INSIDE

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India May - June 2016

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PROVEN METHODS FOR DETERMINING THE CAUSE OF MACHINE FAILURES

Contents

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May-June 2016

Publisher's Note

High cost of production is the biggest challenge faced by any organization and one of the major reasons for this is idle time of machines which is either caused by their breakdown or improper working. The idle time of the machine disturbs the whole process flow. Identifying total defect cost and failure cost shows how vast amounts of money are wasted throughout an organization when a failure happens. The bigger the failure, or the more often it happens, the more resources and money is lost. The profits that could have been made are gone, wasted, and it can never be compensated. This also lowers the moral for the workmen and others involved in the manufacturing and maintenance of the organization.

Today, modern lubricants are regarded as high end construction parts that play an integral role within the equipment or machine on which they are used. It is therefore critical that any system set up to monitor the condition of a machine are also capable of monitoring the condition of the lubricant. Lubricant plays an important role in keeping the pace of production.

The cost of lubricant in any industry is typically 1-3% of the maintenance budget, however more than 40% of equipment failures are lubrication related i.e. due to wrong choice or incorrect handling of lubricants. Hence avoidable. Many investigations require a tiered approach. It's like peeling back an onion. Each layer or tier guides the subsequent analytical and investigative steps

In the current issue we will share with you The Proven methods for determining the cause of machine failure.

Readers will also find a very interesting article by the guru of lubrication, Jim Fitch who describes the power of Root Cause Pre Failure Analysis in which he explains abnormal wear is not like a bad rash, which tends to go away on its own in time. Instead, it's more like early-stage cancer, which requires intervention and treatment. Oil analysis can't fix a failed machine. That's what mechanics do. It can provide pre-failure alerts, both cautionary and critical. If a root cause is detected, such as the wrong oil, dirty oil or wet oil, these conditions can be remediated quickly.

We got an overwhelming response from or readers on the last issue which dealt with a better way to test Grease Consistency and drew keen attention of the industries and professionals.

We are very glad that or readers are so responsive with their suggestions and comments and that's the key point for us to deliver the unmatched in-depth articles on lubrication and Tribology . Please share your ideas and views so that we can serve you better .

Your feedback and suggestions are very important for us.

Warm Regards.

Udey Dhir

JIM FITCH, Noria Corporation

The POWER of Root Cause PRE-FAILURE ANALYSIS

Abnormal wear is not like a bad rash, which tends to go away on its own in time. Instead, it's more like early-stage cancer, which requires intervention and treatment. Oil analysis has exceptional abilities to detect abnormal conditions, both root cause (like dirty oil) and predictive (active failure in progress).

Root cause failure analysis is post-mortem. It starts with failure and works backward in search of one or more root causes. The knowledge gained reveals a plan of needed change that will prevent or delay the recurrence of similar failures. Failure is indeed a strategic teacher of better ways to design, manufacture and maintain machines.

The whole purpose of machine condition monitoring, like oil analysis, is to enable organizations to foretell the future. It produces data that points to the existing problems and the seriousness of these problems. Action is required to confirm a problem's existence, determine and verify the root cause, and finally to remedy the problem. Sadly, this is where most oil analysis programs are delinquent. The fault lies equally with the laboratory and the end user.

The Lost Art of Troubleshooting

Oil analysis can't fix a failed machine. That's what mechanics do. It can provide pre-failure alerts, both cautionary and critical. If a root cause is detected, such as the wrong oil, dirty oil or wet oil, these conditions can be remediated quickly. This is proactive maintenance at its best.

Approximately 10 to 20 percent of

Be a **pre-failure investigator** and finish the process before the machine's service **life finishes first.**

samples analyzed by oil analysis laboratories have one or more non-conforming conditions. The vast majority of these are predictive in nature, like abnormal wear. However, the origin of the impending failure (e.g., a particular bearing) and the root cause(s) typically remain uncertain to both the laboratory analyst and the end user. Routine oil analysis for predictive maintenance is an effective screen for abnormal conditions but ineffective at problem troubleshooting alone.

Presently, oil analysis laboratories are barely more than data generators. The evaluators used by these labs have limited time to spend troubleshooting and diagnosing individual samples with reportable conditions. Most evaluate several hundred data sets each day. They also rarely have a background in machinery lubrication, tribology, failure modes or machine design, and are generally unfamiliar with machine operating conditions and the exposures these machines and their lubricants face.

Be alert to the false promise or expectation that the laboratory can be your troubleshooter. Troubleshooting requires additional steps and persistent, timely action by the end user or designated troubleshooter. Unlike a bad rash, these problems don't go away on their own. The offending condition must be identified, contained and surgically removed. The oil analysis report with the red alert only initiates the process. Be a pre-failure investigator and finish the process before the machine's service life finishes first.

Critical machines that are in critical alarm need quick and effective troubleshooting by a qualified investigator. The following are examples of common conditions often found on oil analysis reports that require unrelenting investigative analysis:

- High/low viscosity
- High wear metals
- High particle count
- Coolant leak
- Fuel dilution
- Varnish/sludge
- Rapid oil aging
- Cross-contamination

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- Sudden high acid number (AN)
- Demulsibility issues
- Air-handling issues
- Dark oil issues
- Hot running conditions

Build the Case File

Troubleshooting requires discovery of anything and everything that might reveal the origin, root cause and severity of the problem. In the medical world, this investigative process is performed by pathologists. Forensic investigations go through very similar steps. Start by building the case file and leave no stones unturned. In addition to routine lab data and historical trends, seek the following:

- Companion condition monitoring data (vibration, infrared thermography, temperature history, pressure history, etc.)
- External inspections
- Internal inspections including a borescope
- Abnormal operating data (loads, speeds, etc.)
- Lubricant product data
- Service history (recent oil/filter changes, repairs, teardowns, etc.)
- Operator interviews/observations
- Preventive maintenance (PM) inspection history
- Past reliability history

More testing of the in-service lubricant could be required to dig deeper into the core of the problem. You may want help in selecting the tests that best

answer your troubleshooting questions. Also, you might need a specialized laboratory that is equipped for complex analytical and tribological studies. For instance, one or more of the following tests may be necessary:

- Sediment analysis
- Used filter analysis
- Scanning electron microscopy (SEM)/energy-dispersive X-ray spectroscopy (EDS) of debris fields
- Inductively coupled plasma (ICP) acid digestion testing of large solids
- Composition particle counting
- Particle characterization
- Grease analysis
- Flender air-handling test
- Gas chromatography
- Metallography (machine surface morphology)
- Fourier transform infrared (FTIR) spectrum analysis
- Film strength analysis
- Organic solids analysis

88%

of oil analysis programs employ particle counting as an analytical method, according to a recent survey at MachineryLubrication.com

Many investigations require a tiered approach. It's like peeling back an onion. Each layer or tier guides the subsequent analytical and investigative steps.

Most importantly, don't fail to take action. The problem won't go away on its own. Take full control of the investigation and understand the urgency. Get the help you need. Use the knowledge gained from pre-failure as your teacher.

About the Author

Jim Fitch has a wealth of "in the trenches" experience in lubrication, oil analysis, tribology and machinery failure investigations. Over the past two decades, he has presented hundreds of courses on these subjects. Jim has published more than 200 technical articles, papers and publications. He serves as a U.S. delegate to the ISO tribology and oil analysis working group. Since 2002, he has been the director and a board member of the International Council for Machinery Lubrication. He is the CEO and a co-founder of Noria

Proven Methods for Determining the Cause of Machine Failures

By Thomas L. Lantz

Machine failures are the bane of every maintenance department. Determining their exact cause can also be rather difficult. The equipment failures discussed in this article defied quick solutions and were quite costly in manpower, material and downtime. Various resolutions were proposed and tried with little success until thoughtful analysis was undertaken. The systematic approach that was employed as well as the results that were achieved in these three examples should provide a better idea of how to analyze similar types of equipment failures in your facility.

Failed Back-up Bearings

In a steel rolling mill, small rolls approximately 2 feet in diameter perform the actual rolling of the steel to reduce its thickness. Since surface quality is so important, these rolls must be re-ground often; the small diameter makes them easier to handle. Due to their small diameter, these rolls must be "backed up" by larger 3-foot-diameter rolls to prevent bending and distortion of strip thickness. Normally, the smaller or "work" rolls are driven and have anti-friction bearings, while the back-up rolls (undriven) have Babbitted or plain bearings. The work rolls are lubricated by grease or oil mist. The back-up bearings receive oil from a circulating system. The back-up rolls usually stay in the mill for several weeks of rolling before requiring regrinding. Bearing failures on these rolls are rare. Figure 1 illustrates this arrangement.

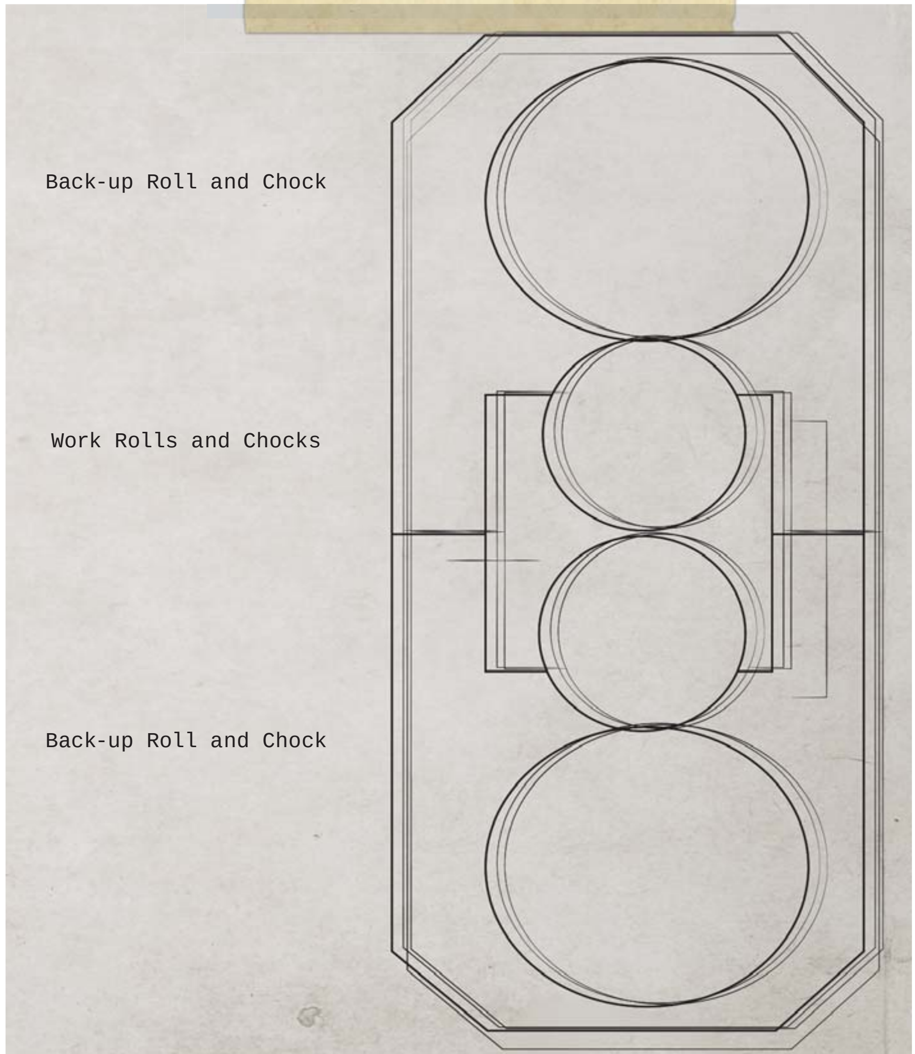


Figure 1. A four-high rolling mill arrangement

Back-up roll bearing failures suddenly began increasing on the last six finishing stands for no apparent reason. Department management instantly blamed the lubricant in the oil circulating system. Although every load of new oil was checked by a laboratory for quality, samples were taken from the system and checked at an outside lab to be sure there was no contamination. Each checked out perfectly. The oil was purchased on specification, every load was sampled, and years of records were on file to prove consistent incoming quality. The

POSSIBLE CAUSES OF BACK-UP BEARING FAILURES	
Personnel Related	Rebuilding practices, skill-level training, motivation level
Systems or Operations Related	Incorrect screw-down loading, mill cocked, mill thrusting, excessive water level in oil, low oil pressure (with indicator not on), separator bar loose, water sprays impinging seals
Maintenance Related	Oil line disconnected, bearing chock dimensions out of specification, oil cleanliness, oil temperature, age of bearing, incorrect oil specifications, oil quality not to specification, inadequate pump flow, oil pressure switches not calibrated, improper oil flow to bearing (orifice error), rockers broken, debris in shim pack, cracked sled, incorrect bolt specifications (two-piece chocks), incorrect bolt torque on nuts (two-piece chocks)
Material Related	Oil viscosity too high or low, improper Babbitt quality, incorrect Babbitt thickness, worn housing liners, worn chock liners, worn locator pins (two-piece chocks), bearing too small for mill loads

oil flow to the bearings was also checked and determined to be on target.

