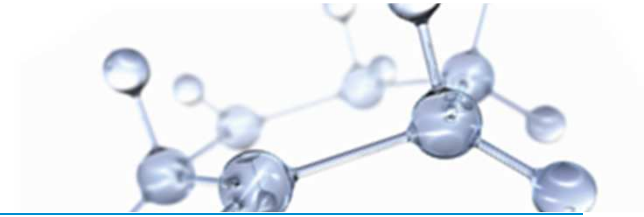

Group IV base stocks - PAO

UTS Seminar
St Petersburg Sept 13-15, 2011
Sandy Reid-Peters



ADVANCED
SYNTHETIC
BASE STOCKS | *Innovative
lubricants
start here*

Topics



- Polyalphaolefins (PAOs)
 - What are they?
 - How are they made?
 - Difference between metallocene and conventional PAO
- Key features of PAO & mPAO and how they compare to mineral oils
- Safety/Regulatory items
- Summary

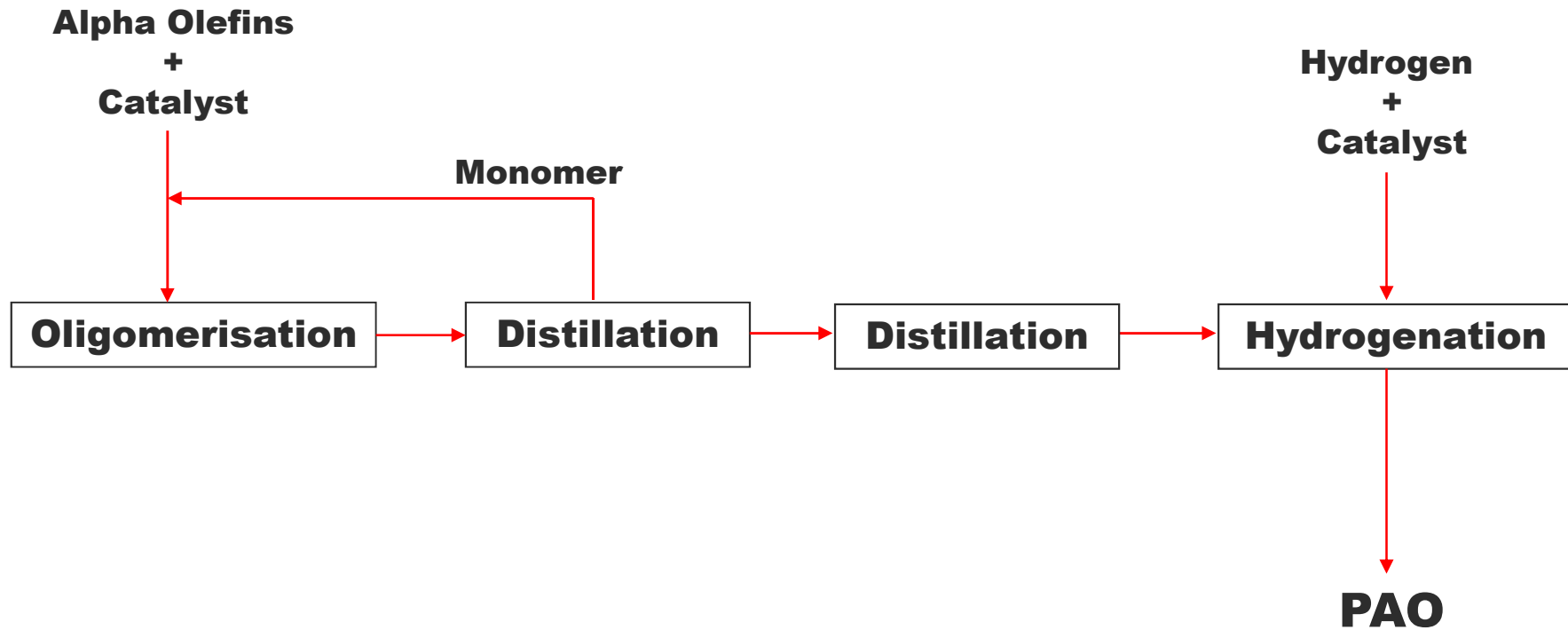
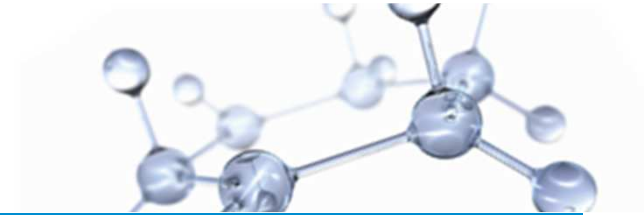
What are PolyAlphaOlefins (PAO)?



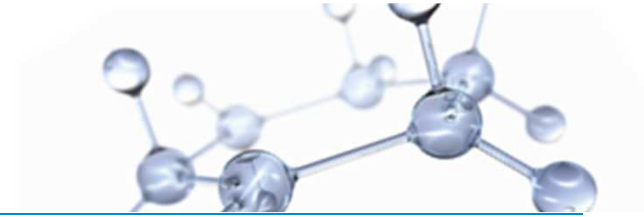
- Synthetic high performance base stocks
- Hydrogenated (saturated) olefin polymers
- Manufactured by the catalytic oligomerization of linear alpha olefins
- Wax-free combination of molecules of predetermined chain length

Polyalphaolefins have a well defined structure versus the multiple composition of a mineral oil

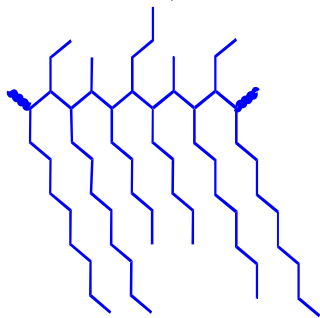
PAO manufacturing process



PAO molecular structure

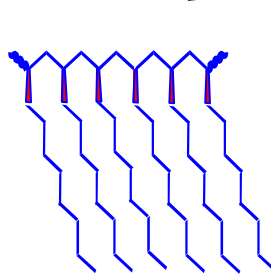


- Random distribution of short & long side-chains

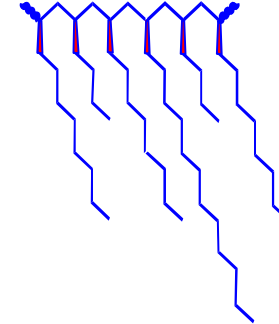


Conventional PAO

Uniform, comb-like structure with absence of short side chains



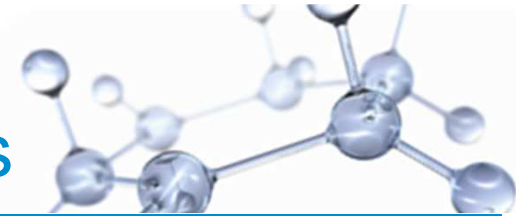
HVI PAO



Metallocene PAO

mPAO base stock builds on ExxonMobil's metallocene catalyst expertise

Characteristics of polyalphaolefins



The properties of PAOs that make them so useful are:

