

Synfluid® mPAOs: High Viscosity Base Oils for Exceptional Lubes and Greases

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Commercial Marketing Forum

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Outline

- High Viscosity PAO Supply / Demand Outlook
- Synfluid® mPAO Introduction
- Physical and Lubricant Properties Compared to Conventional PAO
- Advantages in Formulations of Lube Oils and Greases
- Summary
- Questions



Synfluid® mPAOs Overview

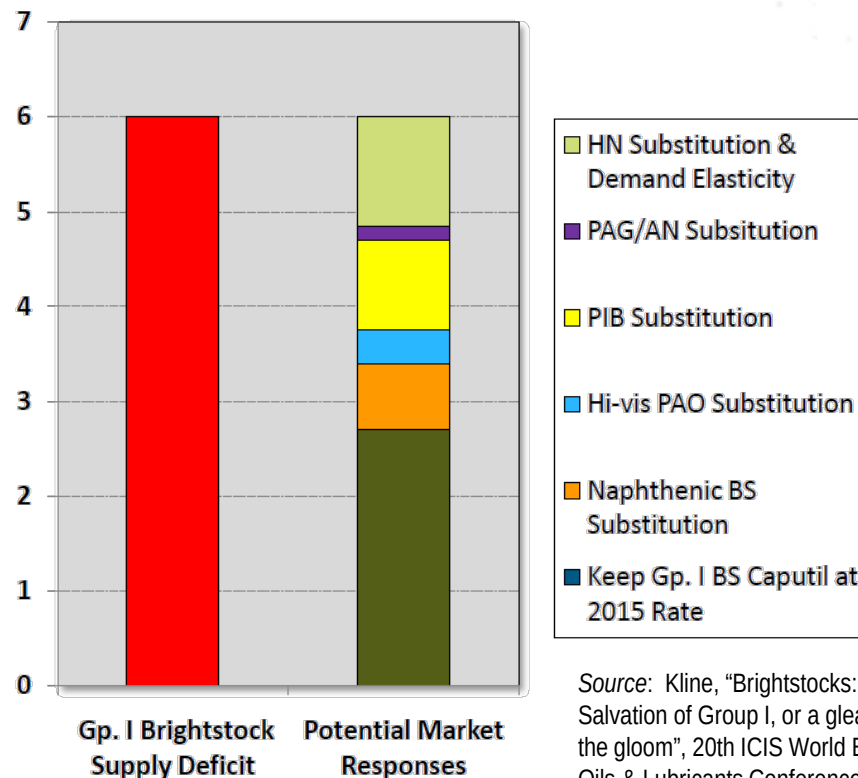
- Synfluid® mPAOs are prepared using Chevron Phillips Chemical's proprietary technology
- Viscosity Grades
 - Synfluid® mPAO 65 cSt
 - Synfluid® mPAO 100 cSt
 - Synfluid® mPAO 150 cSt
- Our proprietary technology provides improved properties compared to conventional HV PAO:
 - Viscosity Index
 - Pour Point
 - Low Temperature Viscometrics
 - Oxidative Stability



HV PAO Supply and Future Demand

- Chevron Phillips Chemical LV & HV PAO Supply:
 - 48 kTA LV PAO Cedar Bayou, TX
 - 60 kTA LV PAO Beringen, Belgium
 - 9 kTA HV PAO Pasadena, TX
- Announced Cedar Bayou Expansion Investment of 10 kTA LV PAO for 2017
- Typical Applications:
 - Industrial Gear Oils
 - Transportation Gear Oils
 - Racing Oils
 - Greases
 - Compressor Oils
 - Hydraulic Fluids

Illustrative Supply/Demand Responses to
Global Group I Brightstock Shortage in 2025
(KB/CD)

