LUBE-TECH

NO.36

STRATEGIES FOR EFFECTIVE CONTAMINATION MONITORING AND CONTROL

It has been estimated that the exclusion of system contamination costs about one-tenth what it would cost to remove the contamination once it has entered our system. Therefore, we must evaluate the options associated with the exclusion of contamination vs. the removal. Advances in proactive maintenance have produced numerous products that will prevent the ingression of contamination. We need to look at the proactive options for maintaining lubricant and mechanical reliability and for sealing our systems from their surrounding environments. First, we need to take a detailed approach to identifying what is appropriate for our equipment.

We need to look at:

- What is contamination and how do we identify it?
- How can we get a qualitative or quantitative measure of the contamination?
- What are the effects associated with the different states of contamination?
- Where are the entry points for contamination on our systems and what are the options for exclusion at these locations?

Contamination is often defined as anything that, pollutes, infects or has an undesirable affect something else. This is a very broad definition when referring to lubricant and equipment reliability. The most common forms of contamination in hydraulic and lubricated equipment are solid particles, air, heat and water. Other forms of contamination found in hydraulic and lubricated equipment include, but are not limited to fuel, glycol and radiation. Though contamination can exist in several states, they all have detrimental effects on our lubricant and our machine surfaces in one way or another. Generally, oil contamination will modify the physical and chemical properties of the lubricant and chemically attack and destroy machine surfaces.

Solid Particle Contamination

Solid contamination is the most common form of contamination and exists, at some level, in virtually every hydraulic and lubricated system. Solid contamination also exists in brand new lubricants before they are even put into your equipment. Solid contamination is the most common because it has the opportunity to enter our system at several locations. Because we will never be able to remove all the solid particles, we have to set limits to determine how many particles we are willing to allow in our lubricant. Our oil analysis program should dictate an ISO 4406 Solid Contamination Code target level that we are trying to maintain.

Solid contamination can be built into our system, it can be airborne, it can enter your system in new oil top-ups, through defective seals and through cross contamination from filter carts. We want to be able to minimise the amount of solid contamination that is ingressed into our system and be able to remove the dirt that is already in our system.

The biggest culprit for letting dirt enter your system is the air breather. Most systems come with a standard paper media breather with a nominal rating of about 40uM. This means that the smaller, more destructive particles are able to get into your system very easily. Upgrading a standard breather to a high-efficiency filter is easily done using commercial bayonet adapters and quality synthetic hydraulic filters.

Adding new oil to a system is a very common practice that can also yield high concentrations of contamination. Industry has no guidelines for new oil cleanliness which means that it may end up at your plant with a cleanliness code of up to 23/20 or higher. Pre filtering your new oil before it enters your system is a very efficient way of minimising the particle contamination and reducing the damage those particles will cause. Even opening our system fill port to add new oil is a cause for concern in many plant environments. Adapter manifolds are available that maintain a closed system, even when filtering the oil, topping up the fluid or draining the tank.

Cylinder rod seals also let solid contamination pass by into our system. Quality rod boot bellows are an effective way of covering the rod on extension and keeping it clean.

Solid contamination can also be generated within our systems as mechanical components come in contact with each other. When this happens we need to ensure that we have an efficient means of removing the particles before they have the opportunity to generate more wear?

Size, shape, colour and hardness are key characteristics of identifying where the solid contamination originated. The analysis of a particle will lead to the identification of the component that is wearing if we have properly identified the metallurgy if our system components. Depending on the type of metal, some metals, like copper, lead, steel and iron will act as a catalyst and accelerate the natural tendency of the lubricant to become acidic and oxidise.

There are several filtration options available for the removal of solid particle contamination in our systems. We have to consider location of our filters, media type, cost and beta rating. Our goal is to include a filter on our system that has a beta rating that will allow us to achieve an ISO cleanliness code equivalent to our target setting.

