What Boat Captains and Marine Surveyors Should Know about Oils and Oil Analysis

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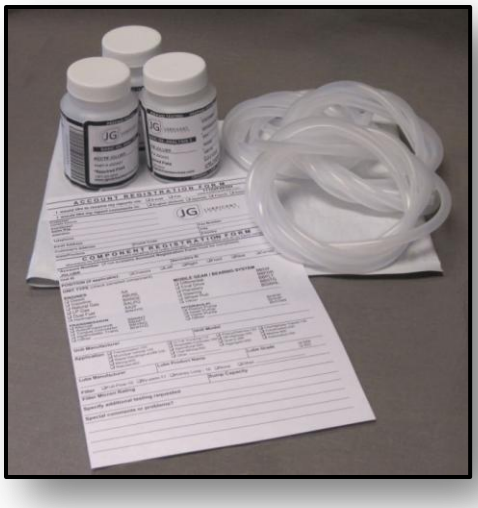


The following article is intended for Boat Captains, Marine Surveyors, Marine Fleet Owners and Marine Equipment Engineers and Technicians. The information covers:

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

Factors Affecting Useful Oil Life - 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.

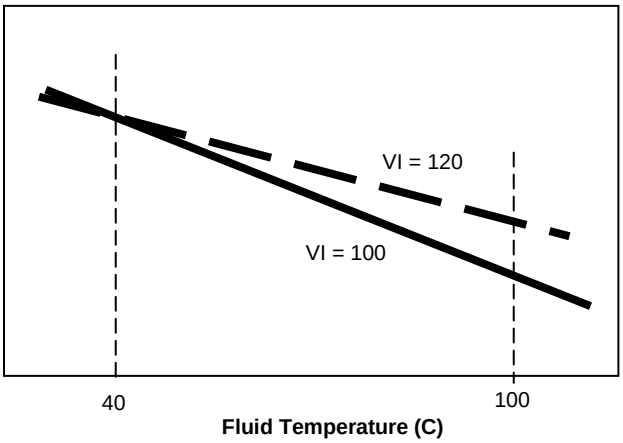
Viscosity - First, let's examine the oil property known as "Viscosity". **Viscosity is defined as resistance of an oil to flow at a given temperature.** Viscosity is typically measured and reported at two temperature set points: 40C (104F) and 100C (212F). In order to maintain sufficient viscosity to 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 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

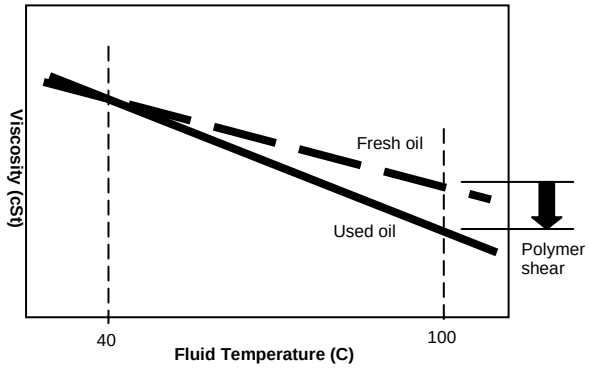


Viscosity Index Improvers are very long chained molecules (polymers) that are designed to expand with increased temperature resulting in higher viscosity than would be available with only the base oil.

[1] SAE = Society of Automotive Engineers

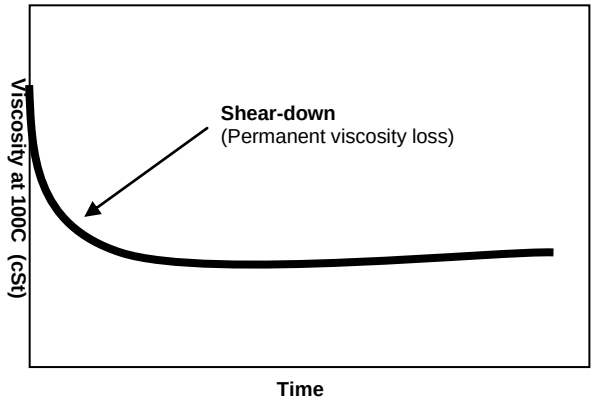
Viscosity Stability - With time these VII polymers are cut-up *(sheared)* as they pass through highly loaded gears and bearings. The process is known as "shear-down" (see Figure 2). Shear-down is permanent and the viscosity is never gained back. Topping off with new oil will temporarily increase the 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



