# Machinery Lubrication

INDIA March - April 2019

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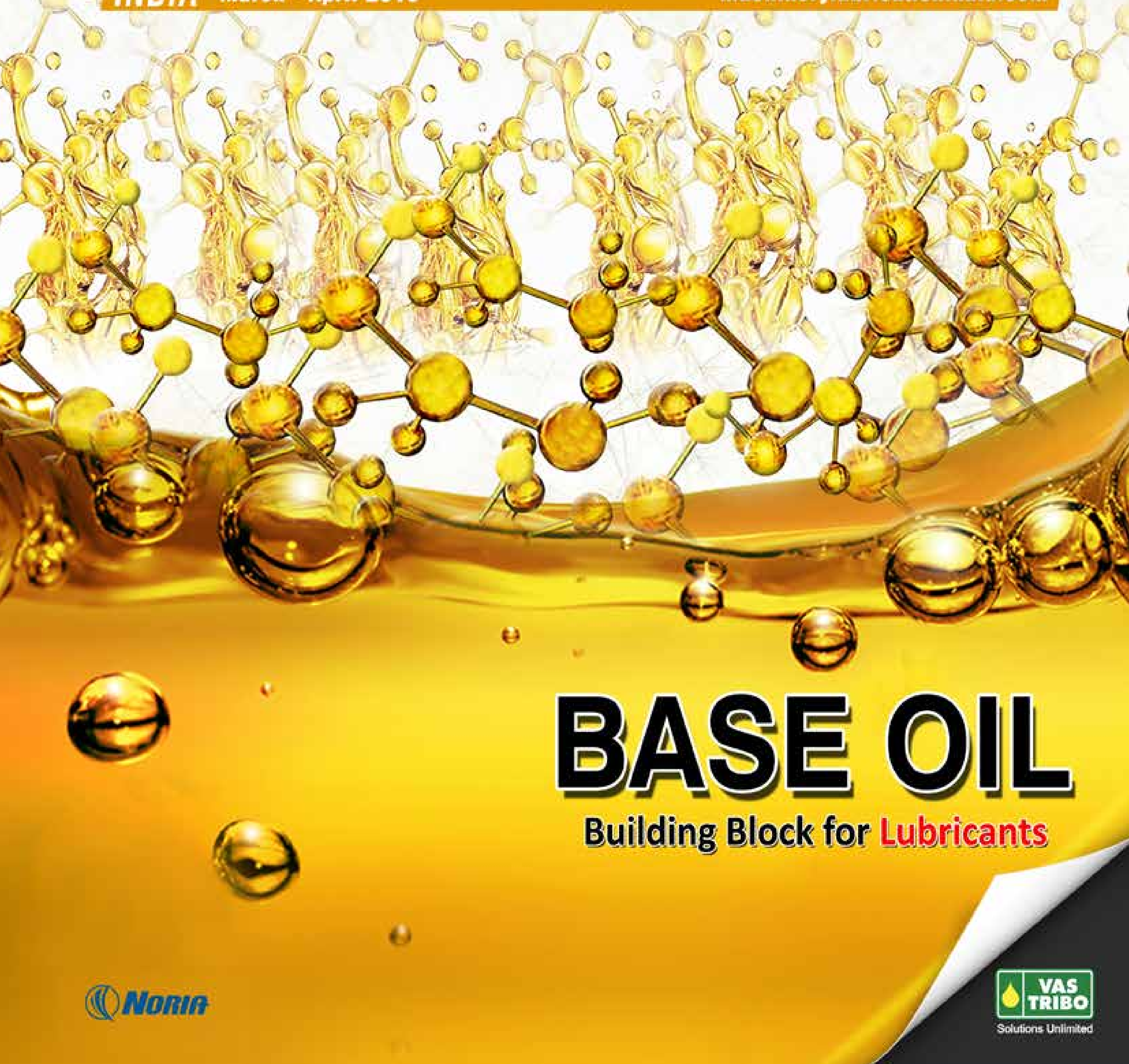

# BASE OIL

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## EDITORIAL FEATURES

# Publisher's Note

Throughout the world, tightening environmental legislation has lead to stricter performance standards. This is forcing the need for high performance lubricants. The introduction of all-hydroprocessed Group II and Group III base oils in the mid 90s made tighter specifications possible. These base oils have high oxidation stability, low volatility for a given viscosity grade and are essentially sulphur-free. In automotive engine oils, by far the largest market for base oils, there is an increasing trend to low and mid SAPS specifications (Sulphated Ash, Phosphorous and Sulphur) and lighter viscosity grades. Due to their high sulphur content, Group I base oils cannot be used in formulations designed to meet these specifications. Formulators must use Group II or Group III base oils. These base oils significantly improve the performance of many industrial oils and greases as well. The increased demand for all-hydro processed Group II and III base oils has lead to significant production expansion globally. In North America, over 60% of the supply is already Group II quality or higher. Given the increasing demand for Group II and III base oils and the corresponding declining demand for Group I base oils, some high cost Group I manufacturing facilities are vulnerable to closure. As the market evolves, it is important that lubricant manufacturers have a secure and 'future-proof' base oil supply strategy in place.

Growing industrialisation and the need to meet higher-quality motor oil specifications is driving demand. New formulations will emphasize these characteristics:

- lighter viscosity grades for increased fuel economy
- low volatility for reduced oil consumption
- improved oxidation and thermal stability for longer drain intervals
- improved high-temperature, high-shear (HTHS) viscosity characteristics for application to modern engine designs.

Many of these characteristics are also highly desirable in greases. Producing a low-viscosity and low-volatility lubricant requires a highly paraffinic, high-viscosity index (VI) base stock. High oxidation stability and thermal stability are obtained by using base stocks that contain minimal amounts of unstable aromatics. Base stocks that have these qualities include synthetics such as polyalphaolefins (PAO) and hydroprocessed mineral base oils.

When you are choosing base oil, there will be tradeoffs in the lubricant properties required for the application. A common example is viscosity. Higher viscosity provides adequate film strength, while lower viscosity offers low-temperature fluidity and lower energy consumption. In some cases, you may prefer to have a balance between the two so there isn't too much of a compromise on either side.

Although it's not necessarily important to understand the way in which the oil was manufactured, it is critical to know the available base oil options and the advantages and disadvantages they provide. Optimizing your lubricant selection can help minimize the incidence for machine failure. While synthetics are justifiably more expensive than mineral oil, the cost of equipment failure is typically much higher. If cost is a key factor in your decision, be sure to choose wisely.

We would like to thank our readers for the great response to our previous edition's cover story – "3 Causes of unreliable equipment and how to eliminate them" and other articles. Our current issue's cover story is "Base Oil-Building block for Lubricants" which will help our readers to understand the performance and future trends of Base Oils.

We welcome your feedback & suggestions.

**Warm regards,**

**Udey Dhir**

Jim Fitch | Noria Corporation

AS I SEE IT



# Who Should Inspect Your **Lubricated Machines?**

"Ultimately, you seek skillful and dependable completion of the entire inspection plan by one or more inspectors with the time, skills and resources to perform their tasks."

Perhaps you've heard that machine reliability is everyone's responsibility. In a general sense, this is very true and needed. We should all keep our eyes alert to issues, large and small. We should propitiate an inspection and proactive maintenance culture. Inspection is largely about relentless and purposeful sensory observation. Any competent and responsible person near a machine can and should serve as the inspector of the moment.

It's not just about the machine. There are five inspection operating states, as I discussed in a previous column. Take machine parts, for instance. They frequently are staged in warehouses or on shelves and pallets near operating machines and other active work areas. Sooner or later these components become an integral part of the machines or machine trains where they are intended to be used. Inspection is a cradle-to-grave process, including all the parts that build to a complete and functioning machine or train.

Whatever impaired state or condition the part sustains or is exposed to eventually will be transferred to the operating machine. Even the smallest components that are infected with issues can metastasize and impart hazards and destruction to operating process lines and beyond. It's not the cost of the repair but rather the cost of lost production that matters, often at many multiples of the repair cost.

Still, due to the potential consequences of failure, inspection requires responsibility and accountability. I've previously discussed the need for an inspection plan that outlines the role and skills of the inspector. The tasks of inspectors are broad and, in many cases, also difficult. Each task, as defined in the inspection plan, requires a corresponding skill set. The skills must match the tasks, not generally but specifically. Each inspector should qualify his or her actual inventory of skills to the required skills defined by the tasks (and procedures). Gaps in these skills must be closed by training or perhaps by means of a staffing change.

## Operator-driven Inspection

In some organizations, the best choice for such an inspector is the machine operator. This is the person who works near the machines and is sometimes in front of the machines eight to twelve hours a day. Because of this, many operators can recognize subtle differences between normal and abnormal conditions. This is often referred to as operator-driven inspection (ODI) and is preferred by numerous organizations, such as those that rigorously follow the principles of total productive maintenance (TPM).

The effectiveness of ODI is heavily influenced by the maintenance culture and the skills of the operator to take full responsibility for each element of the inspection plan. Other issues are also at play here, including machine readiness and the availability of needed inspection tools or aids. Asking operators to see what they don't want to see can be unpleasant, tedious and at times thankless. This is where an unrelenting, inspection-intensive culture comes into play. When issues are discovered, there is the need for these operators to make the case for maintenance to troubleshoot, repair or perform other adjustments to realign the machine to a healthy state.

Operator-driven maintenance is like the car owner who is also the operator/driver. This is the same person who checks the oil level and tire pressure, looks for oil on the driveway, and notices strange sounds and smells. On occasion, he or she might look under the hood and check the service manual. Not all car owners are good at these inspections, but many are and accept these tasks eagerly.

The industrial and commercial assets of large organizations are increasingly running a lean staff. This can stretch operators beyond practical limits in performing all the inspections needed to ensure the required level of reliability and safety. In such cases, the responsibility must be shared or completely delegated to skilled full-time inspectors.

## Inspector Generalists

Some inspectors may be specialists who work full-time in all or certain disciplines of condition monitoring. The inspector might also be the resident expert who only does inspection routes. The advantage here is the ability to have more rigorous training and continuous practice. Combine broad and deep inspection knowledge with a linguistic understanding of other condition monitoring technologies (e.g., oil analysis, vibration, thermography, etc.) and the value of the expert inspector can be enormous.

Inspection expertise can be both horizontally and vertically integrated. Horizontal integration is another way of saying cross-disciplinary inspection. Inspector knowledge would include skills involving many technical disciplines relating to lubrication, tribology, oil analysis, mechanical machine design, electrical, instrumentation, safety and operational inspections. This is the inspector jack-of-all-trades, also known as a generalist.

Frequently, it makes little sense to conduct one survey for lubrication followed by a similar inspection for electrical systems on the

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same machine. If your plant has different maintenance planners for different maintenance functions (mechanical, electrical, production, etc.), inspections can easily be divided once the information has been gathered. The critical path is obtaining good data and all the data.

However, be wary of the weakest link. Some inspectors may be proficient with mechanical assessments but guess at other disciplines like electrical systems and instrumentation. Ultimately, you seek skillful and dependable completion of the entire inspection plan by one or more inspectors with the time, skills and resources to perform their tasks. Cutting corners usually proves hazardous.

## Inspection Technicians and Inspection Analysts

Vertically integrated inspection deploys deeper subject-matter expertise in the field of inspection. Even this is difficult to achieve considering all the possible inspection disciplines across the various types of machines found in large industrial plants. Vibration analysis, oil analysis, acoustics analysis and infrared thermography each have an extensive education curriculum with corresponding certification testing requirements. These are professional career paths that are recognized by ISO 18436 with three levels of competency (Category I, II and III).

Sadly, as of this writing, no equivalent curriculum or competency testing is available for inspection technicians and inspection analysts. That is soon to change as Inspection 2.0 gains traction in the world of condition monitoring.

When defining the inspection technician, think of these individuals as specialists with Category I or II credentials in the field of inspection. They have the skills to perform numerous inspection tasks on many machine types. They also have above-average subject-matter competency in other ancillary inspection tasks and methods. Inspection technicians are people who perform regular inspection routes and practice extensively in their field.

Inspection analysts can be defined as resident experts with deep subject-matter knowledge and experience across many disciplines (mechanical, electrical, instrumentation, safety, etc.) on inspection tasks and methods. Inspection analysts do not have job cross-functionality. They also are not operators, mechanics, electricians or lube techs. Access to this degree of inspection knowledge is the essence of Inspection 2.0.

Inspection analysts are trained, certified and have extensive experience performing inspections. They have the ability to see what others cannot. They don't just look or hear but rather examine carefully and probe further. They also have a good toolbox of needed inspection aids. They possess encyclopedic knowledge on various inspection subjects as well as the other technical areas of condition monitoring. And, they know what goes on within the exoskeleton of the machine being inspected.

Effective inspection analysts are hired guns or resident experts who can be called in to assist in troubleshooting efforts. Alternatively, they can be deployed to perform inspection routes on machines designated as high criticality or are known bad actors. An inspection analyst is a certified Category III inspector. All large industrial plants should have at least one inspection analyst on staff. ML

### About the Author

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

# BASE OIL

## Building Block for Lubricants

By Dr. A S Kathait

Throughout human history, energy has been a key enabler of living standards. This has triggered the evolution of lubrication to give the longer life to machinery & tools. A lubricant can be defined as a substance which can reduce the friction and surface damage resulting upon rubbing of two solid surfaces. Lubrication technology has advanced significantly in recent times, but the roots of lubrication extend back further than imagination. Some of the historical perspectives & milestones are placed here:

From its humble beginnings over 3000 years ago, lubrication technology has seen many phases of evolution. As it continues to evolve at an ever-increasing rate, base oil performance is making a larger contribution to finished lubricant performance. E.g. Turbine oils are the most dramatic example which typically contains over 99% base oil. Base Oils are an integral part of a lubricant providing performance characteristics and benefits.

