Machinery Lubrication

India March-April 2016

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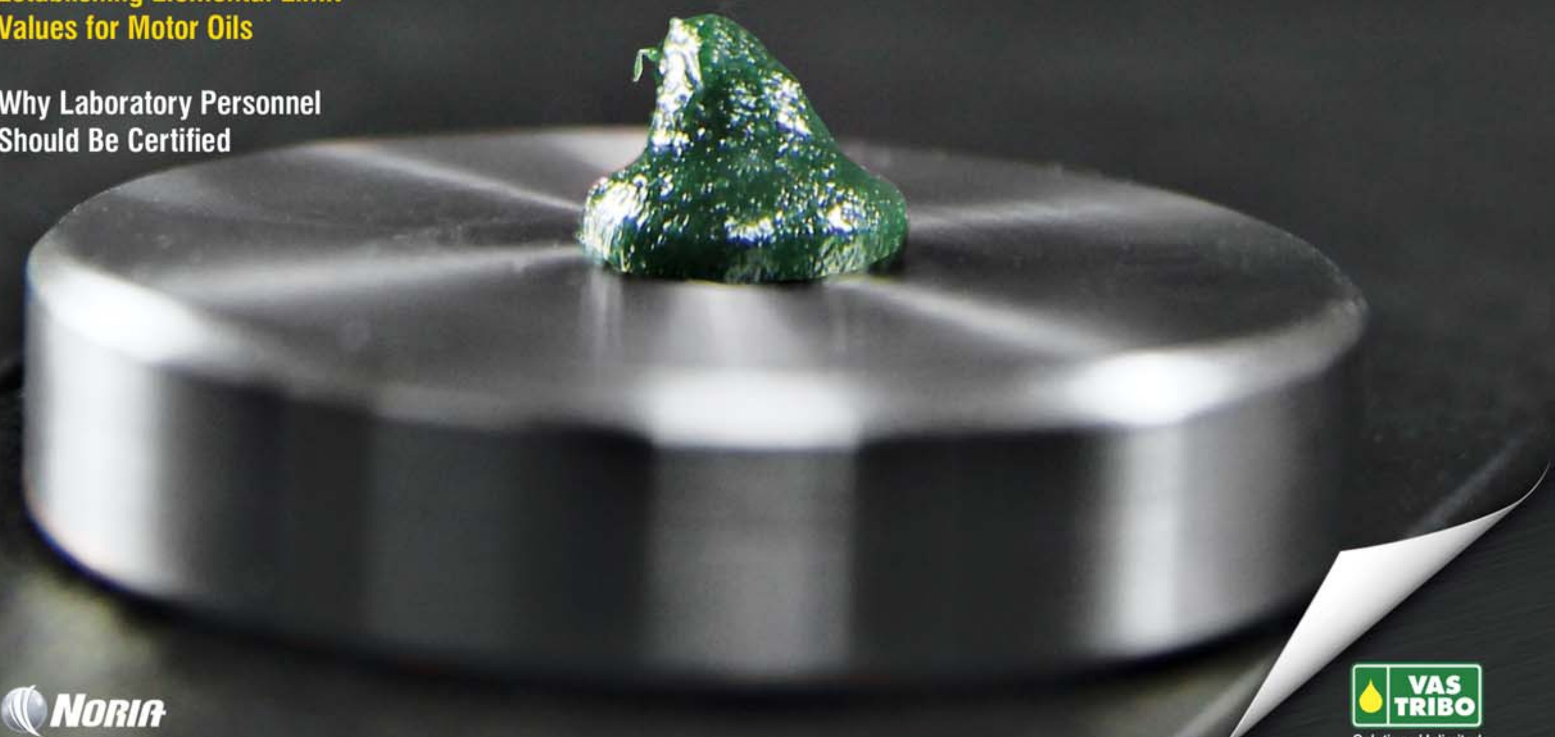

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Publisher's Note

The Indian grease market is the world's third-largest and currently at 1,20,000 MT per year and growing approximately 2 percent per year, according to the data shared at NLGI India Chapter Conference held at Ambay Valley Resort, Pune recently . That would rank India well behind China and North America but ahead of Japan and Europe's biggest markets.

Lithium & Lithium Complex greases continue to dominate the market, accounting for about 90 percent, with all other types of greases accounting for the balance 10%. The quantity of Poly urea products is negligible. The trend toward higher technology greases may see an upward trend in the next five to ten years due to the use of wide variety of industries of modern equipment from foreign original equipment manufacturers that recommend or require use of higher quality greases.

Your magazine was the media partner for the event.

We also actively participated in the Servo Mining Meet 2016, which was organised at Ranchi recently. Our mining domain expert Mr Michael Hooper from New Zealand spoke on "Driving Efficiency & Productivity gains in mining through use of latest lubrication practices" at the plenary session, besides another paper on "Monitoring Oil for Equipment Health".

Your magazine continues to bring generic and specific lubrication and lubricating oil related news and views as required in the current domestic industrial environment. Engine oil quality remained the prime focus in the first issue of this year. Of note were industrial and auto engines upgraded and updated in line with specialized outputs required.

A lubricant may therefore choose to remain generically well thought of, or be tailored for specific use. At hand are stated properties required for engine oils as with viscosity and viscosity classification related to the operating condition.

Similar reasoning leads on this issue of the cover story and current maintenance culture. We delve into the behavioural sciences to present remedies and the fact that companies, big and small, would benefit from a culture intervention even if it is outlined through a formal program. At stake is company reputation through efficient maintenance of plant assets.

Our specialists provide answers through remedies for such company culture if taken for granted. Most of that, as always, lies with management and leadership even when the right people are in the right jobs. The idea is to prevent machinery failure by pre-empting that failure besides having to take corrective measures after a breakdown.

In other words, today's maintenance toolbox should not just be used for repair and take corrective measures. Tools and devices that inspect and control conditions that might lead to failure or are incipient symptoms of failure have also to be kept at hand. How-to's are also provided, such as education and training, learning and workweek control.

Warm Regards,

Udey Dhir

JIM FITCH, Noria Corporation

REMEDIES for a Bad Maintenance CULTURE

You may not be surprised to know that most companies need a culture intervention – something like a 12-step program. This column will discuss behavioral issues that are often at the core of a culture of neglect and mediocracy. It borrows much from management science and leadership principles.

Over the years, we have had hundreds of conversations on this topic with individuals working in the field of maintenance and reliability. Some come from organizations infected with culture problems, while others represent businesses that have emerged from a successful transformation. Then there are those organizations that achieved transformation but regressed to their bad habits and past addictive practices.

Of course, the best predictor of future behavior is past behavior. Past behavior establishes reputation, which many people use to judge others. You can judge culture in a similar way to help predict future maintenance and reliability performance. Behavior, values and decisions are all components of employee engagement. Engagement sharply impacts individual and business performance.

A positive, nurturing maintenance culture is a critical plant asset. Consider that when people do good work, they feel good about themselves and their job. When people do bad work, they feel bad about themselves and their job. Feeling bad is a serious morale problem that multiplies and spreads. The simple solution is to enable people to do good work that is recognized and celebrated.

This is both problem and solution. Culture drives behavior. Behavior influences quality of work. Quality work is fundamental to plant reliability and the cost of reliability. Why do we care? Reliability fosters job security and builds shareholder value. Bad culture is dysfunctional and sparks a chain of despair for all stakeholders. No amount of expertise in lubrication and machine reliability will overcome the destructive aftermath caused by rotten maintenance culture. It has inertia that over time becomes increasingly difficult to change.

Good culture has inertia, too. It fuels a chain of reinforcing successes. Small successes beget larger and more sustainable successes. Creating a good culture starts and ends at the top, at the leadership level. When good leaders are in charge, everyone wins. When bad leaders are in charge, the culture becomes negative/hostile/stagnant, and everyone loses. Good culture also emerges from management's aspiration for improvement and the inherent desire to do good work. It relates to skills, tools, work plans and machine readiness. So how do you create an environment that fosters good culture?

Signs of a Bad Maintenance Culture

Breakdown maintenance and bad maintenance culture go hand-in-hand. Constantly reacting to machine failure demotivates maintenance staff. In such cases the plant's machines control the work schedule, not the other way around.

This reminds me of the phrase, "People don't quit their jobs; they quit their bosses." Employees quit because they aren't properly managed or leadership hasn't created an appropriate organizational culture. Regardless, good culture is the remedy for most things.

Machine reliability is a behavioral science, cascading down from management to the plant floor. Years of root cause analysis (RCA) has confirmed that bearings don't just die; they're murdered. They are killed by people who don't know how or don't care to prevent these failures. Good culture changes behavior and enables reliability.

It doesn't take long to recognize the signs of bad maintenance culture, although the profile of this culture can vary considerably. The culture profile might be characterized by indifference, blame, tension between operations and maintenance, frustration/anger, distrust, pessimism, high staff turnover, waste of time/resources, excessive human errors, aging work-order backlog, frequent unscheduled maintenance events, crises and unprofitability.

8 Remedies for a Bad Culture

Management and leadership both define and catalyze the culture of an organization, good or bad. Even bad culture that is rooted in high institutional inertia can be changed. This change may be more difficult and even somewhat disruptive, but it is far from impossible. Still, nothing happens without an unwavering management commitment to create a sustainable foundation for change.

Do you think culture is something that keeps your plant manager awake at night? Maybe he doesn't know how it's impacting the company's bottom line. Managers who understand and see plant reliability as a means to plant profitability have the desire to inspire and support culture initiatives that build charged-up and prosperous maintenance teams. Stopping the management revolving door is also important.

The role of management on group behavior and culture has been the subject of countless books and publications. It relates to team building, engaged team members, empowerment, communication, goal setting, defining mission/vision/values and so much more. You can't cheerlead your way into sustained cultural transformation, nor can you manage by memo. Two excellent books for managers are *Good to Great* by Jim Collins and Verne Harnish's *Scaling Up: How a Few Companies Make It ... and Why the Rest Don't (Mastering the Rockefeller Habits 2.0)*.

Another way to find wisdom is to study the success of others. What are the common threads of a successful maintenance culture? There are several, and most aren't specific to maintenance but are foundational to any operating organization. Because of this, you can leverage the experiences of numerous teams that have successfully tackled the culture transformation challenge. To get you started, I've done some research and have listed the pillars of good maintenance culture below.

1. The Right People

We've all heard that employees are a company's most valuable asset. This is true, but only when the right people are in the right jobs. Incompetent or poorly matched people working in maintenance positions can present sizeable operational and cultural risks rather than being productive assets. Select, nurture and inspire the right people to build a prosperous maintenance culture.

2. Job Skills and Know-how

As previously mentioned, when people do good work, they feel good about themselves and their job. People want to do the right things right the first time and every time. However, many people suffer from unconscious incompetency. In other words, they are unaware or in denial of the level of their incompetency. Others

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Machinery Lubrication India Volume 21 - Issue 2, March-April 2016 is published bi-monthly by VAS Tribology Solutions Pvt. Ltd. Operation Office:213, Ashiana Centre, Adityapur, Jamshedpur-831013, India.

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are fully aware that their skills are desperately lacking.

A prosperous plant culture is a learning culture. Education, when effective, takes people out of their comfort zone. It not only builds intellectual capital but over time fosters a behavioral desire to do the right things right every time. It also builds team loyalty and dedication to achieving business goals. People learn differently, so don't assume knowledge is only acquired in a classroom. Certification instills pride and should be the capstone to each learning stage by providing visible recognition of skill competency.

Next, create an environment of standardized work, also known as procedure-based maintenance. This takes the guesswork out of the thousands of maintenance tasks that must be routinely and periodically performed. These shouldn't be just any old procedures and often are not even those found in machine service manuals. Instead, they should be refreshed with modern concepts in lubrication and maintenance. Seek the help you need to get these procedures right.

3. The Tools

Much new technology has entered the world of lubrication and machine maintenance in recent years. As the old-timers are retiring, so must many of their tools. Today's maintenance toolbox should not just be used for repair and corrective measures. It should also contain tools and devices that inspect and control conditions that might lead to failure or are incipient symptoms of failure. These include inspection tools, condition monitoring instruments, contamination control devices and much more.

As mentioned, an extremely good starting point would be education and creating a culture of strategic training instead of just-in-time (reactive) learning. Training programs that present modern and technology-based concepts in lubrication and maintenance will also detail the tools that enable them. With education and tools comes pride in one's work and profession. This is a precursor to good maintenance culture, so don't skimp.

Consequences of Periodic PM Forgetfulness

Lubrication requires constant attention. Vigilance is perhaps a better word. It's easy to forget the things you are not motivated to do, yet rarely do you forget those activities you are passionate about and desire to do. We are all driven by instinct to seek out the things we enjoy or that give us a gratifying reward.

Because it's hard to find happiness in performing most routine maintenance tasks, it is not uncommon for many of them to become periodically forgotten or perpetually postponed. Much of this is actually "conscious forgetfulness," similar to procrastinating. Why does this happen? It is most likely due to a lack of rigor, which is the result of a lack of structure, measurement and incentive.

