

Machinery Lubrication

India March - April 2014

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2nd ICIS Indian Base Oils
& Lubricants Conference
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Particles:

Friend or Foe?

Understanding the Value of
Particles in Oil Analysis

INSIDE

Don't Ignore Viscosity Index when
Selecting a Lubricant

The Effects of EP Additives on
Gearboxes



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Publisher's Note



*D*r. E.C.Fitch, father of Noria's founder & President Jim Fitch has done some pioneering work at Oklahoma State University on particle count and its importance in lubrication. However, it has only been in the last 10 to 15 years that industry, has started to fully realize the importance of fluid cleanliness.

Considered by many to be the single most important test for used oil analysis, whether you are conducting onsite particle counting, or relying on a commercial lab, there can be no doubt that a host of problems can be quickly and easily determined by monitoring the number and size-distribution of particles in an oil sample. The importance of clean oil cannot be over emphasized. Particle count data is an invaluable part of any proactive condition-monitoring program, from ensuring that abrasive bearing wear is minimized, to determining if a hydraulic fluid is clean enough for reliable operation.

The cover story in this issue talks about particles and understanding the value of particle in oil analysis. To the mechanical engineer and tribologist, the presence of particles is an indication that contaminants have entered the system or that certain components are wearing abnormally. Particles that are

smaller than the minimum clearances could result in abrasive wear, which in turn causes premature aging or failure. Large particles could result in blockages of oil channels, which could lead to oil starvation. Thus, both conditions spell trouble to these role players.

Base Oil is critical to the lubricant industry from the point of view of quality, price and availability. Keeping this in mind, we have been involved with a number of Base Oil & Lubricants Conferences in Asia (India, UAE, China etc). One such conference is being organised in Mumbai by ICIS from 28th to 30th April 2014. Reputed global & domestic participants are likely to interact on issues of interest. We will carry an article on Base Oil Refining and the regular article on Base Oil (Trends, Import / Export Data & Availability).

In the viewpoint section of the magazine, there is an article on the critical role of the additives in lubrication. Whether they are enhancing, suppressing or imparting new properties to base oils, additives play an important role in machinery lubrication. Additives are organic or inorganic compounds dissolved or suspended as solids in oil. They typically range between 0.1 to 30 percent of the oil volume, depending

on the machine. The article further discusses the three basic roles of additives and polarity of additives as defined by the natural directional attraction of additive molecules to other polar materials in contact with oil.

We had been receiving feedback regarding the non delivery of the print magazine from some of our readers. Keeping this in mind, we have upgraded our delivery mechanism and hope that all subscribers will receive the magazine well in time.

We would like thank our readers for your feedback on our articles in Machinery Lubrication India. Your feedback is very important to us. Please keep them coming so that we can continue to provide you with cutting edge articles on lubricants, lubrication and reliability.

We would also like to take this opportunity to wish all our readers and advertisers a Happy Holi, the festival of colors.

Warm Regards,

Udey Dhir

Don't IGNORE VISCOSITY Index When SELECTING a LUBRICANT

Too often the viscosity index (VI) is disregarded as a lubricant selection parameter. One reason is simply because it is poorly understood. Some people think the viscosity index is incorporated in the ISO Viscosity Grade, but it is not. It stands alone as an independent lubricant performance differentiator.

We all know that viscosity is the single most important physical property of a lubricant. It is a crude measure of a lubricant's molecular constitution from the standpoint of hydrocarbon chain size. Viscosity is determined by creating friction between the molecules from fluid movement. The higher the intermolecular friction (longer molecular chains), the higher the viscosity.

Viscosity determines film thickness and

film strength in machines. It also influences other important factors such as those in the table below.

However, a lubricant's viscosity is meaningless unless the temperature is noted, i.e., the temperature at which viscosity is measured. Conversely, machines don't care about temperature

design (e.g., bearing), loads and speeds. You may recall that the well-known Stribeck curve doesn't have a temperature variable.

That said, because machines require a certain viscosity, and temperature is known to have a dramatic influence on viscosity, it is imperative that you take

The higher the viscosity index, the more stable the viscosity across a range of temperatures.

as it relates to viscosity (loosely speaking). Minimum, maximum and optimum viscosity requirements demanded by machines don't take temperature into account. Instead, a machine's viscosity requirement is based on such things as component

the average operating temperature and temperature range into account when selecting viscosity. Remember, the ISO Viscosity Grade system only reports viscosity at a single temperature: 40 degrees C. Most importantly, for any candidate oil, you need to know how viscosity changes relative to a change in temperature.

The viscosity index was developed for this purpose (ASTM D2270) by E. Dean and G. Davis in 1929. It is an empirically derived, unitless number. Based on the methodology, Pennsylvania crude (paraffinic) was set as a benchmark at one extreme, representing low viscosity changeability relative to temperature. At the other extreme was Texas Gulf crudes (naphthenic). If a lubricant was similar to the Pennsylvania crude, it was

FACTOR	REASON
Wear rate and machine life expectancy	Viscosity influences boundary, mixed-film and full-film lubrication (Stribeck curve)
Lubricant temperature and lubricant life expectancy	Mechanical and fluid friction cause heat, which shortens lubricant life
Machine sensitivity to particle contamination	Thin films increase a machine's contaminant sensitivity
Energy consumption	Mechanical and fluid friction consume more energy
Extreme cold and high temperature conditions	Influences part movement (e.g., crankability) and chemical stability (e.g., oxidation)
Fluidity	Ease at which lubricants reach vital frictional zones in machines

The Effects of Viscosity

assigned a VI of 100. If it was similar to Texas Gulf crude, it was assigned a VI of 0. Halfway in between was a VI of 50, and so forth. The higher the VI, the

89%
of lubrication professionals consider an oil's viscosity index when selecting a lubricant, according to a recent survey at machinerylubrication.com

more stable the viscosity across a range of temperatures (more desirable). The temperatures used to determine the VI are 40 degrees C to 100 degrees C.

An Internet search on “viscosity index calculator” will direct you to several Web pages. You can use these calculators in a variety of ways. For instance, if you know the viscosity of a lubricant at two different temperatures, you can use the calculator to give you an estimation of the VI. Better yet, you can enter a single known viscosity (and temperature) and VI (commonly found on a lubricant’s product data sheet) to calculate the viscosity of the same lubricant at any other temperature (say, a machine’s operating temperature). Lubricants with VIs as low as minus 60 are available today. Other lubricants can have VIs ranging over 400. However, the vast majority of lubricants on the

market will have VIs in the range of 90 to 160.

Let’s take a look at two different oils that share one common property – they’re both ISO VG 150. However, one of these oils (Oil A) has a VI of 95 (mineral oil), while the other (Oil B) has a VI of 150 (synthetic). Now let’s examine the viscosity of these oils from minus 20 degrees C (minus 4 degrees F) to 100 degrees C (212 degrees F). This is shown in the table below.

Comparing the 95 VI oil to the 150 VI oil, there is a 236-percent difference in viscosity at minus 20 degrees C and a minus 25-percent difference at 100 degrees C. Of course, there is no difference at 40 degrees C. As mentioned previously, the machine dictates the viscosity requirements based on its design and operating conditions. These conditions influence temperature, which in turn influences viscosity, which influences the protection provided.

Many machines use a common lubricant across numerous frictional zones and have varying loads, speeds and temperatures. Outdoor mobile equipment typically works under these challenging conditions. For such machines, there is no easy way to identify optimum viscosity by a theoretical calculation. Instead, the ideal viscosity is estimated using actual

field measurements by applying a trial-and-error approach (simply testing with different viscosity oils and measuring temperature and wear protection).

For machines of constant load, constant speed and constant ambient temperatures, the ideal viscosity very often results in the lowest stabilized oil temperature. Oils of lower or higher viscosities (than the optimum viscosity) will typically increase the oil’s stabilized temperature due to either churning losses (too much viscosity) or mechanical friction (too little viscosity).

If conditions are not constant (variable loads, variable speeds, variable ambient temperatures, etc.), then there is a need for not only the optimum viscosity but also a high viscosity index to stabilize the optimum viscosity. The more variable the conditions, the greater the need for high VI oils.

Also, keep in mind that for a great many machines there has been no past experimental or theoretical effort to identify the optimum viscosity. Viscosity selection is more of a wild guess. This too calls for a high VI lubricant.

You must also consider that the ISO Viscosity Grade system (ISO 3448) is based on 50-percent increments between grades. As such, if you go from ISO VG 100 to VG 150, it is a 50-percent jump. When the viscosity options are all 50 percent apart, it is difficult to achieve precision lubricant selection. These large viscosity steps are further magnified at lower temperatures. This is yet another reason to select high VI lubricants.

An oil’s VI can also tell you useful information about a lubricant’s formulation, including the type and quality of base oils. For instance, highly refined and pure mineral oils

TEMPERATURE DEGREES	-20° C (-4° F)	20° C (68° F)	40° C (104° F)	60° C (140° F)	80° C (176° F)	100° C (212° F)
Oil A, VG 150: Viscosity (cSt) at VI = 95	37,000	550	150	56	26	15
Oil B, VG 150: Viscosity (cSt) at VI = 150	11,000	435	150	65	34	20
Viscosity difference between Oil A and Oil B	+236%	+26%	0%	-14%	-23%	-25%

Comparison of Two Different Oils with the Same Viscosity Grade

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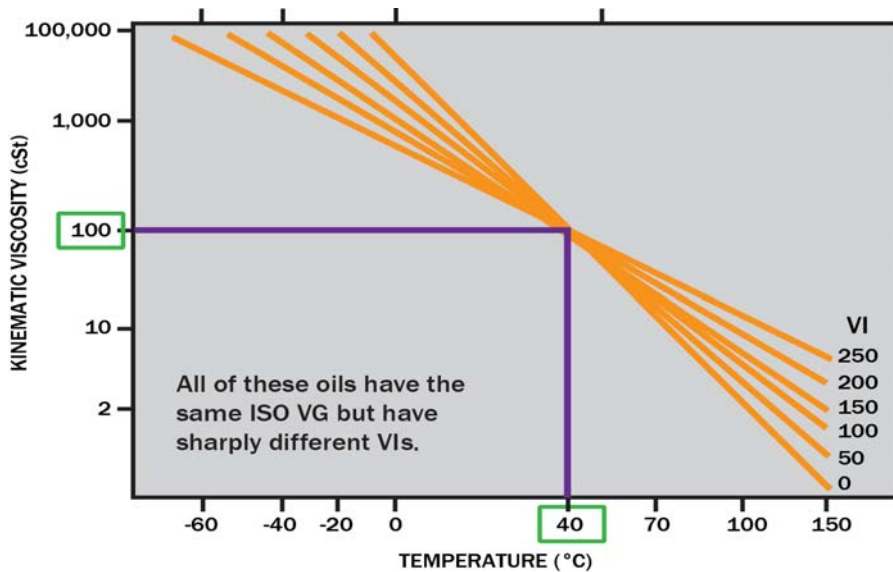
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will have correspondingly higher VIs. Certain additives, such as viscosity-index improvers and pour-point depressants, influence VI as well. Remember, oils loaded with VI improvers, especially of certain types, are prone to permanent loss of VI and viscosity over time. There are ASTM tests for measuring the VI stability of lubricants exposed to high shear.

Did You Know? The vast majority of lubricants on the market have a viscosity index in the range of 90 to 160.

Viscosity index values are on almost all product data sheets for commercially available lubricants. This simple number is there for a reason and should be strongly considered when writing a specification for lubricants in nearly all machine applications. ■

High or Low Viscosity Index?

A lubricant may merit having a high VI for one or more of the following reasons:

- The optimum viscosity is not known
 - Varying loads and speeds exist
 - Varying ambient temperatures exist
 - To boost energy efficiency
 - To boost oil service life (lower average temperature)
 - To boost machine service life (fewer repairs and downtime)
- Cheaper, lower VI lubricants may make sense if:
- Speeds and loads are constant
 - Temperature is constant (constant ambient temperature or a heat exchanger is in use)
 - The optimum viscosity at the operating temperature is known and is consistently achieved

About the Author

Jim Fitch, is the CEO and a co-founder of Noria Corporation and is also director and board member of the International Council for Machinery Lubrication. He has a wealth of “in the trenches” experience in lubrication, oil analysis, tribology and machinery failure investigations. Over the past two decades, he has presented hundreds of courses on these subjects. He serves as a U.S. delegate to the ISO tribology and oil analysis working group.

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CONSIDER Contamination CONTROL BEFORE BUYING Hydraulic EQUIPMENT

These days, best-practice contamination control is more like an accepted pre-condition for reliability. Given contemporary advances in technology for excluding and removing contaminants, it could be said that failure to control contamination is a failure of machine design rather than a failure of maintenance.

That said, effective contamination control is not something to be taken for granted. The results you get are only as good as those you demand, which is why it never hurts to be reminded of the reliability benefits of kicking fluid cleanliness up a notch. Consider the following case study:

A sugar mill was operating a fleet of more than 20 sugar cane harvesters. The typical fluid cleanliness of the

hydrostatic transmission for the ground drive on these machines was ISO 22/20, and they were suffering regular pump failures — three pumps per machine, per season, on average.