The beta rating of a filter indicates the overall efficiency of that particular filter when tested as per ISO 4572 Mutipass Test. This test measures the amount of particles at a specific size and those greater than the indicated size, upstream of the filter, in relation to those same particles downstream of the filter. This value gives us a % efficiency that we can assume our filter has. For example, a filter with a Beta 10 = 100 rating means that this filter will remove 99.00% of all particles 10um and larger.

There are three ways we can quantify the particle contamination in our lubricants. Optical Microscopy, Automatic Optical and Automatic Pore Blockage. When quantifying solid particles in lubricants, the international standard is the ISO 4406 Solid Contamination Code. This standard gives us a three number code, which corresponds directly to the concentration value for particles at 2um, 5um and 15um per ml. The relationship of the ISO code we get from our particle count is extremely important because it indicates the size distribution of solid particles as well as the quantity. Usually we can conclude that the larger the particle, the newer the wear. If the particle count indicates high concentrations of large particles, action should be taken to identify the characteristics of these large particles.

Water Contamination

Water can be introduced to your lubricant much the same way as solid contamination. The difference is that many of us do not recognise water as a harmful or destructive contaminant or a root cause to mechanical and lubricant failures. We unknowingly put lubricants contaminated with water into our systems every day. Therefore, it is important to make a proactive effort to minimise the amount of water ingression before and after the lubricant is put into service.

Water in our oil can be the root cause of many destructive by-products. Water by itself in oil can increase the rate of oxidation by six to as much as ten times. A combination of water and a metal catalyst such as copper will increase this level even further. Water in oil encourages rust, loss of lubricant film strength, change in viscosity, foaming, acid and sludge formations. Water will also deplete our lubricant's additive packages such as rust inhibitors, anti-moisture and de-mulsifying agents and create by-products such as sludge, bacteria, acids and sediment. Water also has undesirable effects on our machine surfaces. Corrosion, cavitation, sticky valves and filter plugging are all moisture-related effects.

Water ingression begins at the manufacturing level. Most new lubricants will have some level of dissolved water in them. Though we can't control the amount of water ingressed into the lubricant before it reaches our plant, we seldom recognise the opportunity for moisture ingression when it does reach our plant. When new oils are in storage the change in surrounding temperature will cause the oil in its container to expand and contract. When the oil contracts in cooler temperatures it will draw in anything surrounding the container seal, including air, dirt, debris and moisture. This ingression will

(Continued on Page II)

occur regardless of the container being sealed or previously opened. Leaving container lids open or not sealed tightly will introduce greater amounts of contamination ingression. Humid environments, equipment wash downs, poorly maintained leaky water coolers and poor system breathers are all potential sources for the ingression of water into our systems. Taking a proactive approach to restricting the amount of water that can enter our systems will help maintain the reliability of our lubricants and our equipment.

Most industrial lubricants are naturally hygroscopic, which means they have a natural attraction to water. Typically, new hydraulic oils can hold up to approximately 200 parts per million (ppm) of dissolved water. This level will vary depending on the characteristics of the oil. Dissolved water means that the water is held throughout the oil in single molecules. In this state the oil is clear and clean looking and the water is invisible. When water is concentrated from approximately 200 to 1000 ppm, we call this the emulsion stage. When the water is emulsified in the oil it means that water molecules have joined to form larger single concentrations that are held in suspension evenly throughout the oil and give the oil a cloudy appearance. Any concentrations of water in new hydraulic oil greater than approximately 1000 ppm will be able to separate from the oil and settle to the bottom of the reservoir. We call this free water. As oil ages the values discussed above will increase significantly.

It is important to be able to recognise when and how water can be introduced to our systems, more importantly we need to know how we can remove it once it is there. We need to consider the cost associated with removing water from our lubricant. Water removal filters are an excellent, relatively inexpensive way to take small amounts of water from our lubricant. For example, if our target level of moisture in our oil is 500 ppm, and our lab result indicates that there is 700 ppm of water, a water removal filter will bring us back into our target range. For levels of moisture far greater than 1000ppm we have to employ more precise methods of water removal. Vacuum dehydrators, centrifugal separators and settling tanks offer excellent water and particle separation from oil but are often very expensive to procure and maintain and may even outweigh the cost of simply replacing the contaminated oil with new oil.

