November-December 2019

Machinery Lubrication

INDIA

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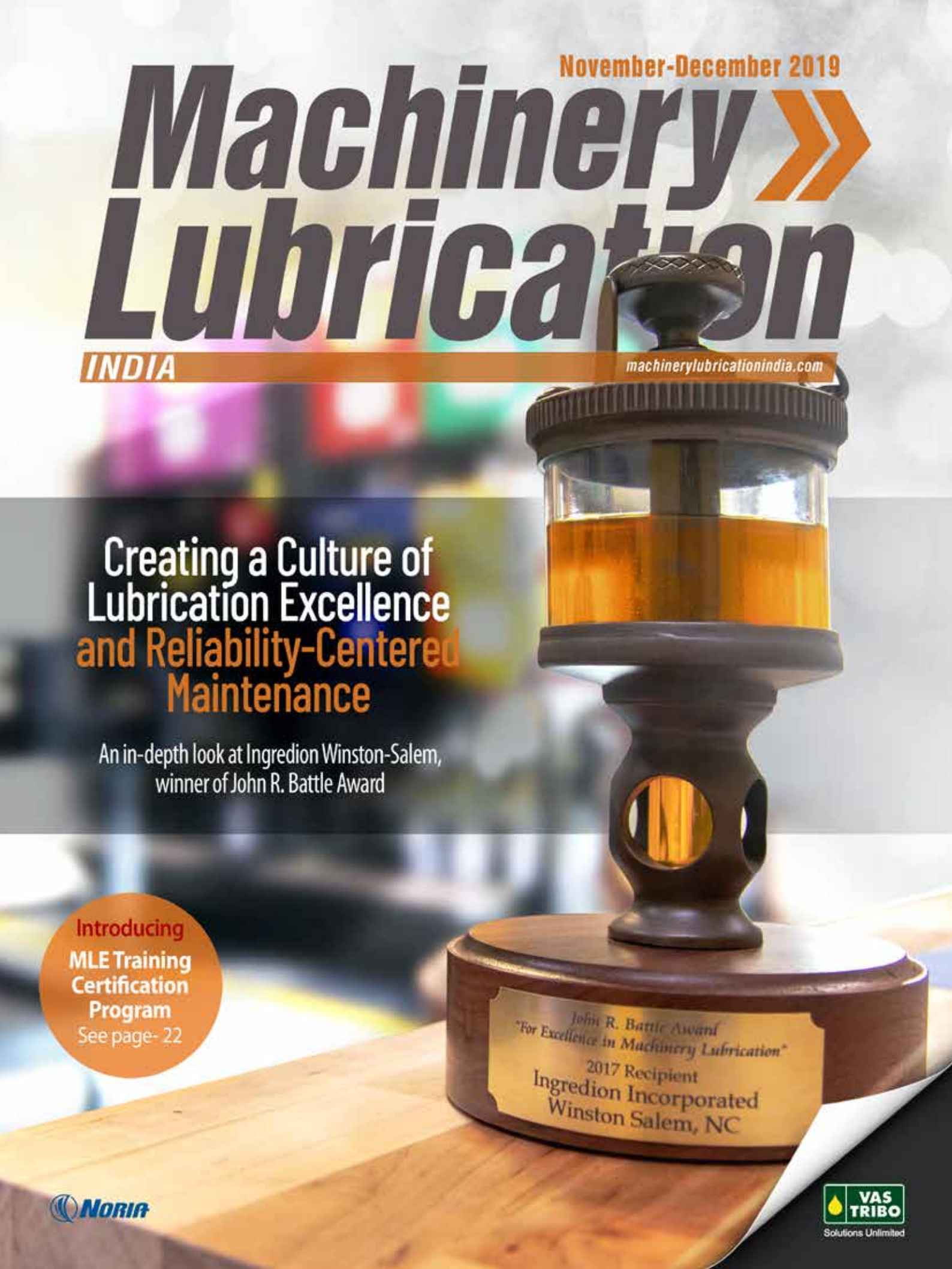
Creating a Culture of Lubrication Excellence and Reliability-Centered Maintenance

An in-depth look at Ingredion Winston-Salem, winner of John R. Battle Award



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Publisher's Note

What exactly does it mean to be excellent at lubrication? Is lubrication excellence a destination, or is it a journey on the path to re-inventing a plant's entire approach to lubrication?

Unfortunately, many organizations approach lubrication excellence like a program, similar to a capital project, with a defined beginning, middle and end. In other words, it is something that must be defined by a clear return on investment within a predetermined time period.

Lubrication excellence is not about one single activity or collection of activities over a specific time period, but rather a continual journey which should be aimed at changing the lifestyle of the plant. Lubrication excellence involves changing the process of lubrication, not just purchasing tangible products or services.

The first phase in the process is planning. Training is clearly a critical component of the cultural transformation process. In addition to a general training course, it is appropriate to have open forum discussions with various groups and departments to discuss their specific roles.

During the planning phase, it is also necessary to assess the organization's computerized maintenance management system (CMMS) and other planning support systems to define how the new program needs to be structured from a document management and information flow perspective.

There are four major activities in the design and install phase of the transformation process: design, installation, documentation, and coaching and ad hoc training. The design aspects are technical in nature and require individuals with special skills and experience to complete.

Lubricant contamination control is an effective mechanism. The oil analysis and inspection program is the scorecard for a controlled and managed lubrication program. It ensures that contamination control and lubrication management efforts are effective. Likewise, oil analysis provides advance warning, which enables a decisive and targeted response to abhorrent machine and/or lubricant conditions that could compromise reliability.

Many lubrication problems begin with poor handling and inventory practices. It is necessary to optimally design a lubricant purchasing, storage and handling process.

Occasionally, it is necessary to adjust the lubricant selection. Several reasons may prompt such a decision.

Once the various aspects of the new lubrication program have been designed, it is usually necessary to purchase and install hardware, and in some cases, software and instruments.

Upon completion of the design and installation phase, and after procedures are written, it is time to deploy lubrication excellence.

Today, managers and owners must look to maintenance and reliability to improve profits in their plants and factories. For most, improving lubrication practices represents "low-hanging fruit" that is ripe for the picking. Many have attempted to shortcut the pathway to lubrication excellence by purchasing special lubricants, instruments or other gadgets. Regrettably, but predictably, many have failed.

Don't expect these changes to come overnight. To succeed, you must engage in sustained effort to transform the culture and usher in the new business-as-usual.

We would like to thank our readers for the great response to our anniversary issue. Our current issue's cover story is "Creating a Culture of Lubrication Excellence and Reliability-Centered Maintenance" which will help our readers to know how a company creates a world-class lubrication program.

Wishing you all Happy and Prosperous New Year 2020 filled with abundance joy and treasured moments.

Warm regards,

Udey Dhir

How the IIoT Is Changing **Condition Monitoring**

"The IIoT does not and cannot make all other forms of condition monitoring obsolete, but it is a powerful enabler."

The industrial internet of things (IIoT) and Industry 4.0 are already unleashing enormous value in plants around the world. It seems that today's younger, digital workforce is the energy that propels this change. Past efforts had been sluggish to say the least.

Modern consumer products have put connected devices in our pocket, on our wrist, in our ears, in our car and throughout our home. IoT is projected to deliver between $1.9 and $4.7 trillion of economic value by 2025. The IIoT for asset monitoring is expected to produce $200-$500 billion in economic value by 2025. Condition-based maintenance (CBM), involving real-time sensing and predictive maintenance, is viewed as the "easy win" among all IIoT applications. Many new online sensors are being introduced each year (see Figure 1).

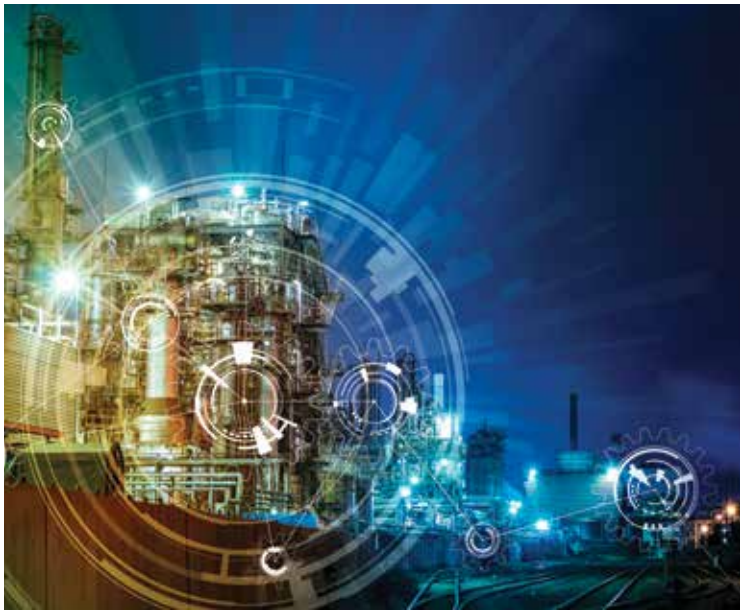

Figure 1. The plethora of new sensors in the condition monitoring space is impressive. This emerging trend is bound to change the field of condition monitoring forever.

Condition Control Is the New Game

Condition monitoring describes the data collection function needed to sustain machine reliability. Intelligent machines and smart factories require the ability to respond and make agile course corrections to this data. Data analytics is the buzz term related to converting data into smart, actionable information. When used to foretell a future

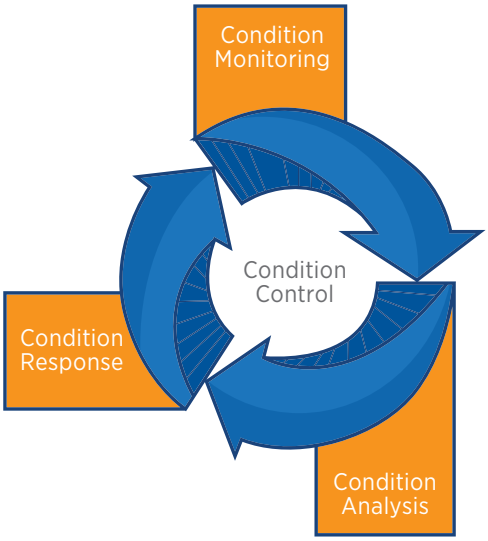

Figure 2. Condition monitoring is only the data acquisition stage of condition control (sustained reliability). Condition analysis converts this data into meaningful information about the state of the machine. Condition response puts this information to work by converting it into actionable course corrections, executed either by humans or autonomously by the machine.

event, it often is referred to as predictive analytics. Either way, it takes condition monitoring one step further — a very important step. This could be called condition analysis.

However, we're not done, as we need the response piece. This is the function of doing something actionable (real-time course corrections) with this information. This is called condition response. But we're still not done. We now need to return to condition monitoring to confirm that we have positive feedback to these actions. Did the course correction really work to remedy a problem or improve overall machine performance? Perhaps another course correction must be tested?

The IIoT is a critical enabler that some say is long overdue. It implants sensors that are "tuned in" to the real-time dynamics of our machines. After all, the failure development period (P-F interval) can vary from milliseconds to years. The IIoT provides the continuous vigilance to the onset of anything that is changing and might compromise reliability and sustainability of our machines and processes. Figure 2 shows a simple illustration of the circular condition control process. It's time to morph condition monitoring into condition control.

Real-time Sensing and Edge Computing

Today, more and more machines are fitted with onboard "edge computing" or distributed intelligence. Data is still fed to the cloud or a centralized location, but decisions can be made locally. There's also artificial intelligence (AI), which involves computers powered by sophisticated, self-learning software using algorithms that mimic human intelligence. AI is more common in consumer products but is still in its infancy in industrial product applications, especially condition monitoring.

More practical and effective is augmented intelligence. With augmented intelligence, the human's super-computer (brain) teams with man-made computers to collect and convert data to actionable information. For instance, visual operator inspection data

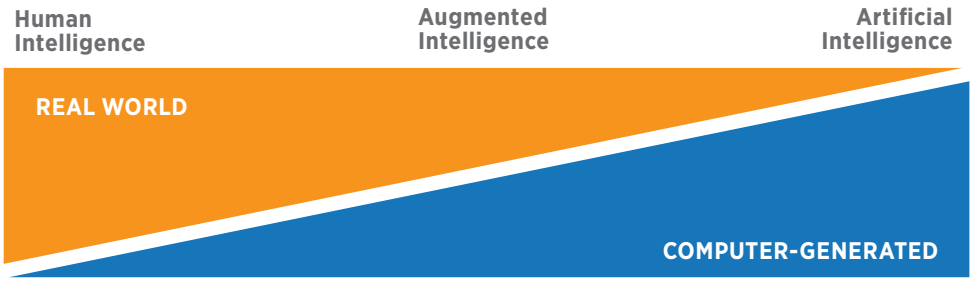

Figure 3. When human intelligence is augmented by artificial intelligence, the optimum result can be achieved.

