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## The Evolution of Base Oil Technology

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**Abstract:** 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. Turbine oils are perhaps the most dramatic example because they typically contain over 99% base oil.

Early lubrication began with animal fats and oils and slowly evolved to petroleum-based oils. Many generations of refining processes have since improved on Mother Nature. Early processes such as acid treating and solvent extraction improved the quality of base oils by removing some or most of the worst molecules from the oil. Later processes like hydrotreating, catalytic hydrocracking, catalytic dewaxing, and modern wax hydroisomerization transformed feed molecules into molecules with improved lubricating qualities.

Modern wax hydroisomerization, in particular, makes base oils with very low impurities and typically water-white appearance. Now, about one third of all base oils manufactured in North America are of such high quality.

Looking to the future, the trend is toward even higher base oil purity, higher viscosity index (V.I.), lower volatility, and longer life. The distinction between heavily processed mineral oils and traditional “synthetic” oils will continue to blur.

The evolution and future of base oil technology will be discussed in more detail in this paper.

**Keywords:** base oil, evolution, history, hydrocracking, solvent

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## **Early Base Oil Processing**

Base oil technology has undergone many phases of evolution. In the first phase, animal fats were used as lubricants. Ancient inscriptions dating back to 1400 BC show beef and mutton fat (tallow) being applied to chariot axles. Very little changed over the next 3000 years except that the oils sometimes came from more exotic animals such as whales.

In 1852 petroleum-based oils first became available. They were not widely accepted at first because they did not perform as well as many of the animal-based products. Raw crude did not make very good lubricant. The base oil industry was on the very steep part of the learning curve.

But as the demand for automobiles grew, so did the demand for better lubricants. Soon lubricant manufacturers learned which crudes made the best lubricants. Then they improved on Mother Nature by refining the crude into narrow distillation cuts with varying viscosity. By 1923 the Society of Automotive Engineers classified engine oils by viscosity: light, medium, and heavy. Engine oils contained no additives and had to be replaced every 800-1000 miles.

In the 1920s more lubrication manufacturers started “processing” their base oils to improve their performance. Three popular processing routes were:

### *Clay Treating*

Clay similar to kitty litter was used to soak up and remove some of the worst components in the petroleum base oil. These compounds were usually aromatic and highly polar compounds containing sulfur and nitrogen.

### *Acid Treating*

Concentrated sulfuric acid was used to react with the worst components in the base oil and convert them into a sludge that could be removed. Although this process effectively cleaned up the oil, it was expensive. This technology has virtually disappeared from North America due to environmental concerns about the acid and sludge [1].

### *SO<sub>2</sub> Treating*

SO<sub>2</sub> treating was a primitive extraction process to remove the worst components in the lube oil using a recyclable solvent. Unfortunately, the solvent was highly toxic. Although it also has been virtually phased out [1], it was a useful stepping stone to conventional solvent extraction.

## **Solvent Refining**

By approximately 1930 solvent processing emerged as a viable technology for improving base oil performance using a fairly safe, recyclable solvent. Most base oil producers in the world today still use this process.

Approximately two-thirds of the base oil in North America is currently manufactured using this route. Solvent refined base oils are commonly called Group I base oils which are characterized as those having less than 90% saturates (>10% aromatics) and more than 300 ppm sulfur. Table 1 shows all the base oil groups as defined by the American Petroleum Institute (API) Publication 1509.

Table 1 – API Base Stock Categories (API Publication 1509)

Group	Sulfur, Wt %		Saturates	V.I.
I	>0.03	and/or	<90	80-119
II	≤0.03	and	≥90	80-119
III	≤0.03	and	≥90	≥120
IV	All Polyalphaolefins (PAOs)			
V	All Stocks Not Included in Groups I-IV (Pale Oils and Non-PAO Synthetics)			

The solvents and hardware used to manufacture solvent-refined base oils have evolved over time, but the basic strategy has not changed since 1930. The two main processing steps are:

1. Remove aromatics by solvent extraction.
2. Remove wax by chilling and precipitation in the presence of a different solvent.

