Polyalkylene glycols (PAG) have been around for years in brake fluids, automotive AC compressor lubes, water based hydraulic fluids, synthetic MWF and water based quench fluids.

New PAG have OTMOL (oil tolerant) and OSMOL (oil soluble) technology.

OTMOL and OSMOL greatly expand PAG applications.
DOT Brake Fluids

DOT does not allow mineral oil based hydraulic brake fluids for automobiles and trucks.

Only non-varnish forming silicone and water miscible EO/PO PAG are capable of surviving the harsh high temperatures of repeated braking friction.

Hydroscopic DOT 4
Innovation

- Dow oil miscible and soluble PAG are products that will produce *discontinuous* innovations.

- These polyalkylene glycols are *once in a generation* technology leaps.

PAG Structure
– EO/PO only
Mineral Oil Soluble Polyalkylene glycols

Ethylene oxide:
- Highest O/C ratio
- Water soluble
- Solid products
- High MW

Propylene oxide:
- Limited oil solubility
- Low pour point
- Liquid products

Octene oxide:
- Lowest O/C ratio
- Fully oil soluble
- Low pour point
- Liquid products

Butylene oxide:
- Water insoluble
- Oil soluble
- Liquid products
PAG Greatest Benefits

- No varnish formation
- Can be blended 50:50 with mineral oil to practically eliminate varnish – clean gears
- Blends are lower cost; only ~3X over conventional base stocks compared to full PAO synthetics at 5X
Oxidation of PAGs – Ether Oxidation

Like all organics, PAG’s can oxidize under high temp. operations

Oxidation by-products include aldehydes, ketones, low mol weight acids

Oxidation by-products are SOLUBLE in the base oil & unlike mineral oils DO NOT FORM DEPOSITS AND VARNISH – key benefit of PAGs
Inherent Lubrication

- Shell 4 Ball Wear gives an average of 0.5 mm wear scar for base PAG fluid without any additives
- In contrast, mineral oils and PAO have 4 Ball Wear scars of greater 1.3 mm if no additives are present
Case Study

Papermaking machines expose about 1,500 different bearings to harsh conditions including water, heat, steam and paper dust. ST Paper had previously had poor results with PAO and older hydroscopic PAG fluids.
Paper Mill

Headbox | Wire section | Press | Drying | Calender | Reel

Fibre-suspension on an endless wire | Pressing cylinders | Heating cylinders | Paper is cooled, smoothed and rolled

Beloit Corp

50% Water → Dry Paper
Mill Environment

Paper mill oil lubricates the gears, bearings and hydraulics

- High heat due to drying of pulp (135F)
- Very steamy – oppressive humidity
- Paper shards – cellulose fibers everywhere
- Small sump size (2,000 gallons)

All conditions very hard on any lubricant
Mill Decision makers are Reliability Engineer and Maintenance staff

-Keep the mill running-
Bearing Lubrication

The OSP based paper machine lube ISO 320 is used to lubricant the Yankee dryer bearings on either side. These bearings are subjected to high load and high temperatures with replacement costs of over $40,000 each. Up time is critical for profits (or loss).
Problem: Dry Bearings and Gear Boxes

Automatic lubricators have floats that stick on causing a false full reading due to varnish.
Varnish is the Enemy
Cascade of Failure

- Mineral oils oxidize and polymerize under heat and pressure in air.
- Polymerized varnish is sticky and attracts dirt
- The dirt imbedded in varnish causes wear much like abrasive glued to paper.

