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# Oil Soluble Polyalkylene Glycols

## Abstract
The lubricant industry has a history of innovation spanning more than a century. Recently a new range of API Group V base oils, called oil soluble polyalkylene glycols (OSP), has been introduced. Unlike conventional polyalkylene glycols (PAG), the new OSPs can enhance the properties of existing hydrocarbon oils by providing a range of functionalities. This article will briefly describe OSPs, highlight some of these functionalities and also illustrate their practical benefits for use in synthetic gear oils as a selected application to illustrate their multi-functionality. Research in this area is still new but formulators and equipment builders now have another tool for solving some of their tribology and lubrication challenges.

## Introduction
Most lubricants in use today are derived from API Group I-III base oils as the dominant formulation component. However for some applications and equipment, semi-synthetic or indeed full synthetic lubricants are needed to provide a desired functional performance. These lubricants often comprise an API Group IV (polyalphaolefin) or a Group V base oil in which they are used as primary or co-base oils in formulations. Group V base oils include several classes of products such as synthetic esters, alkylated naphthalenes and phosphate esters. These are often polar materials with lower aniline points than classical mineral base oils and offer a plurality of functionalities some of which can include good film forming behaviour, high solvency power and cleanliness features, anti-wear and extreme pressure properties and so on. Many of these materials are used as co-base oils in hydrocarbon oils to enhance their performance or as performance enhancing additives.

Polyalkylene glycols are another class of Group V base oil. They were first invented in the 1940s and are used in many niche applications such as worm gear lubricants, rotary screw air compressors, reciprocating gas compressors, anhydrous hydraulic fluids [1, 2] and more recently gas turbine oils [3]. In these applications they demonstrate excellent deposit control, good thermo-oxidative stability and fluid longevity, and offer excellent friction control for improving energy efficiency of equipment. PAGs are also used as additives in water based lubricants and functional fluids such as metal cutting fluids, fire resistant water glycol hydraulic fluids and quenchants. However unlike other Group V base oils, their use as additives to boost the performance of hydrocarbon oils has not been possible in the past simply because they have a low hydrocarbon oil solubility. The majority of polyalkylene glycols used today in lubricants are derived from downstream derivatives of ethylene oxide and/or propylene oxide. Recent research has shown that butylene oxide and its combination with other oxides can lead to oil soluble polyalkylene glycols (OSP) and if carefully designed, these polymers can offer many of the excellent functional properties of traditional PAGs and provide formulators with a new building block for solving problems that may not be possible with existing technologies.

Research into the functional performance of OSPs is still in its infancy but in the past three years some unique features and benefits have been discovered. This article will explain more about OSPs and some of their key functionalities. It will have a special focus on gear oils and particularly their unique air release properties. In recent feature articles in "Lube" magazine [4, 5] the importance of fast air release for lubricants in some types of equipment has been discussed and this article builds on that theme.

## Aspects of Oil Soluble PAGs
The oil soluble polyalkylene glycols in use today span a wide range of molecular weights and viscosities. Table 1 provides an overview of some of their key properties. Since there is a high degree of flexibility in designing OSPs, it is possible to extend this range and build polymers with even lower or higher molecular weights and functionalities. The polymers range from the classical ISO-32 through to ISO-680 viscosity grades. The lowest viscosity polymer, OSP-18, has a kinematic viscosity of 4mm2/sec at 100°C which is similar to a classical PAO-4 base oil. Their viscosity indices range from 123 to 196.

| | Method | OSP-18 | OSP-32 | OSP-46 | OSP-68 | OSP-150 | OSP-220 | OSP-320 | OSP-460 | OSP-680 |
|---|---|---|---|---|---|---|---|---|---|---|
| Kin. viscosity at 40°C, $mm^2/sec$ | ASTM D445 | 18 | 32 | 46 | 68 | 150 | 220 | 320 | 460 | 680 |
| Kin. viscosity at 100°C, $mm^2/sec$ | ASTM D445 | 4.0 | 6.4 | 8.5 | 11.5 | 23.5 | 33 | 36 | 52 | 77 |
| Viscosity Index | ASTM D2270 | 123 | 146 | 164 | 166 | 188 | 196 | 163 | 177 | 196 |
| Pour point, °C | ASTM D97 | -41 | -57 | -57 | -53 | -37 | -34 | -37 | -35 | -30 |
| Fire point, °C | ASTM D92 | 220 | 242 | 240 | 258 | 258 | 258 | 260 | 265 | 270 |
| Density at 25°C, g/ml | ASTM D7042 | 0.92 | 0.94 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| Aniline point, °C | ASTM D611 | <-30 | <-30 | <-30 | <-30 | <-30 | -26 | n/d | n/d | n/d |

*Table 1. Typical physical properties of Oil Soluble Polyalkylene Glycols (OSP).*