September - October 2024

# Machinery Lubrication

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# BIODEGRADABLE ENGINE OILS

# Publisher's Note

The impressive success of Indian athletes at the Paris 2024 Paralympics, underscores the significance of perseverance, teamwork, and strategic planning in achieving remarkable results on the global stage. This achievement serves as a valuable analogy for industrial maintenance, which also requires a comprehensive approach that combines different strengths—particularly advanced technologies like vibration analysis, oil analysis, and other technologies—to achieve optimal machinery health.

In today's competitive environment, constant innovation is crucial. Industries must refine their strategies by utilizing data and technology, much like athletes who monitor performance metrics to stay at their peak. In machinery maintenance, the integration of vibration analysis and oil analysis provides a more complete and accurate picture of machine health. This combined approach helps identify potential issues before they escalate into major failures, thereby minimizing costly downtimes.

India's ongoing digital transformation across various sectors highlights the importance of adopting new technologies to maintain a competitive edge. The industrial sector, particularly in lubrication and maintenance, can benefit from advancements such as smart cities and AI-driven automation. Embracing these cutting-edge tools can significantly enhance performance and reliability in machinery maintenance.

Sustainability is another critical factor, exemplified by national initiatives like the National Green Hydrogen Mission. As industries worldwide shift towards greener solutions, the adoption of biodegradable lubricants reflects a commitment to eco-conscious practices. These lubricants not only reduce environmental impact but also ensure regulatory compliance without compromising performance.

Addressing issues such as shear-stress-induced deposits in bearings requires going beyond traditional methods. Specialized monitoring techniques, integrated with temperature and vibration checks, are essential for detecting hidden threats early and preventing long-term damage. This approach parallels athletes refining their techniques to achieve better performance.

The ongoing discussion between predictive and proactive maintenance is relevant for optimizing maintenance strategies. Instead of choosing one over the other, industries should combine both approaches to achieve the best outcomes. Predictive maintenance forecasts potential failures, while proactive maintenance ensures consistent care, ultimately minimizing downtime and extending the lifespan of machinery.

Tribology—the science of friction, wear, and lubrication—continues to be vital in modern lubrication strategies. From its early days with pioneers like Leonardo da Vinci to contemporary advancements, tribological insights help industries refine their approaches to reduce wear and enhance machine longevity, similar to how athletes perfect their techniques for improved performance.

The nuclear power industry faces unique challenges in maintaining proper lubrication, dealing with factors like radiation, contamination, extreme temperatures, and difficult access. Innovations such as radiation-resistant lubricants, advanced filtration systems, and robotic maintenance are critical in ensuring safety, reliability, and efficiency—demonstrating the value of adopting cutting-edge solutions in even the most demanding environments.

As we explore the insights in this issue of Machinery Lubrication India, let us draw inspiration from the success of athletes and national initiatives. The key to success in machinery maintenance lies in integrating the right technologies, strategies, and sustainable practices. This approach not only optimizes machine performance but also contributes to a more sustainable and efficient future. We encourage our readers to provide feedback, contribute articles and case studies, and continue their support as advertisers and subscribers to help us enhance the content and layout of the magazine.

Warm regards,
Udey Dhir

# HOW VIBRATION AND OIL ANALYSIS COMPARE AND CONTRAST

The condition-monitoring universe consists of a myriad of tools and technologies that are available to help detect and remediate machine reliability problems. No single tool comes close to doing it all, circumventing the need for all others. Everything depends on using these tools at the right time, the right place and in the right way.


These tools include our senses (used in inspection), oil analysis, vibration, thermography, motor current, and ultrasound. Because of the broad swath of science and function related to their use, the application and benefit of these methods are frequently misunderstood. For instance, years ago the following statement was published in a major trade publication in an article written by a vibration expert:

"In a purely technical sense, lubricating oil analysis is not a predictive maintenance tool. Rather it is a positive means of selecting and using lubricants in various plant applications. This technique evaluates the condition of the lubrications, not the condition of a machine or mechanical system."

Needless to say, I was stunned to read these words and immediately fired off an email to the author followed by a telephone conversation. I strongly encouraged him to attend one of our oil analysis courses, even going so far as to giving him a complimentary pass. He never did.

That experience punctuates the importance of good training across the many condition-monitoring disciplines. At minimum, there is a need for awareness. In such a dynamic era of "digital-this" and "wireless-that", continuing education is an endless quest.

This article primarily addresses two specific technologies that collectively represent a large portion of the annual spend on condition monitoring: oil analysis and vibration. They are not competitive or alternative methods. Instead, they should be viewed as collaborative.

They are powerful when fully and skillfully deployed. Used alone, they leave gaping holes on the state of health of our machines.

## The Power of Inspection

I've written extensively on the power of inspection to exploit our keen senses and the supercomputer in our head. Our sense of sight (or "eyeometer") is not rivaled by any optical camera technologies available today. In perhaps the most powerful "camera" of all, we use our senses to continuously examine our surroundings as we drive through the streets of our cities, subconsciously taking mental “snapshots” of what we see. Photons instantly alert us to dashboard data, traffic conditions, stop lights, pedestrians, and road hazards. Vehicle sounds and horns flow more data to our brain to process. Our tactile senses are applied to the pedals and movement of our vehicle as we turn, change acceleration, and course along undulating pavement conditions.

We process this data to make real-time changes in the control of our vehicle (steering, braking, acceleration). Why do I bring this up? When you put technology and instruments in the hands of people, they begin to trust their own senses less.

Despite all that we can and should extract by the power of inspection, our machines are largely exoskeletons made of cast iron and plate steel. Photons will not penetrate these barriers, but we can instead extract the data we need from other methods including oil analysis and vibration analysis.

But, aided by the use of sight glasses, along with audible sounds and the sense of touch, we can also use inspection to pick up critical oil-analysis and vibration data.

## Turning On the Voice in Your Oil

Oil touches the most critical and concerning surfaces in our machines. These include the frictional zones in our bearings, gears, pistons, and cams. As a common medium, it’s darn hard for a machine to fail or have a failure-inducing condition without the oil knowing about it first.

Just name your poison: corrosive agents, misalignment, overloading, material defects, lubricant starvation, wrong viscosity, dirty/wet oil, etc. — something will show up in the oil. It’s like a flight data recorder.

Let’s take particles for example: They are known to be both a major cause of failure (abrasion, contact fatigue, stiction, erosion) and a major consequence of failure (wear debris), regardless of the cause. So, if particles are the cause and/or effect of failure, wouldn’t we want to be rigorously monitoring them in our lubricants?

Consider this: If our machine’s lubricant is tested and found to be extremely clean, what can we conclude about the health of our gears and bearings?

There are exceptions, of course, and oil analysis doesn’t alert you to certain well-known failure modes, such as machine imbalance, shaft cracks, misalignment,-looseness, soft foot, and resonance. However, these conditions soon transition through failure stages to produce wear debris along the way.
Wear debris are excavated particles from bearing and gear surfaces due to mechanical impact and sliding conditions. These particles will trigger analysis alarms.


Catching abnormal wear and critical machine faults long before catastrophic-failure is one of the main advantages of oil analysis. If accelerated abrasive wear suddenly occurs in a bearing with 90% remaining useful life (RUL), this can be detected and the condition corrected. In


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**Machinery Lubrication India** Volume 73 - Issue 5, September-October 2024 is published bi-monthly by VAS Tribology Solutions Pvt. Ltd. Operation Office:213, Ashiana Centre, Adityapur, Jamshedpur-831013, India.

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contrast, abrasive wear may actually attenuate bearing and gear vibration until so much material is lost and precipitous failure commences.

Palo Verde Nuclear Generating Station found that "for oil lubricated bearings the oil analysis results usually show up earlier than the vibration indications. If the bearings removed for only oil analysis alarms had been allowed to run, the vibration symptoms would have eventually shown up."

The pie chart in their report (presented to the Vibration Institute), shows that oil analysis detected bearing faults 40% of the time not reported by vibration, while vibration detected bearing issues 33% of the time not reported by oil analysis.

***Only 27% of the time did both technologies see bearing faults in unison.***

For rolling element bearings, Palo Verde claimed to pick up incipient failure usingwear-debris analysis 18 months out, in contrast to vibration, which typically detected failures only one month out using Spike Energy. Similarly, a Monash University study induced various failure modes in gear boxes and reported that oil analysis caught the threatening conditions on average 15 times sooner than vibration analysis. They also pointed out that certain types of failures we reundetected by oil analysis. They also pointed out that certain types of failures were undetected by oil analysis.

A well-known disadvantage of oil analysis is the requirement to pull a sample that needs to be packaged and sent off to a commercial lab. At times, several days can pass before data arrives on the client's dashboard.

However, many modern oil analysis programs include the use of portable instruments and, for certain machines, online oil sensors. Onsite oil analysis lab care also common that allow tests to be run at the plant the same day.

## The Power of Vibration Analysis

It is widely known that vibration analysis has limited use in particular applications involving slow-moving, reciprocating, hydraulic, and articulating machines. Even journal bearings and multistage gearboxes can pose real challenges for vibration analysis.

That said, vibration analysis is highly important — almost foundational — to machine condition monitoring.

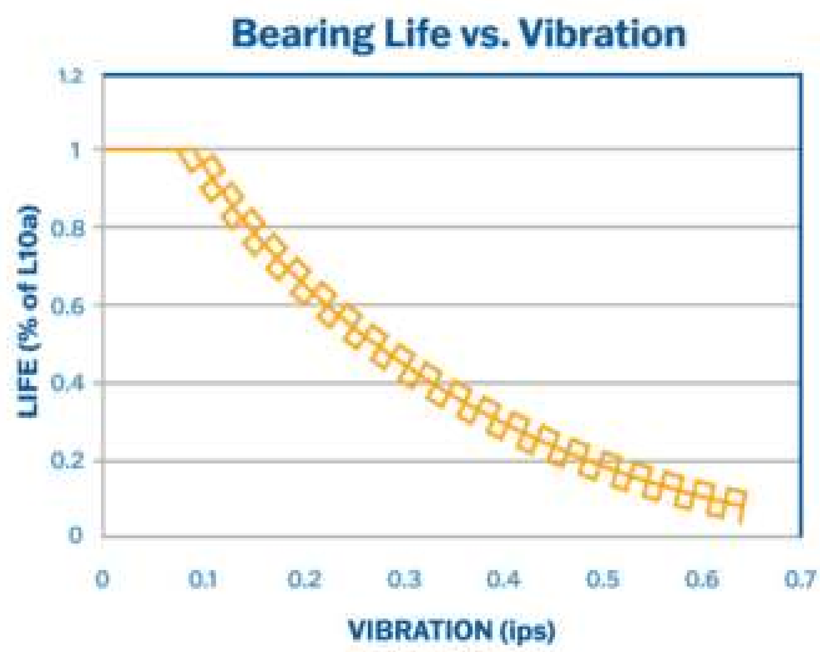
The list of faults that can show up at one-times (1X) running speed is long. These can include misalignment, unbalance, looseness, partial rub, broken gear tooth, rotor bow, coupling problems, cracked shaft, and broken motor rotor bar. Most of these issues relate to an increase in dynamic forces or a reduction in effective stiffness.

In contrast, oil analysis would struggle to detect any of these faults at the time of initiation. Think of the P in the P-F interval. Like oil analysis, vibration has blind spots or at least areas of blurred vision. Let's take journal bearings as a case inpoint:

The following is a commonly seen timeline to bearing wipe. It is apparent that early detection depends on alarms from oil analysis, inspection and temperature.

1. Problem initiation
2. Wear debris and darkening of oil
3. Increasing in bearing metal temperature
4. Audible vibration
5. Last hurrah

No doubt, when in comes to vibration analysis a great deal of the focus should be on mitigating root causes, also referred to as "proactive maintenance". As aforementioned, root causes for vibration include balance, alignment, looseness, soft foot, resonance, to name a few. While using vibration analysis to catch impending bearing failure (predictive maintenance) is also valuable, often the P in the P-F interval is way too close to the F. In other words, most of the



remaining useful life can be gone.

Vibration analysts have reported that 90% of the problems they detect are balance and alignment related, or in other words, destructive precursors to bearing failure. If such conditions go uncorrected, the vibration will use up all the available bearing clearance, and in doing so, will "nibble away" at the bearing surfaces, effectively making its own clearance (wear) while vibration continues to increase.

This condition robs thousands of hours of bearing service life. Take a look at the chart in Figure X. When vibration overalls are high (say, due to alignment and/or balance), the penalty on bearing life is severe — cause and effect.

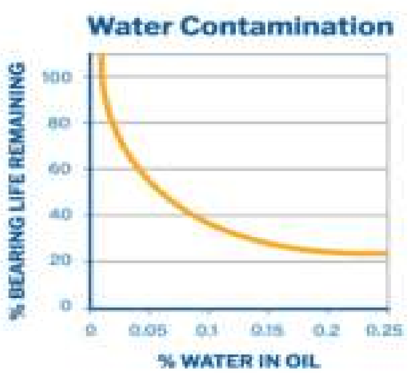
Particle and water contamination of lube oils can have a similar effect of bearing life as shown in Figures XY and XZ.

