







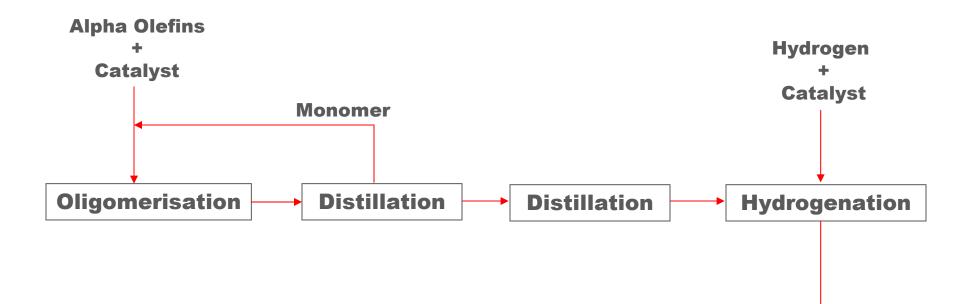
What are <u>Poly Alpha Olefins (PAO)?</u>

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





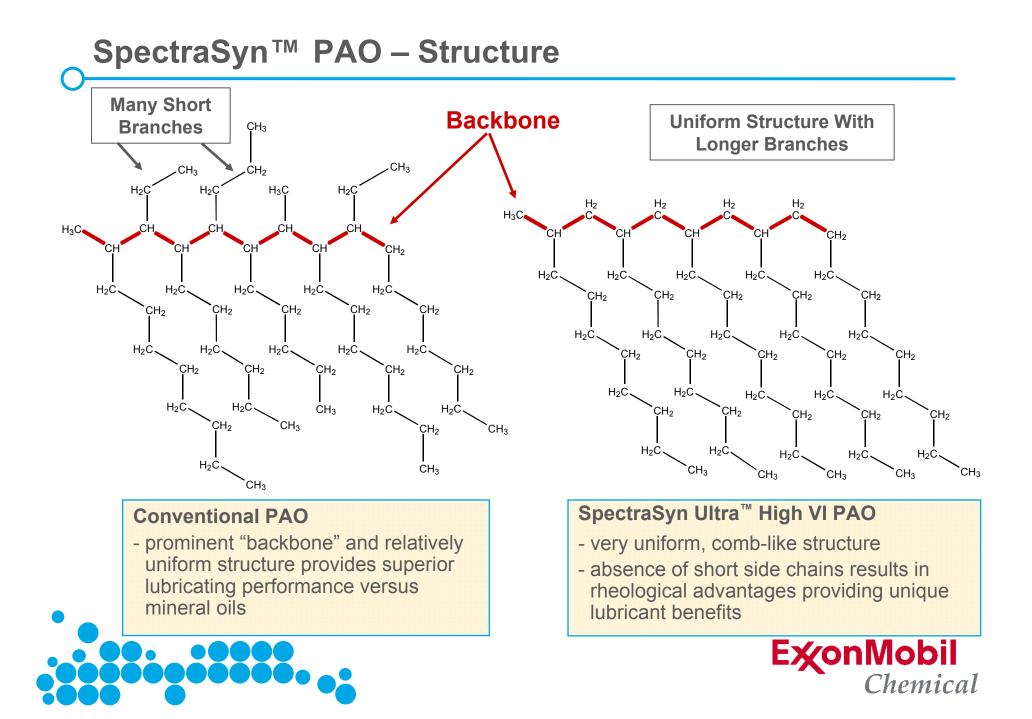
PAO Manufacturing Process





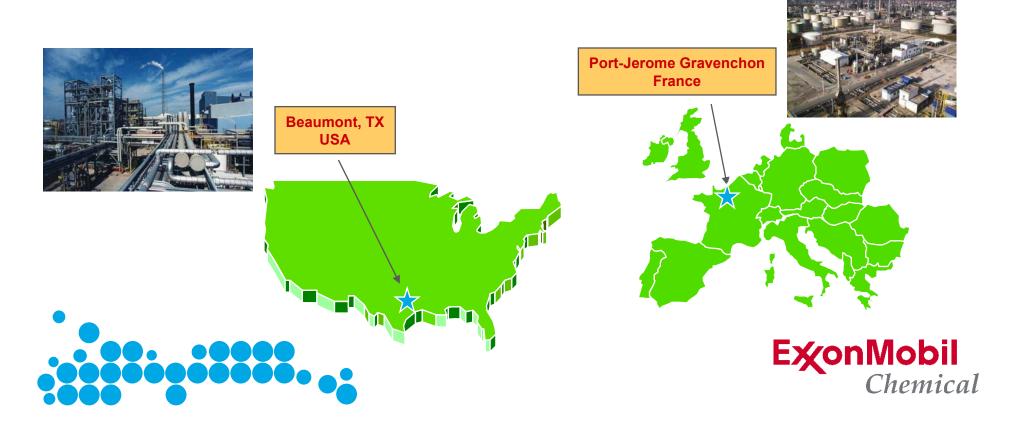


PAO



ExxonMobil PAO Manufacture

- Dedicated reactor trains
- Full range of viscosity grades (2 1000 cSt@100°C)
- Manufacturing Facilities:
 - ★ USA Beaumont, Texas
 - ★ France Port-Jerome Gravenchon



PAO Key Features

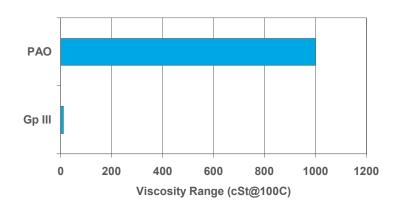
Compared to conventional mineral oils, PAOs have

- Higher viscosity index
- Lower temperature fluidity
- Lower volatility
- Better oxidative stability
- Greater thermal stability
- Lower traction force

Compared to Group III oils, PAOs have

- Much wider viscosity range
- Slightly higher viscosity index
- Lower temperature fluidity
- Similar or lower volatility
- Better oxidative and thermal stability