Delinquent preventive maintenance (PM) can become habit-forming, leading to even more delinquency and a general cavalier attitude among maintenance workers toward punctuality and work quality. This "mañana mentality" or constant procrastination can lead to a destructive downward spiral. Common symptoms relating to lubrication include widely fluctuating oil levels, inspections that don't get performed or reported, filters and breathers that don't get changed on time, oil samples that never get taken or are collected improperly, oil that is not changed on time, and bearings that don't receive a timely shot of fresh grease.

Periodically forgetting to perform lubrication and other maintenance tasks is equivalent to periodically accepting preventable failures. You can and should do better.

4. Machine Readiness

In addition to a change in your skills and toolbox, you will need to change your machinery. You must ready your equipment for wellness and maintainability. Even today's new machines won't be equipped with the ancillary hardware to enable quality lubrication and maintenance. Many machine modifications are often required. These include hardware and accessories related to inspection, safety, sampling, oil analysis, contamination control, oil handling, instrumentation and lubricant application. Effective training programs will describe what changes are needed and why.

5. Planning, Scheduling and General Organization

In maintenance, there is a need for good workweek control. The whack-a-mole approach to maintenance workday scheduling is destructive and costly. Activities need rhythm with few surprises. While this requires proper planning and scheduling, it also demands a built-in early warning system. You can't plan and schedule corrective action if you can't proactively see the need. As mentioned, an organization plagued by chronic unscheduled maintenance is an organization that is suffering from bad maintenance culture.

Condition monitoring includes both

	MICRO (Trees)	MACRO (Forest)
LEADING (What is going to happen)	Particle count	Contamination control compliance
	Viscosity	
	Elemental analysis	Fluid properties compliance
	Varnish potential	
	Moisture analysis	PM compliance
	Oxidation stability	
LAGGING (What just happened)	Wear debris analysis	Percent planned maintenance
	Thermography	Uptime/downtime
	Vibration analysis	
	Acoustics	Overtime hours

Figure 2. Example of a yield stress test

proactive maintenance and predictive maintenance. Proactive maintenance sees and responds to failure root causes long before a repair is needed. A good maintenance culture is a proactive maintenance culture. Make breakdown events a rare exception.

Predictive maintenance is a companion to proactive maintenance. It sees and responds to failure symptoms, the earlier the better. Just as it is best to catch disease early, so too is it important to catch faults and impending machine failure early. Thankfully, technology is available to allow machine condition monitoring at a very high level. When it is well-executed, reactive maintenance is transformed to planned maintenance. This will help get work orders into compliance and reduce or eliminate the backlog of aging work orders. See the sidebar on the consequences of periodic PM forgetfulness.

6. Measurement

When you measure, you are communicating what is important. Likewise, those things that are not measured are assumed to be unimportant. Beware of what you don't measure. People subconsciously work the metric. They know how they are being evaluated and respond in their work behavior accordingly. Constant performance measurement, reporting and course corrections are signs of a good maintenance culture.

Measurement should come in many forms and at many different levels, including lagging indicators, leading indicators, macro indicators and micro indicators. Macro indicators are more holistic (the forest), providing a big picture view of plant reliability. General asset utilization numbers, such as overall equipment effectiveness (OEE), are good examples of macro metrics.

Micro indicators see the trees and the weeds. They look at failure causes and symptoms. Machine vibration overalls and lubricant cleanliness levels would be examples of micro metrics. Many of these performance indicators will report what just happened (lagging indicators), while others report what is going to happen (leading indicators). See Figure 1 on page 6.

7. Motivation and Desire

Maintenance workers are more than just arms and legs performing a mindless task. They are productive knowledge workers who not only can carry out the job plan but also can create, innovate and improve the quality and efficiency of the work performed. Empowerment amplifies a company's intellectual capital by stimulating the minds of its employees. When employees can act on their thoughts and opinions, they instill pride in their work and are the most productive. This is the definition of engagement.

Recognition and reward are also important to culture. Many companies fail to properly recognize and reward employees who have excelled at creating value. Time and again, we see lube techs at the low end of the pay scale. Some companies enter the cycle of despair by hiring low-skilled workers and paying them accordingly. Too often companies use demeaning job titles such as calling a lubrication technician an "oiler." An oil can is an oiler. It is an object that performs a mechanical and repetitive task. A lube tech is a thinking human being who has mastered the skills needed to perform his job and whose impact on a machine/team/organization is conveyed as important.

There are also many nonmonetary types of rewards. Companies that fail to celebrate when they don't have broken machines to fix lose out on this culture-strengthening opportunity. See the sidebar on how to stop overtime pay as a counter-incentive to machine reliability.

8. Investment

Organizations that are lean to the extreme harm their maintenance culture. Many who work in the lubrication and maintenance field have the mindset that there is always enough time and money to fix a problem but never enough time or money to prevent it. At the core of the problem is procuring cheap oil, cheap filters and cheap people instead of buying the proper tools, lubrication accessories, software and instruments. Too often companies, especially publicly traded ones, are driven by the desire to see how much money they can earn between now and next Tuesday. Investment is a long-term strategy that cultivates a productive culture.

The Denial Syndrome

The root of maintenance culture problems is often a culprit called denial. When confronted with maintenance and lubrication issues, organizations tend to move away from the denial problem in stages. Following are common management thoughts that characterize these four stages:

Denial — Ignore it. Pretend you don't have a problem. Hope it will go away.

Rationalization — It's for others. We're doing fine. We have a good program.

Lip Service — Let's create a study group to see what we might do. Who else is doing it? Let's do a survey.

Panic — Urgent, we're behind! We've got to catch up! We've got to change everything now!

Fixing Overtime Pay as a Counter-incentive to Machine Reliability

Overtime pay is often viewed as a counter-incentive to reliability. That is, the more reliability, the less overtime pay (needed to repair machines). However, you can flip this around to achieve a novel proactive overtime strategy.

For example, at the beginning of the work year, maintenance workers are given 500 hours of proactive overtime pay. The workers get paid for the overtime regardless, but there's an interesting catch. They have to work the 500 extra hours only if needed to keep machines operating. They now are stakeholders (like stockholders) in reliability and are motivated to do everything possible to keep machines running so they don't have to work the overtime. The company benefits from high asset utilization and lower repair bills. The maintenance workers benefit from overtime pay for hours they don't actually have to work.

There are likely other ways to achieve similar shared benefit when machines are vigilantly maintained. You cannot force people to be motivated, but you can give them many positive incentives. Remember, we generally do only those things we enjoy or that reward us.

Maintenance culture transformation is no easy task. Take ownership of your program by beginning the process of dismantling bad maintenance culture and replacing it with the pillars described above. Create a shared vision of what you are trying to achieve. What will it look like? How will the company benefit? How will team members benefit? Until you fix the culture issue, you cannot rise to the lofty state of excellence in maintenance and reliability.

Jeremy Wright | Noria Corporation

Why Communication is KEY for a SUCCESSFUL Lubrication Program

After years of traveling the globe designing and implementing best-practice lubrication programs for some of the largest manufacturing and processing facilities, I started making a list of the important qualities from projects that were considered major successes. One attribute that always seemed to appear at the top of the list was communication.

As an outside contractor, I can only influence so many things at these facilities. The way in which a viscosity calculation is performed or the decision on how to store lubricants is relatively the same at most every plant, and I can easily make recommendations according to best practices. However, I found myself asking why some companies are able to take these recommendations and make huge strides often within just a few weeks of implementation, while others seem to drag on for months or maybe even years.

56%

of lubrication professionals say there are poor lines of communication between the front-line workers at their plant and management, based on a recent poll at MachineryLubrication.com

One commonality I discovered was that every plant that achieved a fast implementation and a quick return on investment had great communication and a culture that thrived on that communication. Most of these organizations had a standard operating procedure for this type of communication. The interaction was almost always face to face and rarely done through videos, publications, large meetings or an electronic billboard in the breakroom. Although these are all great communication methods, they lack the punch needed to convey the importance of these projects and only involve one-way communication, leaving a lot to be desired in terms of giving both parties a voice in the conversation.

When implementing change, such as when designing or redesigning a lubrication or reliability program, people need to know why the change is being made and how it will affect them.

The Question of Why

Understanding the need for change is the first step in creating new behaviors within a facility. If you assume that business processes will change as a result of your lubrication or reliability initiative, then you must assume that behaviors, which are driven by habits and rituals, will also need to change.

To drive behavioral change, you must communicate the need for change as it relates first to the overall business and second to those involved. If you expect your team to demonstrate the new values of your business through their own behaviors, then they must understand why. This is not the "how." Conveying how is simple. The why is a much harder conversation to have and is usually driven by underlying business needs that are not always easy to convey. This conversation should focus on how the change will affect the individual and why the change is necessary in the first place.

Countless studies indicate that when communicating the business need for change, the most effective communicator in an organization is the CEO. However, the same studies also reveal that when it comes to front-line team members, they prefer to have the why conversation with their direct supervisors because they feel more connected and comfortable with them.

The first part of this communication process should prepare the facility for transformation or change. These conversations should include why the change is necessary, the plan or process for change and the role each individual will play, as well as any objections, which is where the two-way communication occurs.

It's important for the messages and conversations to be consistent. Everyone on the leadership team must have an excellent understanding of the project. Some people may try to discredit the improvement process or challenge leadership's commitment if they receive mixed messages. Make sure you and your peers are aligned, and don't be afraid to use a script. It's not so much the presentation quality but rather the content of the communication that is key. People will recognize the position of the individual within the organization, e.g., the senior manager or their direct supervisor, and will tune into the message being delivered, not the delivery method.

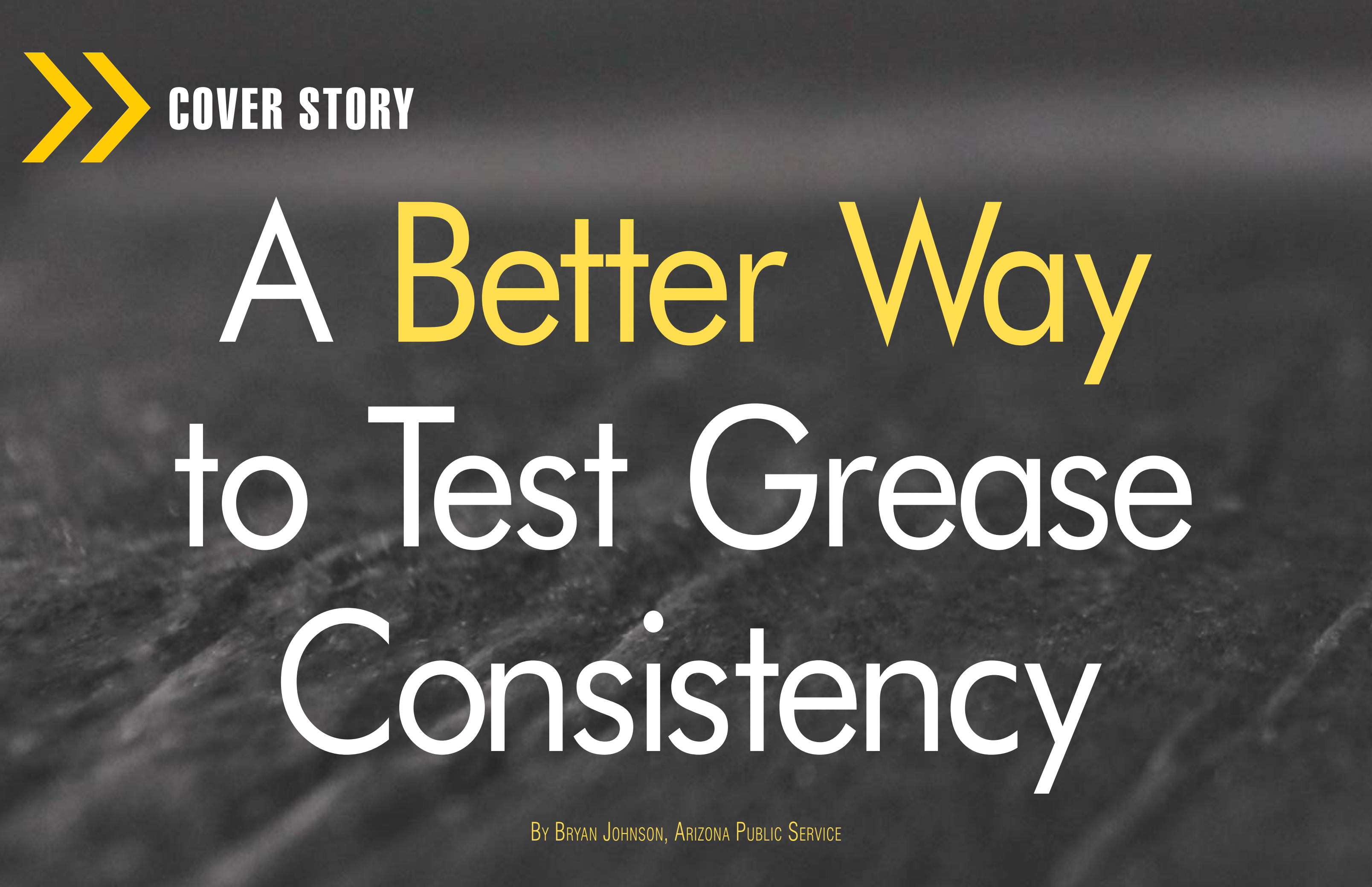
Start by identifying the topics of your communication and then the target audience for each topic. This can be done by examining the groups of people impacted by the changes. Next, select the preferred media for each topic, keeping in mind that the best communication method is face to face from a direct supervisor.