The sugar mill contracted a local hydraulic engineering firm to investigate the recurring pump failures. They recommended a specification change to the ground-drive hydraulic motors and an upgrade of the filtration.

One machine was modified as a prototype, and after showing promising results, two more machines were modified in the first season. The ISO cleanliness code on the three modified machines was 18/15 or better.

By the fourth year, 15 machines had been modified. The mill was now

Factors in Setting Target Cleanliness Levels

There are two important factors for hydraulic systems that can help you set target cleanliness levels. One is how sensitive the components are to contaminants. This is called contaminant tolerance.

The second factor is pressure. There is a disproportionate relationship between pressure and contaminant sensitivity. Basically, the greater the pressure, the far greater the contaminant sensitivity the components have to contamination.

After you have considered the component type and the pressure, also consider the duty-cycle severity, the machine criticality, the fluid type and safety concerns. All of these factors collectively can be used to set target cleanliness levels in hydraulic systems.

changing out one variable piston pump per machine every three seasons — a nine-fold increase in pump life.

Armed with this data, the sugar mill convinced the cane-harvester manufacturer to incorporate the same transmission and hydraulic filtration design at the factory.

This is not a scientific study into the benefits of improving fluid cleanliness alone, because clearly, other changes were made to the hydraulic circuit in addition to upgrading the filtration. We're also not told what influence (if any) these modifications had on other

OPERATING PRESSURE	<1,500 PSI	1,500- 2,500 PSI	>2,500 PSI
Servo Valve	16/14/12	15/13/11	14/12/10
Proportional Valve	17/15/12	16/14/12	15/13/11
Variable Volume Pump	17/16/13	17/15/12	16/14/12
Cartridge Valve	18/16/14	17/16/13	17/15/12
Fixed Piston Pump	18/16/14	17/16/13	17/15/12
Vane Pump	19/17/14	18/16/14	17/16/13
Pressure/Flow Control Valve	19/17/14	18/16/14	17/16/13
Solenoid Valve	19/17/14	18/16/14	18/16/14
Gear Pump	19/17/14	18/16/14	18/16/14

Example of Hydraulic Fluid Cleanliness Targets



ISO Codes. Right on Target.

hyprofiltration.com



Knowledge is power.

Check out the Hy-Pro Filtration blog to learn everything you need to know about Target ISO Codes.



It could be said that failure to control contamination is a failure of machine design rather than a failure of maintenance.

important operating parameters such as pressure and temperature.

But what can't be disputed is the drastic improvement in pump life. As a result, the equipment end user demanded that the machine manufacturer improve the specification (and initial cost) of the equipment they were purchasing. Of course, this was after the economic benefits of doing so had been clearly demonstrated to the end user.

For this hydraulic equipment owner, it was a case of "I once was blind, but now I see." Prior to this education, they likely would have looked at two cane harvesters of similar capacity from competing manufacturers and bought the cheapest one — with little or no regard to machine reliability or life-of-machine operating costs.

Even though they got it the wrong way around, this machine owner got it in the end. If you're a hydraulic equipment buyer/owner, the key takeaway of all of this is that the best time to consider these issues is before you purchase a piece of equipment.

By starting with the end in mind, you get the maintenance and reliability outcomes you desire — before the machine even gets delivered. Like in the cane harvester example, you specify the contamination control targets you want to achieve based on your reliability objectives for the piece of equipment and instruct the manufacturer to deliver the machine

appropriately equipped to achieve these targets.

Based on the weight and viscosity index of the hydraulic oil you plan to use, you determine the minimum viscosity and therefore the maximum temperature at which you want the machine to run. You then instruct the manufacturer to deliver the machine equipped with the necessary cooling capacity based on the typical ambient temperatures at your location, rather than accepting hydraulic system operating temperatures dictated by the machine's one-size-fits-all designed cooling capacity — as is the norm.

For example, say you are about to purchase a 25-ton hydraulic excavator that is fitted with brand "X" hydraulic pumps and motors. According to the pump manufacturer, optimum performance and service life will be achieved by maintaining oil viscosity in the range of 25 to 36 centistokes. You also know that in your particular location that you expect to use an ISO VG 68 weight hydraulic oil, and the brand of oil you are already buying has a viscosity index of 100.

This being the case, the pump manufacturer tells you, based on the viscosity and viscosity index of the oil you plan to use, that if your new excavator runs hotter than 70 degrees C, the performance and service life of the pumps and motors will be less than optimum. Not only that, with 70 degrees C as the maximum operating temperature, the oil, seals, hoses and almost every lubricated component in the hydraulic system will last longer.

So being the sophisticated hydraulic equipment user that you are, you say to

the manufacturer before you order the machine: "I expect ambient temperatures at my location as high as 45 degrees C, and under normal conditions (i.e., no abnormal heat load in the system), I require this machine to run no hotter than 70 degrees C. If you deliver it to the site and it runs hotter than 70 degrees on a 45-degree day, then I'll expect you to correct the problem — at your cost."

You could continue by specifying other requirements that have an impact on hydraulic component reliability, such as that all hydraulic pumps have a

71%

of machinerylubrication.com visitors consider contamination control targets before purchasing new equipment

flooded inlet, that no depth filters or screens be installed on pump intake lines and that no depth filters be installed on piston pump and motor case drain lines.

At the very least, as the cane harvester story demonstrates, the next time you or the company you work for are purchasing hydraulic equipment, be sure to define your fluid cleanliness and operating temperature / viscosity targets in advance and make them an integral part of your equipment selection process. ■

About the Author

Brendan Casey is the founder of HydraulicSupermarket.com and the author of *Insider Secrets to Hydraulics*, *Preventing Hydraulic Failures*, *Hydraulics Made Easy* and *Advanced Hydraulic Control*. A fluid power specialist with an MBA, he has more than 20 years of experience in the design, maintenance and repair of mobile and industrial hydraulic equipment. www.HydraulicSupermarket.com.

Human Factors Engineering: THE NEXT FRONTIER IN RELIABILITY

Over the 20 years that I've been in the reliability engineering field, most of our effort to improve the dependability of manufacturing processes has been equipment focused. I've been no exception. On the surface, it seems to make sense. It's the equipment that breaks down, isn't it? Yes and no.

A few years ago, I asked our readers to tell me what goes wrong in the factory based upon the general failure cause categories outline in the U.S. Department of Energy's root cause analysis standard (DOE-NE-1004-92). You replied that the equipment is to blame in less than 20 percent of the occurrences. Nearly 80 percent of what goes wrong can be attributed to people issues. Problems with procedures and training (combined) are responsible for nearly 40 percent.

Personnel/human error constituted a little more than 22 percent of the vote. Management oversight represented about 9 percent. Also, design problems totaled roughly 9 percent.

Really, though, wouldn't you agree that if we had good procedures, training and supervision that we'd go a long way toward minimizing personnel/human error? The bottom line is that human factors are responsible for 75 to 80 percent of what goes wrong in the factory. It's time for us to align our efforts accordingly.

Analysis and Classification

The U.S. Secretary of Defense proclaimed in a memorandum that "world-class organizations do not tolerate preventable accidents." This led to an edict to reduce

preventable errors by 50 percent and resulted in the formation of the Department of Defense Safety and Oversight Committee and the relatively new branch of reliability management called Human Factors Engineering (HFE). The intent was to develop and standardize a human performance coding, analysis and management system throughout the DoD; it is called the Human Factors Analysis and Classification System (HFACS). While it was developed to improve aviation safety, it is fully applicable to any reliability-critical application or industry (including manufacturing) where people are highly integrated in the business processes.

DoD statistics suggest that human error is a causal factor in 80 to 90 percent of all mishaps. As previously discussed, my

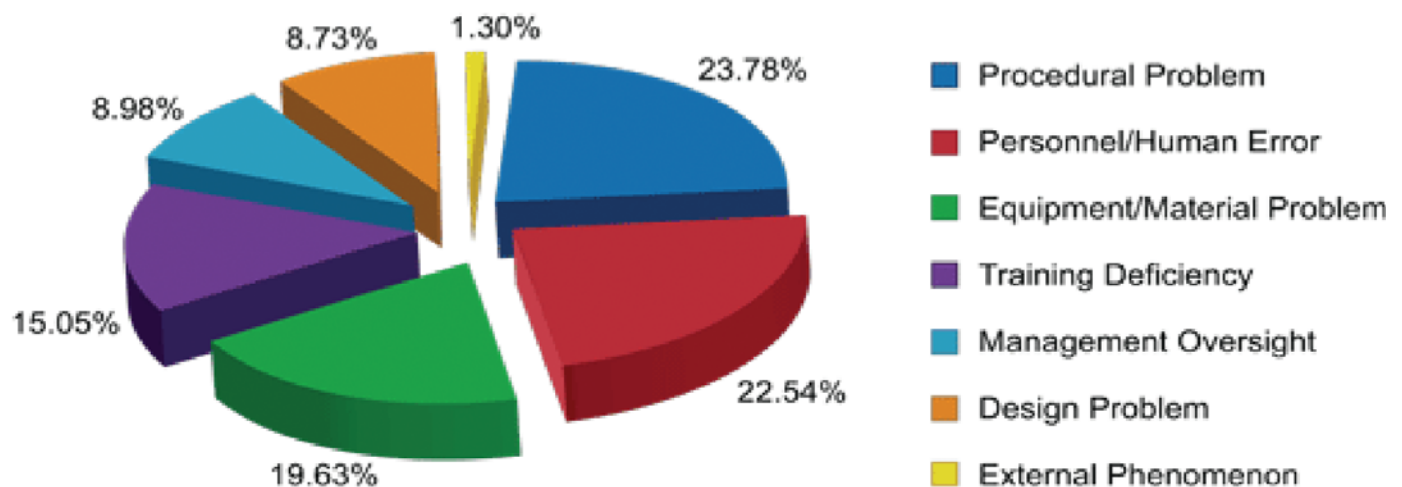


Figure 1. Reader Data on the Causes of Failures in the Factory

research into the manufacturing industries similarly suggests that human error accounts for around 80 percent of what goes wrong in plants and factories. Since human error is the dominant failure mechanism in most systems (healthcare being no exception), it should be the focal point of our reliability management system.

The human factors classification system is broadly organized into the three latent failure and one active failure categories.

1. Organization Influences (Latent Failures/Conditions): This category includes the failure to provide adequate resources, an appropriate organizational climate and/or sufficient organizational processes, such as procedures.
2. Unsafe Supervision (Latent Failures/Conditions): This category includes inadequate supervision, planned operations that are known to be inappropriate, failure to correct known problems and violations made by supervisors.
3. Preconditions for Unsafe Acts (Latent Failures/Conditions): These include:
 - environmental factors, such as the physical and technological environment;
 - condition of the individuals, including cognitive and psycho-behavioral factors;
 - condition of the individuals, including physiological state, physical/mental limitations and perceptual errors; and,
 - personnel factors, including coordination, communication and planning errors, and self-imposed stress such as fitness, alcohol/drug use, nutrition, etc.
4. Unsafe Acts (Active Failures/Adverse Events): These include errors caused by lack of skill and/or clear instruction,

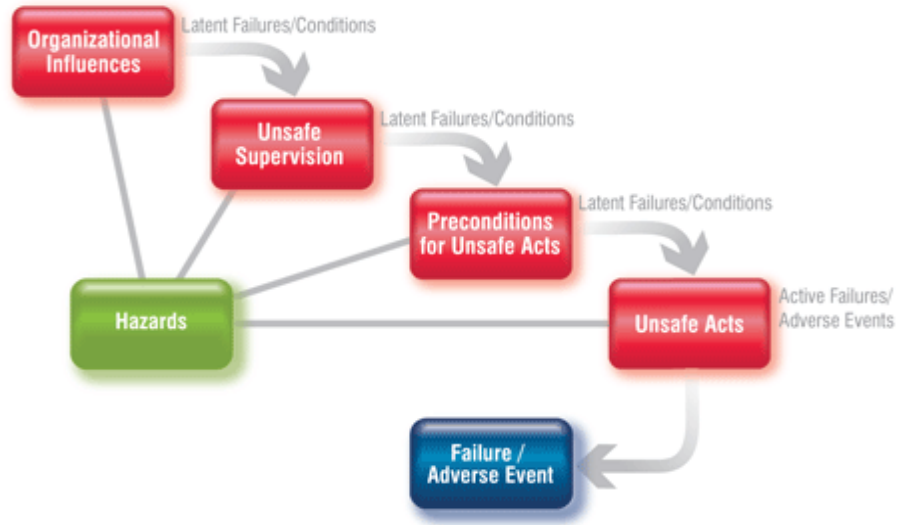


Figure 2. How Latent and Active Human Acts Lead to Adverse Events

errors in judgment, and errors in perceptions. They also include violations.