At this point, the mill was losing a bearing per week. Previously, one lost bearing per year was normal. Costs were skyrocketing, and a mill shutdown was a real possibility. A meeting with supervisors and repairmen was held to consider all the ways a back-up bearing could fail. The compiled list is shown in the table on page 11.

This list was meant to be all-inclusive, so some items might not apply to a particular mill. When trying to determine the cause of any bearing failure, you should concentrate on what has changed recently if the problem is of recent origin. Something has changed, and that possibly includes current practices.

Analysis

Several items on the list were deemed very unlikely or had been recently checked, so they were not considered. The remaining items were divided up among all personnel. After all other items on the list checked out, the bearing chock dimensions were investigated. A bearing chock is a housing into which the bearing is fitted before being placed on the roll. The bore into which the bearing was inserted was 3 feet in diameter. The internal dimensions of the chock are critical. The difference between the vertical and horizontal measurements cannot exceed 0.05 inches or the bearing will not seat properly.

The location of the bearing failures was random, so no pattern could be discerned. The losses occurred on both the drive side and the operator's side of the mill on six finishing stands.

The bearing shop was fortunate to have a meticulous supervisor who recorded everything on a computer. Each bearing chock was numbered and a record kept of which stands each was in during any rolling schedule. The computer records proved that four chocks were involved in all the bearing failures. This was surprising, but the cause still had to be proven.

The four chocks were set aside and unused for a time to see what would happen. All bearing failures ceased. Checking the internal dimensions of these four chocks showed wear well beyond tolerances for good bearing seating. These chocks were immediately sent out for rebuilding, and normal bearing life resumed.

The Kepner-Tregoe method was also helpful in the analysis of the failed bearings. Rather than listing all the possible causes of a problem, the Kepner-Tregoe method seeks to describe what the problem is or is not, where it occurs or does not, when it occurs or does not, and its extent. Basically, you are building a fence around the problem to keep good information inside and under consideration and bad information out. You are determining what has changed from the previous "problem-free" condition. The true cause will satisfy all the conditions unearthed by using this method. If one condition cannot be satisfied by the suspected cause, it must be discarded and another considered.

With this bearing problem, the worn chocks satisfied all the conditions of location, timing and capability of causing the problem. None of the other possible causes could do that. Also, setting the suspected chocks aside amounted to changing only one parameter at a time, which prevented confusion of the issue.

Hydraulic Pump Failures

In this particular plant, most of the hydraulic systems used vane pumps. Losses were very high, and it didn't take much analysis to determine that 80 percent of the pump gang's time was being occupied changing pumps. It was also necessary to increase the crew size to keep up with the work. A fishbone diagram was prepared that listed all the possible causes of short pump life (see the table below).

Analysis

Because vane pumps are very sensitive to dirt, and steel mills are inherently dirty, it was suspected that the vane pumps might not be the correct type for this environment. An investigation determined that the pump gang was rebuilding failed pumps with parts from other failed pumps. The pump manufacturer advised strongly against this practice and insisted that only new, matched sets of vanes, rotors and wear plates be used when rebuilding units. This clashed with long-standing

POSSIBLE CAUSES OF EXCESSIVE PUMP FAILURES

Personnel Related	Rebuilding practices, skill-level training, motivation level, inadequate time (rush to complete)
Systems or Operations Related	Improper pump starting by operators, low oil level warnings ignored
Maintenance Related	Dirty oil (filters need to be changed), undersized suction lines, systems receiving dirt during maintenance, loose suction lines (air entering), suction lines are too long, inattention to overheating oil
Material Related	Hydraulic oil quality level, incorrect parts used, inferior parts purchased, incorrect pump for the job, incorrect system design for the job, incorrect fluid used

practice in the plant.

The strategy was to change pump types. Gear pumps are less expensive than vane pumps and much more resistant to dirt. They also fail gradually, giving a warning by moving all cylinders more slowly. Vane pumps fail suddenly without warning.

It was also noticed that all systems in the plant were designed with the pump and motor sitting atop the tank. When the pump is started on this type of system, the mechanics are cautioned to "jog" the pumps, meaning to start and stop the motors at least three times before walking away to ensure the pump has picked up a prime. However, the operators often would start the pumps, and there was no guarantee that they would do it properly. If the pump does not pick up a prime, air entering the suction line will cavitate and destroy the pump.

While plant personnel were deciding what to do about these pump losses, anti-wear hydraulic fluids were just coming on the market. Oil companies claimed longer pump life would be possible with these fluids. This strategy was added to the list of possible actions.

Overheating oil was also persistent on all the systems and generally started with a problem in the unloading system. Assuring the coolers worked properly helped, but quick diagnosis and repair of the unloading system only brought minimal improvement in pump losses.

Action

Since it appeared that the pump losses had multiple causes, the decision was made to correct the easiest possible cause first — the fluid. Switching to anti-wear fluids made a small improvement.

Next, better filters were installed on each system. Changing these filters on a monthly basis became the routine because the bypass indicators were not trusted. In addition, it was easier to schedule the changes on the same shift. This also resulted in some improvement.

The practice of "filter-fill" was then begun. Previously, in order to fill a system, millwrights would bring a drum of fluid to the site and insert an air pump into the large bung hole. They would pump oil directly from the drum into the system through an opening in the top of the tank. When the drum was empty, they often would place the air pump on the ground, take the empty drum away and return with a full drum.

To counter this, all openings in the top of the tank were plugged except for the breather and a spin-on-type filter attached to an opening in the tank. The mechanic had no choice but to connect the hose to the filter when filling the tank. By this method, all dirt on the pump or in the oil was stopped by the filter. This led to improved pump life.

Subsequently, the vane pumps were changed to gear pumps in order to prevent the pump gang from attempting repairs. When a gear pump fails, it cannot be repaired properly except in a specialty shop. The strategy was to keep low-skill personnel from trying to make repairs. Pump life improved markedly with this action.

Still not satisfied, the plant converted its hydraulic tanks to vertical tanks with the pumps mounted beside them. This gave the pumps a "positive head" and lessened the chances of them being starved for fluid. This move was the most productive of all. Pump life increased so much that the pump gang thought someone else was doing their work.

This problem provides an excellent example of what to do when there's a multitude of possible causes and all are believed to be contributory. If none can be eliminated as a possible cause, then correcting the easiest one first is a good strategy. Plants frequently live with a problem that should have been corrected years ago. These "lived-with" problems take up a lot of maintenance time and become routine or part of the "how we do things around here" syndrome. Constantly be on the lookout for these problems and eliminate them, but only after proper analysis.

Work Roll Bearing Failures

In the mill described previously, the work roll bearings were the anti-friction type. A total of 40 bearings were in the mill at one time, and all were lubricated with grease. The grease's performance characteristics were specified by the mill, and every load was tested when received. Typically, 15 to 20 bearings were lost each year, primarily on the faster finishing stands. The losses, which usually were attributed to age or misdirected water sprays and only occasionally to grease, were considered

POSSIBLE CAUSES OF WORK ROLL BEARING FAILURES

Personnel Related	Rebuilding practices, skill-level training, inadequate greasing, personnel changes
Systems or Operations Related	Duration of rolling schedule, water sprays impinging seals, location of the losses
Maintenance Related	Grease change, grease quality, worn bearing chocks, wear plates on mill, wear plates on bearing chocks
Material Related	Bearing manufacturer, spacer change, age of bearings

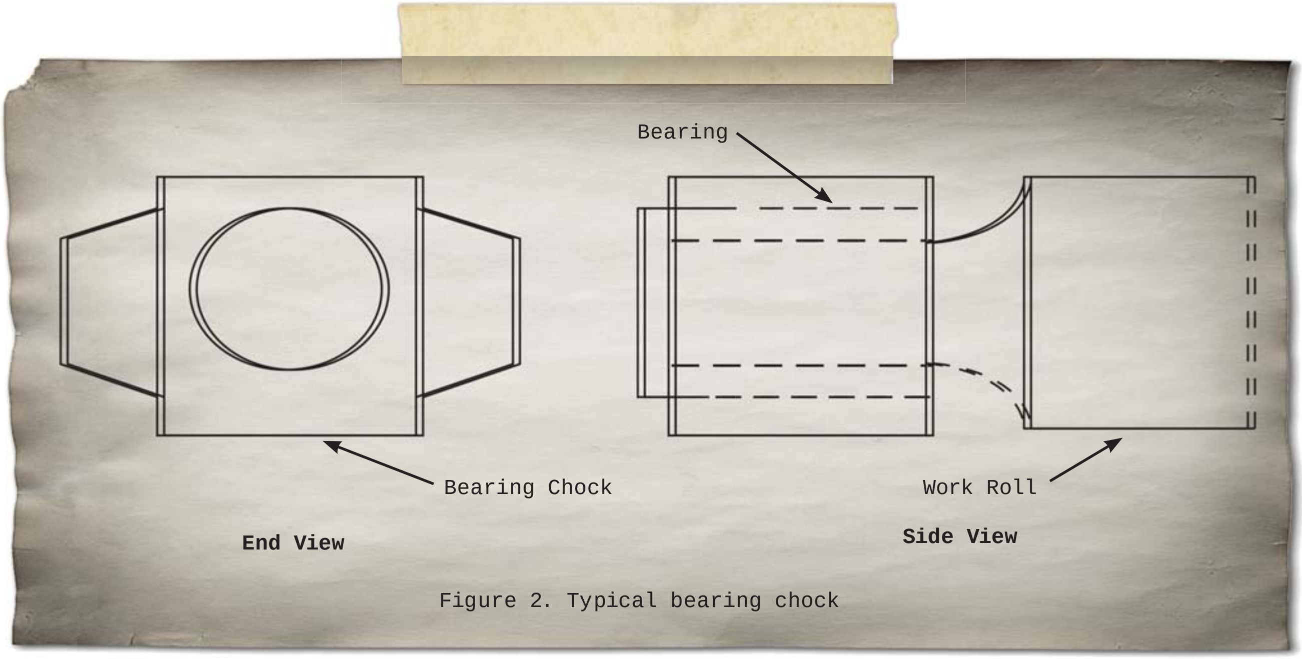


Figure 2. Typical bearing chock

normal and difficult to reduce. Figure 2 illustrates the typical bearing.

When the work roll bearings suddenly began failing on the finishing stands at the rate of one per day, a fishbone diagram was prepared to list the possible ways the bearings could fail (see the table below).

Operations management immediately blamed the grease. Even though years of records were available to confirm the grease's quality, samples were taken. All the results were perfect.

