JG Lubricant Services, LLC
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Sales: 877-971-7799 (Ext. 1)
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www.jglubricantservices.com

TECHNICAL INFORMATION SHEET

Assessing Oil Life and Part Wear Through Oil Analysis

Thank you for considering JG Lubricant Services for your oil analysis supplier.

The enclosed technical information is intended for fleet managers, maintenance chiefs and equipment engineers and covers:

- Factors affecting useful oil life
- Oil properties
- How oil properties change with use
- Assessing oil life and part wear through oil analysis

<u>Factors Affecting Useful Oil Life</u> - In any given lubricant *(such as engine oil, transmission fluid or gear oil),* there are three main factors that influence the "useful life" of the lubricant: Viscosity Stability, Oxidation, and Contamination.

While it is important to understand how these factors affect oil life, it is equally important to realize that none of these factors can be measured or monitored except through a thorough and ongoing oil analysis program.

Viscosity

Viscosity is defined as resistance of an oil to flow at a given temperature. Viscosity is typically measured and reported at two temperature set points: 40C (104F) and 100C (212F).
In order to maintain sufficient viscosity to support heavy loads in gears and bearings, the thickness of the oil film must be greater than the combined surface finish on the bearing balls *(or rollers)* and the bearing race. Likewise, the oil film thickness in a gear mesh must be greater than the combined surface finish of the gears in mesh. Under the right conditions *(speed, load, and temperature)* these surfaces never come into contact due to the separating oil film. The ratio between the oil film thickness and the combined surface finishes of the parts is known as "Lambda Factor". Lambda Factor should always be greater than 1.0 in order to minimize wear and maximize part life. Oil film thickness is determined by oil viscosity, oil temperature, applied load and surface speeds. Where speed is insufficient to build an adequate oil film *(Lambda Factor less than 1.0)*, the contacting parts are said to be operating under "boundary lubrication". Anti-wear agents and/or Extreme Pressure *(EP)* additives are included in oil formulations to protect against wear caused by boundary lubrication. These anti-wear agents and EP additives are complex polymers that are designed to decompose, at a predetermined temperature, and form a surface film on the highly stressed parts. These protective films are "sacrificial" as they are consumed over time. This protective film then carries the load without harming the metal parts.

Selecting the correct viscosity for the operating conditions *(speed, load, and temperature)* ensures that gears and bearings remain durable, with very little pitting or other damage, over long periods of time.

In most "multi-grade" lubricants *(engine oils, transmission fluids and gear oils)*, the base oils are selected based on their cold temperature properties where equipment is operated at extreme starting conditions. These lighter base oils allow reduced cranking torque since the oil can more easily flow if it exhibits lower viscosity at low temperature. In order to have sufficient viscosity for gears and bearings at operating temperature, formulators add Viscosity Index Improver (VII) additives to the base formulation.

All lubricants exhibit a "Viscosity Index". Viscosity Index indicates the amount the viscosity changes with change in temperature. Viscosity Index is calculated based on two temperature points: 40C and 100C as shown in Figure 1. The base oil, or base oils, used to blend a lubricant will exhibit some measurable Viscosity Index. The higher the Viscosity Index, the less the viscosity changes with temperature. Viscosity Index Improver (VII) additives are used in multi-grade lubricants, such as in SAE[1] 5W-30 or 15W-40 engine oils

[1] SAE = Society of Automotive Engineers

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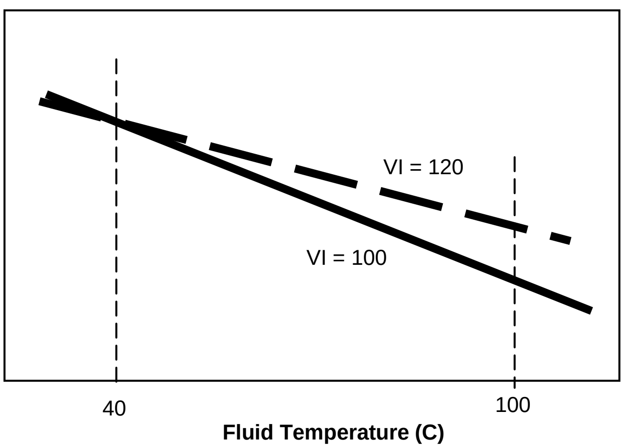
or in most automatic transmission fluids and gear oils. These VII additives are made up of very long chained polymers. Viscosity Index Improver additives (polymers) are designed to give additional viscosity to the base oil at operating temperature.

