

Understanding polyalkylene glycols

(and where to apply them)

By Wil Escobar

Their high VIs, low pour points, high-temperature stability and biodegradability make these synthetics the lubricant of choice for many industrial applications.

Lubricant sales have been on a bumpy ride and will continue on this rocky course for the foreseeable future. According to a previous TLT article,¹ growth for mineral-based lubricants has

been flat or declining for the past decade and a half.

Synthetics, on the other hand, have been showing positive growth, with many experts predicting more of the same. Case in point: Synthetics in 2006 comprised between 3.0% and 3.8% of the total global lubricants market. Although the exact percentage growth varies from source to source, experts agree synthetics are growing and will continue to do so through 2012.

Polyalkylene glycols (PAGs) represent about 24% of the total synthetic lubricant market worldwide.³ Despite a highly competitive global lubricants marketplace and corporate initiatives to reduce overall costs, PAGs are poised to appeal and grow once their distinctive lubricating properties and their applications are understood.

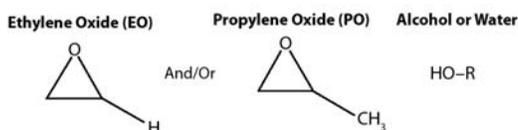
What is a synthetic?

Caltex, a subsidiary of Chevron Corp., defines a synthetic lubricant as one “made chemically by reacting materials of a specific chemical composition to produce a compound with planned and predictable physical and chemical properties.”⁴ Although synthetic lubricants all come to share the same definition, they differ significantly in their chemical structure, manufacturing and performance properties. To better understand how PAGs are made, we will need to don our chemistry hats for just a moment.

How PAGs are made

PAGs are manufactured by combining ethylene oxide (EO) and/or propylene oxide (PO) with a nucleophilic starter such as an alcohol or even water. The following example, as shown in Figure 1, helps illustrate this:

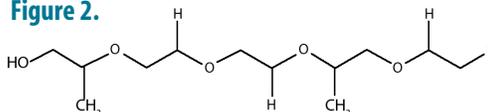
Figure 1.



Though PAGs are typically copolymers of ethylene oxide and propylene oxide, they also can be manufactured from the polymerization of any alkylene oxide. Their distinctive chemistry, due to the various combinations of raw materials, allows formulators to design a wide range of polymeric structures, viscosities and functionalities. In other words, different percentage mixtures of EO and PO produce unique performance properties not achievable with other synthetic lubricants (i.e., PAOs or Group III).⁷

Formulators, therefore, are able to customize formulations based on a customer's specific needs and/or applications. Examples of a copolymer's flexibility are the viscosities available, which range from a very light 5 cSt oil all the way to as high as a 250,000 cSt. Figure 2 shows a visual representation of a water-soluble random copolymer (EO/PO).

Figure 2.



Random Co-Polymer Water Soluble Lubricants

A mixing ratio of EO/PO = 50/50 or 60/40 produces water-soluble polymers. The reason for blending a mixed copolymer (EO/PO) is the increase in polarity, which lends to the product's “pseudo EP effect.” As a result, antiwear (AW) and extreme pressure (EP) additives, which are present in high amounts in certain hydrocarbon gear oils, can be kept low in PAGs. One benefit to low additive levels is resistance to micropitting.

Case in point: Experiments have shown EP additives to be chemically aggressive, which may promote micropitting. STLE member Robert Errichello, president of Geartech, a gear design consulting firm, in Townsend, Mont., claims oils without anti-suff (EP) have maximum resistance to micropitting.⁵ Dr. Andy Olver, professor of

Article highlights:

■ *Evaluating the manufacturing process of polyalkylene glycols.*

■ *Consider three PAG weaknesses before selecting for your application.*

■ *Seven steps to switching mineral-based lubricants to PAGs.*

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mechanical engineering at Imperial College in London, states, "While EP oils will improve resistance to scuffing, the EP additives react with the tooth surface, reducing the fatigue life of the gear teeth surface."²