Each item on the list below was then checked or discarded due to recent verification. Only one item stood out as suspicious – the location of the losses. An investigation proved that all the losses had occurred on one particular stand and only on the operator's side of the mill. This pointed directly to that stand housing as contributing to the failures. The wear plates on the inside of the stand housing, which the bearing chocks rubbed against, were checked and found to be badly worn. They were changed immediately. Failures soon returned to normal levels.

These three examples illustrate the effectiveness of using a fishbone diagram to ensure that all possible causes of a failure are considered. The Kepner-Tregoe method can also help to establish what, where, when and the extent of the problem.

The first and last examples arose suddenly with too many people panicking and jumping to conclusions. In all three problems, using a fishbone diagram forced personnel to withhold action until all possible causes were at least written down.

The segments of the diagram – maintenance, personnel, systems and material – are only four of the possible areas to assess. In special situations, there may be others. Consider all the possibilities with a fishbone diagram and use the Kepner-Tregoe method to help narrow down the list. Finally, always remember to look for something that has changed recently. This will be the best approach to determine the cause of your next equipment failure.

Jeremy Wright | Noria Corporation

Making the TRANSITION to Proactive MAINTENANCE

What is reactive maintenance, and how do you know if your company is practicing it? Many people like to hide reactive maintenance and call it something it's not, but if you honestly answer "yes" to any of the following questions, then you likely are stuck in the reactive rut:

Are you measuring how fast a piece of equipment gets fixed once it breaks down? Are you patting guys on the back for fixing broken equipment rather than keeping it from breaking? Do you think cutting maintenance costs starts with manpower and/or material? Are your maintenance costs increasing even though you've implemented sound strategies? Are you rewarding failure?

Some of these questions may sound ridiculous, so let me explain. For example, you may ask what company in its right mind would reward a failure. But do you award overtime to your millwrights or mechanics for coming in at night or on weekends to fix broken machinery? If so, you are rewarding the failure of that machine.

A better strategy would be to reward the team when there are no failures. Don't you think maintenance personnel would focus on keeping a machine in optimum condition if their reward was tied to the machine's continual operation and availability as opposed to its failure? This is a significant cultural issue at a number of the plants I visit, and it is not an easy hurdle to overcome.

Changing from reactive to proactive maintenance requires a different way of thinking, executing and managing. When designed, implemented and managed effectively, proactive maintenance results in optimal asset reliability at optimal cost. Everyone wins. The company gets more value from its machines, the maintenance budget and upfront costs are reduced, profit margins increase, the actual work being done by the team is easier, etc. The list of benefits could span pages.

> "Making the leap to proactive maintenance requires a change that is difficult for most organizations to master because it requires a shift in thinking, processes, procedures and culture."

So why isn't everyone striving to make this change? Change is difficult, and people tend not to like it. Although change is not simple or easy, it is achievable. Not only is change achievable, but lots of people are making it happen.

There are many strategies for change management, including a few I will discuss later. However, the first thing you must do is to believe that making the change will have a lasting effect on the organization and the people within it.

Anyone who works in maintenance and reliability is probably aware of the frustrating consequences of unexpected equipment breakdown (the definition of reactive maintenance). Some organizations have hundreds or even thousands of pieces of equipment to maintain, and a single breakdown could bring operations to a halt. If the organization is running at full capacity, this loss can never be returned. While there's no doubt that fixing something as soon as it breaks is important, few

people realize the high costs associated with working in reactive mode.

Maintenance Management Approaches

There are three basic approaches to maintenance management: reactive, predictive/preventive and proactive. Reactive maintenance, which is precipitated by failure, results from a lack of preventive and predictive maintenance. On the other hand, proactive maintenance keeps equipment serviced and in working order through preventive and predictive maintenance as well as a keen focus on eliminating the root causes of failure.

A reactive maintenance approach can be detrimental to your organization because it means that you could get stuck in a vicious cycle of constant emergency work pushing aside the tasks that could lead to a reduction of that very same emergency work at a future date. Furthermore, reactive maintenance is much costlier than proactive work. This is because reactive maintenance tasks tend to be complex, like tearing apart a gearbox to fix a bearing, whereas proactive maintenance tasks are relatively simple, such as sensory inspections and small corrections.

Starting the Journey to Proactive Maintenance

This type of change cannot be made with a simple flip of a switch. It will be a long, drawn-out process that is more of an evolution than a change. Even when all is said and done, you may never rid yourself of reactive maintenance work. However, you can significantly minimize unplanned repairs.

Implementing an enterprise asset management/computerized maintenance management system (EAM/CMMS) that is customized to fit your organization's specific needs can help in shifting a reactive maintenance program to a proactive one. You will need a way to organize, measure and analyze lots of data. Without the help of software and the supporting structure behind it, your efforts will need to be multiplied many times.

The main goal of this software is to help provide proper planning and scheduling of your preventive and proactive maintenance. Maintenance costs can never be eradicated, but they can be redirected. You want to focus your time, money and energy on making sure that proactive tasks are being completed, because when done correctly, they will result in a massive reduction in reactive tasks. You are in effect trading complex, harder work (reactive maintenance) for easy, cost-effective work (proactive maintenance). Software should be able to help facilitate this trade.

Preventive Maintenance

The first step toward proactive maintenance is using data from past experience to drive your maintenance timelines and decisions. For example, if you know a certain sump pump has a life expectancy of three years for its operational and environmental conditions, and you know this because you have data spanning back a decade, then it would be safe to say that you need to plan and schedule to replace or rebuild the pump at the 2.5-year mark. While this obviously is not the best case scenario, because you might be changing out a perfectly operational pump at the 2.5-year mark, this strategy can reduce overall costs in both the short and long term, as opposed to an unknown catastrophic failure that occurs unexpectedly.

This approach still requires significant manpower to perform tasks that at the time may seem unnecessary. However, this extra effort can pay off in the long run when things like production uptime and being able to plan the work are added to the equation.

According to a case study by the Office of Energy Efficiency and Renewable Energy, practicing periodic component replacement in the form of preventive maintenance saves an estimated 12 to 18 percent over reactive maintenance.

Predictive Maintenance

The next step toward proactive maintenance is being able to assess the machinery's current condition. Predictive maintenance will enable you to better plan corrective actions before the equipment experiences a catastrophic failure. A variety of technology tools can help with this,

45%

of plants utilize a proactive maintenance strategy, based on a recent poll at MachineryLubrication.com

and the main goal of each is to measure failure symptoms or faults. These tools and technologies are usually non-invasive and can monitor machine and component conditions through direct monitoring and analysis.

The one inherent flaw with this strategy is that in most cases you are measuring failure symptoms or faults. This means that by the time you have something to measure, the problem already exists. There is certainly great value in knowing that a problem exists and being able to perform corrective actions before it becomes catastrophic, but you can do better. If your program has evolved to this point, a case study from NASA suggests you are saving up to 50 percent on maintenance costs compared to reactive maintenance.

Proactive Maintenance

Up to this point the evolutionary steps have been quite easy and gradual. Making the leap to proactive maintenance requires a change that is difficult for most organizations to master because it requires a shift in thinking, processes, procedures and culture. Proactive maintenance doesn't focus on repairing machines or being more effective in performing corrective actions on machines that show signs of problems. Instead, it concentrates on eliminating the root causes of the issues. If you can eliminate the root causes, you won't have the failures these root causes eventually would have turned into emergency work.

One of the simplest ways to move toward proactive maintenance is through education or training your frontline people on what to look for and why. This is essentially what proactive maintenance comes down to — knowing the root causes that lead to the majority of machine failures, knowing what they look like and knowing why it is important to correct the issue at this stage versus waiting until later in the P-F (failure) curve. These types of inspections can save organizations tremendous amounts of money, but they are often overlooked for their simplicity.

For instance, consider checking the oil level in a splash-lubricated component. Although this is extremely easy to do and only requires the briefest of training, if not done, it could lead to catastrophic failure of the component and everything associated with a breakdown.

With proactive work, you want to trade the costly breakdown in the future for the time, money and energy up front to perform a simple inspection. This is almost always a favorable trade and will lead to a massive reduction in maintenance and production costs. Of course, it doesn't always work out that way.

Not all programs and strategies fit a perfect mold. Each program needs to balance the cost of implementation with the expense of being complacent. For instance, it is perfectly acceptable to utilize a reactive maintenance mode for a cheap component that is easily changeable and readily available. It doesn't make sense to spend a lot of time, money and energy on a sump pump that costs $500 from a mail-order catalog, has three available spares, takes five minutes to change and is not part of a critical process.

The ideal program will be able to use a variety of maintenance modes to make sure the plant is running as efficiently and effectively as possible. Understanding the different maintenance philosophies and having an excellent grasp of operations, machine criticality, costs, etc. will be essential in adopting a balanced approach at your plant. Only once all the variables are fully understood can you optimize your program and start getting the most from your people and machines. ■

About the Author

Jeremy Wright is the vice president of technical services for Noria Corporation. He serves as a senior technical consultant for Lubrication Program Development projects and as a senior instructor for Noria's Machinery Lubrication I and II training courses. He is a certified maintenance reliability professional through the Society for Maintenance and Reliability Professionals, and holds Machine Lubricant Analyst Level III and Machine Lubrication Technician Level II certifications through the International Council for Machinery Lubrication. Contact Jeremy at jwright@noria.com to learn how Noria can help you make the transition from reactive to proactive maintenance.

Steffen Bots, Oelcheck

How to Interpret Oil Analysis Reports

The ability to interpret oil analysis results is crucial for guiding decisions about preventive maintenance activities. Having someone in your organization who can pick up a report and interpret it in the context of the environment is essential. This is a skill that can easily be developed with a minimal investment in training and certification. This article will address the fundamentals of oil analysis and how to interpret the resulting reports.

Reviewing the Report

Once an analysis is completed, it is important to review the report and interpret the accompanying data. Based on the report, you can determine whether action is needed. The report does not always pinpoint specific problems, but it does provide a starting point for analysis.

Each test should be clearly identified. The information usually is organized in a spreadsheet format with numbers indicating the test results. When looking at your reports, the first thing you should do is to ensure that they are indeed your reports. Be certain the report includes your name, lube type, machine manufacturer and machine type.

The report should also clearly state your machine and lubricant condition. The laboratory should have a rating system that notifies you of normal, marginal and critical levels. In addition, the report should include comments from the analyst who reviewed your results. These comments will help you gauge the criticality of the problem and provide a suggested course of action.

Interpreting Viscosity Results

Viscosity is the most common test run on lubricants because it is considered a lubricant's most important property. This test measures a lubricant's resistance to flow at a specific temperature. If a lubricant does not have the right viscosity, it cannot perform its functions properly. If the viscosity is not correct for the load, the

Kinematic Oil Viscosity in Centistokes

ISO VG	MID POINT	LIMITS (KV 40° C)		ISO VG	MID POINT	LIMITS (KV 40° C)	
	KV 40° C mm^2s^{-1}	Min.	Max.		KV 40° C mm^2s^{-1}	Min.	Max.
ISO VG 10	10	9	11	ISO VG 460	460	414	506
ISO VG 15	15	13.5	16.5	ISO VG 680	680	612	748
ISO VG 22	22	19.8	24.2	ISO VG 1000	1000	900	1100
ISO VG 32	32	28.8	35.2	ISO VG 1500	1500	1350	1650
ISO VG 46	46	41.4	50.6	ISO VG 2200	2200	1980	2420

oil film cannot be established at the friction point. Heat and contamination are also not carried away at the appropriate rates, and the oil cannot adequately protect the component. A lubricant with improper viscosity can lead to overheating, accelerated wear and ultimately the failure of the component.

Industrial oils are identified by their ISO viscosity grade (VG). The ISO VG refers to the oil's kinematic viscosity at 40 degrees C. To be categorized at a certain ISO grade, the oil's viscosity must fall within plus or minus 10 percent of the grade. So for an oil to be classified as ISO 100, the viscosity must fall within 90 to 110 centistokes (cSt). If the oil's viscosity is within plus or minus 10 percent of its ISO grade, it is considered normal. If the oil's viscosity is greater than plus or minus 10 percent and less than plus or minus 20 percent, it is considered marginal. Viscosity greater than plus or minus 20 percent from grade is critical.