## Ultrasound and Stress Wave Analysis

Vibration analysis of low amplitude signals in the high frequency domain (ultrasound) has been used for years to detect abnormal wear in rolling-element bearings. These methods go by different names including:

- Spike energy
- Shock pulse
- Demodulated resonance (Peakvue)
- Accelerated enveloping
- Acceleration spectrum analysis
- Ultrasonic analysis

Values are usually trended with no absolute limits. Success depends on proper sensor mounting as well as the filter settings that are chosen.





One such method, referred to as stress wave analysis, claims to overcome many of these challenges and limitations. Application can be either route-based or via online accelerometers through an IoT network. More importantly, it has promising potential to tease out time-domain events like impact, bearing and gear defects, rubbing, severe sliding, mechanical friction, jerk/slip-friction and electric arching.

Why is this important? Primarily because mechanical asperities can collide or rub due to various reasons. These metal-to-metal contacts result from mechanical causes such as overloading, misalignment, unbalance and shock. Impaired lubrication conditions are frequently responsible too, caused by restricted lubricant supply, viscosity starvation, contamination and AW/EP additive depletion (loss of film strength). Regardless of the cause, when rubbing, sliding, galling, and abrasion occur, they transmit an ultrasonic signal that often gets "lost in the sauce" with traditional FFT spectrum analysis. Conversely, stress wave analysis appears to be able to quantify these time-domain events and send alerts as conditions and severity warrant.

## Collaborative Effort

In vibration, analysts look at such things as gear mesh frequency, blade pass frequency, roller/ball pass frequency and cage frequency. Vibration frequency identifies the source, amplitude tells us how bad it is.

In oil analysis, we look at changes in an oil's physical and chemical properties, particle size distribution, machine metallurgy, particle morphology and composition, corrosive agents and varnish potential. It's a whole different ball game.

The initial onset of wear from dirty oil, or "impaired lubrication", does not cause the excitation forces that lead to frequency-domain vibration alarms. However, given enough time for wear to advance, vibration signals become clearly detectable. Sadly, this often occurs at less than ten percent of the bearings remaining life.

Ranking failure modes by probability and consequences (also called "criticality") is a good strategy for laying out your condition-monitoring game plan, machine by machine. Each ranked failure mode needs one or more matching condition-monitoring strategies for early detection. Using this approach, vibration and oil analysis can be seen to work closely together. But don't forget about other condition-monitoring methods, including inspection, ultrasound, motor current, and thermography.

Combining condition-monitoring technologies gives us a much more complete picture of the state and health of our machines. One helps fill in the gaps of the other. The need for combined monitoring is especially true for multi-stage gearboxes, plain bearings, rotary screw compressors, roots blowers, and rolling element bearings. When both technologies pinpoint the same problem, the diagnosis and follow-up recommendations are rarely inaccurate

# BIODEGRADABLE ENGINE OILS

## What are Biodegradable Engine Oils?

Biodegradable engine oils are designed to degrade organically and quickly in the environment, reducing their persistence and potential harm to ecosystems. Conventional engine oils are primarily sourced from petroleum, making them slower to biodegrade and possibly damaging to the environment if not properly disposed of. In contrast, biodegradable engine oils are typically made from renewable and sustainable resources, such as synthetic esters or plant-based oils.

### Characteristics of Biodegradable Engine Oils:

1. **Biodegradability :** These oils are designed to degrade into simpler, non-toxic compounds via natural microbial processes, thereby reducing pollution and environmental damage.
2. **Performance :** Early formulations of biodegradable engine lubricants encountered difficulties in maintaining the same level of performance as standard petroleum-based oils. However, research and development initiatives have increased their performance over time.
3. **Low Toxicity :** Biodegradable engine oils are meant to be low in toxicity, lessening their detrimental influence on aquatic life and soil.
4. **Certification :** Some biodegradable engine oils may be certified by organizations such as the American Petroleum Institute (API) or the European Ecolabel, indicating that they meet environmental and performance standards.
5. **Application :** Biodegradable engine oils can be utilized in a variety of applications, including two- and four-stroke engines in small equipment like chainsaws, lawn mowers and motorcycles, as well as some larger diesel engines.

As per the recent market study by Allied Market Research, the global biodegradable engine oil market is estimated to cite the fastest CAGR during the forecast period. The industry is mainly driven by developing automotive sectors and rising industrialization in emerging economies. However, the rising consumption of edible vegetable oils is expected to provide remunerative growth opportunities for the industry in future.

### Upcoming Trends in the Biodegradable Engine Oil Sector

- Biodegradable Additives : In addition to producing base oils from renewable sources, there is growing interest in developing biodegradable additives that can improve the performance of these engine lubricants .These additives could be utilized to improve anti-wear qualities, reduce friction, and increase engine efficiency.
- Emphasis on Circular Economy: As sustainability becomes a bigger concern, there may be a trend toward developing biodegradable engine oils within the framework of a circular economy. This includes examining the complete life cycle of the product, from raw material procurement to end-of-life disposal or recycling.
- Strategies by Frontrunners: Collaboration between lubricant manufacturers, automakers and environmental organizations may intensify to accelerate the development and implementation of biodegradable engine oils.
- Improved Performance: Researchers and producers are trying to improve the performance of biodegradable engine oils to meet or exceed the capabilities of conventional petroleum-based oils. This involves improving lubrication, wear protection, temperature stability, and engine cleanliness.
- Industry Standards and Certifications: With the increased demand for ecologically friendly products, there may be increased efforts to establish industry-wide standards and certifications for biodegradable engine oils. This will allow consumers to make more informed decisions while also ensuring the oils fulfill strict environmental and performance specifications.

There are numerous benefits of using biodegradable engine oils. Frequently used to lubricate and protect the engine's moving parts, biodegradable oils can minimize wear, prevent corrosion and keep engines clean, resulting in better engine performance and longevity.

Some biodegradable engine oils have been designed to compete with traditional oils in terms of durability. This can potentially result in longer oil change intervals, lowering oil change frequency and reduction of overall maintenance expenses. Other biodegradable oils feature qualities that improve cold-start performance, resulting in smoother engine operating at low temperatures.

For consumers and companies, alike, who aim to be eco-friendly, a commitment to the utilization of biodegradable motor oils could also reinforce a certain brand awareness and recognition, which could, potentially, lead to better sustainability and more eco-conscious environmental practices industry wide.

### Technological Advancements in the Biodegradable Engine Oil Industry

- **Synthetic Ester Blends :** Advanced research into the qualities and combinations of various synthetic esters could lead to the creation of high-performance biodegradable engine oils customized to specific applications and environmental conditions.
- **Advanced Biodegradation Testing :** Advanced testing techniques and standards can reliably analyze the biodegradability and environmental impact of biodegradable engine oils, potentially providing both customers and businesses, alike, with more credible data to make sustainable decisions.
- **Biodegradable Antioxidants :** Antioxidants are essential in preventing engine oil degradation due to heat and oxida-

tion. Biodegradable antioxidants can improve the lifetime and performance of biodegradable engine oils.

- **Nanotechnology in Additives:** Nanoparticles can be used to biodegradable engine oil additives to improve lubrication and wear-resistance. Nanotechnology enables greater additive dispersion and interaction, resulting in increased engine efficiency and reduced friction.
- **Bio-based Polymers :** The incorporation of bio-based polymers into biodegradable engine oils can improve their viscosity index, shear stability, and oxidative stability, assuring optimal performance across a wider temperature range and longer oil-change intervals.
- **Tribology and Surface Coatings :** Advances in tribology (the study of friction, wear and lubrication) and surface coatings could potentially result in the creation of low-friction engine components that work in conjunction with biodegradable engine oils to reduce wear and boost efficiency.

### Recent Developments in the Global Biodegradable Engine Oil Industry

- BP purchased a 30% investment in Green Biofuels Ltd in February 2022 and will work with the company to help decarbonize firms in the freight, maritime, off-road, and construction sectors. Renewable HVO (hydrogenated vegetable oil) fuels derived from green biofuels can be used as a direct replacement for diesel.
- Shell plc's wholly owned companies in the UK, Sweden, the UK, and Switzerland entered into agreements in November 2022, to buy the Panolin Group's environmentally considerate lubricants (ECLs) business. This transaction includes the provision of biodegradable oils.

To sum up, biodegradable engine oils appear to be a promising approach for reducing lubricant environmental impact while maintaining engine performance and efficiency. These eco-friendly oils are made from renewable resources and are designed to degrade quickly. Individuals and businesses can help to protect ecosystems, reduce pollution, and promote sustainability by using biodegradable engine oils.

Furthermore, their compatibility with existing engines and the possibility of prolonged oil-change intervals makes them a realistic and responsible alternative for a variety of applications. As the call grows for more environmentally friendly solutions to the world's increasing energy demands, the adoption of biodegradable engine oils and lubricants demonstrates a commitment to fostering a greener future and sets a positive precedent for more responsible environmental management.

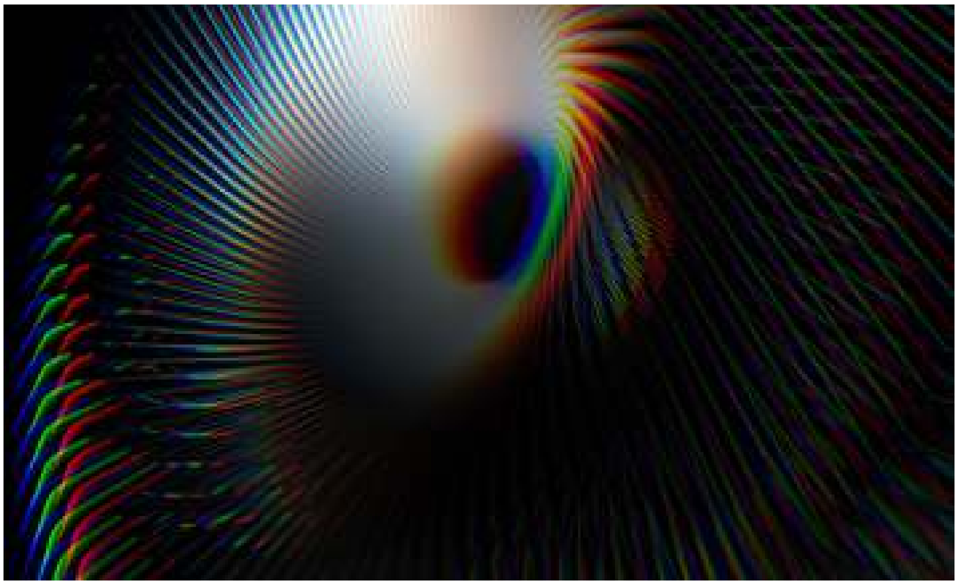
Greg Livingstone, Fluitec; Cody Evans | ExxonMobil



# UNDERSTANDING AND DETECTING SHEAR-STRESS INDUCED DEPOSITS

## Introduction

Imagine a multi-stage compressor train in a petrochemical facility that has one lubricant sump feeding multiple journal bearings. Your oil analysis indicates that the fluid is in ideal condition, with Membrane Patch Colorimetry (MPC) in the single digits, Rotating Pressure Vessel Oxidation Test (RPVOT) close to new oil levels, and no significant contamination present. However, one of the journal bearing temperatures begins to peak, and over time, the temperature trends resemble a saw-tooth pattern, with each peak increasing in temperature. Before long, the temperatures approach the alarm limit, and if left unchecked, an outage may be required.



The problem is that there is not a scheduled outage for 36 months and bringing the compressor down will cost millions in lost production. You take more advanced oil samples, but everything appears to be fine. In this scenario, many operators assume that a mechanical issue is at play, and they closely monitor vibration sensors while calling on OEM and expert consultants to help identify the source of the temperature fluctuations.

This is a common experience for those who have encountered turbine oil severe shear-stress and the resulting localized deposits, also known as hot varnish . This paper will examine this phenomenon and offer suggestions for detecting and remedying it.

## "Traditional" Varnish Formation

Lubricant varnish is a well-studied topic in turbomachinery. It is widely known that as lubricant oil degrades, it generates harmful by-products. Although oxidation is the most common degradation mechanism, there are various other pathways leading to degradation and the generation of by-products. These polar degradation products are not stable in the non-polar oil phase and tend to come out of solution, forming deposits. The associated reliability problems with turbomachinery are well-documented. For example, deposits may cause valves to stick, resulting in unreliable control of turbines and potential trip events.

Varnish formation in hydrogen seals can lead to premature failure, while heat exchangers coated with deposits experience a loss of efficiency. Deposits on bearings can cause accelerated temperatures and increased wear rates.

