INSIDE

Machinery Lubrication

India March - April 2015

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How to Operate a GREASE GUN Safely

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Publisher's Note

In our current issue we will talk about safe & sound procedure of application of grease through Grease Guns. Whilst many industrial users use grease guns for greasing the equipments, but there are still a lot of industrial units who are neither using these nor are aware of these methods. We will also discuss about the various types of grease guns and their operations.

We are also carrying an article on "Choosing a Multi Purpose Grease", which will give the readers an insight into how to choose amongst various grades of Multi Purpose Greases.

Our team covered the 17th NLGI (India Chapter) conference in Feb 2015, and we carry a brief report on that too. The event garnered strong participation from industry & academia alike.

We will also read about how to combat break in wear. When a machine is first put into service, there is a period of time known as the "break-in" period. During this time, the machine creates wear debris as components begin their initial motion. While there are differing opinions on break-in times and methods, a few constants remain. Certain variables come into play such as surface coatings, time in storage and lubricant selection. By balancing all of these variables, you can achieve fewer failures during the early stages of machine life.

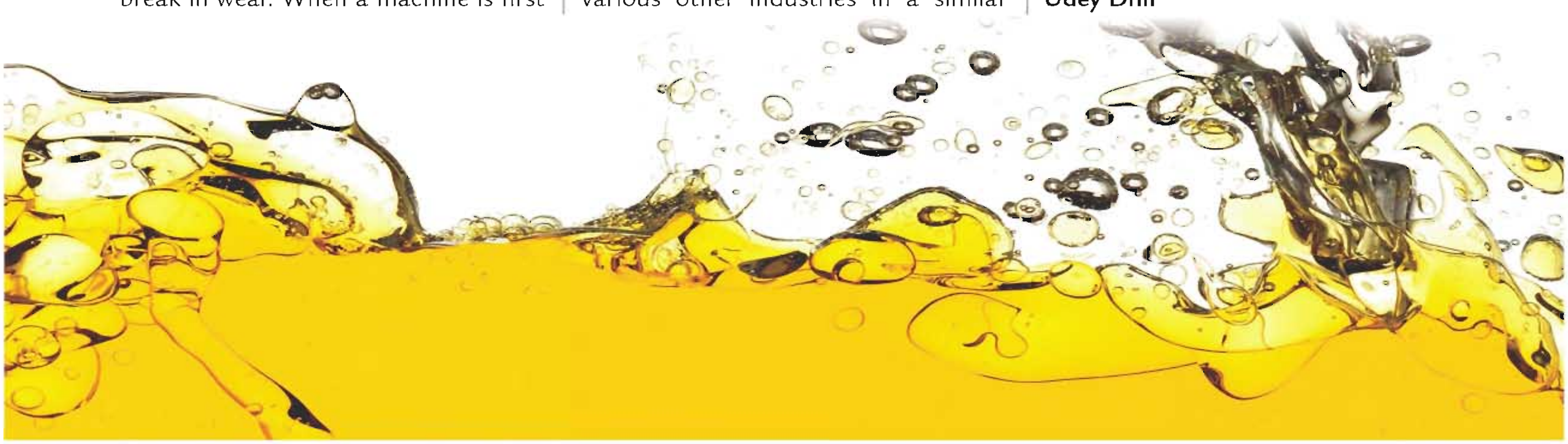
In the previous issue we discussed about Steel Plant Lubrication, highlighting about the steel industry in India, particularly on various techno functional details to be kept in mind while selecting lubricants & implementing a lubrication program. The article generated great interest amongst the readers. We have received requests from various readers to cover various other industries in a similar fashion. Keeping that in mind, we have decided to cover Cement Industry in our next (May-June) issue.

On the request of readers, we propose to start a column in which you could ask questions on various subjects like Machinery Lubrication, Lubricants, MWFs, Oil Analysis and Lubrication Practices. We will have an expert international panel to respond to your quarries.

As usual we welcome our readers' comments and suggestions which enable us to provide you with cutting edge articles. So please keep these suggestions/views coming in to help us serve you better. Your feedback is very important to us.

Warm Regards,

Udey Dhir



JIM FITCH | NORIA CORPORATION

USE ZONE Inspections for EARLY PROBLEM Detection

Early detection means frequent detection. While daily one-minute visual inspections have been discussed previously in *Machinery Lubrication* magazine, many questions remain, including where and how you inspect, what the observed conditions mean, and how you penetrate a machine's exoskeleton exterior without X-ray vision.

There are three important inspection zones in common oil reservoirs and sumps. These zones have a story to tell about your oil and machine. They might be difficult to reach, but difficult does not mean impossible and certainly doesn't mean unnecessary. Let's get inside that exoskeleton and see what we need to know.

Level, Foam and Deposits (LF&D) Zone

Machines don't just need some lubricant or any lubricant. Rather, they need a sustained and adequate supply of the right lubricant. Adequate doesn't just mean dampness or the nearby presence of lubricant. What's defined as adequate varies somewhat from machine to machine but is critical nonetheless. High-speed equipment running at full hydrodynamic film has the greatest lubricant appetite and is also the most punished when starved. Machines running at low speeds and loads are more forgiving when lube supply is restricted. Even these machines can fail suddenly when severe starvation occurs.

70%

of lubrication professionals conduct daily visual inspections of the oil at their plant, according to a recent survey at MachineryLubrication.com

There are four keys to solving starvation problems using proactive maintenance:

1. Identify the required lube supply or level to optimize reliability.
2. Establish and deploy a means to sustain the optimized supply or level.
3. Establish a monitoring program to verify that the optimized supply or level is consistently achieved.
4. Rapidly remedy non-compliant lube supply or level problems.

For non-circulating wet-sump machines, slight changes in oil level can be catastrophic. These include bath, splash, oil-ring, flinger/slinger and similar lubricant supply methods originating from an oil sump. For these machines, frequent confirmation that the correct oil level is maintained has everything to do with machine reliability. This is best done by properly mounted and frequently inspected level gauges.

Some things float, and other things sink. What floats is lighter than oil. It rises by buoyancy. For instance, certain low-density additives can rise and form a visible film on the oil's surface. Air bubbles, water vapor, natural gas and refrigerants are all buoyant. Once they get to the oil's surface, they either release gases into the atmosphere or create bubbles. A stable layer of bubbles forms foam. Foam is disruptive for a variety of reasons, but most importantly it is associated with lubricant starvation. For more

Figure 1. An advanced case of deposits accumulating on metal surfaces above the oil level

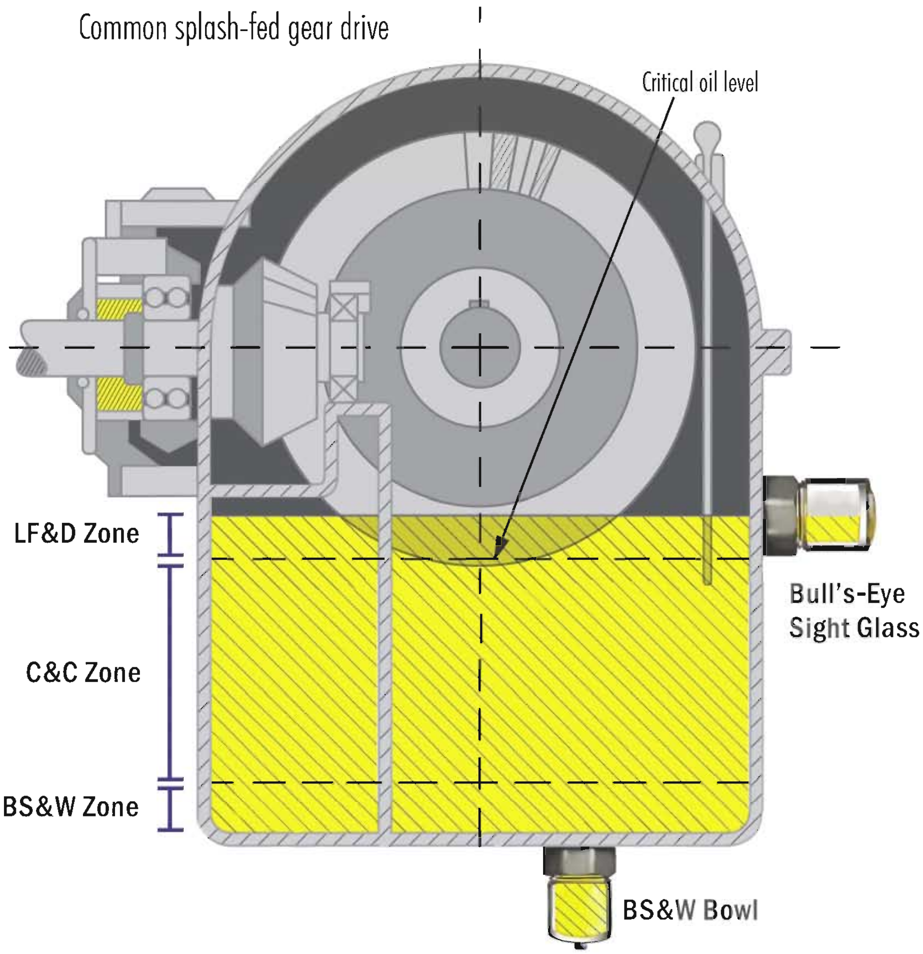


Figure 2. The three inspection zones in common oil reservoirs and sumps

information on the causes and remedies of aeration and foam, see http://www.machinerylubrication.com/Read/690/aerated-oil.

Aeration and foam can be detected as long as you have a window. Sight glasses and level gauges mounted in ports that are centerline to the oil level enable this and should be included in a daily inspection program. This allows both oil level and aeration issues to be checked simultaneously. Optionally, hatches and access ports can also facilitate early detection of abnormal foam and aeration conditions.

Oil level sight glasses and internal tank inspections permit detection of surface deposits as well (e.g., varnish and sludge). The worst of this usually builds just above the oil level, called the splash zone, and looks similar to a tar-like bathtub ring. The cooler metal surfaces above the oil level enable splashed oil to deposit insoluble suspensions (condensation) that accumulate over time. These adherent gums and resins are associated with a range of problems that require early detection including oil oxidation, microdieseling and electrostatic discharge. An advanced case of this is shown in Figure 1. In a similar way, sight glasses can also be used for early detection of deposits. The acrylic or glass used often becomes fouled by deposits when high varnish potential conditions exist.

Bottom Sediment and Water (BS&W) Zone

Sooner or later gravity has a way of dragging things out of oil. On one hand, this is beneficial, as sedimentation and stratification of impurities can have a moderate cleansing effect on the oil. On

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the other hand, there are also many hazards and risks, which will be discussed later.

Most of the things you don't want in your oil are heavier than the oil. These include hard solids (dirt, wear debris, corrosion debris, process solids, etc.), soft solids (sludge, agglomerated oxides, microbial contaminants, dead additives, etc.) and stratified liquids (e.g., free water and glycol).

Low-lying impurities can be referred to as bottom sediment and water (BS&W). BS&W includes all of the following:

- Agglomerated sludge (accumulations of resinous solids, gums, oxides and dead additives)
- Stratified solids (dense zones of soft contaminants, oxides and dead additives)
- Sediment (settled hard contaminants like dirt and wear debris)
- Water and other settled liquid contaminants (e.g., antifreeze)

Often the sludge and sediment found on the bottom of sumps and reservoirs are tightly bound by water. Most oil impurities are polar (water loving) in nature. When free and emulsified water contaminates an oil, this water can act as a mob to collect and bind together these impurities. Eventually, the growing sludgy mass is pulled by gravity to the sump floor. Dirt and wear debris that fell by normal sedimentation can also cling to these sludge pools.

Early Detection of BS&W is Key

As mentioned previously, BS&W is symptomatic of a host of problems and issues related to your oil and machine. Failed and degraded oil, environmental contaminants (e.g., dirt and water), active machine wear and corrosion all produce BS&W. It is so you can start the troubleshooting process and find the originating cause. This can be accomplished by 1) using BS&W bowls, 2) periodically taking drain port samples or 3) using a drop-tube vacuum sampler in which the tube is lowered to the bottom of the sump.

How to Prevent the Fishbowl Effect

In an ideal world, you wouldn't allow bottom sediment and water (BS&W) to accumulate, and oil changes wouldn't be necessary. However, nobody lives in an ideal world. While you can't eradicate BS&W in the real world, you can control its accumulation and resuspension by employing the following suggestions:

- Use a BS&W bowl to monitor and periodically time the purge of BS&W "on condition." This will prevent hazardous accumulations and help track the source and rate of generation.
- After a needed oil drain, use a discharge wand from a filter cart to rinse out remaining BS&W from tank and sump bottoms before refilling with new fluid. Confirm that the rinse was successful by inspection.
- After new oil has been added, circulate the fluid through a filter at the highest flow rate possible before the machine is started and put under load. Use a filter cart, if necessary. Allow the total oil volume to turn over no less than five times. Do a simple patch test or particle count to confirm cleanliness, especially for critical equipment.