Measuring Metals: Elemental Spectroscopy

Analyzing an oil analysis report involves understanding the concentration of expected and unexpected elements in your oil. Some contaminants are picked up as the oil circulates and splashes off different machine components and surfaces. Other contaminants can enter the machine during manufacturing or routine service, as well as through faulty seals, poor breathers or open hatches. No matter how the contaminants enter the oil, they can cause significant damage.

Elemental spectroscopy is a test used to determine the concentration of wear metals, contaminant metals and additive metals in a lubricant. A concentration of wear metals can be indicative of abnormal wear. However, spectroscopy cannot measure particles larger than roughly 7 microns, which leaves this test blind to larger solid particles. As with any type of testing, spectroscopy is subject to inherent variance.

When oil additives containing metallic elements are present, significant differences between the concentrations of the additive elements and their respective specifications can indicate that either incorrect oil is being used or a change in the formulation has occurred. Also, keep in mind that sump sizes can vary in custom applications.

Understanding Wear Limits

When reviewing the wear levels in your test results, look at the trend history of each machine, not just the recommendations from the original equipment manufacturer (OEM). OEMs offer good benchmarks, but it is not wise to just follow their recommendations because most machines are used differently.

For example, two identical pieces of equipment may have vastly different elemental spectroscopy results due to variations in load, duty cycle and maintenance practices. Their results might even show a variety of particle count levels. Both machines could still be considered healthy based on the trending of the analysis.

Trending is extremely important in determining a machine's health. A good rule of thumb is to use your best judgment and review the trend data. Has anything changed with the operating conditions? Have you been running the machine longer? Have you been putting more load on the machine? You should also discuss the test results with the lab analyst before making any decisions.

Watch for Contaminants

Contamination causes a number of oil system failures. It often takes the form of insoluble materials such as water, metals, dust particles, sand and rubber. The smallest particles (less than 2 microns) can produce significant damage. These typically are silt, resin or oxidation deposits.

The objective with contaminants is to detect the presence of foreign materials, identify where they came from and determine how to prevent further entry or generation. Contaminants act as a catalyst for component wear. If the cycle is not broken, wear accelerates and downgraded serviceability results.

Typical elements that suggest

contamination include silicon (airborne dust and dirt or defoamant additives), boron (corrosion inhibitors in coolants), potassium (coolant additives) and sodium (detergent and coolant additives).

Quantifying the Amount of Water

When free water is present in oil, it poses a serious threat to the equipment. Water is a very poor lubricant and promotes rust and corrosion of metal surfaces. Dissolved water in oil produces oxidation and reduces the oil's load-handling ability. Water contamination can also cause the oil's additive package to precipitate. Water in any form results in accelerated wear, increased friction and high operating temperatures. If left unchecked, water can lead to premature component failure.

The Karl Fischer coulometric moisture test is the most common method used to analyze water levels in oil. When reviewing these test results, remember that low levels of water are typically the result of condensation, while higher levels can indicate a source of water ingress. In most systems, water should not exceed 500 parts per million.

Common sources of water include external contamination (breathers, seals and reservoir covers), internal leaks (heat exchangers or water jackets) and condensation.

Determining Oil Condition: Acid Number

Acid number (AN) is an indicator of oil condition. It is useful in monitoring acid buildup. Oil oxidation causes acidic byproducts to form. High acid levels can indicate excessive oil oxidation or additive depletion and can lead to corrosion of internal components.

Acid number testing uses titration to detect the formation of acidic byproducts in oil. This test involves diluting the oil sample and adding incremental amounts of an alkaline solution until a neutral end point is achieved. Since the test measures the concentration of acids in the oil, the effects of dilution often negate the effectiveness of acid number testing.

Similarly, some oils containing anti-wear or extreme-pressure additives that are mildly acidic can also provide false high or low readings due to additive depletion. Acid number values should be considered in concert with other factors such as additive health and water content.

Gauging Particle Counts

The concentration of wear particles in oil is a key indicator of potential component problems. Therefore, oil analysis must be capable of measuring a wide range of wear and contaminant particles. Some types of wear produce particles that are extremely small. Other types of wear generate larger particles that can be visually observed in the oil. Particles of any size have the propensity to cause serious damage if allowed to enter the lubricating oil.

Particle count analysis is conducted on a representative sample of the fluid in a system. The particle count test provides the quantity and particle size of the various solid contaminants in the fluid. The actual particle count and subsequent ISO cleanliness code are compared to the target code for the system. If the actual cleanliness level of a system is worse than the desired target, corrective action is recommended.

Particle counts generally are reported in six size ranges: greater than 4 microns, greater than 6 microns, greater than 14 microns, greater than 25 microns, greater than 50 microns and greater than 100 microns. By measuring and reporting these values, you can gain an understanding of the solid particles in the oil. Monitoring these values also can help confirm the presence of large wear particles that cannot be seen through other test methods. However, particle counting simply indicates the presence of particles and does not reveal the type of particles present.

ISO 4406 CHART

Range	Number of Particles per 100 ml	
Number	More than	Up to and including
24	8,000,000	16,000,000
23	4,000,000	8,000,000
22	2,000,000	4,000,000
21	1,000,000	2,000,000
20	500,000	1,000,000
19	250,000	500,000
18	130,000	250,000
17	64,000	130,000
16	32,000	64,000
15	16,000	32,000
14	8,000	16,000
13	4,000	8,000
12	2,000	4,000
11	1,000	2,000
10	500	1,000
9	250	500
8	130	250
7	64	130
6	32	64

ISO Cleanliness Code

The ISO cleanliness code is utilized to help determine solid contamination levels in both new and used oils. The current ISO standard for reporting cleanliness is ISO 4406:99.

In accordance with this standard, the values used from the particle count data are related to the greater than 4, greater than 6 and greater than 14 micron levels. The raw data at these micron levels are compared to a standard table and then translated to a code value.

It is important to understand the concept behind the ISO code table. The maximum value of each level is approximately two times the value of the preceding level. This means the minimum value of each level is also nearly double the minimum value of the preceding level. This is accomplished by using the ISO code, which is a value that is an exponent of two, dividing that result by 100 and then rounding.

Analytical Ferrography

Analytical ferrography is among the most powerful diagnostic tools in oil analysis today. When implemented correctly, it can be an excellent tool for identifying an active wear problem. However, it also has limitations. Analytical ferrography is frequently excluded from oil analysis programs because of its comparatively high price and a general misunderstanding of its value.

The results of an analytical ferrography test typically include a photomicrograph of the found debris along with specific descriptions of the particles and their suspected cause. Particles are categorized based on size, shape and metallurgy. Conclusions can be made regarding the wear rate and health of the component from which the sample was drawn. The analyst relies on composition and shape to determine the characteristics of the particles. Due to the subjective nature of this test, it is best to trust the analyst's interpretation regarding any action to be taken. This test is qualitative, which means it relies on the skill and knowledge of the ferrographic analyst.

While most lubrication professionals rely on oil analysis to help safeguard their equipment from unplanned downtime, an inability to dissect and comprehend a problematic report often yields inappropriate action when abnormal results appear. Your lab can only provide you with the machine condition data. It is up to you to take action.

By Alan Dellinger, GPM Hydraulic Consulting

Understanding and Troubleshooting Hydrostatic Systems

Hydrostatic drives are used in a variety of applications throughout all types of industries. They are sometimes referred to as hydrostatic transmissions. Anytime one or more hydraulic motors need to be driven at variable speeds with bi-directional capability, a hydrostatic drive is often used. Common applications include conveyors, log cranes, mobile equipment, centrifuges, chemi-washers and planers. Hydrostatic drives are some of the least understood systems because many of the components are located on or inside the hydrostatic pump assembly.

A schematic of a typical hydrostatic drive is shown in Figure 1. The bi-directional, variable displacement pump controls the direction and speed of the hydraulic motor. This type of drive is commonly called a closed-loop system. Notice how the pump's two ports are hydraulically connected to the two ports on the motor, forming the closed loop.

Main Pump

A piston-type pump is always used in a hydrostatic system. The pump volume

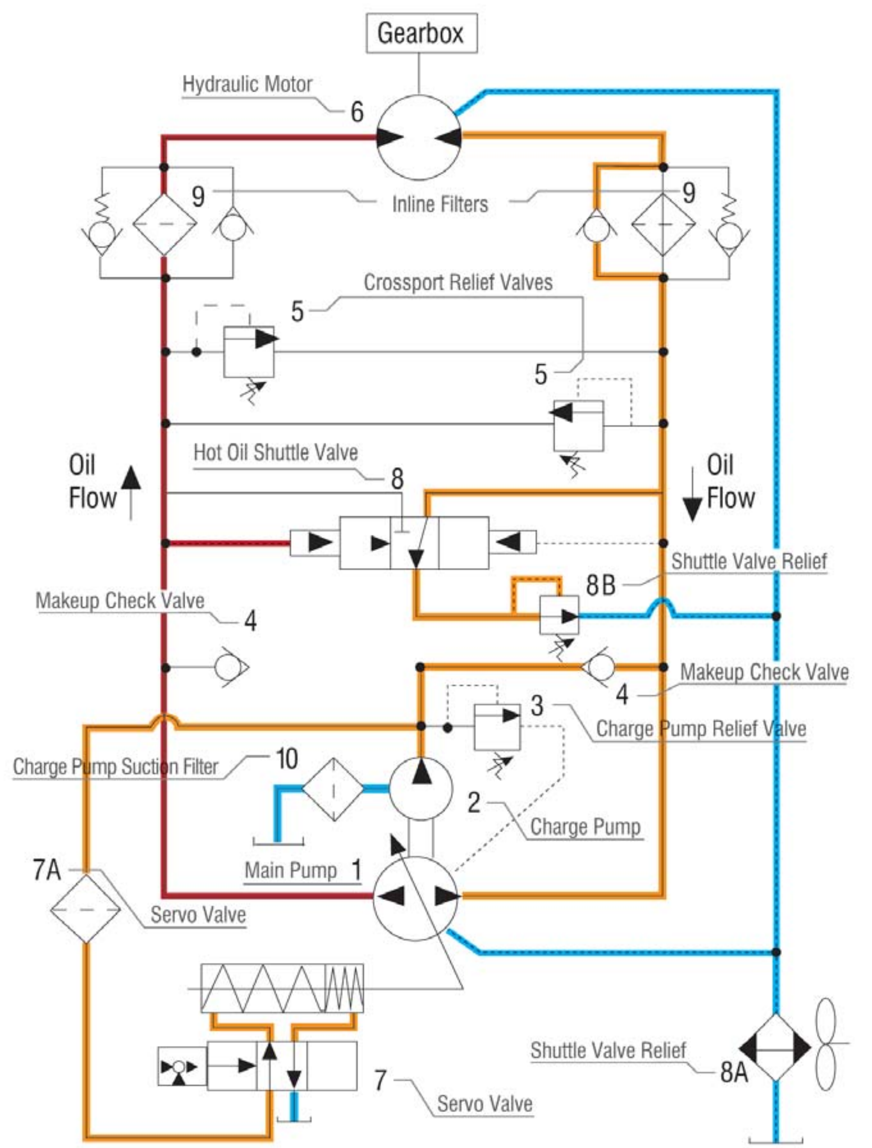


Figure 1. A typical hydrostatic drive

can range from zero to the maximum amount. In Figure 2, the pump swashplate is in the vertical position, which means the pump output is zero gallons per minute (GPM). The swashplate is moved by two internal cylinders, which are controlled by a separate valve or manual lever.