Fig. 1 depicts the common understanding on the process of varnish formation. As the lubricant oil degrades, by-products are produced, which eventually transition from being in solution to suspension, settling out of the oil. Degradation products are soluble, at least in turbomachinery applications, and can move in and out of solution.


*Figure 1: Process by which "cold" varnish is generated*

Soluble degradation products can be proactively measured using the MPC (ASTM D7843) and Ultra Centrifuge (UC) test. This can help turbomachinery operators take corrective actions before reliability problems arise. This common type of varnish, also known as "cold varnish," forms during a cooling phase in the lubricant and settles out in cool or low flow areas.

However, what happens when varnish forms under a different mechanism producing localized bearing deposits? What if oil condition monitoring tests are no longer effective at predicting this formation? In short, more reliability problems.

## Shear-Stress Degradation

Severe shear-stress is a degradation pathway that affects the lubricant in certain turbomachinery applications, particularly those operating at high speeds and under heavy load. Shear-stress is characterized by the transformation of mechanical energy into thermal energy as the shearing force increases, resulting in the generation of high localized temperatures.

In certain turbomachinery applications, the molecular friction generated from shear-stress can result in temperatures reaching several hundred degrees Celsius (Chu Zhang, 2017), leading to instant degradation and the formation of localized deposits. These high temperatures are isolated and localized in the minimum oil film thickness zone, occurring at a molecular level (Yulong Jiang, 2021).

Research of the "Morton Effect", the phenomenon of synchronous rotor instability due to nonuniform heating of journal bearings, is also said to be caused by shear-stress. The Morton Effect causes vibration issues in turbomachinery. Shear-stress is a dominant factor in the generation of nonuniform bearing temperatures. (Jongh, Sept 17-20, 2018)

Directly observing the behavior of turbine oil during operation is not feasible due to the extremely thin oil film, which can be as low as a few microns and may support a several-ton journal bearing rotating at thousands of revolutions per minute. Detecting temperature inside the oil is also not possible, but it is possible to obtain hints about the temperatures reached by analyzing bearing deposits.

Figure 2 shows a varnish-coated bearing pad that had multiple deposit samples extracted from the varnish layer across the surface of the bearing. The majority of the deposits are organic, oxidized oil of an inorganic, like phosphorus-based Extreme Pressure (EP) additive. Typically, EP additives do not react until temperatures of about 200°C are reached. This phosphorus-rich deposit suggests that the oil had temperatures at least this high, forming these localized deposits. It is important to note that these micro-temperature zones are not detected by the bearing thermocouple probes.

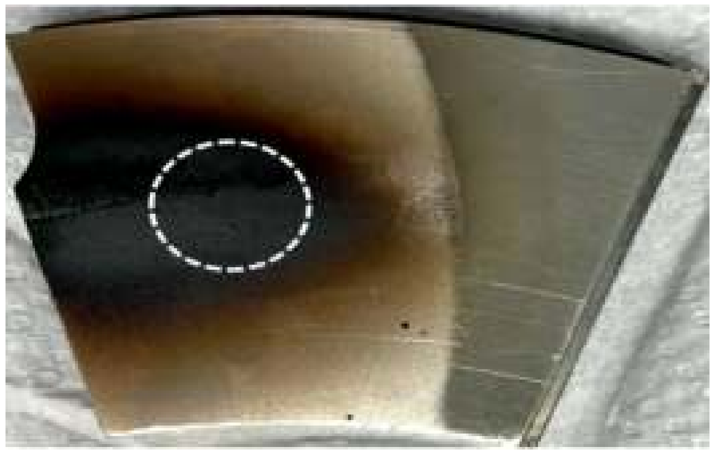


*Figure 2: Bearing pad showing a dark patch of deposits at the highest load zone of the bearing. Deposit characterization of this deposit revealed that it was composed of phosphorus-based EP deposits.*

In this example, phosphorus is an indicator of temperature, but in oils without phosphorus, the same phenomenon can occur.

## The Impact of Shear-Stress Deposits

The carbonization of the oil and subsequent deposit formation impacts the performance of the bearing in three significant ways. First, the deposits act as an insulator, reducing the oil's ability to cool the bearing. This results in bearing temperature excursions, sometimes reaching trip alarm levels. Second, varnish layers act like surface asperities impacting the oil to maintain a solid hydrodynamic wedge. In some cases, the wedge may crack, temporarily allowing metal to metal contact resulting in bearing wear. Therefore, varnish deposits may be accompanied by metal scoring and wear, as can be seen in the pictures below. Third, bearing deposits may induce vibrations, as described by the Morton Effect.

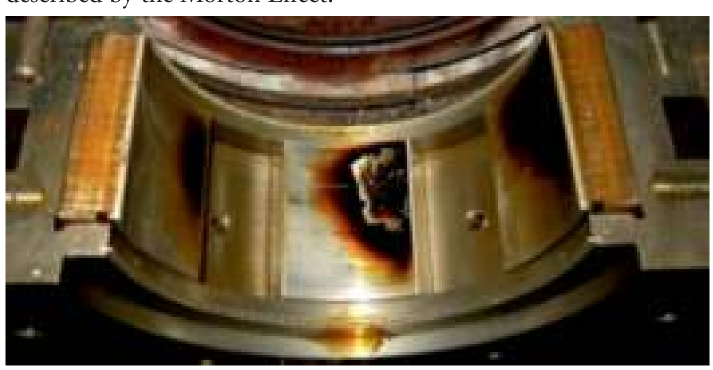


*Figure 3: Deposits and scoring on journal bearing pads.*

Figure 4: Deposits and severe metal wear occurring in the hottest zone of the bearing surface.

## Detecting Shear-Stress Deposits

One of the biggest challenges with shear-stress deposits, or hot varnish, is that because the degradation occurs at a localized level and immediately sticks to metal components, the bulk oil doesn't become sufficiently polluted to detect with oil analysis. In many cases, MPC and UC tests identify no issue, so other condition-monitoring technologies are necessary. Trending bearing temperatures has been shown to be the most reliable of detecting bearing deposits. The signature of a temperature trend often resembles a sawtooth pattern, as can be observed below in Fig. 5.

Figure 5: Sawtooth bearing temperature increases.

In general, bearing temperature spikes (independent of load) indicate varnish. While an increasing sawtooth pattern is almost a sure sign of varnish, it can be detected with even a stable sawtooth form. Shear-stress deposits exhibit inherent catalytic properties. Their formation leads to elevated bearing temperatures, decreased clearances, and an amplified likelihood of further shear-stress occurrence. The film strength of the varnish can be sufficient to move the entire shaft. For those systems running with instrumentation measuring the shaft position, such as a gap voltage vertical probe, one may observe the shaft moving away from the center as the temperature increases and then resuming to its normal position as the temperature drops. This can be observed in Fig. 6:

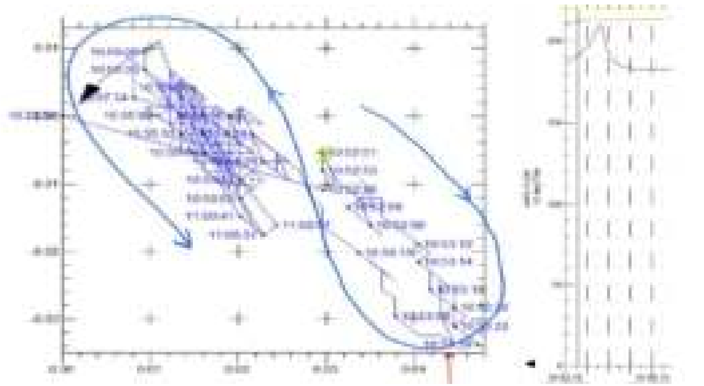


Figure 6: 10-minute snapshot of the bearing shaft position during a temperature spike. The bearing is loaded towards the top-left. As the temperature increases, the shaft moves away from the load zone (suggesting deposit formation). As the temperature spike settles, the shaft moves back towards the load zone.

These deposits are detected by the shape of the temperature plot, and then also observed in the movement of the shaft. Figure 7 presents a concise overview of noteworthy bearing temperatures based on the API 670 thermal couple location. These temperatures are anecdotal norms, but specific machines can experience very different norms.

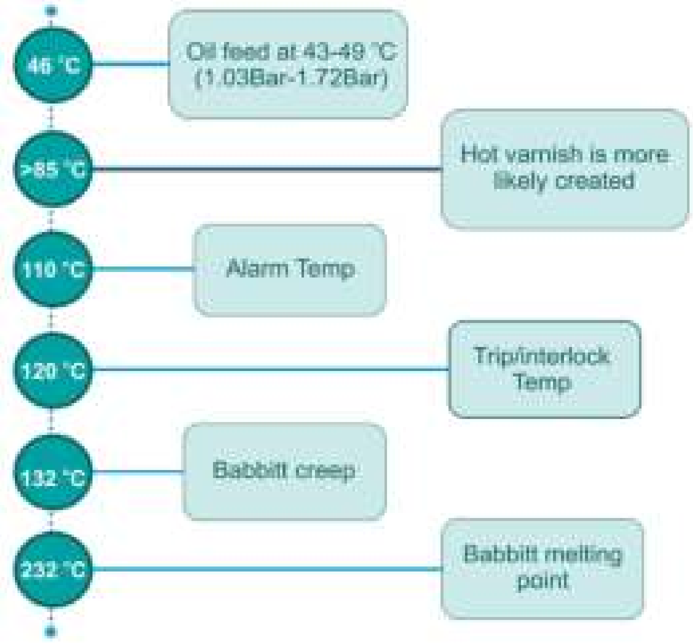



Figure 7: Notable bearing temperatures observed in case studies (based on API 670 thermal couple location).

## The Factors Influencing Shear-Stress Degradation

The two dominant factors that can influence shear-stress degradation are a bearing's load and rotational speed, as illustrated in Fig. 8. Bearing deposits occur in the minimum oil film thickness because this corresponds to the highest load zone of the bearing.


Figure 8: Illustration showing the varnish forms at the minimum oil film thickness point and the two primary forces influencing shear-stress are load and rotational speed.

Shear-stress deposit events occur more frequently in compressors than in turbines. Turbines typically operate at 3,600 RPM in the 60Hz North American market and 3,000 RPM in Europe and Asia Pacific, where the power grid operates at a frequency of 50 Hz. Compressors on the other hand can see bearings operate at an order of magnitude higher, sometimes greater than 50,000 RPM.

## Potential Ways to Mitigate Shear-Stress

Will switching to a different turbine oil help remedy shear-stress deposits? The model to determine shear-stress is complex and still to be defined. Various turbine oil formulations have not been tested in a controlled setting to compare performance. However, anecdotally, bearing deposits due to shear-stress have been observed in Group I, II, III and IV base oil formulations, suggesting that simply changing to a new base-stock formulation will not provide a solution.

Advances in EP-gear load additives combined with additive dispersions that havebeen blended in higher quality base oils have proven to minimize the impact of shear-stress in high-speed bearing applications. Managing deposits due to shear-stress can be addressed mechanically in the turbine by decreasing the load on the oil. This may be accomplished by the following mechanical fixes which have been observed to work:

- Reduce load (operationally feasible but reduces compressor output)
- Opening bearing clearances (Jongh, Sept 17-20, 2018)
- Offset bearing pivot towards its lagging side can improve the angle of attack and allow more oil flow
- Directional lubricating

Although shear-stress degradation is fundamentally a mechanical issue, it may also be possible to address these deposits from a chemical perspective. The use of Mobil™ Solvancer®, an oil soluble cleaner, has been shown to have an immediate impact on deposit formation and often results in significant drops in bearing temperature. The product is also developed for long-term use, ideally providing a long-lasting solution to bearing deposits.

Mobil Solvancer® effectively mitigates deposit formation by enhancing the solubility of the in-service oil, enabling the dissolution of degradation by products.Varnish deposits can be comprised of depleted antioxidants, inorganic additives, and degraded hydrocarbon molecules. Mobil Solvancer® also softens carbon-based deposits, which can act as the glue holding an inorganic deposit like phosphorus onto the journal bearing, and then helping to remove the deposit.

These varnish deposits, when dissolved in the oil, remain inert and pose non operational concerns until they precipitate out of solution. Consequently, the process of dissolving these deposits back into the oil does not have any adverse impact on the oil's condition nor does it pose a risk of catalyzing further degradation.

An example of the impact of adding Mobil Solvancer® to a compressor suffering from shear-stress deposits can be seen in Fig. 9. After a 5% addition of Mobil Solvancer, the bearing temperature excursions stopped over the course of a few hours.


*Figure 9: The impact of adding 5% Mobil Solvancer® to the bearing temperatures of a compressor.*

Although it is not always possible to overcome mechanical issues through chemistry, Mobil Solvancer® is one cost-effective option to consider if bearings are suffering from shear-stress deposits.