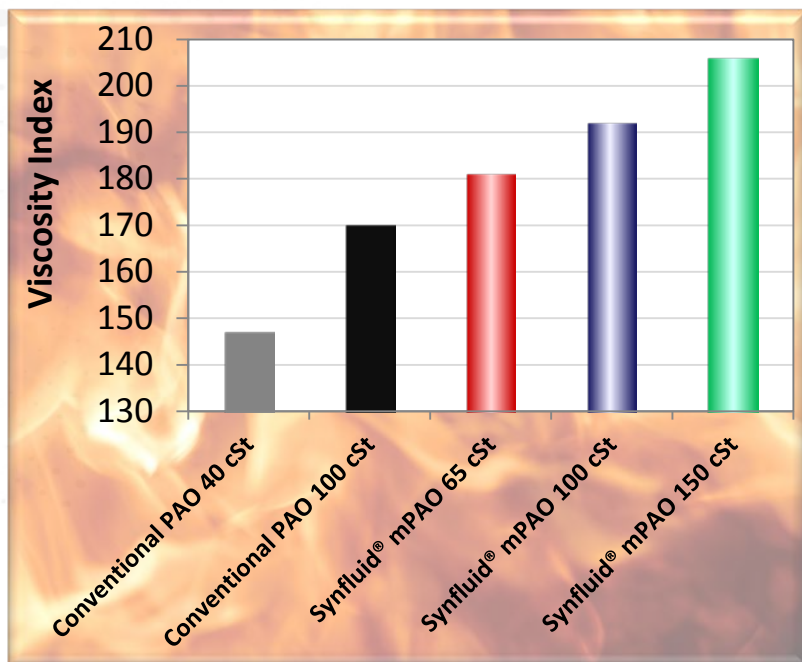


Source: Kline, "Brightstocks: Salvation of Group I, or a gleam in the gloom", 20th ICIS World Base Oils & Lubricants Conference, London February, 2016