To drive the hydraulic motor forward (Figure 3), the bottom cylinder extends to angle the swashplate and deliver fluid out the “A” port. Oil flow is then directed to the motor for rotating the shaft. As the shaft rotates, the oil that flows out of the motor will return to the “B” port on the pump. This port will act as the suction port in this direction.

To drive the motor in reverse, the top cylinder will extend, allowing the swashplate to angle in the opposite direction (Figure 4). The “B” port will then serve as the pressure port, and the “A” port will be the suction port. The amo ally set between 200-300 pounds per square inch (PSI). Once the valve’s spring setting is reached, the charge pump volume will flow through the charge pump relief and into the pump case. The oil then returns to the tank through the case drain line.

The purpose of the charge pump is to provide makeup fluid to the system during operation. There are tight tolerances between the pistons and the barrel in the pump and motor. This means that some of the oil inside the pump and motor will bypass the pistons and flow back to the tank through the case drain lines. Because of this bypassing, less oil flows out of the motor than what the main pump actually requires. The charge pump will supply makeup oil through the check valve, preventing pump cavitation. The charge pump is also used to supply oil to the spring-loaded cylinders for stroking the main pump.

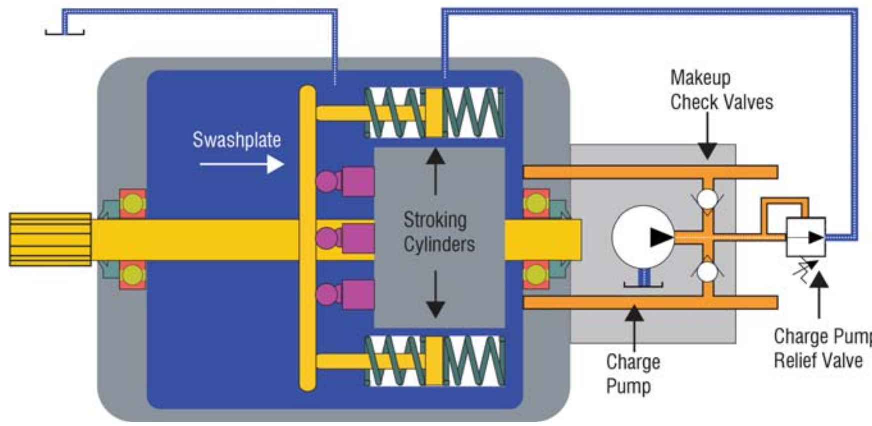


Figure 2. The main pump in idle mode

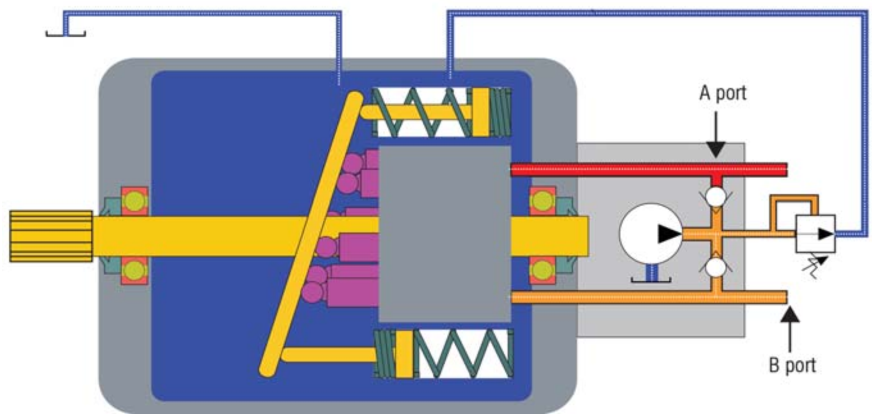


Figure 3. Driving the motor forward

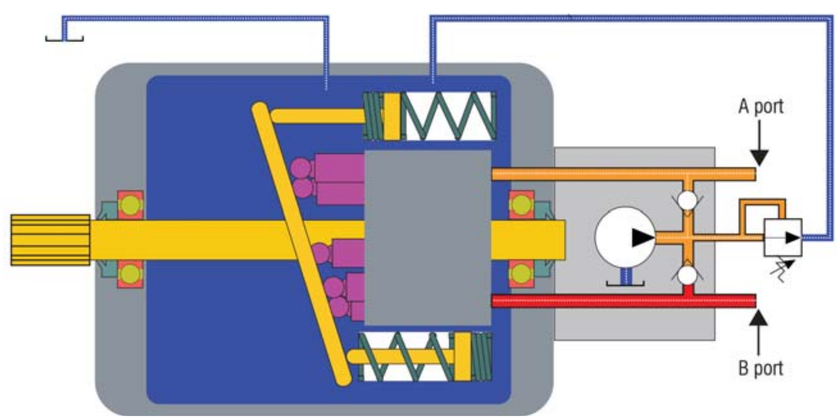


Figure 4. Driving the motor in reverse

Charge Pump Relief Valve

The charge pump relief valve provides a flow path for the excess pump volume to return to the tank in idle mode. The relief valve is normally mounted on or near the charge pump. The outlet flow of this relief valve is usually ported into the pump case where it returns to the tank through the main pump’s case drain line. In the system shown in Figure 2, the relief valve setting determines the pressure in the system when in idle mode. This pressure is typically 200-300 PSI. On systems that utilize a hot oil shuttle valve, a shuttle relief valve determines the pressure on the low side of the loop when driving the motor.

Makeup Check Valves

Makeup check valves permit free flow from the charge pump to the low-pressure side of the loop. At the same time, oil in the high-pressure side is blocked to the low-pressure side by the opposite check valve. The check valves are normally accessed by removing the charge pump.

Crossport Relief Valves

Crossport relief valves limit the maximum pressure in the system. If the motor should mechanically stall, the relief valve on the high-pressure side would open and dump fluid back to the low-pressure side of the loop, protecting the motor from overpressurizing. The valves also absorb shock spikes in the system. To best absorb the pressure spikes, the valves are generally mounted as close to the motor as possible. Depending on the system, the valves may be located on the pump, mounted in a separate block or on the hydraulic motor.

The valves typically are preset to 200 to 400 PSI above the maximum operating pressure. Some drives may have a maximum pressure override, which operates similarly to a pump compensator. When the pressure override setting is reached, the pump volume is reduced to an output of nearly zero GPM. The pump will only deliver enough oil to maintain the pressure override setting. On these systems, the pressure override is set below the crossport relief valve settings.

Hydraulic Motor

The speed and direction of the motor is determined by the variable displacement hydraulic pump. Maximum pressure to the motor is controlled by the crossport relief valve settings. The motor case drain flow should be checked and recorded for future troubleshooting purposes. On systems with hot oil shuttle valves, the tank port of the shuttle relief valve is sometimes ported into the hydraulic motor case drain line. With these systems, checking the case flow would not provide an accurate indication of bypassing. This occurs because excess flow in the system would combine with the bypassing in the hydraulic motor.

Pump Control

The most common method of varying the pump volume is either by a mechanical connection or a servo valve. The mechanical control is done with a cable or other mechanical linkage. In some instances, the mechanical connection shifts a valve on the pump, which ports oil to the spring-loaded cylinders inside the pump. In other cases, the mechanical control is connected directly to the swashplate. An operator will move a joystick or foot pedal to stroke the pump. The gallons per minute the pump delivers are directly proportional to the amount the joystick or pedal is moved. The direction of pump flow and thus the rotation of the hydraulic motor are determined by which direction the pedal or joystick is moved. If the pump is delivering fluid when the joystick or pedal is centered, then the mechanical linkage may need to be adjusted.

Most hydrostatic drives in industrial applications use a servo or proportional valve to control the main pump. The specific valve is usually mounted on the pump housing. The valve is controlled by an input signal into the valve amplifier (normally a positive and negative direct current voltage). The input signal can come from a potentiometer, joystick or

Regular Maintenance Checks

To effectively troubleshoot a hydrostatic drive, some preliminary checks should be made when the system is operating properly in order to establish a reference.

Record the charge pump relief valve setting. When the main pump is idle, the charge pump relief valve setting will be indicated on all gauges in the system. The exception is when a two-position hot oil shuttle valve is being used.

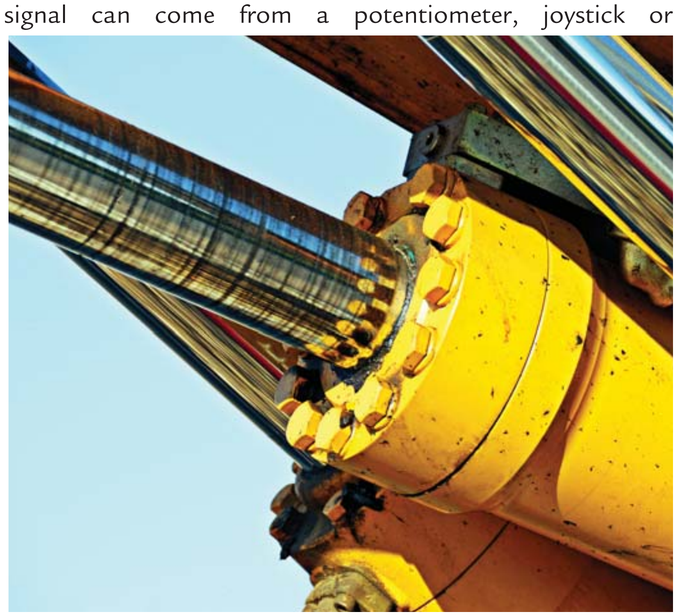
Record the shuttle relief valve setting. Check this pressure on the low-pressure side of the loop when driving the hydraulic motor.

Record the maximum operating pressure. Check when the drive has the heaviest load on the machine. Check in both forward and reverse directions.

Check the command voltage to the amplifier and the current to the servo valve. The motor's revolutions per minute should be recorded for a specific DC signal to the servo valve. Speed problems in hydrostatic drives are usually related to either the incoming DC signal or the servo valve. Some pumps have a displacement indicator. The indicator position should also be recorded for a specific command voltage to the amplifier.

If the motor is a piston type, check the case drain flow. As the motor wears, more oil will bypass. Be sure to check when driving the motor, as excessive bypassing occurs when pressure is at the maximum level. This will not be an effective check if the shuttle relief tank line is ported back through the motor case.

Check the filter indicators. Filters typically have a color-coded or other visual indicator to show the element condition. If the elements are partially plugged on non-bypassing-type filters, the drive will slow down. The filters should be checked and changed on a regularly scheduled basis.



Troubleshooting Hydrostatic Drives

If the neutral position is difficult or impossible to find, check the control valve and linkage. Null the valve if possible.

If the system is overheating, check the oil level in the tank, inspect the heat exchanger, check the inline pressure filters, inspect the crossport relief valves, and check the pump and motor case drains for excessive bypassing.

If the drive only operates in one direction, check the crossport relief valves, the command voltage, the control valve and linkage, and the makeup check valves. Also, inspect the hot oil shuttle valve.

If there is a sluggish response, check the charge pump pressure, charge pump suction filter, charge pump relief valve, hot oil shuttle relief valve, control valve, crossport relief valves, charge pump suction filter and charge pump.

If the drive will not operate in either direction, check the oil in the tank, the control valve and linkage, the command and power supply voltages, the crossport relief valves, the charge pump pressure, the charge pump relief valve, the hot oil shuttle relief valve, the pressure override, and the pump and motor case drain lines for excessive bypassing.

programmable logic controller (PLC). A positive voltage generally will shift the valve into the "A" (straight arrows) position, while a negative voltage will shift it into the "B" (crossed arrows) position.

In Figure 1, the servo valve is shifted into the "A" position to port oil from the charge pump to the spring-loaded cylinder for stroking the pump swashplate. Once the swashplate moves proportionally to the amount the servo valve spool shifts, a mechanical feedback will block the oil flow out the servo valve. The pump swashplate will then stop moving and maintain the selected volume. To reverse the flow direction out of the pump, a negative direct current (DC) voltage is applied to the amplifier. The valve will then shift proportionally into the "B" position and deliver fluid out the opposite port to reverse the motor.

