little impact on your overall maintenance budget. However, the truth is that failed components and overtime due to machine downtime can total as much as 40% of maintenance dollars spent.

In a seminal study published in 2005, Professor Rabinowicz concluded that as much as $5 billion was lost each year in the United States alone due to what he referred to as "loss of usefulness." Even allowing for inflation, that number is likely to be even higher today as equipment is run longer between scheduled maintenance and faster to increase throughput.

Contamination control is the single greatest opportunity for gains in the average lube program. Significant gains in machinery reliability can be made with minimal investments. Equipment life can be greatly extended through proper lubrication maintenance. In today's competitive market, most companies are now realizing that maintaining clean oil is one of the best investments it can make, with contamination at the core of premature machinery failure and diminished lubricant life.

NOW YOU CAN HAVE A LIVE, HANDS-ON PRECISION LUBRICATION DEMO AT YOUR PLANT!

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