Aromatics are removed by solvent extraction to improve the lubricating quality of the oil. Aromatics make good solvents but they make poor quality base oils because they are among the most reactive components in the natural lube boiling range. Oxidation of aromatics can start a chain reaction that can dramatically shorten the useful life of a base oil.

The viscosity of aromatic components in a 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, when hot and cold performance is required, a small response to changes in temperature is desired. The lubricants industry expresses this response as the viscosity index (V.I.). A higher V.I. indicates a smaller, more favorable response to temperature. Correspondingly, many turbine manufacturers have a minimum V.I. specification for their turbine oils. Base oil selection is key for meeting this specification because turbine oil additives do not normally contribute positively to the V.I. in turbine oil formulations.

Aromatics are removed by feeding the raw lube distillate (vacuum gas oil) into a solvent extractor where it is contacted countercurrently with a solvent. Popular choices of solvent 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.

The second step is solvent dewaxing. Wax is removed from the oil to keep it from freezing in the customer's sump or crankcase at low temperatures.

Wax is removed by first diluting the raffinate with a solvent to lower its viscosity to improve low-temperature filterability. Popular dewaxing solvents are methyl-ethyl ketone (MEK)/toluene, MEK/methyl-isobutyl ketone, or (rarely) propane. The diluted oil is then chilled to -10 to -20°C. Wax crystals form, precipitate, and are removed by filtration.

### **Additives Improve Performance**

Over the next several decades, the solvent refining process did not change very much. Finished oil quality improved mainly due to the addition of additives. Additives began to be widely used in 1947 when the API began to categorize engine oils by severity of service: regular, premium, and heavy duty. Additives were used to extend the life only in premium and heavy-duty oils.

Regular engine oils were unadditized and were intended for 80-100 hours of low-severity service. Premium engine oils were additized to extend the life of passenger car engine oils. Heavy duty engine oils were more heavily additized to extend the engine oil life in more severe applications such as commercial trucks and construction equipment.

In 1950 multigrade oils were first introduced which were additized with polymers to enhance the V.I. of the oil which improved the hot and cold performance of the oil.

For several more decades, the lubricants industry continued to rely heavily on additive technology to improve the performance of finished oils. Lubricant quality improved significantly only when the additive chemistry improved. This was the only viable strategy until a significant improvement in base oil technology was available.

### **Hydrotreating**

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 is a process for adding hydrogen to the base oil at elevated temperatures in the presence of catalyst 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.

### **Hydrocracking**

Hydrocracking is a more severe form of hydroprocessing. It is done by adding hydrogen to the base oil feed at even higher temperatures and pressures than simple hydrotreating. Feed molecules are reshaped and often cracked into smaller molecules. 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 byproducts 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. But hydrocracking technology continued to improve [2].

After WWII, predecessors to modern hydrocracking catalyst technology were imported from Germany. Chevron commercialized this technology for fuels production in the late 1950's [3]. 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].

### **Catalytic Dewaxing and Wax Hydroisomerization**

The first catalytic dewaxing and wax hydroisomerization technologies were commercialized in the 1970s. Shell used wax hydroisomerization technology coupled with solvent dewaxing to manufacture extra high V.I. base oils in Europe. Exxon and others built similar plants in the 1990s. In the U.S., Mobil used catalytic dewaxing in place of solvent dewaxing, but still coupled it with solvent extraction to manufacture conventional neutral oils. Catalytic dewaxing was a desirable alternative to solvent dewaxing especially for conventional neutral oils, because it removed n-paraffins and waxy side chains from other molecules by catalytically cracking them into smaller molecules. This process lowered the pour point of the base oil so that it flowed at low temperatures, like solvent dewaxed oils. Hydroisomerization also saturated the majority of remaining aromatics and removed the majority of remaining sulfur and nitrogen species.

Chevron was the first to combine catalytic dewaxing with hydrocracking and hydrofinishing in their Richmond, California, base oil plant in 1984 [5] (Figure 1). This was the first commercial demonstration of an all-hydroprocessing route for lube base oil manufacturing.