Applicable to Manufacturing

The human error coding and management system developed by the DoD is quite comprehensive. In total, they've identified 131 latent and 16 active errors that lead to a failure or adverse event. Likewise, because the failure classification system includes latent and active failures, it is fully applicable to the classification of near-misses as well as actual failure events. By and large, the management system can be adopted in its entirety for use in the manufacturing sector. There are a few that don't apply and probably a few that are missing, but with minor revisions, the DoD-HFACS can and should be immediately employed to analyze and prevent human error in facilities.

The Need to Execute

Kurt Vonnegut said in one of his novels "if it weren't for the people ... always getting tangled up with the machinery; if it weren't for them, Earth would be an engineer's paradise." The bottom line is that people are – and in all likelihood will always be – in the mix. Since that's where most of our problems occur, we'd better get busy to start mitigating human factors risks. To do so, our Failure Reporting, Analysis and Corrective Action System (FRACAS) must contain a Human Factors Analysis and Classification System (HFACS).

The DoD has done the heavy lifting by creating this system. We simply need to execute. If you don't have a FRACAS for collecting failure data, call or e-mail me. You can't manage reliability without it. Remember my axiom for reliability management: Data is the difference between deciding and guessing! ■

TO PLACE AN ADVERTISEMENT

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IS YOUR BEARING GETTING FRESH GREASE?

Use caution with grease lines that run out of the machine frame and are intended to offer easy lubrication access points. Since these line extensions often carry more than a few shots of grease, the grease entering the bearing will not be robust and fresh. Vibration, time and temperature changes can lead to leaching of critical oil components from the grease thickener, leaving a dry soap in the tube. Also, without visual access to the bearing area, there can be numerous undetected problems. The best approach is to provide access to the lube point as close to the

reducer. When you find this problem, first increase the temperature until the water lines quit sweating. Second, perform oil analysis on the reducer and check for water. If this issue isn't corrected, it could be catastrophic.

The "Lube Tips" features innovative ideas submitted by our readers. If you have a tip to share, e-mail it to gaurav@machinerylubricationindia.com

Infrared Scans Can Detect Reservoir Problems

Consider performing infrared scans on your rotating equipment to monitor the operating temperature of your reservoirs. A routine scan of a large gearbox revealed that it was overheating (operating above 190 degrees F) due to failure of the oil cooler pump. The oil was foaming significantly out of the oil sight glass.

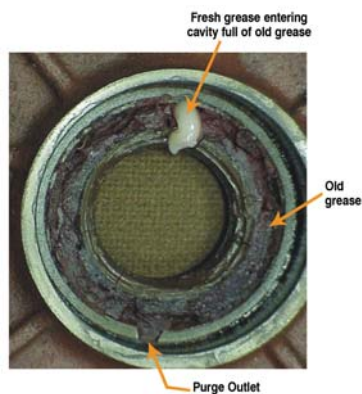
of the side of the pump to the level gauge was plugged with sediment and would not let oil out of the sight gauge to give a true oil level reading. To prevent this, lube technicians need to drain sight gauges periodically to confirm proper functioning.

How Long Should Oil Be Filtered?

When filtering oil, it is a good rule of thumb to run your filtration unit until the total flow through the filters equals the volume of seven times the reservoir capacity. Because of differences in oil viscosities and the bypass valve used to keep the filter pressure in the acceptable range, you may not be able to use rated pump-flow rates to determine how long it will take to reach this goal. However, you can add flow meters on your filtration skid so you will know how much oil has actually gone through the filters. This way you can be sure that you are getting your minimum level of acceptable filtration.

Advice for Labeling Oil Sample Bottles

When labeling oil sample bottles, consider labeling the bottle cap also. If you mistakenly place a cap from a bad sample onto a bottle containing a good sample, the sample is cross-contaminated. Testing of this cross-contaminated sample will yield false data. Labeling both the bottle and its cap will prevent this problem from occurring. ■



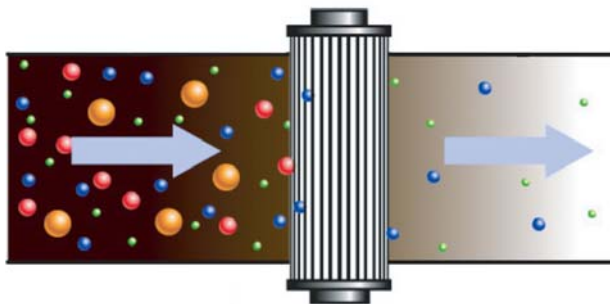
bearing as possible. This enables the bearing to be inspected and ensures that fresh grease enters the lube cavity.

Check Gear Reducers for Condensation

If you have a reducer that is water-cooled and the water temperature is too cold, it could condense and put water in the oil. If you notice the gear reducer sweating, water on the floor or water on the cooling water lines going into the gear reducer, you probably have water in the gear


Sediment in Sight Gauges

A fan pump recently lost an oil-filled bearing due to lack of oil in the sump. The oil level sight gauge used on this pump indicated that the pump was full, but actually it was not. The pipe coming out



Particles: Friend or Foe?

Understanding the Value of Particles in Oil Analysis



*I*n the field of tribology, the word “particles” means different things to different people. The following case studies illustrate how differently the mechanical engineer, tribologist, sampler, analyst and diagnostician interpret the presence of particles.

The Mechanical Engineer and Tribologist

To the mechanical engineer and tribologist, the presence of particles is an indication that contaminants have entered the system or that certain components are wearing abnormally. Particles that are smaller than the minimum clearances could result in abrasive wear, which in turn causes premature aging or failure. Large particles could result in blockages of oil channels, which could lead to oil starvation. Thus, both conditions spell trouble to these role players.

The Sampler

The main concern of the sampler is to produce a homogenous sample that is representative of the bulk volume of oil in the system. The presence of particles complicates the task of the sampler, as particles tend to settle at the bottom of the tank/sump.

Prior to sampling, oil should be hot and well agitated to ensure that the sample includes particles that have settled. For routine oil analysis, the container must not be filled more than 80 percent to enable the laboratory to agitate the sample prior to analysis.

Improper sample handling includes overfilling containers, decanting samples that were originally filled to the top and

68%

of machinerylubrication.com visitors view the presence of particles as a valuable indicator in an oil analysis sample

sampling when the oil has not been circulated sufficiently prior to sampling. Overfilling a container leads to insufficient agitation. Shaking the container prior to decanting will result in large particles remaining at the bottom of the container. There's also the possibility that the less contaminated portion is decanted, causing the laboratory result to be higher than usual.

The Analyst

Once the samples reach the laboratory, the presence of particles directs the tasks and methods that the chemical analyst will use to analyze the samples. The method of sample preparation, the analytical techniques and instrumentation required to ensure that the results are representative of the condition existing in the application all depend on the type, size, properties and distribution of the particles present in the samples.



This illustration shows how particles cause damage to parts in contact. (Ref. Triple-R Oil Cleaner)

Various analytical techniques, including inductively coupled plasma (ICP) spectrometers, the flow cell of Fourier transform infrared (FTIR) spectrometers and some particle counters, rely on peristaltic pumps and transport systems (tubing) to introduce samples to the various instruments. When large particles are present in samples, the possibility exists that the tubing could become blocked.

Analysts also must be aware of the tendency of particles to settle at the bottom of the container. Prior to each

analysis, samples should be agitated sufficiently to ensure a homogenous state. Lowering of the fluid's viscosity either due to fuel dilution in the engine or dilution due to analytical requirements (e.g., ICP) aggravates the tendency of particles to settle. With ICP analysis, the samples must be diluted to assist with the transportation process. Due to dilution, suspended particles are more prone to settle out on the bottom of the test tube and will not be available for analysis. However, no dilution is required with rotating disk electrode (RDE) analysis.

The Diagnostician

Particles can be of value to a diagnostician who studies the shape and nature of particles found in a sample. A scanning electron microscope (SEM) can assist in investigating the root cause of mechanical failure by allowing the diagnostician to pay special attention to evidence such as

scratch marks on particles and methods of particle formation.

Fine filtration is a proactive process aimed at removing contamination and wear particles from the system. If this process is not executed with special care, knowledge and sensitivity to the value that particles add for the diagnostician in root-cause analysis, crucial evidence can be lost.

Case Study #1: RDE vs. ICP Spectrometry

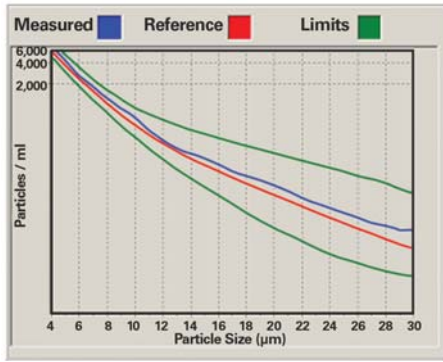
In 2002 the Eskom laboratory changed

from ICP to RDE spectrometry to perform wear metal analysis on used oils. To obtain a new baseline, it was essential to perform both spectrometric methods as well as the ferrous particle quantifier (PQ) on all samples received for a three-month period.

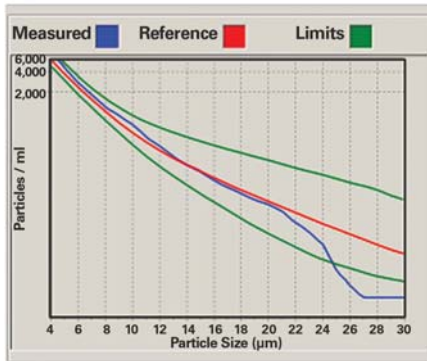
When the spectrometric results were plotted against the PQ values, it was determined that the higher the PQ value was for a sample, the greater the difference between the ICP and RDE results. For a PQ value of 15 milligrams of iron per liter (mg/l Fe), the expected difference between the two techniques was about 0 to 5 ppm. However, above a PQ value of approximately 75 mg/l Fe, the relation seemed to become non-linear, where the differences between ICP and RDE results were from 50 to more than 500 ppm.

One sample with a PQ value of 1,712 mg/l Fe had an iron value of 699 ppm with ICP. The result on the RDE for this same sample was found to be in the region of 3,000 ppm. The difference in results obtained by the two spectrometric methods was as high as 2,300 ppm.

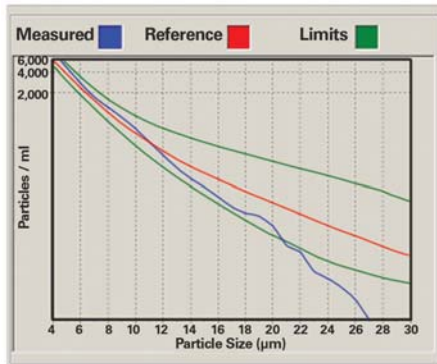
When the wear trends of the unit with the PQ value of 1,712 mg/l Fe were examined, the ICP results gave the impression that the problem was either resolved or stabilized. However, when the RDE results became available, it was evident that there was an increase in wear. The final report recommended the unit be shut down for emergency maintenance.



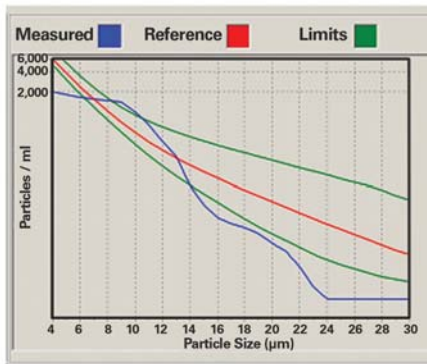
This baseline image taken from a particle examination of the secondary reference material (SRM) shows what the result should look like.



Particle examination of the SRM after approximately 50 percent was decanted to another container. When the decanted portion was analyzed, fewer particles larger than 10 microns were counted per milliliter.



Particle examination of the SRM after being left to stand for approximately 15 minutes. Larger particles (larger than 10 microns) and especially particles larger than 25 microns settled to the bottom.



Particle examination of the SRM while the cell was partially blocked. No pattern was reflected, and the results were all over the place due to the blockage.

engine. When the engine was installed, the maintenance team had difficulty eliminating abnormal vibration in the engine. Eventually, it was determined that a bent flywheel caused the vibration.

As soon as the vibration problem was eliminated, scratching noises were audible. Everything was checked, yet the source of this noise could not be traced. The maintenance engineer decided to involve the laboratory that performed the oil monitoring program in the investigation.

Since the engine was recently refurbished and the original source was unknown, the laboratory had no history on which to base the diagnosis. To obtain more knowledge about the solid content of the oil sample, the lab employed specialized methods, such as the electron diffraction X-ray (EDX) scan technique using the SEM.