## Conclusion

Varnish deposits in journal bearings pose a serious threat to the reliable operation of turbomachinery, as they can lead to increased temperatures and wear rates. Typically, varnish is predicted through oil-analysis tests, such as the MPC or UC test. However, a degradation mechanism called shear-stress can create very high temperatures, resulting in localized deposits. These deposits can occur even when most of the oil is in adequate condition and traditional varnish tests do not forecast a problem. The best way to detect shear-stress induced deposits is by monitoring bearing temperatures and vibrations.

If bearing temperatures are increasing due to shear-stress, mechanical fixes maybe employed to spread the bearing load over more oil to reduce load and improve cooling. Additionally, Mobil Solvancer®, an oil-soluble cleaner, has been found to be effective, with an immediate impact on reducing bearing temperatures.

Note : The term Shear Stress Deposits (SSD) was suggested to the authors by Noria's Jim Fitch in March, 2023. It is descriptive of the thermal distress induced from severe intermolecular friction leading to localized deposit formation. A common name for this phenomenon in the industry is "Hot Varnish".

# PREDICTIVE MAINTENANCE VS PROACTIVE MAINTENANCE. WHY NOT BOTH?

## Definitions:

Proactive Maintenance - A type of condition-based maintenance emphasizing the routine detection and correction of root cause conditions that would otherwise lead to failure. Such root causes as high lubricant contamination, alignment and balance are among the most critical.

**Predictive Maintenance -** A type of condition-based maintenance emphasizing early prediction of failure using non-destructive techniques such as vibration analysis, thermography and wear debris analysis.

The efficient operation of industrial machinery hinges on two critical maintenance strategies: proactive maintenance and predictive maintenance. While both approaches fall under the broader umbrella of condition-based maintenance, their methodologies and impacts are distinct and complementary.

This article aims to demystify these concepts, clearly understanding how each strategy functions, their significance in the maintenance realm, and how they collectively represent a robust defense against machine failures and operational inefficiencies. We offer insights into optimizing maintenance practices for enhanced machine longevity and reliability by exploring their roles, benefits, and challenges.

## Predictive Maintenance – Failure Detection (Early Signs)

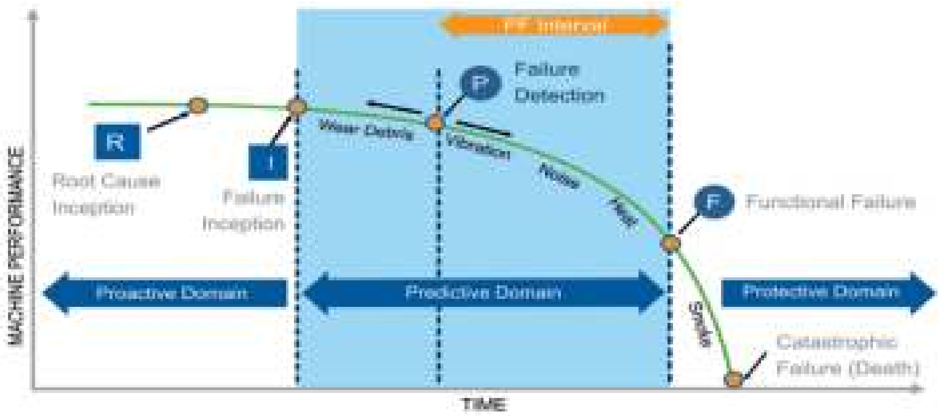
In the daily life of a typical lubricated machine, there can exist subtle wear that quietly mounts, unbeknownst to operators and maintenance teams. At the beginning of this failure mode, the Failure Inception (I) is practically imperceivable. But as it continues and the wear gradually progresses, the symptoms become measurable, and the point of Failure Detection (P) is reached.

*With the right strategy that includes frequency-condition monitoring, the closer failure detection is to failure inception* . This is a crucial objective of predictive maintenance — to detect the signs of failure as early as possible.

Although, if failure is not properly detected, eventually the machine will experience enough wear and tear that it cannot perform work anymore, and the Functional Failure (F) point is reached, along with impact on production. The lack of detection could be due to a number of reasons, but most often due to infrequent monitoring, improper tools or lack of proper training. When gone unchecked, this is then followed by a Catastrophic Failure (Death), where by the machine can seize up and produce collateral damage along the way.

The stages being described here are illustrated by the P-F Curve in the figure below. Traditionally, the P-F curve gets its namesake from monitoring conditions association to known failure modes between the detection of failure (P) and functional failure (F). Prediction of failure with early detection requires the right predictive maintenance strategy. Each failure mode may have a short or long P-F curve.

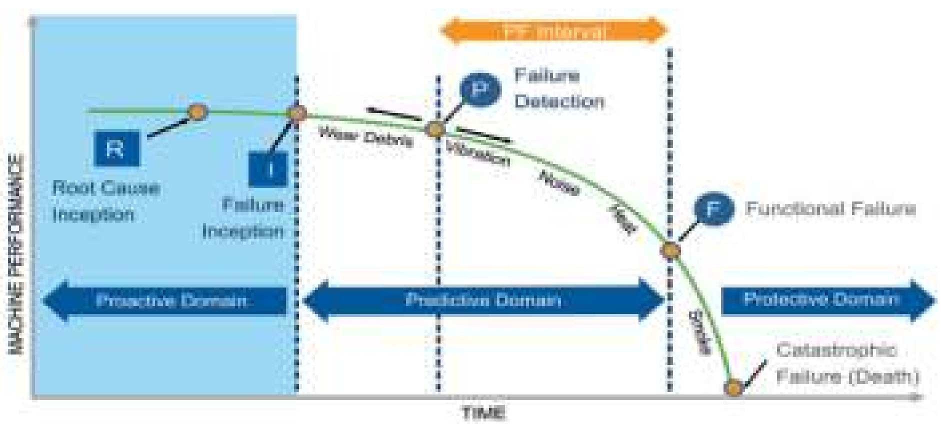
As the curve dips from left to right, the machine performance (y-axis) is negatively impacted. Machine failure gets more severe as time progresses (x-axis) and the symptoms of the machine failure are more easily detectable. But while this increased detection sounds like a good thing, unfortunately, this coincides with impending downtime and increased costs, as the damage is irreparable.




## Proactive Maintenance – Pre-Failure Detection (Root Cause)

All machine failure is a consequence of the actions which preceded it. In other words, it's what we do or don't do in maintenance and operations that ultimately leads to the Failure Inception. This is where machine reliability is put to the test. De we rely on the robustness of the machine, or do we carefully set up our machines for success? Are we really doing what we can to delay the onset of failure as long as possible, at least to the point where the costs justify it? The verdict from decades of studies from user groups, OEMs and research institutes on the most common reasons why bearings and other machine components fail, there is consensus that poor lubrication and insufficient contamination control are at the top of the list of root causes. Their introduction is marked by the point Root Cause Inception (R). The gap between the Root Cause Inception and the Failure Inception is a factor of root cause severity, component sensitivity and gestation time.

This is the crucial objective of proactive maintenance— to detect and correct the root cause conditions that would otherwise lead to failure.




## Adoption of Condition-Based Maintenance Strategies

Predictive maintenance has become more commonplace in industrial facilities with the adoption of condition-monitoring technologies such as vibration analysis, thermography and wear debris monitoring. Particularly while real-time sensor technology and IoT infrastructure has accelerated the implementation. The best predictive-maintenance strategies are where incipient detection of failure is monitored.

When quick correction action is taken, it can minimize the impact failure has on costs of repair and the length of downtime.

Proactive maintenance has also experienced increased attention with a focus on contamination-control strategies and monitoring contaminants and fluid properties with oil analysis. This is attributed, in part, to better education bringing to light the hidden impact contaminants and slight lubrication deficiencies have on machine reliability. When corrective action is taken within this domain, it reduces the number of failures and increases the life of the machines.

As such, the best strategies focus on condition monitoring as far to the left on the P-F curve as possible; this is where cost savings are greatest. But concurrently, this is challenged by the corrective action conundrum. When early detection of failure symptoms in the predictive domain occur, they are often questioned and the corrective action lacks because of a weak signal.

Such is often the case with early-stage wear debris detected with oil analysis.While effective in detecting this faint signal early, the machine appears to function otherwise normally, and corrective action may be delayed as more failure-model confirmation is requested. But as the signal gets stronger and more obvious, so does the proximity to functional or catastrophic failure.

This becomes even more evident in the proactive domain where condition monitoring detects an issue with contamination or lubricant properties. Without a failure actually taking place (yet), questions are raised and action is deferred, despite even the relatively simple corrective actions such as filtration or lubricant changes.

All this can be addressed by proper education to bring awareness to proactive maintenance strategies as a cohesive complement to predictive maintenance, along with a little firsthand evidence.


In practice, both proactive maintenance and predictive maintenance can beperformed side by side as a Condition-Based Maintenance Strategy, or CBM. It should not be assumed that proactive maintenance is the solution all by itself.

In fact, there are many root causes that will go unnoticed with typical proactive-maintenance approaches. Instead, it's designed to tackle the 20% of root causes of failure responsible for 80% of the occurrences of failure (80:20 rule).

That said, predictive maintenance can help detect a majority of the remaining 20%. And since both proactive maintenance and predic-

| | MICRO (Trees) | MACRO (Forest) |
|---|---|---|
| Leading (What will happen) | • Particle count<br>• Viscosity<br>• Elemental analysis<br>• Varnish potential<br>• Moisture analysis<br>• Oxidation stability | • Contamination control compliance<br>• Fluid properties compliance<br>• PM compliance |
| Lagging (What just happened) | • Wear debris analysis<br>• Thermography<br>• Vibration analysis<br>• Acoustics | • Percent planned maintenance<br>• Uptime/downtime<br>• Overtime hours<br>• Schedule / unscheduled downtown |

tive maintenance focus on the monitoring of conditions, they can be tracked with adjacent graphs and Key Performance Indicators (KPIs).

For individual machines, the proactive root cause conditions can be "leading indicators" (indicating what will happen) along side the predictive-failure symptoms that can be considered the "lagging indicators" (indicating what just happened). Just the same way PM Compliance can be a leading indicator and scheduled/unscheduled downtime can be lagging indicators as a plant-wide KPI.

Empower your maintenance strategy with the cutting-edge insights and solutions from Noria Corporation. Whether you're looking to implement proactive or predictive maintenance practices, our team of experts is ready to guide you through every step. Visit Noria to discover a wealth of resources, training programs, and consulting services tailored to elevate your maintenance operations. Let us help you transform your approach to machine reliability and efficiency — start your journey today!

Alex Wilfred | Wilfred Laboratories Pvt Ltd (Ind)


# *Oil Condition Monitoring and Used Oil Analysis: Essential Tools for Machinery Longevity and Efficiency*

Oil is a critical component in the smooth functioning of any machinery. It plays a vital role in lubricating moving parts, transferring heat, and removing contaminants, which ensures the longevity and performance of equipment. However, oil can degrade over time due to factors such as contaminants, heat, and wear and tear. This degradation can significantly impact machinery performance and reliability. To address these issues, oil condition monitoring and used oil analysis are crucial.

## Oil Condition Monitoring

Oil condition monitoring involves regularly checking the quality and condition of the oil used in machinery to ensure it remains fit for its intended purpose. This process helps in:

### 1. Preventing Equipment Failure

- **Early Detection:** By detecting issues such as contamination, oxidation, and degradation early on, maintenance can be scheduled proactively. This helps prevent catastrophic failures and unexpected downtime, ensuring the machinery operates smoothly.

### 2. Extending Machinery and Equipment Life

- **Reduced Wear and Tear:** Regular monitoring ensures that the oil remains clean and free from contaminants, which reduces wear and tear on moving parts and extends the life of the equipment. Early detection of potential issues allows for corrective action before significant damage occurs.

### 3. Improving Efficiency

- **Optimal Performance:** Clean and well-maintained oil ensures proper lubrication of moving parts, effective heat transfer, and effective contamination control. This leads to improved performance, better energy efficiency, and reduced wear and tear on machinery.

### 4. Reducing Maintenance Costs

- **Cost Savings:** Early identification of issues allows for proactive maintenance, which helps avoid costly repairs and replacements. Optimizing maintenance schedules and intervals based on oil condition monitoring leads to long-term cost savings.

## Used Oil Analysis

Used oil analysis involves sending a sample of used oil to a laboratory for detailed analysis. This process provides insights into:

- Oil Condition: Determines the extent of degradation and contamination.
- Potential Issues: Identifies any underlying problems or potential risks to machinery.

## Importance in Today's Industrial World

In today's industrial world, oil condition monitoring and used oil analysis are becoming increasingly important for:

- Preventing Equipment Failure
- Extending the Life of Machinery
- Improving Efficiency
- Reducing Maintenance Costs

Investing in these tools ensures the reliability, longevity, and performance of machinery and equipment across various industries.

