

# Contamination Control

By Rojean Thomas, Trico Mfg. Corp.

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Contamination in lubricating oils is the root cause of premature oil degradation and accelerated wear of machine components. Prevention and control of contamination is very often the most reliable means of preventing equipment failures. Dirt, debris, and water often enter equipment lubrication through vents, lubricators, and seals during normal equipment usage and maintenance. By minimizing the ways that contamination can enter equipment, lubricant and equipment life is prolonged. This paper will cover various contaminants and their effect on lubricant and equipment and different proven methods for controlling contamination ingress

Contamination control is part of proactive maintenance, where the strategy is to minimize the ingress of particulate and other undesirables from the lubricant, to maximize lubricant and machinery life. Controlling contamination is a three step process that involves: 1) Identifying the contaminant 2) Eliminating the contaminant and 3) Excluding the contaminant. Identifying and eliminating the contaminant are important but excluding it will be the most cost effective. It is estimated that the cost to exclude one gram of dirt is approximately 10% of the cost to remove it once it is identified.

Particulate, water, air, heat and other contamination changes the oil chemistry and physical properties as well as chemical and mechanical damage to machine surfaces. (Table 1).

Contaminant	Changes to Oil Chemistry	Changes to Physical Properties	Chemically Attacks Machine Surfaces	Mechanically Destroys Machine Surfaces
Solids	Oxidation ----- Additive Depletion	Viscosity Effects	Adherent Varnish	Abrasion ----- Surface Fatigue
Water	Oxidation ----- Additive Depletion	Viscosity Effects	Acidity Destruction ----- Rust & Corrosion	Cavitation * Scuffing
Heat	Thermal Degradation ----- Oxidation	Viscosity Increase	Varnish ----- Acidity	Film Strength Loss
Air	Oxidation	Oxidation	Rust & Corrosion	Cavitation

**Table 1. Contaminant Effects**

## **Particulate Contamination**

Sources of particulate contamination can be built in, internally generated, external ingress, or maintenance induced. Particles impede lubricant performance and further localize pressure on components causing denting, fatigue, spalling and abrasion to the surface of mating surfaces. The potential destructiveness of particles depends on their size and the ability of these particles to enter the load zone. It is also dependent on the hardness, shape and weight. If the particles are capable of entering critical load zones such as between the rollers and raceways on rolling element bearings, abrasive wear occurs.

Particulate contamination will always be present in rotating equipment and it is important to establish steps towards contamination elimination. First determine what is acceptable cleanliness levels and then take specific actions to achieve these levels. Frequent measuring is required to monitor the progression and determine what changes, if any, are required to hit the targeted levels.

Target cleanliness levels should be established for all lubricating and hydraulic oil using the Manufacturer levels as guidelines. Consider the design of the equipment and application and set life extension targets for each. The action plans to hit the targets should not only include removal of existing but also excluding further contamination. As mentioned previously, the cost of removal will far exceed the cost to exclude.

Factors to consider for excluding contamination include:

- New oil
- Proper storage and handling
- Ventilation and breathers
- Seals
- Service and built-in debris
- Clean reservoirs before installing new oil

Factors to consider for removal of contamination include:

- Proper clearance filters
- Off-line filters for some machines
- Portable filter for other machines
- Proper sump and reservoir management
- Timely filter servicing

### **Excluding Contaminants**

Contamination is perceived to occur only during equipment maintenance and operation but can also be present in the oil prior to it being put into the equipment. New oil needs to be tested to establish a baseline for oil analysis but also to ensure that targeted contamination levels are obtainable. The storage, handling and dispensing of oil are other areas where contamination ingress can occur causing particulate levels to be higher than targeted levels.