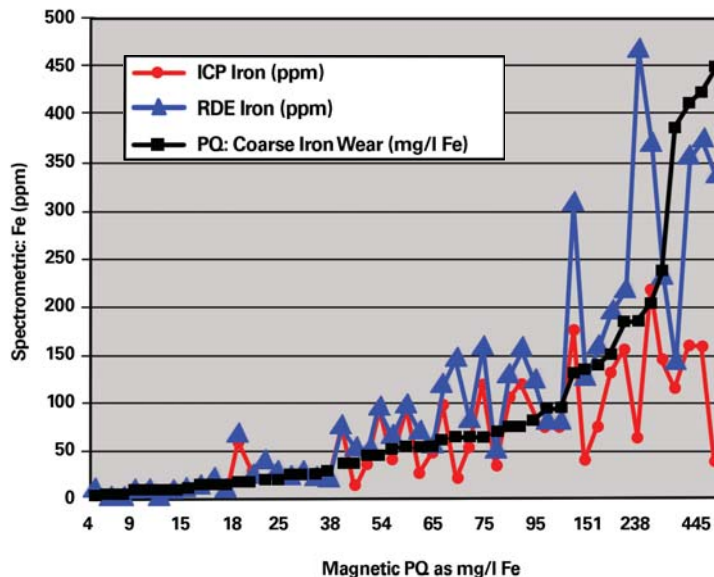
Due to the lower particle size limitation of the ICP, a plateau was reached much sooner than with the RDE. Applications most affected by the ICP's lower size limitation were those that did not have internal oil filtration systems such as gearboxes and certain compressors.

Geometry of the particles being analyzed by the RDE also affected the results. For example, if thin flakes of metal were present in the sample, flakes that had flattened out on the RDE gave a different reading than particles that had not flattened out. Thus, the results on the RDE varied due to the particle size as well as the geometry of the particles.

Case Study #2: Severe Scratching in a Locomotive Engine

The engine of a particular locomotive was replaced with a newly refurbished

To find out if the noise was due to insufficient lubrication, the laboratory determined the oil's viscosity. This was to establish if metal-to-metal contact had occurred as a result of the oil being



This graph charts the relationship between RDE and ICP relative to PQ as determined on samples of different sources.

too thin. A new oil sample of the specified lubricant was submitted for comparison with the oil sample taken from the engine.

A PQ analysis was then conducted to determine the magnetic property of the oil, followed by spectrometric elemental analysis using RDE spectrometry. An EDX scan using the SEM was performed on particles caught after the sample was filtered through a 0.8-micron-filter membrane and rinsed with pentane to remove oil residue.

COVER STORY

The results revealed that the viscosity was acceptable when compared to that of the reference sample, while the PQ values were very high (more than 1,000 mg/l Fe). The RDE spectrometric analysis indicated an increase in copper, iron and zinc when compared to that of the reference sample.

The EDX scan using the SEM found the following components on the filter:

- High occurrence of white metal bearing material
- Metal frets
- Iron, lead and copper shavings with scratch marks
- Metallic iron shaving with lead bound to it
- Zinc particles not in combination with copper
- Mineral/rock/soil containing calcium phosphate and calcium silicate
- Silicon and aluminum silicate
- A piece of silicone

Particles as Enemies

Special evidence, such as the scratch marks on the metal frets, suggested that uneven objects (particles) were responsible for abnormal wear of the liner and/or the crankshaft. The piece of silicone found indicated overuse of a silicone-containing substance like a sealant, which possibly was squeezed out between parts, cured and ripped off

by the hot flowing oil. These silicone pieces could have blocked oil passages, resulting in a damaging situation of oil starvation.

Particles including silicon (quartz) and sand (aluminum silicate) as well as other debris discovered in the oil sample were responsible for the abnormally high wear. Since abrasive wear was the main cause of premature aging and resulted in severe damage to the parts in contact with these objects, the maintenance engineer wanted the reason for the initial ingress of those particles into the system to be investigated.

For the sampler, it was essential to ensure that as much evidence as possible was captured in the drawn sample. In this case, where the ultimate failure would have been catastrophic, the task could have been quite difficult, since all particles had settled to the bottom as the oil cooled. Thus, a typical sample drawn in the normal fashion may not have allowed all the evidence to be captured.

Particles as Friends

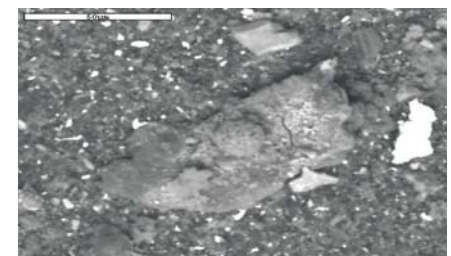
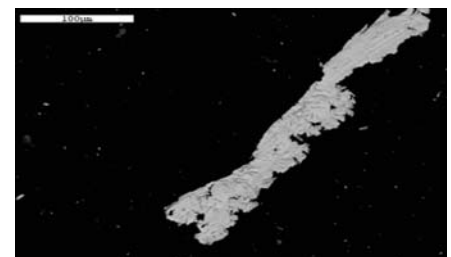
By unlocking the treasure of evidence that was captured in the particles found in the oil, the diagnostician obtained information about the formation of such particles. The presence of metal shavings indicated possible misalignment. Lack of lubrication also was detected, which possibly was due

to blocked oil channels resulting from the presence of foreign particles. The metallic iron shaving with lead bound to it suggested welding due to oil starvation (metal-to-metal contact).

The discovery of a particle with scratch marks led to an investigation of objects that could have been responsible for the damage. One possible culprit was detected in a particle consisting of calcium phosphate and calcium silicate. This specific mineral (possibly apatite) together with particles containing quartz and sand led to the conclusion that the engine originated from a locomotive that was involved in an accident with subsequent derailment where soil was introduced to the engine. Evidently, the soil was not removed successfully when the engine was refurbished.

Case Study #3: Wrist Pin Bearing Failure on a Diesel Locomotive

Prior to a wrist pin bearing failure, oil samples from a diesel locomotive were sent to two different laboratories for



An iron shaving with scratch marks (left) and soil (right) were found in the oil sample.

routine oil analysis. The first laboratory issued wear alerts on possible wrist pin bearing wear four weeks prior to the failure, while the second laboratory indicated no abnormal wear was taking

Ionization Energy and Spectrometric Analysis

The available ionization energy to energize large particles reaches a plateau, which is one of the reasons different spectrometric methods have limitations concerning particle size (3 microns maximum for ICP and 8 to 10 microns maximum for an RDE spectrometer).

Spectrometers, as they are applied today, are blind to large particles. Traditional methods of determining large particles (larger than 10 microns) are acid digestion (expensive and hazardous), microwave digestion (expensive and time consuming) and direct ferrography (does not include non-ferrous metals).

Rotrode filter spectroscopy (RFS) was developed to provide an improved spectroscopic method for analysis of used oils for condition monitoring/predictive maintenance without the particle size or metal-type limitations of previous combined spectrochemical and direct ferrographic techniques.

COVER STORY

place. A resample was taken, and again the second lab did not find any abnormal wear, while the first lab issued another wear alert.

The fleet owner decided to stop the locomotive to find out whether the alerts issued by the first laboratory were justified. It was discovered that the wrist pin bearing had failed with damage to four power packs. An investigation was launched to determine the root cause that resulted in the different diagnoses from the two laboratories.

Routine oil monitoring tests were performed, including spectrometric analysis using RDE spectrometry and PQ. An EDX analysis using the SEM on



These images of a locomotive engine reveal wrist pin bearing failure.



These photos of a locomotive engine indicate a severely scored liner and piston wear.

the filter debris was conducted after the sample was filtered through a 0.8-micron-filter membrane and rinsed with pentane to remove oil residue. The results of the RDE spectrometric analysis revealed an increase in silver, copper and iron, while the SEM analysis confirmed the presence of particles larger than 10 microns.

Since both laboratories performed similar analysis on a routine basis, the investigation focused on the differences in the techniques used by the two labs. The only major difference found was that the laboratories employed different spectrometric techniques to determine the wear metal content of the samples, namely ICP and RDE spectrometry.

The primary variation between the two techniques is the way the sample is introduced to the system. For ICP analysis, the sample is diluted prior to introduction to the instrument. Therefore, it's possible that the particles settled prior to analysis. The ICP also uses a peristaltic pump and transport system, which is subject to blockages.

In addition, the size limitation of the ICP is 1 to 3 microns, while the range of the RDE is 8 to 10 microns. The SEM analysis confirmed the presence of particles larger

than 5 microns, so it seems the failure progressed beyond the point where the ICP could detect the wear particles but remained within the range of the RDE.

Case Study #4: Scored Liner and Piston Wear on a Diesel Locomotive

As part of an oil analysis program, the crankcase oil of a locomotive was monitored on a monthly basis. However, no samples were received for the period between January and the end of June. The engine failed at the end of September.

The reason for concern was that all laboratory reports returned with no indication of an increase in wear metal content. An investigation was initiated to explain why the laboratory tests failed to detect any increase in wear when it was evident that abnormal wear was taking place from the mechanical failure that occurred.

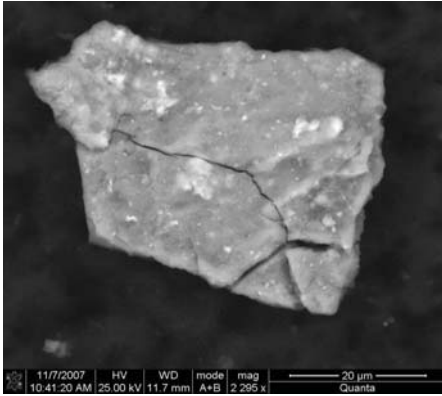
Since no abnormalities were found except for fuel dilution over a prolonged period, the investigation focused on sampling intervals and techniques that could have affected the results.

Routine oil monitoring tests, including spectrometric analysis using RDE spectrometry, were performed, as well as EDX analysis using the SEM on the filter debris after the sample was filtered through a 0.8-micron-filter membrane and rinsed with pentane to remove oil residue.



COVER STORY

The results showed severe fuel dilution. The RDE spectrometry indicated no increase in metal content since the previous sample was analyzed. The EDX analysis revealed that isolated large particles (larger than 20 microns) of heavy metals and other inorganic oxides were present on the filter. Many of the larger particles were iron or iron oxides. The small particles consisted mainly of calcium sulphate.



A particle larger than 20 microns was found in the oil sample.

Lowering of the fluid's viscosity, which may have resulted from fuel dilution in the engine, aggravated the tendency of particles to settle. Therefore, it is possible that suspended particles had settled to the bottom of the sump and were not included in the sample.

In the earlier stages of failure, smaller particles were produced (likely during the period when no samples were submitted). As the failure progressed, the size of the particles increased. Since particles larger than 10 microns were found, it is possible that the failure progressed beyond the point where the RDE could detect the wear particles. Thus, severe fuel dilution over a prolonged period of time combined with not submitting oil samples at the initial stages of failure resulted in the inability to detect the failure through a routine oil analysis program.

In conclusion, it is apparent that removal of particles from a system prior to sampling by means of indiscriminate filtration, improper sample handling and settling of particles can result in the loss of important evidence that could lead to the early detection of possible failures or assist in root-cause analysis. Remember, the purpose of oil analysis is to avoid failure before it happens. Sensitivity with regards to particle sizes and size limitations of analytical techniques relative to sampling intervals is vital to reach this ultimate goal. In the end, the success of an oil analysis program to detect possible failure modes relies on the ability of the mechanical engineer, tribologist, sampler, analyst and diagnostician to treat and react to the presence of particles in the appropriate manner. ■

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The CRITICAL ROLE of ADDITIVES in LUBRICATION

Lubrication professionals often become very familiar with the base oil viscosity of their lubricants. After all, viscosity is the most important property of a base oil. Baselines for incoming oils are set and the health of the lubricant is monitored based on viscosity alone. However, there is more to lubricants than just viscosity. It's crucial

Whether they are enhancing, suppressing or imparting new properties to the base oil, additives play an important role in the lubrication of machinery.

to understand the role of additives and their function(s) within the lubricant.

Additives are organic or inorganic compounds dissolved or suspended as solids in oil. They typically range between 0.1 to 30 percent of

Too Much of a Good Thing

When using oil additives, more is not always better. As more additive is blended into the oil, sometimes there isn't any more benefit gained, and at times the performance actually deteriorates. In other cases, the performance of the additive doesn't improve, but the duration of service does improve.

In addition, increasing the percentage of a certain additive may improve one property of an oil while at the same time degrade another. When the specified concentrations of additives become unbalanced, overall oil quality can also be affected. Some additives compete with each other for the same space on a metal surface. If a high concentration of an anti-wear agent is added to the oil, the corrosion inhibitor may become less effective. The result may be an increase in corrosion-related problems.

63%

of lubrication professionals monitor additive health as part of their oil analysis program, according to a recent poll at machinerylubrication.com

the oil volume, depending on the machine.

Additives have three basic roles:

- 1) Enhance existing base oil properties with antioxidants, corrosion inhibitors, anti-foam agents and demulsifying agents.
- 2) Suppress undesirable base oil properties with pour-point depressants and viscosity index (VI) improvers.
- 3) Impart new properties to base oils with extreme

Enhance Existing
Base Oil Properties

Antioxidants
Corrosion Inhibitors
Anti-foam Agents
Demulsifying Agents

Suppress Undesirable
Base Oil Properties

Pour Point Depressants
VI Improvers

Impart New Properties
to Base Oils

EP Additives
Detergents
Metal Deactivators
Tackiness Agents

pressure (EP) additives, detergents, metal deactivators and tackiness agents.