Training is a major contributor to answering the question of why. I have been asked many times to be the catalyst for change through education. It's quite remarkable how easy this is. Instead of just telling the audience that changes are coming and how the changes will affect them, I like to first teach them about the subject matter. I let them come up with their own solutions and help drive them to the same conclusions about change that have already been made by upper management. This process is so predictable that in almost every instance the response has been, "That makes perfect sense. Why haven't we always been doing it that way?"

Communication is one aspect of the improvement process that it would be extremely difficult to have in excess. However, ineffective communication has the ability to derail any improvement project. Be diligent in your communication planning and message. With the correct culture and process in place, you should never hear the words "failure to communicate" as a root cause for program or project failure.

About the Author

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



COVER STORY

A Better Way to Test Grease Consistency

By Bryan Johnson, Arizona Public Service

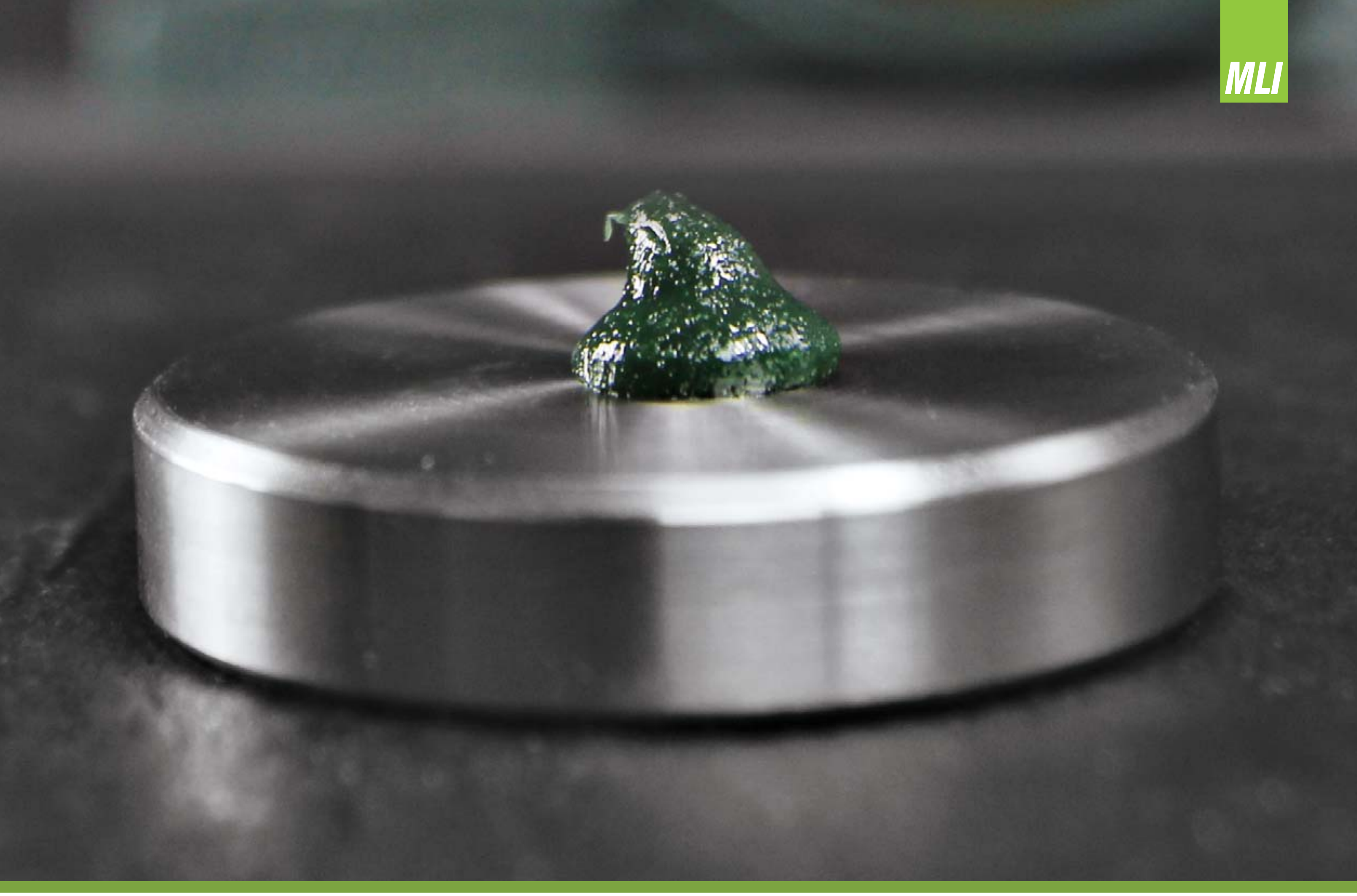
Grease is a complex material that can be manufactured using dramatically different base oil viscosities and thickener types. Variations in soap content and composition can be expected as grease batches are made. Grease testing is primarily performed to support quality assurance and marketing of new grease products. Cone penetration is considered the most important of the laboratory-performed tests. While this ASTM test method provides a measure of grease consistency or stiffness, it is not well-suited for used grease, as it requires a large sample, which precludes its use for in-service testing. Alternative tests to cone penetration have been developed in which touch is utilized to characterize grease stiffness, but these test methods typically are crude and do not lend themselves to accurate results or trend analysis. However, other options that involve the use of stress rheometers have proven to be not only acceptable but preferred for monitoring the consistency of new and in-service grease.

Problems with Cone Penetration

The cone penetration method employs a weighted cone that is dropped into a fixed-size volume of grease for a defined time period. The depth that the cone is able to penetrate the grease is used to rate the grease's consistency with a scale developed by the National Lubricating Grease Institute (NLGI). This test utilizes three different cup and cone sizes. The cups vary from a large (full scale) size of about 290 milliliters (ml) to a small size of 3.8 ml (one-quarter scale). The cup size determines the amount of grease required to conduct a test. Test samples obtained from field sources are generally much smaller than would be required for a cone penetration test.

Many sumps in field-lubricated applications contain less total grease than the cup volume of 290 ml, which is the minimum quantity needed for the full-scale test. Even a volume of 3.8 ml (one-quarter scale) is still greater than the majority of samples obtained from the field. Since more grease is needed to conduct a penetration test than is generally available, this test methodology is clearly a poor choice for an in-service or condition monitoring test.

The cone penetration test can be performed in a worked or unworked condition. The intent is to test the grease samples with a similar level of pre-conditioning for a more consistent result. The common pre-conditioning of a worked cone penetration sample test is to be sheared for 60 strokes. However, this pre-conditioning practice is only intended for new greases. In-service



grease receives no pre-conditioning prior to machine operation; the machine simply starts.

The reporting method used for the cone penetration test is also very crude, and the results can be misleading. The NLGI numbering system appears to be linear (0, 1, 2, 3, etc.), but the grease consistency changes are not linear. For example, it would be reasonable to assume that an NLGI 4 grease would be twice as stiff as an NLGI 2 and four times as stiff as an NLGI 1. However, this is not the case.

Figure 1 was developed by determining the surface area in contact with the grease for increasing depths of the cone. These depths were then compared and plotted. It is clear that the change in surface area in contact with the grease is non-linear.

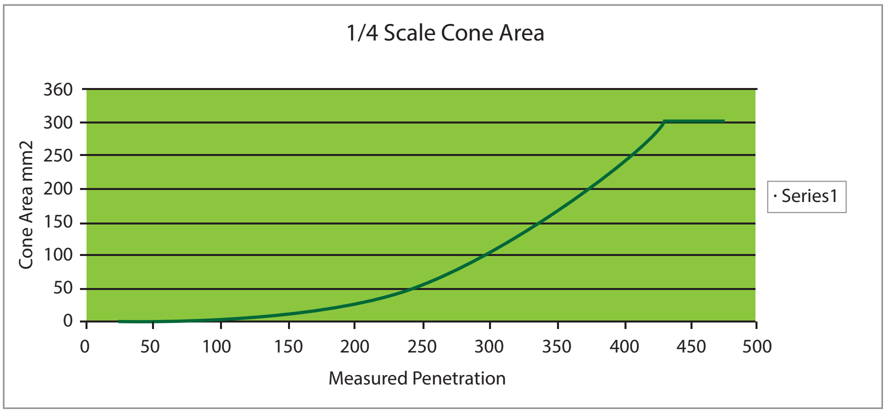


Figure 1. Cone area change with increasing depth

Use of the NLGI scale permits tremendous product variation, which becomes more pronounced with stiffer greases. This allows the producer a huge manufacturing margin in the product's rheological properties within a given NLGI grade.

The NLGI scale also provides gaps in the numbered measurements. These gaps are very large when considered in units of stress (pascals). For example, a grease defined as NLGI 2 can be manufactured at either end of the scale. The extremes, when compared in stress measurements, have differences in stiffness of 175 percent from the high to low end of the NLGI 2 grade. The range in pascals for the gap between the NLGI

3 and 4 greases is the same as the total range from the soft end of NLGI 00 through to the midpoint NLGI 2 (see Table 1). These gaps can be a bit of a minefield, and confusion is likely for those not familiar with the non-liner nature of the NLGI measuring system.

Using a Rheometer

A rheometer is an instrument capable of measuring the physical properties of a grease by varying or holding constant an applied load, a temperature and an oscillatory shear. It is successfully used in many industries with a broad variety of applications. A rheometer also requires minimal quantities of test material when compared to cone penetration, with typical grease test volumes of 0.4 to 0.25 ml.

Use of a rheometer to test grease samples is very limited within the grease industry. While a rheometer measurement is likely to be unfamiliar to many, it can be reported in accepted scientific units (pascals) and in a manner that does not include gaps.

Yield Stress Test

The yield stress test is useful when comparing rheometer-derived data to cone penetration. This test produces a stress that ramps up from very low to high at an increasing rate. It plots a data point at even time increments. As the test runs, each successive data point plots in a near vertical pattern as long as the material is primarily elastic and in a more horizontal orientation when it becomes fluid and flows. The intercept/line fit from the flatter sloped portion of the plot to the Y axis is used to determine the yield stress. This measurement represents the stress at which the grease shifts from being a more elastic material to more of a fluid under the prescribed test conditions (Figure 2).

Temperature can significantly influence the results of a yield stress test, which makes temperature control vital. This is accomplished with a heat sink at the instrument.

Some rheological tests are designed to take hours or days to complete. These lengthy tests can be expected to yield precise results but are not practical for most in-service grease samples within a production testing environment. The ideal production test would be one that provides a reasonably accurate test result and has a short test duration.

The yield stress test results shown in Figure 2 were obtained by performing a series of tests to include a stress and frequency sweep within a common test sequence, with the yield stress test performed last. The tests chosen prior to the yield stress test were useful in determining the grease's characteristics. Some pre-conditioning of each grease sample resulted from the test sequence used.

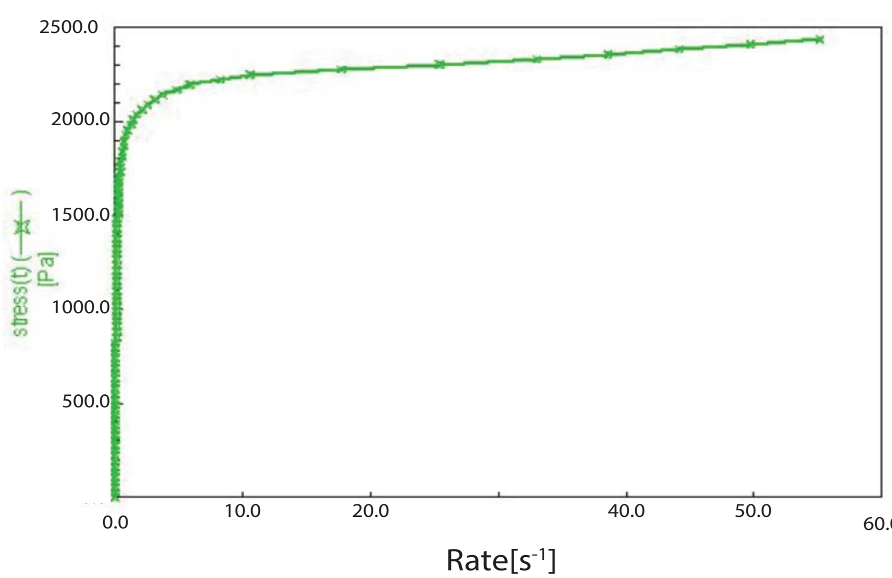


Figure 2. Example of a yield stress test

The initial sample was placed on a 25-millimeter flat plate and lowered to a typical 1-millimeter gap distance. The grease was then trimmed to ensure an even edge with no undercutting of the sample. Upon completion of each test within the sequence, the head was automatically lowered by software within the instrument to ensure contact between the fixture and no undercutting of the sample. The sample edge was not trimmed between tests within the sequence. The settings for gap reduction used to lower the head were the same for each sample.