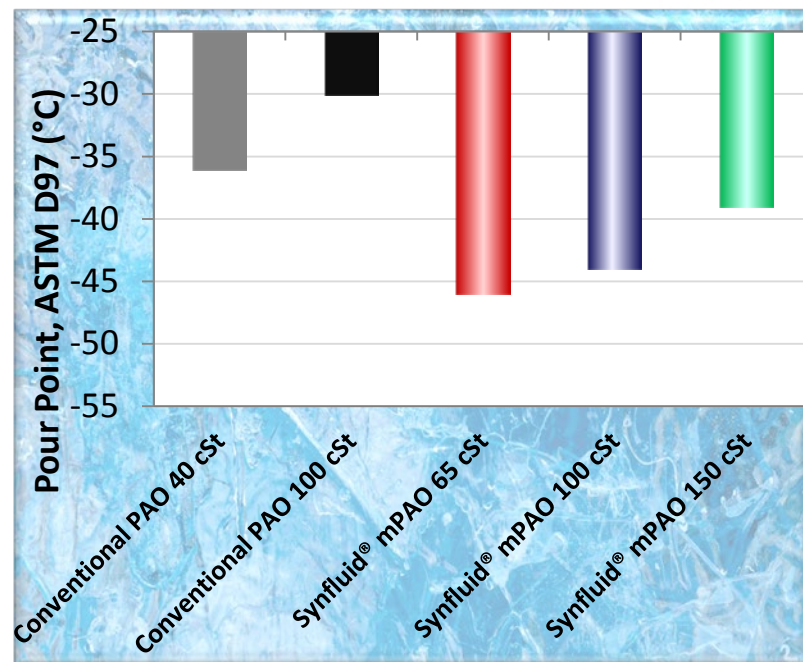


High Viscosity PAO: Conventional vs. mPAO

Viscosity Index



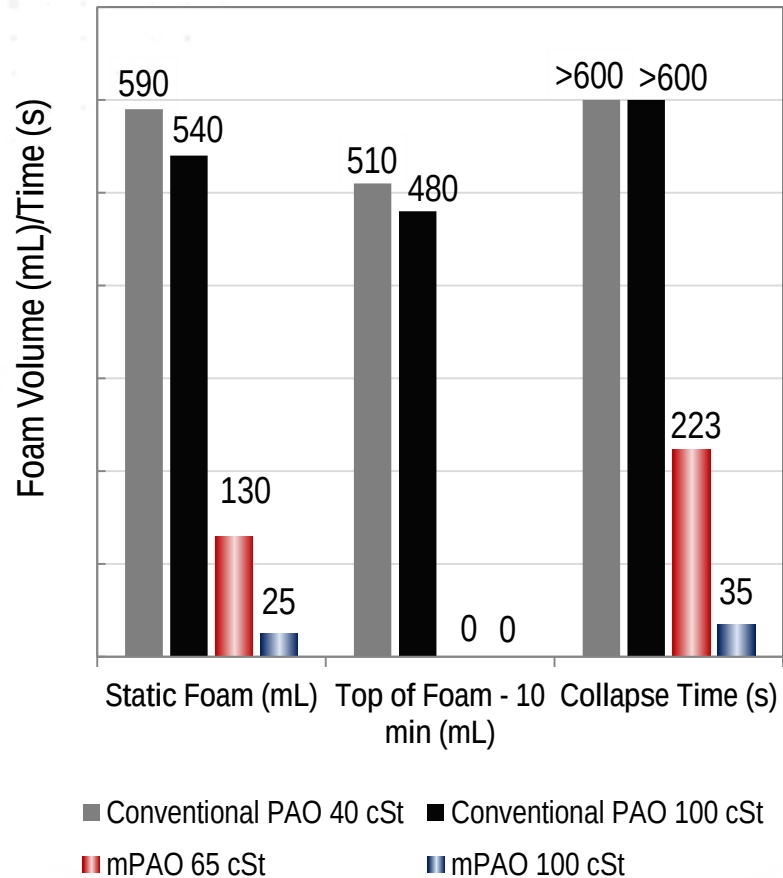
Pour Point



- Synfluid® mPAOs offer very high viscosity indices; providing less viscosity loss at high temperatures and excellent low temperature properties
- Pour points are extremely low for high viscosity grade materials!



Foaming Characteristics (Sequence I ASTM D892)