### The Evolution of Base Oil Technology

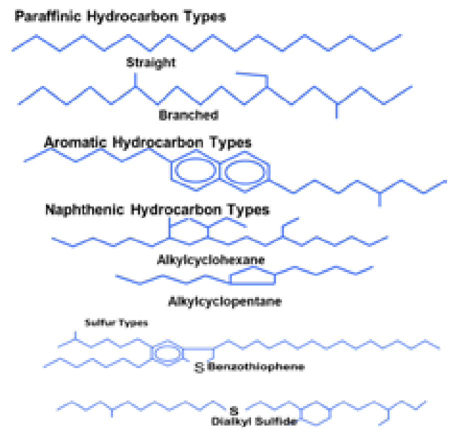
Early lubrication began with animal fats and oils and slowly evolved to petroleum-based oils over the period. Base oil is the name given to oils initially produced from refining crude oil or through chemical synthesis. It is the oil with a boiling point that range between 288°C and 566°C. It consists of hydrocarbons with 18 - 25 carbon atoms. It is classified into various grades including Neutral (N), Solvent Neutral (SN) and Bright Stocks (BS).This oil can be either paraffinic or naphthenic in nature depending on the chemical structure of the molecules.

These base oils come from three primary sources: Crude oil; Chemical synthesis and Natural resources other than crude oil (fats, waxes, vegetables, etc.). In order to obtain the different kinds of minerals, a refining process is employed to separate crude oil into the different types through processes of distillation, cracking, hydrogenation and dewaxing. Crude oil contains three primary hydrocarbon types: Paraffin, Naphthenic and Aromatics. The American Petroleum Institute (API) has introduced a broad classification for all types of base oils as shown in Table 1. Five groups of which indicate performance level of base oils. This grouping also helps to distinguish the broad chemical composition, to minimize lengthy testing for blending and substitution purposes.

## Refining Processes for Base Oil Production

Based on the API classifications of base oils, refining processes of Group I to III base oils are primarily selected on viscosity index

**Fig-1**




ranges as shown in Table 1.

Base oil composition depends upon the following two factors:

**a) Crude Oil Source**

Crude oil sourcing depends upon the each oil field because of its unique composition which affects the output of refining process. The crude composition mainly consists of

- Types of Hydrocarbons (Paraffinic/ Aromatic/Naphthenic/sulphur type)
- Sulphur
- Nitrogen

The other factor of crude sourcing depends upon availability which is normally influenced by

a. Economics
b. Abundance Availability
c. Logistics
d. Current political & market scenario

**b) Refining Process**

A crude oil itself a source various petroleum products which are extracted/converted by suitable refining /conversion processes. Various fractions of crude oil are given in Fig- 2 & 3:

The manufacture of lube base oils can be done using any of the following processes below, [Wright, (2014)]

**Fig-2** **Various Fractions of Crude Petroleum Products**

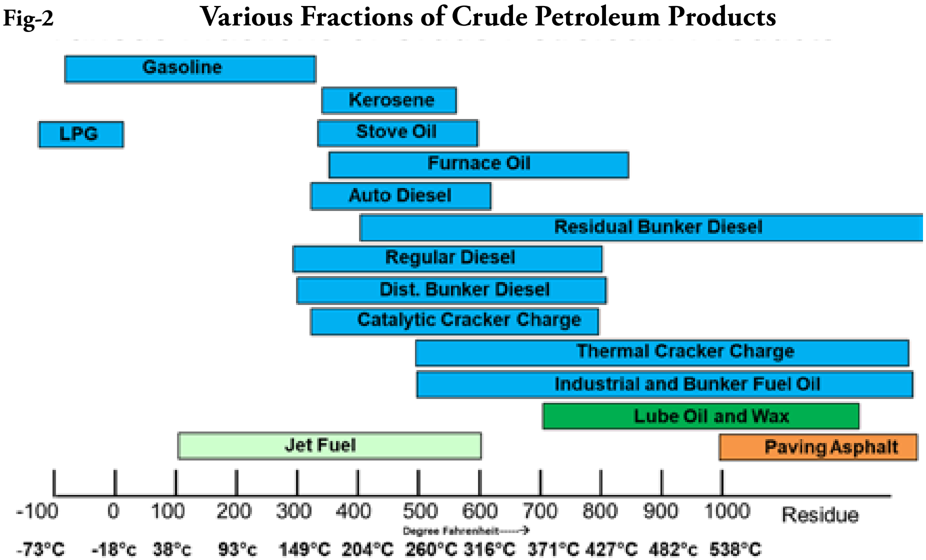


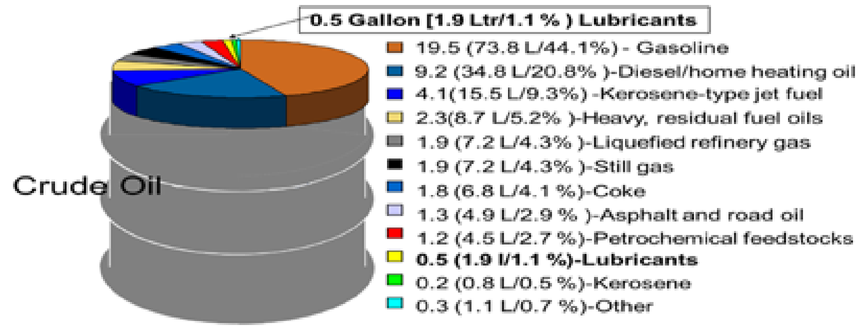

**Table. 1**

| API Group | Saturates | Sulfur | VI Group | Typical Manufacturing Process |
|---|---|---|---|---|
| I | <90% | >0.03% | 80-119 | Solvent Processing |
| II | >90% | <0.03% | 80-119 | Hydro processing |
| III | >90% | <0.03% | ≥ 120 | (Severely Hydro-processed/ Catalytic dewaxing) |
| IV | N.A | N.A | N.A | Poly Alpha Olefins (PAO) |
| V | All other Base Stocks which are not covered in Group I to IV (Polyglycols, Esters, Silicons, etc.) | | | |

A. Extraction Process
B. Conversion Process

**A. Extraction process**

According to Wright (2014), the extraction process is achieved in a sequence of processes namely: Distillation, De-asphalting, Extraction (Dewaxing (Catalytic dewaxing, solvent dewaxing), Fig-3 **Products Matrix & Lubricants in a 42 Gallon Barrel (1brl/158.987 Ltrs) of Crude Oil**




Finishing (clay contacting or Hydrogen finishing).

**1. Distillation process**

This process separates the atmospheric residue mixture into a series of fractions representing different viscosity, ranges from 90 - 500 neutrals. The neutral number is the Saybolt Universal Seconds (SUS) viscosity at $100^0$ F. The residue contains the heavier base oils such as the bright stocks. (150-250 SUS at $210^0$F). The latter is separated from resins and asphaltenes prior to introduction into the extraction process.

**2. De-asphalting**

It takes the residuum from the bottom of the distillation column and removes asphaltenes that are dark in colour and form carbonaceous deposits on heating. The process separates bottom residue into two products i.e. de-asphalted oil (DAO) and tar. De-asphalted oil is similar to the lube distillates but possesses higher boiling points and used for bright stock production.

**3. Extraction Process**

This process involves the removal of impurities such as aromatics, sulfur and nitrogen compounds. Aromatics make poor quality base oils because they are among the most reactive components in the natural lube oil boiling range. Oxidation of aromatics can start a chain reaction that can dramatically shorten the useful life of base oil. The viscosity of aromatic components in base oil also responds relatively poorly to changes in temperature. Lubricants are often designed to provide a viscosity that is low enough for good cold weather starting and high enough to provide adequate film thickness and lubricity in hot, high-severity service. Therefore, to meet the requirement of hot & cold performance, the small response to changes in temperature with respect to viscosity is desired. The relative property of base stock which indicates the response to cold & hot performance is expressed as VI (Viscosity Index). A higher VI indicates a smaller, more favourable response to temperature. Conventionally, solvent extraction was adopted as the purification process, in which aromatics are removed by feeding the raw lube distillate into a solvent extractor where it is counter-currently contacted with a solvent. The popular choices of solvent in the oil industries are furfural, n-methyl pyrrolidone (NMP), and DUO-SOL™. Phenol was another popular solvent but it is rarely used today due to environmental concerns. Solvent extraction typically removes 50-80% of the impurities (aromatics, polars, sulfur and nitrogen containing species). The resulting product of solvent extraction is usually referred to as a raffinate.

**4. Dewaxing Process**

This process removes wax to improve the pour point and low temperature properties of base oil. To improve the low temperature properties of base oil following dewaxing processes are used:

a) Solvent Dewaxing: It utilizes dewaxing solvents like methyl-ethyl-ketone (MEK), toluene or phenol to be mixed with the waxy oil. The mixture is then cooled to a temperature 10 to 20 degrees below the desired pour point. The wax crystals are then removed from the oil by filtration.

**More desirable alternatives to solvent dewaxing are:**

b) Catalytic dewaxing – Catalytic dewaxing was a desirable alternative to solvent dewaxing especially for conventional neutral oils, because it removes n-paraffins and waxy side chains from other molecules by catalytically cracking them into smaller molecules. This Process improves the pour point & low temperature properties of the base oil.

c) Wax hydroisomerization - The more advanced form of the catalytic dewaxing process. This process isomerizes n-paraffin and other molecules with waxy side chains into branched chain molecules with very desirable quality like lowering of pour point & superior lubricating qualities of base oils rather than cracking them away. In 1993, the first modern wax hydroisomerization process was commercialized by Chevron. This was an improvement over earlier catalytic dewaxing. Hydroisomerization also saturates the majority of remaining aromatics and removes the majority of remaining sulfur and nitrogen species. Modern wax hydroisomerization makes products with exceptional purity and stability due to extremely high degree of saturation. They are very distinctive because, unlike other base oils, they typically have no colour.

**5. Hydrofinishing Process**

It is the final process in the manufacturing of base oils. Its aim is to improve color and thermal/oxidative stability of base oil. In this process hydrogen is added to base oil at an elevated temperature in the presence of catalyst. Hydrotreating is a more recent form of purification process. By reaction of hydrogen with some remained sulfur and/or nitrogen containing molecules, these sulfur/nitrogen containing compounds are decomposed into smaller molecules. A great majority of sulfur, nitrogen and aromatics are thus removed. This massive reforming process produces molecules that have improved isometrics, oxidative stability and product colour.

**B. Conversion Process**

The following, according to Wright (2014), is a simplified description of the conversion processes: Distillation, Hydrocracking, Hydrodewaxing / Hydroisomerization, Hydrotreating.

1. Distillation process

This process separates the atmospheric residue mixture into a series of fractions with different molecular weight and viscosity ranges.

2. Hydrocracking

Hydrocracking is a more severe form of hydro processing. In hydrocracking, the base oil feedis subjected to a chemical reaction with hydrogen in the presence of a catalyst at high pressures above 1000 psi and temperatures above 650°F/340°C. Feed molecules are reshaped and often cracked into smaller molecules. The naphthenic and aromatic carbon rings are broken and re-joined using hydrogen to form an iso-paraffin structure. In this process a great majority of the sulfur, nitrogen, and aromatics are removed. Molecular reshaping of the remaining saturated species occurs as naphthenic rings are opened and paraffin isomers are redistributed, driven by thermodynamics with reaction rates facilitated by catalysts. Clean fuels are by-products of this process.

A primitive version of the hydrocracking process was attempted for lube oil manufacturing in the 1930s but was soon abandoned for economic reasons after the solvent refining process was commercialized. Later hydrocracking technology continued to improve over the period.

In 1969 the first hydrocracker for Base Oil Manufacturing was commercialized in Idemitsu Kosan Company's Chiba Refinery using technology licensed by Gulf [4]. This was followed by Sun Oil Company's Yabucoa Refinery in Puerto Rico in 1971, also using Gulf technology [2].

3. Hydrodewaxing

In this process a hydrogenation unit is used to deploy a catalyst that is specific to conveying waxy normal paraffin to more desirable isoparaffin structures.

4. Hydrotreating

The process helps to introduce saturation of any unsaturated molecules by adding hydrogen to base oil at elevated temperature( above 600°F/316°C)& pressure (Above 500 psi ) in presence of catalyst. Hydrotreating was developed in the 1950s and first used in base oil manufacturing in the 1960s by Amoco and others. It was used as an additional "cleanup" step added to the end of a conventional solvent refining process. Hydrotreating process helps to stabilize the most reactive components in the base oil, improve color, and increase the useful life of the base oil. This process removed some of the nitrogen and sulfur containing molecules but was not severe enough to remove a significant amount of aromatic molecules. Hydrotreating was a small improvement in base oil technology that would become more important later. Most of the unsaturated hydrocarbon molecules turned to saturated hydro carbon chain after hydrotreatment. These saturated molecules are more stable and will be able to resist the oxidation process better than the unsaturated molecular variety.

Several different reactions occur in this process, the principal ones being:

i. Polar compounds containing oxygen, sulphur and nitrogen removal.
ii. Aromatic hydrocarbons conversion to saturated cyclic hydrocarbons.
iii. The breaking up of heavy polycyclo-paraffin to lighter saturated hydrocarbons. These reactions take place at very high temperatures (380 - 420°C) and pressures (216 – 217 Bars) in the presence of a catalyst. The hydrocarbons that are formed in the process are very stable (Wright, 2014).

## Group I Base Oil Processes

Producing Group I base stocks starts with vacuum gas oil (VGO), one of the heavier streams coming out of the crude unit. Solvents are used to selectively remove 50-80% of the impurities. However, the treated base oils stream still has paraffins that need to be removed to produce usable base stocks. The paraffins are removed by a dewaxing process that uses solvents taken to a low temperature, where the wax is precipitated out.