In 1993, the first modern wax hydroisomerization process was commercialized by Chevron [6]. This was an improvement over earlier catalytic dewaxing because the pour point of the base oil was lowered by isomerizing (reshaping) the n-paraffins and other molecules with waxy side chains into very desirable branched compounds with superior lubricating qualities rather than cracking them away. Hydroisomerization was also an improvement over earlier wax hydroisomerization technology, because it eliminated the subsequent solvent dewaxing step, which was a requirement for earlier generation wax isomerization technologies to achieve adequate yield at standard pour points. 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 color.

By combining three catalytic hydroprocessing steps (hydrocracking, hydroisomerization, hydrotreating), molecules with poor lubricating qualities are transformed and reshaped into higher quality base oil molecules. Pour point, V.I., and oxidation stability are controlled independently. All three steps convert undesirable molecules into desirable ones, rather than have one, two, or all three steps rely on



Figure 1 – *Richmond Lube Oil Project*

subtraction. Among the many benefits of this combination of processes is greater crude oil flexibility; that is, less reliance on a narrow range of crude oils from which to make high-quality base oils. In addition, the base oil performance is exceptionally favorable and substantially independent of crude source, unlike solvent-refined base oil.

### **Group II – Modern Conventional Base Oils**

Lube base oils made by hydrocracking and early wax isomerization technologies showed favorably differentiated performance which prompted the API to categorize base oils by composition (API Publication 1509) in 1993, as shown earlier in Table 1. Table 1 shows that Group II base oils are differentiated from Group I base oils because they contain significantly lower levels of impurities (<10% aromatics, <300 ppm S). They also look different. Group II oils made using modern hydroisomerization technology are so pure that they have almost no color at all. From a performance standpoint, improved 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 byproducts that increase base oil viscosity and react with additives.

The modern hydroisomerization process licensed by Chevron under the name ISODEWAXING gained acceptance rapidly since its introduction in 1993. In fact, about one-third of all base oils manufactured in North America are now manufactured using this process (Figure 2). A similar trend can be seen in the rest of the world as well.

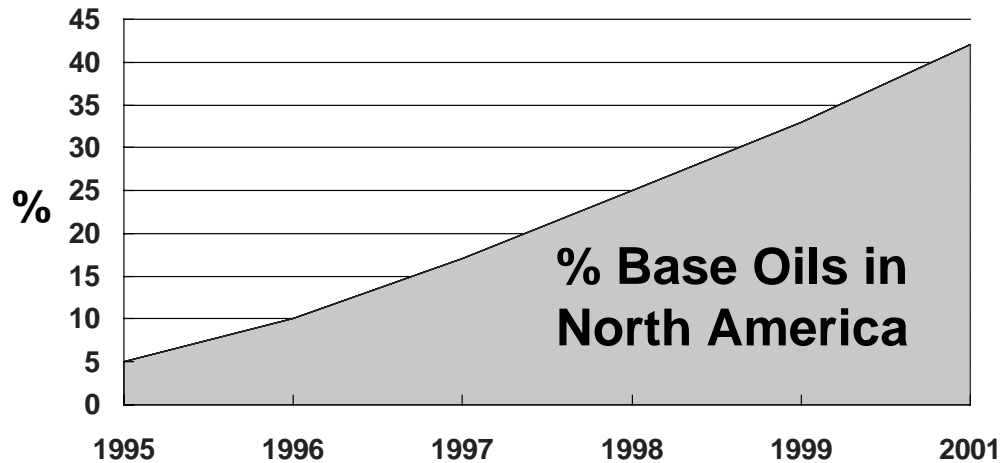


Figure 2 – Greater Availability (Chevron + Licensees = 42% by 2001)

More recently, Mobil (ExxonMobil) added to this trend by commercializing an all-hydroprocessed route for Group II production {Mobil Selective Dewaxing (MSDW<sup>TM</sup>)} which they installed in their Jurong Refinery in Singapore in 1997. Exxon-Mobil also added a hydroprocessing step (Raffinate Hydroconversion or RHC) to a solvent refining plant in Baytown, Texas, to upgrade its capability to Group II.

Group II base oil technology, along with specially designed additives has already had a tremendous impact on finished oil performance. In some applications including turbine oils, lubricating oils formulated with Group II base oils can outlive expensive traditional “synthetic” oils made from PAO.