A short dwell or recovery time of less than a minute was allowed between each test within the sequence. Use of a multiple test sequence enabled each grease sample to be tested in a similar manner and with a similar level of pre-conditioning. The test that produced consistent pre-conditioning was a frequency sweep test, which was set to run for approximately seven minutes. The entire sample testing took only a few minutes longer. The yield stress rheometer test required less than a minute of the overall test time to complete.

Test Data

A population of 54 new or used field samples were tested using both the one-quarter-scale cone penetration method and the yield stress rheometer test. This population consisted of six different types of new greases including a polyurea, lithium complex, calcium complex, and clay and calcium sulfonate. In-service used grease

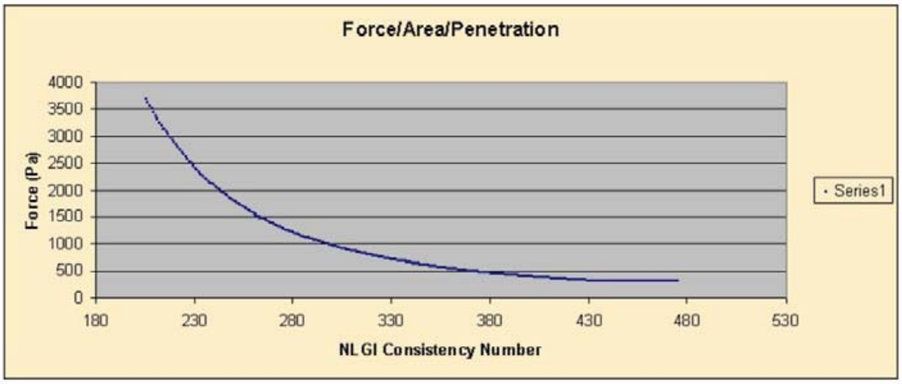


Figure 3. Comparison of NLGI and rheometer scales

NLGI GRADE	RHEOMETER LOW END (PA)	RHEOMETER HIGH END (PA)	RHEOMETER GAP TO NEXT GRADE (PA)	% DELTA FROM PREVIOUS GRADE HIGH TO NEXT LOW
00	56	98	32	32.6%
0	130	227	73	32.1%
1	300	527	160	32.2%
2	697	1,221	396	36.9%
3	1,617	2,833	917	32.4%
4	3,750			

Table 1. Comparison of rheometer-generated consistency to the NLGI scale

	NUMBER TESTED	AVERAGE (PA)	1 SIGMA (PA)
Lithium 12 Hydroxystearate	41	797	105
Calcium Sulfonate	20	316	16
Clay	20	1,247	187

Table 2. Repeatability of data from the yield stress test

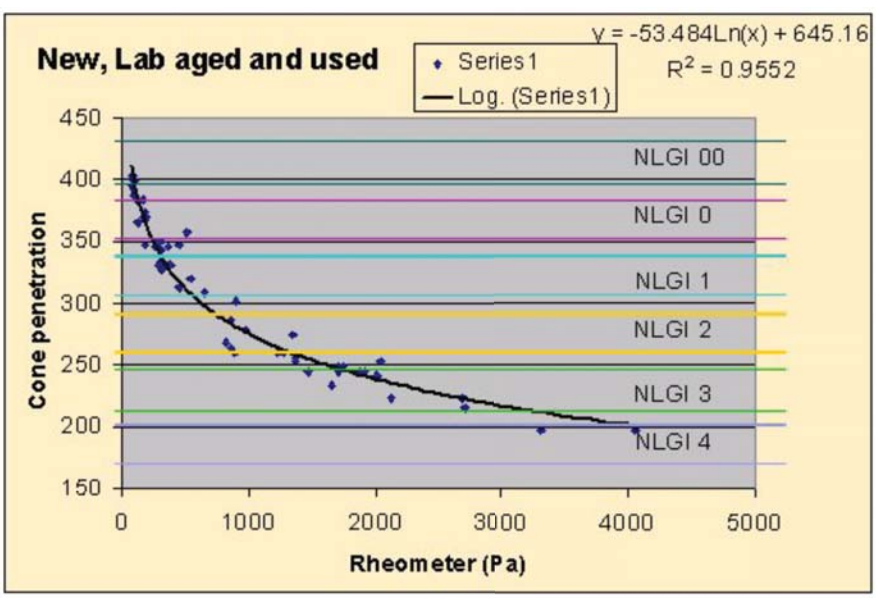


Figure 4. Correlation of raw test data from cone penetration and a rheometer

samples included clay- and calcium-complex-thickened greases. Two of the samples tested were provided by NLGI to help determine cone penetration values from a group of collaborators. The material type of these samples was unknown.

All grease samples were treated as unworked, with the only pre-conditioning being the process of obtaining the test sample from the bulk grease and placing it into the cup. No efforts were made to determine the level of working that the used samples received while in the field. The cone was dropped into each sample three times, and the average measured test value was reported. The tests were conducted at a laboratory ambient temperature, which was typically at 22-24 degrees C.

When compared to rheometer-generated data, the non-linear aspect of the NLGI scale is clearly seen in Figure 3. Figure 4 shows samples measured by both methods and how the points correlated. The rheometer measurements are compared to the NLGI scale in Table 1. Note that the gaps between the defined consistency ranges become progressively larger with the stiffer greases.

Repeatability

To determine instrument and test sequence repeatability, three grease types were used in the test sequence, with multiple runs performed on each grease. The source of the grease was a single container for each type. The grease types tested included lithium 12 hydroxystearate, calcium sulfonate and clay-thickened greases. The test results are provided in Table 2.

The clay- and lithium-thickened greases had a deviation of approximately 15 percent from the mean, while the third grease had a deviation of about 5 percent. The repeatability of the instrument was not stated. The differences found in repeatability are expected to be larger from in-service grease than from grease originating from a single batch of fresh grease. The non-linear aspect of the NLGI scale can be seen in the overlays shown in Figure 4. Grease with consistencies above grade 4 as measured by NLGI were not found in machines. The accuracy of the equation for data beyond NLGI 4 is unknown.

	CONE PENE-TRATION (MM)	YIELD STRESS (PA)	FREQUENCY SWEEP 0.1 R/S (PA)	FRE-QUENCY SWEEP 1 R/S	FRE-QUENCY SWEEP 10 R/S	FREQUENCY SWEEP 100 R/S
Kettle	277	1,136	13,290	22,219	28,596	51,933
Contactor	292	871	7,669	10,304	13,974	19,737

Table 3. Comparison of “same” greases

Other Applications

Not only can a rheometer be used to replace an arguably outdated industry test and with less sample and mess than cone penetration, but it can also be utilized with a variety of test methods to learn more about a grease.

As mentioned previously, variations within a grease manufacturer’s product label can and do occur. These are captured as part of a manufacturing tolerance, which includes instrument accuracy, and in the case of cone penetration, a range defined by the NLGI scale. However, the cone penetration test is limited and cannot be expected to determine if a product manufactured by a different process and under a single manufacturer’s label is truly the same or if significant fundamental differences may exist.

A recent study compared simple lithium grease manufactured from the same starting materials but with different manufacturing processes. The grease samples came from batches made with either a Stratco contactor or a kettle. These greases were manufactured as equivalents and compared well through several tests. Both were given an NLGI 2 classification.

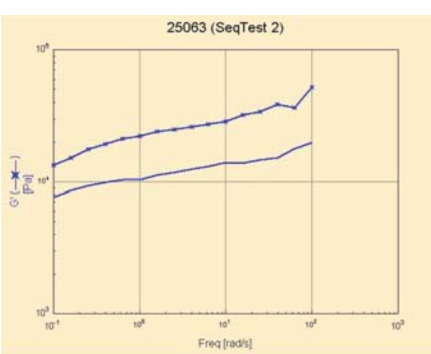


Figure 5. Frequency sweep of similar greases with different manufacturing processes

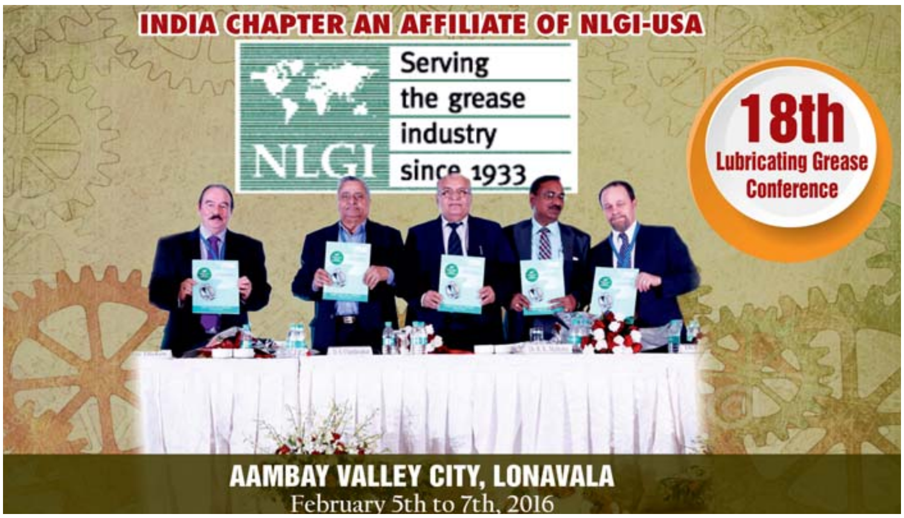
Samples from these greases were then measured using rheometer techniques and a common rheometer test method defined as a frequency sweep. This method applies a constant stress between a fixed lower plate and an oscillating upper plate, beginning at 0.1 radians per second and ramping up to 100 radians per second at a constant temperature of 30 degrees C. The grease in this test is evaluated in a dynamic environment, and its response measured.

The samples from the kettle and contactor were tested for yield stress, cone penetration and frequency sweep. The data obtained is shown in Table 3. It should be noted that these samples are the same according to the NLGI scale but vary by nearly 25 percent based on the yield stress rheometer test.

Although described as similar, the greases tested in a very different manner. Under the defined test conditions, one grease appeared to have almost twice the elastic strength of the other grease. The magnitude of the G stresses measured for each grease was so different that an argument could be made that the greases were not the same and might be best suited for different applications. Without a discriminating test, the potential exists that these greases could be packaged under the same label. Indeed, this is likely to occur.

In conclusion, a rheometer has proven to be capable of providing data similar to cone penetration with better accuracy and test results in accepted scientific units. This avoids the use of a seemingly arbitrary scale that could easily cause users to make incorrect assumptions about a grease. In addition, rheometer testing can be performed with a very small sample, which is an important consideration when condition monitoring based on used grease samples is the objective.

NLGI-INDIA CHAPTER CONFERENCE



India Chapter of NLGI USA held their eighteenth Annual Lubricating Grease Conference in Amby Valley City, Lonavala between February 5th to 7th, 2016. Some 26 papers were presented in all, with four main business discussions taking place for the 300 delegates, which included 26 overseas attendees. A separate technical exhibition covered 14 exhibits as pointed out by the Chief Guest Dr. R K Malhotra.

Key note address was delivered by Dr. Gareth Fish to cover friction and efficiency losses in grease lubricated components in a variety of applications by using friction modifiers. Joe Kaperick spoke of acidity and basicity effects on performance properties of lithium 12-HAS. A grease production survey was presented in detail by a number of individual speakers.

19th Lubricating Grease Conference will be held at Varanasi from 2nd to 4th February 2017

Steffen Bots, Oelcheck

Establishing Elemental Limit Values for Motor Oils

Limit and warning levels from elemental spectrometric analysis serve as indicators of the amount of foreign particles found in used oil that is still tolerable or, when compared with fresh oil, indicate when the altered lubricant must be changed. Values well above tolerable wear levels can also indicate an acute damage process. However, it is not easy to specify these warning levels. Hardly any engine or equipment manufacturer defines limit levels for used oil. This is because the operating conditions and times are too specific, and the origins of the foreign particles found in the oil are too diverse. Consequently, determining these factors is one of the essential tasks of every oil analysis. After all, the type, quantity and (to a certain extent) the size of the particles provide valuable information about wear, contaminants and the additives in the oil.