An excellent rule of thumb for setting targets and limits for water contamination is to set them as tight as possible. This allows for early indication for cooler and seal leaks. Every system will have some level of water dissolved in the oil. When this level increases, we should implement a three-step plan. The first step is to identify how the moisture has entered our system. The second step is to prevent the ingression from recurring. The third step is to remove the moisture.

We can measure the level of moisture in several ways. The best way to do so is to perform a crackle test on a sample. The crackle test will give you an approximate indication of how much water is in your oil by the way the oil reacts when dropped on a hot plate at 320 deg. F. This method is very inexpensive, relatively accurate, can be done on-site and tells us as much information as we need to know. We should expect our lubricant to free of water. When we have indication either by visual assessment (emulsified, free water) or crackle test, it is not as important to have a quantitative measure of the level of moisture as it is to find out how it was ingressed and how we can eliminate its recurrence. If an absolute measure is needed, Karl Fischer or Fourier Transform Infrared (FTIR) laboratory tests will give us accurate, trendable moisture quantities.

Heat Contamination

Heat was always considered a problem with simple solutions with regard to hydraulic and lubricating systems. Heat was not often referred to as contamination. Heat can be the cause of many system problems and can also be the result. Heat will result when the system is suffering from it's environment, incorrect lubricant, mechanical wear, excessive load and duty cycles beyond design specifications. We then provide simple "Band-Aid" solutions such as coolers and higher viscosity lubricants without first examining the cause of the heat.

Systems should maintain a constant temperature under normal operation. The effects of environment and abnormal operation may cause changes in operating temperature. We must realise that every 15 degrees Fahrenheit above 125 we reduce the life of the oil by half. Therefore the immediate benefits of cooler running oil are equivalent to the cost of an oil change. Hot running oil has many other disadvantages including viscosity thinning, additive depletion, thermal degradation and varnishing. Conversely, hot running oil has many desirable advantages such as good water shedding and vaporisation and a lower tendency to foam and aerate. Though there are many advantages to hot running oil, the benefits of cool, clean and dry running oil can not be surpassed. Hot running oil is a Band-Aid to reduce other forms of contamination.

Our proactive and preventive maintenance programs must incorporate a trend of our system hot spots in much the same way we trend the other forms of contamination. A simple heat gun scan each time we draw an oil sample from our systems may aid in the diagnosis of machine conditions when coupled with oil analysis reports.

Air Contamination

Air contamination, like water and particulate contamination, exists in some degree in all lubricating oils and exists in four states of co-existence. Mineral oil will suspend certain levels of dissolved air, much like water, to some degree without visual indication. Typical levels for dissolved air is less than 10%. When the level of air in oil increases past 10% to 30% we call this entrained air. This is when air bubbles cause cloudiness in the oil. When the air to oil mixture reaches greater than 30% air, there is very visible, stable foam on top of the oil level.

Free air is difficult to identify and is often caught in dead legs of your system, stand pipes and high points.

Air is one of the hardest types of contamination to control and is usually designed into the system. Therefore, we should look at preventing air contamination from a redesign standpoint. System return lines cause turbulent zones in sumps and reservoirs and force air into the oil. You must identify the appropriate way in which to remedy the air entrainment in the specific design of your system. Return line diffusers, sump and reservoir baffling and anti-foam additives in our lubricant will significantly reduce the amount of air present in our oil.

When air does co-exist in your lubricant, there are several effects you must be aware of.

Air in oil will accelerate additive depletion and oxidation, increase the compressibility of hydraulic oil, loss of system controls, sluggish machine operation, loss of film strength and cavitation. We can identify aeration in our lubricant when we see an increase in lubricant viscosity and a change in lubricant colour from light to dark.

Conclusions

If we can successfully identify contamination in our systems, we have a better chance of eliminating the root cause. The key to effective contamination control comes in three parts.

- Identification of the contamination or potential for contamination
- Prevention of occurrence for contamination ingression.
- Removal of contamination.