### Group III – Unconventional Base Oils

Table 1 shows that the API defines the difference between Group II and III base oils only in terms of the V.I. Base oils with a “conventional” V.I. (80-119) are Group II and base oils with an “unconventional” V.I. (120+) are Group III. Group III oils are also sometimes called unconventional base oils (UCBOs) or very high V.I. (VHVI) base oils.

Solvent-dewaxed Group III base oils have been produced in Europe for more than 10 years, primarily by Shell and BP [7]. Group III base oils were not widely available in North America until a few years ago when Chevron and its licensees began making them using the all-hydroprocessing route. These modern Group III oils have greatly improved oxidation stability and low temperature performance relative to the solvent-refined Group III oils. Consequently, many of these older plants are now being upgraded to enable them to make the modern hydroisomerized Group III oils [8].

From a processing standpoint, modern Group III base oils are manufactured by essentially the same processing route as modern Group II base oils. Higher V.I. is achieved by increasing the temperature or time in the hydrocracker. This is sometimes collectively referred to as the “severity.” Alternatively, the product V.I. could be increased simply by increasing the feed V.I., which is typically done by selecting the appropriate crude.

Group III base oils are now widely available in North America because they can be manufactured in large quantities by most of the companies that currently make

Group II oils. Many of these companies have started adding them to their “synthetic” product lines.

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. The most notable exception is arctic oils, which have extremely low pour point requirements and a very small market presence.

#### **Group IV – Traditional “Synthetic” Base Oils (PAO)**

The use of 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. The term “synthetic” was given a special meaning by the lubricants industry because these types of oils were the only components available for high-performance lubricants at that time. Later in this paper it should become apparent how PAOs directly influenced the evolution of mineral-based base oil technology which in turn has influenced the evolution of the term “synthetic.”

The first commercially viable process for making PAO was pioneered by Gulf Oil in 1951 using an  $\text{AlCl}_3$  catalyst. Mobil patented an improved process using a  $\text{BF}_3/\text{AlCl}_3$  catalyst in the 1960s. Mobil first used this new base oil in specialty products such as Mobilgrease 28, which solved a wheel bearing failure problem on aircraft carriers in cold climates [9].

In the 1970s PAOs became a major consumer-sought lubricant component when Mobil Oil commercially marketed its Mobil 1™ engine oils 25 years ago. For the next 15 years, the PAO market traveled a long and winding road battling a slow, steady growth and criticisms of justification for the higher cost compared to conventional oils. In the last 10 years, the PAO market significantly increased, first in Europe and then in North America experiencing periods of double-digit growth. In part, the growth might be attributed to the stricter lubricant specifications in Europe that created a market niche for synthetics and semi-synthetic products [9].

As the lucrative PAO market grew, some base oil manufacturers began using higher-V.I. feedstocks (usually byproducts from wax manufacturing) to make mineral oils with V.I.s that matched the PAOs. These new Group III oils were not manufactured from small molecules like traditional synthetics but they bridged most of the performance gap at a lower cost. Therefore, some lubricant manufacturers, primarily in Europe, began replacing PAOs with these newly available Group III base oils in their “synthetic” engine oils. This created a controversy in the lubricants industry as some synthetic base oil producers and lubricant manufacturers believed that polymerized base oils were the only true synthetics.

The trend toward globalized lubricant specifications and worldwide OEM specifications is now creating more demand for Group III base oils in North America and other continents as well. This is particularly true in North America due to the recent ruling by the National Advertising Department of the Better Business Bureau that Group III base oils can be considered “synthetic” and because modern Group III base

oils, made using hydroisomerization technology, have most of the attractive performance features of early synthetics.