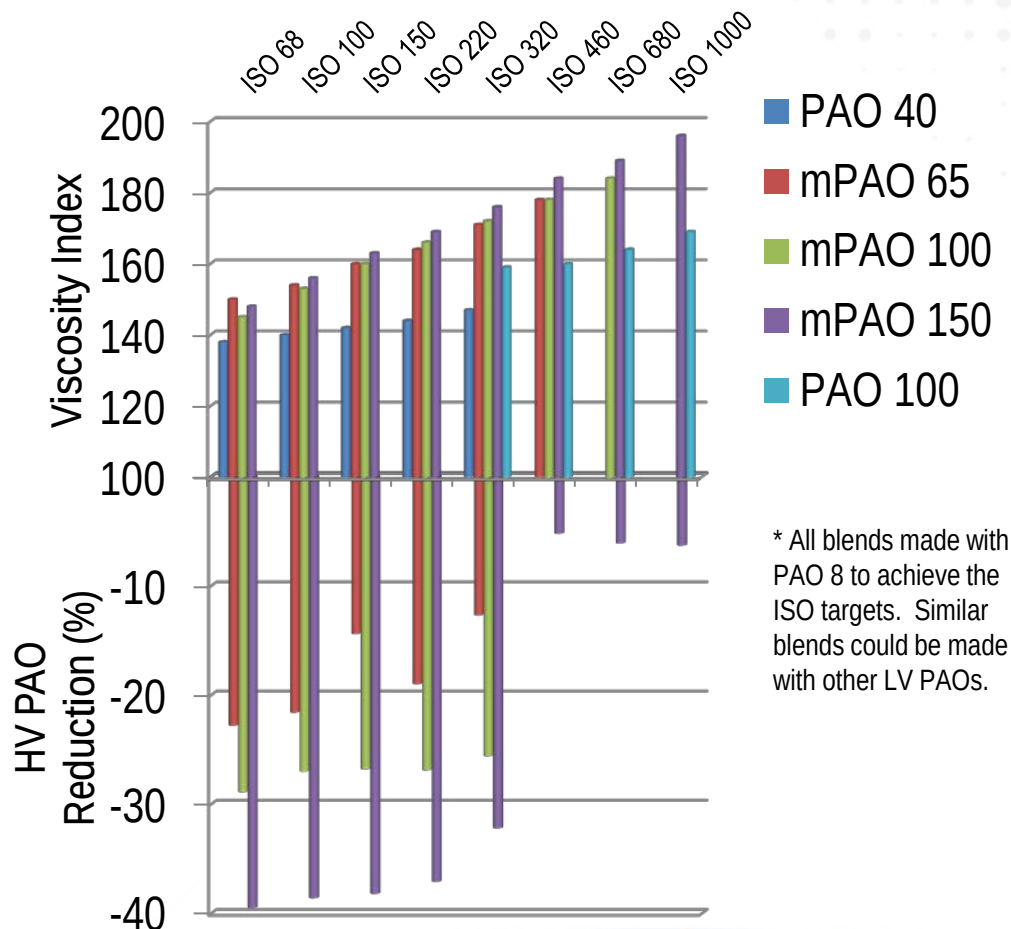


mPAO 100

Conventional
PAO 100

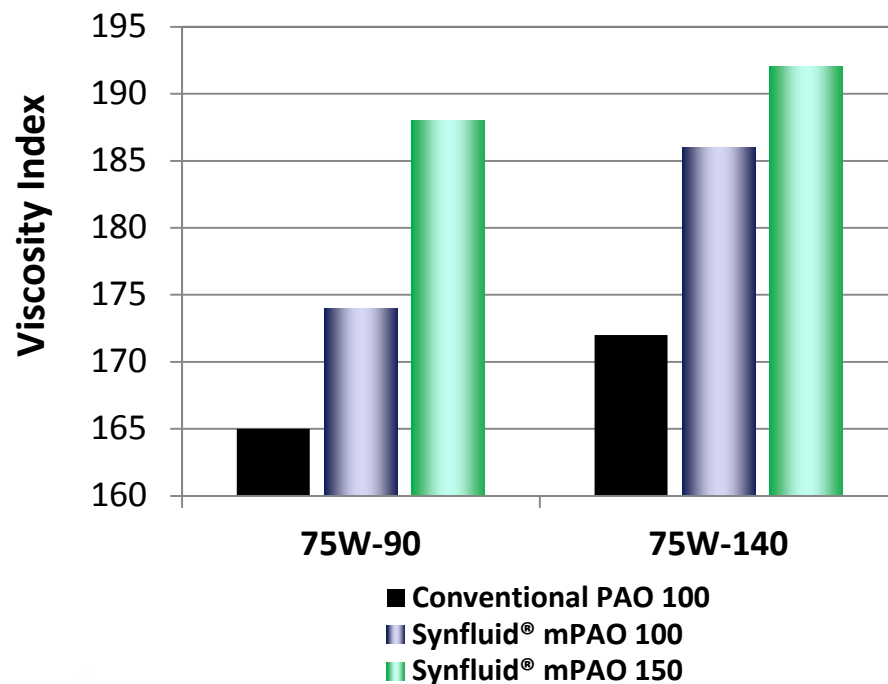
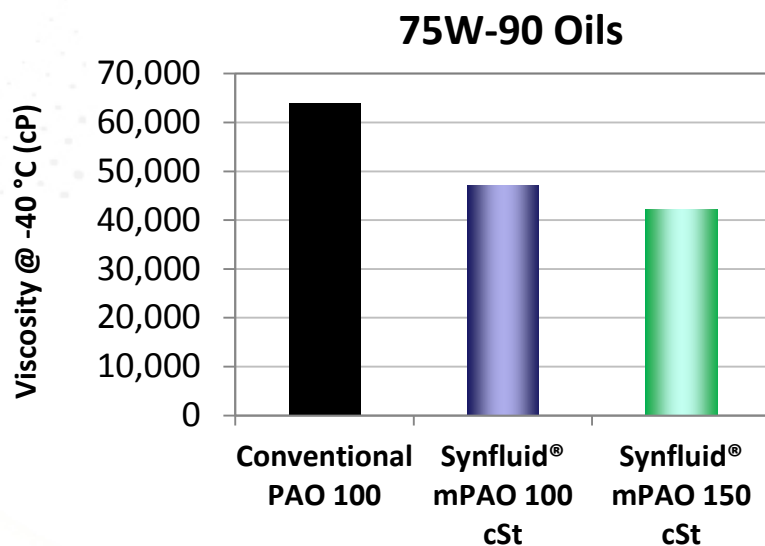
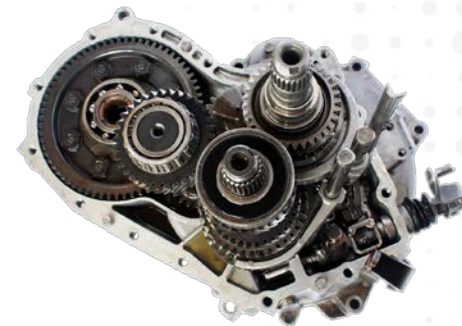
Synfluid® mPAO in Industrial Oils

