Base Oils Explained

Conventional mineral oils, also known as Group I and II base oils, are derived directly from crude oil through less sophisticated refining processes.
Group III base oils, while still derived from crude oil, undergo a more intense refining process, including hydrocracking and hydroisomerization, which results in improved properties and characteristic

Conventional Mineral Oils (Group I & II):

- **Refining Process:** Involves distillation and solvent extraction to remove impurities.
- **Molecular Structure:** Can contain higher levels of n-paraffins, which can lead to wax formation at lower temperatures and potentially affect performance in some applications.
- **Viscosity Index (VI):** Generally lower than Group III oils.
- **Oxidation Stability:** May be less stable than Group III oils at high temperatures.
- **Cost:** Typically less expensive than Group III oils.

Group III Base Oils:

- **Refining Process:** Involves hydrocracking and hydroisomerization, which break down and restructure the oil molecules to create a more stable and uniform product.
- **Molecular Structure:** Contain a higher percentage of saturated hydrocarbons and are less prone to wax formation.
- **Viscosity Index (VI):** Generally higher than Group I and II oils, often above 120.
- **Oxidation Stability:** Generally better than Group I and II oils, allowing them to perform well under demanding conditions.
- **Cost:** More expensive than Group I and II oils.

In essence:

- Conventional mineral oils are a less refined product, suitable for many applications but may not offer the same high-performance benefits as Group III oils.
- Group III oils, while technically mineral oils, are treated more rigorously, resulting in enhanced properties that are often desirable in high-performance applications.
- Almost every lubricant used in plants today started off as just a base oil. The base oil category defines what the oil is made of, how it is manufactured, and how the lubricant handles certain environments such as extreme heat.The American Petroleum Institute (API) has categorized base oils into five categories (API 1509, Appendix E). The first three groups are refined from petroleum crude oil.
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- Group IV base oils are full synthetic (polyalphaolefin) oils. Group V is for all other base oils not included in Groups I through IV. Before all the additives are added to the mixture, lubricating oils begin as one or more of these five API groups.

Group I

- Group I base oils are classified as less than 90 percent saturates, greater than 0.03 percent sulfur and with a viscosity-index range of 80 to 120. The temperature range for these oils is from 32 to 150 degrees F. Group I base oils are solvent-refined, which is a simpler refining process. This is why they are the cheapest base oils on the market.

Group II

- Group II base oils are defined as being more than 90 percent saturates, less than 0.03 percent sulfur and with a viscosity index of 80 to 120. They are often manufactured by hydrocracking, which is a more complex process than what is used for Group I base oils. Since all the hydrocarbon molecules of these oils are saturated,
- Group II base oils have better antioxidation properties. They also have a clearer color and cost more in comparison to Group I base oils. Still, Group II base oils are becoming very common on the market today and are priced very close to Group I oils.

Group III

- Group III base oils are greater than 90 percent saturates, less than 0.03 percent sulfur and have a viscosity index above 120. These oils are refined even more than Group II base oils and generally are severely hydrocracked (higher pressure and heat). This longer process is designed to achieve a purer base oil.
- Although made from crude oil, Group III base oils are sometimes marketed and described as synthesized hydrocarbons. These oils are made from rigorous refining rather than synthesizing.

Group IV

- Group IV base oils are polyalphaolefins (PAOs). These synthetic base oils are made through a process called synthesizing. They have a much broader temperature range and are great for use in extreme cold conditions and high heat applications.

Group V

- Group V base oils are classified as all other base oils, including silicone, phosphate ester, polyalkylene glycol (PAG), polyolester, biolubes, etc. These base oils are at times mixed with other base stocks to enhance the oil's properties. An example would be a PAO-based compressor oil that is mixed with a polyolester.
- Esters are common Group V base oils used in different lubricant formulations to improve the properties of the existing base oil. Ester oils can take more abuse at higher temperatures and will provide superior detergency compared to a PAO synthetic base oil, which in turn increases the hours of use.

API Base Oil Groups

- In the early 1990s, the American Petroleum Institute implemented a system for describing various base oil types. The result was the development and introduction of base oil group numbers.
- Group I base oils are the traditional older base oils created by a solvent-refining technology used to remove the weaker chemical structures or bad actors (ring structures, structures with double bonds) from the crude oil. Solvent refining was the primary technology used in refineries built between 1940 and 1980.
- **Group I** base oils typically range from amber to golden brown in color due to the sulphur, nitrogen and ring structures remaining in the oil. They typically have a viscosity index (VI) from 90 to 105. The base oils on the high end of the scale are often referred to as having a high viscosity index (HVI).
- This relates to how much the viscosity changes with temperature, i.e., how much it thins out at higher temperatures and thickens at low temperatures. Group I base oils are the most common type used for industrial oils, although increasingly more Group II base oils are being used.
- **Group II** base oils are created by using a hydrotreating process to replace the traditional solvent-refining process. Hydrogen gas is used to remove undesirable components from the crude oil. This results in a clear and colorless base oil with very few sulphur, nitrogen or ring structures
- The VI is typically above 100. In recent years, the price has become very similar to Group I base oils. Group II base oils are still considered to be mineral oils. They are commonly used in automotive engine oil formulations.
- Group II "Plus" is a term used for Group II base oils that have a slightly higher VI of approximately 115, although this may not be an officially recognized term by the API.
- **Group III** base oils are again created by using a hydrogen gas process to clean up the crude oil, but this time the process is more severe and is operated at higher temperatures and pressures than used for Group II base oils. The resulting base oil

