Maintaining Lube Oil System Cleanliness in Motor Bearing Applications

Technical Report

Maintaining Lube Oil System Cleanliness in Motor Bearing Applications

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REPORT SUMMARY

Lube oil analysis plays a significant role in assessing contamination levels and managing the condition of the lubricant and machine components. By establishing target levels for lubricant properties, contamination, and machine wear—and measuring actual equipment performance against these limits—utilities can quickly identify and resolve abnormal conditions before internal component damage occurs. This report outlines proactive techniques for maintaining lube oil system cleanliness and reducing internal component wear.

Background
By analyzing and trending the chemical properties of in-service lubricants as well as the amount and types of particulates present, utilities can readily identify and correct typical problems such as lubricant degradation, additive depletion, bearing wear, and contamination before failures occur. The process of collecting data, converting it into useful information, and taking action to resolve degraded conditions is critical to the implementation of any predictive maintenance (PDM) technology. This guideline will discuss the "action and resolution" part of the PDM process as it relates to oil analysis. Ultimately, actions to maintain clean/dry lube oil systems for critical plant motors equate to improved equipment reliability and lower maintenance costs.

Objective
To define maintenance techniques for resolving abnormal conditions and proactively controlling contamination.

Approach
The project team compiled the guidelines in this report based on professional experience and a comprehensive literature search.

Results
During normal equipment operation, particle generation and removal occur continuously within a lube oil system. The rate and extent of this process depends on factors such as equipment load, machine speed, operating temperature, the type of lubricant and additive package, bearing design, the type of filtration system, and environmental conditions. As lubricant and machine conditions degrade, the physical properties of the oil and wear/contaminant levels will change. By monitoring and trending these changes over time—and establishing limits for acceptable operation—utilities can readily identify and resolve lubricant and equipment problems.

A key element in determining the root cause of oil-related problems is the ability to classify the types of wear and contaminants present (both chemical and particulate) and their potential source(s). This requires an understanding of chemical properties of the lubricants being used, the metallurgy of internal components within the bearing reservoir, and the sources of contamination

that can enter the system. Wear and contamination can be classified in four categories: 1) internally generated wear/contamination, 2) external contamination, 3) moisture/water contamination, and 4) by-products from the chemical breakdown of lubricants.

These guidelines describe the effects of wear and contamination in a lube oil system and present a number of techniques for maintaining lube oil cleanliness. Among the techniques discussed is the use of portable filtration units for removing accumulated particles and contaminants. The various water removal methods include 1) the use of centrifuging to separate and remove water from the oil, 2) filtration via desiccant filters that use a laminate-type media with an affinity for free water, and 3) vacuum dehydration, which employs a vacuum to pull oil through the system where it is heated then transferred through a vacuum distillation column where the water is boiled off. Also discussed are removal of oxidation by-products, flushing techniques for bearing sumps during oil changes, flushing techniques for forced oil systems, the use of flushing solvents to remove contamination, and disassembly and inspection of bearing reservoirs.

EPRI Perspective

The Electric Motor Predictive Maintenance Program (documented in EPRI report TR-108773-V2) provides lube oil program acceptance criteria based on results of 2500 oil analyses performed on 300 motors over a three-year period. Since the validity of the oil analysis test data is only as good as the sample taken, emphasis is placed on obtaining representative oil samples from the bearing reservoir. The earlier draft guideline report (TR-108773-V1) suggests how to obtain good bearing oil samples for various configurations of vertical and horizontal motors.

Keywords

Lubricants
Motor bearings
Bearing lube oil system
Operating guidelines
Electric Motor Predictive Maintenance Program

INTRODUCTION

For years, utilities have successfully utilized Lube Oil Analysis to monitor the condition of lubricants and the internal machine components that they lubricate. By analyzing and trending the chemical properties of in-service lubricants, and the amount (and types) of particulates present, typical problems like lubricant degradation, additive depletion, bearing wear, and contamination can be readily identified and corrected before failures occur. The process of collecting data, converting it into useful information, and taking action (when needed) to resolve degraded conditions is a critical element in the implementation of any Predictive Maintenance (PDM) technology. This guideline will discuss the "action and resolution" part of the PDM process as it relates to Oil Analysis, and proactive maintenance techniques that can be utilized to resolve abnormal conditions and control contamination. By maintaining clean/dry lube oil systems for critical plant motors, utilities can reduce machine wear, maximize the life of their lubricants, and minimize the occurrence of lubricant-related failures. This equates to improved equipment reliability and lower maintenance costs.