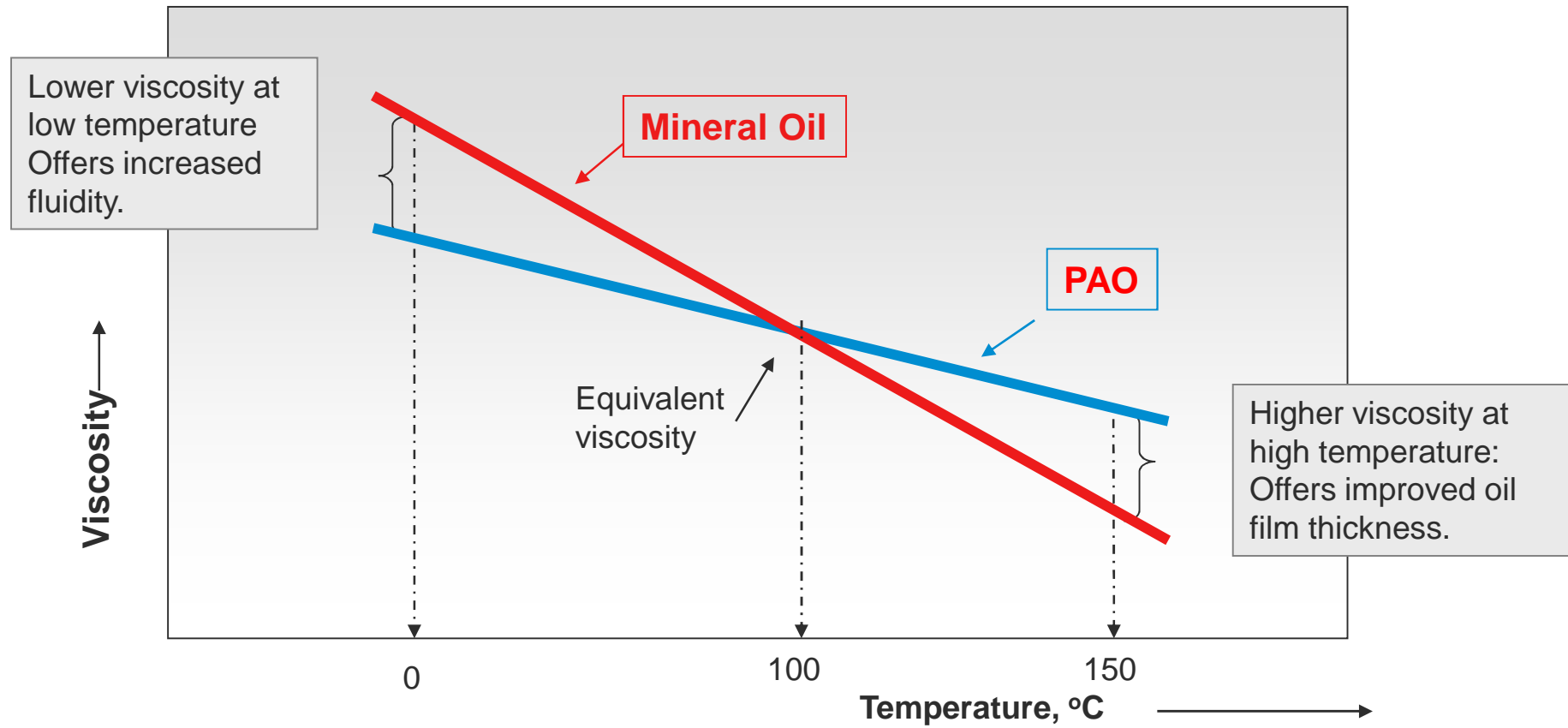
High viscosity index

- Low temperature fluidity
- Low volatility
- Good oxidative stability
- Good thermal stability
- Low traction force
- Low toxicity
- Compatibility with other oils & materials

Performance Advantages

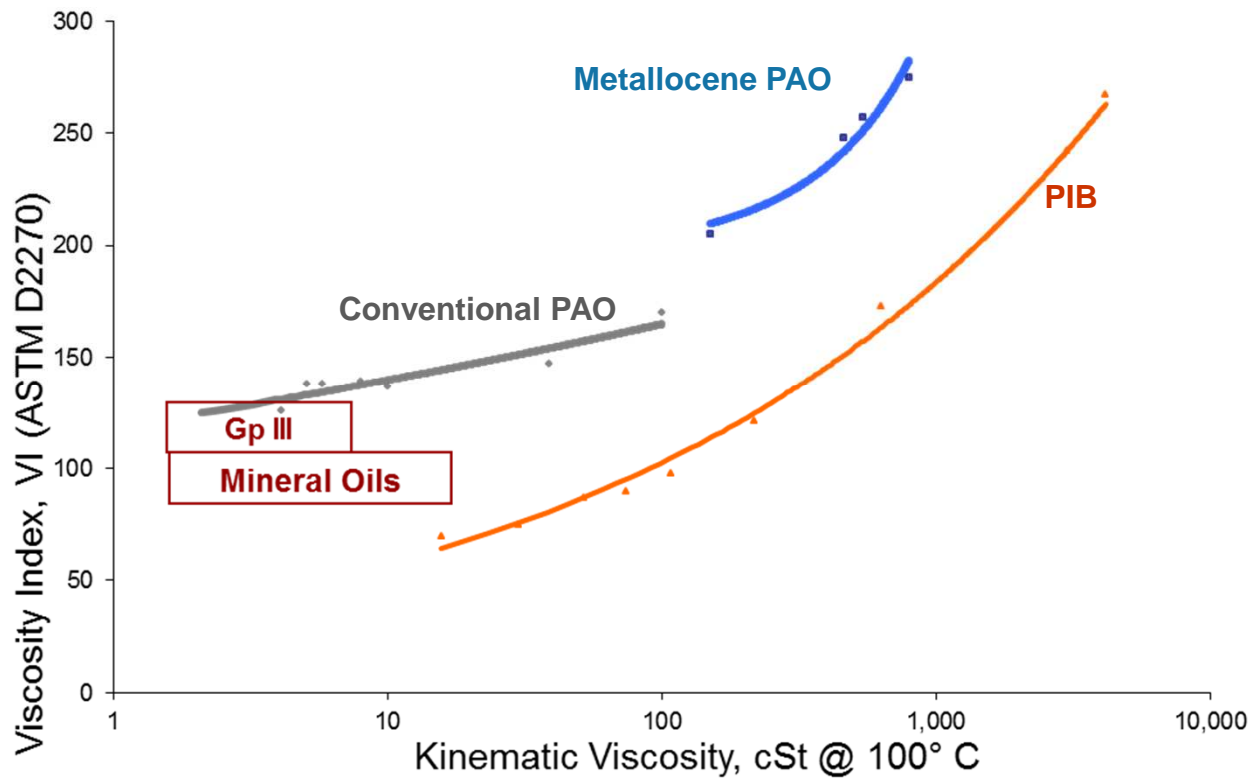
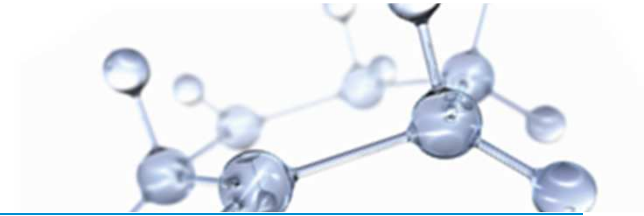
- Wide range of applications
- Wide operating temperature range
- Extended service life capability
- Lower maintenance costs
- Energy savings

Viscosity index



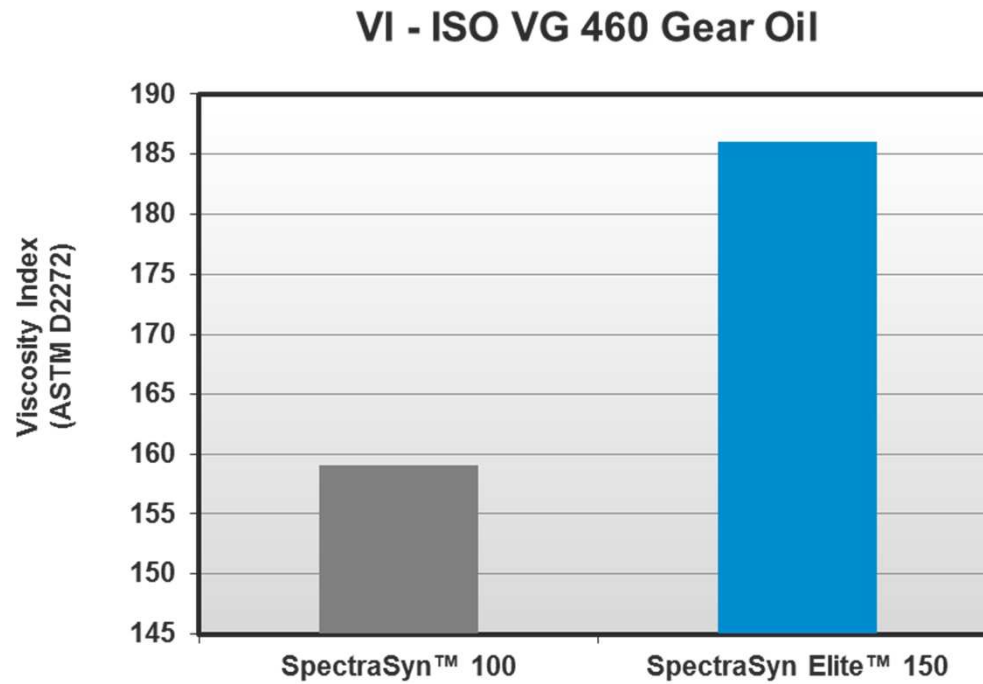
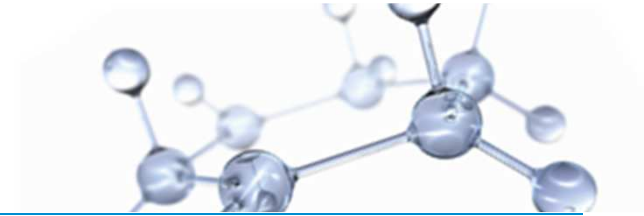
PAO's typically have a higher Viscosity index than mineral oils