When there is no electrical signal to the valve, the pump volume output should be zero GPM. If the hydraulic motor is drifting, either the centering springs on the cylinders need adjusting or the valve needs to be nulled.

The oil flow to the valve is filtered by a non-bypassing 3- to 10-micron element. Most servo valves also contain a small pilot filter that has a 100- to 200-micron rating. If either filter plugs, the pump will stroke very slowly or not at all.

Hot Oil Shuttle Valve and Shuttle Valve Relief

One of the disadvantages of hydrostatic drives is that the majority of the oil stays in the loop and doesn't return to the reservoir for cooling. One way to return some of the oil back to the tank is by using a hot oil shuttle valve. The purpose of this valve is to direct a portion of the flow exiting the motor through a cooler before returning to the tank.

When the motor is driven in the forward direction, the shuttle valve is shifted so the oil in the suction side of the loop is ported to the shuttle valve relief. The charge pump will deliver more oil to the pump suction side than is needed to make up for the bypassing inside the main pump and motor. This causes the pressure to build up to the shuttle valve relief setting (150-220 PSI). The shuttle relief valve will then open and port a small amount of the oil that flows out of the motor through the cooler and back to the tank. The setting of the shuttle relief valve spring determines the pressure on the low-pressure side of the loop. Although not all systems utilize shuttle valves, they are highly recommended to reduce heat in the system.

It is important that the pressure of the shuttle relief valve be set below the charge pump relief valve. If set higher, the excess charge pump fluid will dump through the charge pump relief valve at all times, bypassing the cooler. This can cause the system to overheat. The hot oil shuttle valve and relief valve generally are bolted onto the hydraulic motor. They may also be mounted in a separate block along with the crossport relief valves.

Inline Filters

The fluid in a hydrostatic loop constantly recirculates, except for the oil flow through the shuttle relief valve. The best filter arrangement is to filter the fluid in both directions on each side of the loop. If filtering is not done in both directions, when the pump fails, the contamination from the pump can go directly into the motor or vice versa.

The filters shown in Figure 1 will filter oil as it flows into the motor. If the element becomes contaminated, oil will flow through the spring-loaded bypass check valve. Oil that flows out of the motor will flow through the non-spring-loaded check valve. The filters should have visual or electrical indicators to reveal when the elements are contaminated.

Charge Pump Suction Filter

This filter cleans the oil from the tank to the suction port of the charge pump. It usually is non-bypassing and has a 10-micron rating. The filter should be changed and cleaned on a regular schedule. If it becomes contaminated, the charge and main pump may cavitate.

45%

of lubrication professionals use hydrostatic drives or transmissions at their plant, according to a recent survey at MachineryLubrication.com

Hopefully, by learning about the different components of hydrostatic drives, you now have a better understanding of these important systems and how they should function.

About the Author

Alan Dellinger has been a member of GPM Hydraulic Consulting's team of instructors and consultants since 2000. He has 16 years of previous hands-on mechanical, pneumatic and hydraulic troubleshooting experience with International Paper. Alan has trained more than 2,000 electricians, engineers and mechanics throughout North America and the United Kingdom on how to troubleshoot their hydraulic systems. Contact Alan at gpm@gpmhydraulic.com.

TEST your KNOWLEDGE

This month, *Machinery Lubrication India* continues its "Test Your Knowledge" section in which we focus on a group of questions from Noria's Practice Exam for Level I Machine Lubrication Technician and Machine Lubricant Analyst. The answers are located at the bottom of this page. The complete 126-question practice test with expanded answers is available at store.noria.com.

1. Viscosity index is:

A) An instrument to measure viscosity
B) A unit of viscosity
C) An oil's change in viscosity with pressure
D) Relates to the relative change in viscosity to change in temperature
E) An oil's change in viscosity with shear

2. Single-point grease lubricators:

A) Are able to pump grease to a large number of grease points
B) Are a reliable "set it and forget it" grease-dispensing system
C) Are useful for hard-to-reach lube points
D) Are capable of producing pressures similar to centralized systems
E) All of the above

3. After some possible initial change, as oil ages, the acid number generally:

A) Trends down
B) Trends up
C) Stays very flat
D) Oscillates both up and down
E) None of the above

Answers

1. D

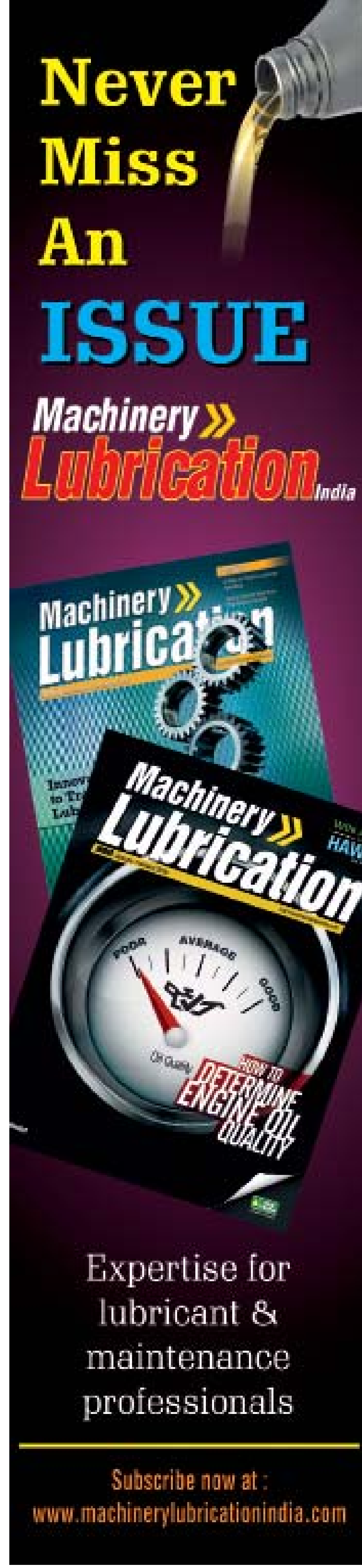
Viscosity is a function of temperature. The change in an oil's viscosity with respect to temperature is represented by the oil's viscosity index (VI), which is unitless. It can be experimentally calculated by determining the viscosity at 40 and 100 degrees C.

2. C

A single-point grease lubricator is used to pump grease to a limited number of grease points (normally one). It should be inspected regularly to ensure it is functioning properly. These types of lubricators are very useful for hard-to-reach lube points, enhancing safety and reliability. The pressure produced by single-point lubricators is much less than centralized greasing systems, so the correct answer is C.

3. B

As oil ages, a series of chemical reactions take place within the oil. This normally results in many chemical species, including acids. The formation of these acids causes the acid number to increase.



Wes Cash | Noria Corporation

BEST WAYS to Combat OIL GELATION

As oil breaks down, a variety of issues can arise, including gelation. This is when the oil is no longer fluid and resists flow. As you can imagine, this leads to poor lubrication and potential machine failure. By understanding what causes gelation and which oils are most prone to this process, you can help to prevent it and ensure your equipment will run as efficiently as possible.

Defining Gelation

According to ASTM International, oil gelation is defined by a rheological condition of an oil characterized by a marked increase in the flow resistance over and above the normal exponential increase of viscosity with decreasing temperature, particularly at lower shear stresses and temperatures. ASTM D5133 is one method that can be used to analyze the tendency of oil gelation. In this test, a candidate oil is heated and then gradually cooled while the viscosity is measured at different temperatures.

The gelation index is a result of this test. As oil is cooled, the viscosity goes up. This value can be plotted on a chart. The slope of the viscosity line versus temperature is analyzed for changes. If the slope rapidly increases at a certain temperature, this should be noted. Once the test is completed, the full chart can be analyzed and the gelation index developed. The temperature at which the viscosity rapidly thickens is known as the gelation index temperature.

This information becomes important as temperatures decline, especially if the equipment operates in a cold environment such as in a freezer or outside in cold climates. Oils most prone to gelation are typically motor oils, particularly those with a higher wax content than others (paraffinic base oils). This phenomenon occurs in colder conditions or in situations where the oil has experienced a gradual cooling. As the viscosity increases due to lower temperatures, certain contaminants or conditions can be achieved in which the viscosity rapidly increases and the oil gels.

Gelation Standards

The American Petroleum Institute (API) has established standards for the gelation index in motor oils. In most cases, the maximum acceptable gelation index is 12, with a maximum

36%

of lubrication professionals have seen the effects of oil gelation in machines at their plant, based on a recent survey at MachineryLubrication.com viscosity of 40,000 centipoise. There is a certain point when an oil simply can't be pumped due to either gelation or to viscosity that is too high. When viscosity increases, a limited flow condition can occur. This is when the volume of oil being pulled through the pump is lower than what is needed to adequately lubricate the motor.

If the oil gels or the viscosity becomes too high, it can lead to another condition known as air binding. In this condition, an air void is created within the oil in the sump. The oil is too thick to fill the void, and thus the pump just pulls in air. This adversely affects the health of the equipment, as it can lead to boundary conditions, excessive wear and ultimately premature failure.

Other methods can also be used to test an oil's cold-temperature characteristics. ASTM D3829 is the standard test method for predicting the borderline pumping temperature of engine oil. With this test, the goal is to identify the temperature at which an engine oil can no longer be pumped. The test results can indicate whether a candidate oil remains fluid enough at certain temperatures or if a different oil should be selected.

Gelation in Gear Oils

Gearsets are another area where the gelation or cold-temperature characteristics of an oil become important. Gear oils generally have a high initial viscosity, which leads to a much higher viscosity at low temperatures. Studies on gear oils lubricating wind turbine gearboxes have shown that these oils can become quite cold at several hundred feet above the ground and in cold climates. The cold temperatures coupled with moisture contamination resulted in the formation of gels in some of the in-service gear oils. This condition can be just as detrimental to the health of the gearbox as the motor oil condition discussed previously.

Gelation Factors

Several factors should be taken into account when determining how well a lubricant will work at colder temperatures and the probability of gelling at these temperatures. These include the base oil, wax content, pour point and the base oil's refining process. All of these will have a marked impact on gelation and the lubricant's cold-temperature characteristics.

If your equipment is operating in extreme cold temperatures, you should consider the base oil used in the lubricant. Mineral base oils have a wide operating temperature range but are often discarded in favor of comparable lubricants with a synthetic base oil. Synthetic oils generally have a higher viscosity index, which means they will remain more fluid in cold conditions and thicker in hotter temperatures.

For machines that require mineral oils, take note of the API base oil category or how refined the base oil is. Crude oils from the ground naturally have a bit of wax in them, which can negatively affect the oil's tendency to gel in cold temperatures. The majority of this wax can be removed through refining. During the dewaxing process, the wax content is reduced or the wax structure is converted to a different structure with better properties. The cold-temperature characteristics are also improved. Typically, the more refined a base oil, the higher the viscosity index and the better the low-temperature properties.

API base oil Groups II and III have lower volatility and lower pour points. When in doubt about which API group a particular base oil falls into, contact the oil manufacturer or consult the technical data sheets.

An oil's pour point is another property that should be analyzed before selecting a lubricant to be used in cold environments. The pour point is the temperature at which the oil will no longer flow due to gravity. As an oil is cooled, waxes remaining in the oil begin to crystalize and congeal together, making the fluid more solid until it stops flowing. Even oils that are virtually free of wax will have a pour point associated with them. If choosing a lubricant for a machine that will operate in extremely cold environments and there are several oils with the same properties except for the pour point, pick the one with the lowest pour point to avoid issues stemming from reduced flow at cold temperatures.

Synthetic base oils are synthesized from different compounds and mostly have no waxes in them. They also have a lower pour point than mineral oils and are often selected for cold environments due to their higher viscosity index and lower pour point. However, synthetic base oils are still at risk of gelation if they become contaminated with certain contaminants such as water and glycol. Routine oil analysis should be performed to look for these common culprits.