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Publisher
Udey Dhir - udeydhir@tribologysolutions.com

Creative Director
smassociates@gmail.com

Advertisement Sales (India)
admin@machinerylubricationindia.com

Advertisement Sales (US/Canada)
Teresa Dallis - tdallis@noria.com

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ads@machinerylubricationindia.com
admin@machinerylubricationindia.com

CORRESPONDENCE
You may address articles, case studies, special requests and other correspondence to our

Operation office :

Editor
213, Ashiana Centre, Adityapur,
Jamshedpur-831013, India
email : editor@machinerylubricationindia.com
Tel: +91-657-2383238
Tel:(USA): +1-918-960-9738

Marketing Office
Rider House, 136,
Sector 44, Gurgaon-122003, Haryana
National Capital Region, India

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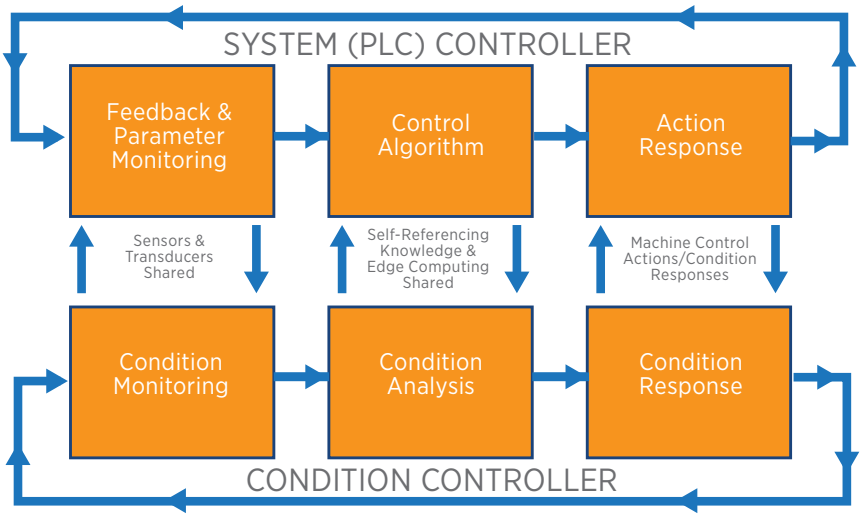

Figure 4. The Intelligent Controller-Controller Interface (ICCI) System shares PLC functions/sensing with machine condition functions/sensing.

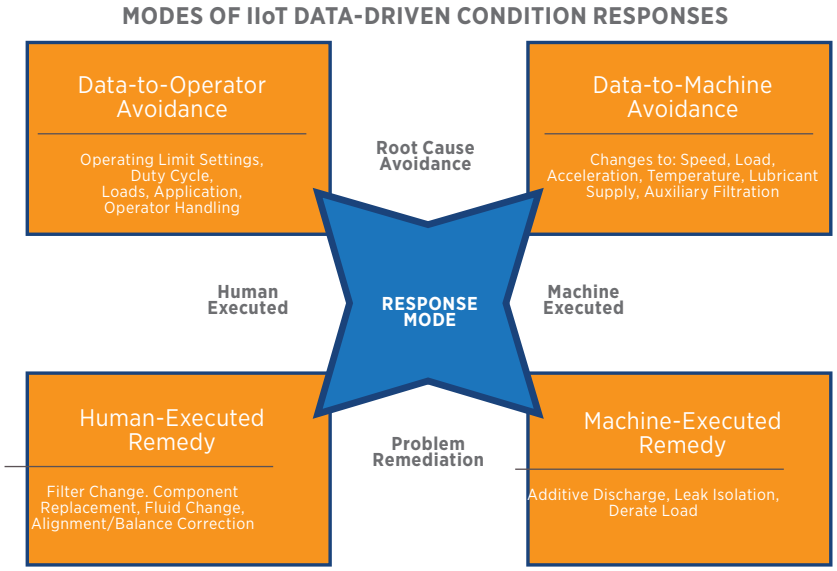

Figure 5. This chart shows how the IIoT provides connectivity for both machine and human executive condition control responses.

that is scanned or keyed into a handheld device can be augmented by pairing it with data generated from online condition monitoring sensors. See Figure 3 for a simple visual on augmented intelligence.

In real time, this data can dictate machine control and movement to optimize and sustain machine health and operating conditions. These are like guidance systems that respond to current conditions, providing adaptive control in response to instant changes. The state of the machine is constantly monitored and recalibrated.

Real-time sensing can be shared between the system controller (like a PLC) and the condition monitoring controller. This provides a functional interface enabled by an IIoT platform for mutual benefit related to machine performance and reliability. Machines with autonomous control features (current or potential) might include hydraulic systems, compressors, paper machines, turbines and many sophisticated process machine trains. The concept of coupling condition control with system control is illustrated in Figure 4.

Machine- and Human-Executed Responses

Of course, not everything must be done in real time. Because of the complexity of some machines and the technology limitations of many condition and operational control functions, both human and machine responses are needed. The IIoT and online sensors can supply the data, while data analytics can translate the data into prescriptive responses. However, the manner and time element of the corrective responses may vary.

This hybrid model probably makes the most sense, as it is the easiest to deploy. But this is a dynamic field that will continue to evolve as technologies advance and machines become smarter and more agile. Examples of how humans and machines can work together are shown in Figure 5.

The Internet of Tribology

Oil is like a flight data recorder. It is exposed to the intimate innerworkings of the machine, seeing both the good and bad. It's the common medium that records data from these exposures which might reveal health or aberrant conditions that can induce future failure. Decades of research in tribology and millions of oil analysis samples have taught us that there's gold in our oil. The data that can prescribe needed actions is this gold. It is detectable and quantifiable.

The means of data acquisition should not only be limited but also multimodal. It can be extracted from samples and analyzed in the laboratory, monitored in real time with online sensors, interrogated using portable data collectors, or examined by skillful and investigative inspectors. Other non-lubricant-related tests and inspections at the machine help complete the picture and establish greater confidence in what's happening now (or not happening).

The IIoT does not and cannot make all other forms of condition monitoring

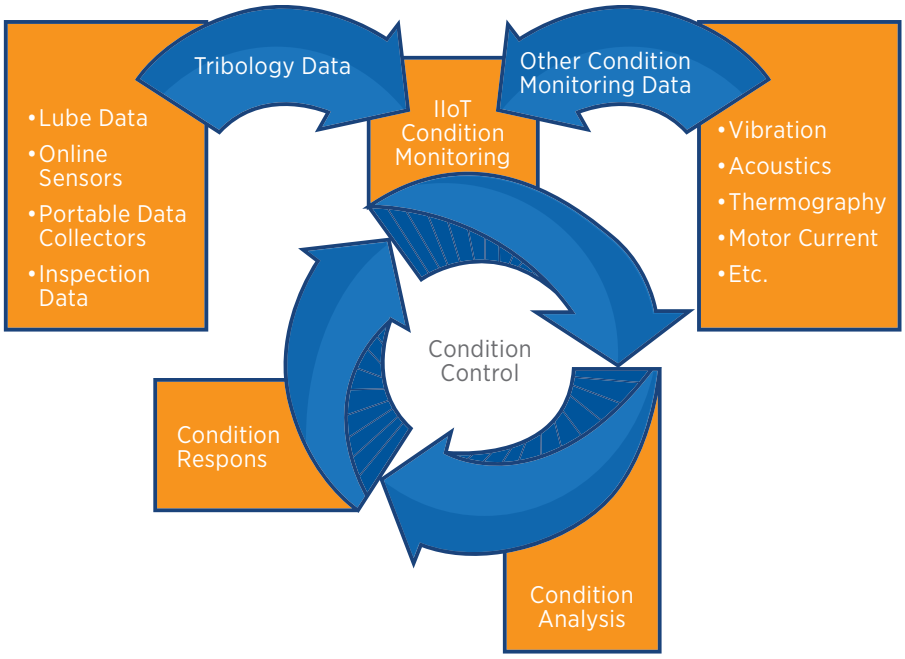

Figure 6. The expanded condition control model shows the IIoT as the primary source of data.

Condition Control Means Machine Agility

Agility is fundamentally important. The ground is always shifting (figuratively), and the machine must be agile and shift in response. It's like climate control. When it's hot outside, the air conditioner responds. When it's cold outside, the heater responds. Sustained machine reliability depends on agile responses to operating conditions and exposures to all things that present risk and impair reliability.

Each machine is unique from the standpoint of what might be changing and how agility (human or machine induced) must respond. Below are some basic examples:

What's Changing

Machine age (changing vibration, heat, acoustic emissions, displacement, alignment, balance, etc.)

- Oil age
- Filter age
- Climate, weather, seasons
- Duty cycle (load, pressure, speed, flow, etc.)
- Operator handling
- Exposures (heat, ingression, moisture, etc.)
- Oil level, leakage
- Grease charge
- Looseness

What's Adjusting to Change

Bleed-in-feed rate of new oil introduction

- Oil flow rate
- Sump make-up rate
- Grease dosage rate and frequency
- Filter use (flow, performance, auxiliary filter, etc.)
- Oil temperature control
- Viscosity correction
- Additive replenishment
- Base oil replenishment
- Machine operation (derating, speed, load, cycle rate, pressure, flow, temperature, etc.)
- Maintenance requisitions
- Inspection requisitions

obsolete, but it is a powerful enabler. Data and information can reach the internet in a variety of different ways that don't involve imbedded sensors. This data can pass through modems or industrial gateways for analysis and storage. As mentioned previously, the response to this data can be autonomous (i.e., machine executed) and human executed. See Figure 6.

The Dawn of IIoT-enabled Condition Control

The foundational pieces of IIoT-enabled condition monitoring have been advancing rapidly for years. Recently, enough of the pieces have fallen into place that working systems are beginning to show solid results. Many companies are waiting as others are taking the lead.

The full potential of IIoT-enabled condition control will evolve over the ensuing decades. While it is in its infancy when viewed in contrast to this full potential, some readers are young enough to see this potential transition to reality. Promising careers will exploit this potential, as will new and emerging companies. The field of machine reliability has an exciting, technology-rich future. It should be a great ride. ***ML***

About the Author

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

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Creating a Culture of Lubrication Excellence and Reliability-Centered Maintenance

An in-depth look at Ingredion Winston-Salem, winner of John R. Battle Award

By Natalie Blythe, Noria Corporation

As the recipient of the International Council for Machinery Lubrication's 2017 John R. Battle Award, Ingredion (Winston-Salem) underwent a complete transformation in its lubricant storage and handling practices, resulting in the company creating a world-class lubrication program. Following is the story of the Winston-Salem facility and its journey to creating a culture of lubrication excellence and reliability-centered maintenance.

History

Nestled in the hills of North Carolina, the Ingredion facility in Winston-Salem was built in 1981 and produces starch and syrups from corn. The plant employs approximately 100 full-time Ingredion employees and contractors. A unique feature of the facility is its use of self-directed work groups, which empowers the employees to do what is necessary to make the plant run.

"There's a lot of ownership at this facility and in everything we do," said Jeff Mohn, maintenance manager. "We have contractors with us for 30-plus years, and you don't stay a contractor that long unless you really love where you are and what you are doing. Ingredion is a great place to work."

The Road to Lubrication Excellence

The Winston-Salem facility's journey began in January 2009 with a lubrication program assessment by Noria. After the findings of the initial assessment, Ingredion learned a great deal about how to make lubrication process improvements.

"I was on the mechanical side and went on the tour with Noria in 2009," said George Warwick, senior maintenance instrument lead. "You're thinking that you're doing it right, but you're not. When Noria gave us their final report, it was like a helping hand reaching out."

Utilizing the Winston-Salem facility's unique usage of self-directed work groups, Warwick, a 28-year veteran of Ingredion and champion of the facility's transformation, decided to lead the charge for change and actively sought out opportunities to help facilitate and improve reliability at the plant. He started attending the Reliable Plant Conference & Exhibition, obtaining information and ideas for implementation at Winston-Salem.

"If I go to a conference or training, I don't look at it as a conference but as an educational experience," Warwick said. "I started going to conferences to get these ideas. You see all these neat gadgets and realize we have an opportunity to improve. I wanted a lubrication building and was told,

'You have one – kind of.' So, two years ago, I worked with the engineer manager. He asked me if there were any special projects I needed. I made the strategic recommendation for the lubrication building, and it was approved."

The facility took information from the initial assessment and findings and began building and upgrading its lubricants storage room with a bulk filtration system. The plant also bought a thermal camera and ultrasonic grease guns.

"Back in the day, I wanted things lubricated, but it really wasn't a concern," Warwick said. "So, time went by, and when the opportunity came for me to be a supervisor, it was time to change."

Prior to the shift, when there was a problem with a machine, it was relayed over the radios, but the maintenance department was not always the first responders on the scene to investigate the issue.

"The lubricator we had would get there before we did," Warwick said. "We'd arrive and see it was a bearing failure. We'd break the machine apart and find fresh grease. We were lubricating just to say we were lubricating. We had no defined routes; it was just this guy taught this guy – this is where you walk, this is what you do and that's how we lived. For me, that created a problem because I didn't know where he was walking and what he was doing."

A few years after the facility's initial assessment, Ingredion had several international plants adopt lubrication best practices with exceptional results. These initial successes, in addition to influence from other Ingredion plants and reliability champions, led to corporate leadership setting a strategy for lubrication and improved asset management at nine North American plants.