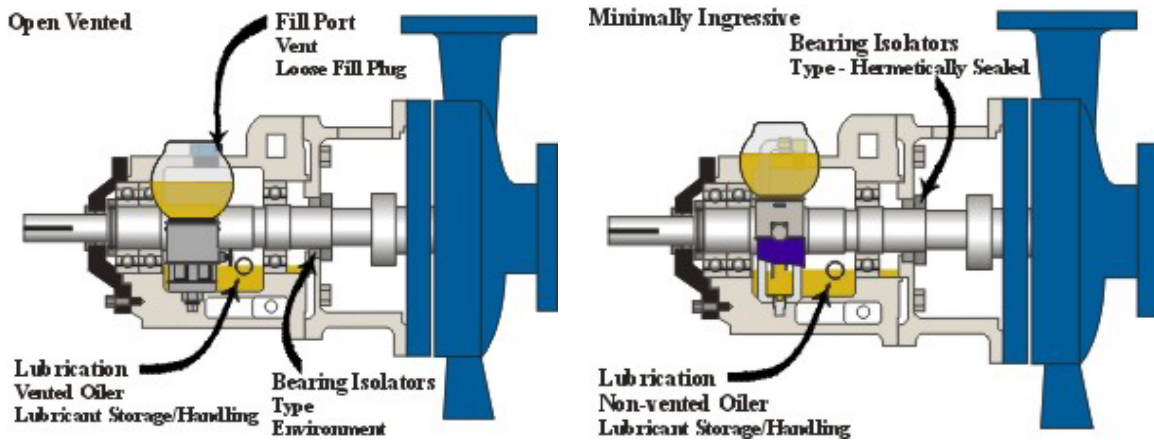
Majority of equipment needs to breath to prevent pressure build up. Breathing occurs through some type of vent on top, through a lubricator and/or through the seals. (Figure 1). Equipment will typically come standard with some type of breather and filter element. Majority of these metallic filtered vents only prevent particles of 10 micron or higher from entering the sump whereas the most damaging particles are typically 1-3 microns. An expansion chamber, desiccant type of breather, spin on filter element or plug should be installed in highly contaminated environments. An expansion chamber has a rolling diaphragm to accommodate the pressure increase maintaining the housing near 0 psi.

Constant level oilers also can be a source of contamination ingress dependent on the type. Constant level oilers require air to function and in vented oilers, this air is ambient allowing for contamination ingress during pressure differentials due to temperature fluctuations. In a non-vented type of oiler, the air supply is the same as the sump air eliminating ingress.

Certain types of seals are better at preventing ingress but still vent to the outside to accommodate the pressure differential. Some seals are not capable of handling the pressures due to equalization and would require an expansion chamber or proper breather.

Bearing isolators are used to prevent lubricant leakage and contaminant ingress. Labyrinth type bearing isolators are the most widely used on modern designed rotating equipment. Bearing isolators allow increase pressure created by normal operation to vent through the seal and proven to be very effective at reducing contamination ingress. The rotor and stator are not in contact, which allows for the venting to occur while preventing wear – prolonging the life of the seal. When bearing isolators are used, it is recommended that the vent plug be removed and replaced with a plug, expansion chamber or desiccant breather along with a non-vented type of oiler.

Lip and Magnetic type of seals are contacting type of design. Lip seals can also be very good at preventing contamination, however being a contacting type, eventual wear to the seal allows for contamination ingress and oil leakages. Face seals are characterized by optically flat stationary and rotating faces loaded together by magnetic force or springs providing a hermetic seal. With contacting type of seals a non-vented type of oiler is recommended and an expansion chamber may be required if seals are no capable of handling pressure increases.



**Figure 1 Contamination Ingression Sources**

### **Removal of Contaminants**

Filtration is the most common method used for removal of particulates. A filtration system can either be stationary or portable dependent on equipment design, criticality, target levels established, and environment. A portable filter cart is used to both clean existing oil as well as transfer fluid from storage containers to equipment to ensure only clean oil is being put into equipment.

Particle counting offers a multitude of benefits and uses including; verifying oil quality, determine if target cleanliness levels are being achieved, troubleshooting and isolating machine problems and various others. Continual oil sampling, monitoring, and trending are required to affectively identify the contaminant, the source, and means of preventing further ingress.

### **Water Contamination**

Pressure differential between the equipment housing and surrounding atmosphere is a leading cause of moisture ingress. Equipment operation where housing temperature fluctuations occur during frequent on/off running conditions, process fluid temperature changes, outdoor use, and air flow over the equipment create this atmospheric exchange as pressure is equalized.