- In blends with a low viscosity PAO, mPAO offers higher viscosity index and lower pour points (<-50°C)
- These improved properties are achieved while requiring *less HV PAO*, which provides for a more economical formulation!



mPAO in Automotive Gear Oils

- Example formulations for mPAO use in 75W-90 oils with PAO 6 as the low viscosity component
- Substantial improvement in low temperature viscosities and high viscosity indices



The above formulations formulated with Additive Company A components

Transportation Gear Oil Example Formulations

75W-90 Formulation	mPAO 65	mPAO 100	mPAO 150	SAE J306
% High-Vis mPAO	32.6	27.4	23.8	
% PAO 4	51.4	56.6	60.2	
% Additive	6.0	6.0	6.0	
% Di-basic Ester	10.0	10.0	10.0	
100°C Viscosity (cSt)	13.8	13.6	13.5	13.5 – 18.5
40°C Viscosity (cSt)	87.2	85.9	84.7	
-40°C Brookfield Viscosity (modified scanning Brookfield, cP)	37,834	39,298	31,253	<150,000
Viscosity Index	161	161	162	
Pour Point (°C)	-57	-57	-57	

75W-140 Formulation	mPAO 65	mPAO 100	mPAO 150	SAE J306
% High-Vis mPAO	65.3	57.7	52.0	
% PAO 4	12.2	19.8	25.5	
% Additive	7.5	7.5	7.5	
% Di-basic Ester	15.0	15.0	15.0	
100°C Viscosity (cSt)	25.6	26.0	26.0	24.0 – 32.5
40°C Viscosity (cSt)	182.8	173.9	172.5	
-40°C Brookfield Viscosity (modified scanning Brookfield, cP)	92,499	74,794	70,142	<150,000
Viscosity Index	174	185	186	
Pour Point (°C)	-51	-51	-51	

- Example formulations for mPAO use within the 75W-90 and 75W-140 viscosity grades
- Excellent low temperature viscosities are achievable with low pour points and high viscosity indices
- Other low viscosity components can be used depending upon finished properties . PAO 4 is used here for an example.