Viscosity index



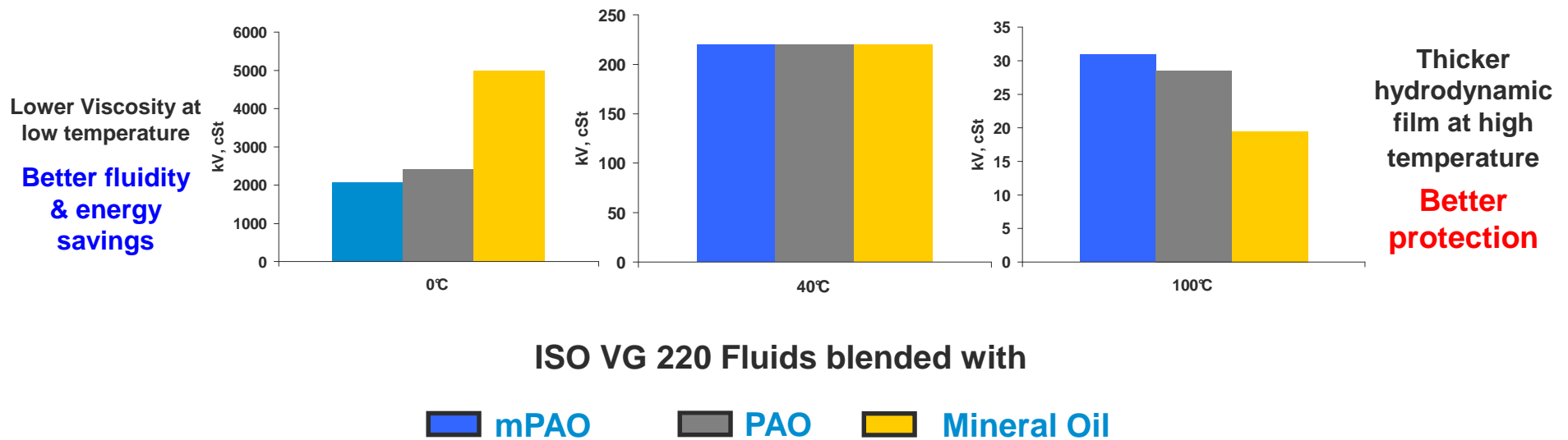
mPAO has a higher VI than conventional PAO's, mineral oils and PIB

Viscosity index



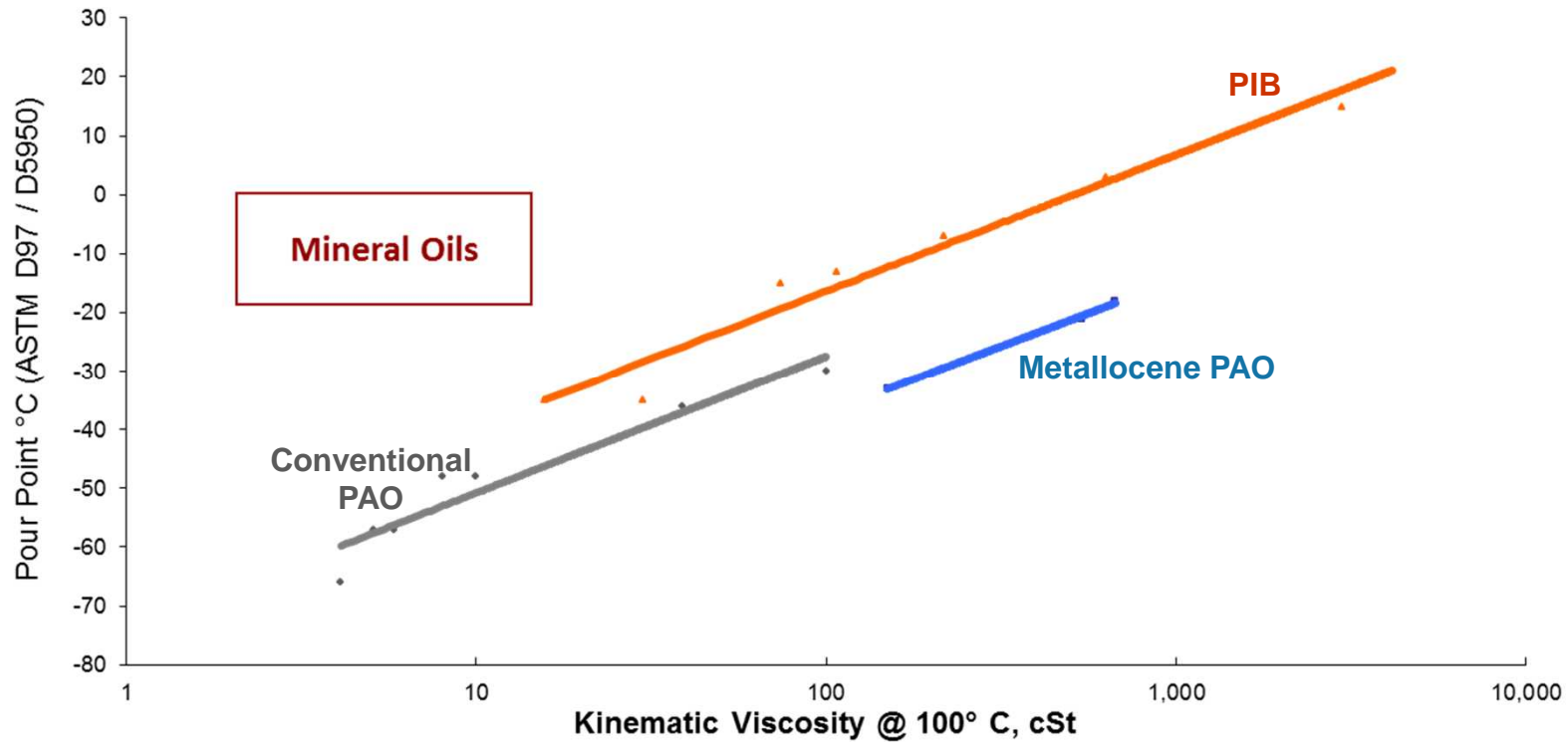
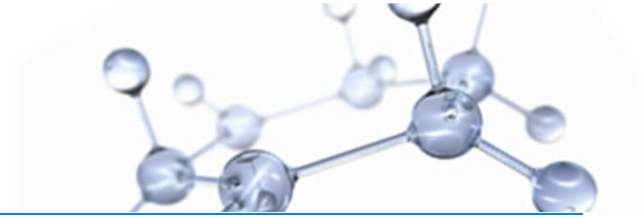
High viscosity mPAO provides improved VI when compared to conventional PAO

Benefits of high viscosity index



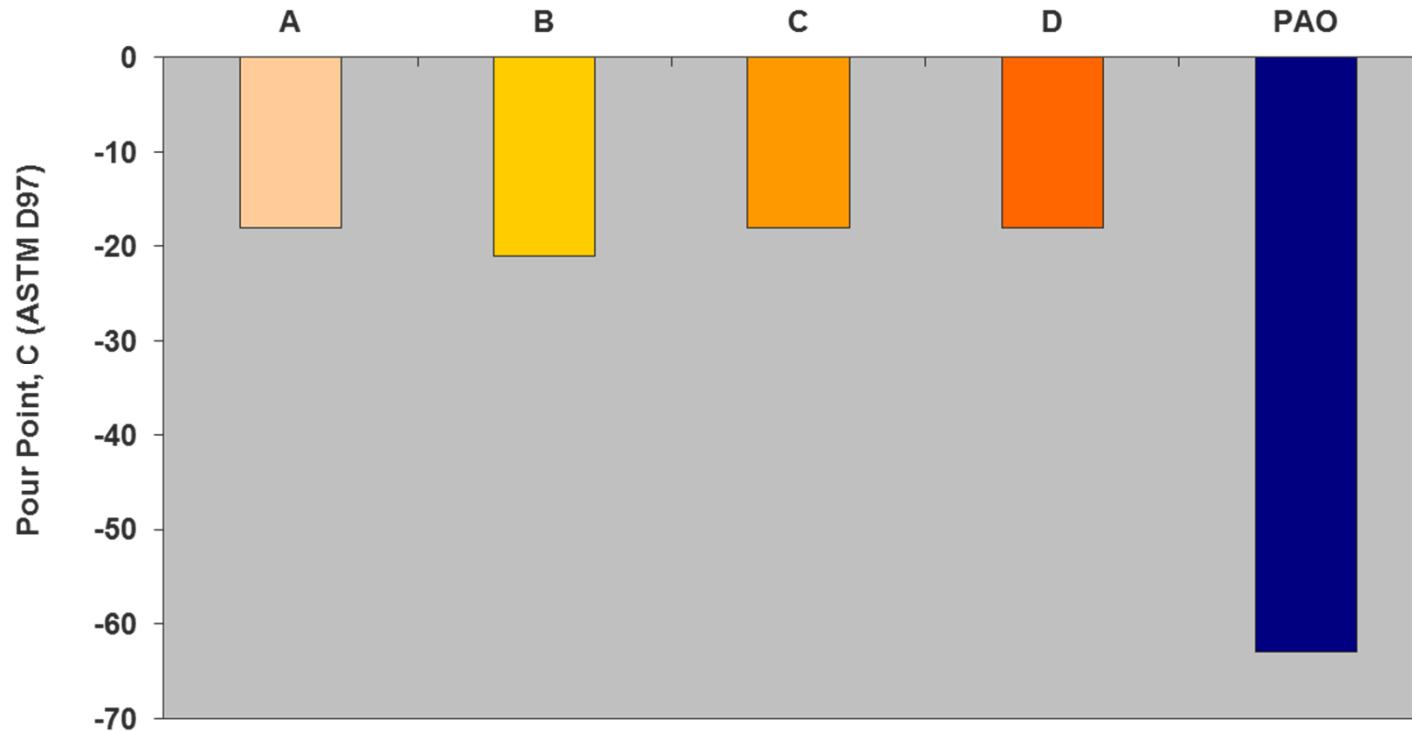
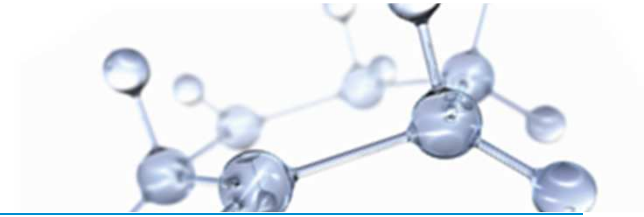
High VI offers better protection at high temperature and better fluidity at low temperature