### **Group III Versus PAO Performance**

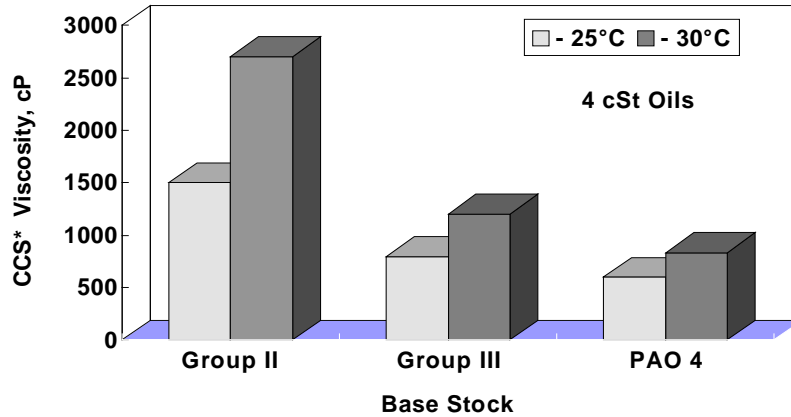
Historically, PAOs have had superior lubricating performance characteristics such as V.I., pour point, volatility, and oxidation stability that could not be achieved with conventional mineral oils. Now, in modern base oil manufacturing, V.I., pour point, volatility, and oxidation stability can be independently controlled. Modern Group III oils today can be designed and manufactured so that their performance closely matches PAOs in most commercially significant finished lube applications.

As well-designed Group III base oils become abundant in the marketplace, the performance gap between Group III and PAO (Group IV) is closing. Here are some key examples:

*Pour Point* – Pour point is the one property where Group III oils allegedly fall short of PAO. While it is certainly true that the pour point of the neat Group III base oil is substantially higher than that of a PAO of comparable viscosity, it is important to understand that the pour point of the fully formulated lubricant (base oils plus additives) is the critical property. Base oils manufactured with modern isomerization catalysts respond very well to pour point depressant additives. For example, turbine oils formulated with conventional Group II base oils (-12°C base oil pour point) are available with a formulated pour point of -36°C. Fully formulated Group III based lubricants can be made with pour points of -50°C or below.

Products such as motor oils made with the lighter-grade PAOs, on the other hand, typically have *higher* pour points than the base fluid, so the gap in final product pour point between PAO-based and UCBO-based lubricants is much smaller than in the base fluids themselves. Moreover, it is entirely possible with modern Group III manufacturing technology to produce base oils of even lower pour point. However, this is not common practice in the industry, because it is more economical to meet finished lube low temperature performance using pour point depressant additives rather than using special Group III oils having exceptionally low pour points.

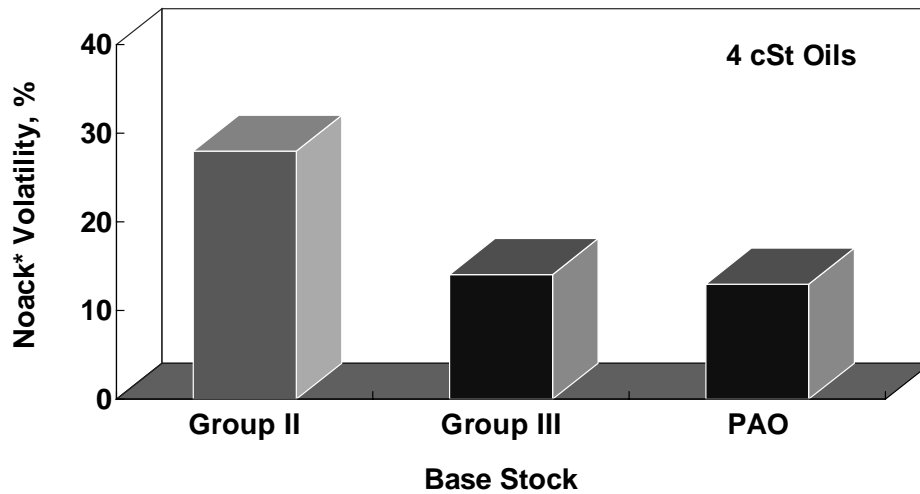
*Cold Crank Simulator* – Viscosity in engine journal bearings during cold temperature startup is a key factor in determining the lowest temperature at which an engine will start. Cold Cranking Simulator (CCS) viscosity, as measured by ASTM Method D 5293, is determined under conditions similar to those experienced in engine bearings during starting. For base oils, this viscosity is determined almost entirely by viscosity and V.I. Since Group III stocks typically have V.I. comparable to that of 4 cSt PAO, one would expect comparable CCS performance. This is demonstrated in Figure 3, where it can be seen that a 4 cSt Group III base oil, with a kinematic viscosity of 4.2 cSt at 100°C and a V.I. of 129, and PAO 4, with a viscosity of 3.9 cSt and V.I. of 123, have similar CCS values, both about half that of a 4 cSt Group II base stock of about 100 V.I. This performance makes the Group III stock very effective for formulating fuel-efficient multi-viscosity engine oils in the 0W-20 to 0W-50 range, one that has historically been achieved only with PAO-based product.