Following refining processes are used for Group I Base Oil manufacturing [Fig- 4]:

***a. Vacuum Distillation***
[Removes metals &heavy asphaltic compounds; fractionates into viscosity cuts]

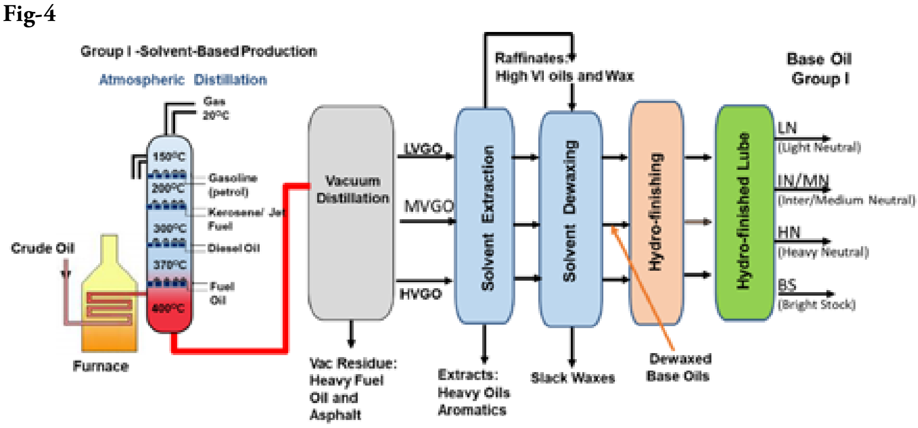
***b. Deasphalting (bright stock only)***
[Removes asphaltenes that are dark in color and form carbonaceous deposits on heating]

***c. Solvent Extraction***
[Removes aromatics, especially the multi-ring aromatics; improves thermal and stability and VI]

***d. Solvent Dewaxing***
[Removes wax; improves pour point, low temperature properties]

***e. Hydro finishing***
[Improves color and the stability of the base stock]

**Fig-4**




## Group II - Modern Conventional Base Oils

All hydroprocessing for base oils starts with the same feed as a solvent plant. However, instead of using a solvent to remove undesirable compounds, the feed is processed in a high-pressure hydro-cracker with catalysts that reshape the molecules, saturate the aromatic compounds and create high quality iso-paraffins. In total, 98-99.9% of the impurities are converted to high quality base oils. Group II base oils are differentiated from Group I base oils because they contain significantly lower levels of impurities (<10% aromatics, <300 ppm S) and almost close to water like colour. Group II oils made using modern hydroisomerization technology are purity means that the base oil and the additives in the finished product can last much longer. More specifically, the oil is more inert and forms less oxidation by products that increase base oil viscosity and react with additives.

Group II is typically produced by processing VGO in a dedicated base oil hydrocracker in a gasoline refinery. Following refining processes involved in Group II/II+

- **Hydro-cracking**
  - Removes O, S and N compounds
  - Converts (saturates) aromatics into naphthenes
  - Converts 'cracks' long chain aromatics and naphthenes to iso- and n- paraffins
- **Catalytic Dewaxing**
  - Converts 'cracks' the wax to lighter fuel products - improves pour point, low temperature properties

or

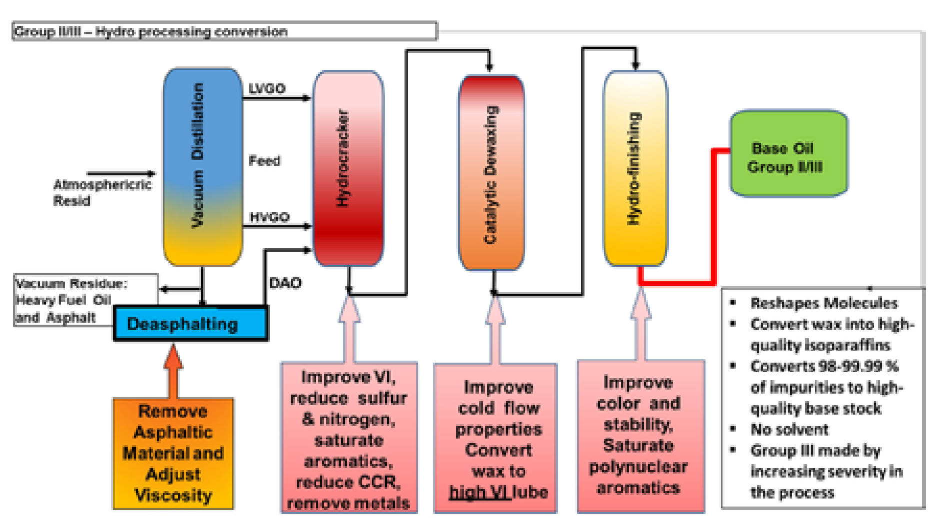
- **Hydro-isomerisation**
  - Converts (isomerises) n-paraffins to iso-paraffins; improves pour point, low temperature properties, increases yields
- **Hydro finishing**
  - Converts trace impurities; Improves color and the stability of the base stock

## Group III - Unconventional Base Oils

API defines the difference between Group II and III base oils only in terms of the VI. Base oils with a conventional VI (80 to 119) are Group II and base oils with an unconventional VI (120+) are Group III. Group III oils are also sometimes called unconventional base oils (UCBOs) or very high viscosity index (VHVI) base oils.

Solvent de-waxed Group III base oils have been in market for last more than 10 years. Over the decades the quality of Group III base oils have been improved significantly as compared to the first generation Group III oils due to upgraded/modern Iso dewaxing process.

**Fig-5**



Group III is primarily produced by processing unconverted oil (fractionators bottoms) from a two-stage diesel hydrocracker. Whilst any diesel hydrocracker can make some Group III feed stocks, they are most efficiently produced in large-scale diesel hydrocrackers. Modern Group III base oils are manufactured by essentially the same processing route as modern Group II base oils. Higher VI is achieved by increasing hydrocracker severity or by changing to a higher VI feed. Fig- 5

Modern Group III base oils have properties which allow them to perform at a level that is significantly higher than "conventional" Group I and Group II base oils, and they substantially match existing levels of performance in finished lube applications already established by traditional synthetic oils.

## Group III+ GTL Base Stocks

The idea to produce base oil for lubricant applications using natural gas as the hydrocarbon source was developed 40 years ago at the Shell Technology Center in Amsterdam, The Netherlands. Several years later, the conversion reaction was optimized in a laboratory bench-scale reactor. During the 1980s and 1990s, this reaction was scaled up to a pilot plant and then to a small commercial plant. During this development process, several optimizations were made and captured in more than 3,500 patents. This innovation culminated into a commercial reality with the opening of the world-scale Pearl GTL plant in Qatar in 2011. Pearl GTL Qatar produces 140 Mbpd of synthetic GTL products and 120 Mbpd of NGL and ethane.

The first large-scale GTL base oil plant started up in 2011. It uses the same hydro-isomerisation process as that used to produce Group II and Group III

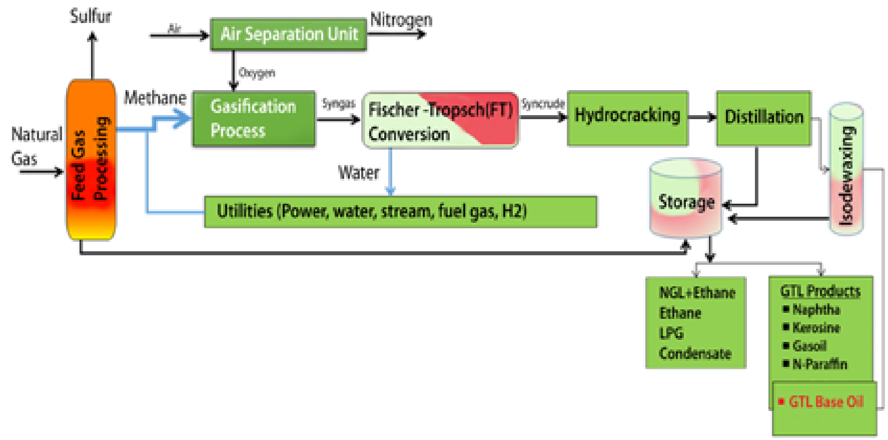



**Fig-6** **GTL Process for Clean Base Oil (Source Shell's GTL process)**

base oils. Like its Group II and Group III counterparts, GTL base stocks have exceptional thermal and oxidative stability. What distinguishes them from other hydro processed base oils are their high VI of 135-145. Consequently, GTL base stocks are classified as Group III+, an unofficial API category that recognizes their higher VI than other Group III base stocks.

The Shell's GTL technology is Fischer-Tropsch (FT) synthesis, based on the catalytic production of paraffin hydrocarbons from carbon monoxide (CO) and hydrogen (H2).18Natural gas, the cleanest-burning fossil fuel, was chosen as the preferred hydrocarbon source because it is affordable, available and environmentally acceptable.

In addition to the FT reaction, there are several other steps involved in the conversion of natural gas to finished base oils and motor oils, as shown in Fig.6. Shell is the world's largest producer of GTL base oils at a commercial scale.

## Group IV - Traditional "Synthetic" Base Oils (PAO)

The word "synthetic" in the lubricants industry has historically been synonymous with polymerized base oils such as poly-alpha olefins (PAOs), which are made from small molecules. Group IV base oils are chemically engineered synthetic base stocks. Polyalphaolefins (PAO's) are a common example of a synthetic base stock.

Polyalphaolefins (PAO's) chemical structure and properties are identical to those of mineral oils. Polyalphaolefins (synthetic hydrocarbons) are manufactured by polymerization of hydrocarbon molecules (alphaolefins). The process occurs in reaction of ethylene gas in presence of a metallic catalyst.

These oils are true synthetic lubricants, made through a process called synthesizing. Manufacturing PAO starts with an ethylene cracker making the simplest olefin (ethylene) from hydrocarbon feeds. The primary cracker feed is naphtha. Ethylene is selectively polymerized into linear alphaolefins (LAOs). The heart of the LAO production is C4, C6 (~16%), C8 (12-13%), and drops off to about 10% for C10 and 8% for C12. The lighter alphaolefins, C4-C8 cuts, are co-monomers for plastics, whilst the C12-C16 cuts typically go into detergents and the very heavy ones -- >C24 go into specialty applications. The C8, C10 and C12 LAO can be oligomerised into

Polyalphaolefins (PAO). Most C8 goes to co-monomer for plastics, only a little goes to PAO. PAO is primarily made from C10 LAO. Additionally, PAOs require a final hydro treating step to fully saturate the double bonds.

PAOs have very stable chemical compositions and highly uniform molecular chains. They have a much broader temperature range and are great for use in extreme cold conditions and high heat applications. They also have higher shear strength, and are less prone to oxidation at higher operating temperatures. Although a little more expensive than the crude API base oil groups, synthetic lubricants have extended life and do not degrade as rapidly as regular oils, thereby saving on oil changes downtime. They are also more energy efficient, resulting in further operating cost savings. These base stocks were first time commercially used in lubricant by Mobil in the 1960s.

Given the competition for feedstock and complexity of the PAO production process, PAO supply will continue to be limited and relatively costly.

## Group V base oils

Group V base stocks include all other base stocks not included in the I, II, III, IV API base oil groups. These include silicone, phosphate ester, polyalkylene glycol (PAG), polyolester, bio-lubes, etc. Sometimes these base oils are mixed with other base stocks to enhance the lubricant's properties.

Polyglycols are produced by oxidation of ethylene and propylene. The oxides are then polymerized resulting in formation of polyglycol. Polyglycols are water soluble.

Polyglycols are characterized by very low coefficient of friction. They are also able to withstand high pressures without EP (extreme pressure) additives. Ester oils are produced by reaction of acids and alcohols with water. Ester oils are characterized by very good high temperature and low temperature resistance. Silicones are a group of inorganic polymers, molecules of which represent a backbone structure built from repeated chemical units (monomers) containing Si=O moieties. Two organic groups are attached to each Si=O moiety: e.g. methyl+methyl (($(CH_3)_2$), methyl+phenyl ($CH_3$ + $C_6H_5$), phenyl+phenyl (($(C_6H_5)_2$). The most popular silicone is polydimethylsiloxane (PDMS). Its monomer is $(CH_3)_2SiO$. PDMS is produced from silicon and methylchloride. Other examples of silicones are polymethylphenylsiloxane and polydiphenylsiloxane. Viscosity of silicones depends on the length of the polymer molecules and on the degree of their cross-linking. Short non-cross-linked molecules make fluid silicone. Long cross-linked molecules result in elastomer silicone.

Group V base oils are used primarily in the creation of oil additives. Esters and polyolesters are both common Group V base oils used in the formulation of oil additives. Group V oils are generally not used as base oils themselves, but add beneficial properties to other base oils. Some examples of Group V Base Oils are: Alkylated Naphthalene, Esters, Polyalkylene glycols, Silicones, Polybutenes. Esters are Group V base oils commonly used in different lubricant formulations to improve the properties of the other base oil. Ester oils can operate at higher temperatures whilst also providing superior detergency compared to PAO synthetic base oils. This improves their oxidation resistance which in turn increases the oil change intervals.