## Conclusion

Oil condition monitoring and used oil analysis are indispensable for maximizing the reliability and efficiency of industrial operations. By prioritizing these practices, businesses can effectively prevent equipment failure, extend machinery life, improve operational performance, and achieve significant cost savings.

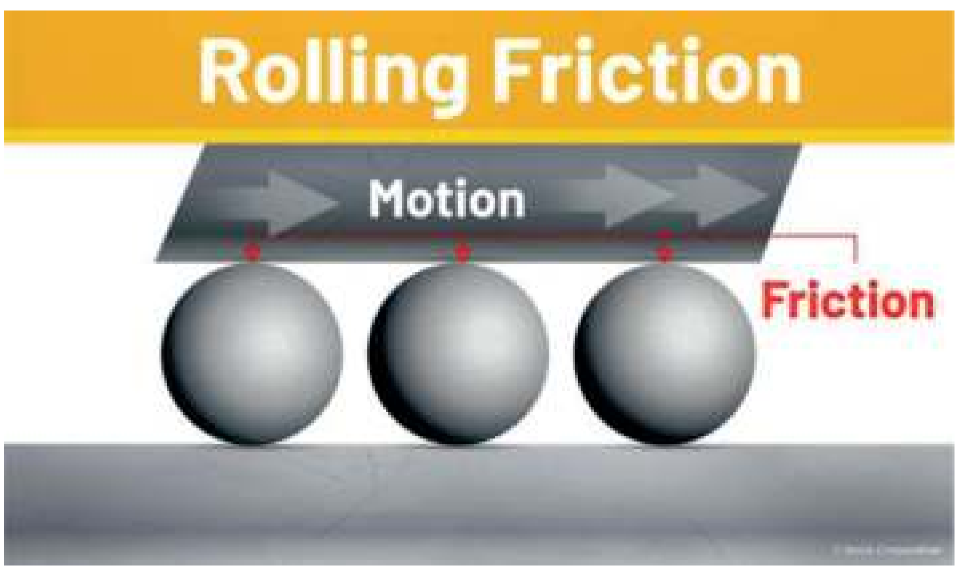
Prioritizing oil condition monitoring is crucial for ensuring the longevity and efficiency of machinery and equipment in today's industrial landscape.

# TRIBOLOGY EXPLAINED

Tribology, the science of friction, wear, and lubrication, is a vital but often overlooked field that impacts our daily lives in profound ways. From the smooth operation of car engines to the durability of prosthetic joints, tribology plays a crucial role in reducing energy consumption, extending the lifespan of machinery, and enhancing human comfort and safety. In this article, we will delve into the fascinating world of tribology, exploring its significance, key principles, and real-world applications that make it an indispensable science in our modern world.


**Friction** is the resistance to relative motion between two bodies in contact. It is not a material property but a system property. Scientists believe it occurs due to the electromagnetic attraction between charged particles in two surfaces that are touching. There are several types of friction, including:

- Static Friction, which occurs when two objects are not moving relative to each other (i.e., like a chair on the ground);
- Rolling Friction, which occurs when two objects move relative to each other and one "rolls" on the other (i.e., a car's wheels on the ground)
- Kinetic Friction, which occurs when two objects move relative to each other and rub together (i.e., a person sliding down a slide);
- Sliding Friction, which occurs when two objects rub against each other (i.e.,-placing a book flat on a table and moving it around); and
- Fluid Friction, which occurs when a solid object moves through a liquid or gas (i.e., a kite moving through the air).



Friction is not considered a fundamental force. It is a non-conservative force meaning that work done against friction is path dependent.

Wear is the gradual removal, damaging or displacement of material at solid surfaces. When it comes to wear, the common types are:

1. Abrasive Wear, which occurs when a hard, rough surface slides across as ofter surface


2. Adhesive Wear, which occurs due to unwanted displacement and attachment of wear debris from one surface to another
3. Fretting Wear, which occurs due to repeated cyclical rubbing between two surfaces
4. Erosive Wear, which occurs when solid or liquid particles impinge against the surface of an object
5. Surface Fatigue, which occurs when the surface of a material is weakened by cyclic loading; and Corrosion/Oxidation Wear, which occurs due to chemical reactions between worn materials and a corroding medium.

Given the various types, tribology also illustrates how wear can undergo many changes in time or undergo changes in operational conditions.

## Tribology and Lubrication

Lubrication is the control of friction and wear by introducing a friction-reducing film between moving surfaces in contact. This film, aka lubricant, can be a solid, fluid or plastic substance with oil and grease being the most common.

Lubricants have several functions, including reducing friction, preventing wear, protecting equipment from corrosion, controlling temperature and contamination, transmitting power and providing a fluid seal.

When it comes to lubrication, there are three different types referred to as regimes: boundary, mixed and full film. Boundary lubrication exists where there are frequent starts and stops, and also where shock-loading conditions are present.

For example, some oils contain additives – such as extreme pressure (EP) oranti-wear (AW) – to help protect surfaces in case full films cannot be recognized due to load, speed or other factors. These EP and/or AW additives adhere to themetal surfaces to form a "sacrificial layer that protects the metal from wear"(Cash, "What is Lubrication?").


Full-film lubrication exists in two forms: hydrodynamic and elastohydrodynamic.Hydrodynamic lubrication (HL) occurs when two surfaces in sliding motion are fully separated by a film of fluid. Elastohydrodynamic lubrication (EHL) is very similar to HL but occurs when the surfaces are in a rolling motion (relative to each other). EHL gets its name from the film's property of elastically deforming the rolling surface to lubricate it, and the film layer in EHL conditions is much thinner than that of HL. This results in greater pressure on the film.

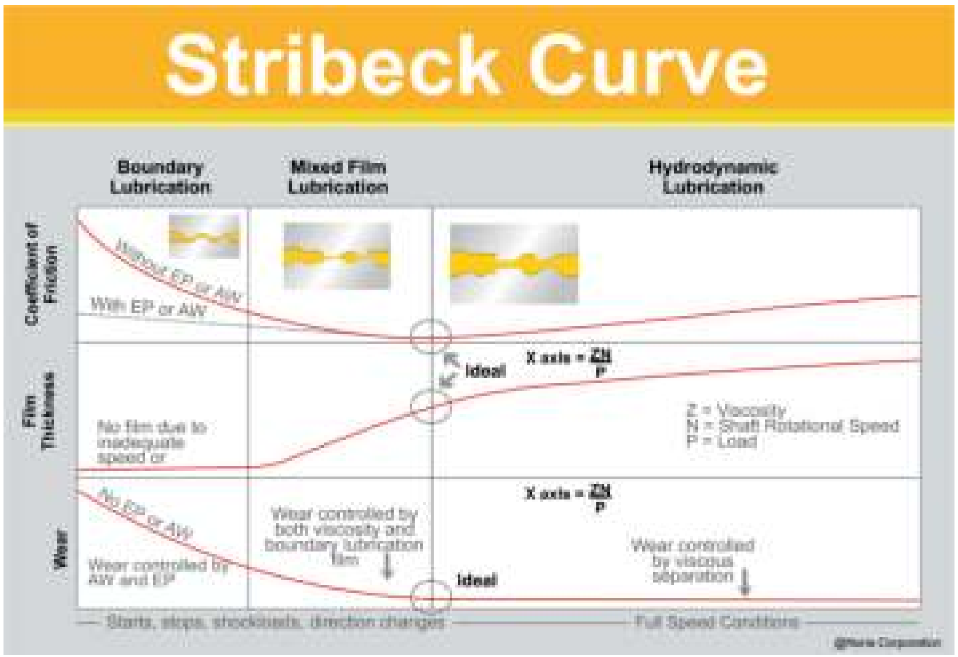
Mixed lubrication, which is a combination between boundary and hydrodynamic lubrication, is when "the bulk of the surfaces are separated by a lubricating layer [and] the asperities still make contact with each other" (Cash, "What is Lubrication?"). As with boundary lubrication, mixed lubrication might also contain additives to create a protective layer on the metal.

There are several fundamental concepts in Tribology, such as Tribosystem,Tribofilm and Stribeck Curve. A Tribosystem is defined as a Tribological System composed of at least two contacting bodies and any environmental factor affecting their interaction ("Tribosystem," Wikipedia). It is essential for tribologists to understand Tribological Systems as it allows them to create and execute Tribological Tests. Another important element of the Tribosystem revolves around the use of Tribological Coatings, as it relates to ferrous and non-ferrous materials.

For example, a diamond-like carbon (DLC) or hydrocarbon coating might be applied to a component or components for reducing friction and protecting against wear. Physical vapor deposition (PVD) coating is another example and involves producing a thin coating by subjecting material from a condensed phase to a vapor phase, resulting in a thin film condensed phase. This is different than chemical vapor deposition (CVD) which produces high-performance solid materials under vacuum. Other Tribological Coatings include:

- Cathodic arc deposition (Arc-PVD)
- Titanium carbo-nitride (TiCN)
- Titanium nitride (TiN)
- Titanium aluminum nitride (TiAIN)
- Chromium nitride (CrN)
- Zirconium Nitride (ZrN)
- Titanium Diboride (TiB2)
- Polycrystalline Diamond (PCD)

Tribofilm, or Tribofilms, are films produced on surfaces and play an integral partin reducing or minimizing Friction and Wear in lubricated systems. Tribofilms are also referred to as boundary lubricant films, boundary lubricating films, tribo-boundary films or boundary films ("Tribofilm," Wikipedia).




The Stribeck Curve is a graph showing how friction in fluid-lubricated contacts is a non-linear function of lubricant viscosity, entrainment velocity and contact load ("Stribeck curve," Wikipedia). It is named after Richard Stribeck, a German mechanical engineer, who first described the concept in 1902. This graph showcases how the generation of lubricant films are critical in the reduction of friction and wear of machine parts.

## History of Tribology

The word "Tribology" comes from the Greek word tribos meaning rubbing, translating the word literally into the "science of rubbing". While the study of the concept dates to Leonardo da Vinci and his studies on the laws of friction, the word "Tribology" was not widely used until Peter H. Jost, a British mechanical engineer, coined the term in the March 9, 1966 Jost Report.

Jost is considered the founder of the discipline of Tribology and from his report, a greater spotlight was placed on the subject. It called for the establishment of Institutes of Tribology, along with the publication of a handbook on tribo-design and engineering.

In an interview conducted by Jim Fitch, founder of Noria Corporation, Jost was asked to describe Tribology's conception and he pinpointed that moment to September 1964 at the Joint Iron and Steel Institute/IMechE Lubrication and Wear Group Conference on Lubrication in Iron and Steel Works in Cardiff.

It was at this conference where failures were discussed, particularly in broken steel mill machinery and equipment. After this, Jost was asked to form a committee to "investigate the question of lubrication education, research and the needs of industry" (Fitch, "Interview with Luminary Professor H. Peter Jost").

Shortly after publication of the Jost Report, the Committee on Tribology was formally established on September 26, 1966 and was charged with several duties, including:

- Advising the minster of technology on measures to effect technological progress and economic savings in the sphere of tribology
- Advising government departments and other bodies on matters associated with tribology
- Examining and recommending to industry the latest techniques on tribology
- Reporting to the minster of technology annually on its own activities and ontrends and developments in tribology considered to be of technological or economic significance to the nation

Tribology has since become an interdisciplinary area linked with biology, chemistry, engineering, materials science, mathematics and physics.

## Applications

Historically, tribology is applied to the most common rolling or sliding components, which are bearings, gears, cams, brakes and seals. These common elements are used in a variety of machines that have relative motion and require some sliding motion and/or rotational motion. This early focus on enhancing operation and extending the life of industrial machinery has evolved into other applications where it has made a major impact on a variety of applications.

## Application in Industry

When it comes to research, tribology ranges from macro to nano scales. While it was traditionally concentrated on transport and manufacturing sectors, it has grown more diversified over the decades and can be divided into the following fields:

## Classical Tribology

As the name suggests, Classical Tribology focuses on friction and wear in machine elements – rolling-element bearings, gears, plain bearings, brakes, clutches, wheels, etc. – as well as manufacturing processes.

## Biotribology

With Biotribology, research focuses on lubrication in biological systems such as human hip and knee joints. In fact, one of the most striking examples of Biotribology is with total hip replacements, which "replace the body's natural ball-and-socket joint with a very smooth metallic (stainless steel or cobalt-chromium alloy) ball at the head of the femur, articulating in a cup in the pelvis made from ultra-high molecular weight polyethylene" (Hutching, "Fifty Years of Tribology").

## Green Tribology

Green Tribology, which was also introduced by Peter H. Jost, looks at minimizing the environmental impact, including ways to reduce tribological losses by using technologies with minimal impact on the environment.

## Geotribology

With Geotribology, the focus is on studying friction, wear and lubrication of geological systems such as faults and glaciers (Wikipedia). As a new facet of Tribology, Geotribology is gaining momentum in the scientific world particularly in its abilities to analyze fault slips.