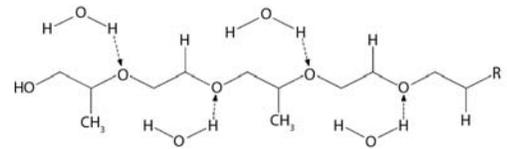
Consequently, PAGs may be beneficial in applications where micropitting is an issue. In addition to its pseudo-EP effect, copolymers of EO and PO are hygroscopic, which means they can absorb moisture from the environment. When left standing they can absorb up to 1% or 10,000 ppm of water. The reason they absorb moisture is the oxygen content in their chemical structure, which allows for high degrees of hydrogen bonding. The following graph, as shown in Figure 3, shows the effect of water on a PAG.

Under normal operating conditions, the water content drops down to levels between 1,000-3,000 ppm.

That said, the water content in PAGs will not deplete bearing life nor increase corrosion since it is not free water. In fact, extensive testing has shown no diminished performance for PAGs with water levels up to 1%.

If 1% water is impressive, consider the results Londonderry, N.H.-based Klüber Lubrication North America L.P. found when it tested its PAG with up to 5% water. According to the following graph (see Figure 4), provided by Klüber, cage wear reduced to less than 19 mg with 5% water vs. 30 mg with 1% water content. The results, at least in this example, contradict what most

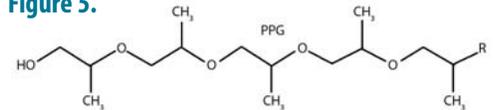
Figure 3.



of us have been taught, which is the more water in your lubricant the less wear protection for your equipment.

PAGs also come in water-insoluble form. For example, propylene oxide homo-polymers are the opposite of water-soluble copolymers (EO/PO). Unlike copolymers, PAGs have a limited viscosity range of 15-680 cSt at 40 C. Figure 5 shows the chemical structure of a water-insoluble PAG:

Figure 5.



Viscosity index

One important attribute of any oil is its viscosity index (VI). As defined by STLE's *The Basic Handbook of Lubrication, Second Edition*,⁸ VI is "an empirical, unit-less number indicating the effect of temperature on the kinematic viscosity of an oil." It should be understood that as the temperature goes up in a lubricant, viscosity goes down. High VI oils should, theoretically, be less affected with temperature fluctuations.

For certain applications, a stable lubricant film is critical in order to minimize wear and extend the equipment's operating life. A high VI is, therefore, critical since viscosity is one of the most important properties of a lubricant. Figure 6 shows typical VIs for three different base oil types:

Figure 4.

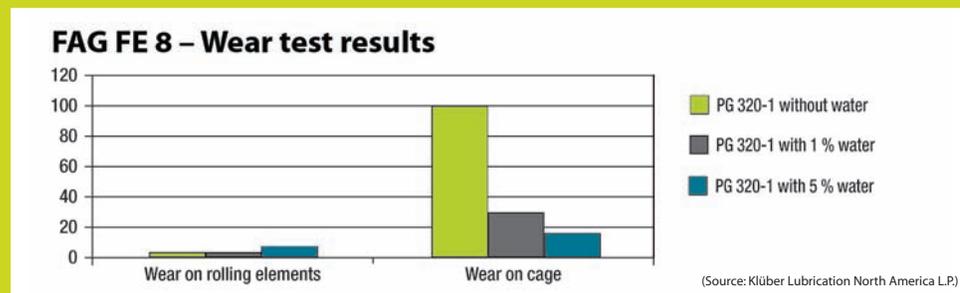


Figure 6.

	Mineral Oil EP ISO 150	PAO Oil EP ISO 150	PAG EP ISO 150
Viscosity index	100	150	232

As Figure 7 illustrates, at low temperatures PAGs do not thicken as much as other common basestocks, and at high temperatures they do not thin down as much. PAGs provide higher viscosity and greater film strength at elevated temperatures, making them ideal for applications where maintaining a lubricant film is critical. For example, cement kilns, the dry ends of paper machines, steel and aluminum calendar roller bearings and ore crushers are applications where PAGs would perform well.