## Performance of Base Oils and Future Trends

The growing demand for high-performance lubricants (owing to their better and improved properties, such as reduced flammability, reduced gear wear, and increased service life), is driving the market. High oxidation stability and thermal stability are obtained by using base stocks that contain minimal amounts of unstable aromatics. Base stocks that have these qualities include hydro processed mineral base oils (Group II, III & III plus) & synthetics such as polyalphaolefins (PAO). Hydro processed mineral base oils vary from high quality and high VI (95 to 105 VI) to excellent quality unconventional base oils (UCBO) with VI ranging from 115 to 140 and above. The most desirable hydrocarbons in base oils are C20+ iso-paraffins with high VI, low pour point, and excellent resistance to oxidation. Naphthenic compounds in this molecular

**Table 2: Typical Hydrocarbon composition of Base Oils**

| S. No. | Hydrocarbon Type | Solvent Refined 100N (Group I) | Hydro-Cracked 100N (Group II) | Advanced HC/HI 4 cSt (Group III) | VHVI 4 cSt HC/HI Synthetic (Group III+) | PAO 4 Synthetic (Group IV) |
|---|---|---|---|---|---|---|
| 1 | Paraffins (n- & iso-) | 20.5 | 18.2 | 40 | 72 | 96.1 |
| 2 | Monocycloparaffins | 27.2 | 33.4 | 35 | 22.7 | 3.9 |
| 3 | Polycycloparaffins | 32.9 | 46.6 | 23.5 | 4.3 | - |
| 4 | Aromatics | 17.8 | 1.7 | 1.0 | 1.0 | - |
| 5 | Thiophenes | 1.5 | - | - | - | - |
| | Paraffins and Monocycloparaffins ( S.No. 1 + 2) | 47.7 | 51.6 | 75 | 94.7 | 100 |

Source : Lubrizol Corp. HC – Hydrocracked HI – Hydroisomerization VHVI – Very High Viscosity Index weight range with long, branched alkyl side chains are also very desirable molecules. For a given viscosity, these highly paraffinic molecules have low volatility relative to aromatics.

Normal paraffins have high VI and high resistance to oxidation. However, they are undesirable as base oil components due to their high pour points. For the same reason, some iso-paraffins, naphthenic and aromatic compounds with long paraffinic chains are also undesirable. Naphthenic aromatics are typically susceptible to oxidation. Polycyclic naphthenic aromatics have low VI and poor stability. Organic molecules, which contain heteroatoms such as nitrogen, oxygen or sulphur, have very low VI and often have poor thermal and oxidative stability. The above desired qualities of improved base oils are achieved by Hydro processing, ISO dewaxing & hydro finishing.

Typical hydrocarbon composition of base oils as given in Table 2 which varies in all categories and differentiate them from each other in terms of performance quality.

Rapid growth in automobile & other industrial sectors due to emerging of new technology, need of higher quality motor& industrial lubricants specifications is driving the demand. New formulations will emphasize the characteristics like lighter viscosity grades for increased fuel economy; low volatility for reduced oil consumption; improved oxidation and thermal stability for longer drain intervals; and improved high-temperature, high-shear (HTHS) viscosity characteristics for application to modern engine designs.

OEMs are recommending the usage of these lubricants for better engine efficiencies and presence of large number of luxury vehicles in the market deriving the demand for high performance lubricants.

The chemical composition of base oils and their respective quality features are broadly given in Table 3 which is finally responsible for performance of lubricants.

PAOs have a broader temperature range and are great for use in applications exposed to extreme cold and/or high heat. With their purity and stability they are becoming increasingly more common in lubrication formulations for high quality applications. A general comparison PAO versus Group III mineral oils with respect to their quality features is given in Table - 4.

**Table 4: Comparison of Group III versus PAO**

| | API Group III | PAO |
|---|---|---|
| Hydrocarbon Type | ~100% Saturates | 100% Saturates |
| Paraffins | 35-80% | 100% |
| Cycloparaffins | 20-65% | None |
| Sulfur | 0-300 ppm | None |
| Nitrogen | Small to None | None |

Ester's and PAO's are often used in blending stocks to improve the characteristics of Group I through III base oils. Esters offer advantages to base oil mixes such as improved solvency of additives, improved sludge dispersancy, lower friction coefficient, improved bio-degradability, and improved thermal stability.

The synthetic market faces many challenges due to improving quality of Group III+ base oils. Due to tightening specifications for automotive lubricants and increased performance expectations for industrial oils all-hydro processed Group II and III base oils will increase in their importance for use in lubricant formulations.

Selected top-tier lubricants requiring PAO will continue to coexist with Group III oils as they have edge over the mineral base oils. But widespread availability of modern Group II and III mineral oils is accelerating the rate of change in lubricant markets. New and improved base oils are helping engine and equipment manufacturers economically meet increasing demands for

**Table 3: Chemical composition & Respective Quality Features of Lube Base Oil**

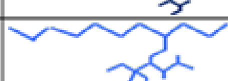
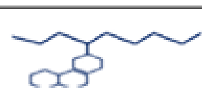
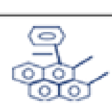
| Chemical Type | Structure | VI | Pour | Oxidation Resistance |
|---|---|---|---|---|
| n-Paraffin (Wax) |  n-paraffin | Very High | Solid @ 50°C | Excellent |
| Iso- Paraffins with Branched Chains |  iso-paraffin | High | Good | Excellent |
| Iso-Paraffins with Highly Branched Chains (PAOs) |  | Good | Good | Excellent |
| Cyclo-Paraffin - Single Ring with Long Chains |  | Good | Good | Good |
| Naphthenes, Polycondensed |  | Poor | Good | Medium |
| Monoaromatics, Long Chains |  | Poor | Good | Medium |
| Polyaromatics |  | Very Poor | Good | Very Poor |

**Fig-7**

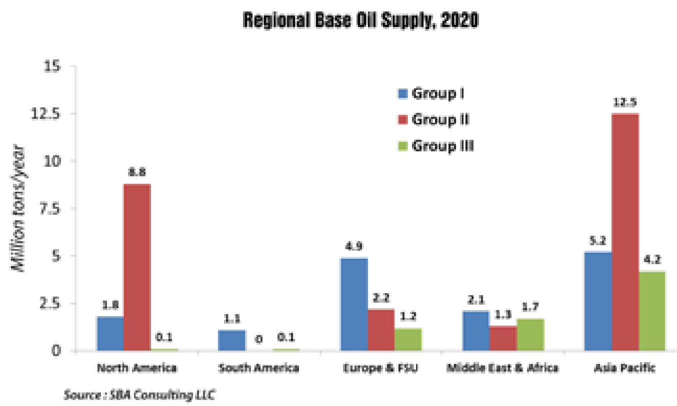



**Fig-8**

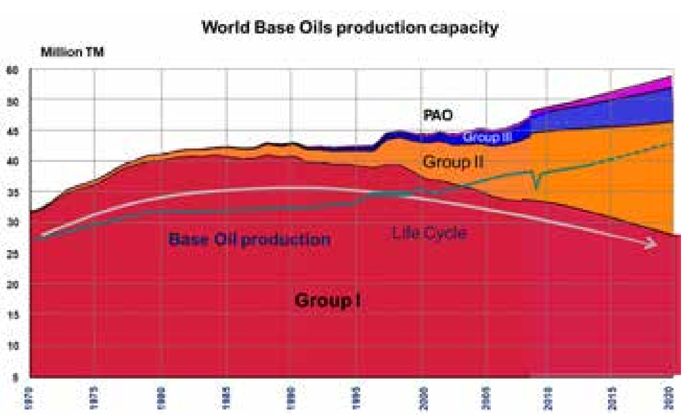
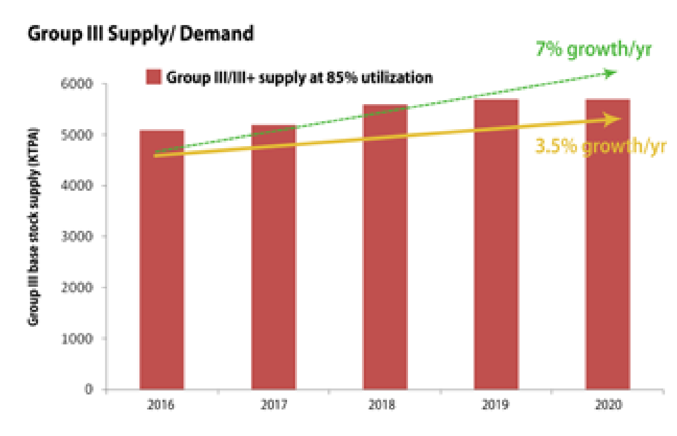



**Fig-9**




better, cleaner lubricants. The current market trend of passenger car motor oil (PCMO) is also shifting from base line Group I base stock to higher category of API base stocks.

As base oil technology continues to evolve and improve, consumers will enjoy even greater protection of automobiles, trucks and expensive machinery such as turbines. Lubrication performance that previously was achieved only in small-volume niche applications, using PAO and other specialty stocks, is now widely available using the new generation of Group II and Group III, III+ oils. Certain applications, such as industrial, heavy-duty diesel and marine lubricants still remain with Group I due to high viscosity and solvency.

## Base Stock Market and Changing Scenario in Indian Context

The global finished lubricants market is moving with slow pace and remains just under 40 million tonnes. In additions, market requirements are continuing to shift toward lower viscosities and higher performance to meet the demands of newer engines. These trends are driving capital investment, which is resulting in a global imbalance in supply and demand for both grades and quality levels. Base stock quality level demand varies significantly by region, and even by country within some regions.

The recent base stock demand trends are expected to continue as lubricants trend to even lower viscosities and improved oxidation stability and deposit control performance. This indicates strongest demand growth in Group III and III+ products.

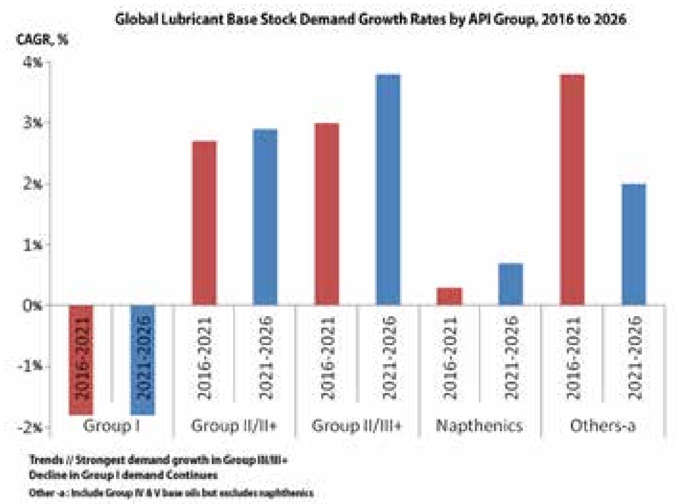
The global base stock market is in a period of relative uncertainty and rapid change. Group I production rationalisations, Group II & III capacity increases, supply and demand imbalances, the introduction of bio-based feed stocks and the explosion in the number of base stocks that may need approvals in lubricant formulations all have a direct impact on lubricant industry.

By 2020, almost one-half of global lubricant demand will come from Asia Pacific. In contrast, Europe, including Russia, will consume only about one-sixth of total production.

The Group III demand continues to increase due to lighter base stocks required for newer engine designs for the key passenger car motor oil (PCMO) sector. This trend began in 2017 and continues to be a global demand driver for the Group III base stocks as OEMs (Original Equipment Manufacturers) continues to push for lighter PCMO oils. The demand of Group III is expected to grow @ 3.5 % growth/year till 2020 and trend is likely to touch 7 % growth/year by 2025-30.

Group I remains a challenge and the proportion of Group I in global base stock consumption has fallen over the period. The trend that is likely to continue and consumption is going to further decline 30-35 % by 2030.The reformulation trends needed to meet tougher crankcase lubricant specifications have pushed Group I base oils out of most of the newer automotive lubricant formulations.

Fig-10




Global base oils demand is expected to show moderate growth to 2026 but efficiency trends are expected to flatten it longer term. Fig:10

On the supply side, global base oils production is gradually shifting to Group II and III, away from Group I base oils. Group II is expected to become the dominant grade, with Group I decline continuing.

## About the Author

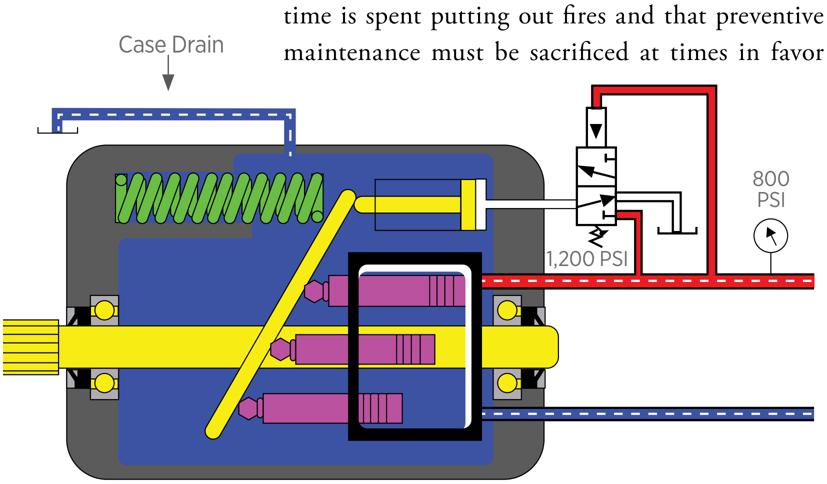
Dr. A S Kathait is General Manager (Lube Quality Control) at Indian Oil Corporation Limited. He has over 28 years of experience in the area of Quality Control of lubes & greases and 6 yrs experience in Crude Oil & Product Evaluation. He holds M.Sc. (Chem), PhD, PGDMM degrees and has published several papers. Contact him at kathaitas@indianoil.in

# Proactive vs. Reactive **Hydraulic Maintenance**

"By checking your systems on a regular basis, you'll often find a failing component before it causes a shutdown of the machine."

There is a lot to be said for reactive maintenance. "If it ain't broke, don't fix it!" is a common refrain across the country. In many of our hydraulic classes, the students tell us that their supervisors will not give them the time for many of the preventive maintenance techniques we teach. Naturally, as hydraulic consultants, we advocate a more proactive routine of maintenance than what we usually find in the facilities we visit.