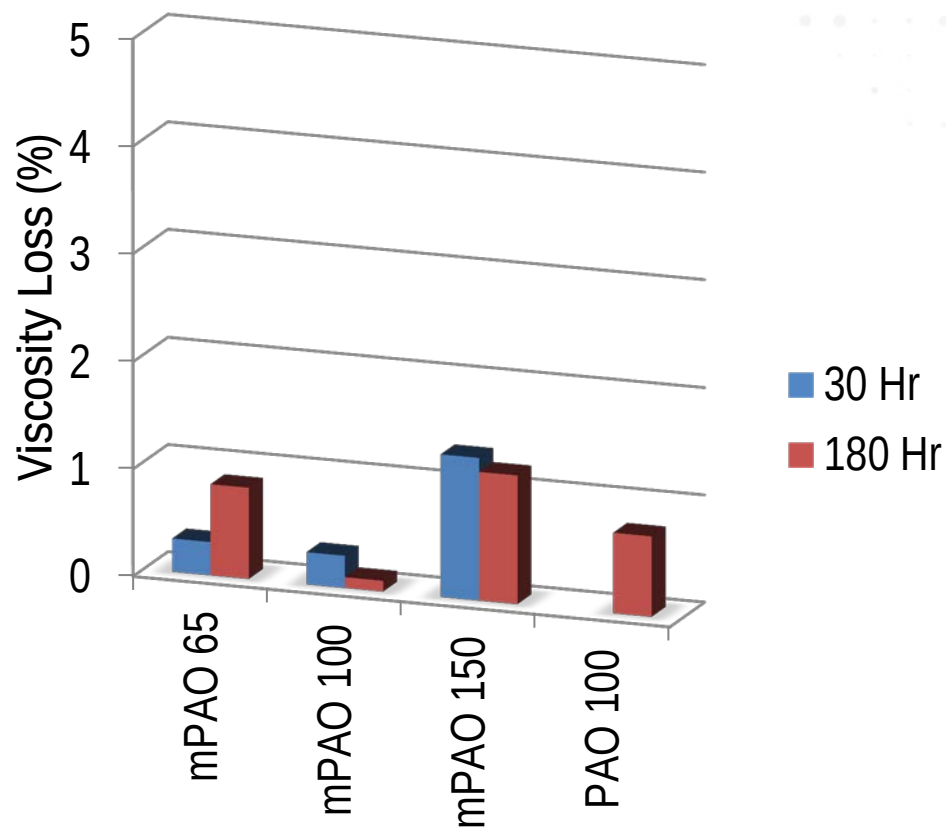
These formulations made with Additive Company B components



Shear Stability – CEC L-45-99 Mod.

Stable Viscosity at Extended Testing

- Very little viscosity loss
- Extended to 180 hours
- Indicates no additional shear expected



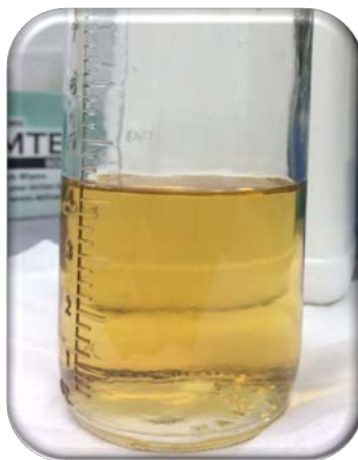
mPAO Additive Compatibility – Industrial Oils

Formulation showing additive compatibility in an ISO 320 Gear Oil

Transparent and Bright – no additive fallout

Formulation

- 87.2% mPAO
- 10% Ester
- 2.5% Additive
- 0.3% PPD



After Blending



After 24 hrs.



After 120 hrs.



Synfluid® mPAO in Lithium Grease (NLGI 2)

Formulation	Weight %
Lithium 12-Hydroxystearate	9.7
mPAO 65	42.4
PAO 6	42.4
Amine Antioxidant	1.0
Phosphorus Antiwear Agent	3.0
Zinc Based Rust Inhibitor	1.5



- Grease post processing: homogenized at 6000 psi
- Formulation developed in conjunction with Triboscience & Engineering Inc., Fall River, MA.