When warning and limit levels are used for the diagnosis of a specific

ELEMENT	UPPER WARNING LEVEL	ORIGIN
Iron (Fe)	80–180	Cylinder block, cylinder head, timing wheels and timing chains, valves, valve tappets and guides, crankshaft, camshaft, rocker arm shaft, piston pins, roller bearings (with chromium), oil pump; rare in residues of ferrocene, a fuel additive for soot reduction; distinguishing between corrosion and wear based on the PQ index
Chromium (Cr)	4–28	Piston rings, crankshaft bearings, piston pins, exhaust valves, gaskets, guide bushes, chrome-plated parts and gears; Fe, Al and Cr are usually found in combination with Si in engines because dust causes the most piston (Al), piston ring (Cr) and cylinder (Fe) wear
Tin (Sn)	12–24	Often together with lead (Babbitt bearings) or copper; running surfaces of connecting-rod bearings, rocker arm shaft and piston pin bearings, solder (consisting of lead and tin) in soldered radiator joints; constituent of some synthetic base oils, additives in fire-resistant fluids
Aluminum (Al)	12–55	Primarily from pistons, oil pump housings, oil coolers, torque converter parts, turbocharger, guide bushes, plain bearings, cylinder blocks of all-aluminum engines (together with silicon) and dust containing bauxite (aluminum oxide)
Nickel (Ni)	1–3	Alloy constituent of exhaust valves, valve guides, turbo-chargers, high-strength gears and turbine blades; instead of being galvanized or chrome-plated, parts such as filter components may be nickel-plated; constituent of heavy oil (together with vanadium)
Copper (Cu)	25–60	Main constituent of brass and bronze; as wear metal from oil pumps, connecting-rod bearings, piston pin bearings, rocker arm shaft bearings, bronze worm gears, and sintered brake and clutch discs; resulting from the corrosion of oil coolers, piping and seals
Lead (Pb)	10–30	Usually in combination with tin and/or copper; connecting-rod bearings, nearly all running surfaces of plain bearings and soldered joints in combination with tin
Molybdenum (Mo)	4–20 Up to 500 in fresh oil	Contained in transmission synchronizer rings, piston rings and heat-resistant steels; component of an antioxidant and friction modifier additive package in modern synthetic multigrade oils and gear oils; rarely as MoS2 oil additives

oil specimen, the interactions between the values and other criteria should also be taken into account. A variety of factors play a role here, including the engine manufacturer, the engine type, the type of fuel used, the oil volume, the motor oil type, the service life of the motor oil, and any top-up quantities (makeup oil). The operating conditions can also vary markedly from one situation to the next. After all, the engine of a heavy construction machine operates under different conditions than the same engine of a truck traveling long distances on a highway at uniform speed.

However, all of these engines have one thing in common: their motor oil contains a lot of valuable information about the oil itself as well as the state of the engine. For example, the microscopic particles suspended in the oil provide an indication of the amount of wear of the corresponding parts or components. Elements such as sodium, potassium or silicon indicate contamination by road salt, hard water, glycol antifreeze or dust. Comparing the amount of organometallic additive elements (such as calcium, magnesium, phosphorus, zinc, sulfur or boron) in the used oil to fresh oil provides an indication of changes to the oil, such as additive depletion or possibly the mixing of different types of oils.

Inductively coupled plasma (ICP) elemental analysis can be used to determine more than 30 different elements in motor oils. In addition to the presence of the elements, atomic emission spectroscopy (AES) by ICP can be used to determine the concentrations of the elements.

Laboratories routinely determine the following elements and values as part of motor oil testing and list them in the lab report: iron, chromium, tin, aluminum, nickel, copper, lead, calcium, magnesium, boron, zinc, phosphorus, barium, molybdenum, sulfur, silicon, sodium and potassium. In some cases,

ELEMENT	UPPER WARNING LEVEL	ORIGIN
Silicon (Si)	15–30 Up to 15 in fresh oil	Intake air dust, anti-foam additive in motor oil, worn seals containing silicone, residues of silicone greases (also in oil sampling syringes), worn aluminum alloys (aluminum engines)
Potassium (K)	2–30	Additive in aqueous media such as glycol antifreeze or cooling water; mineral salt in road salt or tap water
Sodium (Na)	5–30 Up to 800 in fresh oil	Additive in glycol antifreeze or cooling water; road salt, tap water, wastewater or salty air; additive components in some motor oils as a substitute for calcium or magnesium compounds; thickener in lubricating greases
Lithium (Li)	2–10	Constituent of multi-purpose greases (thickener); indication of contamination by grease or assembly pastes
Antimony (Sb)	1–3	Present in some lubricating greases as an EP additive in the form of antimony oxide; in connection with lead or tin in bearing alloys of plain bearings
Silver (Ag)	1–3	Silver-plated running surfaces of highly loaded plain bearings, such as in locomotive engines; silver solder residues; silver is attacked by additive systems containing zinc
Tungsten (W)	1–2	Rare in engine construction; alloy constituent for increasing hardness and corrosion resistance
Titanium (Ti)	1–3	Oil level indicator (float); alloy constituent in springs and valves; from ceramic components; as white titanium oxide in plastics and paints; marker additive in motor oils
Vanadium (V)	1–3	As a constituent of chrome-vanadium steel alloys in valves and valve springs; like nickel, it is a constituent of petroleum; blow-by product when ship engines are operated with heavy oil fuels
Beryllium (Be)	1–3	Cube valves and valve seats; sintered bearings, constituents of sintered ceramic components or in jet engine oils; prohibited in F-1 engines
Cadmium (Cd)	1–3	Components of plain bearings exposed to corrosion; sometimes also deep red pigments in plastics and paints
Cobalt (Co)	1–3	Possibly from components of turbines or from roller bearing alloys in connection with iron
Manganese (Mn)	1–3	Alloying element, usually with iron; steel used in valves, roller bearings, gears or shafts; contaminant in manganese mines (with Si); very rarely additives containing manganese
Tantalum (Ta)		Only found in oil as a constituent of ceramic components
Cerium (Ce)		Only found in oil as a constituent of ceramic components
Zirconium (Zr)		Only found in oil as a constituent of ceramic components

Table 2. Contaminants

other elements are also determined, such as silver, vanadium, tungsten or ceramic elements like cerium and beryllium, which are rarely present in motor oils. They are only listed in the lab report if they are actually proven to be present or if the customer specifically requests this. Tables 1-3 show the possible causes for the presence of the elements found in oil, i.e., whether they are related to contaminants, wear or additives.

Various factors must be taken into account when interpreting a lab report and the values of the elements found in the oil. Naturally, it is not sufficient to simply report the elements and their quantities. In order to assess the measured values, you must know whether the individual elements indicate contamination, wear or changes to the additives. However, these values are also interrelated to a certain extent. The relative proportion of various wear elements provides an indication of the affected machine parts or components, for example. Further, it is important to know how long it has taken for the oil to become enriched with specific wear elements since the last oil change. The operating time of the overall system or the running time of the engine, the oil volume relative to the engine power, and the top-up amounts must also be considered when analyzing or diagnosing warning levels.

In order to reliably assess the values determined for the used oil and their relationship to each other and to other factors, it is necessary to have a suitably large volume of data and analytical expertise. However, additive elements and base oil types can differ considerably depending on the type of oil used, so it is necessary to set suitably broad warning levels. Specific warning levels can only be defined for a specific oil type.

The warning and limit levels listed in Tables 1-3 for wear elements, contaminants and additives are based on a semi-synthetic motor oil (SAE 10W-40) in a modern diesel engine with an oil volume of approximately 25 to 50 liters, using fuel compliant with EN 590 (containing 5 percent fatty acid methyl esters), and with an oil service life of approximately 500 operating hours or a mileage of approximately 47,000 miles.

The basic rule is that warning levels must be set lower for greater oil volume, shorter oil service life, lower engine speed and lighter load conditions.

However, the stated values are distinctly dependent on the oil manufacturer, the correct engine type, the service life of the oil charge, the oil volume and the top-up quantities (if any).

> Warning levels must be set lower for greater oil volume, shorter oil service life, lower engine speed and lighter load conditions.

ELEMENT	UPPER WARNING LEVEL	ORIGIN
Calcium (Ca)	600–5,000	Oil additive, detergent oil additive; improves cleaning and dispersion capacity as well as heat resistance; occasionally calcium-containing dust from building sites, lubricating grease constituent, or from cooling water or tap water containing calcium
Magnesium (Mg)	100–1,500	Oil additive; improves the corrosion protection, thermal stability and dispersion capacity of motor oils; increases the alkali reserve (BN); alloy constituent of engine blocks; hardening agent in hard tap water or salt water
Boron (B)	10–500	Improves engine cleanliness as an oil additive; borates are constituents of cooler antifreeze and corrosion protection media
Zinc (Zn)	Up to 2,000 in fresh oil	Improves wear protection as an oil additive; zinc-plated components such as filter support cores, threaded fittings, paints containing zinc and vulcanized synthetic materials
Phosphorus (P)	600–2,000	Oil additive in almost all types of oil; used to improve EP characteristics and reduce wear; has an anti-corrosion and anti-bacterial effect; reduces friction; renders metal surfaces chemically inert
Barium (Ba)	2–20	Usually not an additive in motor oils; for improving EP characteristics; friction modifier in ATFs; in the form of barium-complex soap; a constituent of greases and assembly pastes
Sulfur (S)	500–6,000	Constituent of base oils based on mineral oil; for this reason, it is present in almost all oils, but in widely varying amounts; along with phosphorus, sulfur is also a constituent of almost all additive packages for wear and corrosion protection, and is often found in connection with calcium and zinc

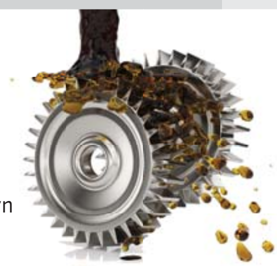
Table 3. Additives

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. After some possible initial change, as oil ages, the viscosity of an aging oil generally:

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



2. Vacuum samplers are needed:

A) On low-pressure lines
B) From unpressurized sumps
C) From pressure lines
D) Answers A and B
E) All of the above

3. Which of the following contributes to poor quality and unreliable oil analysis data?

A) Sampling from drain ports
B) Sampling from cold systems
C) Sampling after an oil change
D) Sampling after a major top-up volume of oil has been added
E) All of the above

Answers

1. B
As oil ages, a series of chemical reactions occurs within the oil, including oxidation and volatilization. Because the viscosity of the oil is directly related to the size of the molecules, any degree of oxidation and volatilization will result in an increase in the viscosity.

2. D
Vacuum samplers are needed when there is not enough pressure to push oil to the sample bottle. Examples include return lines and unpressurized sumps.

3. E
Sampling from drain ports makes the sample unrepresentative because all contaminants and wear metal tend to settle in the bottom of the reservoir. Thus, the sample will not represent the condition of the oil near the lubricated components. When the system is cold, water and other contaminants tend to separate from the oil. Sampling after an oil change or major top-up does not add value, as the oil analysis can be expected to reveal good results or at least highly diluted data.

Lube-Tips™

THE "LUBE-TIPS" SECTION OF *MACHINERY LUBRICATION* MAGAZINE FEATURES INNOVATIVE ideas submitted by our readers. Additional tips can be found in our Lube-Tips email newsletter. If you have a tip to share, email it to us at info@machinerylubricationindia.com.

Remove Buildup and Improve Bearing Life

When vibration analysis is indicating that the lube schedule has become inadequate, it can mean there is a buildup of thickener in the bearing housing. If regreasing does not reduce vibration energy levels, it is time to isolate the equipment, clean out the old grease and repack. You will see a significant decrease in energy levels, which will greatly increase bearing life.

Use Quick Couplers to Prevent Contamination

When changing or topping off an oil supply system with a filter cart, consider using quick couplers to ensure a clean exchange of fluid. Have a "dummy" connection on the cart to fasten to the fill hose when not in use. This will help keep the hose-end coupling clean and prevent contamination. Also, ensure that the coupler on the machine has a cover to prevent contamination.

Minimizing Air Entrainment in Hydraulic Fluids

Return lines into hydraulic reservoirs should be larger than the intake line and generally be positioned below the surface of the oil to minimize air entrainment. Locate the return line as far away from the suction as possible to allow the oil as much residence time as possible. If this is not possible, install a baffle or weir between the suction and discharge lines. One suggestion to improve oil flow in the reservoir is to cut the return line at an angle so that it directs flow back toward the tank wall.

Critical Advice for Filling Gearboxes

Underfilling a gearbox sump obviously can result in a lack of lubrication, but overfilling may be equally destructive. It can cause the oil to overheat as well as produce foam and air entrainment. The fluid may also overflow. Eventually, higher temperatures and increased exposure to air can lead to oil oxidation, which results in sludge, varnish and corrosive byproducts.

Temperature as a Bearing Lubrication Indicator

When a properly packed bearing starts up, there will be an initial rise in the temperature while the grease disperses throughout the bearing and housing before falling off to a steady operating temperature. If the temperature does not drop, then there is too much grease in the bearing or there is a problem with the bearing fit.