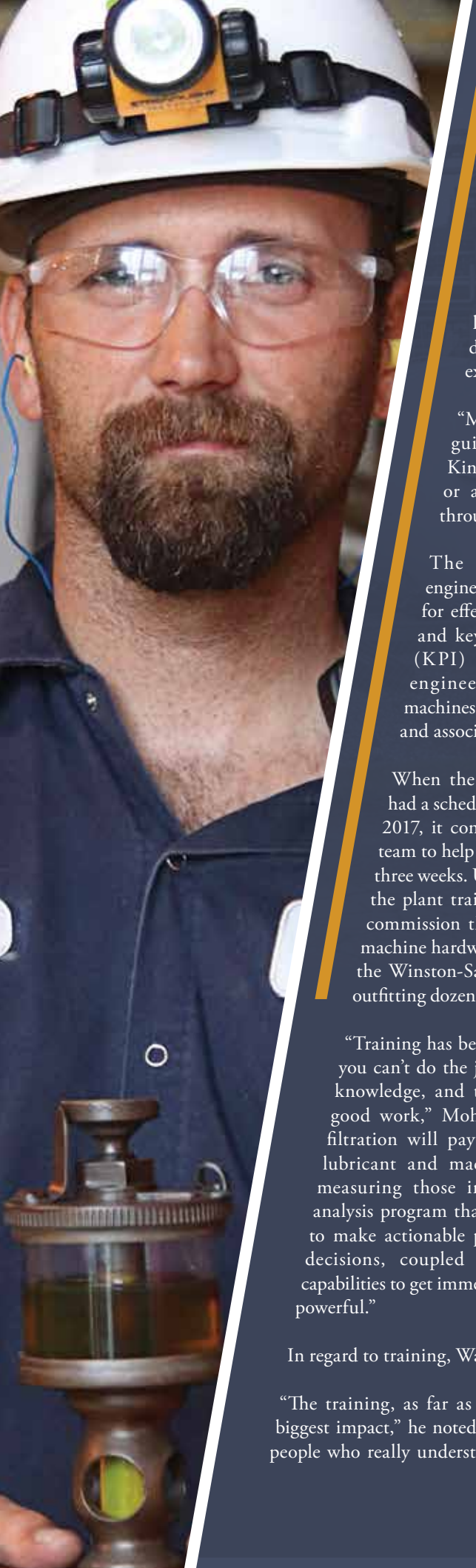
"It wasn't just this plant that made the decision," Mohn said. "Ingredion made the decision to move this way. Then we started bringing in people to assess what our needs were and help make the lubrication program better. From there, we were able to grow and start making changes in our lubrication program at that time."

Mohn, who has been with Ingredion for almost two years, believes his arrival at the facility came at the perfect time.

"It couldn't have been a better time," he said. "The reality is, when I came in, the company itself had made the decision to focus on reliability-centered maintenance (RCM), and when you look at the foundations for RCM, one of those foundations is a lubrication program."

With corporate backing, the Winston-Salem facility had Noria conduct another assessment in 2016. According to Mohn, the plant, including Ingredion employees and contractors, underwent an effort to change the culture through outside training, standardizing processes, knowledge-sharing and hands-on applications to promote reliability excellence.

Working with Noria, the facility implemented a rigorous training program for both employees and contractors, resulting in five certifications in planning and scheduling; two employees becoming certified in vibration and infrared analysis; inception of a Certified Maintenance and Reliability Professional (CMRP) program; the creation of a reliability



engineer position; redefining and hiring a new planner/scheduling position; and promoting Matt King, mechanical maintenance lead, into a leadership role to continue driving lubrication excellence.

"My new role is being a guide for the mechanics," King said. "If they need help or assistance, I help them through that."

The facility ported the engineering to special software for effective route management and key performance indicator (KPI) tracking. Noria's engineering also identified machines that needed modification and associated hardware.

When the Winston-Salem facility had a scheduled outage in November 2017, it contracted Noria to send a team to help manage 14 pipefitters for three weeks. Utilizing Noria's training, the plant trained its team on how to commission the lube room and make machine hardware modifications, which the Winston-Salem crew undertook by outfitting dozens of machines themselves.

"Training has been extremely valuable, as you can't do the job correctly without the knowledge, and that knowledge inspires good work," Mohn said. "We know the filtration will pay dividends in extended lubricant and machine life, and we are measuring those impacts. Having an oil analysis program that is configured correctly to make actionable predictive and proactive decisions, coupled with having in-house capabilities to get immediate results, is extremely powerful."

In regard to training, Warwick completely agrees.

"The training, as far as our group, has had the biggest impact," he noted. "There were only a few people who really understood lubrication, and the ones who didn't who actually got the training, they realized what they weren't seeing. It's like, I know what you do, but until I actually see what you're doing, I don't understand."

With all of these changes in place, the Winston-Salem facility has begun seeing differences in many aspects of the plant. The facility is now in a transitional phase, moving from reactive to more predictive and planned work.

For Warwick, his daily work life has become more structured.

"It's what I wanted it to be," he said. "We had started seeing fewer failures, but now we see the professional side of it. (The lubrication technician) has his cart, he has his lubes, and he's making his equipment checks – I like it."

The facility is also starting to see a time savings as well.

"If you have a bad lubrication program, it's a leading indicator, but if you're doing OK, it's a lagging indicator," Warwick said. "It's hard to justify. It's hard to measure something so important that people take for granted. There's still some fine-tuning, as we're not quite there yet."

In addition to focusing on lubrication excellence, a bonus of the journey has been the awareness sparked in the facility.

"In the beginning, when the lube building was going up, everyone was curious," Warwick said. "People would ask, 'What are you doing?' We'd say, 'Building a lubrication building.' 'Well, what do you need that for?' 'Because we've got a goal to achieve.'"

A 24-hour surveillance system was installed in the lube room due to its contents. Surveillance footage showed that a lot of people were going into the lube room just to see it. From that point, the curiosity grew into more awareness of the lubrication program and its importance for the facility. In fact, the team has noticed an increase in the work orders stemming from operator awareness.

"Awareness has been the biggest improvement," King said. "Everyone can see what the oil levels are. Everyone who has their hands in maintenance sees the benefit of it. Operations is coming around. I know they're noticing because we get work orders."

The machine modifications have also led to increased awareness from operators.

"With the visible sight glasses, we've gotten a ton of feedback when it's low," Warwick said. "I'd like to get to the point where the operator could come and top it off."

Mohn believes one of the main factors in the increased awareness was the company-wide communication during the lubrication program's transformation and Noria's involvement, particularly onsite. In addition to using a town-hall format as a way to communicate the objectives to accomplish, Mohn also went to individual shifts and began talking to people on that level.

"We communicated why we were doing it and the impact," Mohn said. "We also talked about it from a corporate standpoint. We are working with Noria to develop an operator communications/training program so we can help our workforce better understand why we are doing what we're doing, and what our expectations are as well."

Next year the facility will be moving to more of a lean mentality, which should couple well with what is being required of operators in terms of reliability.

"Operator care marries up with what my tasks are from a lubrication standpoint," Mohn said. "You can look at a breather, sight glasses and all those things. As a company, we are working toward that. As a smaller facility, we have an advantage because things are communicated organically. We still have a lot of training to do, and that's where we are heading."

Winning the Battle Award

While the day-to-day changes at the plant became visible to everyone at the facility, the importance – and excitement – behind the transformation became more palpable after receiving notification that Ingredion Winston-Salem had won the 2017 John R. Battle Award for excellence in the application of machinery lubrication.

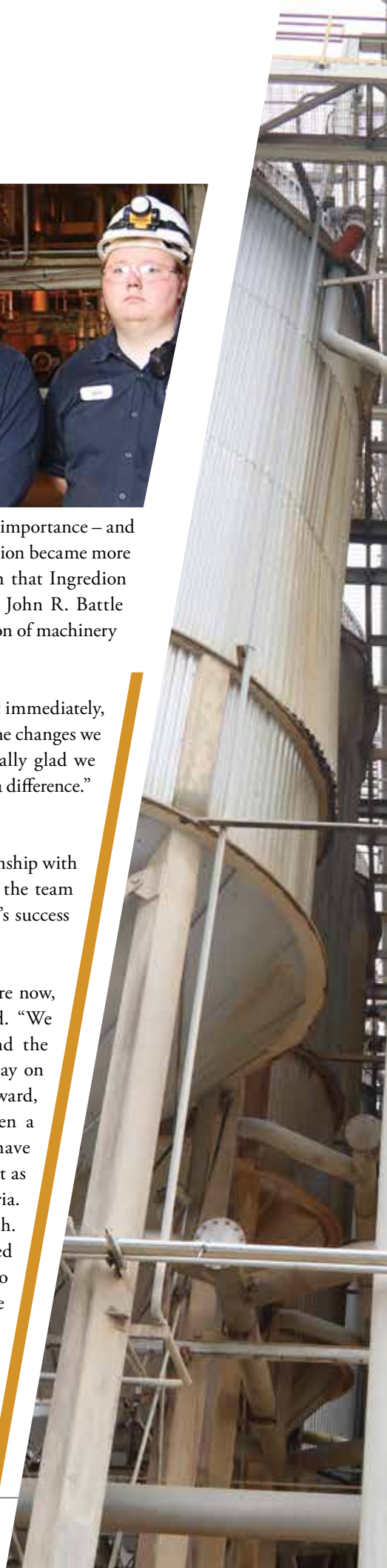
"That trophy changed things almost immediately, adding validity to and recognizing the changes we implemented," Mohn said. "I'm really glad we went after that award. It really made a difference."

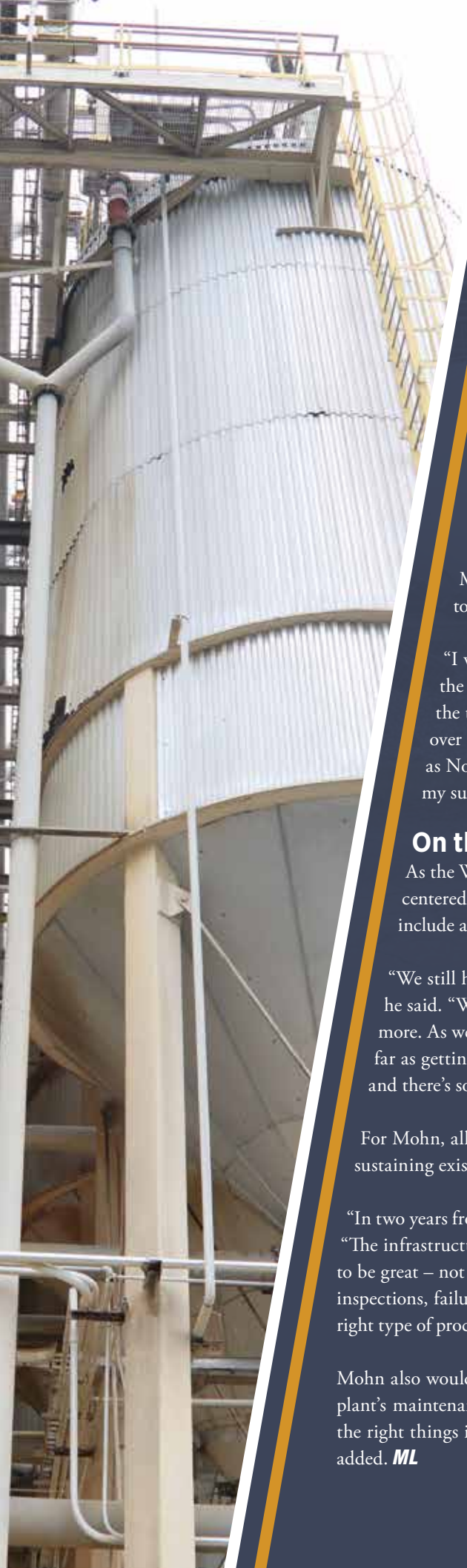
The Noria Difference

The Winston-Salem facility's relationship with Noria has evolved since 2009, and the team realizes that a vital key to the plant's success stems from working with Noria.

"Without Noria, to get where we are now, it would take us years," King said. "We implemented so much so fast, and the continued support has helped us stay on track. We've really been moving forward, and everyone from Noria has been a really big support. It wouldn't have been possible for us to get through it as quickly or as efficiently without Noria. We just didn't have the bandwidth. Even if you went to the class and tried to apply all of that, you're going to miss parts. That's why you need the support from someone outside who deals with that every day."

Warwick, who has the longest relationship with Noria, echoes King's sentiments.





"With our work environment, if we stopped all our work, it would probably take us a year to modify all the machines, but that means we wouldn't get anything else done," Warwick said. "With Noria's help, we made some modifications online before shutdown, and then during shutdown, we made the rest of them in only one week."

Mohn agrees that working with Noria made a significant difference, particularly when it comes to relationship-building.

"It's the personal relationships that have been developed from a support standpoint," he said. "I know I can call up any of the guys who've been here and say, 'I have this problem, I have this need, what do I do?' and I know that I will get that support. That's probably the biggest thing for me, knowing I can do that. I know I can call up Noria to help me and support me in that decision."

Mohn also cites the level of customer service he has received from Noria as a benefit to creating that lasting relationship.

"I would highly recommend Noria," he said. "If I have a problem or if I have a need, the customer service has been incredible. We talk about the customer experience here all the time and developing those relationships that keep customers coming back over and over again. I don't have anyone else I deal with that has embodied that concept as much as Noria. It's that personal relationship and commitment. I feel like they are invested in my success, and I need that."

On the Horizon

As the Winston-Salem facility continues its pursuit of lubrication excellence and reliability-centered maintenance, the team is focused on what the future holds. For King, his goals include additional training and sampling.

"We still have critical pieces of equipment that need to be sampled that we're not sampling," he said. "We've got 50 samples we're sending out quarterly, but there's always opportunity for more. As we get more efficient, we can do more. For my department, we need more training as far as getting people certified in vibration. I've been around lubrication as long as I remember, and there's so much I know now that I didn't know before."

For Mohn, all of the current changes will lead to the Winston-Salem facility having a more self-sustaining existence.