The seriousness of BS&W goes far beyond machine problems that produce sediment and water. BS&W can lead directly to sudden-death machine failure. For instance, disturbing the sediment in oil lubrication systems can produce what is called the "fishbowl effect." Those who have had tropical fish know that the slightest agitation of an unchanged fish bowl causes the water to become murky with sediment, uneaten food and excrement. In the same sense that you wouldn't want a loaded oil filter to burst, sending a dense debris field downstream, you also wouldn't want to agitate the BS&W in your sumps and reservoirs. Imagine this sequence of events relating to an oil change:

1. The drain port of a reservoir is removed, and the aged oil flows out by gravity into a waste oil container.
2. Some of the BS&W is purged with to the reservoir floor.
3. During the drain, oil flowed by gravity toward the tank through piping, valves, pumps and filter housings, carrying suspended particles that were previously trapped in nooks and crannies. Some of these backwashed particles resettle in various locations, presenting the risk that they will be re-entrained into the oil when the machine is restarted.
4. When fresh new oil comes plunging into the reservoir, the BS&W is stirred up into a murky mass.
5. When the machine is restarted, the suspended reservoir muck and the displaced particles in the lines and machine components become mobilized by the flowing fluid and travel throughout the system.
6. Some of these suspended particles induce accelerated wear in frictional load zones (bearings, gears, pumps, etc.), while others get trapped in narrow glands, oilways and orifices, causing restricted oil flow (starvation conditions).
7. The dense concentration of particles and impaired oil flow start a chain of events that ends in

machine failure. This happens more often than you might think.

Color and Clarity (C&C) Zone

Transitions in oil color and clarity (C&C) are common precursors to bottom sediment, sludge, varnish, emulsified water, entrained air and stable foam conditions. For this reason, it's important to know when color and clarity changes are occurring. The oil is trying to tell you where it hurts.

Tracking C&C can be done by simple and routine visual inspections, such as:

- **Color Transitions** – These are transitions from oil chemistry changes and color-producing contaminants. The observed oil color is typically compared to new oil and/or the previous oil that was sampled. Color bodies (chromophoric compounds) alert inspectors to degrading additives, base oil degradation and a host of contaminants possessing unique color markers.
- **Clarity Transitions** – Clarity changes are generally due to the presence of suspended insolubles, entrained air and emulsions. These can range from a slight haze in the oil to cloudy/murky conditions. Advanced conditions result in the oil becoming completely opaque (pitch black). Good lighting is required during inspection, including the optional use of a strong laser light source.

C&C conditions relate to the active body of the oil and are less influenced by gravity and stratification. Still, C&C transitions can be seen when inspecting low-lying oil (tank drains and BS&W bowls) but also elsewhere, such as with an oil level gauge or inline sight glass. You can even examine the oil's color and clarity in a bottle during routine sampling.

Color and clarity correlate to the transmission and spectral absorption of light by oil. Examples of conditions and contaminants that produce color and clarity transitions are shown in the table on page 7.

Teaming Zone Inspections to Learn What's Not Happening

While condition monitoring is about knowing what is happening to your oil and machine, it is also about what is not happening. For example, say you visually inspect your oil and machine in all three zones (LF&D, BS&W and C&C), and observe excellent, healthy conditions. What can you conclude? Well, you can determine that there are approximately 25 things that could be going wrong (in the oil and machine)

> ***These zones have a story to tell about your oil and machine.***

that aren't going wrong just because you have passing marks from these zone inspections. Among the multitude of things not occurring are the following:

- Base oil oxidation
- Thermal degradation
- Additive stratification (dropout)
- Microbial contamination
- Free or emulsified water contamination
- Air induction conditions
- Impaired air-release conditions
- Stable foam conditions
- Antifreeze contamination
- Sludge conditions
- Varnish potential conditions
- Varnish laydown conditions
- Heavy sediment from a failed filter
- Heavy sediment from contaminant ingression
- Advanced machine wear conditions (certain cases)
- Depletion of several important additives

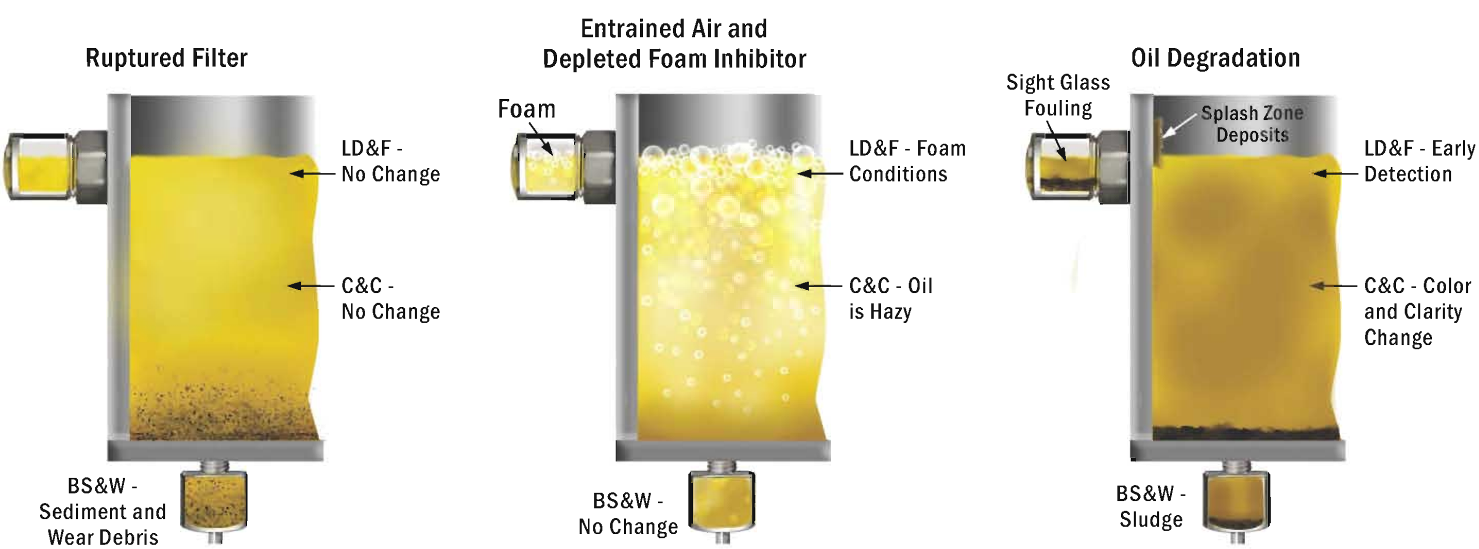


Figure 3. Three examples of using zone inspections

What Influences C&C

OFFENDING CONDITION	COLOR	CLARITY
Wrong oil or cross-contamination (mixed oils)	S	S
Emulsified water	R	A
Dissolved water	R	R
Glycol contamination (coolant)	S	S
Insoluble additives	S	A
Degraded additives	S	S
Base oil oxidation	A	A
Thermal degradation of the base oil	A	A
Chemical contamination	S	S
Hydrolysis	S	S
High oil varnish potential (microdieseling, electrostatic discharge, etc.)	S	S
Entrained air	S	A
Waxy suspensions (cold temperature related)	R	A
Microbial contaminants	R	S
Typical levels of dirt or wear debris	R	R

Oil that is exhibiting issues like those in the list above will require urgent attention to troubleshoot and remediate the offending problem. If the cause of the condition(s) is unclear, laboratory analysis of the oil and/or BS&W may be needed.

It is worth emphasizing that these zone inspections are not a substitute for routine oil analysis. Also, samples that are routinely analyzed by laboratories should not be taken from the bottom of sumps and reservoirs. Instead, they should be extracted from live, turbulent fluid zones using the proper methods and tools.

For those who strive for lubrication-enabled reliability (LER), the opportunity comes from paying close attention to the "Big Four." These are critical attributes of the optimum reference state (ORS) discussed frequently in this column and needed to achieve lubrication excellence. The "Big Four" individually and collectively influence the state of lubrication and are largely controllable by machinery maintainers. They are well-known but frequently not well-achieved. They are:

1. Correct lubricant selection
2. Stabilized lubricant health
3. Contamination control
4. Adequate and sustained lubricant level/supply

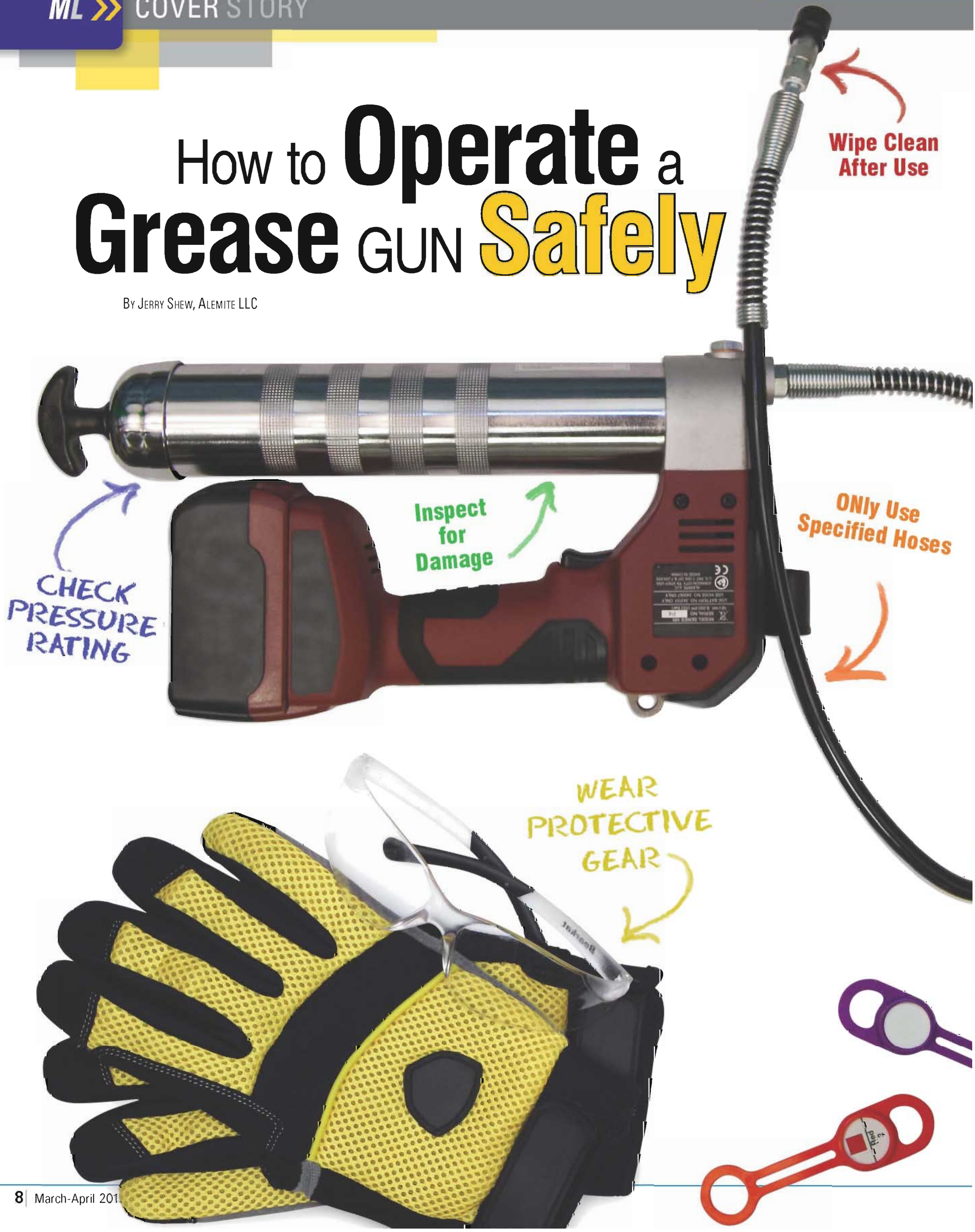
It is comforting to know that the last three of the "Big Four" can be largely examined and confirmed by employing a rigorous zone inspection program. Yes, early detection means frequent detection. It's within your control. Opportunity knocks!

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 director and board member of the International Council for Machinery Lubrication. He is the CEO and a co-founder of Noria Corporation. Contact Jim at jfitch@noria.com.