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MAINTAINING LUBE OIL SYSTEM CLEANLINESS IN MOTOR BEARING APPLICATIONS

Sources of Wear/Contamination

During normal equipment operation, there is a continuous process of particle generation and removal which occurs within a lube oil system that is dependent on many factors: equipment load, machine speed, operating temperature, the type of lubricant and additive package, bearing design, the type of filtration, environmental conditions, et al. As lubricant and machine conditions degrade, the physical properties of the oil and wear/contaminant levels will change. By monitoring and trending these changes over time, and establishing useful limits for acceptable operation, lubricant and equipment problems can be quickly identified and resolved. A key element in determining the root cause of oil-related problems, is the ability to classify the types of wear and contaminants present (both chemical and particulate) and their potential source(s). This requires an understanding of chemical properties of the lubricants being used, the metallurgy of the internal components within the bearing reservoir, and the sources of contamination that can enter the system. Wear and contamination can be classified in four different categories:

Internally Generated Wear / Contamination

Internally generated wear/contamination can be a combination of ferrous and non-ferrous particles that are generated from bearings, slinger rings, seals, and other internal components that come in contact with the lubricant. In forced oil systems, oil pump wear, filter debris, and particulates from system piping/reservoirs may also be present. The particles generated from internal components can be caused by abrasive wear from metal particles and other contaminants circulating in the system, metal surface fatigue, loss of film thickness/strength, and other fault conditions. In order to determine what is wearing, how severe the condition is, and what corrective actions may be required, information regarding the amount, size, and types of particles is required. Typical elements monitored to assess the amount of internal wear present include: iron, copper, tin lead, aluminum, chromium, silver nickel, titanium, and antimony.

External Contamination

Contamination from airborne particulates (dirt, coal dust, organics), process fluids (freon, acids), and other external processes are another source of contamination that can affect lubricant and machine condition. These contaminants typically enter lube oil systems from the outside environment through breathers, fill/vent plugs, access covers, and other entry pathways. Typical parameters monitored to assess the amount of external contamination present include FT-IR spectroscopy, and elemental levels of silicon, sodium, boron, and potassium.

Moisture/Water

One of most common and damaging sources of contamination is water/moisture. Even at low levels, the presence of water will corrode metal surfaces (i.e. rusting), increase oxidation, and reduce the oil film strength (which can lead to increased wear). There are a variety of sources where water can come from (cooler leaks, seal leaks, condensation), and pathways into the lube oil system (through breathers, access covers, vents, and other openings). Depending on the type and severity of the problem, water may exist in three different states: free water, emulsified water, dissolved water. It is important to understand where the source of ingression is and the type(s) of water present, so that adequate corrective actions can be taken to eliminate the problem and restore water concentration levels to acceptable standards.

Byproducts from the Chemical Breakdown of Lubricants

Most industrial lubricants specified for use in motor bearing applications are formulated and manufactured with high quality base stocks and additive packages designed to withstand chemical breakdown during normal operation. As lubricants age and oxidation occurs, additive levels are depleted and eventually insoluable acids and oxides are created that corrode metal surfaces and promote the formation of sludge and varnish. This process is accelerated under abnormal conditions such as high operating temperatures, water contamination, air entrainment, and excessive machine wear. Typical parameters monitored to assess the chemical breakdown of lubricants and oxidation include: FT-IR spectroscopy, Total Acid Number (TAN), and elemental levels of Zinc, Phosphorous, Barium, Calcium, Magnesium, and Molybdenum.

Effects of Wear/Contamination

Internal Wear and Contaminants

Particles generated from internal component wear and external contamination are inherently abrasive to the metal surfaces they come in contact with. They may also chemically interact with the oil itself, causing the formation of insoluable acids. These acids will corrode metal surfaces, deplete additives, and accelerate the chemical breakdown the lubricant.

From a diagnostic perspective, the size of the particles is an important factor in determining what wear mechanisms will occur and the effects that these particles will have as they circulate within the lubrication system. Smaller particles (less than 15um) typically pass through the bearing clearances and contact areas, cutting away at the metal surfaces they come in contact with. This results in the damage to the metal surfaces, fatigue, and the generation of new particles that will be introduced into the system. In some cases these particles may also imbed themselves in the metal surfaces creating a surface anomaly that itself acts as a cutting tool against the opposing bearing surface. Larger particles (greater than 15um) will wear machine surfaces in a similar fashion, or they may break into smaller particles. In either case, the amount of internal component wear will increase, accelerating the amount of abrasive particles and contaminants that are in the system (see Figure 1-1).