Pour point



mPAO has a lower pour point than conventional PAO, mineral oils and PIB

Pour point



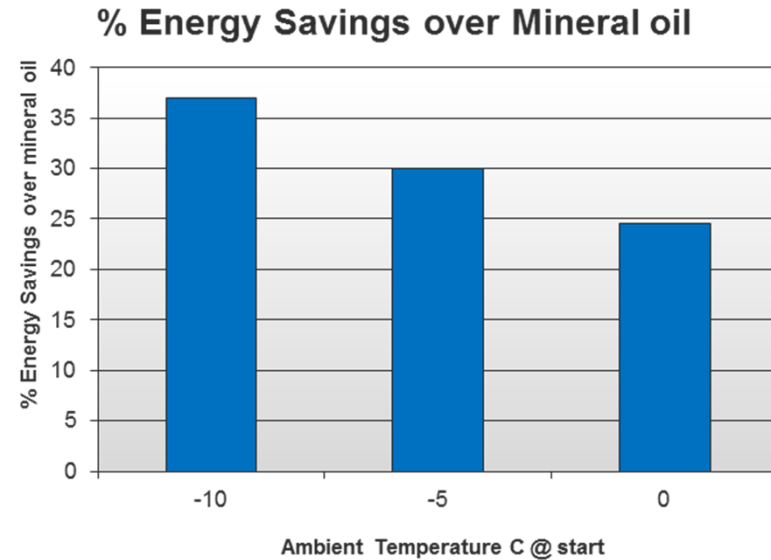
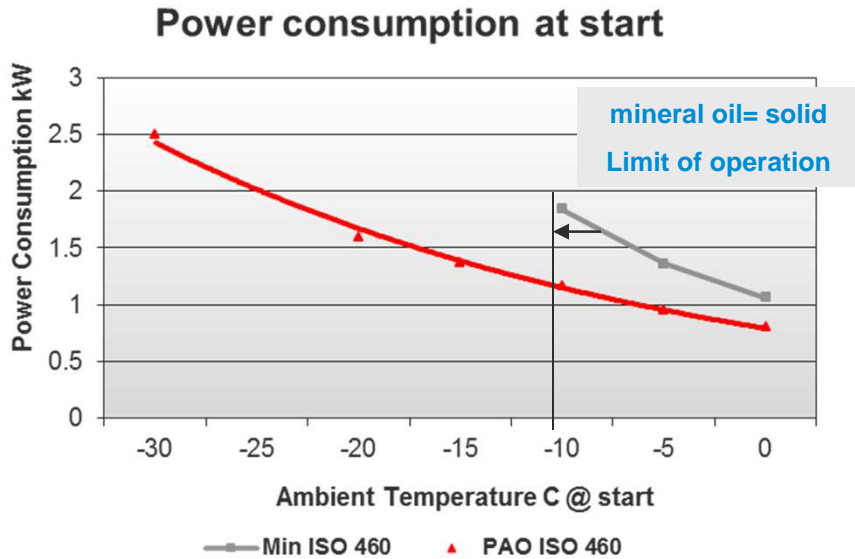
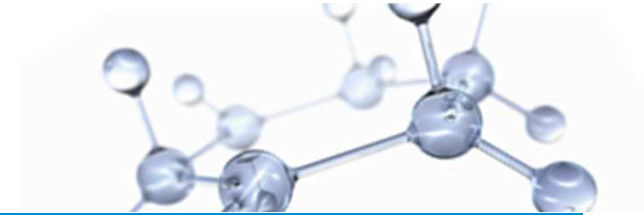
PAO offers significant benefits in pour point

*PAO4, Group IIIA, Group IIIB, Group IIIC, Group IIID are commercially available nominal 4cSt base stocks.

ADVANCED
SYNTHETIC
BASE STOCKS | *Innovative
lubricants
start here*

Source: Exxon Mobil data

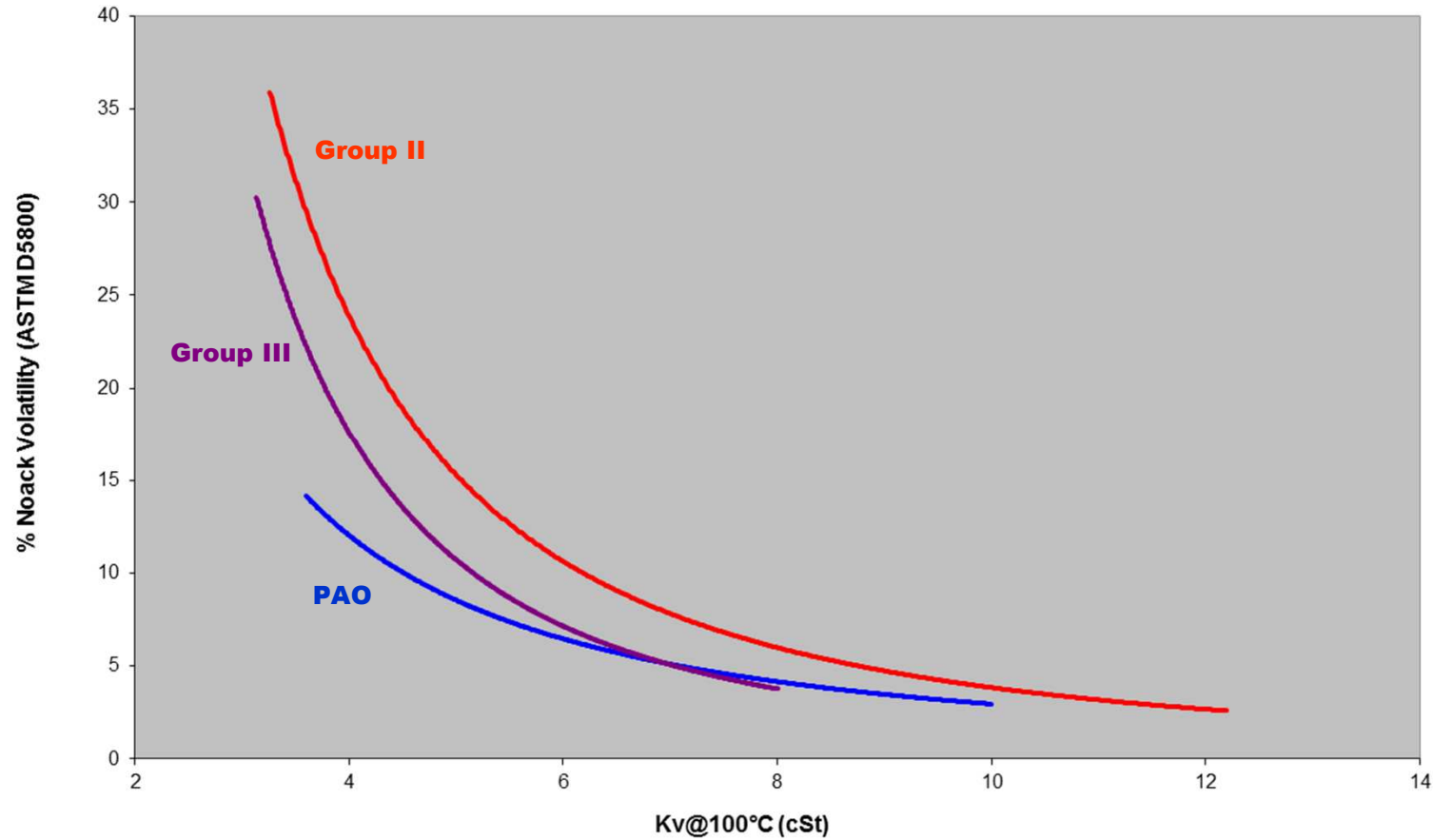
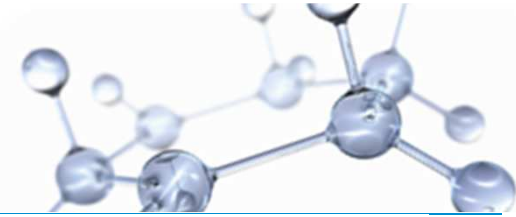
Benefits of low pour point