How to Operate a Grease GUN Safely

By Jerry Shew, Alemite LLC



All machinery must be lubricated to ensure smooth operation and to maximize equipment life. From manufacturing to farming to wind energy applications, grease guns are one of the most common ways to achieve proper lubrication. Although use of grease guns is widespread, these tools deserve respect and should be used in accordance with the manufacturer's safety guidelines to avoid injury.

There are four main types of grease guns on the market: manual, battery-operated, air-powered and AC electric. Each type has its own specific set of guidelines, but many general rules are applicable to all, such as training, proper tool use and care, work area safety and personal safety.

Manual Grease Guns

Manual grease guns include lever-action and pistol-grip models. These popular tools are widely used and are the most economical type of grease gun. Manual grease guns can achieve pressures up to 10,000 pounds per square inch (psi), while plug-valve sealant guns can reach 15,000 psi.

Battery-operated Grease Guns

Battery-operated grease guns are ideal for speeding up routine lubrication tasks. Using this type of grease gun can also help to minimize operator fatigue. These grease guns are rated anywhere from 6,000 to 10,000 psi, depending on the model.

Air-powered Grease Guns

Air-powered or pneumatic grease guns use compressed air to apply pressure to an air piston, which drives the grease piston and forces lubricant out of the coupler into a grease fitting. By depressing the gun's trigger, a steady flow of lubricant is dispensed. Typically, pneumatic grease guns are rated up to 6,000 psi.

AC Electric Grease Guns

AC electric or corded grease guns provide a consistent flow of grease and are often used as an alternative to air-powered tools. AC electric grease guns generally are rated up to 7,000 psi.

Training

Effective lubrication requires specific training, ranging from the actual physical activity of applying the lubricant to the effects of misapplication, including spills and damage to machinery. The operator should be trained on each piece of equipment to be lubricated, as well as each grease gun that will be used to accomplish the task.

"Some general rules of lubrication also should be considered," said Alemite senior product manager Americo dos Santos. "Do not apply lubricants to a machine in operation unless the fittings are located in a safe place. Never reach over, under, through or past moving parts of the equipment to complete your task. You should maintain proper footing and balance at all times to facilitate better control of the tool in unexpected situations."

Although use of grease guns is widespread, these tools deserve respect and should be used in accordance with the manufacturer's safety guidelines to avoid injury.

Proper Tool Use and Care

Whether you are using a manual,

battery-operated, air-powered or AC electric grease gun, the high pressure developed by the tool should be considered. High pressure can develop in different ways. A common situation when high pressure is created involves what is known as a "frozen fitting." When a fitting is not lubricated for an extended period of time, the grease in the line may "cake." Mineral or vegetable oil in the grease gets consumed and leaves a waxy, soap-like base. This soap thickener is what makes grease a semi-solid. Common soaps include calcium stearate, sodium stearate and lithium stearate, as well as mixtures of these components.

High-pressure injection injuries may be caused by accidental injection of grease through the skin and into the underlying tissue. Generally, fingers or hands experience this type of injury, which is most likely to occur when a hose ruptures. Also, some lubrication applications require needle-type accessories that can lead to an injury if used improperly.

"An injection injury may be very small and essentially painless, and the injured person may be tempted to continue working," explained dos Santos. "However, if you receive any type of injection injury, you should seek medical attention immediately. The lubricant will need to be removed and treatment initiated to prevent infection. If possible, provide the medical technician with the brand of grease or oil involved so that the manufacturer can be contacted regarding the possible toxicity of the lubricant."

Safety features are available and precautions can be taken to minimize the risk involved in using high-pressure grease guns. The key is to use the right tool for the job. Do not improvise or change the grease gun configuration for any purpose other than that which it was intended.

It is critical that all of the components utilized are rated for the amount of pressure being applied, so you should use only hoses specified by the grease gun manufacturer. For example, if your grease gun is rated at 10,000 psi and your hose is only rated at 1,500 psi, the situation can become hazardous very quickly.

"It also is essential that you inspect the hose between the grease gun and the coupler before each use," dos Santos stressed. "If there are any signs of wear or damage on the hose, do not use it."

When a grease cartridge is loaded into the grease gun, the follower rod should be securely latched to the end cap so it doesn't spring back unexpectedly. Use care when removing the pull-tab on the cartridge to prevent getting cut by the tab's sharp edges. In addition, always aim the grease coupler away from your body when loading and priming the grease gun. You don't want to take any chances that grease may get into your eyes.

Exxon Mobil Shares perspective on lubricants and grease sector sustainability at NLGI

ExxonMobil Lubricants Private Limited participated at the 17th National Lubricating Grease Institute (NLGI) – India Chapter Annual Conference to showcase its expertly formulated comprehensive range of greases available in India. The conference was organized by NLGI - India chapter from Feb. 12th to 14th, 2015 in Mamallapuram. It is a premier platform for grease-related industry stakeholders in India.

Exxon Mobil's line of industrial lubricants' and grease product portfolio with advanced technology is well positioned to support current economic and industrial growth in the country. The company has an excellent balanced portfolio of state-of-the-art, proven high-performance lubricants that can cater to the needs of a range of industries – including metals, cement, construction, mining, power generation, general manufacturing, plastics, food and beverage, pulp and paper, – all backed by ExxonMobil's technology leadership and unmatched industry expertise.

ExxonMobil's leadership in innovation is accentuated by its commitment to sustainability. This demands an efficient use of resources – human, environmental and operational. Energy efficiency remains one

raw material for both mineral and synthetic-based lubricants, lubricants appear to be the opposite of sustainability", said Paul Grives, Global Services & Grease Marketing Manager, ExxonMobil Fuels, Lubricants & Specialties Marketing Company.

According to Mr. Shankar Karnik,Mobil SHC Brand Manager & Energy Advisor, ExxonMobil Lubricants Private. Ltd., "There is a need for companies across industries to perceive energy efficiency through a strategic lens and align it to efficiently, and using synthetic and energy-efficient lubricants can help achieve those results. In India, we are already working with various stakeholders to meet and exceed industry requirements for energy efficiency through our suite of next-generation technology lubricants."

Backed by more than 100 years of industry expertise, Mobil's range of greases are expertly formulated to meet a wide variety of operating conditions in both

JEREMY WRIGHT, NORIA CORPORATION

HOW Networking Can Help SOLVE YOUR Maintenance Problems

In my primary role with Noria, I travel around the globe designing lubrication programs and conducting failure investigations for some of the world's largest companies. On average, I'm in a new facility every other week. One recurring theme has been popping up a lot lately at these plants. I didn't begin to notice it until I started getting more corporate accounts. The first occurrence was so obvious it nearly slapped me in the face.

I had been contracted to perform a failure investigation for a company that sounded eerily similar to the one I had just visited. In fact, I thought someone had messed up my schedule because the project was identical to the previous one with the only difference being the plant location. It was the same company, division, equipment and product being manufactured.

When I arrived at the second facility and began collecting data, the circumstances between the two failures were identical. During the exit meeting for the project's data-collection phase, I asked if anyone had ever heard of a similar problem. Not a single person spoke up. I proceeded to tell them about another Noria customer who had the same failure symptoms on the same type of equipment. They listened very intently at that point as I described the entire process and our findings from the first failure. They all agreed that this indeed sounded like the problem they were having. When I informed them that this previous failure had occurred at their sister plant, they were shocked.

55% of lubrication professionals say their organization does not stress the importance of networking among other plants, divisions and industries, based on a recent poll at MachineryLubrication.com

Even though this was the same company, product line, machine and problem, these workers were completely oblivious to what was happening. Their line of communication had been severed. Their senior management had pitted them against one another, so the likelihood of them sharing information for better reliability and increased uptime/ production was slim.

I've seen this several times over the last few months, and it extends much further than just to sister plants. If it's happening at your organization, you need to know that you are not alone. There are people dealing with the same maintenance concerns that you are. They may have been able to easily solve that problem that has confounded you for months. However, the issue is not about finding solutions but rather finding the same solution to the same problems over and over again, because all the tools at our disposal are not being leveraged.

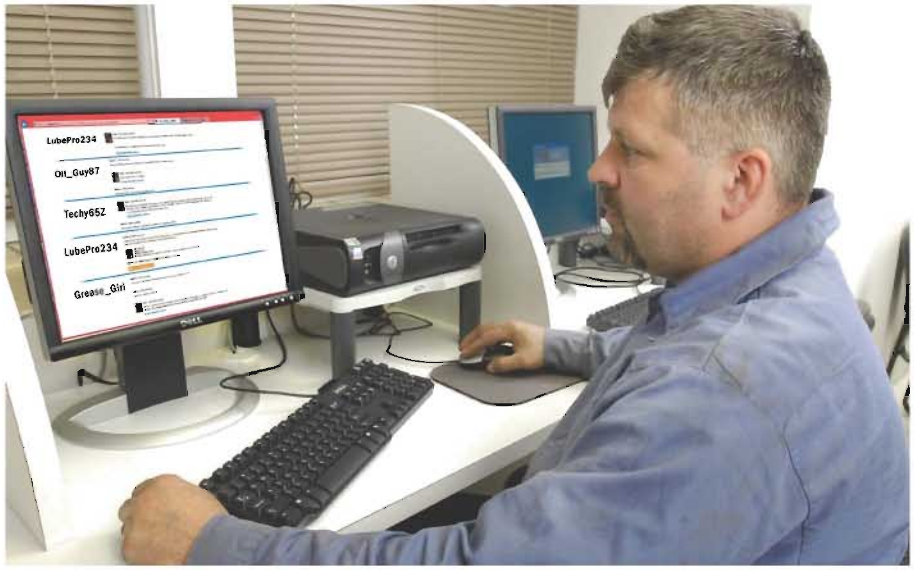
Enter the age of networking. Recently, I was having trouble with the assembly of a clutch and brake linkage for a 1968 Camaro I am restoring. I wasn't sure where, how or in what orientation the plastic bushings were to be mounted on the shaft. Within seconds (with the help of my friend Google), I was able to find a forum that deals solely with first-generation Camaros. There was a specific topic on the proper assembly of the pedals complete with pictures, and a member of the forum had taken the time to write step-by-step instructions on proper installation. The contributors to this forum don't get paid for their contributions. They do it because they want to help the group as a whole.

Why hasn't this become more common for plant maintenance? Why don't we employ more of the tools available to us? Even some of the most fundamental forms of communication like picking up the phone and having a conversation with a sister plant are not being utilized.

We live in the age of information, and yet some companies are choosing not to use it and are actually blocking certain lines of communication.

Of course, not all companies operate in this manner. I have had the pleasure of dealing with a few that are open and trying to foster a knowledge-sharing environment. They attend conferences as a group and not only network among themselves (if from different plants) but also intermingle with people from other industries. You would be surprised at what the steel industry has in common with the cement industry in terms of machinery lubrication.

It doesn't end with just face-to-face or over-the-phone meetings. The Internet and social media are quickly becoming go-to places for solutions. Shouldn't there be a massive online gathering of maintenance professionals to discuss the pertinent issues? This likely doesn't yet exist because many in the maintenance field are late adopters when it comes to technology solutions. The only way for this type of arrangement to work is for the majority to start contributing. We can't let all these workers retire with the knowledge they have accumulated without getting them to share some of it.



I would love to do my part and offer my services to anyone who wants to be heard. If you have information that would benefit the maintenance, reliability and lubrication community, please pass it along. I'm willing to use the resources at my disposal to help grow the information database and encourage knowledge sharing. All I need is the information.

About the Author

Jeremy Wright is 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.

LOREN GREEN, NORIA CORPORATION

Determining Proper OIL FLOW to Journal BEARINGS

While traveling and teaching lubrication fundamentals courses at various facilities across the country, I am constantly reminded of the misconceptions that are rampant in our industry. Recently, I was asked the question, "How do you determine the proper circulating oil flow to a journal bearing if you know the shaft speed, clearance, oil type and temperature?"

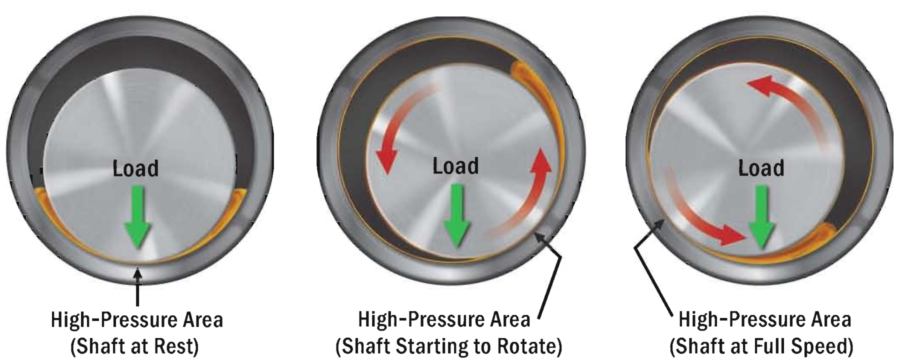
Like many things in lubrication, the answer is not nearly as simple as it may seem. Several concepts must be explained, including some of the design processes that are involved in determining the correct journal and bearing dimensions, materials and lubrication requirements.