Polar Additives

Additive polarity is defined as the natural directional attraction of additive molecules to other polar materials in contact with oil. In simple terms, it is anything that water dissolves or dissolves into water. A sponge, a metal surface, dirt, water and wood pulp are all polar. Things that are not polar include wax, Teflon, mineral base stock, a duck's back and water repellents.

It's important to note that additives are also sacrificial. Once they are gone, they're gone. Think about the environment you work in, the products you produce and

MACHINE	COMMON ADDITIVES USED	PERCENT OF OIL VOLUME
Engines	Antioxidant, corrosion inhibitor, detergent/dispersant, anti-wear, anti-foam, alkalinity improver	10 - 30%
Steam turbines, compressors	Antioxidant, corrosion inhibitor, demulsifier, anti-foam	0.5 - 5%
Gears (spiral, bevel or hypoid)	Anti-wear, antioxidant, anti-foam, sometimes corrosion inhibitor, extreme pressure	1 - 10%
Gears (worm)	Extreme pressure, antioxidant, corrosion inhibitor, fatty acids	3 - 10%
Hydraulic systems	Antioxidant, anti-wear, anti-foam, corrosion inhibitor, pour-point depressant, viscosity index improver	2 - 10%

the types of contaminants that are around you daily. If you are allowing into your system contaminants that additives are attracted to, such as dirt, silica and water, the additives will cling to the contaminants and settle to the bottom or will be filtered out and deplete your additive package.

Polar Mechanisms

There are a few polar mechanisms such as particle enveloping, water emulsifying and metal wetting that are worthy of discussion.

Particle enveloping means that the additive will cling to the particle surface and envelop it. These additives are metal deactivators, detergents and dispersants. They are used to peptize (disperse) soot particles for the purpose of preventing agglomeration, settling and deposits, especially at low to moderate temperatures. You generally will see this in an engine. It offers a good reason to repair and eliminate any issues as soon as they are detected through an appropriate oil analysis test slate.

Water emulsifying occurs when the additive polar head clings to a micro-

droplet of moisture. These types of additives are emulsifying agents. Consider this the next time you observe water in a reservoir. While it is important to remove the water, determine where the water entered the system and repair it using a root-cause maintenance approach, you must also keep in mind that the additive package has been affected. In lubrication terms, this is known as additive depletion. A proper oil analysis report can determine the health of the additives remaining in the lubricant.

Metal wetting is when additives anchor to metal surfaces, which is what they are supposed to do. They attach to the interior of the gear casing, gear teeth, bearings, shafts, etc. Additives that perform this function are rust inhibitors, anti-wear (AW) and EP additives, oiliness agents and corrosion inhibitors.

AW additives work specifically to

protect metal surfaces during boundary conditions. They form a ductile, ash-like film at moderate to high contact temperatures (150 to 230 degrees F). Under boundary conditions, AW film shears instead of surface material.

One common anti-wear additive is zinc dialkyldithiophosphate (ZDDP). It reduces the risk of metal-to-metal contact, which can lead to increased heat, result in oxidation and negatively affect the film strength.

Whether they are enhancing, suppressing or imparting new properties to the base oil, additives play an important role in the lubrication of machinery. Remember, when the additives are gone, they're gone, so don't forget to check your additive package. ■

About the Author

Pete Oviedo is a senior technical consultant with Noria Corporation, focusing on machinery lubrication and training. He has more than 20 years of experience with machinery and rotating equipment, as well as an understanding of laser alignment, balancing rotating equipment, thermography, magnetic particle and ultrasonic flaw detectors. Contact Pete at poviedo@noria.com.

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	Delhi NCR, India	April 15-17	9th International Symposium on Fuels & Lubricants (ISFL) sayanae@indianoil.in / www.isflindia.org/
	Dubai, UAE	April 16-17	3rd Base Oil & Lubes Middle East 2014 alycia@ccconnection.org / www.baseoilubes.com
	Mumbai, India	April 28-30	2nd ICIS Indian Base Oil & Lubricants Conference www.icisconference.com/indianbaseoils
	Lake Buena Vista FL, USA	May 18-22	STLE 69th Annual Meeting & Exhibition www.stle.org

Grease Analysis - Monitoring GREASE SERVICEABILITY and BEARING CONDITION

Approximately 90 percent of all bearings are lubricated with grease. But how much do you know about the grease or greased bearings in your plant? Grease analysis is certainly not for every bearing. . . maybe it's not even for most bearings. But when you have a need to know, a thorough analysis of the grease in question can prevent headaches and save money.

Historically, the analysis of grease has been confined to new grease testing for product acceptance and quality control. Technically, this was due to the sample size required to perform conventional ASTM (American Society of Testing and Materials) methods on grease samples. However, over the last couple of decades, new analytical methods have made it possible to profile the serviceability of grease using as few milligrams of sample as possible (0.00003527 of an ounce).

Sampling In-service Greases

The philosophical issues with sampling used greases are twofold. First, if the whole bearing must be sent to the lab just to get at the grease under the shield, what good is the analysis? Second, if you can get to the bearing grease without dismantling the bearing, is the sample reliable and representative of the condition of both the grease and the bearing?

These two problems are quite different. If a plant has hundreds of greased bearings that are so hard to get to that they must be removed and sent to the laboratory for grease analysis, the data obtained on a few bearings may need to be extrapolated across the entire bearing population to draw appropriate conclusions. An example of this might be to identify the root cause of a number of repeat bearing failures plant-wide. Experience shows that within a given application and environment, most of the failures, if they are lubrication-related, will stem from the same root cause. Therefore, it is worth the effort to take a group of bearings with varying service life and submit them for analysis. Once complete, the test results can be used to make an informed decision about grease selection, regreasing intervals, common wear mechanisms and typical cleanliness levels.

The second philosophical issue, that of whether the grease sample is truly representative, is slightly more complex to resolve. In this case, the technician needs to be aware of the differences in information that can be obtained from grease located at the bearings raceway interfaces, compared to grease that has been pushed out and is around the outside area of the housing, in much the same way as sample point location is vital when taking used oil samples.

Generally, the grease sample of interest is the grease doing the work at the contact interfaces, in the load zone of the bearing. This grease sample will have the most evidence of wear, contamination and degradation and in general will be the most representative, although it will likely also be the most difficult to obtain.

Analyzing Used Grease Samples

Changes in Grease Consistency

Grease is made up of base oil, a gelling agent or soap thickener (sometimes called filler) and additives, which perform in much the same way as oil additives. The consistency of grease is controlled by the type and ratio of the gelling agent to the oil and its viscosity. Grease can harden or soften in service due to the effects of contamination, loss of oil or mechanical shearing.

The classic way in which the consistency of a grease is measured is using the cone penetration test (ASTM D217). In this test, the grease is heated to 25°C (77°F) and placed below the tip of the test cone, as shown in Figure 1.

The cone is allowed to drop into the grease; the amount of penetration is measured by the penetrometer in tenths of a millimeter. The greater the penetration, the thinner the grease consistency. The test is often repeated



Figure 1. Standard Penetrometer Cone

after “working” the grease to replicate the effects of mechanical shearing. In fact, worked penetration of new greases is the property upon which the NLGI (National Lubricating Grease Institute) grease consistency classification system

NLGI Number	Worked Penetration mm	Description of Consistency
000	445-475	Semi-liquid
00	400-430	-
0	355-385	Viscous liquid
1	310-340	-
2 (buttery)	265-295	Will flow
3	-	220-250
4	175-205	Resist flow
5	130-160	-
6	85-115	Hard and wax like

Table 1. Setting Alarms for Metals Analysis is based, as shown in Table 1.

Cone penetration using ASTM D217 requires a large volume of sample and is not normally performed on used grease samples. An alternative method, ASTM D1403 uses ¼ or ½ the sample volume of ASTM D217 making it more amenable to used grease analysis.

A more modern alternative to cone penetration, for estimating changes in the consistency of used greases is Thermal Gravimetric Analysis (TGA). TGA analysis measures the mass of a substance in relationship to temperature and is used to determine the loss of material with increasing temperature. The analysis can be carried out in an inert atmosphere such as nitrogen or a reactive atmosphere such as oxygen. Typically, a few milligrams of the sample

is weighed and heated under controlled conditions. The weight loss at specific temperatures allows the technician to evaluate the oil/gelling agent ratio as compared to new (unused grease), as well as the presence of volatile compounds such as water, allowing any

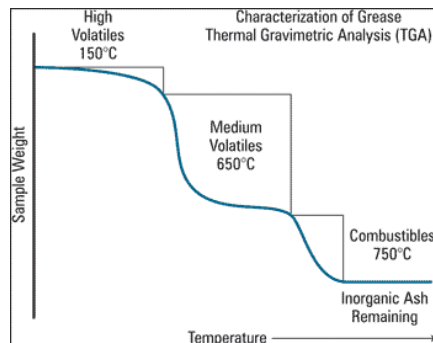


Figure 2 . Example of a TGA Grease Profile

significant change in gelling agent chemistry to be determined (Figure 2).

Antioxidant Levels in Grease

Greases, like oils, contain a variety of additives. Antioxidant levels are of particular interest in identifying the useful life of the grease. Differential Scanning Calorimetry (DSC) is a modern analytical method for measuring the onset of oxidation in used grease (ASTM D5483). When compared to the new reference grease, the test can be used to determine the remaining useful life (RUL) of a grease. This test is analogous in the information it seeks, if not in methodology, to the RPVOT test commonly used to determine the RUL of turbine oils and other lubricating oils.

DSC works by placing a sample of used grease into a test cell. The cell is heated and pressurized with oxygen. When the grease starts to oxidize, an exothermic reaction occurs, which liberates heat. By measuring the onset of the reaction in the used grease (commonly called the induction point) in reference to the new grease, an estimate of the oxidation stability of the grease can be made .

Viscosity of Grease

The viscosity of grease is often misunderstood. The viscosity typically listed on a new oil data sheet is usually the kinematic viscosity of the oil used in blending the grease measured, using the standard ASTM D445 method. The kinematic viscosity of the base oil is important in ensuring the correct grade of grease, containing the correct grade of oil is used for lubrication purposes. However, we can also measure the viscosity of the grease itself. Since a grease is non-Newtonian, we can only measure the apparent viscosity because the viscosity of a non-Newtonian fluid changes with shear stress (see “Understanding Absolute and Kinematic Viscosity” by Drew Troyer). The apparent viscosity of a grease is determined using ASTM D1092. This test measures the force required to force the grease through an orifice under pressure. As such, this test is an ideal way of determining the flow characteristics of grease through pipes, lines, dispensing equipment as well as its pumpability.

Rheology measurements of grease may soon replace both the cone penetration and the apparent viscosity measurements. Rheology is the study of the deformation and/or flow of matter when it is subjected to strain, temperature and time. A rheometer only requires a few grams of sample to perform the analysis, yielding much more information than the cone penetration or the apparent viscosity measurements. This makes the rheology measurement an ideal test for small amounts of used grease.

Dropping Point

The dropping point of a grease is the temperature at which the grease changes from semi-solid to a liquid. The dropping point establishes the maximum useable temperature of the grease, which is typically set at 50°C to 100 °C below the experimentally

determined dropping point. Dropping point can help to establish if the correct grease was supplied or is in use, and to determine if a used grease is good for continued service.

Contamination of Used Grease

Many bearings fail prematurely due to contamination. Grease contamination can come not only from common environmental contaminants such as dirt and water, but also cross-contamination from other grease types. This is a major issue with greases because many gelling agents are incompatible, resulting in either a significant change in consistency (either thicker or thinner), or a separation of the oil from the gelling agent. There are a number of ways to determine the presence of contaminants in a used grease sample.

Contamination from water or other grease types can be identified by Fourier Transform Infrared Spectroscopy (FTIR) Analysis. FTIR can also measure gelling agent type and concentration, along with oxidation by-products.

If cross-contamination with different types of grease is suspected, it may also be feasible to perform elemental analysis (after acid digestion) to look for common metals present in the gelling agent. For example, a grease that is supposed to be an aluminum complex grease, but has become contaminated with a calcium sulfonate complex grease will show both aluminum and calcium in spectroscopic analysis, indicating a contamination problem.

Alert and Alarm Management Methods

The methods for establishing criteria, and methods for alert and alarm values vary according to the experience of the user. Alert values are those considered to be above or below the norm, while alarm values are those beyond a safe operating level. One of the primary concerns in establishing a new database is setting the criteria at a level that will

alert the operator to a change in the machine or lubricant, give that operator enough advance warning to make a timely decision, yet realistic enough so that premature alerts do not occur.

Absolute Values

Absolute values, also referred to as fixed or hard number, may be assigned to any characteristic. These values are based on the equipment type and grease type and grade. In some cases, fixed values may be obtained from the original equipment manufacturer. In cases where there are no recommended values, the fixed limit may be set using the experience of the laboratory with the specific lubricant and machine combination. It is important to remember that hard number alert values are a place to start a program, which contain many unknown factors.