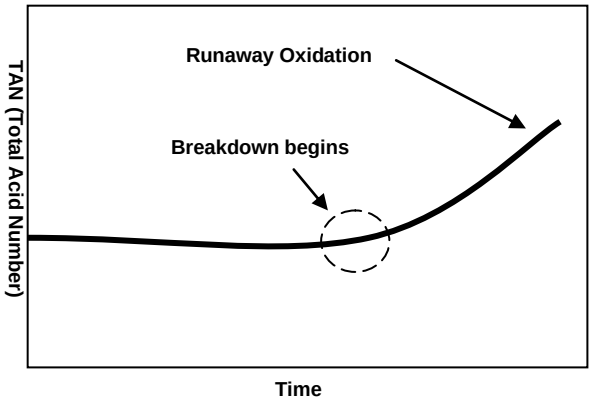
Oxidation – All lubricants oxidize over time. Oxidation rate depends on:

- 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 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

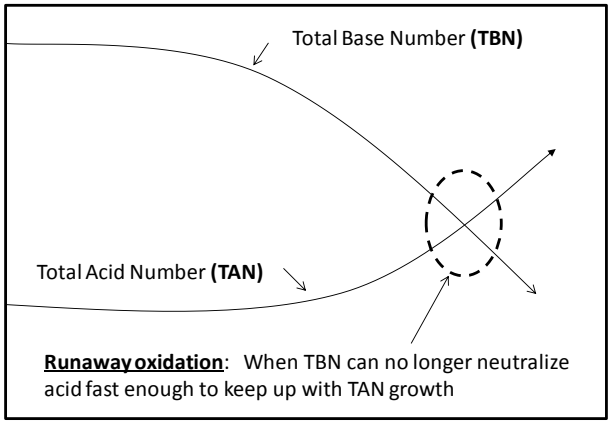


Total Acid Number - Oxidation is typically measured using Total Acid Number (TAN) as defined by ASTM D664. A sample of used oil is titrated with drops of potassium hydroxide (KOH) until the acid is neutralized and the amount added is called the Total Acid Number (TAN) as measured by milligrams of KOH 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 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 the breather or introduced when new oil is put into the system or when the oil is topped off. Debris can also accumulate from wear metals and water from condensation. Most oils contain dispersants to handle some of this debris and keep it in suspension but, as time goes by, the debris tends to build up and begin to block filters. If the debris is from wear metals, this may result in secondary pitting wear in 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 gearboxes, TBN (Total Base Number) for engines, water content, soot content, wear and additive metal contents, and contamination debris through particle count.

JG Lubricant Services provides (3) levels of testing (as shown in Figure 5):

- **Basic** - The Basic Kit looks at everything except the oxidation state of the lubricant. Though it is still an excellent tool for evaluating overall lubricant conditions, it cannot be used to extend drain intervals since it does not measure oxidation (resistance to changes due to heat absorption).
- **Advanced** - The Advanced Kit is our "core kit" and gives the Marine Surveyor all the testing needed to fully inspect both the lubricant and equipment condition. This kit is also designed to be used in helping clients to safely extend drain intervals.
- **Ultimate** – The Ultimate Kit measures all of the lubricant and equipment wear parameters plus it also measures particle counts and ISO Cleanliness Code for applications where filtration is critical.