David Brown Radicon single reduction gearbox (30:1 gear ratio)
Overnight soaking at ambient temperature before start

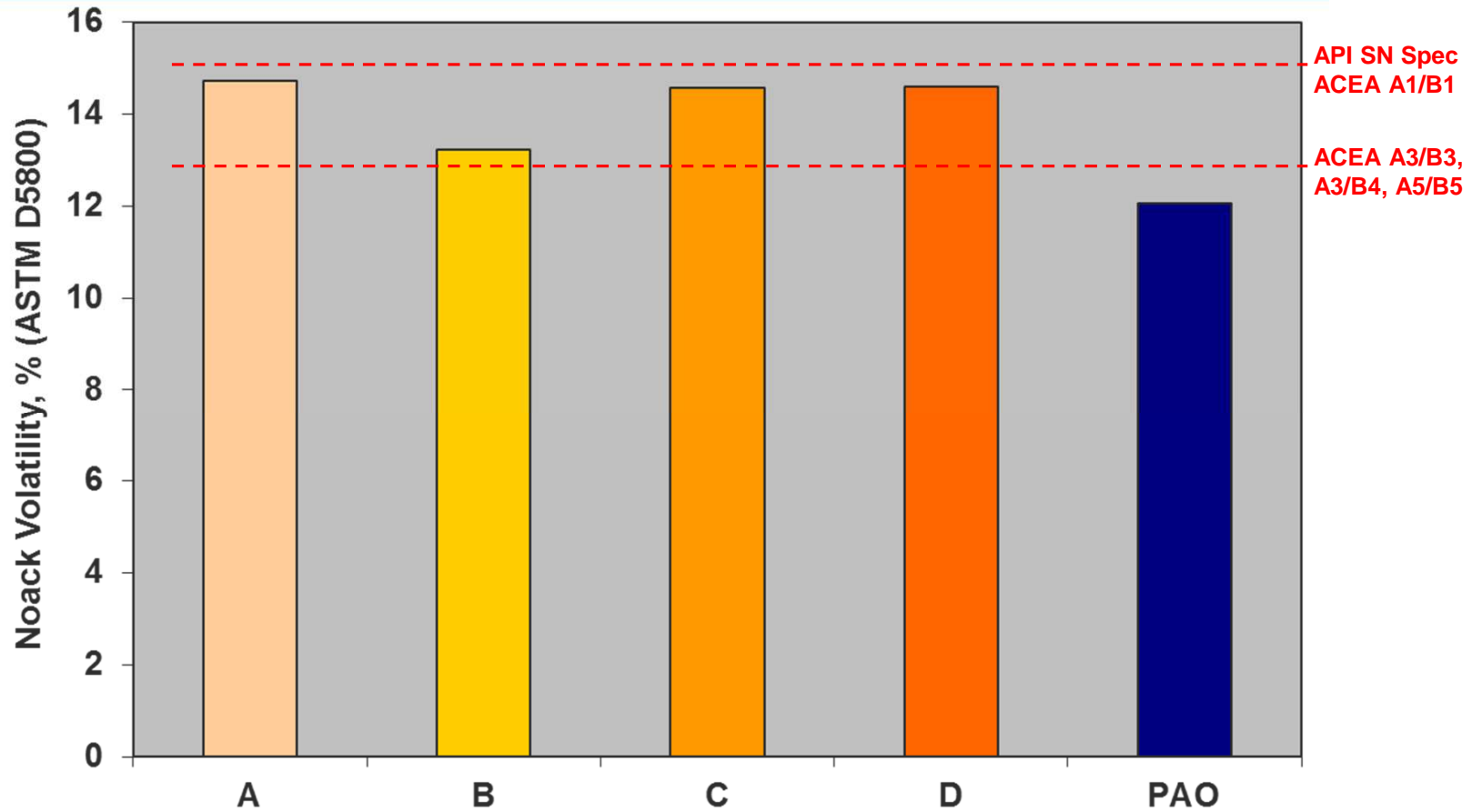
PAO can provide advantages over mineral oil in cold climates or low temperature applications

High temperature volatility – Noack



PAO generally have lower volatility than mineral oil

Noack volatility



PAO offers low volatility to meet current engine oil specifications

*PAO4, Group IIIA, Group IIIB, Group IIIC, Group IIID are commercially available nominal 4cSt base stocks.

ADVANCED
SYNTHETIC
BASE STOCKS | Innovative
lubricants
start here

Source: Exxon Mobil data

Oxidation stability



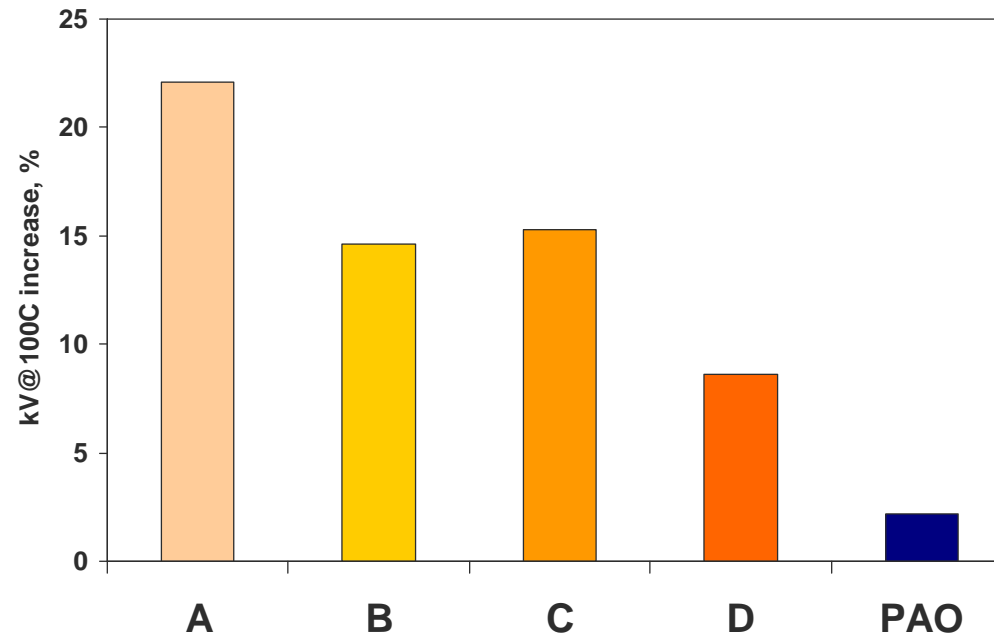
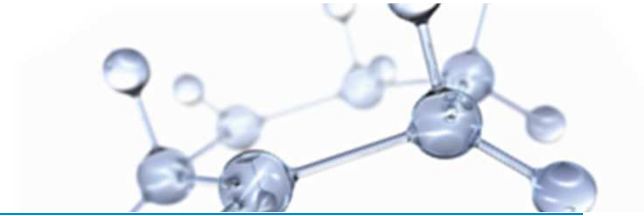
- **Good oxidative stability is essential for applications at elevated temperatures with air contact**
- **PAO's show excellent oxidative stability when formulated with suitable antioxidants**

Product	Mineral Oil Group II	6 cSt PAO	40 cSt PAO	100 cSt PAO
% Vis Change @ 100°C	215.7	3.5	2.6	1.8
TAN change, mg	14.5	0.1	0.08	1.1
Lead loss, mg	160.7	0.9	0.1	0.2
Sludge	moderate	nil	nil	trace

B10 Oxidation test (M334-1)
Base oil with 2% antioxidant
163°C for 72 Hours
4 metal specimens
Air flow 10L/hr