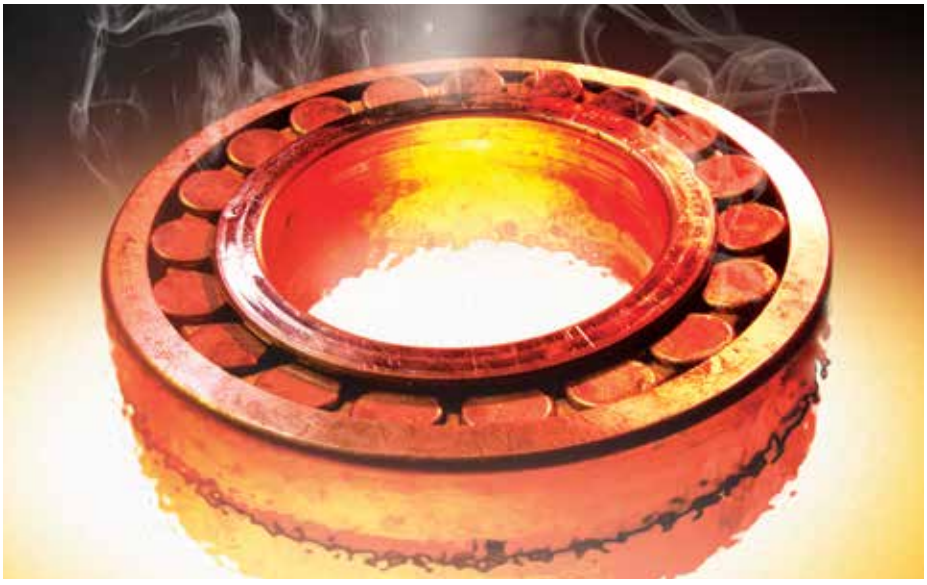
"In two years from now, the goal is to have self-sustaining sections within the organization," he said. "The infrastructure is designed to – at some point – operate on its own. That would mean we need to be great – not good, but great – at root cause analysis, because that will take what we find in our inspections, failures, etc., and put that all together and generate the right type of standard of work, right type of procedures and right type of bill of materials so we have what we need when we need it."

Mohn also would like to take the successful elements from the lube room and move them into the plant's maintenance infrastructure. "It's really good linkage to how it's all supposed to work with the right things in the right place, and moving that deeper into the maintenance organization," he added. ***ML***

By Alejandro Meza | Noria Corporation

Guidelines for SELECTING High-temperature LUBRICANTS

Nowadays most industries have processes that require machines to operate at high temperatures. These applications demand special lubricants that can handle extreme operating temperatures by maintaining their lubrication properties, keeping the system clean and providing a reasonable service life. The ultimate goal is to sustain high machine reliability while controlling maintenance costs. In many cases, a synthetic lubricant may be the best choice.



What is Considered a High Temperature?

Before selecting a high-temperature lubricant, you must first know when a temperature is considered to be high. Unfortunately, there is no single right answer to this question. For the sake of reference, generally an oil that is able to work at temperatures higher than 210-250 degrees F (100-120 degrees C) for a normal or extended drain interval may be assumed to be a high-temperature lubricant. Of course, other sources may have different opinions on this temperature range.

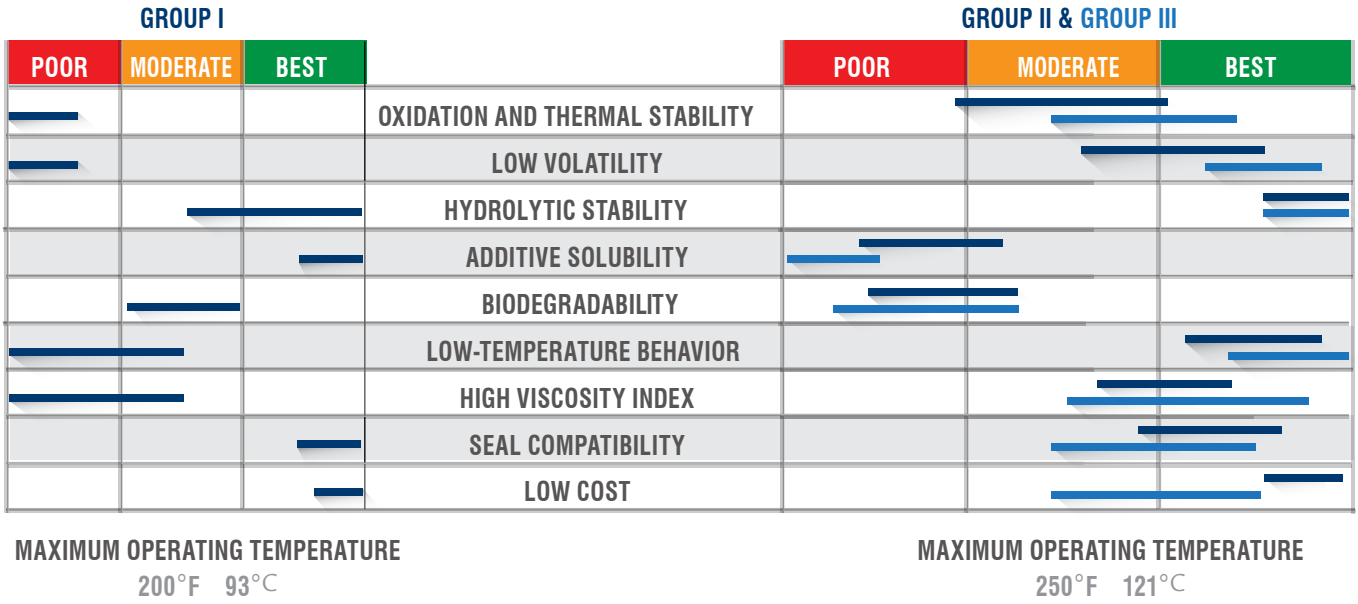
The well-known Arrhenius rate rule, which relates to lubricant use versus temperature, states that for every increase of 18 degrees F (10 degrees C), the oil life is cut in half. This equation was originally formulated for mineral oils, but while the lifespan is different for various product technologies, the rule is applicable for both mineral and synthetic lubricants. This means that a mineral oil with a weak formulation may be used at higher temperatures if it is changed frequently, but that is not practical or cost-effective in most cases.

The same principle applies to the base stocks used in greases. The grease's thickener influences the performance at higher temperatures due to its oxidation

80%

of lubrication professionals use high-temperature lubricants on the machines at their plant, based on a recent survey at MachineryLubrication.com

Comparisons of Operating Temperature Ranges for Different Lubricant Base Stocks



resistance, as well as the dropping point that it imparts to the grease. It is recommended to use a grease below its dropping point to ensure the lubricant stays in place. See the sidebar on page 30 for a few simple rules to help determine the maximum operating temperature based on a grease's dropping point.

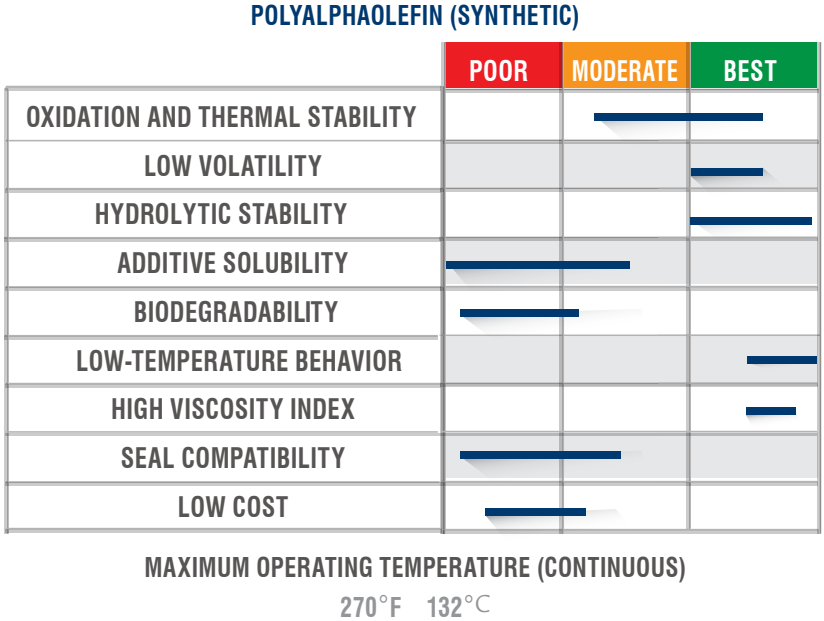
High-temperature Operation

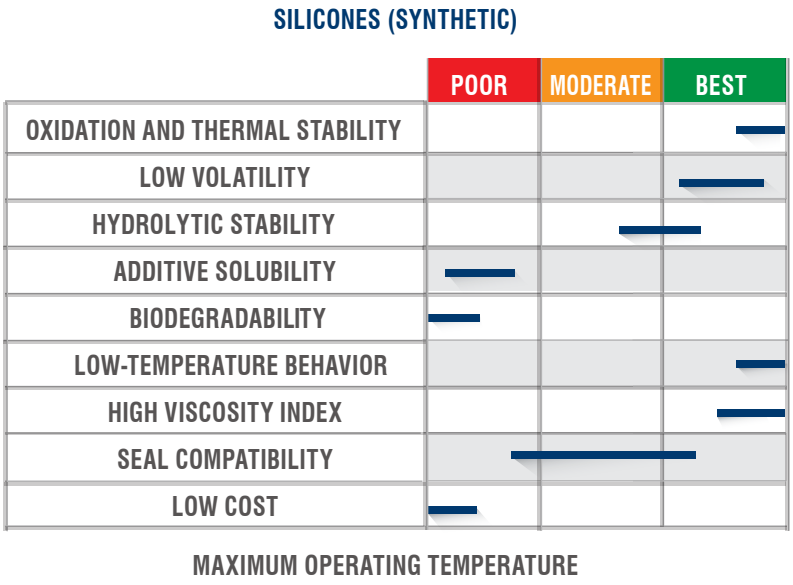
A lubricant's operating temperature will depend on several factors, such as the heat produced in and around the machine. Heat may also be generated as a result of normal or abnormal conditions. Normal or expected conditions would include the machine's environment (production process and climate conditions), mechanical work realized by the machine, the combustion action in internal combustion machines and the internal fluid friction of the lubricant. Abnormal conditions would consist of an unusual mechanical issue, excessive loads or speeds, lubricant viscosity that is too low or high, and a deficient insulating material.

Reasons for Choosing a High-temperature Lubricant

Before beginning the lubricant selection process, it is important to consider the reason a high-temperature lubricant is desired or required. For instance, it may be a requirement of the original equipment manufacturer (OEM). This means a particular brand or lubricant type has been tested by the OEM with approved results. In many cases, this is a condition for warranty, so it is advisable to use the recommended lubricant type. Also, always verify the operating conditions to ensure they are consistent with what is expected by the OEM.

Another reason a high-temperature lubricant might be chosen is because of an abnormal machine condition. However, while a better performing lubricant may help mitigate the problem, it is more imperative to





correct the root cause of the issue. New operating conditions or the use of a newtechnology may also be motivation for favoring high-temperature lubricants, along with simply desiring to enhance performance for improved reliability.

Lubricant Selection

The first step in the lubricant selection process for a high-temperature application is to estimate the average operating temperature or temperature range. At this point, a temperature-control initiative may be implemented, such as installing a heat exchanger, insulant or additional ventilation. Also, be sure the OEM requirements and current machine conditions match the lubricant's specifications.

The expected performance improvement should be specific, such as to achieve increased varnish or deposit control, extended relubrication intervals or enhanced lubrication properties. Assess the pros and cons of switching lubricants in terms of cost, compatibility, change-out procedures, etc.

To obtain the desired results, you may need to be more specific in terms of the lubricant's technical properties. The suggested parameters or attributes to consider include the viscosity required by the machine or components at the operating temperature, the film strength properties, the oxidation resistance, the compatibility of the new lubricant with the current lubricant as well as with the synthetic materials in the machine, the potential impact of typical contaminants around the machine, and any OEM or industry standards.

Please note that synthetics are not the only suitable lubricants for high temperatures. Mineral oils with strong refining and additive packages may work as well. Synthetic lubricants must

FLUID	STRENGTHS	WEAKNESSES	APPLICATIONS
Polyalphaolefins (PAOs)	High VI, high thermal oxidative stability, low volatility, good flow properties at low temperatures, nontoxic and compatible with mineral oils	Limited biodegradability, limited additive solubility, seal shrinkage risk	Engine oils, gear oils, bearing oils, compressor oils, high-temperature grease, lube-for-life applications
Diesters and Polyolesters	Nontoxic, biodegradable, high VI, good low-temperature properties, miscible with mineral oils	Low viscosities only, bad hydrolytic stability, limited seal and paint compatibility	Compressor oils, high-temperature grease, co-base stock with PAOs, bearing oils, gear oils, oil mist, jet engine oils
Phosphate Esters	Fire-resistant, biodegrades quickly, excellent wear resistance, scuffing protection	Low VI, limited seal compatibility, not miscible with mineral oils, moderate hydrolytic stability	Fire-resistant hydraulic fluids used in power plants, factories, marine vessels, mining, aircraft and mobile equipment
Polyalkylene Glycols (PAGs)	Excellent lubricity, nontoxic, good thermal and oxidative stability, high VI	Additives marginally miscible, not miscible with mineral oils, limited seal/paint compatibility	Refrigeration compressors, brake fluids (water soluble), fire-resistant fluids (water soluble), gas compressors (low gas solubility), worm and high-temperature gears, chain lube (clean burn off), metal-working and quenchants, H1 food-grade lubricants
Silicones and Perfluoropoly-ethers (PFPEs)	Highest VI, high chemical stability, excellent seal compatibility, very good thermal and oxidative stability	Worst mixed and boundary film lubrication properties, not miscible with mineral oils or additives	High-temperature fluids, specialty greases, lubricant-contacting chemicals, some brake fluids

also be changed. Their advantage over mineral oils is that the change intervals are extended. Typically, the higher the operating temperature, the greater the benefit of using a synthetic lubricant.