Figure 5: Oil Analysis Kit Descriptions

OIL ANALYSIS KIT DESCRIPTIONS

Analysis Kit Type	TESTS INCLUDED IN KIT								
	Basic Protection					Additional Diagnostics			Debris Analysis
	Elemental Analysis (ICP)	% Water	% Fuel Dilution	% Soot	Viscosity at 100C	Total Base Number (TBN) [3]	Total Acid Number (TAN) [4]	Oxidation and Nitration (IR)	By Particle Count or Particle Quantifier
BASIC [1]	●	●	●	●	●				
ADVANCED [2]	●	●	●	●	●	●	●	●	
ULTIMATE [5]	●	●	●	●	●	●	●	●	●

1. **Not recommended for extended drain interval sampling** *(consult JG Lubricant Services)*
2. **Recommended for extended drain interval sampling**
3. **Engine oil samples are tested for TBN** *(not included on transmission and gear oil samples)*
4. **Transmission and gear oil samples are tested for TAN** *(not included on engine oil samples)*
5. **Debris Analysis by Particle Count** *(if gearbox is filtered)* ; **Debris Analysis by Particle Quantifier** *(if gear box is unfiltered)*

In closing, at JG Lubricant Services, we understand the importance of properly assessing the seaworthiness of new and used boats, yachts, fishing vessels and other marine equipment. **We use ASTM standardized testing at our "state of the art" ISO 17025A certified laboratories while offering highly competitive pricing to bring you the best possible value.** We have the ability to properly assess both new and used lubricants to verify their physical and chemical condition. We also measure changes in the lubricant and determine how it may be affecting equipment wear. You receive a detailed report that lists test the test results along with an overall Severity Rating and easy to understand comments and recommendations on what to do next.

For Boat Captains, oil analysis means your equipment will remain as "worry free" as possible and ready for your next group of clients or your next day's work, whatever it may be.

For Marine Surveyors, JG Lubricant Services is an Affiliate Member of the Society of Accredited Marine Surveyors (SAMS) and offers a 10% discount to all members.

Adding oil analysis to your professional assessment puts you **ahead of the competition**. Oil analysis allows you and your client to:

- **Get the most from engine, transmission, and gearbox lubricants**
- **Protect and maintain seaworthiness of power train components**
- **Find small issues long before they become big problems or failures**
- **Increase resale values**
- **Reduce warranty risk exposure for the client and the insurance company**

JG Lubricant Services can assist you in determining what you'll need to get started, how to work with oil analysis data, and whether or not you're getting the most from your engine oils, transmission fluids, and gear oils. We can help you assess marine equipment and let you know if wear is an issue or when the oil is being run too long. We'll work with you to design an oil analysis program that results in improved

equipment life, optimized oil lives, increased equipment uptime, and reduced maintenance costs to improve your bottom line.

NOTE: For more about oil analysis, visit us online at www.jglubricantservices.com or visit our Marine page www.jglubricantservices.com/marine-oil-analysis.html.

About the Author

Tom Johnson is President and Co-Founder of JG Lubricant Services, LLC. He holds a Bachelor of Science degree in Mechanical Engineering Technology from Purdue University and has over 30 years of engineering experience. Prior to forming JG Lubricant Services, Tom held the position of Transmission Fluids Engineer for Allison Transmission[2] for the last 20 years of his career. Tom retired from GM and Allison Transmission in 2009. While in his former position at GM and Allison Transmission, Tom worked closely with global oil and additive companies and wrote most of Allison's lubricant specifications. He directed, managed and oversaw the testing and approvals of hundreds of transmission fluid and engine oil formulations for Allison Transmission. He also served as a key member of GM's Automatic Transmission Fluid and Engine Oil Committees. Tom also held a key position as a member of the SAE[3] Lubricant Review Institute Engine Oil Committee where he participated on a multi-OEM panel to review and approve engine oils to US Army specifications. In this capacity, 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.

Contact us:

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- **Technical Assistance**, call 877-971-7799 (ext 2) or email technical@jglubricantservices.com.

How and Where to Purchase:

Oil analysis kits and supplies can be ordered direct from our online store at http://www.jglubricantservices.com/online_store.html. We've also recently partnered with MarineMax. MarineMax offers Marine Oil Analysis Starter and Replacement Kits in their stores or you can get them online at www.boatinggearcenter.com. In addition, MarineMax offers oil analysis as part of their diagnostic tools at all of their Service Centers.

[2] Allison Transmission is the world's leading producer of heavy duty automatic transmissions and a former division of the General Motors Corporation.

[3] SAE = Society of Automotive Engineers