Sources of water contamination can be similar to sources of particulate contamination such as through system vents/breathers, constant level oilers and seals. Other sources of water contamination is from coolers and heat exchangers, precipitation due to a fall in temperature, introduction of contaminated top up fluid, rain entering outside storage reservoirs, rain entering into barrels stored incorrectly, and in facilities requiring water wash down.

Water will affect the lubricants ability of providing a proper fluid film causing premature failure and excessive wear. Corrosion, cavitation, and premature oxidation and filter plugging of the oil are other symptoms of water contamination.

Water exists in oil in three phases, dissolved, emulsified and free. (Figure 2). In dissolved water, water molecules are dispersed one-by-one throughout the oil, like humidity. In emulsified water it is dispersed as very small droplets in the oil that is creamy and hazy. Free water will settle to the bottom as water is heavier than oil. When moisture is introduced into the housing, the oil absorbs it at a variable rate depending on temperature, type of oil, and lubricant agitation. Typically, oil will hold more moisture at higher temperatures similar to air and synthetic oil generally will hold more than a mineral oil.



**Figure 2. Dissolved, Free, and Emulsified Water**

Water promotes chemical and physical changes in the base oil and encourages aeration problems. Water leads to stable emulsions, higher viscosity, non-Newtonian properties and reduces electric insulating properties of oil. Free and emulsified water are the most damaging to lubricant and equipment but dissolved water should also be limited to below 70% saturation level.

In order to prevent water/moisture ingress, understand potential sources and take steps at prevention such as:

- Hermetically seal bearing areas
- Repair leaking rotary steam joints on dryers
- Inspect heat exchangers and steam coils
- Do not allow water to fall onto equipment
- Use desiccant air filter breathers on vents to reduce condensation
- Train operators in proper use of cleanup hoses
- Keep hatches and covers on reservoirs closed tightly

Various methods exist for removal of water and it is important to understand which phases of water each method is capable of removing. Cost of each type of method can also vary significantly and will be a factor in the decision making of which method to use.

The following is a summary of different methods and which phase of water is removed.

- Bottom sediment & water bowls (BS&W) / sump bottles
  - Free water
- Headspace dehumidification (Desiccants)
  - Primarily dissolved
- Headspace Air Drying

- Dissolved, emulsified, and limited free water
- Gravity separation
  - Free and some emulsified
- Centrifugal separation
  - Free and some emulsified
- Coalescing separation
  - Free and emulsified
- Adsorbent polymer separation
  - Free and emulsified
- Vacuum distillation
  - Free, emulsified, and dissolved
- Air stripping dehydration
  - Free, emulsified, and dissolved

## **Heat Contamination**

Heat is not always recognized as a contaminant but it affects both the lubricant and equipment. Change in viscosity is the first effect of heat contamination and second is oxidation. For every 18 deg. F. increase in temperature the oxidation rate of mineral oil doubles, or the life of the oil is cut in half. Heat does have some advantages as it gives good water shedding, lower foam and aeration tendencies, and improved particle settling rate.

## **Air Contamination**

Not typically considered a contaminant, but the presence of air in its various forms may have an impact on the ability of the lubricant to perform its desired function. Distributed throughout the bulk of the oil, the oil appears cloudy and is often mistaken for water. During visual inspection air will move up where as water moves down. Air also exists in different phases similar to water: Free air, dissolved air, entrained air and foam.

Air contamination affects oil compressibility, causes poor heat transfer, film strength loss, oxidation and cavitation. Different causes of air contamination are: low oil level, cascading of oil into reservoir, insufficient resident time to allow foam to break, and air leakage into pump suction through pipe fittings.

## **Summary**

Minimizing contamination related failures of both the lubricant and equipment can be accomplished by first identifying the contaminant, removing the contaminant, and excluding the contaminant. Identifying and removing the contaminant can be the easiest but it is most cost effective to exclude. Understanding the source of contaminants needs to start with when the oil is received and followed all the way through to each specific piece of equipment. Surrounding environment needs to be considered as well as design of equipment to ensure reliability is optimized.