Simple Technique for Inspecting Oil Sump Bottoms

Over time, debris can collect at the bottom of an oil sump. An easy and inexpensive way to determine the condition of a tank bottom on turbine packages is to use a 1/2-inch PVC pipe that is long enough to reach the bottom of the sump. Glue a collar on one end with a piece of clear Lexan glued into it. Position the pipe close to the bottom and insert a borescope. It works like wearing a diver's mask underwater, allowing you to clearly see the debris and then document its condition.

Easy Grease Test Uncovers Bearing Issues

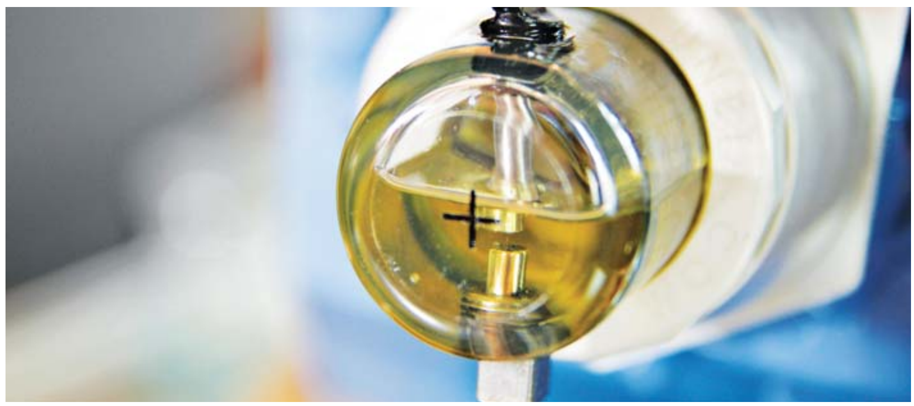
Here is a simple onsite test for checking bearing condition with grease ferrous debris analysis. When the equipment is available, obtain a small grease sample from the bearing and dissolve it with a solvent in a small, clear oil sampling bottle. If you have multiple bearings, try to use the same amount of grease and solvent for each.

After the grease is dissolved into a liquid, tape a small, round button magnet to the outside of the bottle. Tilt the bottle at an angle so the liquid flows up toward the cap on top of the magnet. After 30 minutes, stand the bottle straight up so the liquid flows back down and let the ferrous debris dry inside the bottle with the magnet still attached. After it dries, remove the magnet and you can see if there is any ferrous metal. You can use this method with multiple samples in order to determine if one bearing is wearing faster than others.

Bennett Fitch | Noria Corporation

HOW TO EQUIP LUBE TECHS FOR SUCCESS

Of all the different types of gear configurations, worm gear systems are considered the most problematic because they present unique lubrication challenges due to their distinct design. To overcome these challenges, you must understand not only the complexities of worm gears but also which qualities to take into account when choosing a worm gear lubricant.



WORM GEAR DESIGNS

A worm gear is a non-parallel, non-intersecting axis design consisting primarily of two gear elements: the worm, which is the driving gear in the shape of a spiral or screw, and the worm gear or worm wheel, which is the driven gear in the shape of a common spur gear.

Technically, the entire worm gear system should be called a worm drive or worm gearset to avoid confusion. The worm always drives the worm wheel. This design characteristic is due to the extreme helical angle, which is nearly 90 degrees. The worm drive resembles the design of the crossed helical gear configuration, except the gear teeth on the worm of a worm drive will circle around the helix at least once. Since the worm may have as little as one tooth that spirals radially around the helix, the number of teeth on the worm is more appropriately identified by the number of starts or threads.

There are three categories of worm drive designs that describe the degree to which the gears mesh together: non-throated (non-enveloping), single-throated (single-enveloping) and double-throated (double-enveloping) or globoidal.

Non-throated or non-enveloping is the most basic design in which the worm and worm wheel are both cylindrical in shape. This allows for simplistic manufacturing, but the limited contact zone of a single point on one or two gear teeth can become problematic.

In single-throated or single-enveloping designs, one of the gear elements (most commonly the worm wheel) has concave helical teeth for contour or envelopment of the gear teeth onto the worm. This enables the contacting zone to increase to a line.

68%

of lubrication technicians do not have the necessary tools to perform their jobs effectively, according to a recent survey at MachineryLubrication.com

Double-throated (double-enveloping) or globoidal designs not only have concave helical teeth on the worm wheel, but the worm is also shaped like an hourglass so the two gear elements wrap around each other during motion. This results in nearly eight times more contact area (in the shape of a radial band) with three or more teeth in contact.

As the contact surface area increases, the torque capacity, load-holding ability (shock load resistance) and durability are improved. Enveloping gear designs also have a lower anticipated wear rate as a result of the load distribution. Worm drive manufacturers attempt to optimize this contact relationship between the two gear elements for improved reliability.

Other notable advantages of worm drives over potential gear system alternatives include higher gear ratios. A worm drive is designed with a gear ratio of more than 200-to-1, in comparison to that of a helical gear, which may be limited to

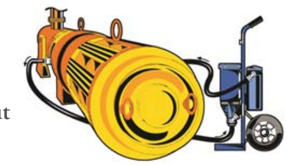
10-to-1 on a single reduction. The gear ratio for worm drives is the number of teeth on the worm wheel to the number of threads (or starts) on the worm.

The high gear ratio and configuration of the two gear elements allow for a compact design, making the worm drive a great option for space-limited areas. In addition, the number of moving parts is reduced along with the opportunities for failure. Fewer moving components also result in relatively low noise production and vibration.

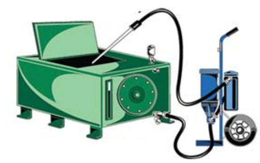
Due to the extreme helical angle, switching the direction of power is nearly impossible. The worm wheel cannot be rotated independently to force movement on the worm. This self-locking ability eliminates the need for a backstop, which may be required in alternative gear systems.

Filter Cart Applications

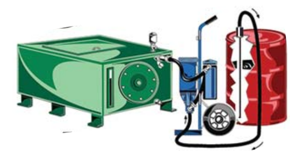
POWER FLUSH — This involves reducing the oil level in the tank or sump and flowing oil at a high velocity across the bottom to push out low-lying sediment.



WAND FLUSH — A wand is attached to one of the cart hoses and is used first to discharge at high pressure (kicking up adherent debris). Then the flow is reversed, and the wand vacuums the sediment.



TRANSFER CART — Oil is transferred from a storage container (tote, drum, etc.) to the machine's lube compartment.

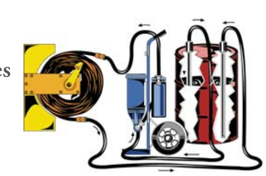


CLEANING STORED LUBES — In this application, the cart multipasses fluid out of and back into the drum or tote to draw down contamination.

SYSTEM DRAIN — Sump and reservoir drains will wash out debris better if the waste oil is pumped out as opposed to simply flowing out by gravity.

LINE FLUSH — Remote lines and components often need to be partitioned to enable flushing. This can be done easily with a filter cart.

HOSE CLEANING — Before new hoses are installed on a machine, they can be flushed of debris using a filter cart.



OFF-LINE FILTRATION — Filter carts can be mounted permanently to a machine to supplement filtration.

REPAIRS AND EQUIPMENT REBUILD FLUSHING — After machines are serviced, they need to be flushed thoroughly before they are returned to service.

FLUSHING DURING EQUIPMENT COMMISSIONING — New machines have original fabrication debris and dirt that have ingressed during transport and storage.

With the precise movement of worm drives, particularly in double-enveloping designs, backlash (play between gear teeth) can be greatly minimized. This is crucial in certain applications such as robotics.

LUBRICATION CHALLENGES

Worm drive designs have one major drawback: the relative motion between the mating teeth of the two elements is almost entirely sliding. This poses a significant challenge because the lubricant is continually scraped aside. The sliding friction losses result in elevated temperatures and inadequate hydrodynamic pressure development. Consequently, wear debris generation can increase. In many cases, the higher temperatures will be the limiting factor on the worm drive before the loading limitations are reached. The load distribution of enveloping gear designs can lessen this problem, but the challenge still persists.

Also, because of the sliding nature of the worm drive, metals with a low coefficient of friction are generally used. The worm wheel typically contains yellow metals, while the worm is usually made of steel. This results in more favorable wear characteristics, better loading ability and less heat generation. Yellow metals like bronze that are used on the worm wheel can present unique lubrication challenges when selecting a compatible additive package. With this metallurgical combination, it is also expected that the worm wheel act sacrificially in comparison to the worm due to the relative effort and costs in worm drive rebuilds.

LUBRICATION SOLUTIONS

Gearing designs and materials have been modernized through the years to achieve better load-carrying capability, higher torque conversions and improved longevity. Sophisticated testing platforms and computerized methods have provided a better understanding of common worm drive failure modes and offered clues for optimizing the solutions. Lubricants are no exception to these enhancements for worm drives. Generally speaking, a high-quality worm drive lubricant will have low friction, high oxidation resistance, good anti-wear protection and high viscosity index.

The Right Base Oil

While using lubricants formulated with mineral oil is quite common within worm drives, employing synthetic base oils generally results in improved gear efficiency and lower operating temperatures. Figure 2 illustrates lubricant life and oil change interval expectations for polyalphaolefins (PAOs), polyalkylene glycols (PAGs) and mineral oils over a range of oil sump temperatures. This is supported by the Arrhenius Rate Rule, which states that for every increase of 10 degrees C in the average oil temperature, the chemical reactions double.

The energy transmission efficiency of the gear system's input and output can be significantly influenced by the lubricant selected. Figure 3 specifies the improved efficiency when choosing a synthetic over a mineral oil, particularly PAGs, which have an inherently low coefficient of friction. PAGs are also known to reduce operating temperatures and total losses. Additional comparisons between mineral and PAG base oils are seen in Figure 4.

PAGs do have some drawbacks, most notably their higher costs. They also are not compatible with some seal materials, plastics and paint coatings, so always confirm compatibility when switching to PAGs.

The Right Additive

One of the most important jobs of a gear oil additive is to form a protective or sacrificial barrier between contacting surfaces when the conditions exceed that of the bulk oil's film strength. An additive package for a lubricant in a worm drive must be selected with care, since the yellow metals often contained within worm wheels can be adversely affected by corrosion from the activated sulfur within the extreme-pressure (EP) additive. Advancements in additive formation with deactivated sulfur have helped to reduce or eliminate these corrosive attacks.

Worm drives can present a unique boundary lubrication challenge, with the focus more on friction reduction than on the effects of wear. In these applications, a specific type of mineral-based lubricant known as a compounded oil can be used. This lubricant is formulated with up to 10 percent fatty acid (natural oil) or acidless tallow as the compounding agent along with rust and oxidation inhibitors and other additives. This results in improved lubricity, reduced friction and decreased sliding wear.

EP oils are still commonly used in worm drive applications where they are formulated with yellow metal compatibility. However, both compounded oils and EP gear oils have a working temperature limitation of approximately 80 degrees C before oxidation rates rapidly increase, resulting in acidic products that can attack cupric worm wheel materials.

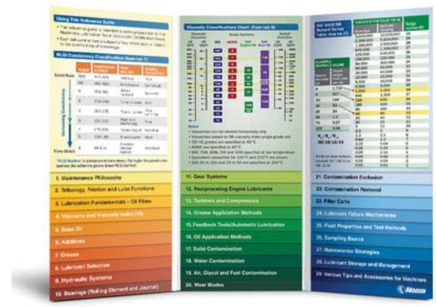
The Right Viscosity

Aside from the ambient and operating temperature, the correct viscosity will depend on several variables of the final worm wheel, including the pitchline velocity, center distance and revolutions per minute. The following tables provide recommendations for the ISO viscosity grade selection on cylindrical and double-enveloped worm drives according to the American Gear Manufacturers Association (AGMA) 9005-E02 standard.

As these recommendations and the oil change interval chart show, temperature has a significant impact on effective lubrication. Not only are the lubricant and machine longevity negatively affected by higher temperatures, but worm drives in particular have trouble with temperature spikes. As a result, if higher temperatures are expected, more effective alternatives for base oils and additives should be selected. Synthetics oils such as PAOs and PAGs perform better than mineral oils due to their naturally higher resistance to thermal degradation. Nevertheless, an increase of 32 degrees C above the ambient temperature in single-throated worm drives (37 degrees C for double-throated worm drives) is not considered excessive for the operating conditions.

The Right Oil Level

As with most splash-lubricated gear systems, the oil level in a worm drive is essential to maintain accuracy. Depending on the position of the worm relative to the worm wheel, a small drop in oil level could be the difference between ideal lubrication and no lubrication. When monitoring the oil level in the three most common worm drive positions, adhere to the manufacturer's recommendations,



which will often be in line with the following standards for

When the pitchline velocity of the worm elements exceeds 10 meters per second, particularly with double-enveloping worm drives, a force-feed lubrication system is recommended to spray the entire face of the worm.

The Right Visual Inspections

Besides monitoring the oil level, a sight glass should be regarded as a window into the oil's condition. This may include visual checks for unusual oil darkening (a sign of oxidation), visible sludge, solid particles and moisture. These inspections can be performed more efficiently when the sight glass is extended out from the gear housing so light can be passed through it, as in the sight glass shown below.