PAO offers better oxidation stability than mineral oil

Oxidation stability



B10 Oxidation test (M334-1)
Base oil with 1% anti-oxidant
163°C for 72 Hours
4 metal specimens
Air flow 10L/hr

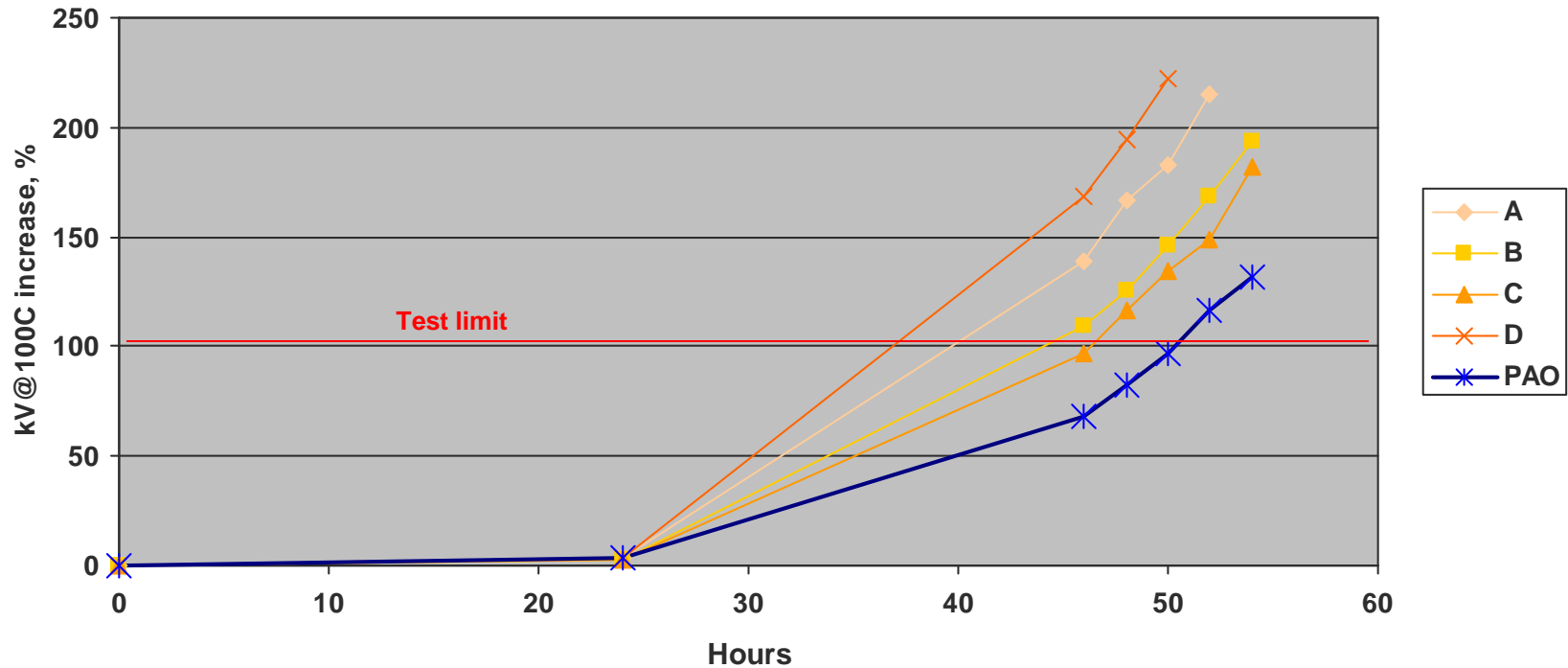
PAO offers good oxidation stability under extended service conditions

*PAO4, Group IIIA, Group IIIB, Group IIIC, Group IIID are commercially available nominal 4cSt base stocks.

ADVANCED SYNTHETIC BASE STOCKS | Innovative lubricants start here

Source: Exxon Mobil data

Oxidation stability



In house bulk oxidation test
Base stock with 1% antioxidant
165°C
Iron catalyst
Air flow 500mL/min

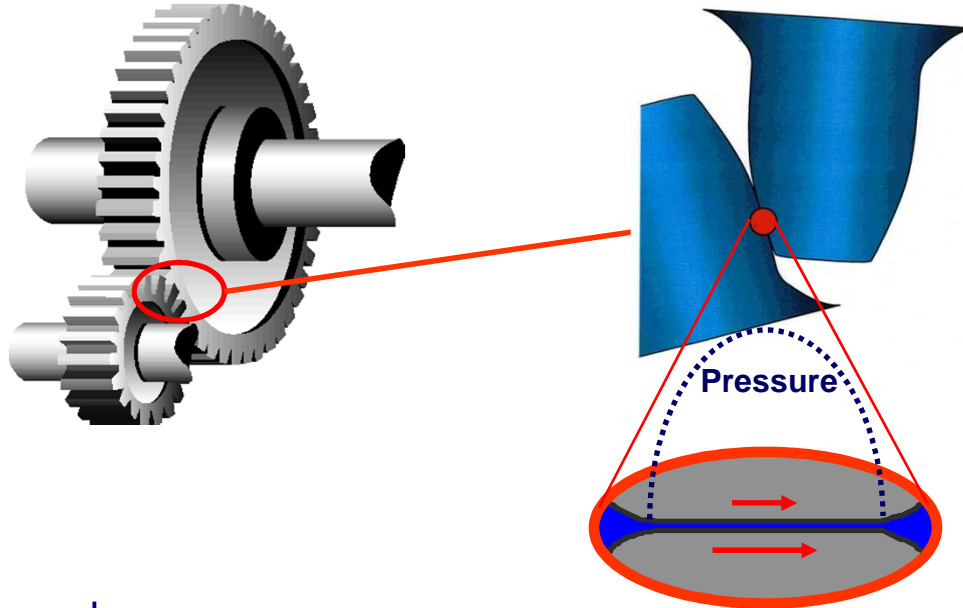
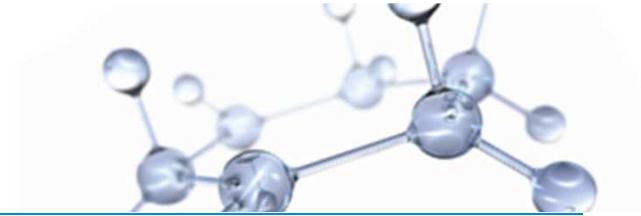
PAO again shows good oxidation stability in engine oil screening test

*PAO4, Group IIIA, Group IIIB, Group IIIC, Group IIID are commercially available nominal 4cSt base stocks.

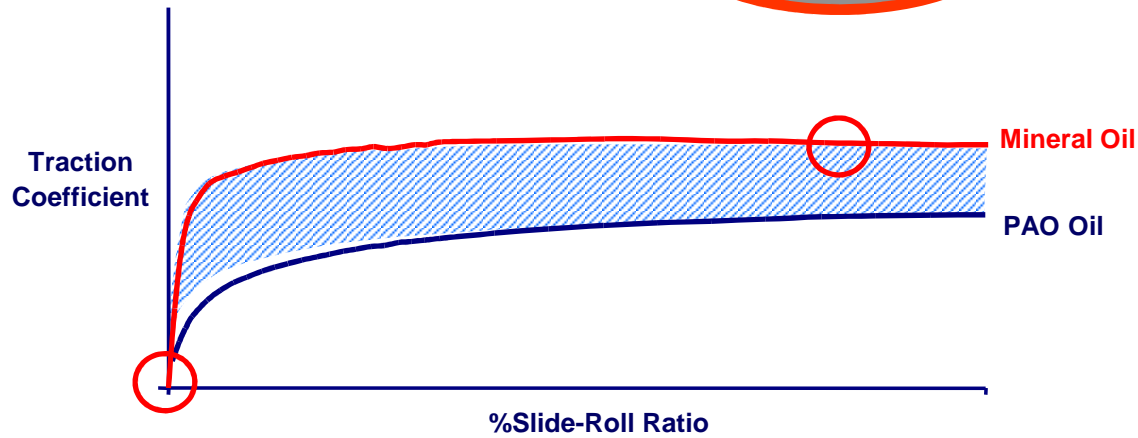
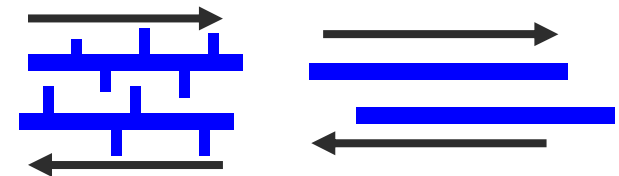
ADVANCED SYNTHETIC BASE STOCKS | Innovative lubricants start here