## Nanotribology

With the development and commercialization of microelectromechanical systems MEMS) and nanoelectromechanical systems (NEMS), the field of Nanotribology has emerged as a strong focus. This particular application studies tribological phenomena at a nanoscopic scale, which refers to structures with a length scale applicable to nanotechnology. Nanotribology has gotten a boost in its research since the invention of Atomic Force Microscopy (AFM), which is a high-resolution form of scanning probe microscopy (SPM).

## Tribotronics

Another industry application is Tribotronics, which is a facet of research combining machine elements and electronic components to create active tribological systems and increase a machine's efficiency and lifetime.

## Computational Tribology

With Computational Tribology, the aim is modeling the behavior of tribological systems by combining several disciplines such as contact mechanics (i.e., the study of the deformation of solids that touch each other at one or more points), fracture mechanics (i.e., the study of the proliferation of cracks in materials) and computational fluid dynamics (i.e., the study of using numerical analysis and data structures to solve and analyze problems involving fluid flows).

## Space Tribology

Space Tribology looks at tribological systems with the ability to operate under the harsh environmental conditions of outer space, particularly due to extreme temperature fluctuations.

## Open System Tribology

Open System Tribology studies tribological systems exposed to and affected by the natural environment.

## Importance of Tribology

In the beginning, Tribology and Tribology research was focused on the design and effective lubrication of machine components such as bearings. Over time, there has been a shift in tribology's focus to include several aspects of modern technology.

Traditional applications, which fall under Classical Tribology, highlight the importance of tribology as it pertains to the sliding surfaces in most mechanical components, which are critical to energy efficiency and maximum life expectancy of those components. Within the transportation industry, traditional tribology research focused on reliability but in more modern times, the focus has shifted towards energy consumption and increased efficiency, resulting in more complex lubricants. For example, Tribology can reduce carbon dioxide emissions by increasing energy efficiency.

In addition to the transportation industry, tribology has played a vital role in the manufacturing sector, particularly in metal-forming operations. Understanding tribology in manufacturing is important as it can increase productivity while reducing costs. Two other sectors where tribology has significant importance is power generation and residential. The importance of tribology has only increased over time. In fact, Congressinal Representatives Tim Ryan (D-Ohio), Dan Lipinski (D-Illinois) and Mike Doyle (D-Pennsylvania) introduced H.Res.306 on May 2, 2017, to magnify the importance of tribology. Still awaiting further action, H.Res.306 "recognizes the impact of tribology … on the United States economy and competitiveness in providing solutions to critical technical problems in various industries."

This legislation also "encourages federal agencies to develop and install programs related to tribology" … "encourages the formation of public-private partnerships to advance fundamental research and speed up the development of Tribology-related products" … and "encourages the National Academy of Engineering to conduct a survey on the status of tribology research in academia and government laboratories and to recommend a course of action to accelerate innovations in tribology" (Ryan "H.Res.306").

## Lubrication and Tribology

Lubrication and tribology go hand in hand. The use of lubricants dates back to images from ancient civilizations in China and

Egypt showing the application of lubricants to reduce friction from dragging heavy stones used in building.

Lubricants are used to separate two sliding surfaces, minimizing direct surface contact and reducing tool wear and power requirements. Lubricants also conduct heat and contaminants away from the interface. The majority of lubricants are liquids, composed of oil and additives; but, some lubricants are gases and solids.

Before selecting the proper lubricant, the tribological system needs to be identified. These identifying markers, or parameters, include the type of motion, speed, temperatures, load and operating environment.

Type of motion is the first parameter of the tribological system. The motion can be sliding, which requires hydrodynamic lubrication (HL) theory for analysis, or rolling, which would require elastohydrodynamic lubrication (EHL) theory.

The difference between those two is simple; HL theory focuses on reducing friction and/or wear of rubbing solids by adding the proper lubricant that goes between the rubbing solids, creating a thin liquid film (Tribonet.org). As discussed, EHL is a type of HL where significant elastic deformation of the surface takes place, drastically altering the shape and thickness of the separating lubricant film (Tribonet.org).

In some cases, the motion is a combination of sliding and rolling, which occurs in certain rolling-element bearings, such as tapered roller bearing. In this instance, the lubricant's chemistry would need to be fine-tuned for optimal performance.

The second parameter of the tribological system is speed, which can be divided into three categories: fast, moderate and slow. In determining the ranges for speed categories, it is essential to know the Stribeck curve and how to calculate it. As stated, the Stribeck Curve is a graph that shows how friction in fluid-lubricated contacts is a non-linear function of lubricant viscosity, entrainment velocity and contact load. By knowing the speed of the contact, the proper lubricant can be selected to reduce friction.

Temperature is the third tribological parameter and a vital one as all lubricants have specific temperature ranges for optimal performance and effectiveness. Due to its chemistries, some lubricants operate within a broad temperature range, while others perform optimally at lower temperatures. By identifying the tribological system's temperature, a tribo-engineer is able to accurately select a lubricant(s) that will enable a machine to achieve optimum operating life and performance.

Next on the list is the load, which is an important component affecting the lubricant requirement. If there is a light load, a lubricant designed to minimize fluid friction – while still providing metal-to-metal friction protection – would be needed since the application is sensitive to frictional torque.

Adversely, if there is a heavily loaded application, one would need to select a lubricant containing specific additives to protect against extreme wear, galling and pitting.

The final parameter is the operating environment. If the tribosystem is operating in an environment subject to moisture or water, the required lubricant needs to be resistant to water washout or contamination, as well as provide good anti-corrosion properties. When the application exists in an environment containing chemical liquids and vapors, the required lubricant must be resistant to these chemicals and vapors.

If the application's environment is in a vacuum or partial vacuum, the application's atmospheric pressure must be within the operational limits of the lubricant and above its vapor pressure at the operating temperature (Lauer,"Tribology: the Key to Proper Lubricant Selection").

After identifying the system and its parameters, the tribo-engineer (or lubrication engineer) employs different lubricant chemistries to determine the optimal lubricant for the application. In addition to choosing lubricants based on chemistry, the tribo-engineer also needs to analyze the application based on the tribological system, which includes an analysis on speed factors, elastohydrodynamic (EHD) lubrication, bearing-life calculations, extreme-pressure lubrication, emergency lubrication and other special application requirements.

## Tribological Test Methods

In the past (and even today), testing tribological properties of materials involved building entire systems to run specialized tests such as field tests, bench tests, component tests and model tests.

Model tests, for example, allow for film thickness, friction and wear measurements to be conducted. Other tests include electrical and interferometry methods, the pin-on-disc test, the twin disc test, a reciprocating test and a rotary tribotest.

Tribology testing should always be designed and carried out to meet a defined need, and it is essential as it results in vital information regarding any failure mechanisms of mechanical components.

## What is a Tribologist?

A Tribologist is a student of, or expert in, the field of Tribology. Leonardo da Vinciis one of earliest and most famous Tribologists for his studies on the laws of friction. Peter H. Jost, British mechanical engineer and author of the ground-breaking Jost Report, coined the term "Tribology" in 1966 and is considered the father of the discipline.

Those involved in the development, maintenance, and continual improvement of lubrication programs are Tribologists by extension.

For further reading on tribology, please see our article, "A Comprehensive Exploration of Tribology: Unveiling the Historical Evolution."

# KEEP THE GREMLINS OUT OF YOUR DRUMS AND TOTES

This is no laughing matter. Most plant maintenance workers are oblivious to the amount of contamination that invade drums and totes that sit idle in storage. Even worse is the general ignorance of the damage caused by these intruders after they arrive. An attitude of "out of sight out of mind" leaves these lubricants vulnerable initially, and later the machine, when the impaired lubricants are put in service.

## False Perception of Sealed Containers

Drums and totes exposed to day-night temperature swings tend to have the greatest potential for particle and moisture ingression. As temperature changes, air is inhaled and exhaled through due to temperature-induced pressure changes in the head space of the vessel. This can easily occur even though the ports appear to be sealed tight. Experience has taught us that a threaded bung or ventcap on an oil drum is no assurance of a tight fit and seal. The larger the headspace and the wider the temperature swing the more pronounced the problem.

Incoming air brings with it moisture and often small particles. As the vessel continues to cool, condensation sweats the headspace ceiling and walls. Water drips into the oil where it is absorbed and free water falls to the vessel flow and puddles. Each evening or cooling cycle the precipitation/condensation occurs again.

More and more water and particles travel downward and build up in the bottom zone of the drum or tote. It is not uncommon for inches of sludge water to accumulate. The best way to prevent this and ensure a sealed container is through the use of a protective device that increases the headspace air pressure, which acts as a barrier against contaminants.

## So What's the Big Deal?

Cold oil can also cause additive precipitation. The colder the oil the bigger the issue. The additives stratify to the lower zone of the vessel where the water and dirt reside.

What occurs next seems to be relatively unknown or at least unspoken by people who are in charge of lubricant and machine-health. Once the precipitating additive make contact with the low-lying water, they combine to form a pasty, sludgy mass. The chemistry of the additives changes by hydrolysis and oxidation.

In other words, the additives are dead. Nor can they be resuscitated by agitation or heating. The condition is irreversible.

Eventually the time will come when the maintenance staff begins dispensing oil from the vessel into transfer containers or directly into the machine's sump or reservoir. If the vessel is a drum, a pump pick-up tube is inserted through the bung hole and pushed down to the bottom. This is where the gooey, sludge mass of water, dirt and dead additives reside.

This destructive material will be sucked up by the pump and discharged into the machine. Oxidized oil and additives propagate like the Covid virus. As the sludge spreads, this stresses the healthy oil in the machine and before long the entire charge of oil becomes oxidized and turning black. The oil filter will plug and internal oil-wet surfaces will become coated with deposits and varnish.

It is a chain reaction of events that leads ultimately to machine failure.

## Other Concerns

Drums stored outside can get covered with dirt and water. Cold temperatures can draw these contaminants as solids and liquids straight through unsealed openings into the internal space and the oil (or grease). Polar additives like rust inhibitors, fatty acids, anti-wear additives, dispersants and detergents can rapidly become adherent to the surface of these suspended particles. That ties up the additives making them unable to perform its intended function.

There are so many other issues associated with allowing contaminants to invade lubricants in storage. To a large extent the harm done by the contaminant to the lubricant and the machine is far greater than if the same additives were added directly into the circulating oil in the machine.

## How to Stop this From Happening

Don't just assume your drums and totes are unaffected. Take the following steps to help ensure they stay clear from moisture ingression:

- Do everything possible to keep your stored lubricants sealed from cyclic ambient air movement.
- Avoid storing your lubricants in areas where temperatures change.
- Avoid storing your outdoors exposed to dust, precipitation and day-night temperature changes.
- If needed use a drum cover to keep the top of your drums clean.
- Use a headspace alarm device to quickly alert you to breached seals and other unsealed vessel openings.
- If bottom sediment and water are suspected, sample the bottom of the vessel for inspection before pumping the oil into the machine.
- Always discharge new oil through filters before entering machine.

# THE UNSEEN CHALLENGE: MAINTAINING PROPER LUBRICATION IN THE NUCLEAR POWER INDUSTRY

In the heart of every nuclear power plant lies a hidden challenge that plays a crucial role in the facility's safety, efficiency, and longevity: maintaining proper lubrication. While the nuclear power industry is renowned for its stringent safety measures and rigorous maintenance procedures, the complexities and unique challenges of lubrication are often underestimated. This article will delve into nuclear lubrication, exploring its critical role and the challenges engineers and technicians face in ensuring it functions flawlessly.

## Radiation-Induced Breakdown

The most prominent challenge in nuclear lubrication is the pervasive presence of ionizing radiation. Nuclear power plants are environments where radiation is a part of daily life, and this radiation can have a detrimental effect on lubricants. Radiation-induced breakdown of lubricants can lead to their degradation and the loss of their lubricating properties. This poses a significant challenge for the industry, as maintaining consistent lubrication under such conditions requires specially designed radiation-resistant lubricants.

## Contamination Control

Nuclear power plants adhere to strict contamination control measures to prevent foreign materials from entering critical systems. Contaminated lubricants can be a serious issue, causing equipment damage and system failures. Therefore, ensuring that lubricants remain uncontaminated is a constant challenge. Lubrication engineers must employ sophisticated filtration and purification techniques to maintain the purity of lubricants in such a sensitive environment.

## Extreme Temperatures

Nuclear processes often generate extreme temperatures, which can harm conventional lubricants. High temperatures can cause lubricants to break down, lose viscosity, and ultimately fail to protect the equipment. Consequently, special high-temperature lubricants are required to ensure that components function optimally under these conditions.

## Cryogenic Conditions

Conversely, some nuclear applications operate under cryogenic conditions, particularly in research reactors, where extremely low temperatures are the norm. Conventional lubricants can become brittle and lose their lubricating properties in such conditions. Lubricants specifically designed for low-temperature applications are essential to ensure that equipment continues to operate efficiently.