If possible, a bottom sediment and water bowl should also be used. This will help capture any solid particles or liquids that are heavier than the oil and provide a daily visual inspection point.

The Right Choice

The goal of any chosen lubricant should be to protect the worm drive from undesirable levels of friction, the dangerous effects of corrosion and inefficient operation. Assessing and achieving the optimum reference state for every style of worm drive in regard to its operating and environmental conditions will come down to one thing: justifying the costs of improved lubrication practices to minimize the risk and potential consequences of failure. Fortunately, improving lubrication practices for worm drives should not be costly and may be as simple as confirming that the lubricant meets the minimum requirements while performing visual inspections and even oil analysis for effective condition monitoring. Just as worm drives are some of the most simplistic and beneficial gear designs, the lubrication practices that they require are equally unique and essential..

About the Author

Bennett Fitch is a senior 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.

Suzy Hitchcock, ICML

WHY LABORATORY Personnel Should Be CERTIFIED

The certification of laboratory-based personnel is essential in supporting quality lab systems, as some accreditations do not guarantee technical accuracy. Most lab systems are designed to ensure repeatability of the process, data, product, etc., but repeatability is not necessarily accuracy.

Accuracy in the oil analysis field generally has two dimensions: test results and interpretation. Laboratories require accuracy in both. Lab accreditation typically only addresses the test method in terms of accuracy and repeatability. Accuracy of interpretation involves the certification of individual analysts' skills, not of the lab's quality management system. This falls under the auspices of ISO standards for personnel qualification and assessment.

The certification of analysts can be divided into two categories: laboratory analysts, who are usually in an external lab, and field analysts, who are typically at a plant. Both must work together to determine the condition of assets and the rates of deterioration. The key differences are primarily the test method knowledge of the laboratory-based analyst versus the asset failure knowledge of the plant-based analyst. Both knowledge bases are required for accurate oil analysis, which is why individuals from each category should be certified.

The International Council for Machinery Lubrication (ICML) provides certification of analysts in both fields. The organization has always advocated the need for separate certification programs for laboratory-based analysts from those designed for field-based personnel.

ICML's Laboratory Lubricant Analyst (LLA) Committee assembled a group of lab managers and did extensive work to define and standardize the sets of skills needed for laboratory practitioners around the world. The group expanded the original LLA certification to a three-tier program with specific qualifications. The categories were developed for laboratory technicians (level I), laboratory analysts (level II) and senior laboratory analysts or lab managers (level III).

LLA candidates are required to have a minimum of one, two or three years of experience for levels I, II and III, respectively. A minimum of 24, 48 and 80 hours of cumulative training on the body of knowledge for the chosen level is also a prerequisite.

Subject areas for LLA I include sample handling and preparation, lubricant health monitoring, reagent management and instrument calibration. At this level, practitioners are expected to be able to perform simple tasks related to the handling and testing of machinery lubricant samples in a laboratory setting according to established procedures.

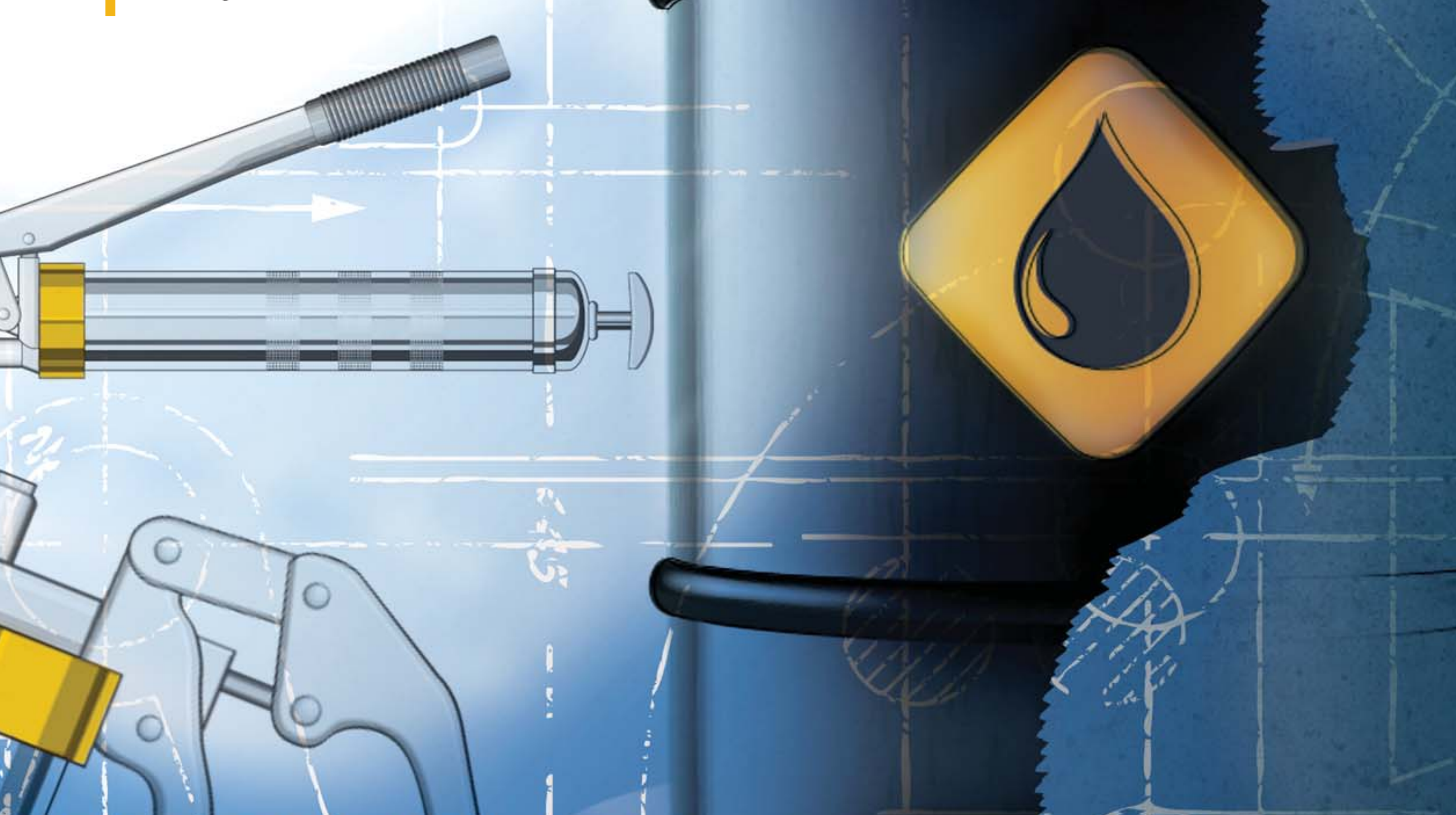
LLA II candidates receive more training hours in lubricant health monitoring, including testing for wrong or mixed lubricants, the various forms of contamination (water, glycol, soot, fuel, air, particle, etc.), wear particle (debris) monitoring and analysis, data interpretation, quality control, and lubricant functions and failure modes. LLA III candidates must obtain additional training in wear particle (debris) monitoring and analysis, data interpretation, quality control, and lubricant functions and failure modes. Besides these topics, the training covers sensorial inspections, environmental effects on results, alternate technology data correlation and personnel training.

ICML's programs form the basis of the current ISO personnel certification standards. As the accreditation of quality management systems (QMS) expands to include asset management, it is interesting to note that the latest series of ISO asset management standards requires personnel to be competent in the necessary knowledge and skills. Knowledge management continues to be a key area in this new standard series. Essentially all quality management systems require personnel to be deemed competent in the tasks they undertake, and this extends to suppliers. Given the mandatory requirement for continual improvement within any QMS, oil analysis will become increasingly important in the delivery of effective asset management programs. ■

MACHINERY LUBRICATION'S
2015 LUBE ROOM CHALLENGE

Transforming Lubricant Storage and Dispensing Methods to Best Practices

Machinery Lubrication recently issued its annual Lube Room Challenge for readers to submit exceptional lube rooms that incorporate best-practice features. A number of readers were proud to show how their lubricant storage and dispensing methods have been transformed. The following entries showcase how designing a proper lube room is one of the first steps to achieving lubrication excellence.



Samarco

Samarco is a privately owned Brazilian mining company that produces iron-ore pellets. In 2010, the management team decided to drastically change their lubrication practices, as they realized this was an area in need of improvement that could bring great results. Their plan involved several changes, with one of them being a new lube room.

In early 2014, Samarco began making modifications. By the end of the year, the new lube room was completed. However, it is now more than just a lube room. With a training room and a modern onsite laboratory, it was designed to hold the lubrication technicians and all members of the team.

Previously, the lube room was partially open and exposed to a very dirty environment. Access to the room was not controlled. Lubricants were poorly handled, and funnels and buckets were often used. New lubricants were not sampled or filtered before use. There was a lack of receiving procedures, quality control and spill containment. Breathers were not used on drums or containers of new lubricants. One filter cart was utilized to filter all types of lubricants, and it only removed particles and did not have the right filters for the task. New oils that were filtered were stored outside. The onsite laboratory had old equipment and could only perform a few tests. In addition, the lab had no ventilation, and several chemicals were stored inside. Lubricant identification was also poor, as unmarked oil and grease drums were frequently seen.

After all the changes were made, the new lube station featured different rooms for the treatment of used oil as well as for receiving and treating new oil. New oil is pumped through hard piping to the treatment room. Now only the filtration technician has access to the treatment room. There is also a new lab, a training room, offices and a storage room for filters, breathers, quick-connects, etc. All storage cabinets for chemical products are also fireproof.

There are four offline absolute filtration stations for used oils and 12 stations for new oils. Each has three minimess valves to draw samples. Oils are delivered

Samarco's old lube room was partially open, and access to the room was not controlled.

Previously, new oils that were filtered were stored outside.

Before the improvements were made, only one filter cart was used to filter all types of lubricants.

Lubricants were poorly handled, and funnels and buckets were often used.

to reusable containers by individual reels. An identification system was created with colors and shapes for all oils and greases. The spill containment for each container has the same capacity as the container. If the container leaks, the oil goes to an external container with a 2,000-liter capacity.

The new onsite lab has modern equipment and a technician who is able to quickly test new and used oils. There's also a storage area for lubrication-related materials such as breathers, reusable containers, Zerks, etc.

By filtering its new oil, Samarco has been able to extend oil change intervals, as lubricants are delivered to machines with the appropriate cleanliness levels.

Access to the lube room is now controlled.

An identification system was created with colors and shapes for all oils and greases.

New oil is pumped through hard piping to the treatment room.

Samarco is now filtering more than 20 percent of all used oils.

The lubricant receiving room is separate from the treatment rooms.

Great River Energy

Great River Energy is a not-for-profit electric cooperative that generates and transmits electricity for members in the suburbs of Minnesota's Twin Cities, up to the Arrowhead region and down to the southwestern portion of the state. The electric coop recently performed a makeover on its lube room, which resulted in the consolidation of oils from 12 varieties to eight. This not only decreased inventory but also reduced confusion and lessened the chances of cross-contamination.

For bulk oils such as turbine oils and hydraulic fluids, Great River Energy purchased 120-gallon totes that can be easily and safely transported to the point of use. Breathers were also added

Before

After

Great River Energy's lube room transformation resulted in the consolidation of oils and lessened the chances of cross-contamination.

to the totes to inhibit moisture ingression. When needed, oil is now pumped into sumps using a filter cart.

For smaller oil quantities, color-coded dispensing containers were acquired for each oil type. To help identify the oils, color-coded labels have been applied to all equipment in the field and a color-coded chart is displayed in the lube room. A new shelving system has also been installed to maximize storage space.

Shoco Oil

Shoco Oil's new bulk lube facility in Colorado Springs, Colorado, was built to store and produce lubricants for the Rocky Mountain region. It was designed utilizing industry best practices to ensure that product integrity and oil cleanliness are not only achieved but also maintained.

The facility includes 10 8,000-gallon atmospheric-controlled tanks, for a total capacity of 80,000 gallons. Incoming oil is unloaded through temperature-corrected meters into the storage tanks. The piping for each tank is painted in accordance with the product color-identification policy. All oils coming into the facility are pumped through individual filter canisters before entering the bulk tanks. Tank inventory levels are checked by a re-transmittable tank monitoring system that can be viewed remotely.

The facility also has installed an in-line filtration system for each of the bulk tanks. This provides the capability to achieve the ISO codes that meet the manufacturer's requirements. All bulk and packaged lubricants are also dispensed using temperature-corrected flow meters and are confirmed with certified scales

All incoming oils at Shoco Oil's bulk lube facility are pumped through individual filter canisters before entering bulk tanks.

All bulk and packaged lubricants are dispensed utilizing temperature-corrected flow meters.

The piping for each tank is painted in accordance with the product color-identification policy.