Source: Exxon Mobil data

EHL & traction

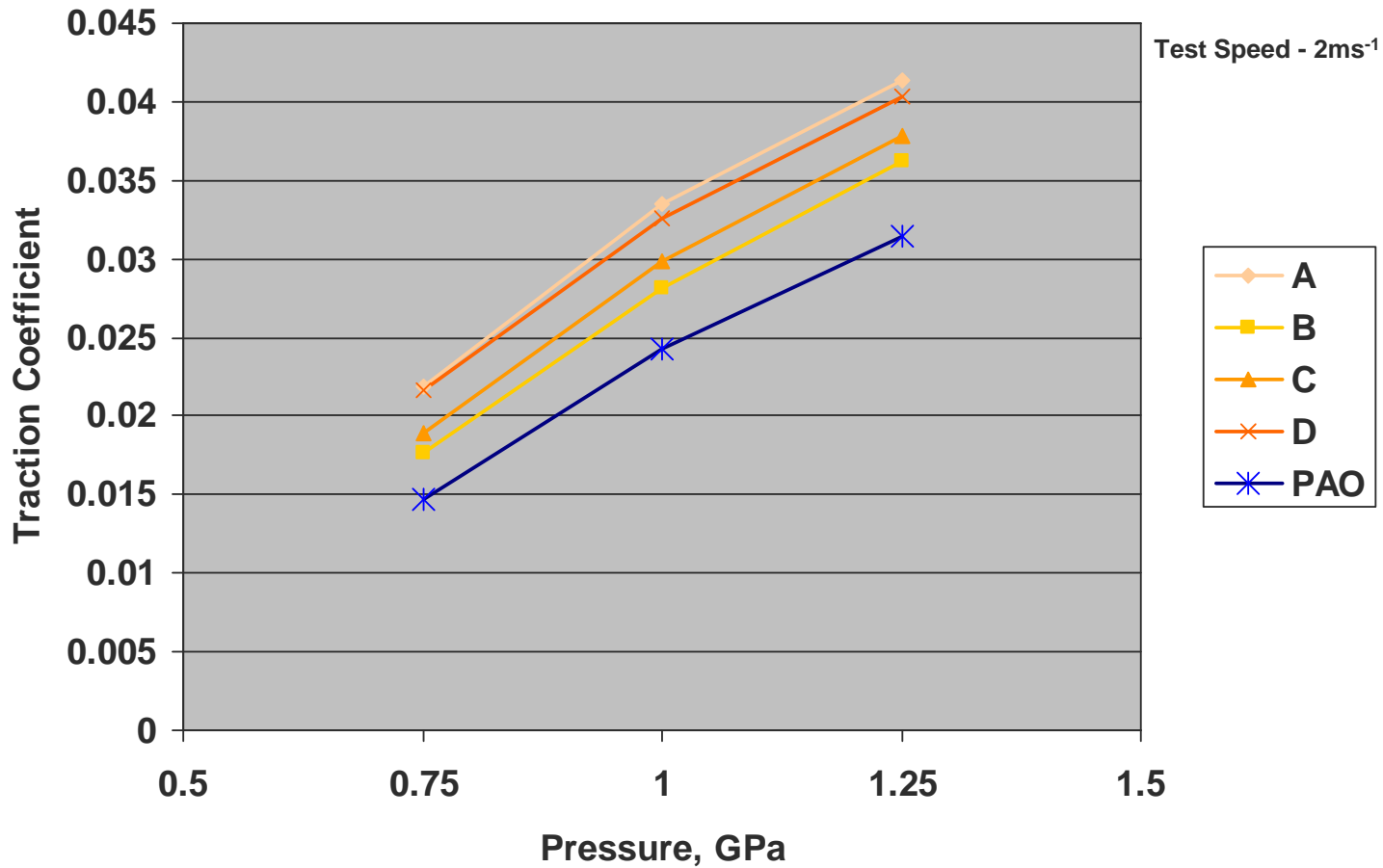
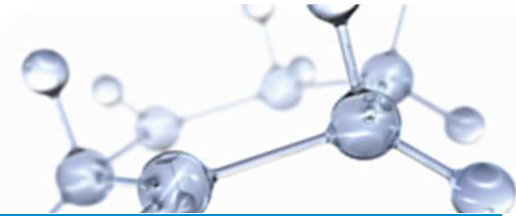


Energy losses are determined by the characteristics of the oil under high pressure



Low traction base stocks save energy over most of the meshing cycle

MTM traction coefficient @ 60C



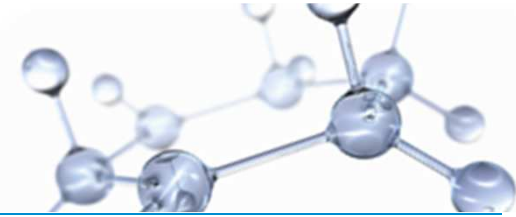
PAO offers lower traction which helps with energy saving in EHL contacts

*PAO4, Group IIIA, Group IIIB, Group IIIC, Group IIID are commercially available nominal 4cSt base stocks.

ADVANCED SYNTHETIC BASE STOCKS | Innovative lubricants start here

Source: Exxon Mobil data

Energy saving with PAO gear oil

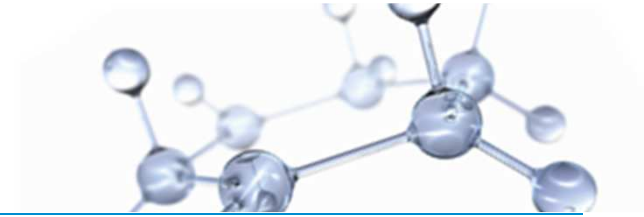


- Polyethylene extruder gearbox in North America* powered by 12,700 hp (9.47MW) electric motor
- Satisfactory operation with standard product.
- Electrical motor shutdown due to high bearing temperature (>85C) when handling high density material – reduced throughput to maintain operations.

Motor bearing oil upgraded to fully PAO synthetic oil.	Measured reduction in bearing temperature (81°C → 75°C on standard material & < 78°C for high density material) Production benefit of \$3600/hour
Gearbox subsequently changed to synthetic gear oil	3.1% energy savings → \$2210/hr electric cost savings

Other key features of PAO

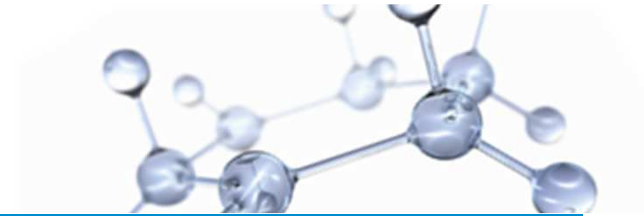
(applicable to ExxonMobil grades)



- Low toxicity
- Hydrolytically stable
- Excellent additive response
- Compatible with mineral oils, Esters and Alkylated Naphthalene
- Meet FDA Requirement under 21 CFR 178.3620(b) Technical White Mineral Oil
- Can be used to formulate lubricants for incidental food contact
 - NSF Approval For Incidental Food Contact (USDA H1)
 - Listed in the NSF White Book (<http://www.nsf.org/usda/Listings.asp>)
 - Kosher approved
 - Halal approved

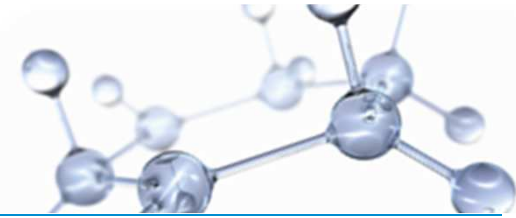


PAO typical applications



EMCC Product Names	Gasoline & Diesel Engines	Automatic Transmissions	Industrial/Automotive Gears & Transmissions	Hydraulic systems	Industrial Bearings	Rotary Air and Gas Compressor	Hydrocarbon Refrigeration Compressor	Grease	Turbines	Heat Transfer Fluid	Automotive Hydraulic Fluids	Mist Lubricant
PAO 2		●	•	●			•	•		●	●	
PAO 4	●	●	●	●	•	•	•	•	●	•		●
PAO 6	●	●	●	●	●	●	•	●	●			●
PAO 8	●		•	•	●	●	•	●	•			●
PAO 10			•	•	•	●	•	●	•			•
PAO 40	●		●	●	●	●	•	●	•			•
PAO 100			●	●	●	●		●	•			•
PAO 150	●		●	●	●	●	•	●	•			

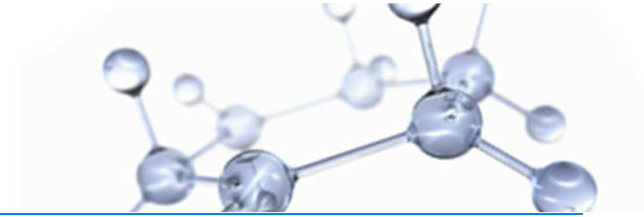
- Most common application uses
- Less commonly used