This approach to controlling contamination will ensure that we maintain not only lubricant reliability, but equipment reliability as well. A concise audit of our equipment and lubricant storage and handling practices will indicate potential for contamination ingression and we can then take a less costly proactive approach to the exclusion of contamination, rather than a more costly reactive approach. In all assessments of controlling contamination, the cost associated with the removal vs. the exclusion must be considered. An effective contamination control strategy, focused on exclusion, implemented into your proactive maintenance program will benefit your entire mandate and maintain unsurpassed lubricant and equipment reliability.

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BACK TO BASICS: WHERE DOES LUBRICATION MANAGEMENT FIT WITHIN MAINTENANCE AND RELIABILITY STRATEGY?

In the first of a 'Back to Basics' series, Martin Williamson of independent oil analysis and machinery lubrication training and consultancy firm Noria UK, looks at the issues of where Lubrication Management fits within a Maintenance and Reliability Strategy.

With increasing demands for profitability, yet with limited markets, businesses are seeking internal measures to reduce operating costs in the manufacturing and service sectors. One of the key areas of focus is the Maintenance function. However, reduced maintenance will result in unreliable machines, with short term savings resulting in long term expenses of rectification of neglected systems.

Smart maintenance allows for better quality of attention, yet with long term, sustained, reduction in maintenance overheads. In the early part of my career in mechanical engineering, the iron ore mine and processing plant in which I spent my training period attained a 50% increase in productivity yet with a sustained 50% decrease in maintenance costs. Much of this was achieved through a strategy of implementing Proactive Maintenance with a strong focus on lubrication.

In the last 20 years Reliability Centred Maintenance (RCM) has become the norm for selecting an appropriate and optimised maintenance strategy for machinery. RCM considers the criticality of the machine to the business, and the maintenance strategy selected will be either:

- Break-down
- Scheduled
- Predictive
- Proactive
- Or require redesign

Breakdown maintenance is, as the name implies, a strategy of awaiting breakdown and acting in response to that. This is fine on low priority machines where capital costs and criticality to the process are unimportant. In lubrication terms, this is similar to simply changing the oil when it appears dark, smelly and gritty - the lubricant has recognisably failed. There is no planned activity relating to the lubrication schedule, nor an immediate consequential failure process resulting from that breakdown of the lubricant. But the signs will be there that the machine is suffering acutely as a result, and the experienced maintenance engineer may not associate those symptoms with the actual cause.

In practice, very few maintenance engineers will operate a policy of breakdown strategy with respect to the oil. More realistically, many maintenance engineers will simply rely on a schedule of lubrication activities - a schedule-based strategy. The schedule may be based on recommendations from the lubricant supplier, or the OEM, or both. The schedule will often as not be conservative and so lubricants with a reasonable remaining life may be disposed in order to fit with an historical schedule, despite the continuing improvements in oil performance offering longer life. For small volume, non-critical machines, this policy probably works best, but for larger volumes it can lead to expensive waste.

This is where the process of condition-based maintenance strategies applies, and where the real cost savings can be applied. These strategies are a matter of predicting problems, and seeking to monitor root causes of failure, and considering redesign to eliminate repetitive failures. Oil analysis has a role to play within this, both at a predictive level and at a proactive level. More importantly, lubrication management should be proactively based, thus eliminating the root cause conditions that can lead to lubricant and machine failure, or short service life.

It is important to consider a few basic rules of a sound lubricant strategy. These basic rules are fundamental in most aspects of maintenance but are worth repeating here in the sense of the lubrication parallel.

By buying cheap lubricants and ignoring the basic fundamentals of lubricant management, this often leads to breakdown scenarios where machines fail to achieve reliability and maximum potential life, and the consequences of the potential breakdowns are catastrophic. However, it is important to consider the right lubricant to meet the demands of that machine's design, a process of optimisation.

Not bothering to do essential and frequent root cause focussed checks on the lubricant and machine, in order to save time, will lead to guaranteed reduced life of the lubricants and the machinery. The inspection process may be a simple site based inspection of the oil levels, or the colour of the oil, or it maybe oil analysis with a focus on contamination monitoring and lubricant condition analysis.