Base Stocks Used at High Temperatures

The charts on page 29 compare the operating temperature ranges of different base stocks for mineral and synthetic lubricants. Note that these ranges represent normal values according to the base stock type. They do not reflect the comparative life of the lubricant. At high temperatures, the lifespan of synthetics is much longer than similar mineral oil products. There are also more synthetic base stocks that can work at high temperatures, such as diesters, polyglycols, polyolesters, etc.

The table on the right can be used as a general reference for the maximum service application of greases according to the thickener in the formulation.

The chart at the bottom of the page compares how grease consistency changes with temperature in two greases: simple lithium and lithium complex. The latter is classified as a high-temperature grease even in formulas with mineral oil.

Strengths and Weaknesses of High-temperature Lubricants

When choosing a high-temperature lubricant, you must be aware of the potential drawbacks in order to select the best possible product. The table on page 30 provides the strengths and weaknesses of common synthetic lubricants.

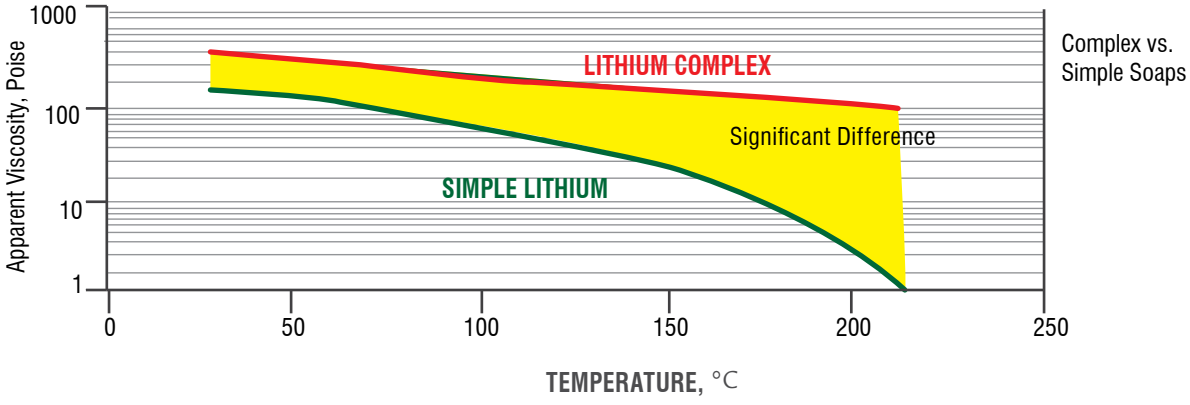
These charts are intended for general reference only, as various technologies in the marketplace may result in different specifications or performance.

TYPE	DROPPING POINT, °C	MAXIMUM SERVICE TEMPERATURE, °C
Simple Lithium	175	120 to 135
Lithium Complex	250+	150 to 175
Polyurea	250+	150 to 175
Calcium	90	60 to 70
Anhydrous Calcium	140	90 to 110
Calcium Complex	260+	190 to 220
Modified Clay	280+	190 to 220
Sodium	190	135 to 150
Sodium Complex	250+	170 to 190

Remember, when selecting high-temperature lubricants, follow the appropriate methodology to determine the right option according to your equipment conditions and reliability objectives. Always weigh the pros and cons, and analyze the expected economic and operational benefits so you can be sure you are choosing the correct lubricant for your high-temperature application. ■

About the Author

Alejandro Meza is a senior technical consultant with Noria Corporation. He has more than 20 years of experience in the lubricant industry, technical services, quality assurance, training, consulting and development in the United States, Brazil, Mexico and the Americas region. Contact Alejandro at ameza@noria.com to learn how Noria can help you choose the right lubricant for your high-temperature applications.



Comparison of How Grease Consistency Changes with Temperature in Two Greases

You observe rusted products after use of water miscible metal working fluid

It all started with our sales team receiving a call from one of the customers complaining about our metal working fluid (MWF). Our MWF was being used to produce mild steel (MS) square pipes. The sales person went to the customer's site and sent us this picture, showing components with clear rusting.

Obviously something was wrong. One of the expected functions of MWF is that the components should be protected against rust, which is not possible if plain water was used. We asked for sample of the undiluted MWF from drum. The laboratory tests showed the undiluted product meeting all the specifications. So, off we went with our team to understand the issue. What better way to analyze the problem than fish-bone diagram (Ishikawa diagram).

Material:

- The MWF, itself, was OK. This was confirmed by our quality control (QC lab).
- Water being used for dilution was tested in our lab and reported to have hardness 650 ppm. This was acceptable since our MWF was OK up to 1000 ppm.
- The components were of MS and our MWF was OK for MS.

Machine:

- The fluid circuit was found to be OK. The system had mesh installed to trap debris before fluid was sent to MWF sump.
- The nozzles during operation were in good condition ensuring that the components were properly wetted thus avoiding chances of untreated part of component liable to rusting. (The customer had 23 operating stations on their shop floor, each with two nozzles – all in good working condition).

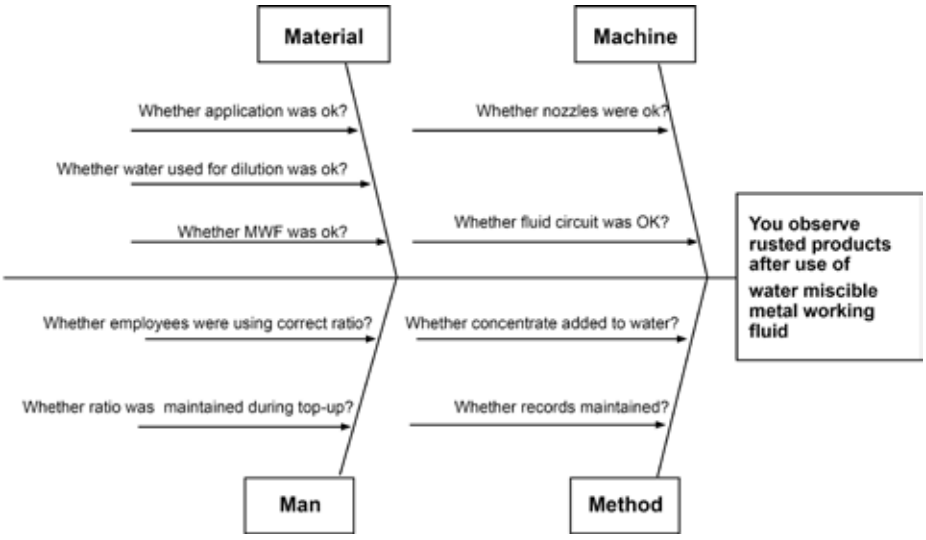
Man:

- The customer's employee confirmed that he was using 8% MWF + 92% water, as specified by us.
- He also confirmed that this ratio was being maintained even during top-up.

Method:

- The customer's representative confirmed that MWF was added to water and not vice-versa.
- It was also confirmed that all records were maintained.

There must be a catch somewhere. So we asked them to show us the records. And we found an unintelligent mistake.



Fish-bone diagram (Ishikawa diagram)

They were adding 8 lit of MWF to a drum of water, which were about 200 lit. They should have been taking 8 lit MWF for 100 lit of water or 16 lit for a drum. Entire emphasis was on "8 lit" and not on the quantity of water to which MWF was added; so the required percentage was not achieved. The customer rectified the mistake and upon next follow-up, no rusting of components was noticed.

What we had missed out in our fish-bone diagram was shelf life of MWF, though on post analysis the MWF was found to be within shelf life. Any emulsifiable product has quite short shelf life compared to general lubricants. A product which has outlived its shelf life forms poor/weak emulsion which can ultimately lead to loss of properties i.e. rust prevention, wearing of tool etc.

Similarly, ratio of MWF depends slightly on water hardness but within range specified in product datasheet. Lower dosage, again, does not give full benefit of the product. There are specific MWF to be used for cast iron and different ones for aluminum etc – use of wrong MWF may or may not give all desired benefits. Adding water to concentrate gives poor emulsion stability, MWF may separate out in the sump. This will lead to circulating fluid having lower percentage of MWF. This is very clearly evident with MWF floating on top of sump tank. Faulty nozzles may miss out part of component and hence lead to rusting.

Now, the above incident is only an example. The important thing is to carry out a thorough analysis using any good tool (we had used fish-bone/ Ishikawa diagram). We do not claim that the above diagram is exhaustive. If fish-bone diagram is used, brain storming to get most exhaustive is highly recommended. Once the cause is identified, it is very easy to work out a solution.

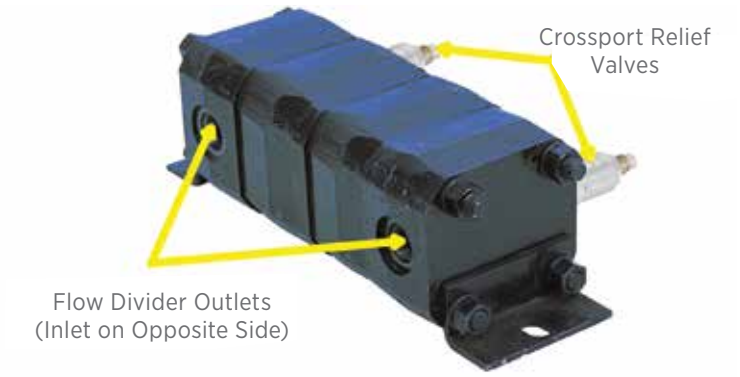
About the Author

Manoj Srivastava graduated as Chemical Technologist. He has 32 years rich experience in strategic planning, plant operations with proven abilities in enhancing production process operations, optimizing resources, capacity utilization, escalating productivity & operational efficiency while curtailing costs and expenses in various lubricant companies in India and Africa (Tanzania). He is experienced in carrying out lube surveys/ audits & lubrication training for end customers. Contact Manoj at manojsri64@gmail.com

What You Should Know About Hydraulic Flow Dividers

"The problem with flow dividers is that even new actuators will bypass different amounts of flow."

Flow dividers are common components in hydraulic systems. They are used whenever it is important to deliver equal flow to two or more actuators or sets of actuators in a series. There are two types of flow dividers: the motor type and the orifice type. This article will focus on the motor type, as shown on the right.

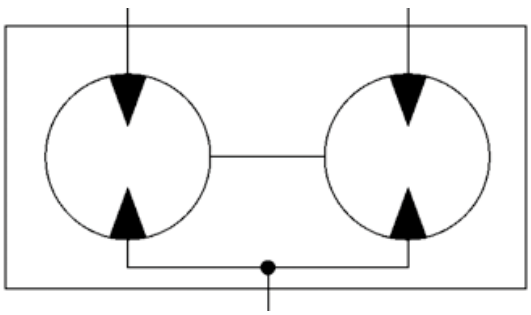


An example of a flow divider

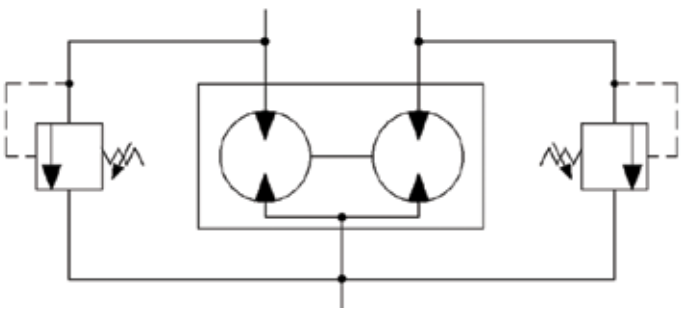
Motor Type

The motor type is comprised of two or more motors (usually gear motors) sharing a shaft. There is a single input shared by the motors and an output for each. The hydraulic symbol can be seen in the illustration below.

If a flow divider has two motors, each of the same displacement, it is called a 50-50 flow divider, as it delivers half the flow that is input out of each motor. However, this type of flow divider can be configured with as many motors as needed, and the displacement of each motor can be different. For example, if one motor has a displacement that is three times that of the second motor, it would be called a 75-25 flow divider. Any combination may be designed, but the most common are those with motors of equal displacement so the input flow is divided equally between each outlet to the actuators. If the actuators are also of



A flow divider schematic symbol



A flow divider symbol with crossport relief valves

equal displacement, this will ensure they all move at the same speed.

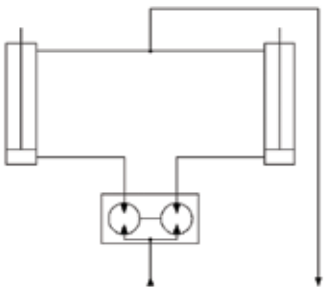
The problem with flow dividers is that even new actuators will bypass different amounts of flow. Regardless of how minuscule this difference in bypassing may be, the actuators can be significantly out of synch after only a small number of machine cycles due to the extreme tightness of the flow divider. This is where adjustments come into play.

Crossport Relief Valves

Adjustments are made via crossport relief valves. Many people assume the purpose of these valves is to absorb shock. While they will indeed absorb shock, their primary purpose is to allow some slippage to keep the actuators moving in synch. When the actuator that is bypassing the least amount reaches its stroke limit, the actuator that is bypassing somewhat more will not be quite at its limit. With the crossport relief valves in place, pressure can build in the line of the actuator that has reached the end of its stroke until the crossport opens. Flow can then continue to the slower actuator and enable it to reach its limit.

A lot of flow dividers come with crossport relief valves built in, but some do not. If the actuators are mechanically connected, it usually is advisable to either purchase a flow divider with built-in crossport relief valves or add a set of crossports to the assembly.