**\*ASTM D 5293**

Figure 3 – Cold Cranking Performance, Group III Comparable to PAO

*Noack Volatility* – Noack volatility of an engine oil, as measured by ASTM D 5800 and similar methods, has been found to correlate with oil consumption in passenger car engines. Strict requirements for low volatility are important aspects of several recent and upcoming engine oil specifications, such as ACEA A-3 and B-3 in Europe and ILSAC GF-3 in North America. Figure 4 shows that from a blender’s perspective, Group III base oils are similarly effective as PAOs for achieving these low volatility requirements in engine oil applications. The V.I. of modern Group III oils typically match or exceed PAO, so they can match the volatility of PAOs at a reasonable distillation cut width.



**\*ASTM D 5800**

Figure 4 – Group III Performance Versus PAO, Comparable Noack Volatility

*Oxidation Stability* – Oxidation and thermal stability are among the most important advantages that “synthetics” bring to the table. Better base oil stability means better additive stability and longer life. High stability is the key to making the premium-

quality finished oils of the future with longer drain intervals. Here Group III oils routinely challenge PAO performance.

The stability of modern Group III stocks depends mostly on their V.I., because V.I. is an indication of the fraction of highly stable isoparaffinic structures in the base oil [10]. However, because modern Group III stocks also undergo additional severe hydrofinishing after hydrocracking and hydroisomerization, they achieve an additional boost in stability because only trace amounts of aromatics and other impurities remain in the finished stocks. On the other hand, PAO performance seems to depend largely on residual olefin content. Olefins are an intermediate in PAO production that contribute to instability.

Figure 5 illustrates that base oil quality can have a big impact on the oxidation stability in turbine oils. The Turbine Oil Stability Test (TOST), or ASTM D 943, measures the time required for a turbine oil to oxidize to the point where the total acid number reaches 2.0 mg KOH/g. Unadditized Group I base oil fails in about 200 hours. A modern high-quality turbine oil formulated with Group I base oil typically fails in less than 7000 hours. A high-quality Group II formulated oil can run more than twice as long before it fails.