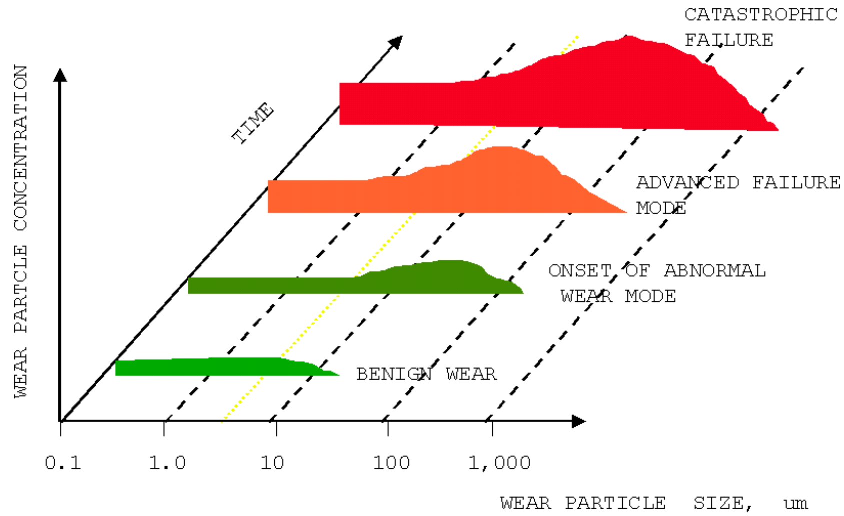

Figure 1-1
Failure Progression Due to Wear

Moisture/Water

Water is one of the most harmful contaminants that can affect lubrication systems since it degrades both lubricant and machine condition. At low concentrations, the presence of water will increase the rate of oxidation, and deplete additives through the process of hydrolysis. As conditions worsen, insoluable acids are created that cause corrosion of the metal surfaces, pitting, bearing fatigue, and the generation of abrasive rust particles which accelerates machine wear. These acids also breakdown the chemical properties of the lubricant, and lead the formation of sludge and varnish. Under extreme conditions, large amounts of water can lower viscosity and reduce film thickness, to the point where metal-to-metal contact may occur. The end result is inadequate lubrication and reduced bearing life. A study by Timken Bearing Co., which measured the effect of water on bearing life, identified a 75% reduction in bearing life from just 0.1% water (see Figure 1-2).

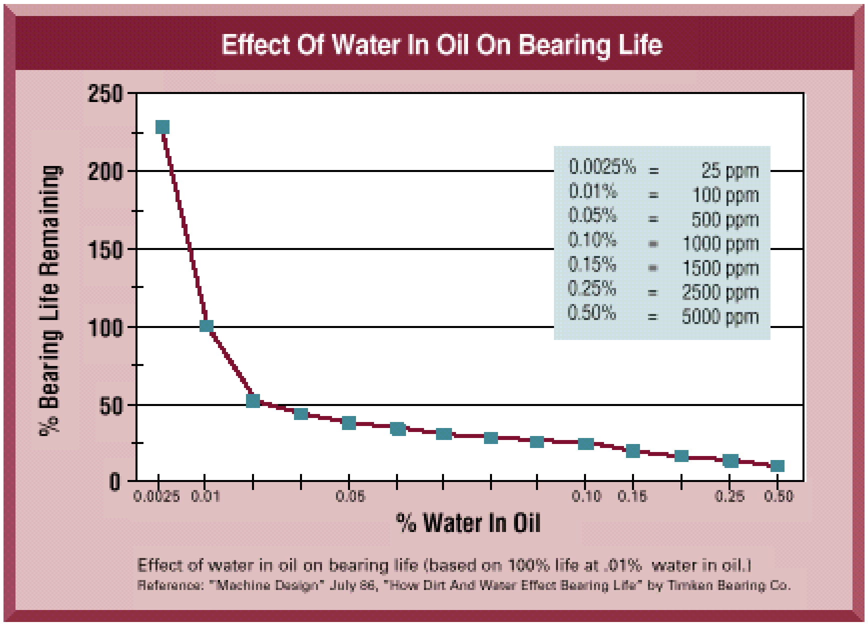

Figure 1-2
Effects of Water Contamination on Bearing Life (Courtesy of Parker Filtration/Timken Bearing Co.)

Byproducts from the Chemical Breakdown of Lubricants

The chemical breakdown of lubricant properties from oxidation creates insoluable acids and oxides that deplete additives, corrode metal surfaces, and promote the formation of sludge. As the amount of insoluables accumulates, the viscosity will increase, causing greater fluid friction and an increase in operating temperatures. These higher temperatures will increase the rate of oxidation and the chemical breakdown of the lubricant. Under extreme conditions, lacquering may occur as oxidation deposits harden and adhere to metal surfaces. In forced oil systems, where the lubricant may act as a hydraulic medium, the accumulation of sludge deposits can also cause slow and erratic control.