Synfluid® mPAO in Lithium Grease - Properties

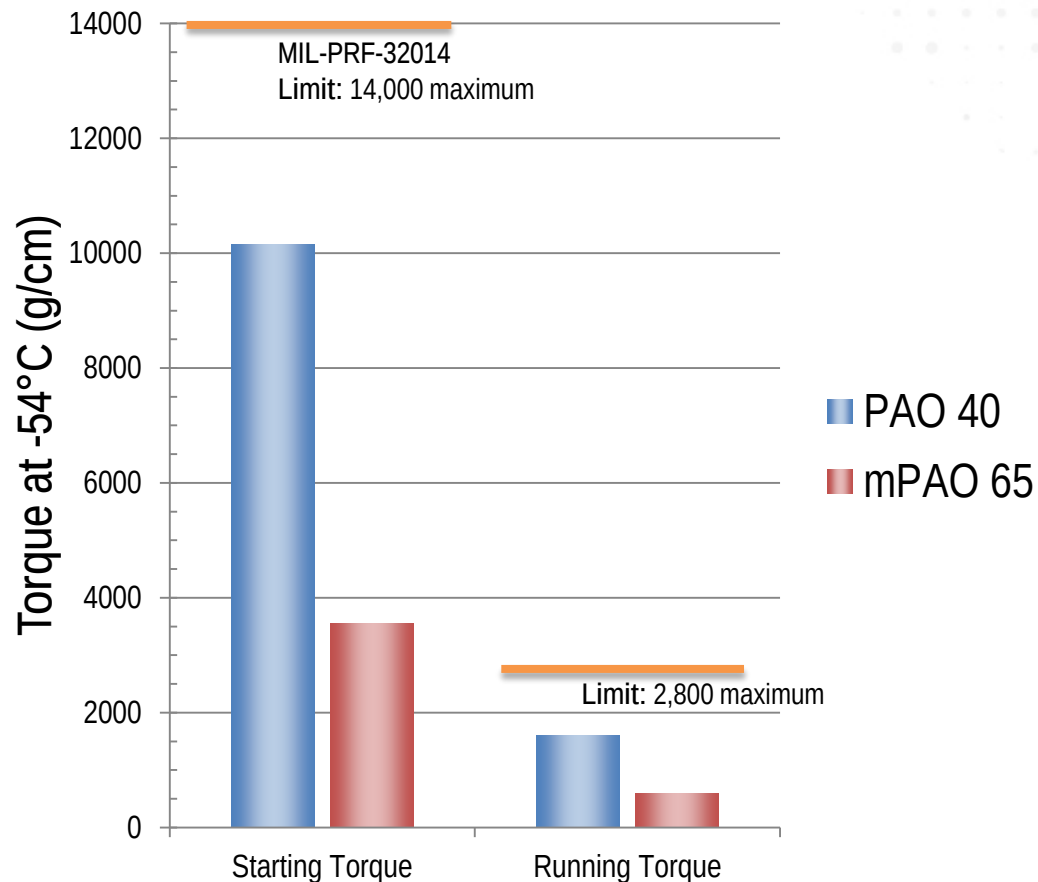
Test	Method	mPAO Based Grease	MIL-PRF-32014A Limits
Color	Report	Light Beige	
Appearance	Report	Smooth	
Base Oil KV40°C, cSt	ASTM D445	122.8	140 cSt max
Base Oil KV100°C, cSt	ASTM D445	18.06	16 cSt min
Base Oil VI	ASTM D2270	164	
Unworked Penetration	ASTM D217	270	
Worked Penetration, 60x, mm /10	ASTM D217	279	265 – 305
NLGI Grade	ASTM D217	2	
Worked Penetration, 10,000x, mm /10	ASTM D217	321	350 max
Oil Separation, 24h at 100°C,%	ASTM D6184	1.7	8 max
Copper Corrosion, 24h, 100°C	ASTM D4048	1b	1b max
Dropping Point, °C	ASTM D2265	200	200 min
Water Washout, 40°C, %	ASTM D1264	5.8	15 max
Four Ball Wear, 40kg, 75°C, 1200 rpm, 1h, mm	ASTM D2266	0.54	0.65 max
Low Temperature Apparent Viscosity, T-C Spindle, 1 rpm -54°C, cP	CTM-4 (Brookfield)	13,660,000 (See Chart)	
Oxidation Induction Time, 210°C, min	MIL PRF 32014 (PDSC)	59.7	
Evaporation, Temp at 5% Mass Loss, °C	TGA	249.66	