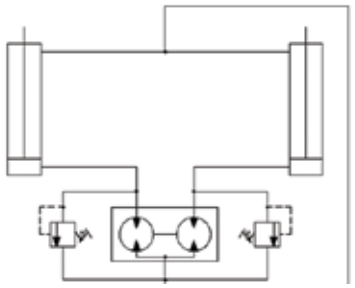
While speaking at a conference a few years ago, I met a woman from the Department of Transportation. After I had spoken, she introduced herself and said she had attended the conference in hopes of finding someone who could offer some advice on a ferry ramp that had recently been installed. Since my topic included hydraulic troubleshooting, she thought I might be able to assist.



The ferry ramp cylinder/flow divider configuration

The ferry ramp was a relatively simple hydraulic system but of a rather unique and expensive design. Two enormous cylinders were mounted on the ocean floor to lift and lower the ramp. Since the cylinders had to be installed by divers, each one cost more than $1 million.

After installation, the ferry ramp worked very well. The ramp would lift, the ferry would move under it, and then the ramp would lower onto the ferry so vehicles could



Crossports added to the original ferry ramp installation

be driven aboard. Once the ferry had been loaded, the ramp was lifted, and the ferry proceeded to the island.

After only a couple of months, significant vibration was observed. Before long, the ramp had to be shut down for fear the mechanical infrastructure would be damaged because it was twisting toward one side. Plans were made to replace one of the million-dollar cylinders after only a few months of operation.

The representative from the Department of Transportation was now asking me whether I had an idea of anything else that could be causing the vibration? I agreed to help and asked if she could provide some schematics of the system. She emailed me a file with the schematic. The design was about what I expected. Downstream of the power supply and four-way directional valve, a flow divider and two cylinders were shown, similar to the illustration at the top of page 24.

What I did not see on the schematic was a set of crossport relief valves at the flow divider. Often, crossport relief valves, while in place, may not be drawn on the schematic, so I asked her to verify their presence. It turned out the crossports had been omitted from the system, and the small difference in cylinder bypass had rendered them out of synch.

I recommended a set of crossports be installed so when the first cylinder reached the end of its stroke, its associated crossport would open and allow the second cylinder to complete its stroke before stopping the movement of the ramp, as illustrated on page 24. Once the crossport relief valves were added, the cylinders synched up and all vibration ceased. A million-dollar cylinder replacement was avoided by installing a $200 set of crossports.

Cautions and Recommendations

If crossports are built into the flow divider, they likely will come factory-adjusted. This will work fine for most applications, but they may not be as responsive as you would like. Actuator damage is also possible at high pressures because flow dividers have a tendency to amplify pressure to one side. Typically, when the flow divider and crossports are part of the original design, their recommended setting will be provided. In the absence of designer specifications, I recommend the crossports be set approximately 200-400 pounds per square inch higher than the pressure required to move the heaviest load at each output of the flow divider. ***ML***

About the Author

Jack Weeks is a hydraulic instructor and consultant for GPM Hydraulic Consulting. Since 1997 he has trained thousands of electricians and mechanics in hydraulic troubleshooting methods. Jack has also taught radio-wave propagation for the U.S. Air Force and telecommunications equipment operation and repair for the Central Intelligence Agency at American embassies overseas.

Understanding Your **Bearings Prior to Lubrication**

"A bearing number contains all the pertinent information needed to devise a best-practice maintenance strategy for the equipment."

The type of bearing selected for operation in a machine determines how it should be maintained for maximum equipment life. Of course, if you installed the bearing, you should know its type and configuration as well as its lubrication requirements prior to operation. Unfortunately, you often do not have the luxury of knowing which bearings are installed, especially with new or rebuilt equipment. This is when reading the bearing number and realizing what it is telling you will become important.

Understanding which bearing type is installed and about to be lubricated is one of the main issues facing lubrication programs today. Frequently, this is overlooked or not given a second thought. Grease-lubricated bearings seem to be a bigger challenge than oil-lubricated bearings, as the configuration tends to have a greater impact on grease than it does oil. This also leads to blindly applying grease to any Zerk fitting that may be apparent. However, just because a grease fitting exists on a machine does not mean it should be greased or have lubricant applied. In fact, greasing components can actually result in a shorter life for the equipment and induce a failure mode.

What You Should Know

To properly lubricate a bearing, you must first know some key information about it. This would include the bearing type, whether it has additional design features, if it should be lubricated, its size and speed, as well as if it is the original bearing or has been replaced.

The first place most people look to find this information is in a maintenance manual or on an equipment tag. Many manuals offer all the details you need with exploded views or parts lists. Bearings generally are listed by a set of standard numbers that identify all the specifics, allowing you to order a new bearing or determine proper relubrication activities.

A more recent trend is for an original equipment manufacturer (OEM) to provide a generic part number or claim the bearing is proprietary. This requires the end user to order spare parts from the OEM or call a technical center to obtain the necessary information.

In addition to maintenance manuals, there is often a vast

Examples of equipment tags

amount of information on the machine. The bearing type and operational data may be listed on metal plates commonly referred to as "tags." Although these are more readily found on equipment like pillow-block bearings and electric motors, some pumps, gearboxes and compressors may also have them. A shorthand code usually indicates which bearing is being identified on the tag. This typically is listed as drive end (DE), non-drive end (NDE) or opposite drive end (ODE).

You may also see inboard and outboard bearing or input and output. This refers to a bearing supporting a shaft through the piece of equipment. The motor's drive end is the side that the shaft is coupled to the component. The back or fan side is denoted as the non-drive end. Thus, the side closest to the motor or coupling is the drive or inboard side, while the other is the non-drive or outboard side.

Decoding Bearing Numbers

After the equipment tag has been located and the bearing numbers uncovered, you will see a series of numbers and letters. This code is the key to unlocking which type of bearing is in use within the machine. Depending on the manufacturer, the machine's age and the country in which it was made, the code may be displayed in different formats.

Perhaps the most widely used system is employed by SKF bearings. It utilizes a numeric code for the bearing's basic designation. This will contain many of the details you are most concerned about, including the roller type, size and configuration. A series of letters or numbers will also designate unique features, such as the use of shields or seals and if there are special clearances for this particular component. All of this information can be a goldmine when developing a reliability initiative, as each bearing will behave differently and may require different maintenance activities.

000	AAA	00	AAAA	0
Bore	Type	Width & OD	Cage Shields or Seals & Modifications	Internal Fit Up
Code	**Space No.**	**Common Symbols**	**Description**	
Bore	1, 2, 3	17 or 105	Inside diameter of bearing in milli-meters; refer to bearing catalog	
Type	1, 2, 3	BC	Ball bearing, single row, radial, non-filling slot	
		BL	Ball bearing, single row, radial, filling slot	
		BD	Ball bearing, double row, radial, non-filling slot	
		BF	Ball bearing, double row, radial, filling slot	
Width & OD	1, 2	00	6000 series bearing	
		02	6200 series bearing	
		03	6300 series bearing	
		04	6400 series bearing	
Cage Shields or Seals Modification	1, 2, 3	X	Manufacturer a standard bearing cage	
		P	Metal shield permanently fastened	
		S	Contact seal permanently fastened	
		G	Snap ring groove on OD with snap ring	
Internal Fit Up	1	3	Internal clearance greater than standard	

AFBMA Code System for Bearings

An example of a bearing number in this format would be 6203ZZ. This designation indicates that the bearing is a single-row, deep-groove ball bearing that is for light duty with a 17-millimeter bore and shielded on both sides.

The next designation is known as the Anti-Friction Bearing Manufacturers Association (AFBMA) code system. It has similar components in that it utilizes an alphanumeric system to indicate the bearing's dimensions and configurations. The code starts with the bearing's bore, which is followed by the type, width, outside diameter and any modifications, such as seals or shields. In this nomenclature, the bearing from the previous example would be denoted as 17BC02PP.

Both of these systems, along with a host of others, can be cross-referenced against each other. Published tables are available to assist you in looking up the details for each system. Your spare-parts vendor can help you check this information as well. It generally will be most important to identify these numbers when you are performing calculations for greasing or vibration data. They also can be useful when your equipment needs to be repaired and you want to replace a bearing with the same style or type.

Guidelines for Rebuilds and Repairs

Depending on the type of equipment, you may choose to perform rebuilds in-house. This can offer better control over which

replacement parts are selected and installed prior to the machine being placed back into service, which is especially critical when replacing bearings. While the same size bearing normally is put back into service, the bearing's configuration may change. Using a bearing that is different from the type listed on the equipment tag can result in a maintenance-induced failure.

An example of this would be switching from a bearing that must be periodically regreased to one that is sealed and should not be greased. If this sealed bearing is installed and there is no indication of it now being a maintenance-free bearing, someone may apply grease to the housing and pressurize the cavity, forcing grease into places where it shouldn't be. Over time, the grease can build up and cause a failure or contribute to a failure mechanism due to increased heat or drag. Therefore, whenever the replaced bearings are not the same as those that were installed initially, every effort should be made to document this in the computerized maintenance management system (CMMS) or on the equipment.

When repairs are made by an outside company, such as a rebuild shop, documentation should be provided detailing which bearing was replaced and what is now in the machine. Many shops can also make new equipment tags so the information on the tag can be kept up to date and accurate. Otherwise, an additional tag must be added to the machine stating it has been rebuilt and offering a shorthand account of what was done or where to find information regarding the rebuild. Working with the shop to create an efficient process for performing and documenting each rebuild will be key to knowing which replacement parts have been installed in your equipment.

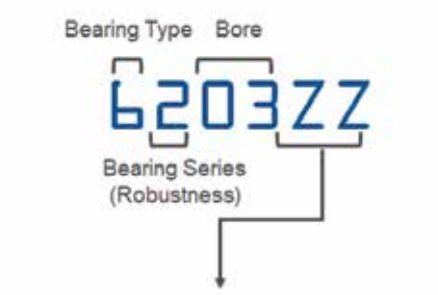
55%

of lubrication professionals can read a bearing number and understand what information it indicates, based on a recent survey at Machinery-Lubrication.com

When I serviced compressors, the work usually was completed after an equipment breakdown. The goal was to get it operating again as quickly as possible. This frequently led to corners being cut and broken parts being replaced with ones that weren't quite the same as the originals. When the machine would break down again, another technician might replace the part with something slightly different. This often resulted in a significant deviation from what the manufacturer intended or what was required for the machine to run at its peak efficiency. The same thing can happen when bearings are replaced. Although changing certain bearings or their configurations may produce some improvements, if it is done in a silo with no information disseminated to the rest of the organization, it can cause problems in the machine.

Replacement parts should be documented on a work order and recorded in the CMMS. While you likely won't want to update a bill of materials for a piece of equipment if you can't use the original parts, there should at least be some notes regarding whether a part has changed and why. This will require diligence by all parties involved. These documents have largely been converted to electronic forms, so it is much easier to get the information into the hands of the people who need it.

Finally, if you replace a bearing with one that doesn't require periodic relubrication, you can ensure greasing will not create an issue by replacing the grease fittings. This can be achieved during a rebuild and will involve pulling the current fitting and replacing it with a plug. Not only will this reduce the risk of someone applying grease where it isn't needed, but it can also be used by both in-house and contracted teams alike.



Z	Single Shielded
ZZ	Double Shielded
RS	Single Sealed
2RS	Double Sealed
V	Single Non-contacting Seal
VV	Double Non-contacting Seal
VR	Snap Ring and Groove
M	Brass Cage

SKF Bearing Numbers

With some attention and effort, you won't have to play a guessing game to know which bearings are inside your equipment and what that means to your organization. By doing a little homework, you can unlock a wide array of information to improve your lubrication program as well as your overall reliability. ***ML***

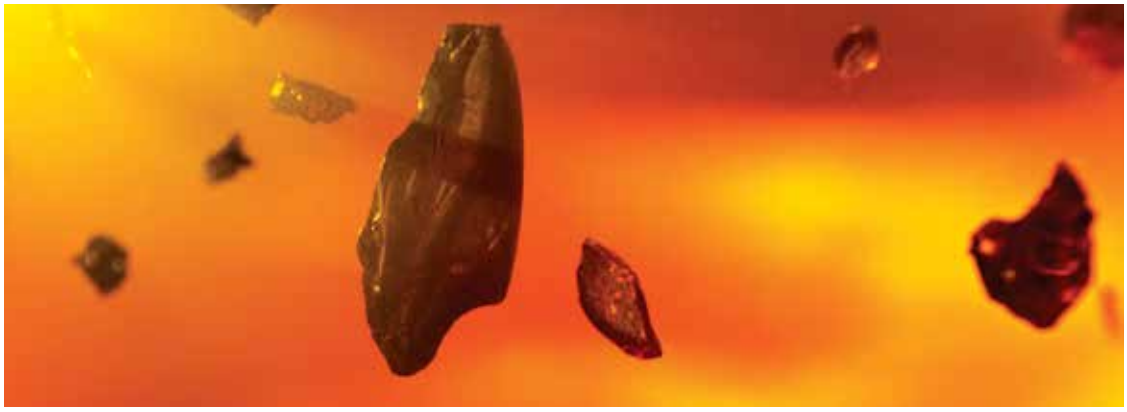
About the Author

Wes Cash is the director 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 Oil Analysis II and Machinery Lubrication I and II training courses. Wes holds a Machine Lubrication Technician (MLT) Level II certification and a Machine Lubricant Analyst (MLA) Level III certification through the International Council for Machinery Lubrication (ICML). Contact Wes at wcash@noria.com to learn how Noria can help you determine the best way to lubricate the bearings in your machines.

Devin Jarrett | Noria Corporation

Particle Counts: **What They Mean and How to Use Them**

"By better understanding the ISO cleanliness code, setting appropriate **targets and closely monitoring your particle counts, you can determine how dirty or clean your oil is.**"



When my wife and I started getting serious about the future during our love-struck dating days, we began talking about what kind of family we envisioned. We both wanted a large family and for our kids to be close in age in hopes they would have a closer bond when they became adults.