Maintaining Lube Oil System Cleanliness

Lube Oil Analysis plays a significant role in assessing contamination levels and managing the condition of the lubricant and machine components. By establishing target levels for lubricant properties, contamination, and machine wear, and measuring actual equipment performance against these limits, abnormal conditions can be quickly identified and resolved before internal component damage occurs. Controlling contamination is a key element in maintaining lube oil system cleanliness and reducing internal component wear. The following section outlines proactive techniques that can be used to resolve lubricant and contamination problems that are identified through periodic oil analysis activities, and the application of these practices for typical lubrication problems.

The Use of Filtration for Contamination Removal

The use of portable filtration units is an effective technique for removing particles and contaminants that have accumulated in bearing lube oil systems. Important factors that need to be considered when designing a filtration solution include: the type and quantity of contamination present, the amount of degradation that has already occurred, and the filter media used. In cases where the equipment is operating well, and the contamination is only a result of long-term build-up of wear and debris, filtration can be very effective. In cases where the equipment is operating in a known failure mode, environmental conditions are severe, or system design is inadequate to prevent the continuous ingress of contamination, filtration will only be an effective short term solution; the root cause of the problem (i.e. the source of contamination) must still be corrected in order to prevent its reoccurrence.

When utilizing filtration techniques to remove contamination, an understanding of filter types, filter ratings, and filter efficiencies is required in order to select the right filter for the job. There are two basic types of filter media: surface media or depth media. Surface media filters are typically wire mesh elements with fixed pore sizes that capture particles as the fluid flows straight through the element. Depth media filters are usually cellulose or fiberglass elements with filter pores that vary in size and are inter-woven together to create an indirect path for fluid flow. A relative comparison of characteristics for surface versus depth filters is provided in Figure 1-3.

Media Material	Capture Efficiency	Dirt Holding Capacity	Differential Pressure	Life in a System	Initial Cost
Fiberglass	High	High	Moderate	High	Moderate
Cellulose (paper)	Moderate	Moderate	High	Moderate	Low
Wire Mesh	Low	Low	Low	Moderate	High
Reference: The Handbook of Hydraulic Filtration: Parker Filtration					

Figure 1-3
Filter Media Comparison Matrix

Besides the type of filter, filter rating and Beta Ratio are important design parameters that should also be considered when selecting a filter for removing contamination. Filter rating specifies the size of particles that are captured by the filter (in microns). There are two types of filter ratings that are commonly used by manufacturers to specify filter performance characteristics: nominal and absolute. Nominal filter ratings specify the size of particles removed at a pre-determined efficiency level (which can vary from 50-99% depending on manufacturer). Absolute ratings, as the name implies, have 100% efficiency at the specified particle size.

Beta Ratio is a measure of the particle capture efficiency of a filter at a specific particle size, and is defined in the equation below. The more efficient the filter is in removing contamination, the higher the Beta Ratio (see Figure 1-4).

$$\mathbf{B}_x = \left(\frac{\text{\# of particles upstream of the filter > particle size } (x)}{\text{\# of particles downstream of the filter > particle size } (x)} \right)$$

where *x* is a specific particle size (microns)
(as measured by ISO 4572 Multi Pass Beta Test)

$$\text{Efficiency}_x = (1 - 1/\text{Beta}_x) * 100$$

Beta Ratio (at given particle size)	**Capture Efficiency (at same particle size)**
1.5	33.3%
2.0	50.0%
5.0	80.0%
10.0	90.0%
20.0	95.0%
75.0	98.7%
100	99.0%
200	99.5%
1000	99.9%

Figure 1-4
Beta Ratio vs. Capture Efficiency

When selecting a filter, it is imperative that BOTH filter rating and efficiency be specified to ensure the filter will be capable of reducing contamination to the desired cleanliness levels. In journal bearing applications, equipment manufacturers recommend removing all clearance size particles from the system in order to reduce wear and maximize bearing life. To achieve this, the Pall Corporation (major manufacturer of filtration products) recommends utilizing at least a 7um filter with a Beta Ratio of 1000. This type of filtration will remove 100% of all particles >7um, and 90% of all particles >3um, resulting in a ISO cleanliness level of 16/14/12.

It is important to realize that in order to resolve any lube-oil-related problem, analysts must treat the cause, not just the symptoms. The use of filtration techniques can be very effective in resolving abnormal increases in particulate levels, especially when a large concentration of the particles present are smaller wear or contaminants that have accumulated in the system over a long period of time. If large wear particles are pre-dominant, it is usually an indication of an internal machinery problem that requires further investigation. In these situations, the use of filtration will only provide short-term relief to a more significant problem that will probably arise again. Reservoir size is also an important factor in determining whether or not to utilize filtration to remove contaminants. In larger oil reservoirs, the use of filtration is often a justifiable solution. In smaller oil reservoirs, it is usually more cost effective to flush and change the oil, rather than utilizing filtration techniques. Some general guidelines for determining when filtration techniques should be considered include:

1. Larger lube oil reservoirs (greater than 10-15 gallons)

2. When particle count measurements have increased above some pre-determined target level as a result of a long-term build-up of wear particles and/or external contamination, especially when the increases are greatest in the 5, 10, and 15 micron regimes.