High-temperature stability

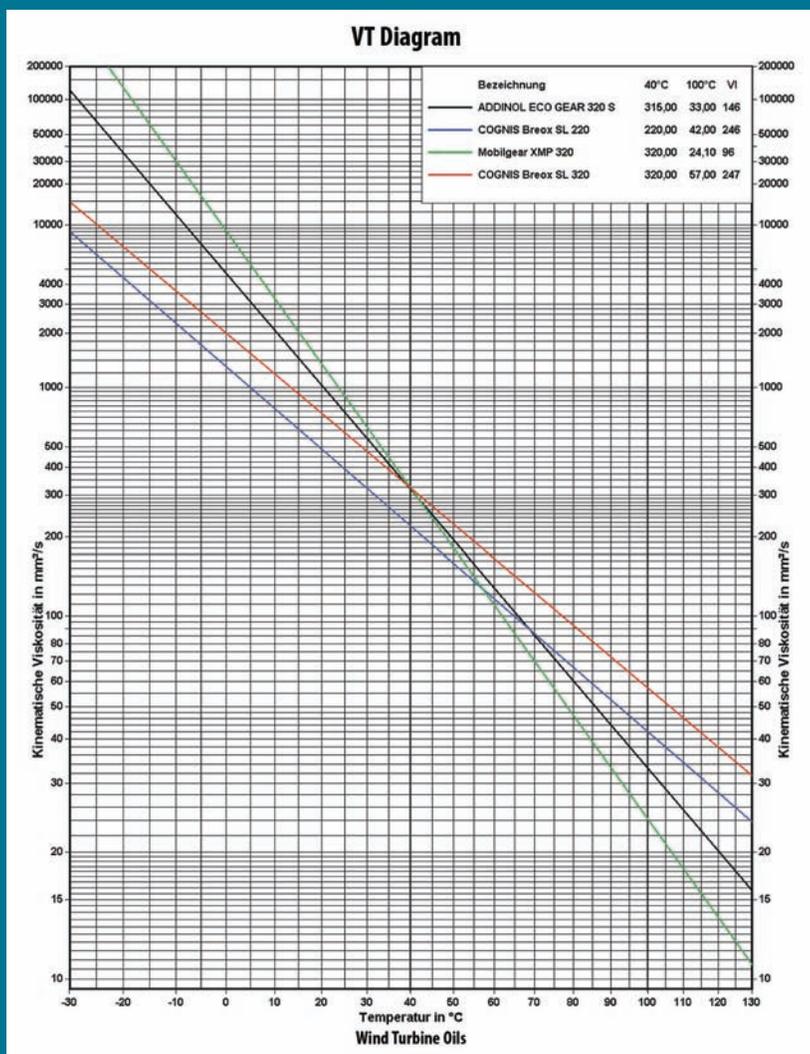
Varnish is a death sentence for any equipment wanting to operate at peak efficiency. It can run havoc on heat transfer systems, servo valves and many other applications.

Oxidation is, according to Nguyen Truong, technical consultant at Noria Corp. in Tulsa, Okla., the “root cause of varnish formation.”⁹ One clear advantage of a PAG is its ability to hold polar oxidation products in solution, thus preventing sludge and varnish from developing. Additionally, PAGs demonstrate superior stability to high shear environments, alkalis, heat and acids.

Energy savings

Energy, no matter its origin or how it's produced, is finite and is becoming more expensive. As energy sources dry up and/or become more difficult to extract, companies, nations and individuals must take steps to reduce and conserve its use. Industry could benefit by understanding how

Figure 7.