is clear and colorless but also has a VI above 120. In addition, it is more resistant to oxidation than Group I oils.

- The cost of Group III base oils is higher than Group I and II. Group III base oils are considered mineral oils by many technical people because they are derived directly from the refining of crude oil. However, they are considered synthetic base oils by other people for marketing purposes due to the belief that the harsher hydrogen process has created new chemical oil structures that were not present before the process. It has synthesized (created) these new hydrocarbon structures. See the section on synthetic base oils in this book.
- Group I, II and III base oils basically reflect the evolution in refining technology over the past 70 or 80 years.
- **Group IV** base oils are polyalphaolefin (PAO) synthetic base oils that have existed for more than 50 years. They are pure chemicals created in a chemical plant as opposed to being created by distillation and refining of crude oil (as the previous groups were).
- PAOs fall into the category of synthetic hydrocarbons (SHCs). They have a VI of greater than 120 and are significantly more expensive than Group III base oils due to the high degree of processing needed to manufacture them.
- **Group V** base oils comprise all base oils not included in Groups I, II, III or IV. Therefore, various synthetic esters, polyalkylene glycols (PAGs), phosphate esters and others fall into this group.
- A recent study on the use of base oils in today's plants in comparison to a little more than a decade ago found a dramatic change has occurred. Present-day Group II base oils are the most commonly used base oils in plants, making up 47 percent of the capacity of plants in which the study was conducted.
- This compared to 21 percent for both Group II and III base oils just a decade ago. Currently, Group III accounts for less than 1 percent of the capacity in plants. Group I base oils previously made up 56 percent of the capacity, compared to 28 percent of the capacity in today's plants.
- Remember, whichever base oil you choose, just be sure it is appropriate for the application, temperature range and conditions in your pl

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What Is Synthetic Oil?

Synthetic oil is a lubricant made up of artificially made chemical compounds; these compounds are made by breaking down and then rebuilding petroleum molecules. Under a microscope, a drop of synthetic oil shows millions of molecules all nearly the same size and structure. Conversely, mineral or conventional oil is made using refined crude oil. A drop of conventional oil under a microscope shows millions of molecules all with different shapes, sizes and structures. Synthetic oil can be fully synthetic or a synthetic blend and be derived from multiple base types.

Full synthetic oils use a synthetic base stock, are uniquely designed molecule by molecule without using petroleum and include additives meant to help the degradation of the oil. A **synthetic blend**is a mix of conventional motor oil and synthetic base stocks. Adding the synthetic base stock to the conventional mineral oil gives you a little bit more protection than just using the conventional oil by itself. A full synthetic oil is much superior compared to group 111 mineral oil.

There are multiple types of synthetics with distinctly different properties and applications. However, most synthetics used in automotive service are polyalphaolefins (PAO). For simplicity, the primary reference to synthetic oils in this article will relate to PAOs.

Synthetic vs. Conventional Oil

Most vehicles are capable of using either synthetic or conventional mineral oil that meet the American Petroleum Institute's (API) and International Lubricant Standardization and Advisory Committee (ILSAC) specifications. However, synthetic oils are often marketed as having superior performance when compared with conventional oil. This superior performance may only relate to certain properties but not others. It is possible that some formulations of conventional mineral oils may exhibit superior performance on certain properties.

There have been numerous studies over the years comparing synthetic oil to conventional mineral oil. Most notably the American Automobile Association (AAA) used certified labs using American Society for Testing and Materials (ASTM) standardized test methods to examine differences in engine oils marketed as conventional versus those marketed as full synthetic.

Among other things, AAA found that, on average, synthetic oils outperformed conventional oils by 47 percent in the conducted tests. The selected tests evaluated several important physical, chemical and performance properties including shear stability, deposit formation, volatility, cold-temperature pumpability, oxidation resistance, and oxidation-induced rheological (viscosity) changes.