Ignoring basic operating system parameters such as temperature, flow rate or pressure that is off specification may suggest a lubricant or machine fault.

In order to maximise the machine and oil potential life it is important to ensure the equipment is operated within the design capability. However, with production demands, this may not be easily achievable. Therefore redesign is a possibility, either as an upgrade to the lubrication aspects of the machine or as a redesign of the system itself. However, at a basic level, before considering expensive re-design under these increased load conditions, ensuring that the machinery is properly aligned, balanced, and fitted with quality components is crucial. Moreover, increased frequent of these checks of the lubricant and machinery are necessary under these demanding conditions of increased production.

The issue in all of this is that if the plant is to increase its productivity, yet retain, or even improve on its reliability, and gain life extension over current machinery service performance, then there are some basic principles that must be followed.

- Select appropriate, quality lubricants and components that meet the demands of the system design to ensure optimised reliability needs.
- Ensure that all the root cause conditions are set correctly prior to commissioning or before start-up. In lubrication terms, that means ensuring a supply of clean, dry and cool oil, which will mean addressing such issues as storage, handling and dispensing practices.
- Undertake regular checks of any root-cause conditions to ensure these are not beyond acceptable limits during machine operation.
- Keep production within the safe limits of the component capabilities to avoid accelerated wear or catastrophic failure. This is often not an option when maintenance must bend to production demands, so the above options are really the only way forward.

Figure 1 highlights the importance of spending time on machines and lubricants that are not yet broken. Proactive strategies seek to extend machine and component (including the lubricant) life, and minimise problems associated with their reliable operation. The benefits of this

(Continued on Page IV)

are actually far reaching, providing financial gains in areas often overlooked. For example, in the case studies in which Noria have participated, it is found that frequent benefits are found in the following areas as a result of a sound lubrication maintenance and reliability strategy:

- Improved Health and Safety with an associated risk cost reduction. More inspections with minimal maintenance intervention will reduce exposure of staff to risk associated tasks.
- Improved environmental compliance within ISO 14000 series. Apart from the image perception of the ISO 14000 series for a company, changes in practices can again minimise risk costs associated with fines and penalties. In addition, sound lubrication practices can minimise energy consumption (Climate Change Levy) through more efficient manpower and equipment usage and minimised heavy maintenance tasks.
- Compliance within ISO 9000, which now requires maintenance, tasks, including lubrication activities, to be written and audited for completeness.
- In the Pharmaceuticals and Food/Beverage markets, better practices will again minimise risks associated with product contamination, reducing risk-based costs.
- A defined lubrication strategy will further allow employee development by setting out the task and education training requirements for personnel, and offer a company a route for lubrication engineers to follow in career development.

A properly designed lubrication management strategy that fits with the maintenance strategy developed for a site will offer.

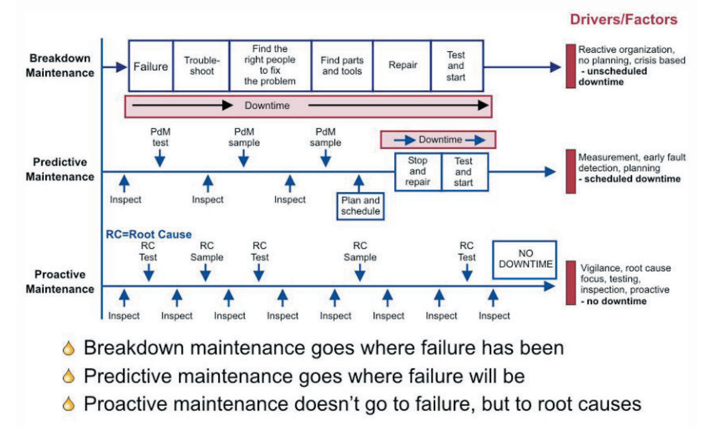

Figure 1 – Time and effort management in maintenance strategies.

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