Several names are used for these types of bearings, such as journal bearings, sleeve bearings and plane bearings, just to name a few. The basic function of a journal bearing is generally to support a shaft. This type of bearing usually is chosen for applications that are not subject to changes in shaft speed or load.

There are three major components of this type of system: the stationary part or the bearing, the moving part or the journal, and the lubricant. The system's metal components may consist of any number of materials. The bearing normally is made of a softer metal than that of the journal to prevent wearing of the moving element.

Typically, the lubricant enters the bearing from the center and passes through to the ends where it leaves the bearing. The lubricant performs several functions including providing controls for friction, wear, corrosion, temperature and contamination, as well as a power transmission component.

In journal bearing lubrication, three basic lubrication regimes apply: hydrodynamic or full film, mixed film, and boundary. It is important to note that regardless of how well a metal surface is machined, imperfections still exist. These little peaks and valleys are known as asperities. The three lubrication regimes essentially refer to the amount of contact between these asperities.



The vast majority of journal bearings are designed to operate in the hydrodynamic (full-film) regime. However, these bearings spend a portion of their operating life in the other two regimes as well, so they also deserve an explanation.

In his article "Boundary Lubrication, an Appraisal of World Literature," W.E. Campbell defines boundary lubrication as: "... lubrication by a liquid under conditions where the solid surfaces are so close together that appreciable contact between opposing asperities is possible."

In short, boundary lubrication is the regime where metal-to-metal contact occurs and the largest portion of wear is generated. The vast majority of the load is being carried by these asperities with very little, if any, being carried by the lubricant. This typically takes place upon equipment startup.

In mixed-film lubrication, a little contact between the asperities still exists, but the lubricant is also supporting some of the load. This

Gallons Per Minute (GPM)

$Q=29.3 \times 10^{-9}(L+.0043(W/D))mD^2N$

Drops Per Minute

$Q=3.32 \times 10^{-3}(L+.0043(W/D))mD^2N$

Where:

- D = journal diameter (in inches)
- L = bearing length (in inches)
- m = bearing clearance factor
- N = rotational speed
- W = steady load to be supported (in pounds)

transpires shortly after startup but prior to reaching normal operating speed. Harry C. Rippel's book, *The Cast Bronze Bearing Design Manual*, describes mixed-film lubrication as: "... part of the total load carried by the bearing is being supported by individual load-carrying pools of self-pressurized lubricant and the remaining part by the very thin contaminating film associated with boundary lubrication."

Once the normal operating speed is reached, full-film or hydrodynamic lubrication is achieved. In this regime, the two metal surfaces are separated by a lubricant film to such a degree that the asperities no longer come in contact. It makes perfect sense that if you maintain full separation of the metal surfaces with a lubricant in between, no mechanical wear will occur. In fact, it has been stated that as long as this condition exists, these bearings can operate indefinitely without wear.

This process can be compared to water skiing. While the boat is idle, the skier is in the water, which is equivalent to a boundary condition with the lubricant providing no support to the shaft. As the speed increases, the skier rises out of the water. This is similar to the mixed-film regime, as the water is providing some support to the skier. Once the boat is up to speed, the skier is fully out of the water and riding across the surface (full-film or hydrodynamic lubrication).

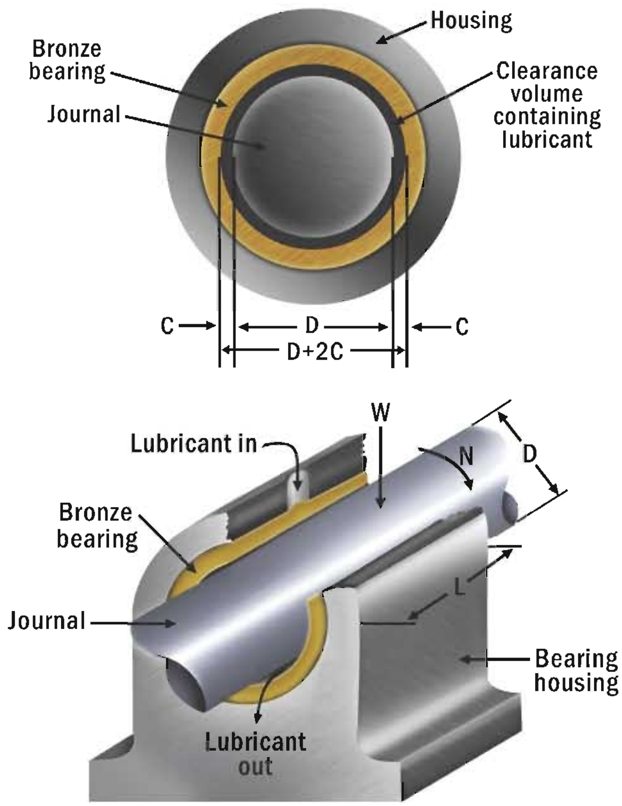
Fluid pressure is generated in the lubricant film, which is able to support load due to its viscosity. Lubricating oils have a significant pressure-viscosity coefficient. This means that the greater the pressure on the lubricant, the higher the viscosity at the pressure point. In the case of rolling-element bearings, this pressure is high enough to raise the lubricant's viscosity to the point where it will deform the bearing's rolling elements. This pressure-viscosity coefficient is what provides the load-carrying capacity of a journal bearing.

With a better understanding of lubricant films, let's now look at the two equations for determining the lubricant oil feed to ensure a sufficient quantity of lubricant to support the load in a journal bearing. The equation you use to calculate the proper circulating flow will depend on whether you are working in gallons per minute or in drops per minute. The equations can be seen in the box above.

While most of the variables in these formulas are straightforward, the clearance factor (m) may be confusing for some. It can be determined by calculating the diametral clearance (2C), which is equal to the bearing bore diameter minus the journal diameter. Obviously, the clearance will be much smaller than the journal diameter (D), so this value is multiplied by 1,000 to make calculations easier. Therefore, the clearance factor is: m=1,000(2C/D).

Returning to the original question about establishing the proper oil flow to a journal bearing, in this instance, the clearance was known. The diameter and length should be easy to obtain either by taking a measurement or by checking the documentation. The speed was also known, so the only value left to find is the load (W). This is simply a matter of determining the weight of the rotating element divided by the number of bearings.

Once all the values have been identified and the appropriate equation selected for gallons or drops per minute, you just need to enter the numbers into a calculator.



Typical journal bearing

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SUSAN BENES, FEI

Alternatives To Traditional Wear Particle Analysis

Many of the methodologies existing today for oil testing provide only one key parameter of diagnostic information such as particle size or chemical composition. While a single parameter can offer clues as to what is occurring in an engine or motor, more often than not it is inconclusive. Laboratories frequently recommend a battery of tests to obtain a more comprehensive diagnosis. This often leads to confusion as to how to interpret the data or even which method to request and how often. However, a new way of evaluating wear debris allows a complete diagnosis to be achieved with one test that can be performed by in-house maintenance technicians.

SEM/EDX

Historically, scanning electron microscopes (SEMs) have been viewed as manual imaging instruments that require qualified users in specialized environments. Recent advances in SEM technology have provided more compact, easy-to-use instruments applicable to a more industrial setting. When combined with an energy dispersive X-ray (EDX) detector, the SEM has the ability to perform quick, quantitative compositional measurements. An SEM not only can measure and record the size and shape of a wear debris particle, but it can also determine the particle's elemental makeup, thereby combining the physical and chemical worlds of wear analysis into one.

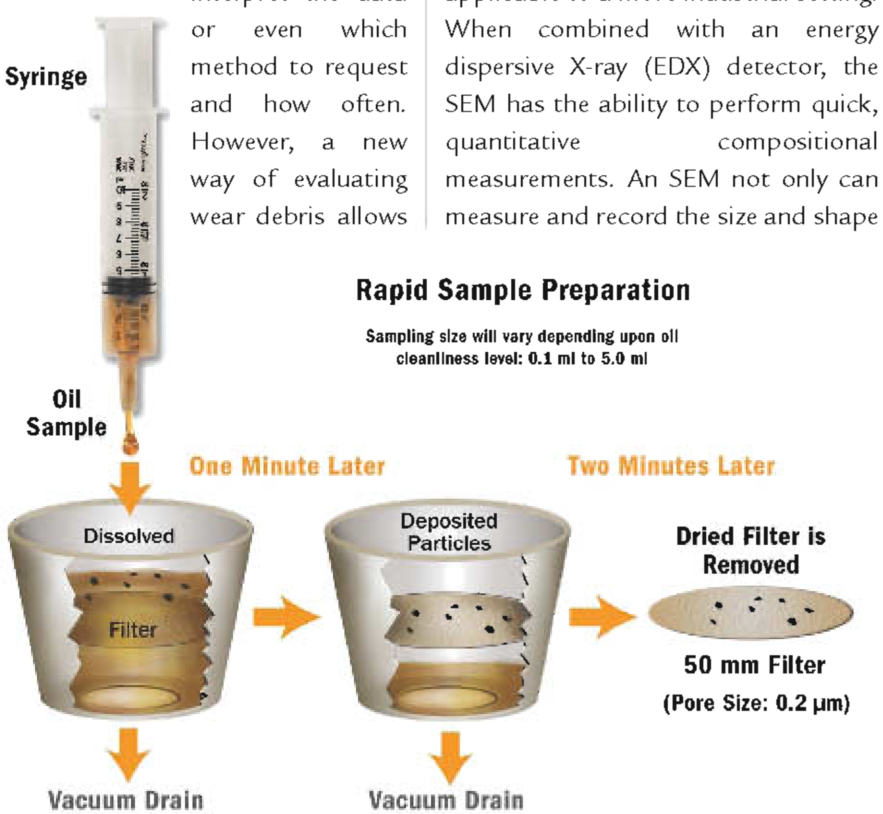

Figure 1. Sample preparation of oil samples for SEM/EDX analysis

An automated SEM/EDX wear debris analysis system uses a single hardware control configuration for both the SEM and EDX components, making it more compact and robust for industrial wear debris applications. Simplifying the system even further, the instrument is set up to operate via pre-programmed recipes that allow the user to walk up to the system, load the samples, initiate the run and walk away, only to come back later to sample reports. All calibration and instrument operation is automated and does not require user management or monitoring.

Utilizing back-scattered electrons (BSE) on an SEM enables the system to take advantage of the strong correlation of the average atomic number of the particles and the BSE signals. Hydrocarbons and other particle types with a low average atomic number tend to scatter fewer electrons than metallic particles and other particle types with a high average atomic number. Thus, in a BSE image, metallic particles look bright, while organics look dark.

One of the main differences between

Figure 2. Sample setup

SEM/EDX and traditional methods is in its sample preparation. Figure 1 illustrates the sample preparation and analysis expectations of the SEM. Ultimately, a small portion of the oil sample is needed to prepare a representative sample on a filter membrane. Once loaded into the system, these analyzers move the beam across the full field through a sequential array of fairly coarse steps, constantly searching for a particle of interest and moving to the next field instead of capturing a high-resolution image of the frame. A particle is detected when the contrast intensity level of the particle exceeds the predefined threshold background set for each analysis activity.

This particle-sizing sequence initiates a rotating 16-cord algorithm to measure the particle's morphological characteristics. As illustrated in Figure 3, a series of cords are drawn across the diameter and through the center of the particle at equal angular spacing. Particle size and shape measurements are then derived from these cords. All variables are then collected for each unique particle in sequence across the filter.

After the particle is detected and measured, an energy dispersive X-ray spectrum is acquired at the center, perimeter or along each cord for every particle detection event. Figure 3 illustrates the dynamic scan and rotating 16-cord algorithm during the particle measurement and EDX elemental X-ray collection phase.

Once particles are characterized by size, shape and elemental composition, user-defined rules place them into a "class." For instance, if the user is interested in only high iron samples, a rule can be put in place to classify all particles with high iron content. Those particles will then be grouped and reported in the assigned "class." If needed, the particles can be relocated and further examined by the operator. The system provides a customizable reporting tool and automatically generates reports of the analyses. A database stores all analysis results for monitoring long-term trends with engine or gearbox wear.