3. When spectrochemical and/or wear particle levels have increased more than three standard deviations above median values, and the primary concentration of particles is smaller particles (i.e. less than 15 microns)

4. When existing lubrication systems lack sufficient filtration capability to continuously remove normal wear (i.e. systems with no filtration or systems where external filtration can be used periodically to supplement existing filtration capabilities).

Water Removal Techniques

The removal of water and its effects is a challenging task that be handled in a variety of ways. In order to determine which water removal method is best, it is important to know what form the water is in: free water, emulsified water, or dissolved water. Free water is the easiest to remove since it has not chemically reacted with the lubricant. Dissolved water is the hardest to remove, requiring dehydration processes to separate the water from the lubricant. Three (3) common technologies which can be used to remove water contamination are:

1. Centrifuging -Relies on the centrifugal forces to separate and remove water from the oil; centrifuging is effective in removing free water and some emulsified water, and is ideal for removing large quantities of water and/or cleaning up large lube oil reservoirs.

2. Filtration using Desiccant Filters -Desiccant filters use a laminate-type media with an affinity for free water, and are useful in removing small amounts of free water. As water passes through the filter, it bonds to the media and is trapped within the element.

3. Vacuum Dehydration -Vacuum dehydration is the most effective process for removing water since it is capable of removing free water, emulsified water, and up to 80% of all dissolved water. It utilizes a vacuum to pull oil through the system where it is heated to approximately

150°F, and then transferred through a vacuum distillation column where the water is boiled off (see Figure 1-5). Vacuum dehydration systems are capable of reducing water levels down to 0.005% (50 ppm).

The use of the above technologies is dependent on the target level of water contamination desired, and the actual type and amount of water present. In journal bearing applications, where water contamination can reduce film strength and increase the risk of metal-to-metal contact, water levels must be maintained as low as possible. As a result, vacuum dehydration is the most effective technique to use. It is also the preferred method anytime dissolved water is present, since it is the only technique that is capable of removing this type of water. In cases where only free water is present in small concentrations, the use of desiccant filters can be a viable alternative, depending on the desired target level for water. In cases where only free water is present, in large concentrations, centrifuging is often the preferred alternative, since it is specifically designed to remove large amounts of water.

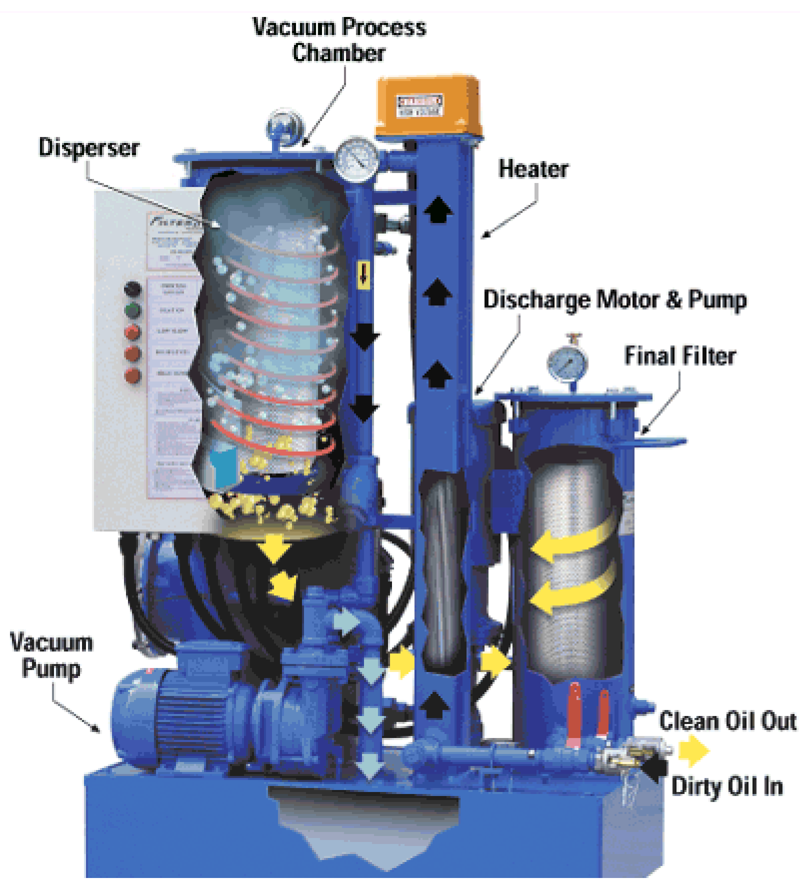

Figure 1-5
Vacuum Dehydration Unit (Courtesy of Kaydon)