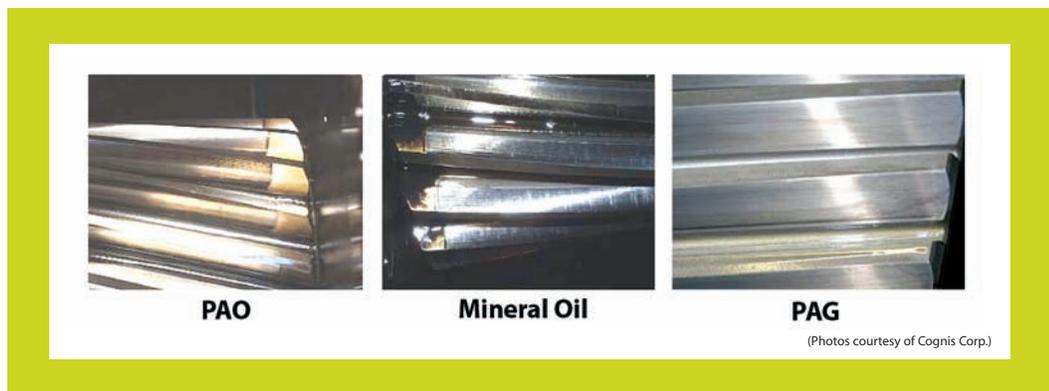


PAGs can help reduce energy usage.

For example, worm gears are quite common in industry and are used mainly where large gear reductions are necessary. The challenge with worm gears is that there is a lot of sliding motion in their design, which makes them inefficient energy users. What makes PAGs good for energy savings are their low coefficient of friction, which stud-

CONTINUED ON PAGE 38

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ies have shown can help improve efficiency in worm gears by as much as 15%.⁶ Other benefits are lower equipment operating temperatures, longer equipment life and a reduction in waste as a result of their long oxidation life.

Pour point

Equipment operating at very low temperatures need oil that flows quickly to lubricate moving parts. Hydraulic equipment operating in Arctic weather conditions, for example, require such a lubricant. Certain viscosity PAGs have pour points of -50 C. Additionally, PAGs are wax-free and do not require pour point depressants.

Biodegradable/food grade

As mentioned previously, PAG chemistry is flexible, allowing formulators to custom blend products depending on the application. Case in point: Biodegradable PAGs often are required for industries such as in agriculture, forestry, marine, offshore and mining. Some PAG lubricants are also food-grade accredited, a requirement for food manufacturers where the possibility of contact with food is possible.

PAG weaknesses

Most, if not all, lubricants have certain characteristics or weaknesses that must be considered before they are selected for an application. PAGs exhibit the following three weaknesses:

1. Conversion from a hydrocarbon oil to a PAG requires adherence to careful cleaning procedures.
2. PAGs may affect rubber, cork or leather seals.
3. PAGs, in general, are not compatible with phenolic or alkyd paints.

Application considerations

It should be clear that PAGs are intended only for certain applications where other lubricants do not perform as well. If the application does warrant a PAG, two items must be addressed prior to switching.

First, although PAGs are fully compatible with epoxy paints, care should be taken with phenolic paints. Consult the OEM on whether the equipment contains phenolic paints. Second, PAGs are compatible with most seal materials, but be careful with some of the older outdated materials such as rubber, cork and leather, which may be affected by PAGs.

Flushing procedure

Once the questions on internal paints and seals have been satisfactorily addressed, the following steps are needed to switch from a mineral-based lubricant to a PAG:

1. Run the equipment until it reaches operating temperature.
2. Immediately after shutting down, drain the sump and any "low spots" as much as possible.
3. Remove the filter element.
4. Refill the sump with the correct amount of PAG.
5. Run the equipment until it reaches operating temperature.
6. Drain out the reservoir after the equipment is shut off.
7. Replace the filters and refill with the correct amount of PAG.

Note: Because of their incompatibility with mineral oils, PAGs need to be segregated before being disposed.

Conclusion

As newer equipment becomes smaller and more powerful, demands on the lubricant rise significantly. Further, environmental concerns coupled with higher energy costs are pressuring lubricant manufacturers to blend products to address these challenges.

For these reasons PAGs, with their high VIs, high-temperature stability, energy savings potential, low pour points and biodegradability, are in a position to meet some of these demands now and far into the future.

Acknowledgment

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PAGs are manufactured by combining ethylene oxide and/or propylene oxide with a nucleophilic starter such as an alcohol or even water.

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