Synthetic oil is quickly becoming the new normal, with nearly 70 percent of new cars in the 2019 model year getting either fully synthetic or a synthetic blend oil, according to Consumer Reports. Even as the number of new cars requiring synthetics continues to increase, it remains important for consumers to follow manufacturer recommendations for their vehicle when it comes to changing their oil. "Semi- or full-synthetic oils are required for most newer cars, but it is vital that the automaker's recommendations be followed, or accelerated engine wear and other problems could result," Michael Calkins, Technical Services Manager for AAA tells Machinery Lubrication.

The advancement of synthetic oil has put the microscope on conventional oil. Even though conventional oil lubricates your car's engine adequately in most cases, there are some possible disadvantages to using it. These disadvantages may or may not be realized or noticed depending on various factors like marginal fluidity at extremely low temperatures, thermal and oxidative stability (prolonged chemical stability at high temperatures) and viscosity protection (against wear and friction) at high engine loads and temperatures.

Advantages and Disadvantages of Synthetic Oil

So, what are the advantages of switching to a synthetic as opposed to a conventional motor oil? When looking at the pros and cons, synthetic lubricants can offer meaningful advantages. The following are some of the most significant **advantages** synthetics (PAOs) generally have over conventional engine oils. Note, the list below assumes that the additive package would be similar between the two options which is rarely the case. Most synthetic lubricant formulations for automobiles would have a superior additive package making the comparison more complex. In other words, is the superior performance the result of the synthetic base oil or is it due to the superior additive(s) or a little of both?

- When exposed to certain conditions, conventional mineral oils are usually more prone to chemical degradation (oxidation) compared to synthetics. These harmful conditions include combustion byproducts, fuel contamination, water contamination, metal particles, acids, pro-oxidants and extreme heat (e.g., from combustion). Exposure to these conditions commonly occur in engines. Oil degradation can cause sludge, varnish or deposits, corrosion, viscosity change and impaired engine performance.
- Synthetics have a naturally higher viscosity index. This means the viscosity changes less (more stable) as temperature changes during normal engine startup and operating conditions. Viscosity is an important property of lubricants that produces the film thickness or clearance between metal surfaces that slide or rotate against each other. Without this film thickness, excessive friction and wear would occur.
- At extremely low temperatures, it is more possible for mineral oils(compared to synthetics) to become so thick (high viscosity) that the oil is unpumpable or is unable to circulate effectively within the engine. Lack of oil circulation can cause lubricant starvation conditions and engine failure.
- Synthetic engine oils are generally less volatile than mineral oils. This means there is less loss of the oil to the engine's exhaust stream causing atmospheric pollution. This could also mean less need for makeup oil between oil changes.

- Possibly the biggest advantage and the reason synthetic oil is so popular, is that it has a longer lifespan than conventional oil. The recommended change interval for synthetic oil is around every 5,000 to 7,000 miles, with some brands touting a much longer interval (15,000 to 25,000). The biggest reason for the longer oil change interval is described in the first bullet above. Regardless of the kind of oil you use, it is still recommended to change your oil at regular intervals recommended by your manufacturer.

A few **disadvantages** of synthetic oil to be aware of include:

- Probably the most glaring downside of synthetic oil is the cost. The price of synthetic oil is around two to four times the price of conventional oil.
- Synthetics may be more prone to additives precipitation during cold storage conditions. This stratifies certain additives which can potentially lead to their complete separation from the oil.
- Mineral oils require more viscosity index improvers (an additive) than synthetics. This additive contributes to reduced viscosity friction by a mechanism known as shear-induced temporary viscosity thinning.

Synthetic Oil Verses Semisynthetic Oil.

Synthetic oil takes the lead for best performance. It provides superior lubrication, which translates to longer life and better equipment protection and efficiency. Synthetic oil remains stable at high temperatures, so it lowers the risk of thermal breakdown. it is made from methodically synthesized materials. Semi-synthetic oils offer reliable performance but may not provide the same level of protection in high-stress situations. it is made from conventional mineral oil and certain portion of synthetic oils. Semi-synthetic oils including group 111 oils delivers adequate performance for most applications, but their lifespan is shorter than full synthetic oils. Semi-synthetic oils including group 111 oils delivers adequate performance for most applications, but their lifespan is shorter than full synthetic oils.

Conclusion:

Synthetic oils provides superior lubrication, which offers better equipment protection and efficiency. Synthetic oil remains stable at high temperatures, so it lowers the risk of thermal breakdown. it is made from methodically synthesized materials. Semi-synthetic oils offer reliable performance but may not provide the same level of protection in high-stress situations. They are made from conventional mineral oil and certain portion of synthetic oils. Semi-synthetic oils including group 111 oils delivers adequate performance for most applications, but their lifespan is shorter than full synthetic oils.

References: The above statements and references were extracted from published articles in Machinery Lubrication and CRC published book on Synthetics, Mineral oils and Biobased Lubricants, Chemistry and Technology

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