Preventing Gelation

When it is impossible to find an oil that stays thin enough in cold environments, a common solution to avoid the pitfalls of restricted flow or excess viscosity is to install a lube oil heater. These types of heaters can keep oil warm enough to allow it to flow as well as reduce the overall system pressure when the oil would otherwise be too thick to pump. Low-wattage heaters, electric blankets and steam piping are popular heating accessories designed to help the oil remain at a consistent temperature. If you are planning to utilize a heater, make sure it doesn't heat the oil too much, as this can degrade the oil and shorten its life. If steam is used, the oil should be routinely inspected for water ingression.

Benefits of Gelation

The tendency of an oil to gel at specific temperatures and with certain contaminants isn't always a bad thing. In fact, this property has been used in cleaning up spilled oil, particularly oils spilled in large bodies of water. The Environmental Protection Agency employs "gelling agents" to form gels in spilled oil while not reacting with the water. These agents are blended into the oil slick through mechanical agitation or through the action of the waves in the body of water. Once the oil gels, the agents can then be easily removed by skimming or any other form of separation.

While not all oils perform the same way with contamination and cold temperatures, most problems associated with the thickening of lubricants can be avoided with a good contamination control program and by selecting the right lubricant for the application. Routine oil analysis can help detect issues related to oil gelation before any significant machine damage occurs. If temperature-control devices such as heaters must be used, inspect them often for any signs of faults. Also, check the oil temperature to avoid overheating. With proper attention and care, the lubricants you use in cold temperatures can provide a long service life with few if any difficulties. ■

Most problems associated with the thickening of lubricants can be avoided with a good contamination control program and by selecting the right lubricant for the application.

About the Author

Wes Cash is a senior technical consultant with Noria Corporation. He holds a Machine Lubrication Technician (MLT) Level II certification and a Machine Lubricant Analyst (MLA) Level III certification through the International Council for Machinery Lubrication (ICML). Contact Wes at wcash@noria.com.

The BENEFITS of Professional CERTIFICATION

Seeking professional certification is a common practice for people in all types of industries worldwide, and for good reason. Certification signifies an individual's expertise and training to employers, peers and clients (where applicable), and also helps industries as a whole define and maintain standards.

Certification involves much more than passing an exam and adding a line to a résumé, especially in industries that rely on machinery and ever-changing technologies. Because it serves as both a credibility earmark and an industrial standard, certification must entail careful preparation and regular updating to keep up with new developments in the industry.

Why Get Certified?

A major incentive for most professionals is an increase in pay. Even if individuals aren't motivated directly by their employer, *Machinery Lubrication* surveys have consistently found that those with International Council for Machinery Lubrication (ICML) certifications make more money, and those who become certified are likely to receive a pay increase shortly thereafter.

Of course, monetary gain is just one aspect to consider. Certification denotes training, and numerous studies show that job satisfaction and employee performance hinge on strong training and continuing education. As an effective training "receipt," certification exemplifies these benefits perfectly for both the individual and the employer. Organizations that value training and certification tend to see lower personnel turnover and increased productivity, which subsequently yield greater profits.

Even for the industry as a whole, certification provides valuable cohesion of practitioner standards and a path for advancement where they may not otherwise exist. A level of certification also acts as an excellent benchmark for job postings, industry regulations and technologies becoming the norm.

Why Recertify?

Because certifications are important validators for individuals, employers and industries, it is critical that being certified represents credible excellence, not just a passing grade on an exam.

In order to reflect a professional's skill set and expertise as accurately as possible, earning a certification must be a thorough, challenging process. However, without regular updates, certifications would become obsolete and ultimately useless. As technologies and protocol evolve, so must an individual's skills and experience. Recertification is the best method for ensuring that certified individuals are in fact proficient in the necessary aspects of their field and demonstrate it every day in their jobs.

Typically, recertification is a straightforward process that is not as

CATEGORY	POINTS	MAXIMUM	DOCUMENTATION
Training	1 point per day	10 points	Proof of attendance (certificate, badge or letter from training company on its letterhead) and a copy of the course outline
Employment	4 points per year	12 points	Letter from employer (on company letterhead) with title of signer shown
Article Publication	2 points per article	6 points	Copy of article and table of contents of the book, proceedings, magazine or journal in which it was published
Conference Attendance	1 point per conference day	6 points	Proof of attendance (certificate, badge or letter from conference organizer on its letterhead) and copy of program

ICML Recertification Criteria

challenging as the initial training/exam process of becoming certified. The focus is more on the professional development of individuals. Are they continuing to learn new things? Are they effectively meeting the demands of their jobs? Are they engaged in their industry via events and conferences or making important contributions by writing papers and magazine articles?

How to Renew ICML Certification

ICML certifications expire three years from the date of an individual's exam. All certifications are renewed via a points system. Points must be earned during the three years of valid certification.

To recertify, submit a completed application to ICML with proof of any of the criteria shown below totaling 15 points. Additional requirements may apply. Please visit ICMLonline.com for complete recertification criteria and deadlines. ■

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Don't Overlook Bearing Lubrication Basics

When rolling-element bearings are lubricated from oil held in a sump, attention to the oil sump level indicator could help extend bearing life and reduce bearing temperatures due to churning and metal-to-metal contact from oil starvation. As a general rule, the lowest rolling element should be half covered with oil when the bearing is stationary. This may seem like a simple rule to observe, but it is surprising how often it is overlooked.

Reduce Oil Sampling Mistakes

When installing oil sampling ports on equipment, try to incorporate permanent sample port identification tags. These tags help minimize confusion regarding the actual location of the sample port on the equipment and ensure that samples are drawn from the correct location. Sample port identification tags also help guarantee the proper label is fixed to the bottle before it is sent to the lab.

Keeping Destructive Particles Out of Oil

One of the biggest culprits for letting dirt into hydraulic and oil reservoirs is the air breather. Many systems come with a standard paper media breather that has a nominal rating of about 40 microns. This allows the smaller, more destructive particles to get into the system easily. Upgrading a standard breather to a high-efficiency filter is easily done using commercial bayonet adapters and quality synthetic hydraulic filters.

How Temperature Affects Lubricant Selection

The main factor that limits the use of mineral oils in high-temperature applications is their oxidation stability rather than the viscosity thinning or thermal stability. In the presence of air, it is generally not advisable to use mineral oils in any application at temperatures above 200 degrees F (93 degrees C).

Outdoor Lubricant Storage Tip

To minimize water and particulate contamination from entering new drums of oil, it is preferred to keep drums indoors and stacked horizontally. However, when it is necessary to store drums outdoors and uncovered, here is a technique that may be used to remove water from the top of a drum.

Attach a paper towel to the top of the drum. Allow the paper towel to hang over the edge of the drum so that the water wicks through the towel and down the side of the drum. Water will continue to travel from the top of the drum to the ground so that breathing of water through the bungs is reduced.

Creating Oil Analysis Performance Standards

Most people have heard the words of ignorance that "oil is oil" when it comes to lubrication. An equally false notion is that "oil analysis is oil analysis." Just as you would create performance standards for selecting and purchasing lubricants, there needs to be a pre-engineered task description of the work to be done by an oil analysis lab — basically an oil analysis performance standard.

Visual Oil Inspection Method

Appearance and color provide an easy means to detect changes that have taken place in oil. These changes include contamination with other oils, water contamination (often evidenced by haziness/cloudiness when in excess of 200 parts per million depending on the oil type) and oxidation (darkening of the oil). The oil should be clear and bright with no sediment or visible water (haze or layered). Comparing the oil's color to new, unused oil can be useful in the examination process.

Advice for Changing Filters

When is the correct time to change a filter? When the differential pressure gauge reads 25, 40 or is topped out? Some systems have a built-in pressure relief that may never allow the back pressure to indicate the need for a filter change. Writing the date when the filter was last changed on the filter or tag can help. Including the filter part number has also proven useful. Consider covering the date and part number with plastic so it isn't wiped off during cleaning.

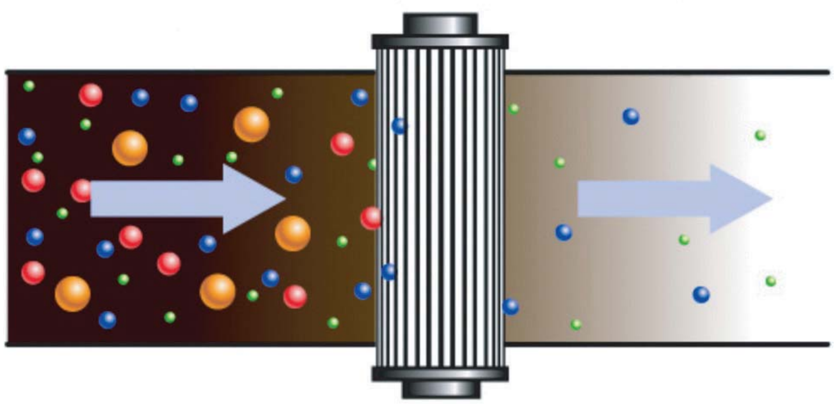
PETROMIN ENGINEERS TRAINED WITH UBRICATION INSTITUTE

Petromin Corporation conducted their second in house training program on "ADVANCE MACHINERY LUBRICATION" and Industry specific training at their Head Office Jeddah, Kingdom of Saudi Arabia. 31 Engineers/ Technicians from various regions of Kingdom of Saudi Arabia and Countries participated and were trained in a 4 day training program. The training was conducted by Lubrication Institute (an associate of Vas Tribology Solutions.) Industry specific program was very interactive . Cement ,Power and Mining were specifically covered.

Noria Skill Training on Machinery Lubrication and Oil Analysis was conducted by Lubrication Institute at its public training program, recently. Training was followed by ICML Certification Exams. Details of Noria Skill Trainings on Lubrication Enabled Reliability for Indian subcontinent can be found at institute's website (lubrication-institute.com).The next public trainings are scheduled for November 2016.

"We are having a discussion as to whether way lube can be overfiltered.

"We use 220 way oil on our mechanical presses, and the question was whether we could clean the oil too much. What is the standard way lube filtration recommendation, if there is one?"



The question of whether more is always better when it comes to filtration is a common concern. The answer isn't as simple as you might think. It has been proven that cleaner oil decreases bearing and machine wear, thus increasing equipment life expectancy. However, there are issues to consider when striving for very low ISO cleanliness codes.

One of the first things to take into consideration is the machine's tolerances and need for clean oil. Hydraulic systems are notorious for needing clean oil, especially when compared to an industrial gearbox. That's not to say that gearboxes don't require clean oil. It just depends on the machine's age, criticality and equipment cost. In other words, the fluid cleanliness should be matched to these conditions.

After determining the required machine cleanliness, you must select a filter to achieve these levels. The filter's micron rating is commonly referred to as the benchmark of filter performance, but this only tells half the story. The beta ratio completes the picture of the filter's true performance and capability. While the micron rating tells you how fine or how coarse the filter media is, the beta ratio tells you how efficiently it catches particles at that micron value. For instance, while having a 3-micron filter is good, it doesn't tell you much about the filter. It could be a 3-micron filter with a beta ratio of 2, which is only 50 percent efficient, or as high as 2,000, which is 99.999 percent efficient at the same micron value.

Some filters can actually filter at a sub-micron level. As they become more aggressive, filters can begin to strip out some additives, affecting lubricant health. For example, defoamants are among the most common additives to be filtered out, as they are quite large. Depending on the filter media, other additives may be at risk as well. If using a chemically active filter such as fuller's earth, polar additives (extreme pressure, anti-wear, demulsifiers, etc.) can be stripped, affecting the lubricant's additive package and ability to protect the machine's surfaces.