It's not that we don't understand the demands of real-world industrial settings. We understand them all too well. Our livelihood depends upon it. We know that much of a maintenance professional's time is spent putting out fires and that preventive maintenance must be sacrificed at times in favor of continuing production. But we also know that a machine behaving strangely is a machine that will soon transform from an asset to a liability. The trick is to know when to just leave it alone and when to intervene. There are a few times when not taking action will almost definitely result in machine failure.



The case drain of a variable-displacement pump prevents pressure from building against the shaft seal.

## Moving Too Slowly

When a machine moves more slowly than it used to, it's not just tired. A reduction in speed means a reduction in flow. Either the pump isn't delivering as much flow as it used to or the flow it delivers isn't getting to the actuator. Think about how a hydraulic component fails – it leaks. Either it leaks onto the floor, in which case the problem is obvious, or it leaks internally, a condition called "bypassing." Find the bypassing component and you will find your speed problem. Ignore it and you will find yourself with lost production time.

If it's the pump that is bypassing, it will need to be replaced. But don't replace it right away just to "see if that will fix it." There are some quick ways to check the pump to determine its condition. The easiest way to check an electrically driven fixed-displacement pump is to measure the current draw of the electric drive motor. The following formula can be used to determine the horsepower required to drive a pump: Electric motor horsepower=gallons per minute x pounds per square inch x 0.00067.

This formula provides for 13 percent more horsepower than what is required hydraulically. This is necessary


A suction strainer normally is located below the oil level.

due to the mechanical and heat losses in the pump.

If you have a pump that supplies a volume of 30 gallons per minute (GPM) and the maximum system pressure is 3,000 pounds per square inch (PSI), the electrical horsepower can be calculated as follows:

Electric motor horsepower=30 GPM x 3,000 PSI x 0.00067, or electric motor horsepower=90,000 x 0.00067, or electric motor horsepower=60.3.

You then can check the nameplate data on the electric motor for the full load current for a 60-horsepower motor. The average full load current for a 460-volt motor is 77 amps. Therefore, if the pressure in the system is 3,000 PSI and the amperage is less than 77 amps, the pump is bypassing.

A variable-displacement pump will have a case drain that will keep pressure from building against the shaft seal. Internally bypassed oil returns to the tank through the drain instead of building case pressure. If a variable-displacement pump has excessive case flow, it is worn and must be replaced. Piston pumps normally bypass 1-3 percent of the maximum pump volume, whereas vane pumps can bypass as much as 5 percent. By permanently installing a flow meter in the case drain line, the case flow can be measured regularly. The pump should be changed when the case drain flow reaches 10 percent of the maximum pump volume. A monthly preventive maintenance checklist can tell you at a glance how your pump is doing. How long would it really have taken to make benchmark checks of the current draw and case flow at times when you knew the pump was good?

The pump is not the only thing that can bypass and slow down your machine. Almost all your components can bypass. This includes directional valves, cylinders, hydraulic motors, proportional valves, relief valves and other pressure-control valves. When a component bypasses, there will be a pressure drop. As we teach in our classes, any pressure drop that doesn't result in mechanical work will generate heat. An abnormal temperature gain across any component indicates bypassing, but there's no way to know what is abnormal unless you already knew what was normal. Thus, it behooves you to be familiar with your machines. An infrared temperature gun can be invaluable in learning normal temperature gains and spotting abnormal ones.

An air heat exchanger should be located near a cool air source.

## Making Strange Noises

Unusual sounds coming from a hydraulic machine shout imminent failure. If your car started making a funny noise, you would check it out or have it checked immediately, wouldn't you? So why do you allow your expensive hydraulic machines to cry out for help as long as they are still producing? Production will halt before long if certain sounds are not addressed.

Aeration and cavitation are common indications of machine failure. Many people don't know the difference between the two, and most will just let them continue until the pump fails and has to be replaced. But if these indicators are caught early, pump failure can be avoided.

Cavitation is a steady, high-pitched whining sound. Aeration is much more erratic and is usually accompanied by a sound similar to gravel rattling around inside a pump. Both will destroy the pump if they are not corrected right away.

The most common cause of cavitation is a plugged suction strainer or filter. Suction strainers are usually below the level of the oil, out of sight and out of mind. If cavitation is heard, check the strainer. Low oil temperature is the second most common cause of cavitation. Never start the machine with oil colder than 40 degrees F (5$^{0}$C). Also, never put it under load until the temperature is at least 70 degrees F (21$^{0}$C). Pump output is directly proportional to drive motor speed. If the drive motor is replaced with one that exceeds the pump's specifications, it will cavitate and destroy itself rapidly.

Aeration results from outside air entering the pump suction. A leak in the suction line, a worn shaft seal or misaligned couplings can all cause a pump to aerate. Remember that the pressure in the pump suction is below atmospheric pressure, so oil won't leak out, but air will leak in. A low fluid level can result in air being drawn into the pump along with the oil, so check your fluid levels.

A few years ago, I was called into a plant that had foam oozing out of a breather 30 minutes after start-up. The eventual cause was a bad coupling that wore the pump's shaft seal. Air entered the system through the shaft seal, which eventually returned to the reservoir and purged out through the breather.

## Overheating

Excessive heat is the second most common cause of hydraulic failures, with the first being contaminated oil. As long as the machine is still making money, most people will allow a heat problem to continue. But if left unchecked, an overheating machine will always result in downtime. Mineral oil begins to chemically break down at 140 degrees F. Varnish deposits develop and cause valves to stick. Viscosity drops, and the oil's lubricating properties begin to diminish. Every component in the machine suffers as a result.

I recently was called into a plywood plant for a system that was shutting down due to a high oil temperature. The system used a 60-gallon-per-minute, variable-displacement vane pump to drive a hydraulic motor. The oil that flowed out of the hydraulic motor was ported through a heat exchanger before returning to the tank. The system ran fine as long as the hydraulic motor was rotating, but a shutdown occurred during long idle periods. A flow meter was installed to check the case drain flow. When operating, the pressure to drive the motor was 350 PSI, and the case flow was 3 GPM. When the system was idle, the pressure built to 900 PSI at the pump outlet port. The case flow then increased to 9 GPM. The case drain line was ported directly to the reservoir, preventing any cooling of the oil. The pump was excessively bypassing at 900 PSI, generating excessive heat.

I am always amazed that people often deal with a heat problem by adding a heat exchanger or increasing the size of the one already in place. This doesn't solve the problem but only masks the symptom.

When a machine is overheating, it is working harder than necessary. Money is wasted by allowing the machine to overheat, and then more is wasted to cool it back down. Keep in mind that if the machine was operating fine two weeks ago and now is overheating, the problem is not a design issue. Something is wrong, and it needs to be addressed. Increasing the capacity of the heat exchanger (or laying bags of ice on the machine, soaking it with a fire hose, opening the doors, etc.) is not the answer. Find the source of the excess heat and correct it.

There are hundreds of possible heat sources in most hydraulic machines, but a few are most common. Incorrect pressure settings cause a lot of heat problems. If a pump compensator is set higher than the relief valve, temperatures will soar. In the absence of designer recommendations, I recommend the relief valve be set 250 PSI higher than the compensator. If the relief valve is dumping, it always needs to be investigated. Remember that relief valves in pressure-compensating pump systems only dump when something is wrong.

Pressures generally are set higher than they should be. This can be a problem with servo and proportional valve systems. Servo and proportional valves are notorious heat generators because they are seldom, if ever, all the way open. There is always a pressure drop across them. Whenever a pressure drop occurs and no useful work is done as a result, there will be heat. The higher the pressure in the system, the greater the pressure drop across the valves and the more heat is generated.

Even if all your pressures are set correctly, the machine can overheat if it has a heat exchanger that is not properly cared for. Air heat exchangers, which are similar to a car's radiator, should be located near a cool air source. The fins must also remain clean, i.e., you should always be able to see daylight through them. If the fins become bent, they must be straightened with a metal comb. Sludge in a reservoir will absorb heat and make it difficult for the reservoir to dissipate it. Sludge can also enter the pump's suction line and contaminate the entire system. Drain and clean the reservoir at least once a year or more frequently in dusty environments.

One of the best proactive measures you can take is to develop a preventive maintenance checklist for each of your hydraulic systems. By checking your systems on a regular basis, you'll often find a failing component before it causes a shutdown of the machine. **ML**

## About the Author

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

Alejandro Meza | Noria Corporation



# Selecting Lubricants for **Pharmaceutical Facilities**

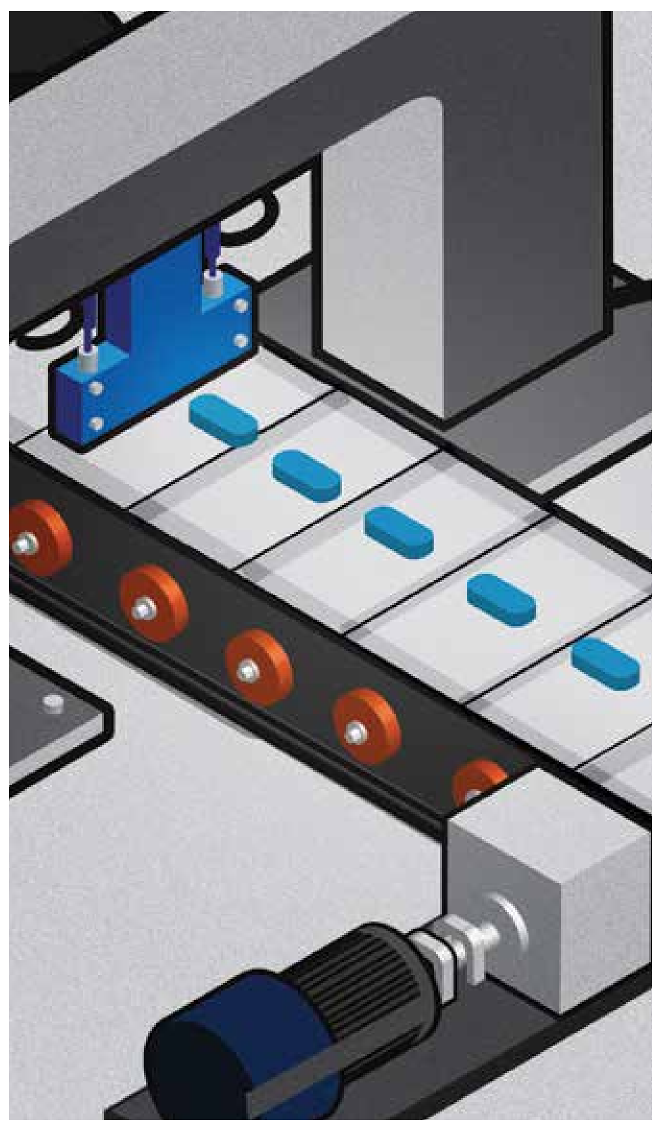
Over the past few years, there has been an increasing interest in the use of food-grade lubricants for machines operating in the pharmaceutical industry. While these lubricants can be beneficial, several other factors must be considered.

Modern machinery used in the production of pharmaceuticals generally requires minimal or even no lubrication, particularly in sections of the production line where the product or its packaging is processed. However, other machines with chains or moving components near the production line may need lubrication, and the lubricant recommended by the equipment manufacturer might not always be classified as H1 food grade or certified according to the ISO 21469 standard. In these cases, it must be determined whether the machinery should be lubricated with conventional lubricants or if there are specific requirements for selecting an appropriate lubricant.

**31%** of lubrication professionals do not know when a food-grade lubricant is required, according to a recent survey at MachineryLubrication.com

## Lubricant Requirements

Lubricant selection should begin by considering the lubrication needs of the component or machine in terms of the load, speed, viscosity and application method. Once these parameters have been



defined, additional requirements must be taken into account, such as food-grade properties. While the use of food-grade lubricants is widely accepted in pharmaceutical facilities, these H1-registered or ISO 21469-certified products are primarily intended for food-processing plants and applications in which there is incidental contact with food.

The U.S. Federal Drug Administration (FDA) provides regulations and good practice recommendations regarding pharmaceutical manufacturing equipment and lubricants within the Code of Federal Regulations (CFR). In 21 CFR 211.65, it states: "Equipment shall be constructed so that surfaces that contact components, in-process materials, or drug products shall not be reactive, additive, or absorptive so as to alter the safety, identity, strength, quality, or purity of the drug product beyond the official or other established requirements."

The document further stipulates: "Any substances required for operation, such as lubricants or coolants, shall not come into contact with components, drug product containers, closures, in-process materials, or drug products so as to alter the safety, identity, strength, quality, or purity of the drug product beyond the official or other established requirements."

From this information, it can be concluded that machine operation should be free of lubricants in sections or components where exposure to a pharmaceutical product or its packaging may occur. Keep in mind this regulation does not specify that lubricants should not be applied in machinery utilized for pharmaceutical production, but rather that lubricants should not come in contact with the drug product. Moreover, while lubrication routes would not be expected in equipment sections that are exposed to the product or its packaging, it is possible to lubricate isolated machine sections.

**IT MUST BE DETERMINED WHETHER THE MACHINERY SHOULD BE LUBRICATED WITH CONVENTIONAL LUBRICANTS** OR IF THERE ARE SPECIFIC REQUIREMENTS FOR SELECTING AN APPROPRIATE LUBRICANT.

The FDA's Good Manufacturing Practice Guidance for Active Pharmaceutical Ingredients offers additional information on lubricants used in the manufacturing process: "Any substances associated with the operation of equipment, such as lubricants, heating fluids or coolants, should not contact intermediates or APIs (Active Pharmaceutical Ingredients) so as to alter the quality of APIs or intermediates beyond the official or other established specifications. Any deviations from this practice should be evaluated to ensure that there are no detrimental effects on the material's fitness for use. Wherever possible, food-grade lubricants and oils should be used."