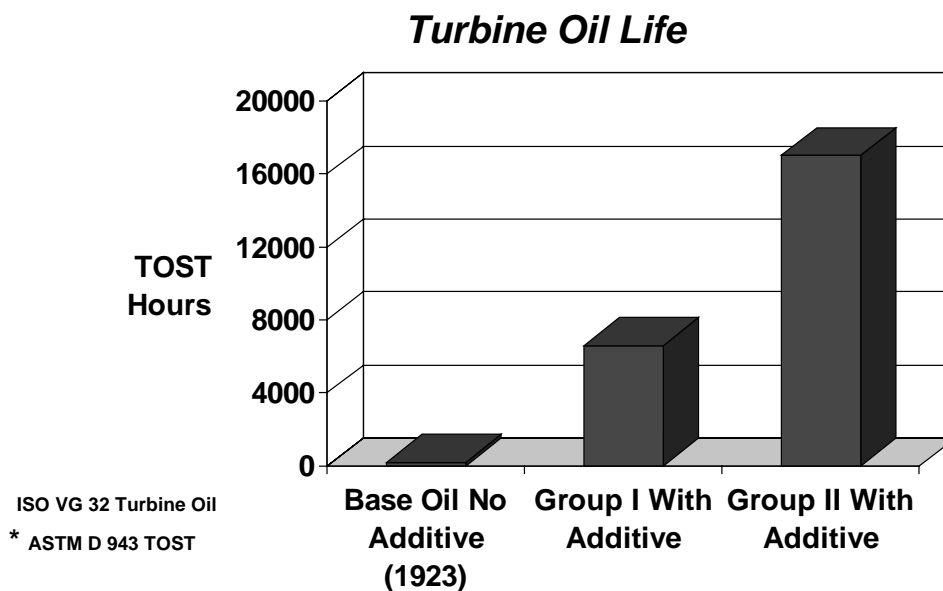
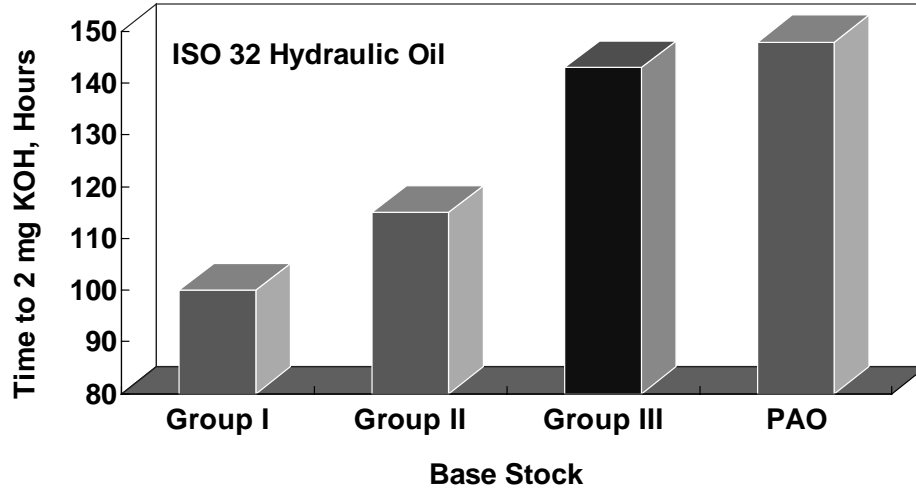


Figure 5 – Higher Base Oil Quality Extends Turbine Oil Life

The benefit of all-hydroprocessed Group III base oils in oxidation stability is illustrated in Figure 6 for hydraulic oils formulated by using the same additive system in four different base oils. Here, the time required to reach an acid number of 2.0 (defined by neutralization of 2.0 mg of KOH/g of oil) in the Universal Oxidation Test (ASTM D 4871), a common measure of oil oxidation, was substantially longer for the Group III formulation than for either the Group I or II products. Moreover, the performance of the Group III product was essentially the same as that for the oil formulated with PAO.



Universal Oxidation Test, ASTM D 4871, at 170°C

Figure 6 – Oxidation Stability, Acid Number in Hydraulic Oils

Table 2 lists a variety of North American lubricants which are based upon all-hydroprocessed Group III base stocks. These products include engine oils, industrial oils, and driveline fluids, and are targeted at the same performance levels achieved by traditional synthetic formulations.

Table 2 - Synthetic Quality Products Utilizing All-Hydroprocessed Group III Base Stocks

Available Now	Upcoming
Semi and Full Synthetic PCMO	GF-3 PCMO (Semi and Full Synthetic)
Semi-Synthetic HDMO	Extended Drain Gear Oil
DaimlerChrysler ATF+4®	High Performance Automotive (Racing) Oils
Ford Mercon® V ATF	Motor Oils
Compressor Oil	Gear and Transmission Oils

### Future Evolution

Looking to the future, the trend is toward lubricants and base oils with even higher purity, lower volatility, and longer life. The molecular structure of base oils will probably look even more like PAO as they become more concentrated in the most favorable molecular species needed for superior lubrication performance. It is likely that recent and ongoing developments in base oil technology will enable lubricants with exceptional performance to be marketed in much greater volumes than was feasible when PAO was the only stock capable of such performance levels.

There are many possible routes for improving base oil quality. Continued evolution of the all-hydroprocessing route is one likely possibility. Selectivity toward desired molecular compositions could be improved by improving the catalysts and the

processing technology. Improving the feedstock can also improve the product. Very paraffinic (waxy) feedstocks such as Fischer-Tropsch wax from natural gas-to-liquids plants can potentially be further processed into high quality base oils. Volumes and applications are expected to grow, as ultra-waxy feedstocks become more widely available.