Comparison of Traditional Methods with SEM/EDX Results

Table 1 presents a side-by-side comparison of various analytical methods. While each of these methods has advantages, SEM/EDX can provide users with a comprehensive analysis as well as more knowledge in dealing with wear debris. The value of the technology is that not only does it give the size, shape and chemical composition of each particle in the sample, but it also permits the user to classify each of those particles based on their chemical composition. This allows classification of the particles into various rules or classes and enables the user to

FEATURE	AUTOMATIC PARTICLE COUNTER	ANALYTICAL FERROGRAPHY	ICP ELEMENTAL ANALYSIS	RDE ELEMENTAL ANALYSIS	SEM/EDX
Sample Preparation Requirements	Usually	Yes	Yes	No	Yes
Particle Detection Range (microns)	2-100	2-500	<3	<7	0.2-2,000
Individual Particle Size and Shape	Usually	Yes	No	No	Yes
Total Element Chemical Analyses Range	No	No	38	32	98
Particle Classification by Chemistry	No	Limited	No	No	Yes
Particle Classification by Morphology and Chemistry	No	Yes	No	No	Yes
Analyses Time (minutes)	5	10	3	3	10 to 30
Ease of Use (1=easy, 5=moderate, 10=difficult)	5	10	5	3	1
Particle Size Distribution	Yes	No	No	No	Yes
Automated Trending	Yes	Limited	Yes	Yes	Yes

Table 1. Comparison of various analytical methods with SEM/EDX

instantaneously identify if particles are wear debris or just steel alloys, carbon, mineral salts or fibers. Diagnosing machine wear becomes much easier because little to no interpretation of the data is needed.

In order to demonstrate the power of the knowledge gained from SEM/EDX when compared to other technologies, real-world samples were collected and tested. Three unique engine oil samples obtained from a local car dealership were submitted to an oil testing lab for analyses. For comparison purposes, several methods were chosen for third-party testing including inductively coupled plasma (ICP) elemental analysis, particle counting via pore blockage and direct-reading ferrography. Each sample was subsampled representatively and also prepared for SEM testing at an in-house laboratory. Results from the third-party laboratory were received and compiled for comparison to the SEM/EDX results.

It should be noted that the purpose of the data comparisons was to demonstrate the added value and benefit of SEM/EDX testing and not to evaluate the data from the third-party lab.

Particle Count Results

Table 2 presents the particle count data for both the SEM and pore blockage methods for three samples.

4406 ISO BIN	SAMPLE 1		SAMPLE 2		SAMPLE 3	
	SEM	PORE BLOCKAGE	SEM	PORE BLOCKAGE	SEM	PORE BLOCKAGE
>2 µm	9,226		16,180		3,198	
>4 µm	4,254	5,513	5,898	10,096	912	4,018
>6 µm	2,228	2,144	2,674	3,926	404	1,562
>14 µm	296	163	112	299	66	119
>50 µm	12	7	4	13	0	5
>100 µm	8	0	0	0	0	0

Note: Data for all samples are normalized to 1 ml

Table 2. Comparison of SEM and pore blockage data for three samples

The pore blockage data from the third-party laboratory was reported using the ISO 4406 reporting standard. For all SEM data, this reporting standard was maintained, but it was also decided to report particles larger than 2 microns to provide an additional perspective on the data.

In the first sample, the particle count was fairly comparable between the SEM and pore blockage results. In the second and third samples, the sizes and counts of the actual particles varied. This could be attributed to sample representativeness between the two samples that were divided for submission to the lab. While this seems likely, it could indicate some of the differences in the testing methodologies, including sample preparation, and particle sizing techniques. For example, pore blockage technology (ISO 21018-3) does not actually count individual particles but rather estimates the particle size distribution using an algorithm based on a measured flow decay across a membrane or a rise in differential pressure. A total number of particles is calculated using an algorithm derived from extensive empirical testing. On the other hand, SEM detects, scans and measures each particle individually, providing size analyses accurate to 0.5 microns.

In all three samples, the largest discrepancies between the two technologies came in the smaller sized particles. While the ISO standard requires that only particles larger than 4 microns are reported, the SEM data could demonstrate the limitations of the pore blockage method as the particle sizes get smaller. Coincidently, this same range of particle sizes (between 2 and 4 microns) would also represent the particles reported by the ICP results.

Chemical Composition Results

Table 3 presents the chemical composition data for all three samples in parts per million (ppm) as reported by the third-party laboratory. It should be noted that no particles larger than 3 to 4 microns would be detected in these results due to the limitations of ICP. Based on the table, the majority of

	IRON	COPPER	LEAD	ALUMINUM	TIN	NICKEL	CHROMIUM	TITANIUM	VANADIUM	SILVER	SILICON	BORON	CALCIUM	MAGNESIUM	PHOSPHORUS	ZINC	BARIUM	MOLYBDENUM	SODIUM	POTASSIUM
Sample 1	5	1	0	2	2	0	0	0	0	0	10	97	1,796	7	571	700	0	71	135	4
Sample 2	12	5	4	2	0	0	0	0	0	0	8	0	1,562	8	643	787	1	3	375	0
Sample 3	14	37	0	3	2	0	0	0	0	0	6	159	1,964	9	630	764	15	83	36	5

Table 3. Metal results (in parts per million) per sample via the third-party lab

	100Cr6	16MnCr5	Cr	Cr Coating	Cr-Ni-Mo	Al203	Al-Alloy	Al-Zn	Brass	Bronze CuSn	Cu	Fe-Cu	High Alloy Steel	Low Alloy Steel	Low Fe	Sn	Steel	Zn Coating	Zn Misc.	Zn-Cr Coating	Zn-P Coating	Ni	Mn-P Coating	Non-Ferrous Metal
Sample 1	18	70	14	7	1	0	0	3	0	1	8	19	22	30	41	12	53	37	396	10	29	4	0	34
Sample 2	233	733	11	7	3	0	0	2	0	5	2	27	260	386	493	20	359	20	908	10	74	11	0	18
Sample 3	22	64	11	18	7	0	0	0	0	0	1	11	20	21	61	3	29	6	243	0	8	0	0	7

Table 4. Number of particles sorted by rule classification for metallic particles

the components in each of the three samples were salts and minerals such as calcium, phosphorus and sodium. There was a significant portion of zinc or molybdenum and boron, which could be coming from additives, coatings and possibly some bearing wear. All three samples also showed some iron and copper, which would suggest motor wear. However, metals like aluminum, tin, nickel and chromium were all but absent.

The key difference with SEM/EDX data is that you not only get the individual particle size and shape but also the actual particle chemistry for each particle detected. The particle chemistries can then be classified into various "rule classes," which are established based on various metal chemistries. Tables 4 and 5 present the SEM/EDX results of each of the particle counts for all three samples classified by standard wear debris chemical rule classes. These classes indicate both metallic (Table 4) and non-metallic (Table 5) rules.

Table 6 shows the most beneficial form of data collected via SEM/EDX. It not only offers the size and shape of each particle but also a chemical classification. This can be an invaluable tool for diagnosing engine wear because the user can consider both the size and chemical composition of the particles to determine what is happening inside the engine.

For instance, in Table 6 a rule for a stainless-steel type of material (or 100Cr6) would be any particle with its highest component as iron greater than 70 percent, along with chromium greater than 1 and less than or equal to 3, manganese less than 1 percent, zinc and chromium less than 5 percent and titanium less than 3 percent. This, along with the second rule classification of 16MnCr5, indicates stainless steel and would suggest that some bearing wear is occurring, especially when considering the larger particle sizes.

In comparing these results to the ICP data, chromium was not detected in any of the samples, including the second sample. When looking at the larger particles detected in the second sample, you can see that various steel (low and high alloy) and stainless-steel components (16MnCr5) are present at particle sizes larger than 50 microns. Again, wear debris of this size could signify significant engine wear.

When examining the smaller sized particles in the second sample, you can see not only the stainless particles but also a significant amount of tin, nickel and chromium particles, which could be indicative of slight engine wear. These metals were not detected at all in the ICP data for the second sample.

Ferrography Results

Direct-reading ferrography was also performed by the third-party laboratory for each of the samples. All three samples were found to have either light wear or moderate wear. No significant or abnormal particles were reported for any of the samples. Ferrous particles were between 5 to 15 microns in size for each of the three samples. Comparing this to the SEM/EDX data, there were numerous ferrous particles in each of the samples, with some as large as 50 microns in the second sample (Table 6).

	High Ca	Ca Misc.	SiAl Mineral	Lubricants	Mineral	Mineral Fiber	Misc.	Misc. Salts	SiAlCa Mineral	Si-O/Si-C/Si-N
Sample 1	82	1,078	86	84	1,694	121	64	151	223	221
Sample 2	9	2,707	4	204	354	214	12	975	11	18
Sample 3	24	633	5	41	233	51	7	50	10	13

Table 5. Number of particles sorted by rule classification for non-metallic particles

Benefits of SEM/EDX

For years, wear debris and oil testing have been performed using methods such as ferrography and particle counters in conjunction with ICP or rotating disk electrode (RDE). Information gained from these technologies has been helpful in diagnosing engine or gearbox wear, but users still struggle with knowing how to interpret data from the laboratory.

RULE CLASS	>=2	>=4	>=6	>=7	>=10	>=14	>=50
100Cr6	233	466	224	120	72	22	0
16MnCr5	733	1,466	766	376	238	86	12
Al-Zn	2	4	2	2	2	0	0
Cr	11	22	16	10	6	0	0
Cr Coating	7	14	6	4	4	4	2
Cr-Ni-Mo	3	6	2	2	0	0	0
Fe-Cu	27	54	40	30	26	4	0
High Alloy Steel	260	520	204	82	34	12	2
High Ca	9	18	12	4	4	0	0
Low Alloy Steel	386	772	324	148	82	36	8
Low Fe	493	986	408	190	88	20	4
Lubricants	204	408	114	54	16	2	0
Ni	11	22	2	0	0	0	0
Steel	359	718	388	200	128	40	12
Zn Coating	20	40	12	6	6	0	0
Zn Misc.	908	1,816	526	220	106	24	6
Zn-Cr Coating	10	20	4	0	0	0	0
Zn-P Coating	74	148	36	6	2	0	0

Table 6. Results for sample 2 showing classification by size and rule class

SEM/EDX offers an alternative to traditional wear debris and particle analysis, and can now be used by a technician with minimal training or a limited scientific background. It can take the place of two or three traditional oil testing methods by allowing the user to report both particle and chemical composition data. The data can then be segmented based on user-defined classes, and clear classifications of wear debris particles can be studied for immediate feedback on gearbox or engine conditions. SEM/EDX can also complement your current oil testing program by offering more intuitive data to diagnose a suspected issue when more traditional testing raises warning signs but is not conclusive.

Regardless of your testing program, it is important to keep in mind that establishing historical baselines and running consistent testing protocols will provide historical wear profiles that can give timely indicators of the changes in the status and rate of wear.

About the Author

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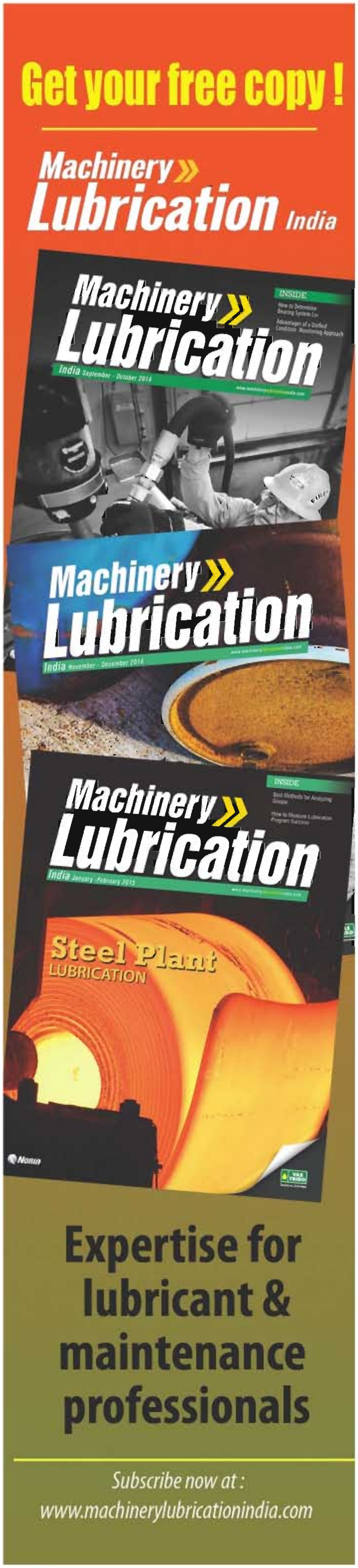

MLI »

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. Which statement is incorrect regarding filter patch tests for solid contaminants?