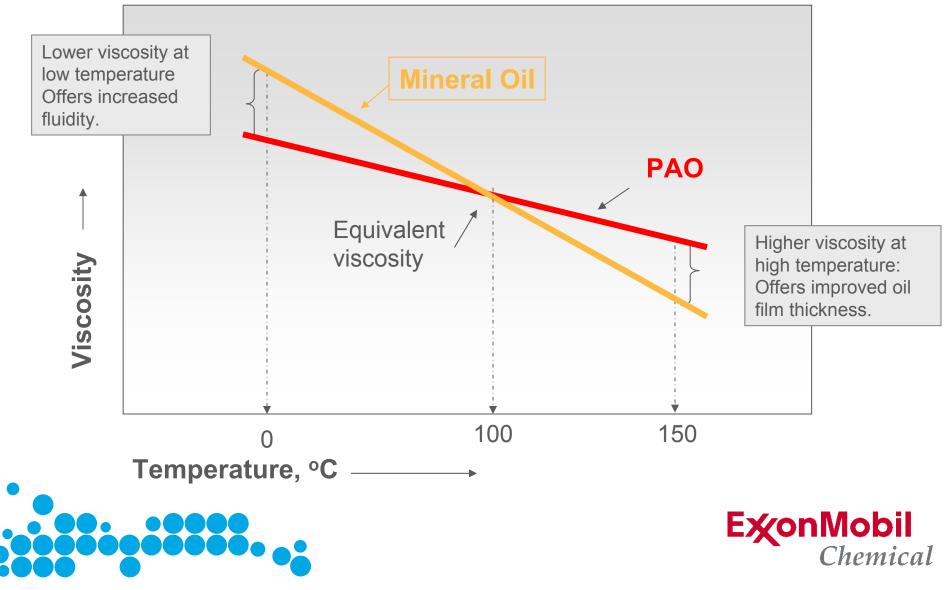




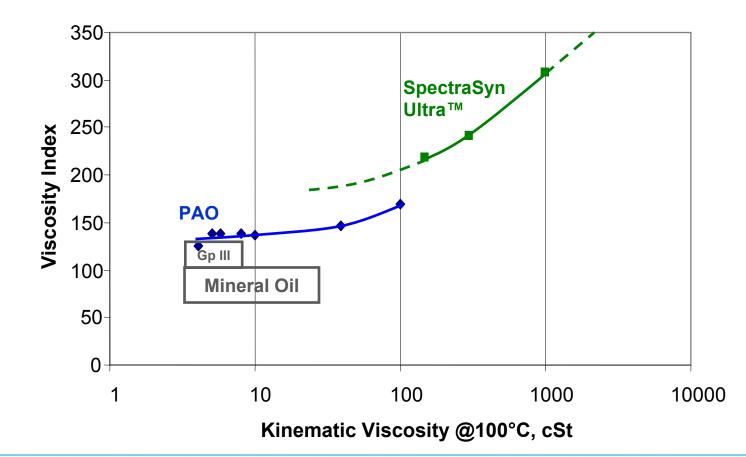


Viscosity Index – Viscosity change with Temperature





SpectraSyn[™] PAOs Have High Viscosity Indices

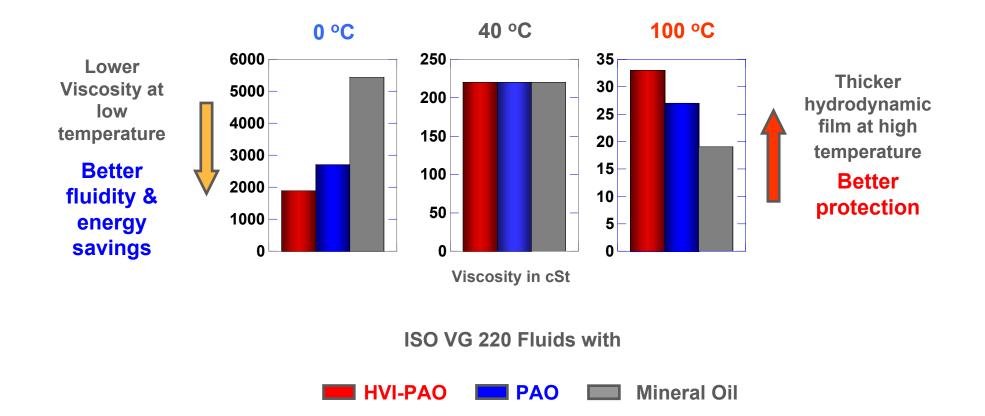


At equivalent viscosity, SpectraSyn Ultra[™] is 40 VI higher than high viscosity PAO, enabling formulations with better protection at high temperatures and reduced energy losses and easier starting at low temperatures