Other competing technologies are likely to emerge. New routes for manufacturing PAOs have been proposed that use cheaper feedstocks such as ethylene and propylene rather than 1-decene [11].

Future improvements in base oil technology will assuredly lead to further improvements in the performance of turbine oils and other sensitive applications with low additive treat rates.

## **Conclusions**

Lubrication technology evolved slowly from ancient times until the middle of the 20<sup>th</sup> century. Then solvent refining technology emerged and displaced naturally occurring petroleum distillates due to its improved refined properties. Starting in the 1960s, hydroprocessing technologies were introduced which improved base oil purity and performance further. In the 1970s and 1980s, Group II base oils were manufactured and recognized as a separate API category in 1993, due to their positive differentiation over conventional stocks. Modern hydroisomerization technologies, such as ISODEWAXING, became widely accepted and grew rapidly since it was first commercialized in 1993. Widespread licensing of this technology has created an abundant supply of Group II oils that have exceptional stability and low temperature performance relative to their Group I and Group II predecessors. This technology is now used to make about one-third of all base oils in North America.

A similar trend appears to be emerging with Group III base oils, especially those made using modern hydroisomerization. They offer most of the performance advantages of traditional PAO-based “synthetic” oils and can be manufactured in volumes unachievable by PAO. Most manufacturers of modern Group II base oils can make modern Group III base oils as well.

Selected top-tier lubricants requiring PAO should continue to coexist with Group III oils as they have for years in Europe. But widespread availability of modern Group II and III mineral oils is accelerating the rate of change in the finished oil markets. New improved base oils are helping the engine and equipment manufacturers meet increasing demands for better, cleaner lubricants. This is particularly true for turbine oils because turbine oils usually contain more than 99% base oil. Turbine oils made from hydroisomerized Group II base oils and the appropriate additives have demonstrated significantly longer TOST lives than turbine oils made with Group I base oils. In fact, they commonly outperform the traditional “synthetics” made with PAO.

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 currently can be achieved only in small-volume niche applications, using PAO and other specialty stocks, will be more widely available using the new generation of Group II and Group III oils.

## References

- [1] National Petroleum Refiners Association, "1999 Lubricating Oil and Wax Capacities of Refiners and Re-Refiners in the Western Hemisphere," January 1999.
- [2] Sequeira, A., Jr., "Lubricant Base Oil and Wax Processing," Marcel Dekker, Inc., Chemical Industries Series, August 1994.
- [3] Stormont, D. H., "New Process Has Big Possibilities," *The Oil and Gas Journal*, 57, 44, 1959, pp. 48-49.
- [4] Company release by Idemitsu Kosan Co, Imperial Chemical LTD, Shell Development Co, "First Lubricant-Oil Cracker," *Oil and Gas Journal*, June 12, 1972.
- [5] Zakarian, J. A., Robson, R. J., and Farrell, T. R., "All-Hydroprocessing Route for High-Viscosity Index Lubes," *Energy Progress*, 7, 1, 1987, pp. 59-64.
- [6] Wilson, M. W., Mueller, T. A., and Kraft, G. W., "Commercialization of Isodewaxing – A New Technology for Dewaxing to Manufacture High Quality Lube Base Stocks," FL-94-112, NPRA, November 1994.
- [7] Min, P. Y., "VHVI Base Oils: Supply and Demand," 4<sup>th</sup> Annual Fuels and Lubes Conference, Singapore, January 1998.
- [8] Howell, R. L., "Hydroprocessing Routes to Improved Base Oil Quality and Refining Economics," 6<sup>th</sup> Annual Fuels and Lubes Conference, Singapore, January 2000.
- [9] Bui, K., "Synthetics II," *Lubricants World*, November 1999.
- [10] Kramer, D. C., Ziemer, J. N., Cheng, M. T., Fry, C. E., Reynolds, R. N., Lok, B. K., Krug, R. R., and Sztenderowicz, M. L. "Influence of Group II and III Base Oil Composition on V.I and Oxidation Stability," AIChE Spring Meeting, March 1999.
- [11] Heilman, W. J., Chiu, I. C., and Chien, J. C. W., "New Polyalphaolefin Base Oil," American Chemical Society Meeting, New Orleans, August 1999.