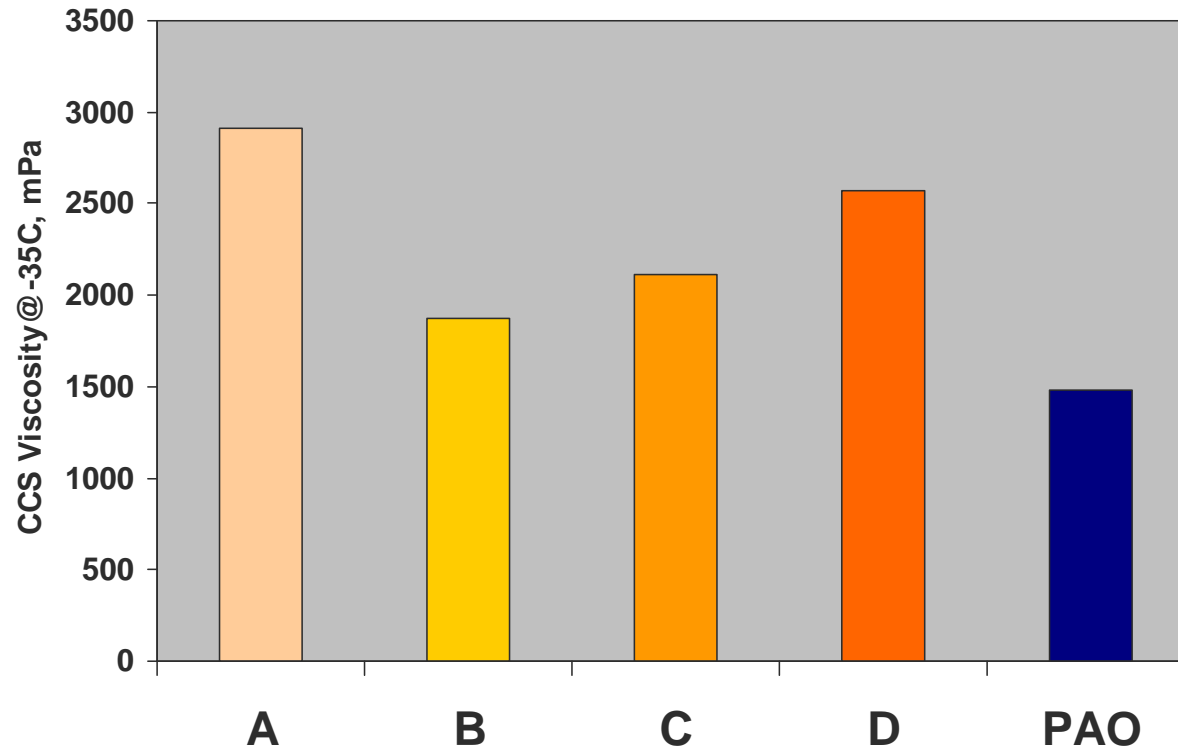
©2011 ExxonMobil. To the extent the user is entitled to disclose and distribute this document, the user may forward, distribute, and/or photocopy this copyrighted document only if unaltered and complete, including all of its headers, footers, disclaimers, and other information. You may not copy this document to a Web site. ExxonMobil does not guarantee the typical (or other) values. Analysis may be performed on representative samples and not the actual product shipped. The information in this document relates only to the named product or materials when not in combination with any other product or materials. We based the information on data believed to be reliable on the date compiled, but we do not represent, warrant, or otherwise guarantee, expressly or impliedly, the merchantability, fitness for a particular purpose, suitability, accuracy, reliability, or completeness of this information or the products, materials, or processes described. The user is solely responsible for all determinations regarding any use of material or product and any process in its territories of interest. We expressly disclaim liability for any loss, damage, or injury directly or indirectly suffered or incurred as a result of or related to anyone using or relying on any of the information in this document. There is no endorsement of any product or process, and we expressly disclaim any contrary implication. The terms, "we", "our", "ExxonMobil Chemical", or "ExxonMobil" are used for convenience, and may include any one or more of ExxonMobil Chemical Company, Exxon Mobil Corporation, or any affiliates they directly or indirectly steward. ExxonMobil, The ExxonMobil Emblem, the "Interlocking X" Device, Synesstic, SpectraSyn, SpectraSyn Ultra, SpectraSyn Plus and SpectraSyn Elite are trademarks of ExxonMobil.

Except as otherwise specified, all charts included in the presentation are based on ExxonMobil data.

Backup



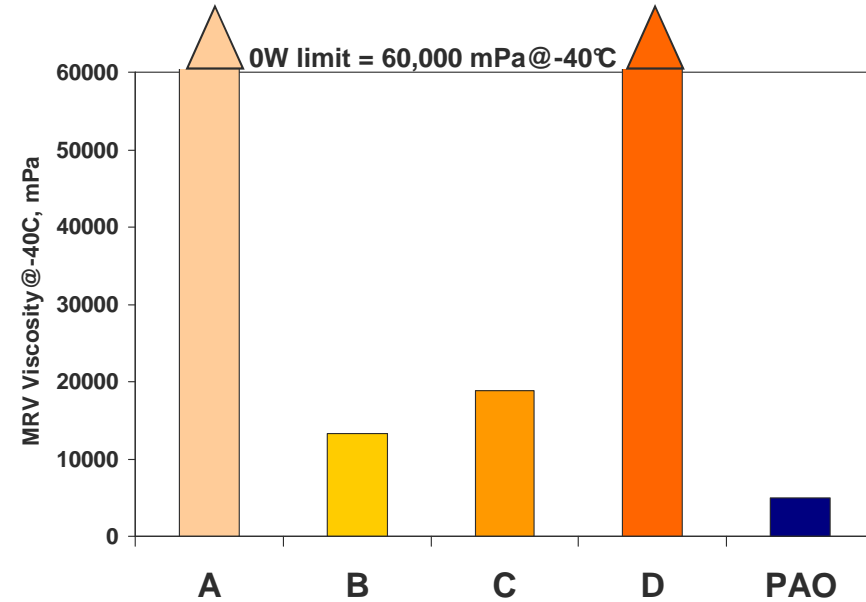
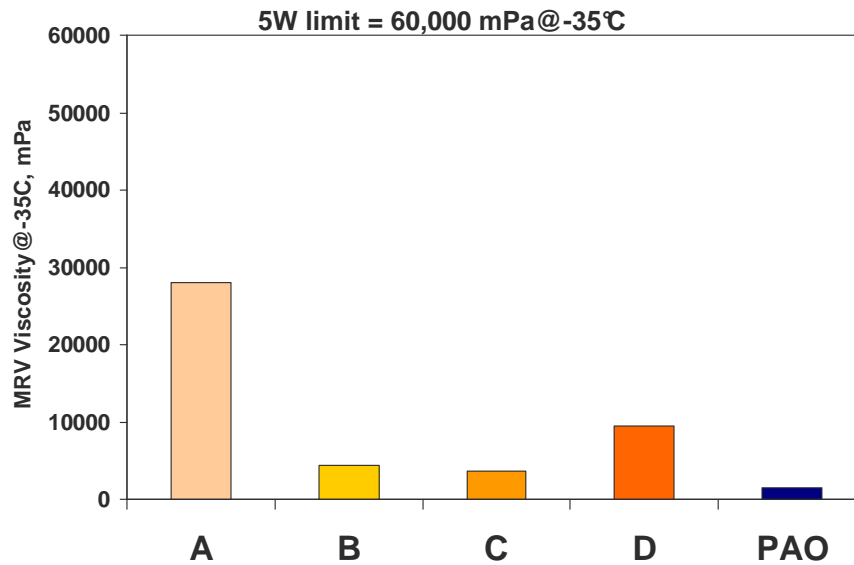
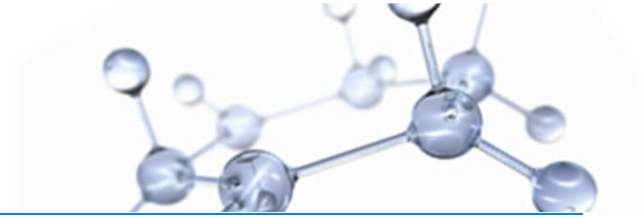
CCS viscosity (ASTM D6293)



OW limit = 6200mPa@-35C
5W limit = 6600mPa@-30C

All products meet CCS requirements for 0W grades but
PAO offers a clear benefit in low temperature starting

MRV viscosity (ASTM D4684)



All products meet MRV requirements for 5W grades

Some products challenged to meet 0W grade requirements

PAO again offers clear benefits for low temperature oil flow