SpectraSyn™ PAO High VI Effect

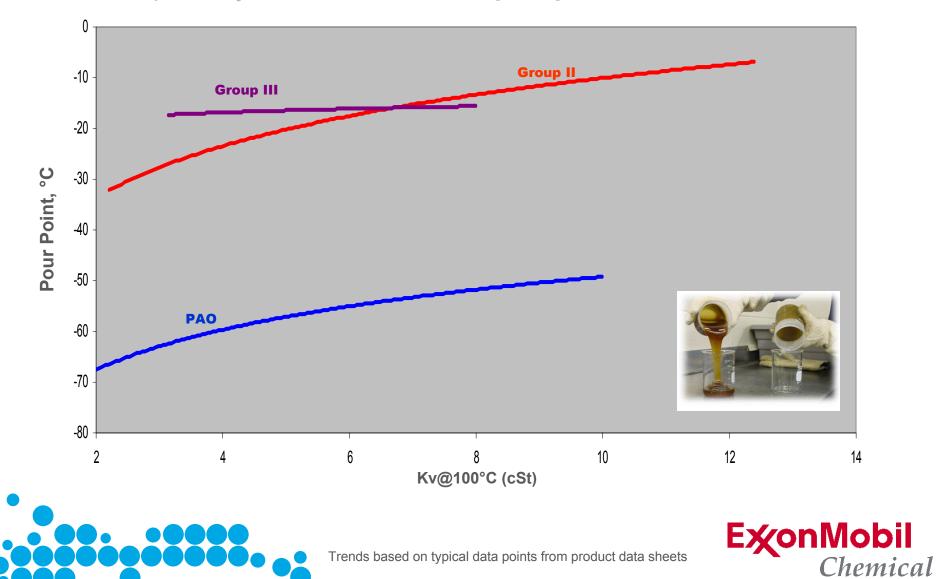






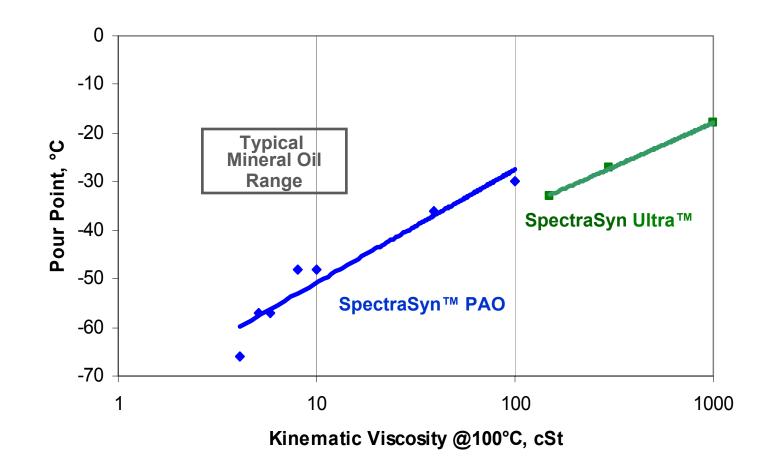
Low Temperature Fluidity – Pour Point

SpectraSyn[™] PAO's have **lower pour points** than mineral oil.



Trends based on typical data points from product data sheets

SpectraSyn[™] PAOs Have Low Pour Points

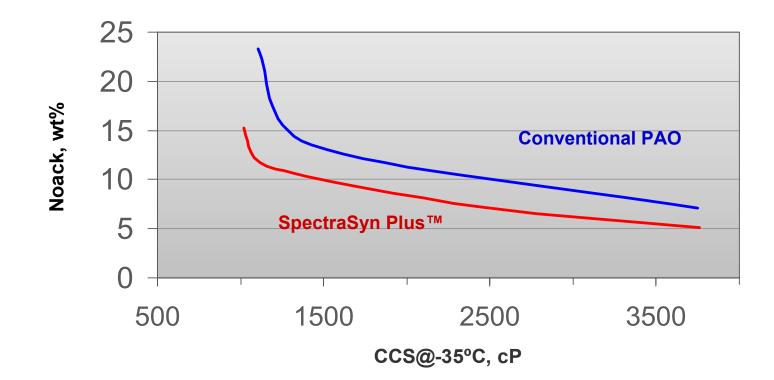


Spectrasyn[™] PAOs flow easily at low temperatures.