This last statement allows for the use of food-grade lubricants in exposed areas of the machine. However, this should be addressed and documented properly. The FDA also permits the use of lubricants in a manufacturing facility or in isolated machine sections when there is no risk of contact with the pharmaceutical product or its packaging.

When a lubricant is needed in an area that is exposed to the drug product, the potential impact should be analyzed to ensure it will not be detrimental to the product's intended fitness for use. This requirement is stricter than the criterion for food-processing machines, which allows a maximum lubricant contamination of 10 parts per million.

In general, sealed-for-life or non-lubricated components should be the first choice for machinery components. Food-grade lubricants are a good option for isolated production machine components that need lubrication. Of course, proper cleaning and sanitizing practices will be required after the application of lubricants within the production area.

## Lubrication-related Requirements

In CFR 21.211, the FDA provides guidance regarding lubrication practices and machine maintenance used in the manufacturing, processing

### Helpful Resources

For more information on this subject, visit the following websites:

**NSF International**
www.nsf.org

**U.S. Federal Drug Administration**
www.fda.gov

**U.S. Government Publishing Office**
www.ecfr.gov

and packing of pharmaceuticals. It emphasizes the importance of maintaining clean equipment and establishing written procedures, including lubrication procedures. If a lubricant change or lubrication issue could impact product quality, written records are required to be kept relating to the affected product batch. However, routine maintenance such as lubrication does not have specific record-keeping requirements.

## Lubricant Selection

For effective lubricant selection in pharmaceutical facilities, one of the first steps should be to classify machines by the application. For support services equipment not located in the production area and that have no potential contact with production machinery or the product/packaging, it is possible to use H2 lubricants, which are not intended for food-grade (incidental contact) applications. These types of machines would include pumps, compressors, gearboxes and hydraulic systems involved in the supply of water, compressed gases and energy. Most lubricants (non-H1) in the market fulfill H2 requirements, while only a limited number have a formal H2 registration. If a compressed air line for production machines requires lubrication, an H1 lubricant would be a good choice.

Machines or machine components that are situated in the production area but with a physical barrier blocking exposure to the locations where products and packages are processed have no formal requirements for lubricant selection. However, food-grade lubricants may be preferred to maximize safe maintenance practices related to the production machines.

For components like sliding ways, chains or conveyors that have the potential to contact drug products or packaging, further analysis is recommended to identify the components' true lubrication needs. Determine whether these pieces must be lubricated, and if so, what lubricant type, application method and frequency would be suitable. For instance, a chain can be lubricated with oil, grease or dry spray.

Clean-room applications may demand the sterilization of tools and machine components. If lubrication is needed, it may be necessary to use not only food-grade quality but lubricants previously sterilized through thermal treatment (autoclave) or gamma irradiation. In these cases, lubricant selection should include additional performance requirements such as high oxidation, chemical or radiation resistance. Special storage and handling procedures may also be required.

Whenever possible, switch to sealed-for-life or non-lubricated components to eliminate lubrication tasks as well as potential lubricant contact. Typically, the pharmaceutical industry utilizes relatively smaller machines and components than other sectors. The equipment also tends to operate in controlled environments. These favorable conditions facilitate the conversion to a sealed-for-life or non-lubricated asset. This recommendation is intended for production areas, but it can also be beneficial if implemented across the facility.

In certain circumstances, an ISO 21469-certified lubricant may be preferred over a lubricant registered as H1 food grade. While both classifications involve food-grade lubricants for incidental contact with products, the ISO certification "reviews the level of quality control applied to the formulation, manufacturing, distribution and storage of the lubricant to ensure it complies with the highest standards of hygiene." Both classifications are managed by NSF International.

Finally, be sure to follow the established protocols for change management and keep a record of all lubricant conditions, analysis, decisions and actions taken. For official recommendations and regulation interpretations, contact the appropriate federal organization. The FDA's Division of Drug Information may also offer further assistance.

### About the Author

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

# When to Use **Fire-resistant Hydraulic Fluids**

"The selection of fire-resistant hydraulic fluids has proven to be a critical **decision in minimizing fire risks and avoiding catastrophic equipment failures.**"

Lubricants for industrial equipment are tasked with many different functions, including protecting against corrosion and wear, transferring contaminants to filters or dissipating heat from hot zones. Most lubricants have specific conditions where they may become flammable, such as when flames, sparks or hot surface conditions occur. This is mostly derived from the lubricant's base oil properties. For this reason, these specific lubricant properties and environmental conditions must be understood and controlled. More importantly, the lubricant should be selected appropriately with the necessary properties to mitigate the potential risks. This is where lubricants called fire-resistant fluids are put into service.

## Environments Requiring Fire-resistant Fluids

Fire should always be a consideration when equipment operates with a lubricated component. However, the risk of fire may be highest when the lubricant in use has a poor flash point and the ignition source or hot surfaces are nearby. When lubricants are pressurized, such as in hydraulic lines, there is a risk of small leaks and a fine spray of lubricant being atomized into the air. These leaks can be the result of component failure at points such as joints, worn hoses and seals, particularly if the systems have recently undergone service or have been operating for a long period of time.

When a leak occurs and fluid sprays, the system becomes more susceptible to fire-related risks. If these pressurized systems operate in an area where there are open flames or near equipment running at high temperatures, such as in steel mills, drum dryers or ovens, a perfect storm of conditions exists that could lead to a catastrophic fire.

The initial combustibility can originate from the fluid or the vapors produced by the fluid. In these high-risk environments, lubricating fluids are designed and specified to meet fire-resistant standards. Examples of industries and equipment where these fire-resistant fluids are recommended include die-casting (presses, mobile equipment kilns and die-casting machines); foundries (furnace controls, molding and coring machines); metalworking (furnace controls, rolling mills, welding machines and hydraulic equipment); forging/extrusion operations (presses and mobile equipment); mining (conveyors, car equipment and continuous mining equipment); and power plants (electrohydraulic control systems and steam/gas turbines).

## Types of Hydraulic Fluids

The types of hydraulic fluids are categorized and defined within the ISO 6743-4:2015 standard. Those with fire-resistant properties, commonly called fire-resistant hydraulic fluids (FRHF), are nested within this standard and broken into six categories: HFAE, HFAS, HFB, HFC, HFDR and HFDU. These fire-resistant hydraulic fluids, along with the HFDS and HFDT categories, are shown in the table on the right.

Types of Fire-resistant Hydraulic Fluids

| CATEGORY SYMBOL | GENERAL CHARACTERISTICS |
|---|---|
| HH | Non-inhibited solvent-refined mineral oils (-10°C to 90°C) |
| HL | Refined mineral oil with improved anti-rust and antioxidant properties (-10°C to 90°C) |
| HM | HL type oils with improved anti-wear properties (-20°C to 90°C) |
| HR | HL type oils with improved viscosity/temperature properties (-35°C to 120°C) |
| HV | HM type oils with improved viscosity/temperature properties (-35°C to 120°C) |
| HG | HM type oils with anti-slip, anti-sticking properties |
| HS | Synthetic fluids with non-fire-resistant properties |
| HFAE | Fire-resistant oil-in-water emulsions with a maximum 20% weight of combustible materials |
| HFAS | Fire-resistant solutions of a chemical in water with a minimum of 80% water weight |
| HFB | Fire-resistant emulsions of water in oil |
| HFC | Fire-resistant fluids of water-polymer solutions with a minimum of 35% water weight |
| HFDR | Synthetic fire-resistant fluids that are phosphate-ester based |
| HFDS | Synthetic fire-resistant fluids that are chlorinated and hydrocarbon based |
| HFDT | Synthetic fire-resistant fluids consisting of HFDR and HFDS blends |
| HFDU | Other types of synthetic fire-resistant fluids |

3 Levels of Flammability Requirements for Lubricants According to the FM 6930 Standard

| GROUP | DESCRIPTION | TYPICAL QUALIFYING FLUIDS |
|---|---|---|
| 0 | Non-flammable; 4 kJ/g or less net heat of complete combustion; secondary fire-suppression equipment not required | Phosphate ester |
| 1 | Usually unable to stabilize a spray flame; spray flammability parameter (SFP) of $5 \times 10^4$ or less; secondary fire-suppression equipment not required | Water-glycol, polyolester |
| 2 | Less flammable than mineral oils, but stabilized flame under certain conditions; SFP greater than $5 \times 10^4$, but less than $10 \times 10^4$ | Oil-in-water emulsions |

## Oil-in-Water Emulsions

These emulsions are formulated to sustain small droplets of oil dispersed in water with constituents of 95 percent water and 5 percent oil. With the vast majority of the formulation containing water, there are distinctive tradeoffs in comparison to a typical hydraulic oil. This level of water content may offer excellent fire resistance and heat-transfer capabilities, but this results in poor lubricity properties and loss of natural corrosion protection. Oil-in-water emulsions tend to rely on additives to provide a more appropriate level of corrosion protection. Due to their low viscosity and limited wear protection capabilities, they tend to be used only in special applications that have low lubricity requirements.

## Water-in-Oil Emulsions

These are called inverse emulsions where the oil is in the majority. Small water droplets are dispersed in oil with constituents of 40 percent water and 60 percent oil. This formulation provides a more balanced package with good fire resistance and excellent heat-transfer capabilities. Although these emulsions have better lubricity and corrosion protection than oil-in-water emulsions, additives are still needed to meet the minimum lubrication requirements for most applications. Water-in-oil emulsions have a milky appearance and are commonly manufactured with viscosities between 100-120 centistokes and a specific gravity of 0.92. Like other water-based, fire-resistant hydraulic fluids, the fire resistance is primarily accomplished by the water in the formulation. When exposed to high temperatures, the water turns into steam, which reduces the oil's combustibility. These emulsions also maintain water droplets at a small enough size so that filtration is still an option.

## Water-glycol Solutions

Often called water-polymer solutions, these are formulated with 60 percent glycol and 35 percent water. The glycol-based lubricants in these solutions offer some benefits, such as a lower freeze point, while the fire resistance and heat-transfer capabilities are provided by the water. They also require additives to supply sufficient lubricity and protection from corrosion and wear. Glycol can impart a higher natural detergency and viscosity index than most other base oils. However, there is a risk of incompatibilities to other fluids, paints and coatings, as well as a tendency of shear thinning when viscosity-index improvers are used.

## Phosphate Esters

Synthetic phosphate-ester base oils are some of the most fire-resistant lubricant formulations. They gain inherent fire resistance from the properties of their molecular structure. Phosphate esters are noncorrosive, have excellent oxidative stability and anti-wear characteristics, and provide operability up to 150 degrees C. They also have good lubricity, particularly in boundary conditions, and are often produced with viscosities of 22 to 100 ISO VG. Their specific gravity is higher than water. However, phosphate esters have a very low viscosity index (less than 60) and are susceptible to hydrolysis. They are frequently used for aluminum die-casting machines, melting furnaces and steel mill applications.

## Other Synthetic-based Fire-Resistant Hydraulic Fluids

Other synthetics, such as polyolester and polyether glycols, have varying capabilities as fire-resistant hydraulic fluids. For the purposes of fire resistance, these may not be as common as other mainstream fluids, although they may offer unique advantages, such as a higher viscosity index and excellent lubricity. Some alternative options are formulated with natural esters for enhanced biodegradability, low toxicity properties and a higher flash point than other non-aqueous fire-resistant fluids. Specialty fluids like these are often delivered with a high cleanliness level, which is important when trying to meet standard cleanliness targets for servo-controlled hydraulic systems.

## Flammability

Factory Mutual (FM) provides approvals and certifications for various fire-protection equipment. Industrial fluids are tested using the FM 6930 standard to classify their flammability characteristics. These evaluations can clarify the limitations of certain hydraulic fluids employed in applications where fire-resistant properties are required. The FM 6930 standard approves lubricants that meet one of the three levels of rating requirements, identified as group 0, 1 or 2 (shown on page 39). Keep in mind this standard is limited to flammability and does not include any other considerations of the fluid or lubricant. These flammability characteristics are tested using the following performance criteria: determination of the chemical heat-release rate of a highly atomized spray of the fluid, measurement of the critical heat flux for ignition of the fluid, and calculation of the fluid's spray flammability parameter (SFP). Emulsion-based fluids must also meet the requirements of the separation resistance evaluation.

## Maintenance of Water-based Fire-Resistant Hydraulic Fluids

Any formulation with higher amounts of water will be more prone to bacteria and other microbial growth. Biocide treatments should be carefully balanced in these systems, especially for oil-in-water emulsions with 95 percent water. In emulsions, the ratio between water and the base oil should be monitored to preserve effective fire resistance. Maintaining a suitable water level will require periodic testing. When restoring the desired amounts of water, always consult the lubricant manufacturer's specifications and any corporate standards that govern fire-protection protocols. Water-based fire-resistant hydraulic fluids should also be periodically checked for their pH levels, corrosiveness, wear protection, controlled storage conditions and shelf life.

## Contamination Control

As with most lubricants in industrial applications, fire-resistant hydraulic fluids should be kept clean, cool and dry. The oxidative and thermal stability will vary greatly among the different types of fluids. Care should be taken to keep oil within the acceptable temperature ranges. Oil analysis is often necessary to check for abnormal levels of contamination, undesirable water concentrations, acid number fluctuations, wear debris, or other changes in the physical or chemical properties of the base oil and additives.

Environmental factors should also be considered when managing the reservoir and other ingression points. Contaminants can easily enter the system when fluid is drawn from the reservoir during operation. These contaminants not only can impair the equipment's functionality but can even alter some fire-resistant properties. Breathers with desiccants and particle filters should be sized appropriately to protect the oil from these airborne contaminants. Don't forget to seal off the headspace entry points. Otherwise, air will simply flow along the path of least resistance, which may not be through the breather element.