"A recent article suggested that particles that are removed from oil reduce failure detection via oil analysis. I use an oil centrifuge on my personal **Cummins engine installed in a pickup, and I use oil analysis at oil change intervals**. What would happen if I sent the residue to a lab to be analyzed after cleaning the 'stuff' out?"

It's true that particles that are removed from oil will reduce the effectiveness of oil analysis to detect failure. Oil analysis cannot detect particles that aren't there. Nevertheless, most particles that are removed by oil filters and centrifugal separators (or centrifuges) are too large to be seen by many oil analysis instruments such as spectrometers. Spectrometers are biased toward smaller particles in the range of 3 microns or less. This is much smaller than the majority of particles trapped by these filters or centrifuges, which typically are around 10 microns or larger. Therefore, the smaller (and just as significant) particles remain in the oil for analysis.

However, larger particles that are trapped by filters or centrifuges are important as well and can be more closely associated with advanced wear. Filter debris analysis provides one possible method for this type of analysis. Several larger commercial laboratories offer this service where a swatch of contaminant-filled filter media can be analyzed.

If a centrifuge is used in the engine, the sediment inside can be gouged out and sent to the lab along with simple instructions for how it should be analyzed and information regarding its source. The best spectrometer in this case would be an X-ray fluorescence (XRF) spectrometer, which is available at many larger commercial labs.

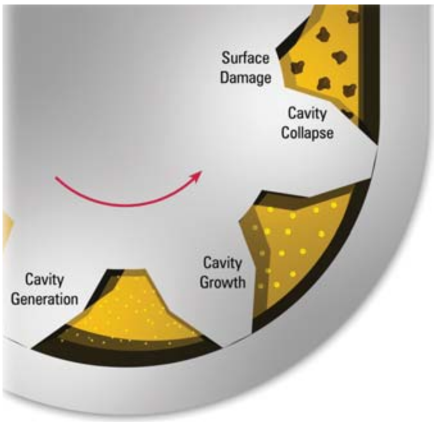
Alternatively, the laboratory could use a solvent to break down the gouged sediment from the centrifuge and then transfer it through a membrane. This would trap the large particles on the surface of the membrane, which could then be analyzed through microscopic analysis or analytical ferrography.

Of course, the majority of sediment and residue found within the centrifuge will be soot or sludge deposits and thus will lack vital oil properties such as dispersancy to be analyzed within the engine oil. This is important to understand because filter/centrifuge debris will be limited to the characteristics of the contaminants, while oil analysis can provide information on the overall characteristics of the oil. Therefore, it is necessary to analyze the oil as well as gather information on the concentration of oil additives and any

changes to the base oil.

Filtration is essential and should not be curbed for the sake of oil analysis. Failure detection via oil analysis is multifaceted. Particles trapped by filtration are only a slice of this process. Continuing to carry out oil analysis in cooperation with filter debris analysis may be the ideal solution for achieving effective analysis while maintaining your motor oil's filtration.

"We think **cavitation wear** may be occurring in our hydraulic system but don't know for sure. **Is there a way to determine this?**"



Cavitation can be determined by three easy means of detection: abnormal noise, high fluid temperature and slow operation.

Abnormal noise can be caused by two sources: aeration and cavitation. Aeration is the more alarming of the two. Sometimes referred to as "hammering," it occurs when air is entrained in the system. Large air bubbles compress and decompress, resulting in a "banging" noise. In severe cases, this can lead to the failure of piping and equipment. It may also be confirmed by foaming and erratic operation of actuators.

In the case of cavitation, the absolute pressure falls below the vapor pressure of the fluid, creating vapor cavities. These cavities will implode, which produces a knocking sound. This can be identified with vibration sensors or acoustical analysis equipment. At times, this may even be loud enough to be heard. The source of this noise is actually the implosion and subsequent micro-jet impinging on the surfaces of the system. Imagine a very small water jet cutting on the system surfaces. This constant impingement sounds similar to a growling or rattling in the system.

High fluid temperature is the result of the compression of air and other entrained gases in the fluid, or when the fluid moves from a high-pressure to low-pressure area without performing useful work. This takes place when the fluid leaks past internal seals in a piston/cylinder arrangement or when there is an improperly adjusted relief valve.

If the heat is not dissipated, it can have an effect on the fluid's viscosity, which impacts the lubrication of the system and components, as well as causes other problems that increase the likelihood of further cavitation. Research has shown that the higher the viscosity, the lesser the impact and likelihood of cavitation. The inverse of this is also true; as the viscosity decreases, the likelihood of damage from cavitation increases.

Slow operation and longer cycle times are usually the first indication that there is a problem. Remember that the operation of the system is based on flow. If there is a loss of speed in your actuators, there is likely a loss of flow somewhere in the system. This is generally caused by leakage, such as from a ruptured hose, blown seals, leaking fittings, etc. These are fairly obvious and easy to correct.

Internal leakage is much more difficult to identify but not impossible. When fluid moves from a high-pressure to low-pressure zone without doing work, heat is generated. This can be determined with infrared thermometers, sometimes in conjunction with flow meters.

In short, noise, temperature and cycle times are good indicators of cavitation in your hydraulic systems. As with everything else, early detection is the best way to prevent equipment failure and subsequent downtime. Be proactive and look for these indicators. Failure to do so can have a huge impact on the bottom line.

If you have a question for one of our experts, email it to info@machinerylubricationindia.com

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For Lubricated equipment, Ferrography is the single most effective machine condition monitoring method available today. Ferrography (Wear Particle Analysis) prevents catastrophic equipment failure through the timely and accurate prediction of abnormal or critical machine wear. No other Analysis technology is able to distinguish with such precision the particulate matter associated with normal wear from that associated with abnormal or critical wear. This analysis saves your time, money and provides peace of mind.

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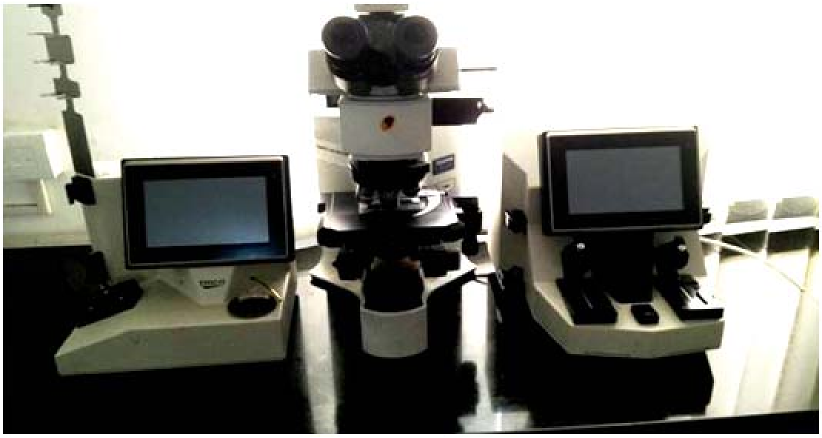

Successful SERVO Mining Meet 2016

Lighting of Lamp by Gopal Singh, CMD Central Coalfields Limited, Ranchi

Indian Oil Corporation (IOCL) called an all India SERVO® Mining Meet 2016 on February 26. It was held at Hotel Radisson Blue in Ranchi. Themed "Driving Efficiency and Productivity in Mining Industry through the use of latest lubrication practices", the program shared newest mining technology trends and consequent challenges in the development of lubricants.

The successful meet was well attended by some 100 official participants from the mining industry both public and private. It included CIL and subsidiaries of CIL, TATA Mines, NMDC and UCIL. Other sectors were represented by OEMs as from the heavy earth moving machinery sector.

After welcoming the delegates R S Dhaiya, (GM Bihar & Jharkhand) of IOCL focused on recent mining operation advances and related need for improved lubricant and fuel use. He noted that SERVO® Mining Meet 2016 was due to usher in lubricant product and service trends with bench marking in the mining sector.

K L Murthy, Executive Director (Lubes-HO in New Delhi) at IOCL delivered the key note address to elucidate the front role of the company and particularly in tribology lubrication technology. On hand are IOCL Lube expertise in tailored, specialty applications.

Chief Guest Gopal Singh, Chairman & Managing Director-Central Coalfields Limited (CCL) graced the occasion to mention IOCL initiatives required to organize SERVO® Mining Meet 2016. He endorsed that it would lead to productivity improvement for the industrial sector with emphasis on requirements to amalgamate outstanding ideas that arise for task force creation.

Senior IOCL personnel among attendees included R. Suresh and Dr S. K. Majumdar of Indian Oil R&D, and T.S.R. Gopalarao. Talks were deliberated with presentations on up and coming technology lubrication needs. Information and interaction led to one plenary and three technical sessions.

Speakers and focus papers were drawn from Indian Oil R&D Centre and VAS Tribology, actively associated with the US Noria Corporation, described as Lubrication Enabled Reliability. Also at hand were the German concern Evonik Industries, mining industry experts and BEML, TIPL and Cummins in India.

DHIREN SHAH

BASE OIL REPORT

Oil prices surged mid march 2016 on word from OPEC officials that Saudi Arabia and other leading exporters will limit their output even if Iran doesn't cooperate. The market shrugged off mildly disappointing data about rising stockpiles in the U.S. to resume a rally that has juiced the market for more than a month. Oil is now up about 47% during that span as speculators have become more optimistic that nearly two year of price declines are finally forcing big producers to slow down. Saudi Arabia, Kuwait and their allies would limit their oil output even if Iran doesn't follow suit, OPEC officials said, a change in tone that paves the way for cubs on crude production to be set next month. Qatar said it would host a meeting on April 17 for oil producers both inside and outside the Organization of the petroleum exporting countries. Light, sweet crude for April delivery settled up $2.12, or 5.8% to $38.465 abarrel on the New York Mercantile Exchange. It was the largest percentage gain in one day since Feb. 22.

Hefty Discounts are also offered by refiners for lifting sizeable quantity. Group I Base Oil prices for neutrals SN -150/500 (Russian and Iranian origin) are offered in the domestic market at Rs. 30.20 – 30.35/30.50 – 30.60 per liter.

The Indian base oil market remains steady with inventories at optimum levels with surplus of imported grades. During the month of January 2016, approximately 193786 MT have been procured at Indian Ports of all the grades, which is 5% down as compared to December 2015. Indian State Oil PSU's IOC/HPCL/BPCL basic prices across the board remain unchanged.

The Indian base oil market remains steady with inventories at optimum levels with surplus of imported grades.

During the month of January 2016, approximately 193786 MT have been procured at Indian Ports of all the grades, which is 5% down as compared to December 2015, Major imports are from Korea, Singapore, USA, UAE, Iran, Taiwan, France, UK, Netherlands, Japan, Italy, Belgium, etc. Indian State Oil PSU's IOC/HPCL/BPCL basic prices across the board remain unchanged.

Base Oil Group I & Group II CFR India prices:-

Month	Group I - SN 150 Iran Origin Base Oil CFR India Prices	N-500 Korean Origin Base Oil CFR India Prices	J- 500 Singapore Origin Base Oil CFR India Prices	Napthenic Base Oil HYGOLD L2000
November 2015	USD 450 – 455 PMT	USD 575 - 580 PMT	USD 565 - 575 PMT	USD 545 - 565 PMT
December 2015	USD 465 – 470 PMT	USD 550 - 560 PMT	USD 545 - 550 PMT	USD 530 - 535 PMT
January 2016	USD 445 – 450 PMT	USD 530 - 540 PMT	USD 525 - 530 PMT	USD 510 - 515 PMT
	Since November 2015, prices have dripped down by USD 5 PMT (1%) in January 2016.	Since November 2015, prices have reduced by USD 45 PMT (8%) in January 2016.	Since November 2015, prices have gone down by USD 40 PMT (7%) in January 2016.	Since November 2015, prices have fallen down by USD 40 PMT (7%) in January 2016.

Origin Wise Base Oil Import to India Country, Qty MT & % December 2015

SOUTH KOREA	89209	44%
UAE	33210	16%
SPAIN	21780	11%
SINGAPORE	19973	10%
USA	20664	10%
BAHRAIN	6174	3%
TAIWAN	3211	2%
IRAN	3673	2%
PAKISTAN	1177	1%
SWEDEN	2074	1%
NETHERLANDS	2195	1%
OTHER COUNTRIES	1696	1%

Port Wise Base Oil Import to India Country, Qty MT & % December 2015

MUMBAI	163099	80%
JNPT	19248	9%
ENNORE	5153	3%
CHENNAI	5796	3%
PIPAVAV	3584	2%
MUNDRA	1587	1%
KANDLA	2639	1%
KOLKATA	2698	1%
OTHER PORTS	1232	1%

Approximately 9397 MT of Light & Heavy White Oil has been exported in the month of December 2015 from Chennai, JNPT, Mundra and Ahmedabad. Compared to last month i.e. November 2015; exports of the country have gone down by 7% in the month of December 2015.

Approximately 6522 MT of Transformer Oil has been exported in the month of December 2015 from JNPT and Chennai.

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