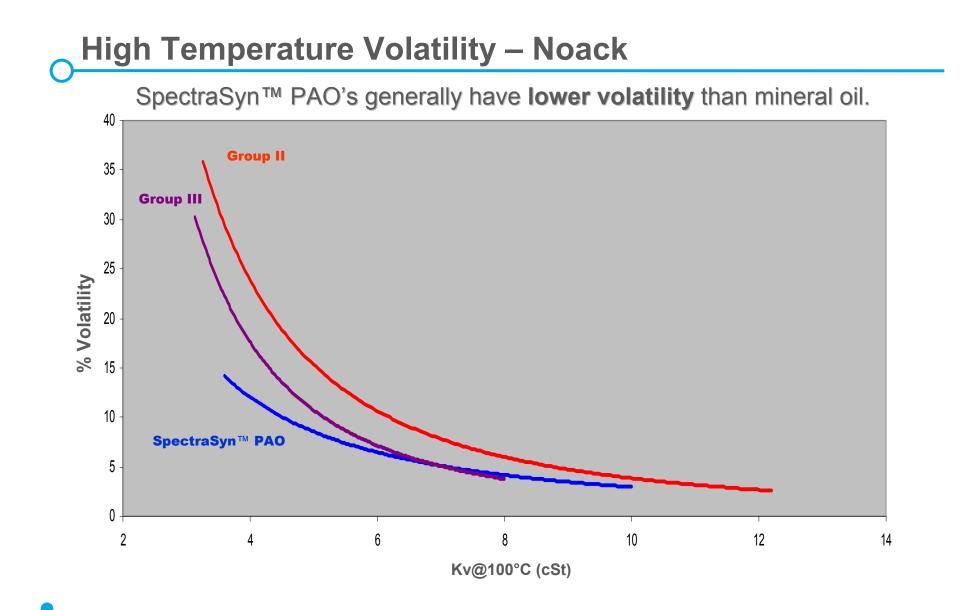
Low Temperature Fluidity – Cold Cranking Viscosity



SpectraSyn Plus[™] PAO offers improved Low Temperature Fluidity



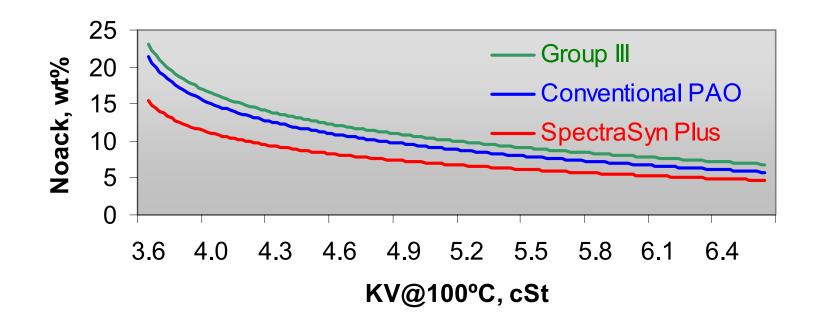




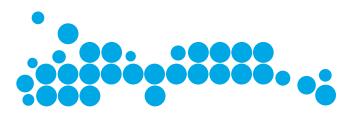
Projected trends based on typical data points from product data sheets







SpectraSyn Plus[™] PAO offers improved Noack Volatility





Oxidation Stability

SpectraSyn™ PAO's have **better oxidative stability** than mineral oil.

- Good oxidative stability is essential for applications at elevated temperatures with air contact
- PAO's show excellent oxidative stability when formulated with suitable antioxidants
- PAO's are more responsive to antioxidants than mineral oil.

Oxidation Stability Test PAO Vs. Mineral Oil (2% Antioxidant)

Product	Mineral Oil	6 cSt	40 cSt	100 cSt
	Group II	PAO	PAO	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

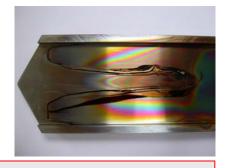




Thermal Stability

Base Fluid	Cleanliness* (10 = Clean)
4.0 cSt Mineral oil	0
4.0 cSt PAO	8.0
4.0 cSt PAO / polyol ester	9.5