During the initial phase of the program, it is not uncommon for the alarm values to remain unchanged and invalidated for a substantial period of time. If the alarm value set is not appropriate for the machine in its unique configuration, the risk of machine failure remains higher than acceptable.

Percent Change

For some tests, such as oil versus gelling agent, it is more appropriate to set values on a percentage change rather than standard deviation. An advantage of this type of alert is that it does not require valid statistical populations if the baseline is considered. Many percentage alarms can be converted to absolutes when the baseline value is a known quantity or the test has published typical values.

Statistical Analysis

Statistical analysis of wear metals is effective on mature databases. This requires a statistically valid population (typically 30 data points or more); therefore, it is normally based on like equipment in a group rather than a single piece of equipment. Once

sufficient historical data for the single machine is available, statistical analysis may be applied to the machine alone.

Trend Performance or Rate of Rise

Setting alert values based on the rate of rise of the data, or on the slope of the curve, for a specific wear metal above a predetermined minimum threshold value can be accomplished after the initial three sets of data are entered into the database. The logic behind the three histories is simply that it takes a minimum of three points to calculate a curve. While this can provide additional information to the analyst, it relies heavily on obtaining correct and consistent operating time values, normally hours. It is also more likely to be invalidated by other variables such as inconsistent sampling techniques.

Setting Limits

In the sample seen in Table 1, it is easy to see which of the samples have high iron, aluminum, copper and silicon. The

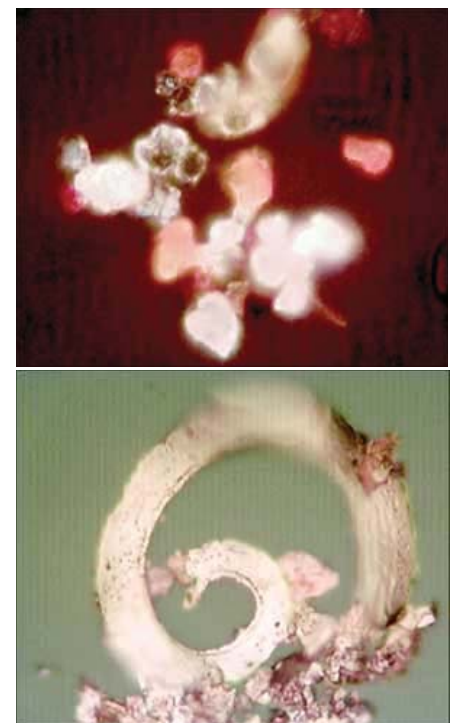


Figure 5. Ferrographic Analysis (top) Shows a Large Concentration of Abrasive Silica in the Grease. The Ferrogram on the bottom Shows Severe Cutting Wear. This Information Helps Identify the Root Cause of Premature Bearing Failures.

alarms set are based on 18 samples from various parts inside of a bearing cavity from different wheel bearings. Many times (as in this case) a data evaluator must make an initial judgment about what is considered normal. After sorting the data set by iron, it is clear there is a break at 144 ppm. Considering all of the samples lower than 144 ppm of iron as normal, the basis for the analysis is established.

- OK Samples: The average (Avg.) of all normal data is added to the standard deviation (STDEV) of all normal data. These samples are considered OK.
- Abnormal Samples: Two times the STDEV of all normal samples plus the Avg. These samples are considered ALERT.
- Critical Samples: Three times the STDEV of all normal samples plus the Avg. These samples are considered ALARM.

Measuring Low Concentration of Water

FTIR can identify the presence of water. However, it is not sensitive to low levels. Water in the parts-per-million (ppm) range can be measured using a variation of ASTM D6304 - Standard Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration. This method allows for the distillation of water using a distillation tower at 120°C (248°F) into a titration vessel where it is solubilized in toluene and sparged with nitrogen. The toluene/water mixture is then titrated using Karl Fischer Reagent as per ASTM D 6304. The levels of detection using this method are in the low ppm range.

Wear Debris and Particle Contamination

Conventional methods for measuring wear debris are ferrographic analysis and elemental analysis. While the quantitative estimation of wear debris is difficult in a used grease sample using elemental analysis, because of the difficulties of obtaining a representative sample, ferrographic analysis, which by its very nature is a qualitative technique, is ideal in determining the active wear mechanism and severity of the problem in grease lubricated bearings.

Ferrographic analysis on used greases is carried out by extracting the wear debris from the sample and analyzing it visually using an optical microscope, in a way similar to how ferrography is used for used oil samples (Figure 5).

By looking at particle morphology, it is often possible with ferrographic analysis to identify the root cause of premature bearing failures to be determined, allowing appropriate corrective action to be taken.

Modern methods of analysis for used grease samples are rapid, sophisticated and require only a fraction of the sample volume necessary in the past. Sound, cost-saving, maintenance decisions can be made using grease analysis as the basis for preventive and predictive programs. ■

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How IMPORTANT is the ISO CLEANLINESS CODE in OIL ANALYSIS?

The International Organization for Standardization (ISO) has developed a cleanliness code that is the primary piece of data reviewed on most industrial oil analysis reports. The value of this code can help determine the overall cleanliness of the monitored system. Often times, an end user will establish a target value to achieve, thus offering a level of confidence so long as the used oil sample meets this established target.

The trend in the oil analysis world is to give too much credit to the value of the ISO cleanliness code. Some laboratories have even begun to only report the ISO code. There is also a heavy reliance on this value by end-user analysts.

In this example, you can see how the particles measured at the given micron levels are assigned the specific code based on where that value falls in the table. For this example, the ISO code would be 20/17/13.

Table 1

	PARTICLES/ML	ISO CODE
>4 microns	9,721	20
>6 microns	1,254	17
>10 microns	326	
>14 microns	73	13
>21 microns	12	
>38 microns	5	
>70 microns	0	
>100 microns	0	

The ISO code is a fantastic tool to use for setting target alarms and establishing a goal to achieve and maintain as it relates to system cleanliness. It is also the perfect value to use for key performance indicator (KPI) tracking, charting and posting. However, the ISO code should play only a secondary role when it comes to evaluating used oil sample data.

How the ISO Cleanliness Code is Determined

Most oil analysis samples that receive

particle counting are getting what is known as automatic particle counting (APC). The current calibration standard for APC is ISO 11171. When sending a sample through an APC, particles are counted either through laser or pore blockage methods. Although different laboratories may report different particle count micron levels, an example of the various reported micron levels includes those greater than 4, 6, 10, 14, 21, 38, 70 and 100 microns.

MORE THAN (p/ml)	UP TO AND INCLUDING (p/ml)	ISO CODE
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8

ISO 4406:99 is the reporting standard for fluid cleanliness. According to this standard, a code number is assigned to particle count values derived at three different micron levels: greater than 4 microns, greater than 6 microns and greater than 14 microns. The ISO code is assigned based upon Table 1. This can be seen in the example on the left.

However, without seeing the raw data, the only thing the ISO

Staying Clean

Why is cleanliness so important? The answer is simple: competition. In such a globally competitive market where products can potentially be manufactured and shipped from overseas at a lower cost than can be manufactured from here at home, maintaining a precise level of reliability and uptime is necessary to keep costs at a manageable level. Contaminant-free lubricants and components will extend the lifetime of both, and in turn increase the overall reliability of the equipment.

code can positively identify is whether a sample has achieved the desired target value. The ISO code does nothing to help determine any type of real trend information unless the value of the raw data at the given micron levels changes enough to raise or lower the ISO code.

What the ISO Code Can Tell You

It's easy to look at the ISO table and notice a pattern. At each row, the upper limit for each code is approximately double that of the lower limit for the same code. Likewise, the upper and lower limits are double that of the upper and lower limits of the next lower code. This is known as a Renard's series table.

73%

of machinerylubrication.com visitors have used the ISO cleanliness code to set target alarms for system cleanliness levels

The unit of measure for particle count data is "particles per milliliter of sample." The particle counters used in laboratories incorporate much more than a milliliter of sample. During the testing process, approximately 100 milliliters of sample are taken into the instrument. The numbers of particles are counted based on this value. The total number of particles is then compared to the

number of times that 2 will go into that total count exponentially.

Using the previous example (20/17/13), this means that at the greater than 4 micron level, the number of particles measured was at the most 2^{20} and above 2^{19} . Since particle count data is reported in particles per mL of sample, the raw data must be divided by 100.

While the general rule of thumb is that for every increase in the ISO cleanliness code, the number of particles has doubled, this certainly is not the case in every situation. Because the number of allowable particles actually doubles within each code number, it is possible for the number of particles to increase by a factor of 4 and only increase a single ISO code.

Table 2

100 ML	1 ML	EXPONENT
16777216	167772.2	24
8388608	83886.08	23
4194304	41943.04	22
2097152	20971.52	21
1048576	10485.76	20
524288	5242.88	19
262144	2621.44	18
131072	1310.72	17
65536	655.36	16
32768	327.68	15
16384	163.84	14
8192	81.92	13
4096	40.96	12
2048	20.48	11
1024	10.24	10
512	5.12	9
256	2.56	8

MORE THAN	UP TO AND INCLUDING	ISO CODE
(p/ml)	(p/ml)	
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8

This table provides a comparison between the data calculated at each exponential level and how that data relates to the standard ISO cleanliness code chart.

This becomes a significant problem when you have a target cleanliness level of 19/17/14, your previous sample was 18/16/13, and your most current sample is 19/17/14. For all reporting purposes, you have achieved and maintained the target cleanliness level of 19/17/14. This suggests that your component should be in a "normal" status. Given the information presented previously, it is easy to see how you could have two to four times the amount

of particle ingress and only increase by a single ISO code or have no increase at all.

The ISO cleanliness code should be used as a target. It is a value that is

Table 3

4 μm	6 μm	14 μm	ISO Code
1,301	321	41	18/16/13
2,500	640	80	18/16/13
2,501	641	81	19/17/14
5,000	1,300	160	19/17/14

This example shows how you could have two to four times the amount of particle ingress and only increase by a single ISO code or have no increase at all.

easily tracked for KPI reporting and a value that most people can easily understand. However, using the ISO cleanliness code for true machine condition support is limited in its effectiveness. The raw data from particle count testing allows

← one more particle
← 4 times as many particles

The ISO code should play only a secondary role when it comes to evaluating used oil sample data.

the end user to confirm data from other tests such as elemental analysis and ferrous index. The ISO cleanliness code does not allow this cross-confirmation to occur. Reviewing the raw data of the particle counter at all reported levels is absolutely vital in performing quality data analysis on oil sample data. ■



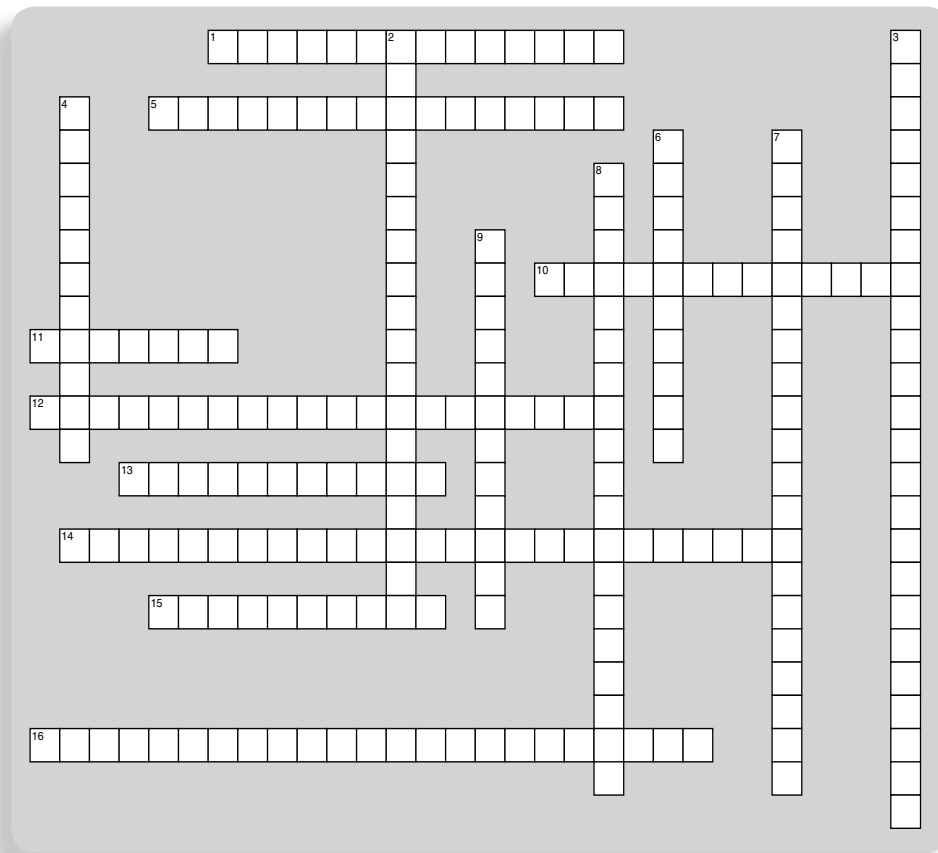
Crossword Puzzler»

Across

- 1 A fluid with a constant viscosity at a given temperature regardless of the rate of shear.
- 5 Porous materials that primarily retain contaminants within a tortuous path, performing the actual process of filtration.
- 10 Coked material remaining after an oil has been exposed to high temperatures under controlled conditions.
- 11 A form of extremely localized attack characterized by holes in the metal.
- 12 Caused by a deterioration of critical wetted surfaces and materials or by a breakdown of the fluid itself.
- 13 A procedure that involves the collection of a volume of fluid from lubricated or hydraulic machinery for the purpose of performing analysis.
- 14 The differential gas pressure at which the first stream of gas bubbles are emitted from a wetted filter element under standard test conditions.
- 15 A process of reclaiming used lubricant oils and restoring them to a conditions similar to that of virgin stocks by filtration, clay adsorption or more elaborate methods.
- 16 The total of the extraneous particles that are introduced in the process of obtaining, storing, moving, transferring and analyzing a fluid sample.