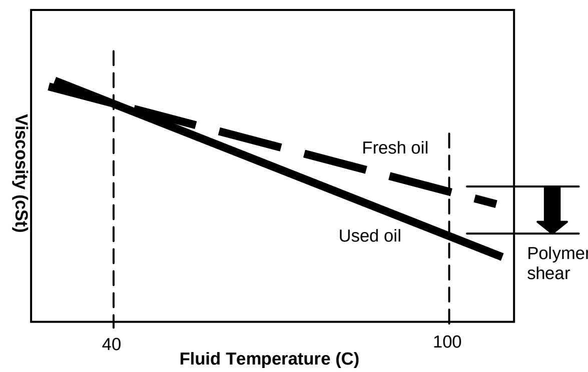
Figure 1: Viscosity Index



Viscosity Index Improvers are very long chained molecules (polymers) that are designed to expand with increased temperature resulting in higher viscosity than would be available with only the base oil.

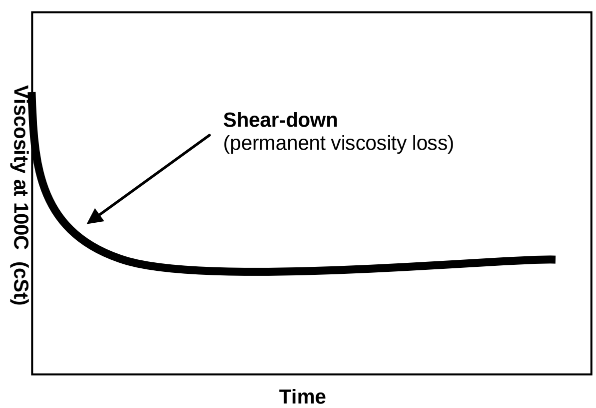
Viscosity Stability - With time these VII polymers are cut-up *(sheared)* as they pass through highly loaded gears and bearings. The process is known as "shear-down" (see Figure 2). Shear-down is permanent and the viscosity is never gained back. Topping off with new oil will temporarily increase the viscosity but the affect is not lasting and soon shearing will again decrease the viscosity.

Figure 2: Shear-down (polymer shear)



Shear-down can progress to the point where there is no longer sufficient viscosity to lubricate gears, bearings and other heavily loaded moving parts and part wear follows. Figure 3 shows a typical curve demonstrating viscosity change (shear-down) with extended use.

Figure 3: Typical Shear Rate



Oxidation

All lubricants oxidize over time. Oxidation rate depends on:

- Initial oil quality
- Total amount of heat the oil absorbs during the change interval

A common "rule of thumb" states that oxidation rate doubles for every 10C (18F) rise in oil temperature.

During the oxidation process, some of the hydrogen bonds in the base oil degrade allowing oil molecules to combine with

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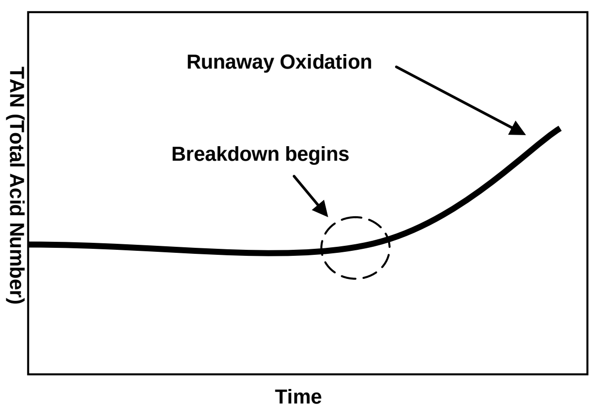
oxygen from surrounding air. This leads to formation of acids which causes the oil to have increased acidity over time. If the oil is not changed and oxidation is allowed to continue, the oil molecules may degrade to a point where they "cross-link" or bond together to form "viscosity growth" which is the end stage of oxidation.

Left unchecked, the oil will eventually become very thick and viscous and reach a mayonnaise consistency. This is known as "run away" oxidation (see Figure 4).

Figure 4: Typical Oxidation Change

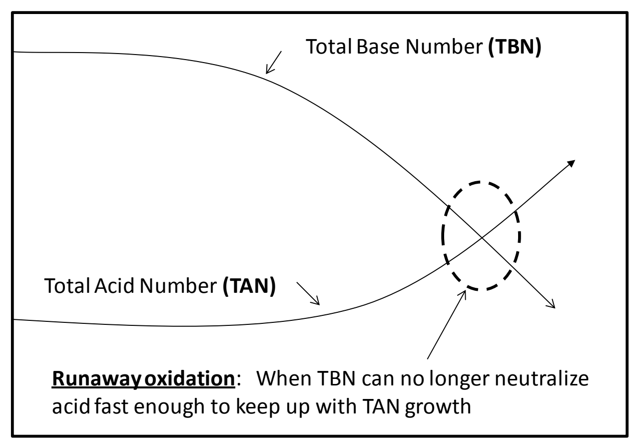


Total Acid Number - Oxidation is typically measured using Total Acid Number (TAN) as defined by ASTM D664. A sample of used oil is titrated with drops of potassium hydroxide (KOH) until the acid is neutralized and the amount added is called the Total Acid Number (TAN) as measured by milligrams of KOH per gram of used oil.