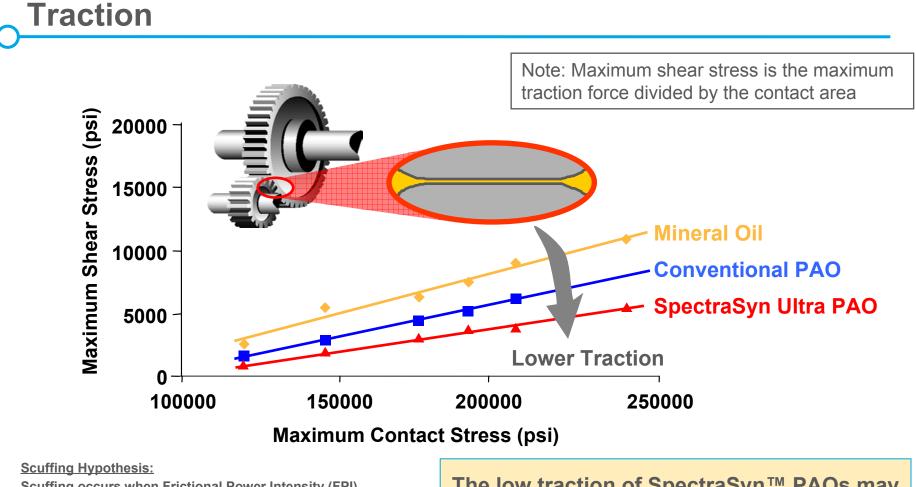
•<u>Panel Coker Thermal Stability Test</u> 310°C aluminum panel splashed by test oil for 6 min baked for 1.5 min Panels rated for cleanliness, where 10 = clean.



PAO withstands high temperatures with minimum decomposition.







Scuffing occurs when Frictional Power Intensity (FPI) exceeds critical limit.

 $FPI = \underline{(Traction)^*(Power)^*(V_2 - V_1)}$ $2^*A^*\lambda$



The low traction of SpectraSyn[™] PAOs may increase allowable gear loading / reduce scuffing & improve gear durability



SpectraSyn[™] High Viscosity PAO Characteristics

	SpectraSyn™ 40	SpectraSyn™ 100
Specific Gravity @15.6/15.6ºC	0.850	0.853
Viscosity @ 100°C, cSt	39	100
Viscosity @ 40°C, cSt	396	1240
Viscosity Index	147	170
Flash Point, Open Cup, °C	281	283
Pour Point, °C	-36	-30
Total Acid Number (TAN), mg KOH/g	<0.10	<0.10
Brookfield Viscosity @ -26°C, cP	102,000	745,000
Fire Point, °C	318	330
Demulsibility @ 82°C, 40-40-0, min	0	0





SpectraSyn[™] High Viscosity PAO

ISO / Wt %	VG 100	VG 150	VG 220	
SpectraSyn [™] 6	33	17		
SpectraSyn [™] 40	47	63	80	
Synesstic [™] 5	20	20	20	
Synessic 5	20	20	20	
ISO / Wt %	20	VG 150	VG 220	VG 320
	20			VG 320 16
ISO / Wt %		VG 150	VG 220	1

ISO / Wt %	VG 100	VG 150	VG 220	VG 320	VG 460	VG 680
SpectraSyn [™] 6	53	42	31	21	11	1
SpectraSyn [™] 100	32	43	54	64	74	84
Adipate Ester	15	15	15	15	15	15

SpectraSyn[™] High Viscosity PAO are the key basestock in formulating wide viscosity grade industrial lubricants.





SpectraSyn™ High Viscosity PAO comparison to PIB

	SpectraSyn™ 40	PIB A	SpectraSyn™ 100	PIB B	PIB C
Kinematic Viscosity	,				
@ 100°C, cSt	39	31	100	108	52
@ 40°C, cSt	396	590	1,240	3,300	1,225
Viscosity Index (VI)	147	75	170	98	87
Pour Point, °C	-36	-35	-30	-13	-23
Flash Point, °C	281	>141	283	>190	>150