Techniques for Removing Oxidation Byproducts

The process of oxidation creates insoluable acids and oxides that corrode metal surfaces and chemically breakdown the oil. The use of electrostatic precipitators is one method that can be used to remove these damaging byproducts. These systems use specialized filter media that charge the carbon insoluables and allow them to be precipitated onto collection plates, and removed from the system. The use Fullers earth filters and ion-exchange resins are alternative methods that can be used to remove these unwanted insoluables. However, care must be taken when utilizing these techniques, as some types of media may also remove additive elements during the filtration process. Lubricant manufacturers should be consulted when evaluating options for removing oxidation byproducts to ensure filtration efforts do not negatively affect the physical properties of the oil.

The Use of Portable Filtration Units for Contamination Removal

The use of portable filtration carts to remove contamination can be a cost-effective technique for maintaining oil cleanliness levels (see Figure 1-6). These self-contained units can be used in a wide variety of situations for controlling and maintaining system cleanliness including:

- Transferring new oil from drums into the system
- Removing contamination from in-service fluids
- Supplementing existing filtration systems to achieve lower cleanliness levels

Figure 1-6
Portable Filtration Cart for Contamination Removal (courtesy of Parker Filtration)

Manufacturers of portable filtration units currently offer a wide range of features and capabilities for removing contamination in lube oil applications. Some of the more important features that should be considered when determining which portable filtration unit to use include:

Features	Benefits
Multiple Flow Rates	Allow the use of the unit in low and high viscosity applications
Two Stage Filtration	Allows the use of one filter for capturing large particles, and a second filter for capturing smaller particles or water
Multiple Filter Options	Allows the use of a wide variety of particulate AND water removal filters
Filter Differential Pressure Indication	Allows users to monitor filter performance and condition to identify when filters require changing
Automatic Bypass Valve Option	Automatically bypasses filter when contamination has built-up to a specified level and the filter has been exhausted
Pump Suction Strainer	Reduces the risk of pump damage by preventing large particles from entering the pump cavity
Sample fittings	Allows sampling of oil during the filtration process to measure effectiveness and determine when target cleanliness levels have been achieved
Safety Valves	Prevents overpressurization of the system and pump damage as a result of improper venting

When utilizing a portable filtration unit to remove contamination, some key design parameters that must be considered are filter size/rating, fluid viscosity, flow rate, and oil temperature. All of these parameters will have an impact on the systems' ability to achieve a desired cleanliness level. From a procedural perspective, the following steps should be followed to maximize the effectiveness of the filtration process:

- All hoses and pipes should be clean and contaminant-free prior to placing them in the oil reservoir; where practical, filter carts should not be shared across different lubricant types to reduce the potential for cross contamination and chemical interaction
- All access covers and open ports should be sealed or plugged to prevent the introduction of contaminants into the system
- If the lube oil system is equipped with a circulating pump, it should be running during the filtration process to flush contamination from internal components and reservoir surfaces and maximize the removal of all suspended contamination
- Filter differential pressure should be monitored during the filtration process to identify when the filter has become exhausted or blocked. Typical limit is 25 psid.

  NOTE: As the filter becomes blocked with contaminants, the differential pressure across the filter will increase (slowly at first, and then exponentially as the filter reaches its end of life).

- When changing filters, they should be inspected for metal particles, sludge, and other contaminants, to identify potential problems that may have gone undetected by the oil analysis testing
- Obtain oil samples during the filtering process to determine when target cleanliness levels have been achieved
- Continue to circulate oil for another 1-2 hours after target levels have been achieved to ensure the effectiveness of the filtration process

The use of portable filtration carts can be very effective in resolving abnormal increases in particulate levels in larger oil reservoirs, especially when a large concentration of the particles present are smaller wear or external contaminants that have accumulated in the system over a long period of time. They can also be effective in removing water contamination, if the quantities of water present are small, and only free water is present. Guidelines previously defined in the sections "The Use of Filtration Techniques for Contamination Removal" and "Water Removal Techniques" should be used for determining when portable filtration is a viable solution.

Flushing Techniques for Bearing Sumps during Oil Changes

As previously stated, the use of portable filtration units may not be the optimal solution for resolving contamination problems in certain applications or conditions. For example, in dead-sump bearing reservoirs that contain small quantities of oil (i.e. less than 10-15 gallons), it is often more cost-effective to change the oil rather than spending the time and materials required to filter out the contamination. Similarly, when an excessive amount of water contamination and oxidation byproducts (i.e. sludge and varnish) are present, oil changes may be a more effective solution as compared to filtration. As a result, it is essential that proper procedures and techniques be utilized during oil changes to effectively remove all contaminants within the reservoir. The following steps are recommended during oil changes to properly flush bearing reservoirs and remove contamination:

- Drain oil as soon as possible after operation while the oil is still hot and particles/contamination are still suspended in the oil.