A) Patch tests use very fine micron filters
B) The patch test is a form of automatic particle counting
C) Patch tests can be done in-house or in a lab
D) Patch discoloration can estimate overall particle concentration
E) The resulting patch can be viewed or weighed to assess the contaminant concentration

2. Which of the following is the single most important property of a lubricant?

A) Viscosity
B) Dropping point
C) Worked separation
D) Base oil type
E) Acid number

3. Drop-tube vacuum sampling of reservoirs and tanks is best done:

A) Off the bottom of the tank
B) Where the oil return line dumps back into the tank
C) Where the oil suction line pulls oil from the tank
D) From the top layer of the oil in the tank where water and dirt have settled out
E) From the middle of the tank

Answers:

1. B
The filter patch test is a simple test used to evaluate solid particles where the oil passes through a fine filter. All listed choices are correct except "B," as there is no automatic particle counting involved in this simple test.

2. A
Viscosity is the most important property of a lubricant. While other properties are significant, the wrong viscosity selection may lead to serious problems in a short amount of time, including metal-to-metal contact if the viscosity is too low or high temperature and its associated problems if the viscosity is too high.

3. B
This will help detect wear metals generated from system frictional zones before the oil becomes diluted in the tank.

DR. ANOOP KUMAR, ROYAL MANUFAC TURING

Choosing a Multi-Purpose Grease: Lithium Complex or Calcium Sulfonate?

It's hard to imagine a machine operating without grease in it, as the majority of dynamic machine operations run on bearings, which need grease for lubrication. Historically, the utilization of grease to lubricate a wheel and axle occurred just after the discovery of the wheel. The first universal greases were crude forms of lime mixed with vegetable oils. These classes of grease continued to be used for almost all kinds of applications requiring lubrication until the industrial revolution.

However, in the last few decades, remarkable progress has been made in terms of machine design. This has affected operating parameters and thus the requirements for lubricating greases. As operating parameters like speed, load, temperature, etc., vary significantly based upon the equipment, it is practically impossible for a single grease to handle all the diversified applications. Consequently, a large number of lubricating greases have been developed, resulting in thousands of greases on the market. The concept of one universal lubricating grease covering all types of applications no longer holds true. Also, from a selection and suitability standpoint, the vast array of available greases can be confusing to consumers.

Grease Composition

Lubricating greases basically are composed of a thickener (10 to 15 percent), base oil (80 to 90 percent) and performance additives (5 to 10 percent). The total global market size of lubricating greases is about 2.38 billion pounds and consists of lithium/lithium complex, calcium, sodium, aluminum/aluminum complex, calcium sulfonate, clay based, polyurea, etc. By far the most popular greases worldwide are lithium-based greases with a market share of more than 75 percent. While various kinds of greases may be required in a particular plant, there have always been efforts to rationalize and minimize the number of

PROPERTY	DESCRIPTION	LITHIUM MULTI-PURPOSE GREASE	LITHIUM COMPLEX GREASE	CALCIUM SULFONATE GREASE	COMMENTS
Stability	Mechanical Stability	+30	+30	<20	A lower number is better
	Roll Stability	8-10%	8-10%	<5%	A lower number is better
High Temperature	Drop Point	~350° F	~500° F	+550° F	Higher drop point, better high-temperature properties
	High-Temperature Life	~80-90 hours	~80-100 hours	>120 hours	A higher number is better
Water Resistance	Water Washout (175° F, 1 hour, % weight loss)	5-10	5-10	<5%	A lower number is better
	Water Spray Off (% grease washed off)	>50%	20-60%	<30%	A lower number is better
	Roll Stability in Presence of Water (2 hours, 10% water)	>10%	>10%	<10%	A lower number is better
Extreme Pressure	Weld Load (kgs.)	250-400	250-500	>500	A higher number is better
	Timken (lbs.)	40-45	40-80	>60	A higher number is better
	Wear Scar Diameter (mm)	0.5-0.6	0.5-0.6	<0.5	A lower number is better
Compatibility with Lithium Greases			Very Good	Good	Easy for changeover

Table 1. Comparison of fully formulated greases

greases from a purchasing and logistics standpoint. This likely has led to the development of multi-purpose greases.

Multi-Purpose Grease

In simple terms, a multi-purpose grease can be defined as a grease combining the properties of two or more specialized greases that can be applied in more than one application. For example, lithium grease can be applied both in chassis and wheel bearing applications of transport vehicles. Traditionally, calcium greases were used for chassis, and sodium-based greases were utilized for wheel bearings. Calcium-based greases have been rated high for water resistance but poor for elevated temperatures. On the other hand, sodium-based greases better cover high temperatures but are not as good in regards to water resistance. When lithium greases emerged in the marketplace, they were found to be superior to calcium and sodium greases, and soon became the most popular multi-purpose greases in industry.

High-Performance Multi-Purpose Greases

In modern machinery design and construction, machines operate under more severe conditions with the expectation of increased productivity and less downtime. This has made it difficult for lithium greases to satisfactorily fulfill these requirements. The National Lubricating Grease Institute (NLGI) GC-LB specification, which is the most closely followed in the transport sector, also requires greases beyond just lithium 12-hydroxy greases.

These stringent requirements can be met by more efficient high-performance greases like lithium-complex, calcium-sulfonate, aluminum-complex, polyurea and clay-based greases. However, because of their compatibility with most widely used lithium greases, lithium-complex and calcium-sulfonate greases appear to be the best candidates of these high-performance multi-purpose greases.

Lithium Complex vs. Calcium Sulfonate

Lithium-complex greases generally possess good stability, high-temperature characteristics and water-resistance properties. Other performance requirements like extreme pressure, anti-wear, rust and corrosion can further be improved by adding suitable additives. These greases also meet the NLGI's GC-LB specification requirements.

Nevertheless, a careful comparison between lithium-complex and calcium-sulfonate greases reveals that calcium-sulfonate greases hold an advantage. Calcium-sulfonate greases out-perform lithium-complex greases both on the data sheet as well as in actual applications. The most important difference between these two types of grease is that calcium-sulfonate greases do not typically need additives to meet certain performance requirements like lithium-complex greases do.

Calcium-sulfonate greases exhibit superior mechanical and shear stability compared to lithium-complex greases, indicating less leakage and run-out during operation. The dropping point and high-temperature life of calcium-sulfonate greases are also better, allowing these greases to be used at higher temperatures.

Unlike lithium-complex greases, which need a significant amount of antimony-zinc or other types of additives, calcium-sulfonate thickeners have inherent extreme-pressure and anti-wear properties. In addition, while sulfonates are known to be natural rust inhibitors, lithium-complex greases invariably need rust-inhibiting additives.

Furthermore, calcium sulfonate, by virtue of its thickener property, provides excellent water-resistance properties and does not break down even in the presence of water. To improve their water-resistance properties, lithium-complex greases usually require tackifiers, which are prone to deplete quickly in the presence of water. Calcium-sulfonate greases are also compatible with lithium and lithium-complex greases.

INDUSTRY	LITHIUM MULTI-PURPOSE	LITHIUM COMPLEX	CALCIUM SULFONATE
Transport	💧💧	💧💧💧	💧💧💧💧💧
Mining	💧💧	💧💧💧	💧💧💧💧💧
Marine	💧💧	💧💧💧	💧💧💧💧💧
Steel	💧💧	💧💧	💧💧💧💧
Power	💧💧	💧💧💧	💧💧💧💧
Agriculture	💧💧	💧💧💧	💧💧💧💧
Food	No	No	💧💧💧💧
Drilling	💧💧	💧💧💧	💧💧💧💧💧

💧 = Fair 💧💧💧💧💧 = Best

Table 2: Comparing grease application suitability

The only limitations with calcium-sulfonate greases are their inferior pumpability and cost. However, recent technological advances have brought these greases up to par with lithium-complex greases. A calcium-sulfonate grease can also be applied in more types of industries compared to lithium-complex greases, thus making it the preferred choice for a high-performance multi-purpose grease. ■

About the Author

Dr. Anoop Kumar is the director of research and business development at Royal Manufacturing. He has more than 20 years of experience in the field of lubricants and greases, along with a doctorate in chemistry from the Indian Institute of Technology. Dr. Kumar can be contacted via email at anoopk@royalmfg.com.

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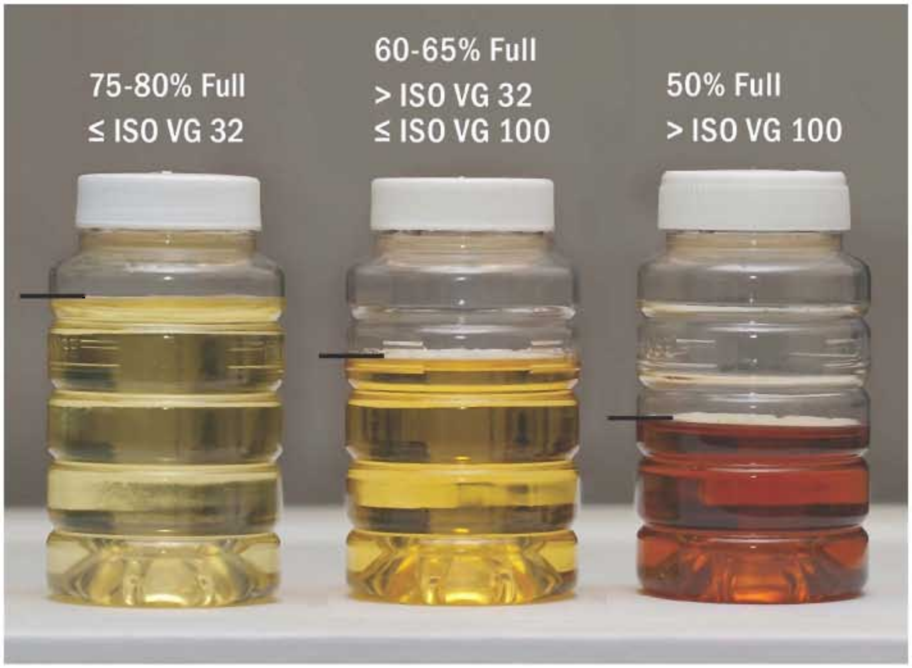
ANATOMY of an OIL SAMPLE: Part 1 – Sample Bottles

The decision to perform oil sampling can be difficult. You must consider whether to spend the extra time to take a sample and the extra money for oil analysis. Once the decision is made, it is critical to understand how to maximize the data's value and minimize any disturbance that could render the sample useless.

No matter how much attention is paid to an oil sample or how effective the laboratory equipment is, the results are meaningless if the sample is not representative of the system's fluid. While this may appear to be common sense, more thought is usually given to the lab or the oil analysis results than the techniques and equipment used in the sampling process.

This article is the sixth installment of a series of "anatomy" lessons within *Machinery Lubrication*. In this issue, the importance of oil sample bottles in obtaining a representative sample will be discussed. Subsequent articles will address proper sampling equipment, selecting a sampling valve and choosing the best sampling location.

It has often been said that particles too small to be seen by the unaided eye are the most destructive in three-body abrasive wear. These particles, which are typically in the 5- to 15-micron range, have the capability of getting trapped between surface gaps rather than shooting through the gap or being held outside the gap. For this reason, particle contamination analysis commonly presents data as three range numbers for particles greater than 4, 6 and 14 microns.



These images show general headspace or ullage recommendations.

Given that these "invisible" particles are substantial, it is imperative to ensure that they are not present within the sample bottle prior to a sample being obtained. This means that drawing a sample into a washed-out soda bottle will not be good enough. Even a sample bottle purchased with the lid and bottle in separate packages will not be sufficient.

Sample Bottle Cleanliness

Rather than using the closest "bottle" you can find or purchasing the cheapest sample bottles on the market, consider the cleanliness levels of sample bottles established specifically for this purpose. The required sample bottle cleanliness will be based on the importance of the sample being taken and the sensitivity of the tests being conducted.

One method of classifying sample bottle cleanliness provides three categories for specifying the range of particles in a bottle. "Clean" oil sample bottles are defined as having less than 100 particles greater than 10 microns

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Reliable Plants 2015 Conference & Exhibition, taking place from May 26th – 28th, 2015 at Yas Viceroy Hotel, Abu Dhabi, UAE. This conference is focused on reliability in plant operations, maintenance, inspection and projects designed for the oil, gas, refinery and petrochemical sector. The purpose of this conference is to effectively contribute in the development of reliability engineering across industries and to empower the Reliability culture.