Filtration is crucial for maintaining the longevity of most hydraulic systems, particularly valves, actuator seals and pumps. Fire-resistant hydraulic fluids can be managed in much the same way, even those that are water-based. First, meet the minimum filtration requirements and limitations defined by the manufacturer of both the equipment and the hydraulic fluid. Then, make any appropriate adjustments to these recommendations to satisfy the cleanliness targets established by your reliability program.

## Considerations During Changeovers

A lubricant changeover in any application should not be completed without careful consideration of the degree of cross-compatibility and amount of residual fluid in the system. Upgrading to a system with a fire-resistant fluid or changing to a different type of base oil will require additional attention. Always drain the fluid while the system is still warm and make every effort to purge all fluid from any low pockets, nooks and crannies. Replace all filters and any other components that have saturated amounts of residual fluid. When changing to a different fluid, always consider the compatibility of the seal materials, paints and other coatings, especially for synthetic-based fluids. It's generally advisable to circulate an appropriate flushing fluid under minimal to no load to pull as much remaining oil from the previous fill. Afterward, fill the system to the correct fluid level with the specified fire-resistant fluid.

The ISO 7745 standard provides general flushing and changeover procedures as well as specific change considerations for viscosity, lubrication, density and compatibility concerns for every base oil combination of fire-resistant hydraulic fluid. Also, always check with the fluid manufacturers for compatibility information.

## Benefits and Disadvantages

Hydraulic fluid requires a unique lubricating ability that can work under pressure and mitigate an array of risks, including fire. These risks and the mode in which the fluid operates at higher pressures can make it easy to justify the use of a fire-resistant fluid. The base oil will be crucial, whether it is a synthetic such as a phosphate ester, which naturally resists combustion, or a water-based fluid, which relies on water vaporization to create steam and smother any imminent fire potential.

Nevertheless, it remains the responsibility of the individual selecting the fluid for the application to carefully consider all the necessary factors. These most certainly will include viscosity, viscosity index, oxidation stability, thermal stability, and anti-wear and anti-corrosion protection. Hydraulic systems that operate with fire-resistant fluids will often need a few modifications, such as shortening or enlarging inlet lines to avoid cavitation or employing certain types of filters for water-based fluids. In any case, the selection of fire-resistant hydraulic fluids has proven to be a critical decision in minimizing fire risks and avoiding catastrophic equipment failures. ***ML***

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# Using Social Media to **Build a Community of Certified Professionals**

> "True virtual community and camaraderie is organic; it can only be crowd-sourced."

Given that the mission of the International Council for Machinery Lubrication (ICML) is to help lubrication practitioners succeed and advance in their professional careers, it makes sense that the organization recently stepped up its activity on social media, particularly on Twitter and LinkedIn. This activity reflects only a small part of the organization's strategic efforts to be more relevant to more people more often than before.

A few months ago, the organization commissioned its first brand/market research. The findings from this study are helping to guide ICML's long-term decisions regarding the most effective ways to serve and support its growing worldwide network of practitioners, trainers, volunteers, partners and members in the years ahead.

ICML has other tactics in the works, too. For instance, the organization's email communications have become more frequent, and a new website was recently launched. For those who have not yet visited the updated site, it now features expanded member benefits, success stories, member recognition and a community discussion forum.

## Community and Camaraderie

Studies have shown that employees often enjoy their jobs for reasons unrelated to compensation. While income is certainly important, it is not necessarily the primary driver that makes team members want to fulfill their duties day after day. For instance, a 2017 study of 615,000 Glassdoor users found that organizational culture and values are the largest predictors of employee satisfaction, while compensation was among the least influential, across all income levels.

This should not be surprising. Many lubrication and oil analysis practitioners probably spend at least as much (if not more) time engaging with their colleagues as they do with their own families. Therefore, job-related relationships are going to impact employee satisfaction one way or another.

"Camaraderie is more than just having fun, though," observed Christine Riordan, president of Adelphi University. "It is also about creating a common sense of purpose and the mentality that we are in it together," which fosters a very real esprit de corps of mutual respect and sense of identity.

But what if you are the only ICML-certified player trying to optimize your plant's lubrication program? How can you develop helpful relationships with a community of like-minded professionals when you are the only one onsite? Beyond spending time with fellow teammates in the physical plant, employees can also find this esprit de corps through professional associations, volunteer activities, and even in virtual communities where they can regularly exchange ideas, establish long-distance


friendships, showcase their expertise and conduct networking. For the lubrication practitioner who needs a job to be more than just a paycheck or who seeks a broader network of associates than is available in his or her immediate workplace, participating in such opportunities can bring a greater level of personal satisfaction. And satisfaction is important, because happy employees are the best employees to have on your lubrication crew. They are inherently productive and confident, motivated to do their best, and more likely to stay with your organization.

## ICML's Role

In as much as ICML exists to help practitioners, it seems fitting that the organization provides opportunities for certified practitioners to be a part of something bigger than themselves, to see and be seen, to visit and build a community. Because its certified practitioners are spread across the globe, ICML's online presence is as good a place as any to get started with virtual camaraderie.

This brings us back to the subject of online discussions for lubrication and oil analysis professionals. Even while developing new website content these past few months, ICML has depended on its Twitter and LinkedIn group channels to serve as community forums of sorts, with the idea that such forums can help foster camaraderie. These venues make it easy for members and partners — in fact, all friends of ICML — to share articles, ideas, links, questions and answers about anything related to lubrication or oil analysis. These channels are also suitable for broader social support, which Riordan notes can include such matters as "rooting for each other on promotions, consoling each other about mistakes (and) giving advice."

ICML does what it can to seed these venues with starter topics and links to relevant articles, but the real community only grows out of personal engagement from certified practitioners and group members. True virtual community and camaraderie is organic; it can only be crowdsourced.

What types of starter topics does ICML find and post? Almost anything that deals generally with vendor-neutral stories that are relevant to its mission, market and members. Additionally, as the organization adds website content, it will also steer followers to ICML-sponsored success stories, case studies and blog posts. In the meantime, it scours the internet to prompt community engagement with a grab bag of Twitter topics and retweets about manufacturing news, people power, lubrication incidents, ICML exams, opinion articles and more. Of course, it's not necessarily easy to grow camaraderie through a virtual community, so these Twitter and LinkedIn channels are just a start.

Years from now when you are retired from industry, what do you think you will miss more: lubrication tasks or the camaraderie of your colleagues and friends? As mentioned previously, ICML is pursuing a number of community opportunities as part of a larger strategy so that 2019 will be a more fruitful and memorable year filled with comradeship for all certified members.

*ML*

# How Controlling Three **Contaminants Significantly Reduces Machine Failures**

"By clearly understanding these issues and the requirements for improving each failure mode, you can help to minimize the repeat offenders."

One major struggle maintenance groups seem to be dealing with today is a growing preventive maintenance (PM) backlog. Over time, some PMs fail to be closed, and work begins to pile up, resulting in large amounts of non-critical work being put on the back burner. Although the task of minimizing or eliminating backlogs can seem daunting at times, there are ways to address this problem while still taking a proactive mindset toward your equipment.

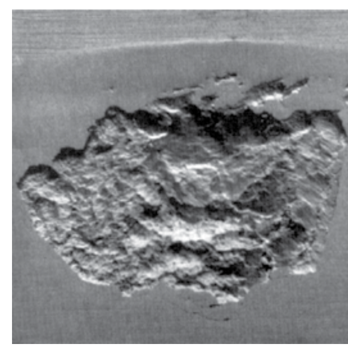
In most plants, many failure-related issues tend to be repeat events. Identifying, addressing and resolving these known and recurring failures or defects in the field will lead to reduced maintenance costs and minimal equipment downtime. This strategy is known as defect elimination.

In the defect elimination process, counteractive measures are developed to minimize failures that are similar in nature. This method often takes place directly after installation of the equipment, but it also offers value at locations where the equipment has been functioning for years. While this practice is typically thought of as only replacing actual components, all aspects of the asset should be considered, including lubrication.

Lubrication defect failures can be broken down into three primary modes: particle contamination, temperature and moisture. By clearly understanding these issues and the requirements for improving each failure mode, you can help to minimize the repeat offenders.

## Particle Contamination

In regard to lubrication, particle contamination can be described as any dirt (silica), metal, soot or soft insoluble material that is not designed to be present but which gains access to the lubrication system. It has the potential to damage the lubricant and the component's lubricating surfaces. As particle contaminants find



their way into a lubricant, they begin to cause different types of wear and drastically affect the additive depletion rate. Wear can occur on the lubricating surface through mechanical wear, chemical wear or surface fatigue. Mechanical wear happens through a variety of different mechanisms. Adhesive mechanical wear, also known as galling, scuffing or seizing, takes place in heavily loaded, sliding-contact locations where poor lubrication is evident. It is most common to see this type of wear with cylinders, gear contacts, rolling-element bearings and cam followers.

Three-body abrasive mechanical wear occurs when a particle becomes lodged between two lubricating surfaces, leading to cutting, gouging and plowing of the component's surface. This type of wear is most apparent with rolling-element bearings, journal bearings, gears and cylinders.

Erosion wear is another concern with particle ingression. It happens when material loss occurs, and solid particles rapidly strike the component surfaces. Erosion wear mainly becomes an issue in hydraulic systems.

Chemical wear or etching is the result of a reactive environment taking place at the surface level. It is caused by combustion byproducts, hydrogen sulfide, bacteria, salts and other factors. This type of wear can appear on many different components and applications, depending on the environmental surroundings.

Surface fatigue also acts as a supplier to particle contamination. This undesired evolution is the result of repeated loading over time, which leads to pitting and flaking of the component surface. Surface or contact fatigue is most prevalent on the mesh point of gear teeth as well as other rolling friction surfaces.

In addition, particle contamination can affect the rate of additive depletion. Additives become a limited resource for protection, as they are designed to be sacrificial in nature while adhering to surfaces or contaminant particles. As the additive count begins to diminish, fewer particles can be eliminated, and component surfaces are inadequately shielded. Contamination then becomes a greater threat.

## Particle Contamination Elimination Strategies

Among the strategies for eliminating or minimizing particle contamination, hardware modifications and component modifications are two available options. Modifying lubrication hardware can have an immediate impact on particle contamination and often comes in the form of breathers and filters. When selecting a filter, several factors should be taken into account, such as the location, configuration, operating pressure, beta ratio, micron size and flow rate. Breathers present another form of protection if properly outfitted. When choosing a breather, consider the pressure in the housing or reservoir, fill port clearance and exposure to the environment.

Component modifications can also minimize particle contamination. Several elements should be evaluated, including the reservoir access points, system pressure and bearing type. While reservoirs are ideal for visually inspecting the lubricant on a large scale, seals and hatches are often left open, allowing external particles to gain access to the system. Ensuring that hatches are properly sealed and modifying existing access points that have a poor design configuration can dramatically reduce particle ingression.

It also is important to assess the system pressure, as positive pressure on a tank or reservoir can serve as a deterrent against airborne particles. Another option would be the addition of magnetic or electrostatic separators to remove ferrous and opposite-charged particles.

One final consideration is the bearing and motor selection. Utilizing sealed or shielded bearings and enclosed motors can help to minimize particle contamination in certain applications.

## Temperature

Dispersing heat is a primary function of a lubricant. Therefore, temperature plays a critical role in a lubricant's physical characteristics. Lubricants that must cope with substantial temperature fluctuations over time tend to have a reduced life cycle. When lubricants function at the edge of their operating temperature range, several issues may arise. The most prominent complications are thermal degradation, oxidation, varnish and film strength deprivation. On the high end of the temperature spectrum, viscosity will be affected with a thinning of the base oil. This can also lead to acidic accumulation, sludge and varnish through weak oxidation stability. These issues can result in flow restriction or starvation along with restricted component movement. Lower temperatures impact viscosity as well, negatively altering the flow rate properties of certain lubricants.

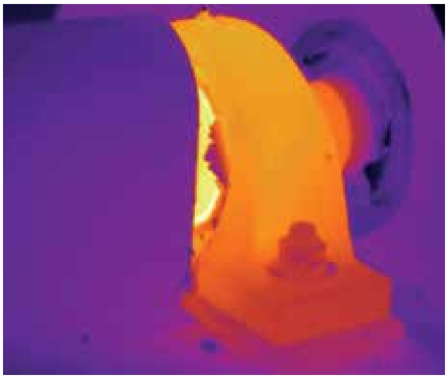
## Temperature Moderation Strategies

To limit temperature-related issues in a lubrication system, it is best to evaluate your lubricant options and component modifications. Re-examine the current oil or grease in systems that have concerns of recurring failures. Ensure the viscosity of the oil or consistency of the grease is appropriate for the system. The correct oil level or lubricant amount is key as well. Reservoirs with oil level indicators that are out of range or bearings with too little or too much grease often operate with temperature anomalies. This information can be checked through sight glasses and level gauges for oil or ultrasound technology for grease applications. Using a synthetic lubricant is another option. Synthetics commonly offer higher viscosity indexes for dealing with a wider temperature range.

Also, be sure the correct type of bearing is utilized for the particular application.

**33%**

of lubrication professionals say premature lubricant failure is a problem at their plant, based on a recent poll at MachineryLubrication.com



While there is some overlap between oil-filled vs. grease-filled bearings, it is important the correct decision has been made. When evaluating between the two, consider speed, location, environment, contamination level and local temperature.

## Moisture

Most sampled lubricants have some amount of moisture. If moisture is allowed to increase, it can lead to failure. Moisture accumulates in a lubricant through several mechanisms, such as handling, storage and general use in the system. It is worth noting that moisture appears in three distinct forms: free, dissolved and emulsified.