## Chemical Compatibility

The nuclear industry employs various chemicals, including coolants and moderators, in its processes. Unfortunately, some lubricants can be incompatible with these chemicals. This challenge necessitates carefully selecting lubricants to ensure they are compatible with the specific environment in which they will be used.

## Long Service Life

Nuclear equipment is designed to have an extended service life, often spanning several decades. To meet these long operational requirements, lubricants must provide long-lasting protection and lubrication without degrading over time. This presents the challenge of selecting and formulating lubricants that can endure for years without performance degradation.

## Safety and Regulatory Compliance

The nuclear industry operates under stringent safety regulations and guidelines. Proper lubrication is critical to maintaining safety, and nuclear facilities must ensure that their lubrication practices comply with regulatory requirements. The challenge here is in adhering to the rules and demonstrating and documenting compliance with regulatory bodies.

## Inaccessible Locations

Nuclear facilities often contain components in hard-to-reach or confined spaces, making lubrication and maintenance tasks exceedingly challenging. Access to these areas may be limited due to radiation risks, equipment design, or other factors. Engineers and technicians must develop specialized tools, equipment, and procedures to address these hard-to-reach locations.

## Monitoring and Inspection

Continuous monitoring and inspection of lubrication systems are essential to identify issues early and prevent equipment failures. This can be challenging in nuclear facilities due to the high radiation levels that can limit human access to certain areas. Engineers often employ remote monitoring technologies, robotics, and other advanced techniques to ensure the integrity of lubrication systems.

## Environmental Impact

Lubrication spills or leaks in a nuclear facility can have severe environmental and safety consequences. Addressing the environmental impact of lubrication practices is a challenge in itself. The nuclear industry must not only contain and remediate any lubricant spills but also develop strategies for minimizing the impact of lubricant use in the first place.

## Supply Chain Concerns

Sourcing specialized lubricants and materials for nuclear facilities can be challenging due to their unique requirements. Nuclear lubricants must adhere to strict standards and regulations. Supply chain disruptions can have cascading effects on the maintenance and operation of nuclear facilities, which makes ensuring a robust supply chain a top priority.

## Solutions and Innovations

The nuclear industry has risen to meet these challenges with a combination of innovation, technology, and rigorous procedures:

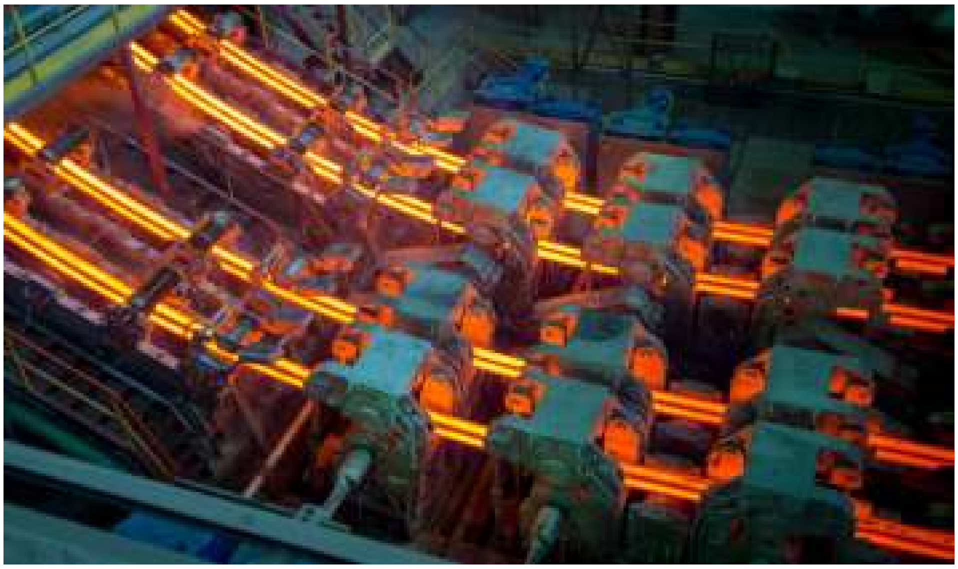
1. **Radiation-Resistant Lubricants:** The development of lubricants specifically designed to resist radiation-induced breakdown has been crucial. These lubricants can withstand the high radiation levels in nuclear environments, ensuring longevity and reliability.
2. **Advanced Filtration and Purification:** Nuclear facilities employ state-of-the-art filtration and purification systems to maintain the purity of lubricants. These systems help remove contaminants and particles that might compromise equipment performance.
3. **High-Temperature Lubricants:** Specialized lubricants operating at high-temperatures have been developed to protect critical components in nuclear-reactors.
4. **Low-Temperature Lubricants:** Lubricants designed for low-temperature environments are necessary for cryogenic applications. These lubricants maintain their fluidity and lubricating properties in extremely cold conditions.
5. **Chemically Resistant Lubricants:** Lubricants are formulated to be compatible with the specific chemicals used in nuclear processes, preventing undesirable chemical reactions and ensuring equipment integrity.
6. **Long-Lasting Formulations:** The nuclear industry collaborates with lubricant manufacturers to create formulations that can withstand long operational lifespans without degradation, reducing the frequency of maintenance and replacement.
7. **Robotic Maintenance:** Inaccessible locations are addressed through robotic systems designed to perform lubrication and maintenance tasks in high-radiation areas without risking human health.
8. **Remote Monitoring:** Advanced sensor technologies and remote monitoring systems enable engineers to monitor lubrication systems closely without direct access to high-radiation zones.
9. **Environmental Stewardship:** The nuclear industry is increasingly focused on minimizing its environmental impact. This includes developing lubricants that are less harmful in the event of spills and taking measures to prevent such incidents.
10. **Diversified Supply Chains:** Nuclear facilities often work to diversify their lubricant supply chains to mitigate the risk of disruptions. This can involve-sourcing from multiple suppliers or maintaining strategic stockpiles.

## Conclusion

Proper lubrication in the nuclear power industry is a hidden yet critical aspect of safe and efficient operation. The challenges of radiation, contamination control, extreme temperatures, and other factors are met with innovation and rigorous procedures. As the industry continues to evolve, the focus remains on finding solutions that ensure the integrity and safety of nuclear facilities, and lubrication plays an essential role in this endeavor. Understanding and addressing these challenges is essential for the nuclear power industry to continue providing clean and reliable energy while maintaining the highest safety and environmental responsibility standards.

# THE EVOLUTION OF POLYUREA GREASES: A GAME-CHANGER IN CONTINUOUS CASTERS

Polyurea greases have revolutionized the lubrication industry, particularly in high-temperature and heavy-load applications like continuous casters in steel mills. Their development marked a significant advancement over traditional soap-thickened greases, offering superior performance and durability. This article delves into the history, structural innovation, and modern-day applications of polyurea greases, with a special focus on their critical role in continuous casting operations.



## The Birth of Polyurea Greases: A 1950s Innovation

The 1950s witnessed a breakthrough in lubrication technology with the development of polyurea greases. Before this, industries relied on lithium, calcium, and sodium-based soap-thickened greases, which often struggled with stability, temperature resistance, and water tolerance. Polyurea greases emerged as a robust alternative, providing solutions to these limitations and setting a new standard in industrial lubrication.

## The Science Behind Polyurea Greases: Structural Innovation

At the heart of polyurea greases lies a unique diurea thickener structure, formed through a chemical reaction between diamine and diisocyanate. This structure imparts exceptional mechanical and thermal stability to the grease, along with a high dropping point and remarkable oxidative stability. Additionally, the development of Tetra Urea structures has further enhanced the performance of polyurea greases, offering even greater thermal stability and resistance to extreme enviro mental conditions. These innovations make polyurea greases stand out, particularly in demanding environments where traditional greases may falter.

## Advancements and Specialization: Catering to Industrial Needs

Over the decades, advancements in chemical engineering and a deeper understanding of polyurea chemistry have led to the creation of specialized polyurea greases. By modifying base oils, additives, and thickener compositions, manufacturers have tailored these greases to meet the rigorous demands of specific industries. Today, polyurea greases are integral to sectors requiring extreme temperature stability, enhanced load-carrying capacity, and resistance to harsh environmental conditions.

## Modern Applications: Polyurea Greases in Continuous Casters

Polyurea greases are now a staple in various industrial applications, from electric motors and pumps to automotive components and heavy machinery. However, their most critical application lies in continuous casters within the steel industry. The extreme conditions of continuous casting, including high temperatures, heavy loads, and exposure to water and contaminants, necessitate a lubricant that can withstand such challenges. Polyurea greases excel in this environment, offering unmatched protection and efficiency.

## Why Polyurea Greases are Essential for Continuous Casters

- **High-Temperature Stability:** Continuous casters operate at intense temperatures. Polyurea greases maintain their structural integrity and lubrication efficiency, preventing premature breakdown and ensuring continuous operation.

- **Exceptional Mechanical Stability:** The shear stability of polyurea greases ensures that they remain consistent under high shear conditions, crucial for the reliability of bearings and other components in continuous casters.

- **Superior Water Resistance:** Water ingress is common in continuous casters. Polyurea greases resist water washout, maintaining a protetive film on components and preventing rust and corrosion.

- **Extended Service Life:** Thanks to their exceptional stability, polyurea greases offer a long service life, reducing the need for frequent re-lubrication and minimizing maintenance downtime.

- **Resistance to Contaminants:** Continuous casters are exposed to mill scale and other debris. Polyurea greases resist contamination, preserving their lubricating properties and protecting equipment surfaces from wear.

- **Oxidative Stability:** Polyurea greases resist oxidation, preventing the formation of harmful by-products that could compromise component integrity and lead to premature failures.

- **Enhanced Load-Carrying Capacity:** The robust load-carrying capacity of polyurea greases ensures protection against wear and damage under the heavy loads typical of continuous casting operations.

- **Broad Operating Temperature Range:** Polyurea greases perform effectively across a wide temperature spectrum, making them suitable for different sections of continuous casters, from high-heat zones to cooler areas.

- **Compatibility with Various Base Oils:** The versatility of polyurea greases allows them to be formulated with different base oils, tailoring their properties to meet the specific requirements of continuous casting processes.

## The Future of Lubrication in Continuous Casters

Polyurea greases have become the lubricant of choice for continuous casters in the steel industry, thanks to their superior performance under extreme conditions. Their ability to deliver high-temperature stability, mechanical robustness, and long-lasting protection ensures the smooth and efficient operation of continuous casters, reducing maintenance costs and extending the life of critical components. As the steel industry continues to evolve, the role of polyurea greases in maintaining operational efficiency and reliability will only become more significant.

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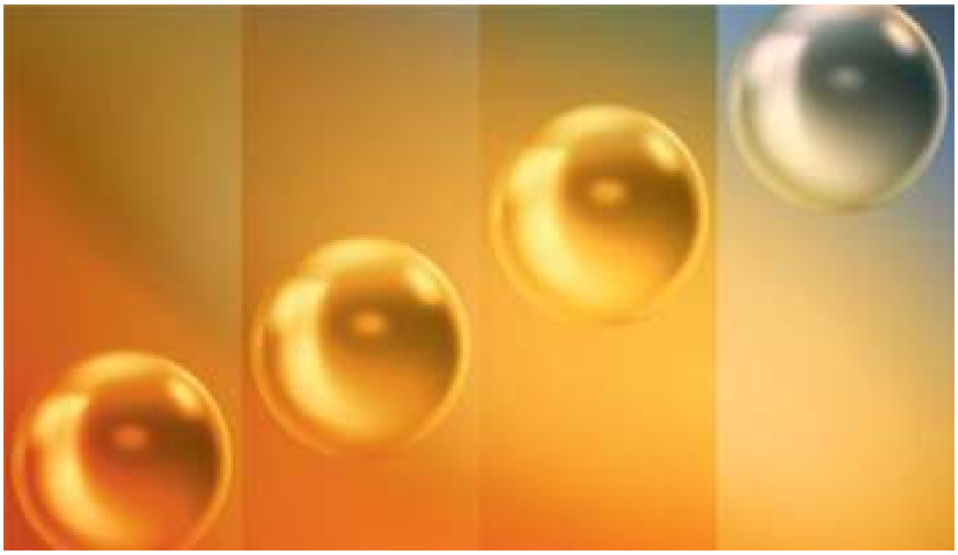
# THE CRITICAL ROLE OF VISCOSITY INDEX IN LUBRICATION

Understanding the importance of each property of a lubricant is more than just about the lubricant — it's a critical factor in ensuring the longevity and efficient operations of industrial machines. At the heart of these properties lies viscosity, perhaps the most important physical **property of a lubricant**, whether it be an **oil or a grease.**

This article reviews the viscometrics of a lubricant, particularly the crucial role of V**iscosity Index (VI)** in lubricant selection.