DOWN

- 2 The energy per unit area present at the boundary of two immiscible liquids.
- 3 The diameter of the largest hard spherical that will pass through a filter under specified test conditions.
- 4 Oxidized ferrous particles that are very old or have been recently produced by conditions of inadequate lubrication.
- 6 A valve that modulates output as a function of an input command.
- 7 Works on the basis that atoms of metallic and other particular elements emit light at characteristic wavelengths when they are excited in flame, arc or spark.
- 8 Ability of additives and certain synthetic lubricants to resist chemical decomposition in the presence of water.
- 9 Occurs when hard particles that have embedded themselves into a soft surface plough grooves into the opposing harder surface.



Get the solution on page 32



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The **FUNDAMENTALS** of MINERAL BASE OIL REFINING

Approximately 95 percent of the current lubricant market share is comprised of conventional (mineral-based) oils. Most people know these mineral oils are derived from a crude stock, but how much do you really know about the refining process?

The petroleum that flows from a well in the form of crude oil comes in many varieties and types, ranging from light-colored oils containing mostly small hydrocarbon molecular chains to black, nearly solid asphalt-like large hydrocarbon chains. These crude oils

The Importance of Refineries

Most lubricating oils come from petroleum or crude oil. In order to get a lubricating oil from a crude oil, the crude oil must be sent through a refinery. The refinery takes from the crude oil a lot of molecules of various sizes and structures that can be used for different things. For example, gasoline, diesel and kerosene are all derived from crude oil. Lubricating oil relates to hydrocarbon molecules of a particular size (in the range from 26 to 40 carbons). Fairly large and heavy molecules are needed to work as lubricating oils. The molecules that are used with gasoline and kerosene are smaller and have fewer carbons in the structure of the molecule. The refinery puts these molecules in little silos based on size and weight, and removes impurities, enabling each of the products from the crude oil to be utilized.

are very complex mixtures containing a plethora of different compounds made of hydrogen and carbon. These compounds (known as hydrocarbons) can range in size from methane (containing one carbon and four hydrogen atoms) to massive structures with 60 or more carbon atoms. This molecular size distribution can be used to our advantage.

After the crude oil is desalted and sent through a furnace where it is heated and partially vaporized, it is sent to a fractionating column. This column operates slightly above atmospheric pressure and separates the hydrocarbons based on their boiling points, which are directly affected by their molecular size. In the fractionating column, heat is applied and concentrated at the bottom. The hydrocarbons entering the column will be vaporized. As they travel upward in the column, they will cool until they condense back into a liquid form. The point at which this condensation occurs

varies again based in part on the molecular size.

By pulling the condensing liquid from the column at different heights, you can essentially separate the crude oil based on molecular size. The smallest of the hydrocarbons (5 to 10 carbon atoms) will rise to the very top of the column. They will be processed into products like gasoline. Condensing just before reaching the top, the compounds containing 11 to 13 carbon atoms will be processed into kerosene and jet fuel. Larger still at 14 to 25 carbon atoms in the molecular chain, diesel and gas oils are pulled out.

Those compounds with 26 to 40 carbon atoms are a tribologist's main concern. This is the material used for the creation of lubricating oil. At the bottom of the column, the heaviest and largest of the hydrocarbons (40-plus carbon atoms) are taken and used in asphaltic-based products.

93%

of lubrication professionals would purchase a lubricant with a high-quality base oil at a higher initial price instead of a lubricant with a low-quality base oil at a lower initial price, according to a recent survey at machinerylubrication.com



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After the distillation process, the compounds need to be refined for their intended purpose. This step in the process is done to reduce the tendency of the base oil to age (oxidize) in service and also to improve the viscosity/temperature characteristics. There are two ways this can be done. The first involves a separation process where there are two products being made: a desired lube product and undesirable byproducts. The second way, which is quickly becoming the favored of the two, is a conversion process. This process involves converting undesirable molecular structures into desirable structures with the use of hydrogen, heat and pressure.

Extraction Process

The following is a simplified description of the extraction process:

Deasphalting

Propane deasphalting takes the residuum from the very bottom of the column (the heaviest, largest molecules) and separates them into two products: tar and compounds that are similar to the lube distillates but have a higher boiling point. This material is called deasphalted oil, and it will be refined in the same manner as the lube distillates.

Solvent Extraction

Solvent extraction is the term used for the removal of most of the aromatics and undesirable constituents of oil

distillates by liquid extraction. Commonly used solvents contain phenol, furfural and sulphur dioxide. The resulting base stocks are raffinates (referred to as neutral oils) and an extract that is rich in aromatic content, which is highly sought after as a process oil or fuel oil.

Dewaxing

After solvent extraction, the raffinates are dewaxed to improve low-temperature fluidity. This process again produces two products: a byproduct wax that is almost completely paraffinic and a dewaxed oil that contains paraffins, naphthenes and some aromatics. This dewaxed oil becomes the base stock for many lubricants, but there is one more process that can be done to make a premium product.

Hydrofinishing

Hydrofinishing changes the polar compounds in the oil by a chemical reaction involving hydrogen. After this process, an observer would notice a lighter-colored product and an improved chemical stability. The final quality of the base oil is determined by the severity of the application of temperature and pressure in the hydrofining process.

Conversion Process

The following is a simplified description of the conversion process:

Hydrocracking

In this refining process, the distillates are subjected to a chemical reaction with hydrogen in the presence of a catalyst at high temperatures and pressures (420 degrees C and 3,000 psi). The aromatic and naphthene rings are broken, opened and joined using hydrogen to form an isoparaffin structure. The reaction with hydrogen will also aid in the removal of water, ammonia and hydrogen sulfide.

Hydrodewaxing

During hydrodewaxing, much like hydrocracking, a hydrogenation unit is used to deploy a catalyst that is specific to conveying waxy normal paraffins to more desirable isoparaffin structures.

Hydrotreating

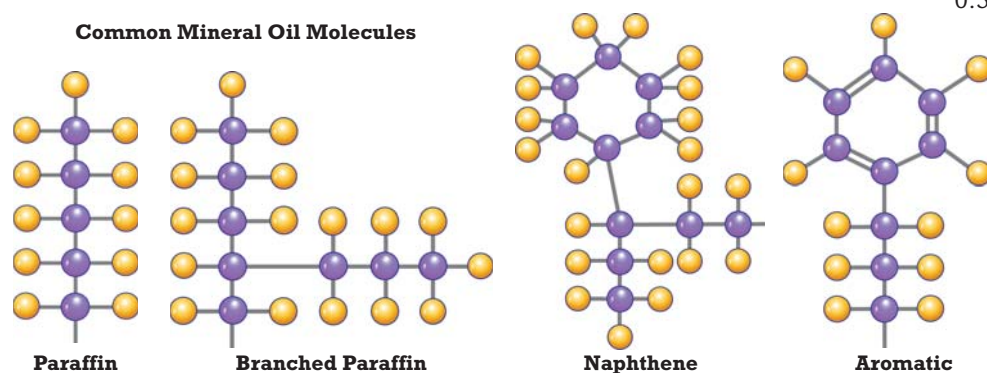
Because the previous two processes involve breaking chemical bonds between two carbon atoms, it is necessary to introduce the saturation of any unsaturated molecules. This is easily done by introducing more hydrogen. These saturated molecules are more stable and will be able to resist the oxidation process better than the unsaturated variety.

There are slight differences in the characteristics of the finished base oil produced by these two processes. The main difference lies in the aromatic content. The conversion process can reduce the aromatic content to around 0.5 percent, while the extraction process

lingers around 15 to 20 percent. This aromatic content has the following effects:

It would appear that the conversion process produces a better quality product, but there is always a trade-off. The cost of refining oil using the conversion

Common Mineral Oil Molecules



CHARACTERISTIC	DIFFERENCE
Color	Conversion produces clear, colorless products
Viscosity Index	Conversion produces higher viscosity indexes
Oxidation Resistance	Conversion produces better oxidation resistance
Thermal Stability	Disappears when power supply is shut off
Carbon Residue	Conversion products produce fewer residuals
Demulsibility	Conversion products separate water more readily
Biodegradability	Conversion products tend to biodegrade faster

process is somewhat higher than the extraction process. This extra cost incurred by the refiner is eventually passed on to the customer. However, in this case, the customer typically gets what he pays for – a higher quality base oil at a higher initial price. ■

About the Author

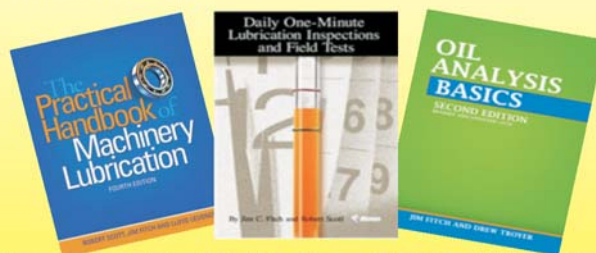
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THE EFFECTS of EP ADDITIVES on GEARBOXES

Oil additives offer a wide range of benefits, but in some circumstances they can actually be harmful to the machines in which they are added. For example, let's look at worm gearboxes. These machines have gearing composed of yellow metal (typically bronze). Certain extreme pressure (EP) additives can chemically react with these softer metals, causing premature wear and even failure.

Worm gearboxes are mainly comprised

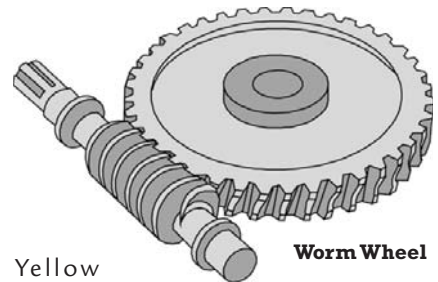
of two units: the worm and the worm wheel. The worm is what actually drives the worm wheel. It is a rod with a helical ridge on its surface that allows it to mesh with the teeth of the worm wheel to provide rotary motion.

These gearboxes are great for achieving high reduction ratios as well as high torque. In order to increase either of

these values, the worm wheel is made larger in diameter. The larger circumference the worm wheel has, the greater the speed reduction and the greater amount of torque will be imparted through the exit shaft.

Generally, the worm is made of steel, while the worm wheel is made of a yellow metal. However, in some cases,

both the worm and worm wheel are steel, or they both may be yellow metals. The worm is always harder than the wheel.



Worm Wheel

Yellow metals, as the name suggests, are yellowish in color. They are alloys that contain copper. A standard definition would be a type of brass having about 60 percent copper and 40 percent zinc. Bronze is another type of yellow metal. These metals have been used for centuries to form gears and other components of simple machines.

EP additives that contain sulfur cause the most damage to these types of metals. Two different types of sulfur may be used within these additives. The first type is active sulfur. Sulfur in its active state readily reacts with metal surfaces to form a ductile metal soap

62% of lubrication professionals use extreme pressure (EP) oils to lubricate worm gears, based on a recent survey at machinerylubrication.com

Copper Strip Corrosion Test

An easy way to determine which form of sulfur is being utilized in your EP oil is to look at the results of the copper strip corrosion test (ASTM D130). In this test, a strip of copper is immersed in the fluid to be tested at 40 degrees C and again at 100 degrees C. The strip is removed after each test and checked for staining of the copper. The results range from very little to no staining (1a) all the way to very dark stains (4c). If the results are in the area of 1b to 2a, then the yellow metals in your worm gearboxes could be at risk for chemical attack.



that is sacrificial and allows opposing surfaces to contact one another with minimal damage. Active sulfur is chemically aggressive, and with yellow metals being softer than steel, they can begin to pit and form spalls due to this chemical attack.

Rising temperatures can increase the rate at which this reaction takes place. This is explained by the Arrhenius rate

reacts with the copper within the brass or bronze. Sulfur, when in contact with copper along with the presence of heat, forms copper sulfide. This simple chemical reaction can have devastating repercussions on the reliability of machines. In extreme pressure situations, copper disulfide can be formed. Both of these crystalline forms of copper are very hard and can cause abrasive damage to soft machine

very cost-effective alternative to steel.