Fast forward a few years, and we had our first four children within five years. Little did we know that the impact of each additional child would be more of a multiplication factor than simple addition. When our youngest turned 5, we decided we wanted one more and chose to adopt a fifth child, knowing full well that life would double for us once again.

Much like the multiplication factor for how quickly our home requires a deep cleaning based on the number of children we have, how clean or dirty your oil is can be determined by multiplying the number of particles in the fluid, according to the cleanliness code developed by the International Organization for Standardization (ISO).

Understanding the ISO Cleanliness Code

To fully understand the ISO 4406 solid contaminant standard, you need to go back to the beginning. Surprisingly, this standard did not originate with ISO but rather the National Aerospace Standards (NAS) organization. During the 1960s, the NAS attempted to bring order to the chaos of particle counts in aircraft hydraulic fluids. The result was the creation of NAS 1638.

The first version of this standard utilized an optical microscope to size solid particles. All the particles within 1 milliliter of oil would be categorized into five size ranges: 5-15 microns, 15-25 microns, 25-50 microns, 50-100 microns and greater than 100 microns. A chart was used to

ISO CODE	PARTICLES PER MILLILITER > 10 µm	NAS 1638 & SAE AS4059F
26/23	140,000	
25/23	85,000	
23/20	14,000	
21/18	4,500	12
20/18	2,400	
20/17	2,300	11
20/16	1,400	
19/16	1,200	10
18/15	580	9
17/14	280	8
16/13	140	7
15/12	70	6
14/12	40	
14/11	35	5
13/10	14	4
12/9	9	3
11/8	5	2
10/8	3	
10/7	2.3	1
10/6	1.4	
9/6	1.2	0
8/5	0.6	00
7/5	0.3	
6/3	0.14	
5/2	0.04	
2/0.8	0.01	

Cleanliness Level Correlation Table

classify the oil's cleanliness with a range of 00 to 12, based on the number of particles in each size range. The lower the number, the cleaner the oil. Prior to this time, a coding system to quantify oil cleanliness had not been established. This method worked well and was largely accepted by industry through the 1970s and '80s.

With improved particle filters, the invention of automatic particle counters and the push for ISO 9000 during the '80s and '90s, several other attempts were made to create industry standards for cleanliness levels by the Society of Automotive Engineers (SAE), the Aerospace Industries Association of America (AIA) and others.

The improvements in particle filters tipped the scales of natural distribution. Filters became more efficient at removing larger particles, which made the larger size ranges less representative of the particle distribution in the oil. With this change in the natural distribution of particles, ISO decided it was no longer necessary to report the concentration of these larger particle ranges.

ISO 4406:87

Recognizing the importance of hydraulic oil cleanliness, the shortcomings of NAS 1638 and the deficiencies of other standards organizations, ISO aspired to create a standard that would more accurately reflect the concentration of particles. The organization also sought to make its classification or code easier to understand while expanding the standard to all lubricating fluids so there would be one accepted standard across all industries.

The process began by reducing the number of categories from five to two with an optional third. It was also decided to use a scale that would count particles of specific sizes and larger, moving away from the range approach. The representative particle sizes chosen were 2, 5 and 15 microns with the 2-micron category being optional. Unlike NAS 1638, which categorized all particle counts for the various classifications with a single number, ISO 4406 represented each size individually. An ISO 4406 code is always shown with the micron sizes listed from smallest to largest.

The second major modification involved changing the scale altogether. What would later become known as the Renard series table was born. The classifications spanned from 0.9 to 30, with each doubling from the lowest to the highest acceptable value. This approach was intended to make each step more meaningful and impactful. It also allowed for a simple method of expressing very small and large particle counts with a single value.

For example, a cleanliness code might be something like 18/14. This would indicate that there were somewhere between 1,301 and 2,500 particles larger than 5 microns and 81 to 160 particles larger than 15 microns. ISO later dropped the 0.9 code and started the chart at 1 when it was determined that obtaining this cleanliness level was highly unlikely and thus unreasonable to include it in the chart.

ISO 4406:99

In the 1990s, there was a push for industry to become ISO 9000 compliant. During this time, it was discovered that the current method for calibrating automatic particle counters (APCs) did not meet the requirements of the ISO 9000 standard. Previously, all APCs were calibrated according to ISO 4402 using Air Cleaner Fine Test Dust (ACFTD). During the process of becoming ISO 9000 compliant, it was determined that this calibration material was untraceable. The exact quantity and size of the particles in the ACFTD were unknown, resulting in inaccurate calibrations. The company that produced the ACFTD calibration fluid also announced that it would no longer be manufacturing the fluid. This led to ISO 11171, which utilizes ISO Medium Test Dust (ISO MTD) from the National Institute of Standards and Technology (NIST). NIST employs a scanning electron microscope (SEM) to accurately measure the number and size of particles down to 1 micron.

In addition to the lack of control over the calibration material, it was also discovered that the particle sizes being reported were

NUMBER OF PARTICLES PER mL		
More than	Up to and Including	Range Number
5,000,000	10,000,000	30
2,500,000	5,000,000	29
1,300,000	2,500,000	28
640,000	1,300,000	27
320,000	640,000	26
160,000	320,000	25
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8
0.64	1.3	7
0.32	0.64	6
0.16	0.32	5
0.08	0.16	4
0.04	0.08	3
0.02	0.04	2
0.01	0.02	1

An ISO 4406 Chart

not the same. Depending on the type of APC used by the laboratory, there were inconsistencies when measuring the same size particles. What was a 5-micron particle in an optical APC (calibrated to ISO 4402)

SAE AS4059 Rev. E (Cleanliness Classes for Cumulative Counts – Particles per 100 mL)

(1)	>1 µm	>5 µm	>15 µm	>25 µm	>50 µm	>100 µm
(2)	>4 µm	>6 µm	>14 µm	>21 µm	>38 µm	>70 µm
Size Code Classes	A	B	C	D	E	F
000	195	76	14	3	1	0
00	390	152	27	5	1	0
0	780	304	54	10	2	0
1	1560	609	109	20	4	1
2	3120	1217	217	39	7	1
3	6250	2432	432	76	13	2
4	12500	4864	864	152	26	4
5	25000	9731	1731	306	53	8
6	50000	19462	3462	612	106	16
7	100000	38924	6924	1224	212	32
8	200000	77849	13849	2449	424	64
9	400000	155698	27698	4898	848	128
10	800000	311396	55396	9796	1696	256
11	1600000	622792	110792	19592	3392	512
12	3200000	1245584	221584	39184	6784	1024

(1) Size range, optical microscope, based on longest dimension as measured per ARP598 or APC calibrated per ISO 4402:1991

(2) Size range, APC calibrated per ISO 11171 or electron microscope, based on projected area equivalent diameter

(3) Classes and contamination limits identical to NAS 1638

was a 6-micron particle using an SEM. This led to the need for a new calibration medium and standard, thus the creation of ISO 11171 for calibration and ISO 4406:99 for reporting. ISO was presented with a major decision to make: Should there be two standards based on the type of APC and method of calibration, or should the current standard be adjusted so it would be compatible with both calibration methods and APC types? It was decided that two standards would create confusion, so the alterative of developing a compatible standard was accepted.

With subsequent accuracy improvements in microscope technologies, ISO realized that the reporting of particles smaller than 5 microns was becoming more reliable. Thus, a third micron size was added as an option to the cleanliness code.

What It All Means

ISO concluded that the concentration of smaller particles was of greater concern than the larger ones. The organization determined that 4-, 6- and 14-micron particles provided the best representation of the particles closest to a lubricant's film thickness. These particle sizes cause the most damage to moving surfaces and thus should be closely monitored.

The method used to calibrate the automatic particle counter should also be considered. This rarely will be presented in any oil analysis report, so you will need to contact your lab or equipment manufacturer to

find out which ISO calibration standard was employed. Again, the most current calibration standard is ISO 11171.

SAE AS4059F

While ISO 4406:87 and 4406:99 have been widely accepted, there is still a significant portion of industries and countries that use SAE AS4059. Several revisions have been made to this standard over time. The most current revision of this standard occurred in September 2013, which is SAE AS4059F. The reporting of this standard utilizes the same table as the NAS 1638 standard shown.

The most current revision has added optional reporting methods to include the ability to report on the specified cumulative particle size count instead of a single code that represents the cleanliness of the oil. You will be able to identify if the code is specific to a cumulative particle size count by a suffix letter after the class. The letter will be between A-E and will tell you what cumulative particle size count category the code represents. For example, a Class 6B would indicate how many particles are greater than 5 microns (optical microscope) or 6 microns (most APCs).

Be careful, though, as the revision of AS4059 may result in different cleanliness classes from those obtained with previous versions whenever the class was specified without any letter size suffix and in some cases when the class was specified with a suffix. Cleanliness classes with no suffix from previous versions of AS4059 are based on particles greater than 6 microns, whereas classes from this revision are based on the number of particles in each of the size ranges except the smallest, 4 microns.

AS4059 now permits contamination limits to be identified in a variety of ways:

- Identical to NAS 1638 — For example, AS4059 Class 8 is the same as NAS 1638 Class 8. The size of particles counted varies depending upon whether an optical microscope or light blockage APC is used.
- Cumulative count above a specified size — Examples: AS4059 Class 8A, AS4059 Class 8B
- Differential counts for various sizes — Examples: AS4059 Class 8B-D or Class 8A-D
- Different classes for cumulative counts of particles greater than a particular size range — An example would be 7B/6C/5D or 7B/4C.

There isn't a right or wrong cleanliness standard to use when setting up a lubrication program. The important thing is that you follow a standard and use it correctly.

Setting Cleanliness Targets

Unlike most of the information in an oil analysis report, particle counts should not use the same trending methods of iron, silica, copper, etc. You will want to watch which direction your particle counts are moving, but this alone should not be used as a failure indicator. There are just too many variables in play. The difference between codes can be one particle or several hundred or thousand particles. For this reason, it is recommended to set cleanliness targets and track particle counts or ISO codes relative to those targets.

Both cautionary and critical alarm limits should be established. Ideally, the cautionary limit will be your target or one code above. The alarm limit might be two or three codes above your target. These limits will help make your decision-making process easier if you should consider cleaning your oil with a filter cart or performing a full drain, flush and fill.

Setting cleanliness targets for each lubricant offers many benefits. The main advantage is the extension of overall machine life, which can lower maintenance costs and increase production cycles. Case studies have shown particle contamination to be the leading cause of machine failures. Therefore, it only makes sense to monitor the concentration of these particles.

Other benefits of setting cleanliness targets include increasing the awareness and visibility of the efforts being made through various lubrication activities. Establishing a moderately aggressive target for your lubricants will require everyone to follow lubrication best practices. It can also create a common goal among maintenance and operations personnel for plants in which the lubrication duties are spread across multiple departments or divisions.

Since not all machines are treated equally, it will be important that cleanliness targets be set appropriately for each machine. For example, hydraulic and turbine systems are far more sensitive to solid contaminants than a gearbox or process pump. The oil's viscosity will also play a significant role. The higher the viscosity, the more difficult it will be to remove particles.

The machine's environment can impact your cleanliness targets as well. A hydraulic system in a controlled environment, such as a pharmaceutical production area, may have a different target than the same hydraulic system inside a cement plant. More potential contaminants in the air can increase the need to maintain cleaner oils, which will require a more aggressive standard. A high-contaminant area may also demand a larger investment to help maintain the appropriate oil cleanliness levels.

Most original equipment manufacturers (OEMs) provide general lubricant cleanliness levels for their machines to meet the warranty expectations. While these OEM targets make for a great starting point, they often do not take into consideration your specific environment or plant reliability goals.

If your facility has a centralized lube room, set an overall cleanliness target for each oil type. When establishing these targets, begin with the most sensitive machine component using each oil and work through the same process for each machine.

Once you have set your cleanliness targets, take a stepped approach to cleaning your oils. Starting with a high-efficiency filter at a small micron level would be expensive. Instead, slowly progress to smaller micron filters over time. When you reach your goal, you can then maintain this cleanliness level with higher efficiency filters.

By better understanding the cleanliness code, setting appropriate targets and closely monitoring your particle counts, you can determine how dirty or clean your oil is, which should then help you achieve your overall reliability goals.

References

Fitch, E.C. (1976). "The New ISO Cleanliness Code – Let's Use It." Fluid Power Research Conference.

Day, M. "What Happened to NAS 1638?" *Practicing Oil Analysis*, December 2002.

International Standard 4406:87. International Organization for Standardization.

International Standard 4406:99. International Organization for Standardization.

About the Author

Devin Jarrett is an account manager at Noria Corporation. He holds a Level II Machine Lubrication Technician (MLT) certification and a Level III Machine Lubricant Analyst (MLA) certification through the International Council for Machinery Lubrication (ICML). Contact Devin at djarrett@noria.com to learn how Noria can help you establish cleanliness targets for your lubricants.

The "Lube-Tips" section of *Machinery Lubrication* magazine features innovative ideas submitted by our readers.

Paper Thermometer Can Reveal Temperature Spikes

In time-critical situations where real-time infrared thermography is impractical and thermocouple/recording equipment cannot be installed, consider temperature-sensitive tapes. These tapes are manufactured in a variety of sensing ranges and will clearly record the peak temperature that a machine area reached since the tape was first applied. A quick visual check is all it takes to read the "paper thermometer."

Quit Replacing Oil Seals

If you are constantly changing gearbox oil seals, check the gearbox breather for plugging. When breathers become clogged, internal gearbox pressure can build and find its way out through oil seals, creating a false impression that the seal has failed. This can become more problematic during summer months.