## Viscosity: The Cornerstone of Lubrication

Viscosity, in its simplest definition, is a measure of a lubricant's resistance to flow, but often analogized as the 'thickness' or 'thinness' of the oil. This very property is what forms the hydrodynamic wedge, or film thickness, that separates machine surfaces — a critical layer that prevents the direct contact of moving metal surfaces within nearly every machine in our industry.

Without it, machine wear would occur almost instantly. When put like that, it's clear why it is treated with such importance, right? Ok, let's move on.

The efficiency of this film thickness is largely contingent on the viscosity of the lubricant. However, viscosity is not a static attribute; it's a dynamic property heavily influenced by a range of factors. Temperature also plays a familiar role in **dictating viscosity.**

Generally, an oil's viscosity increases (or thickens) as temperatures decrease. And conversely the viscosity decreases (or gets thinner) at higher temperatures. This variable nature of viscosity with temperature fluctuations brings us to a fundamental aspect of lubricants — the Viscosity Index.

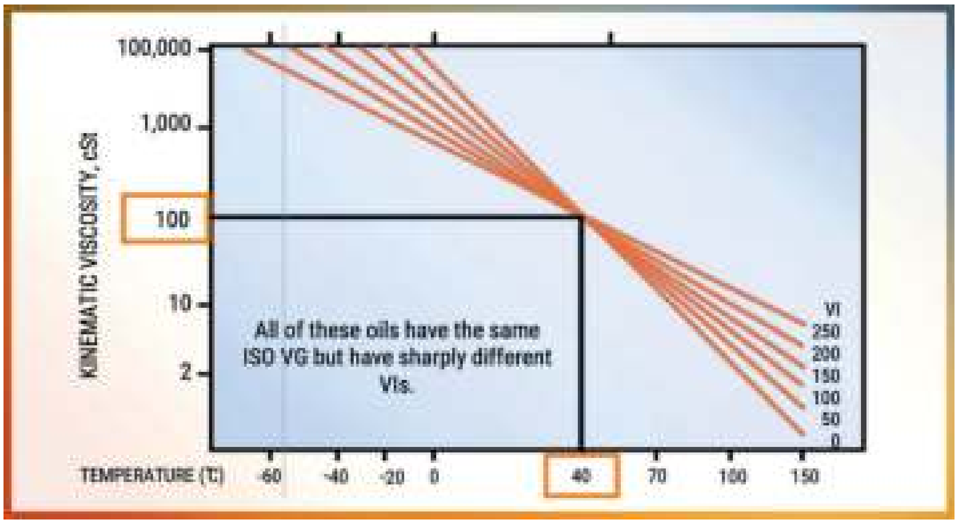
## The Viscosity Index Explained

The Viscosity Index (VI) is a measure that defines how the viscosity of an oil changes with respect to a change in temperature. Understanding VI is crucial to discern whether a lubricant meets the operational requirements of machinery across various temperature ranges. It's not merely a technical specification; it's a compass guiding the selection of the right lubricant for effective machinery maintenance.

The VI of an oil is determined by measuring its viscosity at two standard temperatures: 40°C and 100°C. These values are then compared against a scale derived from two reference oils. Conventional mineral oils typically have a VI ranging between 95 to 100, while highly refined mineral oils stand around 120.

Synthetic oils, known for their superior qualities, can have a VI up to 250 or more. This is a unitless number, but simply put: a higher VI is more desirable as this indicates a lower rate of viscosity change with temperature fluctuations.

This concept can be visualized through a graph with viscosity on the vertical axis and temperature on the horizontal axis. Oils with higher VIs exhibit a more horizontal slope, indicating their ability to maintain a stable lubricating film over a wider temperature range.




## The Impact of Viscosity Index on Different Machinery

Different types of machinery, such as gearboxes, compressors, crankcase engines, and hydraulics, each come with their own set of lubrication needs.These needs are heavily influenced by the machinery's design, operational loads, and speed, which in turn dictate the required viscosity — and by extension, the Viscosity Index — of the lubricant.

In gearboxes or compressors, for instance, the right VI is imperative to ensure that the lubricant maintains an adequate film thickness under varying operational temperatures and loads. If operating temperature were to decrease such as during down periods or cold weather conditions, the viscosity would get too thickwhich would lead to several issues, including increased energy consumption with higher **fluid friction** or restricted oil circulation.

If operating temperatures get too high, then the resulting decrease in viscosity would lead to rapid mechanical wear. Both scenarios result in subsequent failure. Both scenarios are mitigated by a higher VI that is properly selected.

It's clear that high VIs are particularly crucial in machines that experience wide temperature variations. For example, a lubricant in an outdoor compressor duringa cold morning might face drastically different conditions by midday as temperatures rise. A lubricant with a high VI will fluctuate less in terms of viscosity, providing more consistent protection throughout these temperature changes.

Yet, the VI's role goes beyond just managing temperature-induced viscosity variations. It's about ensuring that the lubricant can effectively support the machinery's specific design and operational demands. The ideal lubricant forms a film robust enough to prevent metal-to-metal contact, yet fluid enough to allow for efficient movement of parts.

## Viscosity Index Improvers

The science behind lubrication has evolved to meet the diverse and demanding needs of modern machinery over the decades, leading to the development of Viscosity Index Improvers (VII). These are additives designed to enhance a lubricant's VI, enabling it to operate efficiently over a broader temperature range.

VII are typically polymers added to oil to minimize the rate of viscosity change with temperature (thus increasing the VI). They essentially work by expanding as they heat up, which counteracts the oil's natural tendency to thin at higher temperatures. The use of VIIs is a balancing act — while they offer the advantage of broadening the temperature range over which the oil can operate effectively, they can also introduce complexities.

One of the challenges with VI improvers is that they can be sheared down in service, particularly in high-stress environments like gearboxes or engines. This shearing can lead to a permanent loss of viscosity, and by extension, a decrease in the lubricant's effectiveness.

It's a phenomenon known as Temporary Viscosity Loss (TVL), and it's a critical factor to consider when selecting a lubricant with VI improvers, especially for high-shear applications. With minerals oils often requiring more VII, these scenarios are benefited from the use of synthetics that have a naturally higher VI.

Despite these limitations, the benefits of VII are undeniable, particularly for equipment operating across a wide range of temperatures. The key is in choosing a lubricant with the right balance of VI improvers to meet the specific needs of the machinery without introducing undue risk of shear-induced viscosity loss.

## Best Practices in Viscosity Index Selection

Selecting the right VI for a lubricant is as much an art as it is a science. It requires a deep understanding of the machinery's operational parameters and environmental conditions. Here are some best practices to guide this selection process:

- **Know Your Machinery's Requirements –** Each piece of machinery has its unique viscosity needs based on its design, operational speeds, and loads. Understanding these requirements is the first step in selecting a lubricant with the appropriate VI. For instance, bearings in high-speed machinery may need a lower viscosity oil compared to those in heavy-load, slow-speed gear systems. Lower viscosity oils can be more impacted by small changes in VI, this it's more critical to get right.
- **Consider the Operating Environment –** It should come as no surprise at this point that ambient temperature and temperature variations play a significant role in VI selection. Machinery operating outdoors in variable climates will benefit from lubricants with a higher VI compared to those used in more controlled environments.
- **Balance VI with Other Lubricant Properties –** While VI is crucial, it's not the only property to consider. Balancing VI with other lubricant characteristics, such as base-oil type, additive composition, and wear protection capabilities, is essential for optimal lubricant performance.

## A Case Example in VI Selection

Let's consider the case of a large industrial gearbox operating in a fluctuating climate. During winter, temperatures plummet and cause the lubricant to thicken, which could lead to insufficient lubrication at startup. Conversely, in the summer heat, the same lubricant might become too thin and fail to maintain an adequate lubricating film.

The maintenance team initially used a conventional mineral oil with a moderate VI. However, they noticed increased wear during seasonal temperature changes, leading to frequent maintenance and costly downtime.

The solution came with the switch to a synthetic lubricant with a higher VI and VImprovers. This change resulted in a more stable viscosity across temperature variations, reducing wear and extending the gearbox's service life. This is a common example that underscores the importance of VI in lubricant selection and its direct impact on machinery reliability and maintenance costs.

## Viscosity Index Calculator

In the digital era, where information is at our fingertips, having practical tools to apply theoretical knowledge is invaluable. An interactive Viscosity Index calculator, which is currently under development at Noria, precisely serves this purpose.

The VI calculator is straightforward to use. Simply input the oil's viscosity at 40°C and 100°C, and the calculator will estimate its VI. This tool not only aids in understanding the VI of a current lubricant but also assists in comparing potential alternatives. You can also input a known VI and viscosity at one of the temperature points to calculate the viscosity at the other temperature point.

**Example Calculation:** Let's say you have an oil with a viscosity of 100 cSt at 40°C and 15 cSt at 100°C. Inputting these values into the calculator will yield a VI or 157. This is higher than mineral oil and is likely a synthetic. This calculation should help in understanding how this oil will behave across various temperaturechanges, particularly when assessing whether it is suitable for your specific machinery and operating conditions.

## Final Note

The Viscosity Index is more than just a number on a lubricant's data sheet — it'sa critical factor in ensuring the health and efficiency of your machinery. Understanding and utilizing VI in lubricant selection can significantly improve machinery performance, reduce maintenance costs, and extend equipment life. Whether you are a seasoned maintenance professional or new to the world of industrial lubrication, acknowledging the critical role of VI will undoubtedly enhance your approach to machinery maintenance.

Staying informed and utilizing tools like the VI calculator is an essential part of lubricant selection. It can help ensure that your machinery continues to operate at its peak, regardless of the challenges posed by varying temperatures and operational demands.

If you have any questions at all about how this calculator can be used or other variations with your specific application, please don't hesitate to contact Noria. Remember, the right lubricant, with the appropriate VI, is not just a commodity: it's a vital component of your machinery's health and your operation's success.

# RINL AND IOCL INK 5-YEAR DEAL FOR LUBRICANT SUPPLY AND SUPPORT


Rashtriya Ispat Nigam Limited (RINL), the corporate entity of Visakhapatnam Steel Plant (VSP), has signed a five-year Memorandum of Understanding (MoU) with Indian Oil Corporation Limited (IOCL) for the supply of critical lubricants, including hydraulic oils, lubricating oils, and greases. This agreement, effective from 2024 to 2029, ensures a continuous and uninterrupted supply of these essential products to RINL.

In addition to product supply, IOCL will provide technical support in areas such as condition monitoring of critical systems, bulk oil handling, and used oil management. Training for RINL personnel at IOCL's R&D center in Faridabad is also part of the collaboration, aimed at optimizing lubricant consumption and maintaining efficiency in plant operations. This partnership, which builds on a long-standing relationship first established in the 1990s, was described as a benchmark for industry collaboration towards nation-building by A.K. Bagchi, Director at RINL. Both companies emphasized the mutual trust and professional excellence that have been the cornerstone of their 30-year relationship

# SHELL INDIA EXPANDS NETWORK WITH SILENT SHIFTS AT FUEL STATIONS

Shell India is expanding its fuel station network with a unique initiative called "Silent Shifts," which focuses on inclusivity by employing hearing-impaired, physically challenged individuals, and transgenders. These employees efficiently manage fuel stations across the country, handling tasks such as refueling, cleaning, and customer service, often using sign language and non-verbal communication to ensure smooth operations.

The program highlights Shell's commitment to diversity, creating opportunities for underrepresented communities. Customers have praised the thoughtful service model, and Shell India aims to replicate this inclusive approach at more fuel stations as part of its expansion plans.

Reported in early 2024, this initiative aligns with Shell's broader vision of sustainable business practices and community development, making a positive impact both in terms of employment and customer satisfaction.

# MAK LUBRICANTS WINS 'BRAND OF THE DECADE' AT GOALFEST CONCLAVE 2024

Bharat Petroleum Corporation Limited (BPCL), India's second-largest energy PSU, has announced that its premium brand, MAK Lubricants, received the prestigious 'Brand of the Decade Award 2024' by Herald Global and Brand Advertising Research & Consulting Pvt. Ltd. (BARC). This award recognizes MAK Lubricants' dedication to excellence, innovation, and customer satisfaction over the last ten years. The brand has built strong customer loyalty and adapted to market changes, which contributed to this recognition. Shri Sohail Akhtar, Chief General Manager (Lubes), accepted the award on behalf of the MAK Lubricants team at the Goalfest Conclave 2024 in Mumbai.


Additionally, Shri Subhankar Sen, Business Head (Lubes) at BPCL, was honored with the 'Marketing Meister Award 2024' at the same event. This award acknowledged Shri Sen's leadership in driving the brand's growth and delivering value across different customer segments. He credited the entire MAK Lubricants team for maintaining strong customer connections.

These accolades, awarded by Herald Global, highlight MAK Lubricants' sustained success in the market, demonstrating the brand's commitment to quality and customer satisfaction. BPCL's continued focus on innovation and excellence strengthens MAK Lubricants' position as a trusted brand in India and sets the stage for future global success.

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