In addition, brass properties are easily changed by incorporating different metals into the metallurgy. For instance, lead can be added for enhanced machinability. For increased corrosion resistance, aluminum or tin can be added into the makeup of the alloy. The possibilities are endless for the types of alloys you can make with brass and bronze.

By understanding some simple chemistry and reading the product data sheets of the lubricants you put into your gearboxes, you can increase reliability.

By understanding some simple chemistry and reading the product data sheets of the lubricants you put into your gearboxes, you can increase reliability. When adding EP oil to gearboxes containing yellow metals, remember to check the copper strip corrosion test (ASTM D130) to help predict if there will be any issues with compatibility of the metallurgy within these machines. ■

rule, which states that the rate of a chemical reaction doubles for every increase of 10 degrees C (18 degrees F) in oil operation temperature.

The second type of sulfur used within EP additives is inactive sulfur. It is less likely to bond to surfaces and react chemically.

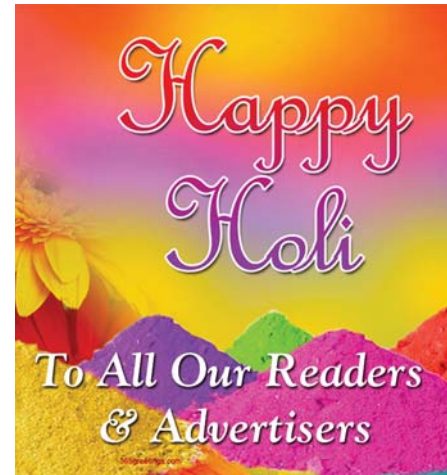
Active sulfur in some EP additives

surfaces. With all the risks associated with chemical attacks on yellow metals, why make gears using these metals in the first place? Brass and bronze are easy to machine into different shapes and yet have good strength and hardness. It all comes down to economics. When you factor in machining costs and raw materials costs, yellow metals are a

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EP additives can cause damage to a worm wheel, which is usually bronze.



BASE OIL REPORT

The price of Middle East crude oils being supplied to Asia appears too high given an increase in supply from Iran, Iraq and rival Russia and muted demand from refiners. While benchmark Oman futures have declined 5 percent since the start of the year to end at \$102.93 a barrel, the price relative to global marker Brent has been rising. Brent is down 4.5 percent so far this year, but both it and Oman have been trading in a fairly narrow range since January. The Brent-Dubai exchange for swaps DUB-EFS-1M fell to \$3.75 a barrel, down from the year-high of \$4.44 on March 14. While the maintenance of refineries may boost margins by removing some product supply, it should have the opposite impact on crude prices as fewer cargoes are purchased. At the same time, supply appears to be rising, with Iran taking full advantage of the thaw in its relations with Western nations over its disputed nuclear programme to boost its exports. Iran's

exports have exceeded the 1 million bpd allowed under Western sanctions for the past four months. Iran's four major Asian buyers China, India, Japan and South Korea - took a combined 1.16 million bpd in February, up from 994,669 bpd in January.

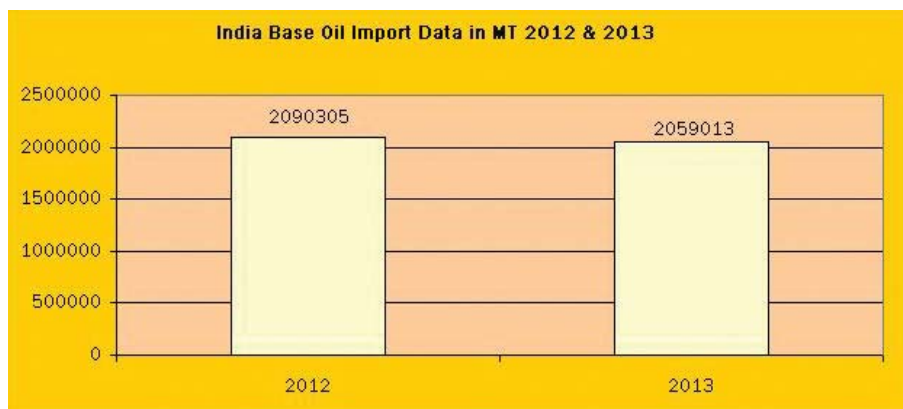
Indian State Oil PSU's IOC/HPCL/BPCL basic prices for SN - 70/N - 70/N-65/SN - 150/N -150/N - 150 marked down by Rs 0.60 per liter on its basic prices, While SN - 500/N - 500/ MakBase - 500 were marked up by Rs 0.10 per liter. Bright stock prices were up by Rs 0.40 per Liter effective March 01, 2014. Hefty Discounts are offered by refiners which are in the range of Rs. 10.00 - 13.00 per liter for buyers who commit to lift above 1500 MT. Group I Base Oil prices for neutrals SN -150/500 (Russian and Iranian origin) are offered in the domestic market at Rs. 60.60 - 60.70/60.90 - 61.30 per liter, excise duty and VAT as applicable Ex Silvassa in bulk for one tanker load.

At current level availability is not a concern.

The Indian domestic market Korean origin Group II plus N-60-70/150/500 prices at the current; level is steady. As per conversation with domestic importers and traders prices have inched up for N - 60/ N- 150/ N - 500 grades and at the current level are quoted in the range of Rs. 60.80 - 61.30/61.75 - 62.45/63.50 - 64.65 per liter in bulk respectively with an additional 14 percent excise duty and VAT as applicable, no Sales tax/Vat if products are offered Ex-Silvassa a tax free zone. The above mentioned prices are offered by a manufacturer who also offers the grades in the domestic market, while another importer trader is offering the grades cheaper by Rs.0.25 - 0.35 per liter on basic prices. Light Liquid Paraffin (IP) is priced at Rs. 61.70 - 62.25 per liter in bulk and Heavy Liquid paraffin (IP) is Rs. 66.95 - 68.10 per liter in bulk respectively plus taxes extra.

During the period January to December 2013, India imported 2.05 million MT of Base Oil.

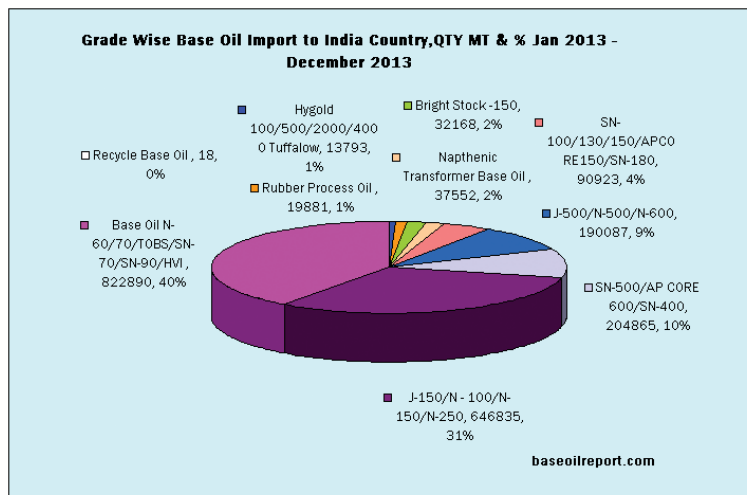
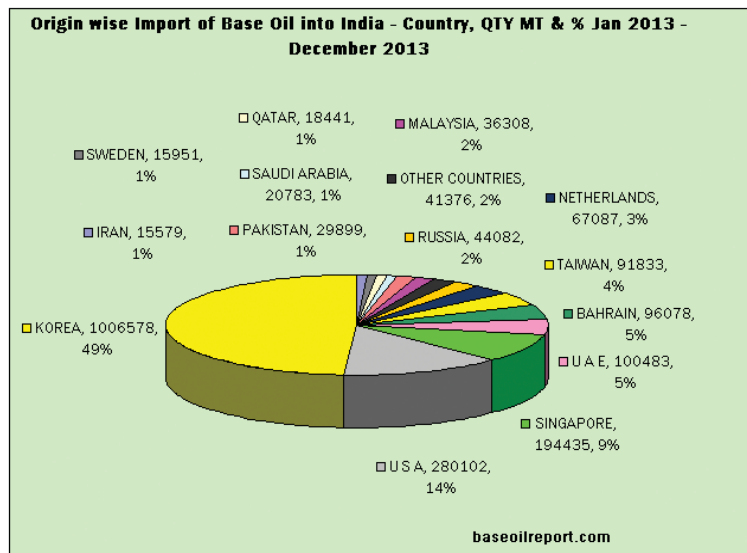
Approximately 11910 MT of White Oils, Liquid Paraffin's (Light & Heavy) has been exported during the month of January 2014 from JNPT, Mundra,



Month	TOBS - 60 Korean Origin CFR India Prices	J-150 Singapore Origin Base Oil CFR India Prices	Group I - SN 500 Iran Origin Base Oil CFR India Prices	Bright Stock - 150 CFR India Prices
January 2014	USD 995 – 1000 PMT	USD 1025 – 1035 PMT	USD 930 – 940 PMT	USD 1095 - 1100 PMT
February 2014	USD 985 – 990 PMT	USD 1010 – 1020 PMT	USD 930 – 935 PMT	USD 1065 - 1070 PMT
March 2014	USD 990 – 995 PMT	USD 1020 – 1030 PMT	USD 945 – 950 PMT	USD 1080 – 1085 PMT
	Since January 2014, prices dipped down by USD 5 PMT (1%) in March 2014	Since January 2014, prices has marked down by USD 5 PMT in March 2014	Since January 2014, prices has gone up by USD 15 PMT (2%) in March 2014	Since January 2014, prices has decreased by USD 15 PMT (1%) in March 2014

GRADE WISE BASE OIL IMPORT	QTY. in MT	%
Base Oil N-60/70/TOBS/SN-70/SN-90/HVI	822890	40
J-150/N-100/N-150/N-250	646835	31
SN-500/AP CORE 600/SN-400	204865	10
J-500/N-500/N-600	190087	9
SN-100/130/150/APCORE 150/SN-180	90923	4
Naphthenic Transformer Base	37552	2
Bright Stock- 150	32168	2
Rubber Process Oil	19881	1
Hygold 100/500/2000/4000	13793	1

BASE OIL IMPORT DATA (COUNTRY)	QTY. in MT	%
Korea	1006578	49
USA	280102	14
Singapore	194435	9
UAE	100483	5
Bahrain	96078	5
Taiwan	91833	4
Netherlands	67087	3
Russia	44082	2
Other Countries	41376	2
Malaysia	36308	2
Pakistan	29899	1
Saudi Arabia	20783	1
Qatar	18441	1
Sweden	15951	1
Iran	15579	1



Ahmedabad, Raxaul LCS, and Chennai port. Compared to December 2013, exports of the country have gone up by 25% in the month of January 2014. It has been exported to 38 countries all over the world.

Approximately 3776 MT of Transformer Oil has also been exported during the month of January 2014 from JNPT and Ludhiana port. It has been exported to Algeria, Bangladesh, Brazil, Egypt, Malaysia, Newzealand, Oman, Paraguay, Indonesia, South Africa, Saudi, Singapore, Syria, Taiwan, Thailand and UAE.

About the Author



Dhiren Shah is a Chemical Engineer and Editor-in-chief of Petosil Group. He is instrumental in developing the various Petosil Brands since inception.

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2014 Training Calendar

Bangalore | 7th April 2014 to 9th April 2014 | Essentials of Machinery Lubrication

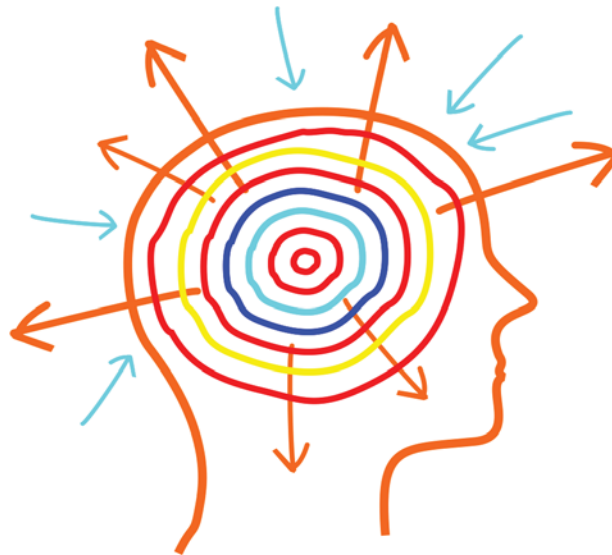
Ahmedabad | 10th April 2014 to 12th April 2014 | Essentials of Machinery Lubrication

Mumbai | 14th April 2014 to 16th April 2014 | Practical Oil Analysis

Kolkata | 10th Nov. 2014 to 12th Nov. 2014 | Essentials of Machinery Lubrication

Mumbai | 13th Nov. 2014 to 15th Nov. 2014 | Advanced Machinery Lubrication

Mumbai | 17th Nov. 2014 to 19th Nov. 2014 | Advanced Oil Analysis



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