Try Oil Mist for Better Contamination Control

In bearing applications where high contamination levels are a concern, consider converting grease lubrication systems to oil mist lubrication. Oil mist systems are slightly pressurized, helping to exclude contaminants. Use a pure mist system for rolling-element bearings and purge mist for gearboxes and journal bearings.

Why Dispersancy Is Crucial for Engine Oils

Coolant contamination, overextended oil drains, water contamination, high blow-by, long idling, high elevation and exhaust gas recirculation can all result in the loss of dispersancy in motor oils. This loss can cause engine deposits, sludge, impaired lubrication and oil flow. ***ML***

Did You Know?

Additional tips can be found in our Lube-Tips email newsletter. To receive the Lube-Tips newsletter, subscribe now at machinerylubricationindia.com

Have Some Tips?

If you have a tip to share, email it to admin@machinerylubrication-india.com

TEST YOUR KNOWLEDGE

This month, *Machinery Lubrication* 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. What percentage by volume of SAE 10W-30 is SAE 30?

A) 0%
B) 25%
C) 50%
D) 75%
E) 100%

2. Magnetic plug inspections:

A) Crudely indicate presence of iron wear
B) Indicate water contamination
C) Indicate copper wear rates
D) Indicate oil circulation rates
E) Indicate corrosion is occurring

3. A filter's differential pressure slowly increases over time. What's wrong?

A) The filter has burst
B) The filter bypass valve is open
C) ISO particle counts should be taken
D) Filter differential pressure does not increase
E) Nothing, it's removing dirt

ANSWERS

1. A

SAE 10W-30 and SAE 30 are totally different oils. SAE 10W-30 is a multigrade oil in which a viscosity-index improver has been added so the oil can be utilized over a wide range of temperatures. SAE 10W-30 oil works as SAE 10 at cold temperatures and as SAE 30 at high temperatures.

2. A

Magnetic plug inspections can indicate the presence of ferrous wear (iron and steel). The magnetic plug will hold ferrous wear particles but not other particles.

3. E

This is an indication that the filter is functioning properly. On the other hand, if the oil is contaminated and the differential pressure is continuously low, this indicates the filter is not functioning (perhaps in bypass).

Lubrication India

FOCUSSED events

The 2nd edition of MatDispens organized by Focussed Events from 14th-16th November 2019 at the Bombay Exhibition Center, Mumbai. The event concluded with keen interest from a growing user base of quality-conscious product manufacturers. With a comprehensive range of solutions for adhesive and sealant dispensing, metering and mixing technologies and precision solutions, it offered visitors a single technology-type grouping of providers that enabled visitors to have the kind of market insight that is just not possible to get at other engineering fairs. For the first time, the ever-important subject of Industrial Lubrication was taken up at "Lubrication India", a co-located theme pavilion at the show. The event hosted Expert Talks by renowned Industry

authorities sharing views and innovations.

The event was attended by 45 exhibitors from Dispensing and Dosing Systems, Dispensing Automation, Adhesive Tapes, Conventional and Speciality Lubricants and Lube Systems and 1503 visitors from Automotive including EV, Packaging and Electronics Manufacturing, Battery, PCB Manufacturers, Consumer goods and Home appliances, Lighting and LED Manufacturers, Food Packaging Industry, Medical Equipment Manufacturers, among others.

X Global Lubricant Week 2019

Global Lubricant Week is a premier annual event for the European downstream petroleum industry. The event has evolved into the highest-profile industry event not only on the Russian but also on the global stage. The primary objective of the Global International Lubricants Week is to set up a direct dialogue between lubricant manufacturers and major customers, identify lubricant demand trends and major changes in the demand components, and encourage cooperation between lubricant developers and manufacturers.

From October 8 to 11, Radisson Royal Moscow Hotel was the venue of the X Global Lubricant Week. The conference hosted a number of events, including the X "International Lubricant Conference 2019", X "Global Grease Summit 2019", X Specialized Exhibition "Services and Equipment for the Lubricant Market 2019", "Lubricants Awards 2019" and evening reception hosted by LUKOIL Lubricants Company, the General Sponsor of the Event. The conference was attended by over 600 participants.

GULF OIL AND PIAGGIO JOIN HANDS TO LAUNCH LUBRICANTS FOR COMMERCIAL VEHICLES

Gulf Oil Lubricants India recently inked a pact with Piaggio Vehicles to market co-branded lubricants for commercial vehicles. The new products have been co-developed for the entire range of commercial vehicles, including the ones conforming to the upcoming BS-VI emission norms.

"This (tie-up) helps us to further grow our business in OEM segment as well as expand our business in the three-wheeler category," Gulf Oil Lubricants MD Ravi Chawla said in a statement. Through this partnership, Piaggio customers will be able to avail top of the line products to enhance the performance of their vehicles and together, the companies will be able to strengthen the usage of these products with their reach and service initiatives, he added.

"Gulf Oil's technical expertise based on its world-class R&D setup and manufacturing facilities in India will certainly provide superior value to 27 lakh Piaggio customers," Piaggio Vehicles CEO & MD Diego Graffi said.

THE NOVEL METHOD TURNS PLASTIC WASTE INTO LUBRICANTS

Scientists have developed a new method for upcycling single-use plastics into high-quality liquid products, such as motor oils, lubricants, detergents and cosmetics. The advance by researchers, including those from North-western University in the US, also improves on current recycling methods that result in cheap, low-quality plastic products.

The catalytic method, described in the journal ACS Central Science, serves a one-two punch by removing plastic pollution from the environment and contributing to a circular economy. The researchers noted that each year, 380 million tonnes of plastic are created worldwide. As the plastics market continues to increase, many analysts predict production could quadruple by 2050, they said. More than 75 per cent of these plastic materials are discarded after one use. Many of them end up in our oceans and waterways, harming wildlife and spreading toxins.

While plastics can be melted and reprocessed, this type of recycling yields lower-value materials that are not as structurally strong as the original material. Examples include down-cycling plastic bottles into a moulded park bench, the researchers said. When left in the wild or in landfills, plastics do not degrade because they have very strong carbon-carbon bonds. Instead, they break up into smaller plastics, known as microplastics. The catalyst consists of platinum nanoparticles - just two nanometers in size - deposited onto perovskite nanocubes, which are about 50-60 nanometres in size. The team chose perovskite because it is stable under the high temperatures and pressures and exceptionally good material for energy conversion. Under moderate pressure and temperature, the catalyst cleaved plastic's carbon-carbon bond to produce high-quality liquid hydrocarbons, the researchers said.

ITC Limited

Lubrication INSTITUTE
www.lubrication-institute.com

Lubrication Institute recently conducted a 3 day training on Essentials of Machinery Lubrication for ITC Limited PSPD, Sarapaka (India). Essentials of Machinery Lubrication course provide the foundational skill sets for applying best lubrication practices and product knowledge.

The training was a great success as the participants enhanced their knowledge on various topics like industrial lubricants, machinery lubrication, contamination control and oil sampling. ICML Certification exam was also conducted, where majority of the participants joined the elite group of certified professionals. For more details on this training program and other trainings,visit - http://lubrication-institute.com/

UPCOMING EVENTS

☑ Mark Your Calendar

JANUARY 2020
28 - 30
TAE 22nd International Colloquium Tribology, Stuttgart / Ostfildern, Germany

FEBRUARY 2020
17 - 21
24th ICIS World Base Oils & Lubricants Conference, London, UK

MARCH 2020
08 - 10
Petroleum Packaging Council Spring Meeting & Tradeshow 2020, San Antonio, Texas, USA

APRIL 2020
02 - 04
ILMA Engage Spring Conference, Asheville, North Carolina, USA

APRIL 2020
21 - 22
UNITI Mineral Oil Technology Congress, Stuttgart, Germany

APRIL 2020
21 - 23
SAE WCX, Detroit, Michigan, USA

APRIL 2020
25 - 28
ELGI 32nd Annual General Meeting, Hamburg, Germany

BASE OIL REPORT

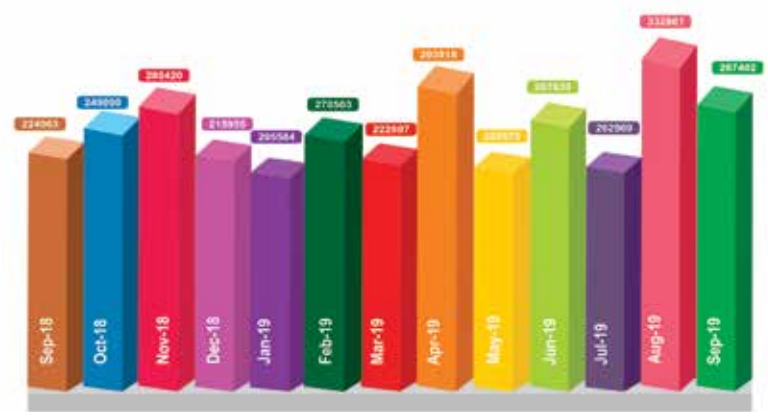
Indian government is focusing on increased use of bio-fuels and raising domestic crude oil and gas production to reduce imports. India needs to bring down its oil import dependence from 77 per cent in 2013-14, to 67 per cent by 2022. But with consumption growing at a brisk pace and domestic output remaining stagnant, India's oil import dependence has risen from 82.9 per cent in 2017-18, to 83.7 per cent in 2018-19. For the current fiscal, it projected crude oil imports to rise to 233 million tones and foreign exchange spending on it to marginally increase to USD 112.7 billion.

The Indian domestic market Korean origin Group II plus N-60–70/150/500 prices at the current level is marginally up for lighter grades and heavier grades. As per conversation with domestic importers and traders prices for N – 70/ N- 150/ N - 500 grades and at the current level are quoted in the range of Rs. 41.55 – 42.10/42.55 – 43.05/48.50 – 48.90 per liter in bulk plus 18% GST as applicable. Discounts being offered for sizeable quantity. The above mentioned prices are offered by a manufacturer who also offers the grades in the domestic market, while another importer trader is offering the grades cheaper by Rs.0.30 – 0.35 per liter on basic prices. Light Liquid Paraffin (IP) is priced at Rs.43.50 – 43.65 per liter in bulk and Heavy Liquid paraffin (IP) is Rs.50.60 – 50.75 per liter in bulk respectively plus GST as applicable.

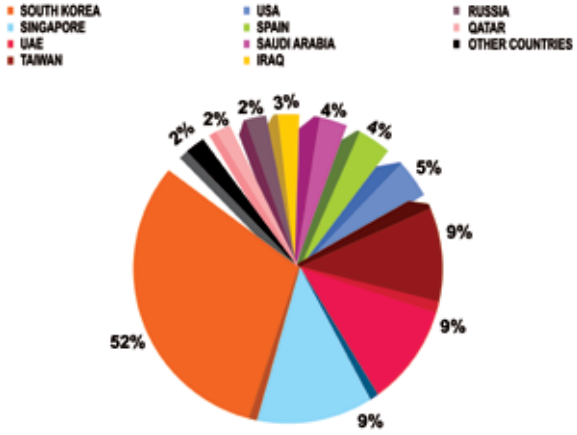
In the month of September 2019, India imported 287402 MT of Base Oil, India imported the huge quantum in small shipments on different ports like 179461 MT (62%) into Mumbai, 29210 MT (10%) into JNPT, 25579 MT (9%) into Chennai, 23530 MT (8%) into Pipavav, 11914 MT (4%) into Hazira, 9364 MT (3%) into Mundra, 5054 MT (2%) into Kandla, 2888 MT (1%) into Kolkata and 402 MT into Other Ports.

Dhiren Shah
(Editor – In – Chief of Petrosil Group)
E-mail- dhiren@petrosil.com

Month wise import of Base Oil in India



Origin wise Base Oil import to India, Country and %- September 2019



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

Month	Group I - SN 500 Iran Origin Base Oil CFR India Prices	Napthenic Base Oil HYGOLD L 500 US Origin CFR India Prices	N- 70 South Korea Origin Base Oil CFR India Prices	Rubber Process Oil (Aromatic Extract) (Drums) Iran Origin CFR India Prices
September 2019	USD 620 – 630 PMT	USD 695 – 705 PMT	USD 625 - 635 PMT	USD 360 – 365 PMT
October 2019	USD 620 – 635 PMT	USD 695 – 705 PMT	USD 625 - 635 PMT	USD 360 - 365 PMT
November 2019	USD 605 – 615 PMT	USD 680 - 690 PMT	USD 610 - 620 PMT	USD 345 - 350 PMT
	Since September 2019, prices have decrease by USD 15 PMT (2%) in November 2019.	Since September 2019, prices have fall down by USD 15 PMT (2%) in November 2019.	Since September 2019, prices have decrease by USD 15 PMT (2%) in November 2019.	Since September 2019, prices have dipped down by USD 15 PMT (4%) in November 2019.

PILOT (Practical Industrial Lubrication Orientation Training)

An accessory and activity based onsite practical lubrication training

PILOT is a skill based lubrication training program specifically designed for lube technicians, operators and shop floor associates. The objective of this training program is to upgrade the skill of technicians who actually perform the lubrication and inspection tasks. This training program is a combination of classroom as well as onsite practical training (activity and accessory based). The main focus of the training program is to illustrate how to perform various lubrication related tasks effectively, effciently and safely.

Main contents of the course include:

- Basics of lubrication
- Contamination control
- Hands on training for handling lubricants
- Sampling
- Field inspection of lubricants

Lubrication INSTITUTE
www.lubrication-institute.com

Phone : +91-657-2383238
Mobile : +91-9431117604
Email : info@lubrication-institute.com
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