Total Base Number - Basic chemistry tells us that bases neutralize acids. "Blow-by" gases that pass by the rings of an internal combustion engine tend to accelerate the oxidation process, especially if higher sulfur content fuels are used. Because most engines produce some level of blow-by gases, oil companies and additive companies work together to formulate oils to include additives that increase the alkalinity of the virgin (unused) oil. This enables oils to sacrifice these additives over time to "fight off" acid buildup from the oxidation process and piston ring "blow-by" gases. Adding these alkaline type additives to engine oils is called "over basing" the oil. The amount of over basing in a given engine oil is determined by the Total Base Number (TBN) of the unused oil. Therefore, we monitor Total Base Number (TBN) to evaluate the amount of acid buildup in engine oils due to the oxidation process. Typically, TBN can decrease up to 65% before the oil must be changed.

Figure 5 shows a typical plot of TBN and TAN. Notice that TBN goes down over time and TAN goes up over time. When they cross is typically the time to change oil as the alkaline additives in the "over based engine oil can no longer neutralize the acid build up, from the oxidation process, fast enough to avoid runaway oxidation.

Figure 5: TBN vs. TAN



Contamination

We've seen that oils can suffer viscosity loss through shear-down and how they can oxidize with due to time at temperature. Both of these affects can shorten oil life and they can often occur simultaneously depending on initial oil quality.

In addition to viscosity change and oxidation, lubricants also tend to collect debris. This debris can be ingested through air inlets, breathers, vents, etc. or they can be introduced when new oil is put into the system or when oil is topped off. Contaminants and system debris can also accumulate from wear metals, soot, internal leaks (fuel or coolant) and water from condensation. Filters can remove solid debris to a point. Other contaminants can be held in suspension by dispersant additives in the oil. However, as time goes by, contaminants and debris build up and begin to block filters. If debris is from wear metals, this may result in secondary pitting gear in

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bearings and gear meshes depending upon the size and hardness of the debris. In summary, oil life is a function of the amount of permanent viscosity loss (shear-down) suffered by the lubricant, the oxidation state of the lubricant, and the amount of debris present. If the oil is run too long, at some point, it will no longer be useful and will lose its ability to provide sufficient lubricating film or protect effectively against runaway oxidation. This can only be assessed by measuring and monitoring the oil properties and corresponding part wear through oil analysis.

Oil Analysis

The main factors that affect oil life can be measured and monitored using oil analysis. Measured parameters include viscosity at 100C, TAN (Total Acid Number) for transmissions and differentials, TBN (Total Base Number) for engines, water content, soot content, wear and additive metal contents and contaminants.

JG Lubricant Services offers three (3) levels of testing as defined on the website "Products" page:

- **BASIC**
- **ADVANCED**
- **ULTIMATE**

Kits are designed to be "multi-use" and can be used to sample any piece of equipment including engines, transmissions *(auto and manual),* differentials, reefer engines, etc. Just tell us on the **Component Registration Form** what you've sampled. We've made processing easy. You can choose from any of our (4) conveniently located ISO 17025A certified laboratories.

For Individual or Independents - Kits are available as "singles" and "3-packs". These kits include everything you need to get started testing your equipment except for a vacuum pump. You'll need to purchase a JGVP01 Oil Vacuum Pump. It's a "one time" purchase and will last for years. These kits and can be purchased from our online store at www.jglubricantservices.com/online_store.com.

For Fleets or Service Centers – For fleets and service centers, we stock kits as 10-packs. These kits come without tubing. Tubing is available for "cut to length" by purchasing either in 100' or 1000' rolls. Fleet or Service Center kits can be purchased from our online fleet and service center store at http://www.jglubricantservices.com/online_store_fleet.html.

Questions

- Call Sales at 877-971-7799 (Ext. 1) or email Sales@jglubricantservices.com.
- Call Technical Support at 877-971-7799 (Ext. 2) or email Technical@jglubricantservices.com.

About the Author

Tom Johnson is part owner and President of JG Lubricant Services, LLC. He holds a Bachelor of Science degree in Mechanical Engineering Technology from Purdue University and has over 30 years engineering experience. Prior to forming JG Lubricant Services, Tom acted as the Transmission Fluids Engineer for Allison Transmission[2] for the last 20 years before his retirement in 2009. While in this position, Tom worked with most of the global oil and additive companies. Tom wrote all of Allison's current lubricant specifications *(including the ground breaking TES-295 specification)*. He directed and managed the testing and approval of hundreds of transmission fluid formulations for Allison Transmission and served as a key member of the GM Automatic Transmission Fluid Committee. Tom was also a key member of the Engine Oil Review Committee for the SAE Performance Review Institute [3] and participated on a multi-OEM panel to review and approve engine oils to US Army specifications. Tom worked closely with the US Army Tank Automotive Command to review military specification oils for use in US Army tactical and combat wheeled and track laying vehicles.

[2] Allison Transmission is the world's leading producer of heavy duty automatic transmissions and a former division of the General Motors Corporation.
[3] Formerly known as the "Lubricant Review Institute"