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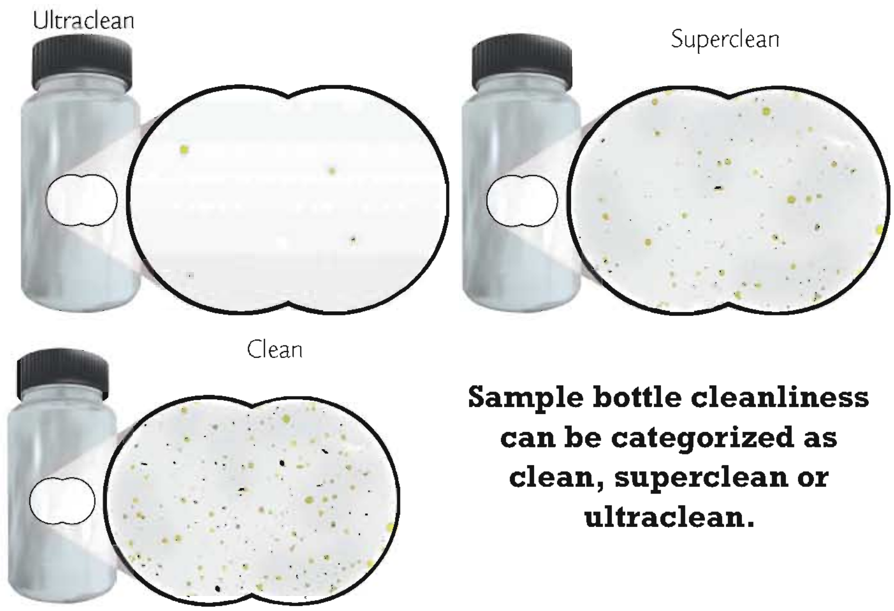
per milliliter of fluid. This cleanliness level is the most common and least expensive. "Superclean" oil sample bottles can be defined as having less than 10 particles greater than 10 microns per milliliter of fluid. "Ultraclean" oil sample bottles are defined as having less than 1 particle greater than 10 microns per milliliter of fluid. ISO 3722 also describes a certification procedure based on randomized testing for cleanliness.



Sample bottle cleanliness can be categorized as clean, superclean or ultraclean.

Sample Bottle Material and Size

Oil sample bottles are available in a few standard materials, namely plastic or glass. The material should be selected based on the type of fluid sampled and the cleanliness requirements. The most common sample bottles are high-density polyethylene (HDPE) or polyethylene terephthalate (PET). HDPE is opaque, which may be its main disadvantage. Not having the ability to clearly see the oil in the bottle prevents visual onsite analysis, which can be helpful in detecting water or heavy particle contamination. On the other hand, PET is clear but generally not suitable for samples at temperatures higher than 200 degrees F. Nevertheless, it has greater compatibility with most industrial lubricants. Compared to glass bottles, both polyethylene-based bottles are fairly inexpensive. However, glass bottles offer the benefits of excellent cleanliness levels and lubricant compatibility.

The sample bottle size should be based on the type of sample fluid as well as the number and type of tests to be conducted. For most standard oil analysis tests, oil samples are taken in a 100- or 120-milliliter bottle. For advanced or exception tests, a 200-milliliter or larger bottle may be required, although bottles larger than 200 milliliters tend to be used for fuel analysis. An example of when a larger sample might be necessary would be for hydraulic fluid testing, especially aviation hydraulic fluid. Sample bottles can also come in smaller sizes for other applications. A breakdown of various types of oil sample bottles is shown in the chart on the left.

When choosing an oil sample bottle, first talk to your oil analysis laboratory. Ask if the lab provides/recommends sample bottles. In addition, find out if the bottles are subjected to testing, as per ISO 3722. You then must establish the cleanliness requirements for your samples. One way to determine the necessary sample bottle cleanliness is to use the signal-to-noise ratio (SNR) technique. As the formula on page 45 indicates, the SNR is defined as the target cleanliness for the machine divided by the contamination identified for the bottle.

	USE	VOLUME	MATERIAL	ISO CLEANLINESS*	COST
	General oil sampling, visual analysis	3 and 4 ounces (100 to 120 milliliters)	PET (transparent)	Superclean	$
	General oil sampling	3 and 4 ounces (100 to 120 milliliters)	HDPE (opaque)	Clean to superclean	$
	Hydraulic fluid	4 and 8 ounces (100 to 200 milliliters)	HDPE/PET (transparent or opaque)	Clean to superclean	$$
	Hydraulic fluid, visual analysis	4 and 8 ounces (100 to 200 milliliters)	Glass (transparent)	Ultraclean	$$$

Oil Sample Bottle Types

*** Cleanliness levels shown are of typical availability and will depend on the bottle distributor.**

These improper oil sample bottles are real-life examples of what a laboratory may receive.

The goal is a higher SNR value. For example, an SNR of 5 would have a 20-percent variance of cleanliness accuracy, while an SNR of 10 would have a 10-percent variance. A higher SNR is achievable with fluids like gear oil that don't require rigorous cleanliness levels. Fluids with greater cleanliness requirements, such as hydraulic fluid, demand cleaner sample bottles to help achieve an SNR value above 5.

$$\frac{\text{Target Cleanliness Level}}{\text{Contamination In Bottle}}$$

$$\text{SNR} = \frac{75^{(15/12)}}{7.5} = 10$$

$$\text{SNR} = \frac{1000^{(19/16)}}{100} = 10$$

Sample Collection

When a sample is taken, it is critical to know how much fluid should be drawn into the bottle. However, it may be more important to understand how much headspace or ullage is remaining in the bottle. This will help the laboratory perform proper agitation before testing. The amount of ullage required will depend on the fluid's viscosity, as more viscous fluids need more room to agitate sufficiently.

Other factors in obtaining a representative oil sample will be discussed in upcoming issues of *Machinery Lubrication*, including optimum sample extraction tools, sample location and sampling intervals, as well as best practices for taking a sample based on the machine type. Remember, if one aspect of the sampling process is neglected, the oil analysis results are at risk of becoming meaningless. Therefore, it is essential to maximize the data's value. This follows the three common objectives of oil sampling, which are to maximize data density, minimize data disturbance and establish a proper frequency. Appropriate sample bottles are just one element that can help you achieve these objectives and enable you to obtain a highly representative oil sample. In return, not only will you be more confident in the oil analysis results, but the sampling procedure will be easier than ever before. ■

About the Author

Bennett Fitch is a technical consultant with Noria Corporation. He is a mechanical engineer who holds a Machine Lubricant Analyst (MLA) Level III certification and a Machine Lubrication Technician (MLT) Level II certification through the International Council for Machinery Lubrication (ICML). Contact Bennett at bfitch@noria.com.

McLagan Helps Control Contamination at Peabody's Coal Mine

Contamination control can be challenging for any coal mine. As the largest coal producer in North America, Peabody Energy's North Antelope Rochelle Mine (NARM) in Wright, Wyo., has learned the importance of oil cleanliness. Lubrication technician Mike McLagan has worked for the company for 19 years and has seen the improvements that have been made to assure lubrication effectiveness with oil analysis and filter analysis. The results have been increased machine availability and reduced costs.

Name: Mike McLagan
Age: 45
Title: Plant Reliability Machinery Lubrication Technician
Years of Service: 19 years
Company: Peabody Energy's North Antelope Rochelle Mine (NARM)
Location: Wright, Wyo.

Q What types of training have you taken to get to your current position?

A A solid foundation for an effective lubrication program has been built with Noria skills training in the introduction to machinery lubrication and practical oil analysis courses. Advanced training in failure analysis and root cause analysis has also been completed.

Q What professional certifications have you attained?

A My certifications include Machine Lubricant Analyst (MLA) Level I and II through the International Council for Machinery Lubrication (ICML). I am also certified as a facilitator analyst and as a Wyoming surface coal foreman.

Q Are you planning to obtain additional training or achieve higher certifications?

A Upcoming certifications within the next 12 months include MLA Level III and Certified Lubrication Specialist (CLS).

Q What's a normal work day like for you?

A My day begins with a safety/startup meeting. With information from this meeting, I will schedule oil changes according to available downtime. Then I check the oil and filter inventories in our lube building and restock accordingly. From there, I make my plant rounds to monitor and record the filter differential pressures, replace filters based on the information obtained from the differential pressures/oil analysis results, and check breathers and seals on the most critical gearboxes. I finish my day at our in-house oil analysis lab to review incoming oil and filter samples from the previous week. I also label and prepare current oil samples for shipment to the oil analysis lab in Spokane, Wash.

Q What is the amount and range of equipment that you help service through lubrication/oil analysis tasks?

A Our plant consists of 14 miles of conveyors transporting coal from our five crushing facilities to five silos, 45,000-ton slot storage and three train load-out stations. Keeping all of this conveyor belt moving requires several large gearboxes driven by 1,500-horsepower electric motors, 18 separate hydraulic systems, 11 large air compressors, 18 holdbacks and hundreds of individual bearings on automatic lubrication systems.

Q What lubrication-related projects are you currently working on?

A I am currently designing an air-driven kidney-loop system to filter and cool small reservoirs of oil (1 gallon or less) to prolong the service life of the holdbacks attached to our main conveyors.

Q What have been some of the biggest project successes in which you've played a part?

A By implementing a kidney-loop system on our large 90-gallon-reservoir gearboxes, we have been able to take our ISO codes from 24/23/17 to 17/13/11 in the gear oil we use. We also had our new lube building featured in *Machinery Lubrication's* 2013 Lube Room Challenge.

Q What do you see as some of the more important trends taking place in the lubrication and oil analysis field?

A Companies are seeing the importance of having certified people in critical roles. Certified world-class analysts equal world-class reliability.

Q What has made your company decide to put more emphasis on machinery lubrication?

A A phenomenal amount of money is lost each year due to friction and wear, which can be offset through training in proper machinery lubrication and oil analysis as the guide to a world-class lubrication program.

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17th Lubricating Grease Conference

February 12 - 14, 2015

The National Lubrication Grease Institute (NLGI- India Chapter) organized the 17th Lubricating Grease Conference from 12th-14th February at the Radisson Blu Temple Bay Resort, Mahabalipuram. The conference was attended by over 250 delegates from across the world. 29 papers were presented across three days on various technical subjects.

The event commenced with an inauguration ceremony by Mr. R Satyanarayana, Chief Superintendent, Madras Atomic Power Station, followed by a welcome address by Dr. R.K Malhotra, President, NLGI India Chapter.

The first session on "Frontiers of Grease Technologies" was chaired by Dr. A.K Bhatnagar & Mr. J.Bhatia. The session included talks on sustainability and the role of grease in our new world economy. The evening was followed by a cultural programme and dinner.

Day two of the conference began with the technical session on "Grease Manufacturing Processes & Formulation" and was chaired by Mr. J.L. Raina & Mr. Anoop Kumar. The session included talks on Solid Oil Bearings and its breakthrough innovation in bearing lubrication by Mr. Mahantesh M. Patil from SKF India Ltd. The talks were followed by Q&A sessions with the audience.

The post lunch session on "Base Fluids for Lubrication Greases" was chaired by Mr. R. Suresh & Mr. A.K Bhan. This session's first speaker, Mr. Mehdi Fathi-Najafi from Nynas AB spoke on Blends being Friends or Foes. Other topics included, Impact of Rheology on Tribological Properties. The evening session was followed by a great live performance and musical night.

The valedictory function was held on day 3, with the best paper awarded to Dr. Frederik Wolf of Anton-Paar and Mr. A.K. Harinarian of IOCL R&D. The event proved to be a good learning and networking experience, and we look forward to the 18th NLGI India Conference.

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How to COMBAT BREAK-IN WEAR

When a machine is first put into service, there is a period of time known as the "break-in" period. During this time, the machine creates wear debris as components begin their initial motion. While there are differing opinions on break-in times and methods, a few constants remain. Certain variables come into play such as surface coatings, time in storage and lubricant selection. By balancing all of these variables, you can achieve fewer failures during the early stages of machine life.

The primary reason machines lose their usefulness is due to the degradation of working surfaces. This can occur for a variety of reasons with a multitude of effects to the rest of the machine. However, when a machine is first put into service, it typically generates more wear than it does after months of use. The rate of wear starts high initially and then gradually declines over time.

Break-in wear can vary based on the surface finish of the components in motion. The surface profile of bearing and gear surfaces can be very smooth or rough depending on the grade purchased as well as the load characteristics that they must support. The small surface irregularities known as asperities exist on all working surfaces. The depth and amount of these asperities will make a difference in the amount of initial running-in wear that will ensue. The smoother the surface (fewer/shorter asperities), the less break-in wear will occur.