  NOTE: When the oil is drained after the machine has been shutdown for a long period of time, water, sludge, and contamination will settle to the bottom of the reservoir and may not get removed when the oil is changed

- Open all drain ports to maximize the removal of contaminants
- Replace all oil filters (if present) during the oil change; inspect filters for metal particles, sludge, and other contaminants to provide an indication of problems that may have been undetected by the oil testing data
- Flush bearing reservoirs with clean, new oil or approved cleaners to remove additional contamination that may still be present (i.e. particles that have adhered to the internal metal surfaces and the reservoir walls)
- Continue flushing multiple times until the oil exiting the bottom drains is clear and contaminant-free
- Refill reservoir with new oil to proper level; whenever practical, use portable filtration units to add new oil to ensure cleanliness and turn over the reservoir at least 4-5 times to remove any residual contamination that may still be present
- Obtain an oil sample shortly after putting the equipment in service to establish new baseline readings and ensure the oil change was effective in resolving the problem

Regardless of the situation or condition, the use of flushing techniques should always be used when changing oil to ensure all unwanted contaminants are adequately removed from the system.

Flushing Techniques for Forced Oil Systems

In forced oil systems, system flushing can be an effective alternative for removing contaminants and wear that have accumulated on internal components, system piping, and reservoir surfaces. This technique uses the existing lube oil pumps to circulate a low viscosity flushing oil (ISO 32) through the system under no-load conditions to wash out loose contamination. By utilizing a light oil, the velocity and turbulence of the fluid being circulated is maximized, which helps to remove particulate matter that may have adhered to internal surfaces. Some important considerations that should be followed during system flushing are outlined below:

- Follow manufacturers' recommendations for selecting the proper flushing oil for the system
- Maintain oil temperature at normal operating ranges to maximize the velocity of the oil (it is recommended that oil temperature be at least 120-140°F)
- Monitor filter condition and replace or clean filters frequently during the flushing process

- After the initial flush, drain the oil, replace filters, and refill with the proper lubricant
- Sample equipment shortly after placing it back in service to assess the effectiveness of the flush and re-establish baseline levels

An alternative flushing technique that can be utilized to eliminate contamination that cannot be removed using conventional methods, is a high velocity flush. Contrary to normal flushing procedures that utilize existing lube oil pumps to circulate the flushing fluid, high velocity flushes use an external pump and filter to flush the oil through the system at 5-8 times the normal flow rate. The oil temperature is also increased (up to 185°F) to thermally shock the system. The combination of high fluid velocity and high oil temperatures greatly enhances the cleaning process and is very effective in removing particles and debris that have adhered to the internal piping and bearing components. Once contamination is removed from the internal surfaces, the fluid is circulated back to the reservoir where it can be filtered out. Equipment manufacturers should be consulted when utilizing this technique to ensure bearing seals and other system components can withstand the high volumes of oil being circulated without causing damage.

System flushing is recommended for larger lube oil systems that have existing filtration that can be used to remove unwanted contaminants. It is particularly effective in removing contamination that may settle in piping sections and/or internal components within the system, that would not normally be purged during an oil change. It is often a quicker and more effective solution when large amounts of wear and/or external contaminants are present.

Use of Flushing Solvents to Remove Contamination

The use of flushing solvents during system flushes and oil changes is another alternative that can be very effective in removing contamination. They are especially useful in removing accumulations of sludge, varnish, and other contaminants that have been generated from oxidation, water contamination, and other processes that have chemically degraded the lubricant. Flushing solvents act as a detergent to dissolve oxidation deposits and loosen insoluable materials, which can then be removed using filtration and other removal techniques. Because high concentrations of these fluids can be potentially damaging to seals, gaskets, protective linings of reservoirs, and other internal components, it is highly recommended that only approved flushing solvents be used. Exxon and Mobil both offer approved flushing solvents (Exxon System Cleaner and Mobilsol A respectively) for use in cleaning and flushing bearing systems. These solvents have a high flash point, rust inhibitors, and dispersants to effectively remove deposits and insoluables, and are compatible with all seals up to a maximum concentration of 20%. The Exxon System Cleaner is solvent-free and oil-soluable, which makes it safe for use with all ferrous and non-ferrous metals used in industrial equipment.