The most common problems related to moisture are additive depletion, hydrolysis, cavitation wear and water-washing. Additive depletion occurs due to excess water contamination soaking up polar additives. The process of hydrolysis arises through the breakdown of base oils and some associated additives, thus accelerating the oxidation process. Cavitation wear is activated through pressure increases in the lubricant when moisture is present. As cavitation takes place, it can cause damage to exposed surfaces. Water-washing presents failure concerns in both grease and oil. Grease water-washing tends to happen through direct contact of water spray with a bearing. In oils, moisture ingression through water-washing typically occurs through the seals.

## Moisture Elimination Strategies

Hardware modifications, lubricant changeouts and component alterations can all be employed to eliminate moisture. Just like with particle contamination, the installation of suitable breathers and filters can also help to address moisture contamination. Again, it is important to understand the parameters of your equipment when selecting filters and breathers.

Bottom sediment and water (BS&W) bowls are another good option for identifying and removing moisture. One thing to consider with BS&W bowls is that you are not preventing moisture from entering the system but simply addressing it once it is already present. Vacuum dehydrators and

dialysis equipment are other alternatives that can aid in the elimination of moisture currently in the system.

A lubricant-related strategy would include using a lubricant with high demulsibility properties. This exploits the oil's ability to separate from water, thus making it easier to remove moisture from the system.

Reservoir containment, headspace flow, sealed bearings and enclosed motor applications are among the various component strategies. Creating headspace flow will minimize humidity, draw moisture from the lubricant and aid in the prevention of condensation in the reservoir.

## The Road Ahead

As you begin to understand the different lubrication failure modes, including why they occur, how they affect lubricants and how you can mitigate or eliminate them, a culture change should begin to take place with new installations and equipment overhauls. Although this is not a quick process, like most successful initiatives, it should pay off over time. Eventually, maintenance personnel should see their repetitive task load begin to shrink, and those lingering PM backlogs will be reduced. ***ML***

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### About the Author


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


## Wear Gloves When Packing Roller Bearings

When hand-packing roller bearings, wear disposable food-grade gloves. This has a two-fold effect. First, it helps keep your hands free from grease, but it also helps keep the bearing free from contaminants. Particles and chemicals on hands can lead to premature bearing failure. Consider placing freshly packed bearings back into their original wrapping to prevent contamination with outside particles.

## Don't Rely on Color Alone

Color-coding can be an effective way of setting up a lubricant management program, but don't use color as the only designation for which lubricant goes into what equipment. A significant portion of the population has partial or total color blindness. In labeling lubricants, colors should be supplemented with either shapes or text.

## Avoid Recurring Water Contamination Problems

Large hydraulic reservoirs operating outdoors often develop a problem with recurring water contamination. The problem often is related to the humidity in the air. When hydraulic systems operate, the oil heats up and expands. If the system is shut down at night, the oil will contract and fresh humid air from the outdoors will enter the reservoir through the breather. By morning, when the outside air temperature has cooled significantly, the humidity introduced into the reservoir usually has condensed into water droplets in the oil. To correct and avoid this, use water-removal filtration offline to remove any free and dissolved water and add a desiccant type breather to filter moisture out of any air entering the reservoir.

## Don't Overlook Barrier Fluids

One often overlooked lubricant is the barrier fluid used in double mechanical seals. Although it may be topped off when the level in the seal pot is low, how much thought goes into maintaining the high-quality lubricant needed for extended mechanical seal life?

Seal faces are lapped to within two helium light bands of flatness and are every bit as precise of equipment as rolling-element bearings. These lubricants are generally added to a seal pot and are expected to perform for the life of the seal. Conditions to consider include temperature, oxidation, coking of the lubricant, cleanliness, PM needs, scheduled changeout or sampling/testing, and possible justification for synthetics. ***ML***

## Did You Know?

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

## Have Some Tips?

If you have a tip to share, email it to admin@machinerylubricationindia.com

# "What is an acceptable tolerance level for the viscosity **index of compressor oil (32 viscosity synthetic oil) for a screw compressor?"**

When it comes to issues of viscosity and viscosity index, there are several questions that must be answered in order to properly set limits and alarms for oil analysis and oil change-out parameters. One of the first things to determine is the proper viscosity to be used in the compressor. This usually requires some research in maintenance manuals as well as understanding which components are being lubricated by the oil.

Within a compressor, there may be gearing, bearings, slides, seals and countless other components that will stress thelubricant in different ways and require a different viscosity.

For simplicity, let's assume that all internal parts need a viscosity of 5.5 centistokes and that the working temperature is 100 degrees C. If you are using ISO 32 oil with a viscosity index of 108, you will hit that viscosity at 100 degrees C. If the temperature increases, the oil will thin and you won't have the same lubricating film needed to fully separate the machine surfaces. If a synthetic base oil or a different base oil with a higher viscosity index is used, the viscosity will be higher at the operating temperatures, providing a safeguard in case something were to happen in terms of higher operating temperatures or contaminants lowering the oil's viscosity. Reducing the operating temperatures with coolers or other means, or raising the ISO grade can also help you achieve a measure of safety.

If the viscosity index were to drop below 108 in this example, you would expect to see advancing signs of wear inside the machine. Therefore, you need to know the minimum operating viscosity to set an alarm and limit on that value.

Most oil labs test industrial fluids at 40 and 100 degrees C. By using these two parameters, you can calculate the viscosity index and extrapolate the viscosity at whatever in-service temperature the compressor is operating.

You should take the approach of setting both upper and lower limits on viscosity, cautionary limits at plus or minus 5 percent, and critical limits at plus or minus 10 percent. Viscosity index could be included as well, as there are many reasons viscosity index could change throughout the life of the oil.

Perhaps the most common way viscosity index changes are byshearing down of the viscosity index improver additive. Over time this additive is cut into smaller pieces and loses its impact in the oil. You then see a drop off in the hightemperature viscosity. This generally is measured or monitored by reading the viscosity at two temperatures.

While there isn't a set level for viscosity index across the board, you can determine the required viscosity index for your machine and then set limits based on how much the viscosity will drop at a given operating temperature. Remember, with viscosity, in most cases it is better to err on the side of caution and have too much rather than not enough.

# TEST YOUR KNOWLEDGE

This month, *Machinery Lubrication* continues its "Test Your Knowledge" section in which we focus on a group of questions from Noria's Practice Exam for Level I Machine Lubrication Technician and Machine Lubricant Analyst. The answers are located at the bottom of this page. The complete 126-question practice test with expanded answers is available at store.noria.com.

## 1. Viscosity-index improver additives:

A) Lower the viscosity of the oil
B) Are large molecular structures that can shear down and become less effective
C) Help prevent oxidation which leads to viscosity changes
D) Lower the viscosity index of the oil
E) Are not really additives at all

## 2. Which of the following describes microscopic water droplets dispersed in stable suspension in oil?

A) Dissolved water
B) Evaporative solution
C) Emulsified water
D) Free water
E) None of the above

## 3. Inspection of used filter elements:

A) Is useless
B) Should only be done by highly trained lab technicians
C) Can provide useful information about wear debris
D) Costs too much money
E) Is difficult because it requires complex instruments

## ANSWERS

**1. B**
Viscosity-index improvers are large molecular structures (long-chain polymers) added to the base oil to increase the viscosity index of multi-season (multi-grade) oils. These long-chain molecules can shear down under high shear force and become less effective. As a result, multi-grade oils should be selected carefully for the application.

**2. C**
Emulsified water represents water globules in stable suspension in oil. This generally is because of the strong bonding between oil and water molecules. Depending on the oil type and condition, some or all of the water in excess of the oil's saturation point forms a stable emulsion that will not separate by gravity even at high temperatures.

**3. C**
Inspecting used filter elements is valuable, especially in identifying wear metal type, shape, concentration, etc. Although used oil filters are often overlooked, testing them can help you avoid potential problems.

# CASTROL INDIA BRINGS TRUCK AASANA TO NAVI MUMBAI

Castrol India in association with The Yoga Institute, recently conducted a training programme of Truck Aasanas for the truck driver community in Navi Mumbai. This programme focuses on the health of truck drivers by encouraging them to use simple yoga postures during their trips to stay fit and healthy. This initiative, as part of the Transform Truckers Abhiyaan, a Zee Media initiative and sponsored by Castrol, will be further conducted across 10 cities in the country to further spread the message of health and wellbeing amongst truck drivers.

A study by Castrol India brought to light the stressful lifestyle of long distance commercial drivers. It found that over 50% of Indian truckers face driving related health issues such as lack of sleep, back and joint pain, neck pain, etc.

Commenting on the activity, Mr. Kedar Apte, Vice President – Marketing, Castrol India, said, "The trucking industry is a significant contributor to our nation's economic growth and prosperity, and truck drivers are a vital force in moving the nation forward."

# QUAKER CHEMICAL OPENS NEW PLANT IN DAHEJ, INDIA


Quaker Chemical Corporation recently held the grand opening of its state-of-the-art manufacturing facility in Dahej, India. The site will be used to produce rolling oils and metalworking fluids for the steel and metalworking market in India, the Middle-East, and east Africa.

"We are very proud of this achievement – the opening of a special facility in a special place. This major milestone is happening as Quaker celebrates more than 20 years in India" said Gulshan Kumar Sachdev, Managing Director, Quaker Chemical India.

The newly built plant incorporated unique features in its design, such as high efficiency induction motors to reduce energy, a water condensation recovery system, and waste water treatment technology that supports Quaker's environmental goals.

"Quaker is truly proud to add this new production capability for the benefit of our regional customers. In particular, this site strengthens Quaker's supply chain in western India, the Middle East, and eastern Africa," said Wilbert Platzer, Vice President Global Operations, EH&S and Procurement.

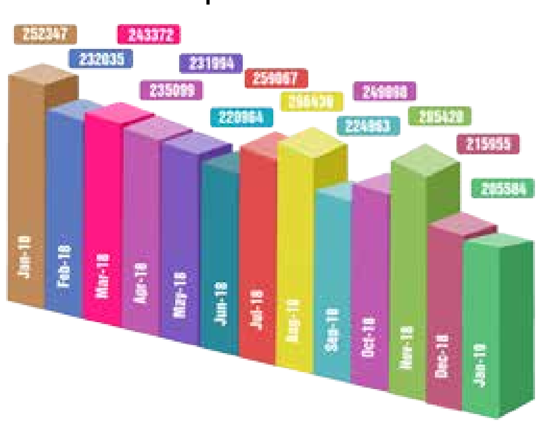
# BASE OIL REPORT

India's crude oil imports from Iran, which have been on a decline since November last year on the back of fresh US sanctions, suffered a 6.5 per cent fall to 1.56 Million Tonne (MT) in January as against 1.6 MT reported in the same month last year. Overall, oil imports from Iran between April-January 2018-2019 rose 16.3 per cent to 21.32 MT, according to data sourced from the Directorate General of Commercial Intelligence and Statistics (DGCIS), an arm of the commerce ministry. India and Iran had on in November last year signed a bilateral agreement to settle oil trades through the state-owned UCO Bank in the Indian currency, which is not freely traded on international markets. Crude imports from Saudi Arabia – the de-facto leader of the Organization of Petroleum Exporting Countries (OPEC) and the second largest crude oil supplier to India -- have been on a steady increase this fiscal year. Oil imports from that nation rose 12 per cent to 4.5 MT in January this year. Overall, oil imports from the Saudi nation have risen 13 per cent to 34 MT in the current fiscal so far.

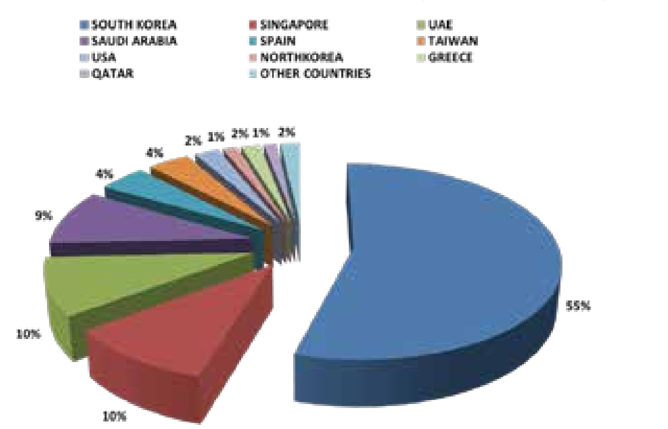
While in the month of January 2019, India imported 205584 MT of Base Oil, India imported the huge quantum in small shipments on different ports like 114572 MT (56%) into Mumbai, 28028 MT (14%) into JNPT, 26513 MT (13%) into Chennai, 13790 MT (7%) into Pipavav, 5971 MT (3%) into Hazira, 4940 MT (2%) into Kolkata, 4871 MT (2%) into Mundra, 4465 MT (2%) into Ennore, 2306 MT (1%) into Kandla and 129 MT into Other Ports.

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

**Month wise input of Base Oil in India**




**Origin wise Base Oil input to India, Country and %- January 2019**




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

| Month | Group I - SN 500 Iran Origin Base Oil CFR India Prices | Group II - N-150 Singapore Origin Base Oil CFR India Prices | N- 70 South Korea Origin Base Oil CFR India Prices | Naphthenic HYGOLD L 2000 US Origin Base Oil CFR India Prices |
|---|---|---|---|---|
| January 2019 | USD 655 – 665 PMT | USD 740 – 750 PMT | USD 680 - 690 PMT | USD 740 – 750 PMT |
| February 2019 | USD 665 – 675 PMT | USD 695 – 705 PMT | USD 665 - 675 PMT | USD 725 - 735 PMT |
| March 2019 | USD 655 – 665 PMT | USD 685 - 695 PMT | USD 655 - 665 PMT | USD 715 - 725 PMT |
| | Since January 2019, prices have remained steady in March 2019. | Since January 2019, prices have fall down by USD 55 PMT (7%) in March 2019. | Since January 2019, prices have reduced by USD 25 PMT (4%) in March 2019. | Since January 2019, prices have reduced by USD 25 PMT (3%) in March 2019. |

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