In boundary conditions (no lubricating film to separate the surfaces), the asperities come in contact with each other more frequently, leading to increased wear and possible metal transfer from one surface to another. This metal transfer is common during the process known as adhesive wear, which occurs when two surfaces are in contact and continue to move past each other. With more asperities, adhesion is also initially high during the break-in phase. All of this leads to greater friction during the infant stage of machine life. As the asperities are ground down against each other, the friction associated with the surfaces moving against each other decreases slightly. This friction is negligible but can account for increased power requirements during startup.

As friction decreases and the asperities begin to smooth out against each other during the running-in phase, a small amount of machine polishing occurs. Consider a machine shaft as it spins relative to a journal bearing. As the bearing's asperities are ground against the shaft, the bearing's surface profile becomes smoother. The resulting polishing effect contributes to the higher levels of wear debris that are seen in a machine when it is first put into service. In extreme cases where the break-in process is carried out incorrectly (excessive loads, speeds and/or lubricant starvation), the polishing effect can be destructive and escalate to galling and severe two-body abrasion. This can lead to the loss of surface profile and thus machine failure during the component's infancy.

Additionally, surface undulations can concentrate loads to small contact areas. These high points wear down during the break-in period, allowing the load to be dispersed over a larger area. Afterward, the break-in wear zone (high points) will often heal over.

To temper or control this surface polishing, many users utilize different lubricants to reduce the amount of wear developed during the first few weeks of machine life. Use of

All machines will generate wear during the break-in phase; it is how you manage this phase that will determine how long the machine will operate afterward.

moderate loads and speeds also helps. One strategy includes the use of oils with extreme-pressure (EP) additives, which can reduce the amount of asperities and smooth the surface profile. As these EP additives build up on machine surfaces, they produce a chemical film. This film contains a small amount of the surface material, which becomes sacrificial. As this layer is rubbed away, it results in a smoother profile underneath and reduced kinetic friction. While this technique may help to address the issue of asperities, it should be used only in moderation, as EP additives can be chemically aggressive and destroy some softer metal compounds, especially alloys containing copper.

Another method involves using a slightly lower viscosity oil during the run-in phase. Along with a lighter load, this can help reduce the severity of the break-in process with generally less wear produced. Although this method works, it also lengthens the break-in period. Combined with the decreased workload, this can cause problems with production goals or process requirements, so it is more often used in situations where spare equipment can be utilized to make up for the loss in capacity.

Others believe that machines should be broken in the same manner in which they are expected to operate. While this is typically the industry standard, it can lead to early machine failure if not monitored. All machines will generate wear during the break-in phase; it is how you manage this phase that will determine how long the machine will operate afterward.

Oil temperature is also influenced during the break-in period. It will often rise from higher friction and then fall as surfaces smooth and load zones are broadened. This is common with large gearsets.

As with all wear debris monitoring, it is important to look at the rate of change and not just the total volume of wear debris. An initial oil sample from a machine may show high iron from machining debris left during the installation process. After a second sample, which may also be high, the focus should be on the rate of change in the metals. This is why tracking hours of runtime between oil samples as well as after adding makeup fluid becomes very important.

58% of lubrication professionals say break-in wear has caused problems in the machines at their plant, according to a recent poll at MachineryLubrication.com

Perhaps the best example of breaking in a piece of equipment comes from the standard vehicle engine. Several break-in fluids are available that help temper wear on bearings, cams and cylinders. These fluids typically have a higher additive load and a different viscosity than the engine oil. A new engine usually is run at a lighter load (lower speed) for a short period before it is considered roadworthy. Most engines are broken in at the factory prior to being installed in a car. However, many mechanics replace engines and must repeat this process to ensure engine health.

A friend of mine experienced this firsthand as he was rebuilding the engine for his drag car. He had just finished putting the final touches on the engine and fired it up. Shortly thereafter, he took the car to the track and lost the engine on his first pass. During the teardown, he discovered most of the bearings were wiped out from what he determined to be a lack of oil. Since the running-in period was so short, the oil didn't have a chance to build up the protective chemical layer on the surfaces to ensure their longevity.

In the initial stage of a machine's life, there are a few things to keep in mind. More friction and wear will occur due to the high level of asperities. As the asperities are ground down, the new surface becomes polished, signifying the end of the running-in period. Explore the use of a break-in fluid to help minimize the risk of machine failure and to reduce the amount of wear experienced during this time. By vigilant monitoring of wear debris as well as understanding the forces at play during the break-in period, you can ensure that your machines will have a longer life and experience fewer breakdowns.

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DHIREN SHAH

BASE OIL REPORT

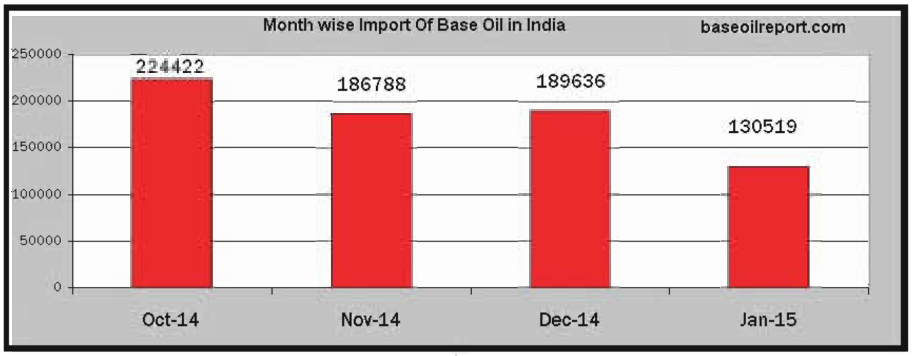
Crude Oil Prices are seeing a down by 51 per cent compared with the same period a year ago March 2014. Prices of Brent crude, which matters more for India, were quoted at $ 58.35 a barrel, Western Texas crude was ruling at $48.54 a barrel. Prospects of recovery in crude oil prices look bleak since supplies in the US have increased to 80-year high of 448.8 million barrels. The US Energy Information Administration (EIA) says that a lot of the world's oversupply is finding its way to storage in North America. Compared with the same period a year ago, inventories are up 20 per cent. The problem of oversupply will continue since the Organization of Petroleum Exporting Countries, which accounts for 40 per cent of the global production, and US shale oil producers are locked in a tussle to assert their supremacy. For OPEC, Saudi Arabia has been the prime force in not agreeing to any production cut, which could boost prices psychologically. For India, the fourth largest crude oil importer, cheaper crude oil will help lower its current account deficit since 71 per cent of the total domestic demand is met through imports. Also, crude oil accounts for 34 per cent of the country's total imports. According to Government data, crude oil imports during January were valued at $8.25 billion, 37 per cent lower than that in January 2014. Shipments into the country during April-January in the current fiscal were 7.87 per cent lower at $124.75 billion ($135.40 billion in the same period a year ago).

Countries from Where Base Oil was Imported

Country	MT	%
Korea	113884	60%
Singapore	21489	11%
Spain	16744	9%
USA	8986	5%
UAE	8699	5%
Taiwan	8668	5%
Bahrain	3121	2%
Saudi	1884	1%
Malaysia	1183	1%
Other countries	4978	3%

The Indian base oil market remains steady with inventories at optimum levels with surplus of imported grades. Major imports are from Korea, Singapore, USA, UAE, Iran, Taiwan, France, UK, Netherlands, Japan, Italy, Belgium, etc. Indian State Oil PSU's IOC/HPCL basic prices for SN – 70/N – 70/SN – 150/N -150 marked up marginally by Rs. 0.20 per liter, while SN - 500/N - 500 is marked down by Rs, 0.40 per liter. Bright Stock price is down by Rs. 0.30 per liter. BPCL prices are awaited. The prices are effective from March 02, 2015. Hefty Discounts are offered by refiners which are in the range of Rs. 15.00 – 17.00 per liter for buyers who commit to lift above 1500 MT. Group I Base Oil prices for neutrals SN -150/500 (Russian and Iranian

Month	Group II - N 70 Korea Origin Base Oil CFR India Prices	SN-500 Iran Origin Base Oil CFR India Prices	Bright Stock - CFR India Prices	Base Oil HYGOLD L -2000
July 2014	USD 1065 – 1075 PMT	USD 1040 – 1045 PMT	USD 1220 – 1230 PMT	USD 1075 - 1085 PMT
August 2014	USD 1055 – 1060 PMT	USD 1045 – 1055 PMT	USD 1235 – 1245 PMT	USD 1070 - 1085 PMT
September 2014	USD 1015 – 1020 PMT	USD 1015 – 1020 PMT	USD 1200 – 1210 PMT	USD 1080 – 1090 PMT
	Since July 2014, prices down by USD 50 PMT (5%) in September 2014	**Since July 2014, prices has marked down by USD 25 PMT (2%) in September 2014**	**Since July 2014, prices has gone down by USD 20 PMT (2%) in September 2014**	**Since July 2014, prices has decreased by USD 20 PMT (2%) in September 2014**



origin) are offered in the domestic market at Rs. 40.80 - 40.90/40.70 - 40.95 per liter, excise duty and VAT as applicable Ex Silvassa in bulk for one tanker load. At current level availability is not a concern.

The Indian domestic market Korean origin Group II plus N-60-70/150/500 prices at the current level have been marked down due to higher inventories level. As per conversation with domestic importers and traders prices reflects minimal changes for N - 60/ N- 150/ N - 500 grades and at the current level are quoted in the range of Rs. 42.00 - 42.60/42.95 - 43.95/43.50 - 43.80 per liter in bulk respectively with an additional 14 percent excise duty and VAT as applicable, no Sales tax/Vat if products are offered Ex-Silvassa a tax free zone. The above mentioned prices are offered by a manufacturer who also offers the grades in the domestic market, while another importer trader is offering the grades cheaper by Rs.0.25 - 0.35 per liter on basic prices. Prices may decline further by another Rs.1.50 - 2.00 per liter due to lack of demand and high inventories. Light Liquid Paraffin (IP) is priced at Rs. 42.30 - 42.40 per liter in bulk and Heavy Liquid paraffin (IP) is Rs. 46.40 - 46.75 per liter in bulk respectively plus taxes extra.

Ports at which Base Oil was Imported

Port	MT	%
Mumbai	150486	79%
JNPT	18170	10%
Ennore	10691	6%
Chennai	6249	3%
Kolkata	2679	1%
Other Ports	1362	1%

Approximately 3358 MT of Transformer Oil has been exported in the month of December 2014 from JNPT, Village Ponneri and Chennai port. It has been exported to Bangladesh, Afghanistan, Brazil, Malaysia, Djibouti, Myanmar, Iran, Newzealand, Oman, Paraguay, Indonesia, South Africa, Srilanka, Saudi, Philippines, Thailand, Vietnam, and UAE.

About the Author

Dhiren Shah is a Chemical Engineer and Editor - In - Chief of Petrosil Group

Export of Light & Heavy White Oil

Australia	Argentina	Bangla-desh	Brazil	Bulgaria	Cambo-dia	Chile	Colombia	Djibouti	Ecuador
Egypt	Germany	Guatemala	Greece	Ghana	Hong Kong	Indonesia	Ivory Coast	Iran	Israel
Jordan	Kenya	Malaysia	Nepal	New Zealand	Nigeria	Pakistan	Peru	Philip-pines	Poland
South Africa	Senegal	Spain	Srilanka	Taiwan	Tanzania	Thailand	Turkey	USA	UK
Ukraine	Vietnam	Yemen	Zaire						

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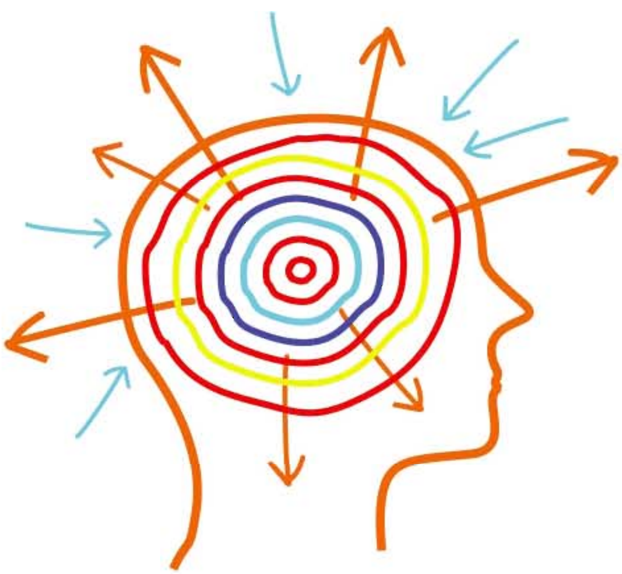
Mumbai	4 - 6th June	Practical Oil Analysis
Kolkata	19 - 21st November	Essentials of Machinery Lubrication
Chennai	23 - 25th November	Practical Oil Analysis
Mumbai	26 - 28th November	Advanced Oil Analysis



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