While clean oil is always better, balancing the needs of the machine with the cost of cleaning the fluid can lead to greater reliability and fewer failures. Remember, when it comes to filtration, it isn't a one-size-fits-all approach. All systems have unique requirements for cleanliness, and they should all be viewed independently.

"How do you interpret the results of a DIN ISO 6614 demulsibility test for turbine oils?

"I'm checking a data sheet of a proposed lubricant's separation power of water and oil, and the test yields a value of less than 30. Is this a good result for the test?"

The ability for water and oil to separate, also known as demulsibility, is an important factor in many industrial oils. The effects of water in oil can be very detrimental to machine surfaces and can greatly reduce machine life. This oil property must be closely monitored, especially in areas where water ingression is common (steam turbines, paper machines, etc.).

There are three states of water in oil: dissolved, free and emulsified. Dissolved water occurs when the molecules are dispersed one by one throughout the oil. As the amount of water in the oil increases, you begin to see emulsions, or water that is suspended in the oil, and then free water. Free water is the water that separates and settles out of the oil. It is typically found in the bottom of the sump or reservoir.

When testing for demulsibility, specific amounts of oil and water are mixed. The resulting solution is then left to separate. The results are reported in the following format: X/X/X (X). This correlates to the amount of oil/water/emulsion and time (in minutes) to reach that level of separation. The best results would be 40/40/0, with a lower number in parenthesis indicating quicker full separation. This result shows that the original 40 milliliters (ml) of oil fully separated from the 40 ml of water. As fluid ages, there tends to be a difference in these values, particularly in oils that have been contaminated with water.

Conversely, 0/0/80 would be the worst possible result. In this case, the oil and water never separate, and what is left is known as a stable emulsion. Of all states of water in oil, emulsified water is considered the most destructive. As oil flows through a system, the emulsified water flows with it and can cause increased machine damage through corrosion, impaired load-carrying capability and a long list of other issues.

A value of less than 30 means that the measured separation occurred in less than 30 minutes. Provided the oil and water separated completely, the oil's demulsibility properties are likely still intact. The best way to know whether the results for used oil are satisfactory is to start with a good baseline. As new oils are delivered, they should be subjected to these types of tests to establish a baseline for comparison. ■

If you have a question for one of Noria's experts, email it to editor@noria.com.

Michael Brown | Noria Corporation

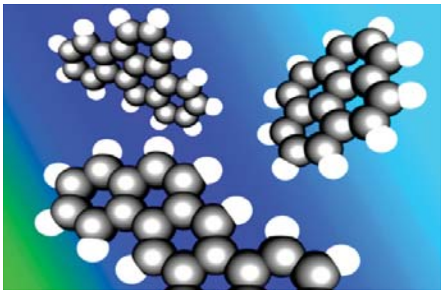
What You SHOULD KNOW About LUBRICANT TOXICITY

The world of lubrication is filled with many and varied lubricant types, and not all of them should be treated in a cavalier manner. In fact, most lubricants should be handled with care and proper personal protective equipment (PPE). The base oils and additives that make up lubricants not only can have catastrophic effects on the environment, but they can also be toxic to your health.

Base Oil Types

Base oils are made up of five different groups, as designated by the American Petroleum Institute (API). These groups help identify base stocks in finished oil formulations to ensure the oil's performance criteria are met.

Group I includes base oils that are acid-treated, solvent-refined and aromatic. These are lubricants with sufficient evidence of carcinogenicity to humans. Group I oils contain compounds called polycyclic aromatic hydrocarbons (PAHs), which can exist in more than 100 different combinations. PAHs occur naturally in the environment but can also be man-made. They are found in tar, coal and various edible oils. PAHs are impurities that have been left behind after the refining process and are the reason Group I oils are considered carcinogenic.



A polycyclic aromatic hydrocarbon structure

Group II oils are described as being mildly hydrotreated. While no human data exists for these lubricants, animal data has indicated possible or probable carcinogenicity. Mild hydrotreating helps reduce the amount of carcinogenic PAHs but does not necessarily eliminate them. Increasing the temperature and pressure of hydroprocessing can eliminate carcinogenic compounds.

Group III base oils are manufactured using the hydrotreatment process but are subjected to higher temperatures or processing times. These highly hydroprocessed or non-conventional oils have improved oxidation stability and low-temperature performance but still contain some impurities that cannot be removed. These lubricants are not classifiable as being carcinogenic to humans. They include base oils that are severely hydrotreated.

The API has classified synthetic engine oils made with polyalphaolefins (PAOs) as a special class of base stock. The term "synthetic" was originally used to refer to Group IV (PAOs) and Group V base stocks. Group IV is used to designate PAO synthetics. All other base stocks, including other synthetics and natural esters (vegetable oils) default into Group V.

Of the refining steps used in preparing lubricating oil base stocks from petroleum, only effective solvent extraction, severe hydrogenation or exhaustive fuming sulfuric acid treatment appear to be adequate in eliminating PAHs. Newly synthesized PAOs (Group IV base stocks) do not contain PAHs.

With few exceptions, Group V synthetic oils are chemically engineered base stocks that do not fall into any of the previous categories. They are typically

62%

of plants have not taken any steps to address the toxicity and safety concerns in lubricant formulations, based on a recent poll at MachineryLubrication.com

ADDITIVE TYPE	PURPOSE	TYPICAL COMPOUNDS	FUNCTIONS
Anti-wear and EP Agents	Reduce friction and wear, and prevent scoring and seizure	Zinc dithiophosphates, organic phosphates, acid phosphates, organic sulfur and chlorine compounds, sulfurized fats, sulfides and disulfides	Chemical reaction with metal surface to form a film with lower shear strength than the metal, thereby preventing metal-to-metal contact
Corrosion and Rust Inhibitors	Prevent corrosion and rusting of metal parts in contact with the lubricant	Zinc dithiophosphates, metal phenolates, basic metal sulfonates, fatty acids and amines	Preferential adsorption of polar constituent on metal surface to provide protective film or neutralize corrosive acids
Detergents	Keep surfaces free of deposits	Metallo-organic compounds of sodium, calcium and magnesium-phenolates, phosphonates and sulfonates	Chemical reaction with sludge and varnish precursors to neutralize them and keep them soluble
Dispersants	Keep insoluble contaminants dispersed in the lubricant	Alkylsuccinimides, alkylsuccinic esters and Mannich reaction products	Contaminants are bonded by a polar attraction to dispersant molecules, prevented from agglomerating and kept in suspension due to the solubility of the dispersant
Friction Modifiers	Alter the coefficient of friction	Organic fatty acids and amides, lard oil, high-molecular-weight organic phosphorus and phosphoric acid esters	Preferential adsorption of surface-active materials
Pour Point Depressants	Enable lubricant to flow at low temperatures	Alkylated naphthalene and phenolic polymers, polymethacrylates, maleate/fumerate copolymer esters	Modify wax crystal formation to reduce interlocking
Seal Swell Agents	Swell elastomeric seals	Organic phosphates and aromatic hydrocarbons	Chemical reaction with elastomer to cause slight swell
Viscosity Modifiers	Reduce the rate of viscosity change with temperature	Polymers and copolymers of olefins, methacrylates, dienes or alkylated styrenes	Polymers expand with increasing temperature to counteract oil thinning
Anti-foamants	Prevent lubricant from forming a persistent foam	Silicone polymers, organic copolymers	Reduce surface tension to speed collapse of foam
Antioxidants	Retard oxidative decomposition	Zinc dithiophosphates, hindered phenols, aromatic amines, sulfurized phenols	Decompose peroxides and terminate free-radical reactions
Metal Deactivators	Reduce catalytic effect of metals on oxidation rate	Organic complexes containing nitrogen or sulfur, amines, sulfides and phosphites	Form inactive film on metal surfaces by complexing with metallic ions

esters, polyglycols and silicone. In this group, most of the attention has been placed on phosphate esters, which have shown the most potential to harm humans. Allergic reactions have been associated with products containing triphenyl phosphate, and a number of health effects have been observed in laboratory animals ingesting phosphate-ester flame retardants.

Additives

Additives are chemical substances that are mixed within lubricants to enhance their performance. There are many different types of additives, and most have the potential to harm the human body. Some of the more popular additives are shown in the table above. The best way to combat additives is to minimize your exposure to them. Always limit contact between your skin and the lubricant.

MSDS

A lubricant's material safety data sheet (MSDS) can enable you to understand the risks to humans, animals and the environment. Each section of the MSDS is numbered and should include the information needed to determine if the lubricant is toxic, as detailed below:

Section 1 — The identification section identifies the chemical on the MSDS as well as the recommended uses. It also provides essential contact information for the supplier.

Section 2 — Hazard(s) identification includes the chemical's hazards and the appropriate warning information associated with those hazards.

By using basic common sense and being informed about the risks, you can avoid many of the problems associated with lubricant handling.

Section 3 — The composition/information on ingredients section identifies the ingredient(s) included in the product, such as stabilizing additives and impurities. It also contains information on substances, mixtures and all chemicals where a trade secret is claimed.

Section 4 — The first-aid measures describe the initial care that should be given by untrained responders to an individual who has been exposed to the chemical.

Section 5 — The fire-fighting measures provide recommendations for fighting a fire caused by the chemical, including suitable extinguishing techniques, equipment and chemical hazards from fire.

Section 6 — The accidental release measures offer recommendations on the appropriate response to spills, leaks or releases, including containment and cleanup practices to prevent or minimize exposure to people, properties or the environment. This section may also include recommendations distinguishing between responses for large and small spills when the spill volume has a significant impact on the hazard.

Section 7 — The handling and storage section provides guidance on the safe handling practices and conditions for safe storage of chemicals, including incompatibilities.

Section 8 — The exposure controls/personal protection section indicates the exposure limits, engineering controls and personal protective equipment (PPE) measures that can be used to minimize worker exposure.

Section 9 — The physical and chemical properties section identifies physical and chemical properties associated with the substance or mixture.

Section 10 — The stability and reactivity section describes the chemical's reactivity hazards and stability information. It is broken into three parts: reactivity, chemical stability and other.

Section 11 — The toxicological information identifies toxicological and health effects information or indicates that such data is not available. This includes routes of exposure, related symptoms, acute and chronic effects, and numerical measures of toxicity.

Section 12 — The ecological information provides information to evaluate the environmental impact of the chemical if it were released to the environment.

Section 13 — The disposal considerations offer guidance on proper disposal practices, recycling and reclamation of the chemical or its container, as well as safe handling practices.

Section 14 — The transport information includes classification information for shipping and transporting hazardous chemicals by road, air, rail or sea.

Section 15 — The regulatory information identifies the safety, health and environmental regulations specific for the product which are not indicated elsewhere on the MSDS.

Section 16 — The other information section indicates when the MSDS was prepared or when the last known revision was made. It might also state where the changes have been made to the previous version. You may wish to contact the supplier for an explanation of the changes.

7 PAHs on the EPA's Priority Chemical List

Acenaphthene

Acenaphtylene

Anthracene

Benzo(ghi)perylene

Fluorene

Phenanthrene

Pyrene

Be sure to read the MSDS for all the lubricants you handle and heed the warnings and recommendations. In many cases, the amount of exposure to a chemical will determine the risks. Some chemicals can build up in the body, with their effects not evident until many years later.

To protect yourself from these potentially hazardous materials, create a barrier between you and the lubricant. Wear gloves and safety glasses as well as oil- or chemical-resistant boots. If possible, keep all exposed skin covered. Also, if the oil is misting, wear a mask or some sort of breathing apparatus. By using basic common sense and being informed about the risks, you can avoid many of the problems associated with lubricant handling. ■

About the Author

Michael Brown is an associate technical consultant with Noria Corporation. He has more than 20 years of experience in heavy manufacturing and holds Machine Lubrication Technician Level I and Machine Lubricant Analyst Level I certifications through the International Council for Machinery Lubrication. Contact Michael at mbrown@noria.com.