The use of flushing solvents to remove contamination typically involves adding a small concentration of the flushing solvent to the lube oil system while the equipment is operating. A 5% concentration is typically recommended to minimize the chemical effects on seals and other internal components, and ensure the added flushing solvent does not lower the viscosity and flash point of the mixture below manufacturers minimum levels. The following procedure is recommended for the use of flushing solvents in operating equipment:

- Replace all existing oil filters BEFORE adding flushing solvent to prevent it from dissolving material already trapped in the filter and circulating it back into the system

  NOTE: Because the flushing solvent will be dissolving and introducing a large quantity of deposits and other contaminants into the system, filter differential pressure should be closely monitored to identify when filters need replacement

- Add flushing solvent to the reservoir at a 5% concentration (or as recommended by manufacturer) while the equipment is operating at normal speed and temperature
- Operate the system for at least 8-24 hours with the mixture installed, and monitor bearing temperatures and other performance parameters to identify potential operational problems
- After the mixture has circulated for the recommended time, shut down the equipment and immediately drain the oil quickly while the oil is still hot and particles and insoluables are still suspended in the oil
- Flush the system with an approved flushing oil or new oil to remove the flushing solvent and any additional particulate matter that may still be present

  NOTE: Flushing solvent must be completely removed to prevent viscosity dilution after new oil is added

- Repeat flushing procedure until the oil being drained is clear and particulate-free
- Add new oil with appropriate specifications and replace all oil filters (if applicable)
- Sample equipment shortly after placing it back in service to assess the effectiveness of the flush and re-establish baseline levels

The use of flushing solvents is recommended whenever excessive oxidation byproducts (sludge and varnish) are present, or in cases where large amounts of wear debris are present. In these situations, there is a high likelihood that particles, sludge, and other contaminants have adhered to the internal surfaces of the oil wetted components, and normal flushing procedures will not be effective in removing all of the contaminants present. The detergent properties of the flushing solvent will aid in the removal of the contaminants and clean the internal surfaces, thus maximizing the effectiveness of the flush. As previously stated, extreme care should be taken when using these solvents to ensure compliance with manufacturers guidelines and recommendations.

Disassembly & Inspection of Bearing Reservoirs

The use of filtration and flushing techniques are non-intrusive methods for removing contamination and maintaining system cleanliness. Under extreme conditions (heavy oxidation, water contamination, varnishing, and sludging), these techniques may not be effective enough to reduce cleanliness levels to the desired range, and bearing disassembly will be required in order to clean the internal components. Disassembly and inspection may also be warranted if large, abnormal wear particles (i.e. wear greater than 30 microns) are present, indicating an internal component problem or damage. When disassembling and inspecting bearing reservoirs, extreme care must be taken to keep dirt and other foreign material from entering into the system. When removing sludge, varnish, and other contamination, approved flushing solvents should be used to clean the bearings, housings, and other metal surfaces. Care should be taken not to expose seals, gaskets, and other internal components that are not compatible with the cleaning or flushing solvents.

Once all deposits have been removed and all internal surfaces are clean, all components should be flushed with new oil to remove any flushing solvent residue that may exist. When assembling, care should also be taken not to use an excessive amount of sealing or pipe compounds, that could work its way into the system and cause damage. Once assembly is compete, the entire system should be flushed with an approved flushing oil or new oil to remove any debris which may have entered the system during assembly. Finally, after the equipment is placed back in service, an oil sample should be taken within 8 hours of operation to assess the condition of equipment and ensure target cleanliness levels have been achieved.

Proactive Measures for Controlling Contamination

The previous sections have outlined some alternative strategies for removing contamination in bearing lube oil systems. These techniques are generally utilized "after the fact" to address the <u>effects</u> of excessive machine wear, water contamination, external contamination, and the chemical breakdown of oil. Although contamination removal techniques are an important part of any Lube Oil Analysis program, it is imperative that the root cause(s) of the problem be determined and corrected to prevent the reoccurrence of the same condition again in the future. Equally important is the implementation of proactive measures to minimize machine wear and prevent contamination from entering the system. The following best practices are recommended for controlling contamination and maximizing the effectiveness of an Oil Analysis Program:

- Use dessicant breathers for reservoir vents to remove moisture and particulate from the air entering the reservoir
- Maintain seals and gaskets to prevent oil leakage (if oil can get out, then contaminants can get in)
- Ensure bearing fill ports and reservoir access covers are properly sealed to prevent the ingress of external contaminants
- Check bottom drains on a regular basis to identify and remove any free or emulsified water that may be present; investigate and resolve the source of water
- Use filtration techniques to add oil and periodically remove contamination from lube oil systems
- Use proper sampling techniques to obtain a representative sample from the "working area" of the bearing
- Ensure lab testing packages are designed to evaluate equipment condition, lubricant condition, and contamination levels
- Use oil analysis results to establish lubricant change intervals; wherever possible, eliminate time-based oil changes
- Implement a formal data management strategy to identify, track, and resolve lubricant-related problems

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