Low Temperature Torque of mPAO based Lithium Grease (ASTM D1478 @ -54°C)

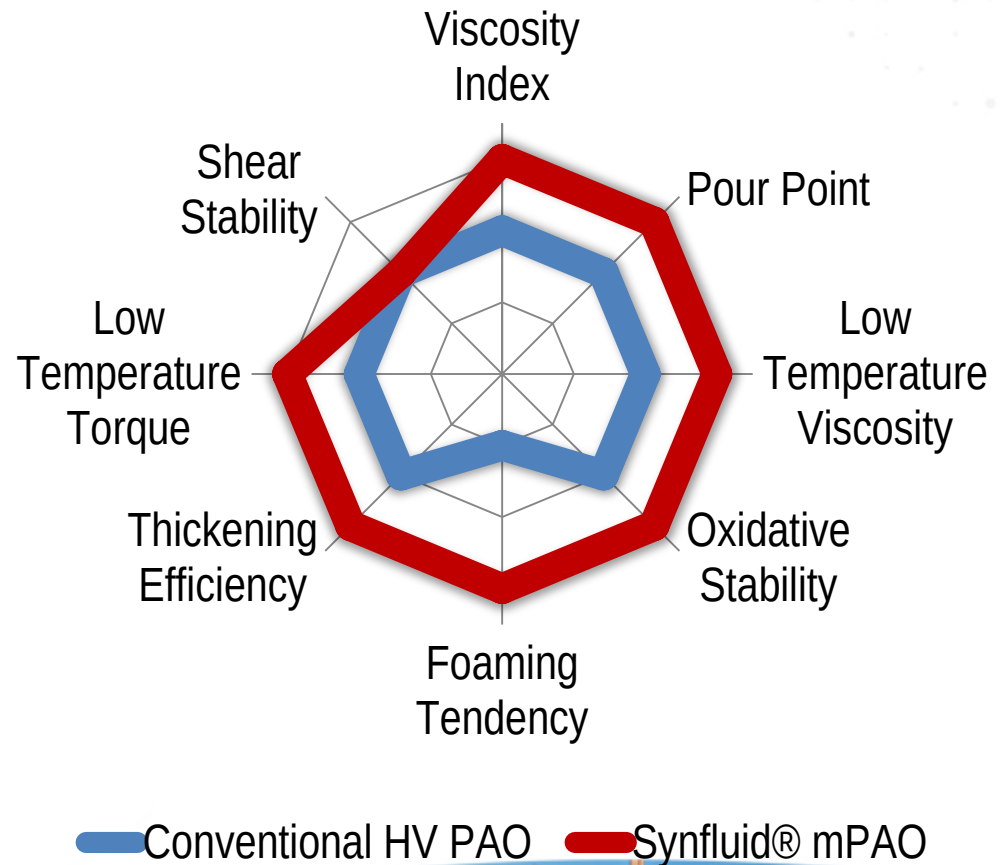
NLGI Grade 2 Lithium Greases prepared with PAO 6 and high viscosity PAOs (PAO 40 or mPAO 65) show significant differences in low temperature torque numbers.

This test indicates the force needed to rotate a bearing initially and while running. Lower torque values equates to lower energy required for starting and running conditions.



Overview: Comparison of benefits of Synfluid® mPAO to conventional HV PAO

- HV PAOs have preformed well over many years. Synfluid® mPAOs offer many advantages as shown here.
- PAOs are used to meet specific technical advantages, improvements to the base oil components should increase the overall formulations space.
- These relatively new materials increase the capabilities for new and developing lubricant applications such as:
 - Industrial and Automotive Gear Oils
 - Bearing Lubricants
 - Greases
 - Hydraulic Fluids
 - Specialty Oils



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Thank You!



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