**Principle Causes of Bearing Failure**

- Insufficient Lubrication, 22%
- Solid Contamination, 33%
- Unsuitable Lubrication, 15%
- Liquid Contamination, 22%
- Mounting & Misalignment, 5%
- Manufacturing Defects, 1%
- Wrong Bearing, 2%
Floating Residual Varnish Clean Up

Not cellulose from paper

Not OSP paper machine lube

Floating varnish matches MO

Also confirmed by SEC, C13 NMR and Pyrolysis GC/MS
Chemtool Rockton, IL

Housed in old Beloit Corp Paper Machine manufacturing plant

Neighboring Paperchine Co. repairs old Beloit machines

Old Beloit paper drum
# HIGH TEMP HD GEAR OIL FOR ASPHALT COMPACTORS

## DESCRIPTION
- CURRENT: GROUP II
- POLYSYN: Polyalkylene Glycol
- BIO SYNTHETIC: 60% CANOLA 40% PAG

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CURRENT</th>
<th>POLYSYN</th>
<th>BIO SYNTHETIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESCRIPTION</td>
<td>GROUP II</td>
<td>Polyalkylene Glycol</td>
<td>60% CANOLA 40% PAG</td>
</tr>
<tr>
<td>VIS @ 40°C</td>
<td>198</td>
<td>194</td>
<td>195</td>
</tr>
<tr>
<td>VIS@ 100°C</td>
<td>26.2</td>
<td>31.2</td>
<td>27.8</td>
</tr>
<tr>
<td>VISCOSITY INDEX</td>
<td>164</td>
<td>205</td>
<td>181</td>
</tr>
<tr>
<td>SPECIFIC GRAVITY @ 60°F</td>
<td>0.870</td>
<td>0.920</td>
<td>0.920</td>
</tr>
<tr>
<td>POUR POINT °C</td>
<td>&lt; -20</td>
<td>&lt;-30</td>
<td>&lt;-30</td>
</tr>
</tbody>
</table>
Why OSP PAG?

- Inconsistent availability of PAO
- PAO base oil very, very sticky, tacky
  - Fines residues in machines, grease-like
- Better corrosion resistance than PAO
- OSP can be used as worm gears lubricants and also in the MWF used to machine worm gears
Base Stock Differences and Solvent Properties

- Petroleum oil and closely related synthetic polyalphaolefins (PAO) are non-polar.
- All additives such as detergents, pour point depressants, anti-wear and antioxidants are polar.
- “Like dissolves like” rule for solubility.
- OSP Polyalkylene Glycols are much more polar than oils. They do solvate their own oxidation by products.

<table>
<thead>
<tr>
<th>Oil</th>
<th>Aniline Point °C</th>
</tr>
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<tbody>
<tr>
<td>VHVI</td>
<td>110</td>
</tr>
<tr>
<td>Paraffinic oil</td>
<td>96</td>
</tr>
<tr>
<td>Naphthenic</td>
<td>71</td>
</tr>
<tr>
<td>PAO</td>
<td>161</td>
</tr>
<tr>
<td>TMP Ester</td>
<td>8.6</td>
</tr>
<tr>
<td>OSP (Oil Soluble PAG)</td>
<td>&lt; -30</td>
</tr>
</tbody>
</table>

Table 1: Solvating Power of OSP: Aniline Point ASTM D 611
# Base Fluid Performance Summary

<table>
<thead>
<tr>
<th>Property</th>
<th>Petroleum Oils</th>
<th>PAO Synthetic</th>
<th>Vegetable Oils</th>
<th>OSP PAG</th>
<th>OSP PAG / Vegetable Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temperature</td>
<td>Poor</td>
<td>Excellent</td>
<td>Very Poor</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>Poor</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>Additive Solubility</td>
<td>Poor</td>
<td>Very Poor</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Oxidation Resistance</td>
<td>Poor</td>
<td>Good</td>
<td>Very Poor</td>
<td>Excellent</td>
<td>Fair</td>
</tr>
</tbody>
</table>

OSP Polyalkylene Glycols (PAG) are best in overall performance.
Manual Transmissions and Rear Differentials Run Too Hot

Transmission coolers are expensive options
Anti-sludging properties are important in fluid drives.

Automatic transmission cases and valve bodies have strict mirror like micro-inch finish requirements for small tight reamed holes and fluid passages.
Summary

OSP excel in high temperature applications

Much lower hydroscopic tendency's that older EO/PO PAG

Compatible with most standard additive packages and seals

Higher density than other synthetic base fluids