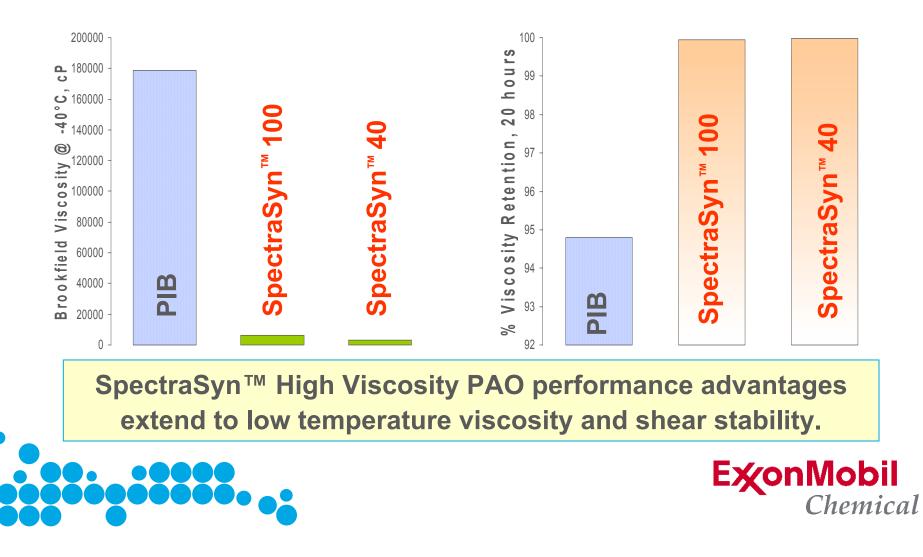
SpectraSyn[™] High Viscosity PAOs have Higher VI, Lower Pour Points and Higher Flash Points than PIBs of Comparable Viscosity



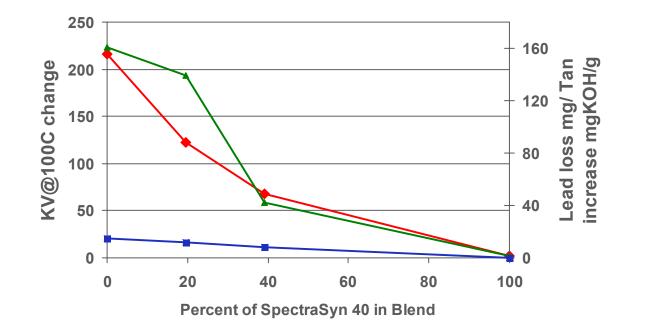


SpectraSyn™ High Viscosity PAO comparison to PIB

Outstanding Low Temperature Viscosity Excellent Tapered Roller Bearing Shear Stability



SpectraSyn™ High Viscosity PAO in Mineral Oil



→ KV@100C Change → Lead Loss, mg → TAN Change

Additions of SpectraSyn[™] High Viscosity PAO to mineral oils improve the oxidation stability of the blends





SpectraSyn[™] PAO in Automotive Gear Formulation

SAE Grade	75W-140
Additive Package, wt %	6.02
SpectraSyn™ 4, wt %	16.94
SpectraSyn™ 100, wt %	57.04
Adipate Ester, wt %	20.00
Viscosity @ 100 °C, cSt	24.8
Viscosity @ -40 °C, cP	120,200
Viscosity Index	172
Flash Point, °C	210
Pour Point, ^o C	-48
Channel Point, ^o C	<-45
Copper Corrosion, 3 h @ 121 °C	1b
Foaming Tendency, Seq. I, II, III, mL	0, 0, 0
Storage Stability & Compatibility	Pass
Shear Loss after Tapered Roller Bearing Test 20 hr, %	0

SpectraSyn[™] High Viscosity PAO can be formulated in wide cross grade automotive gear oil with good shear stability.





SpectraSyn[™] 100 in Industrial gear /Compressor Oil Formulations

ISO VG*	46	68	100	150	
SpectraSyn™ 6 . wt %	74	63	53	42	
SpectraSyn™ 100, wt %	11	22	32	43	
Synesstic™ 5, wt %	15	15	15	15	
PROPERTIES					-
Viscosity @ 100 °C, cSt	7.9	11.1	15.1	20.8	
Viscosity @ 40 °C, cSt	45.3	69.9	104	156	Wide ISO grade
Viscosity Index	145	150	153	156	Better efficiency
Specific Gravity @ 15.6/15.6 °C	0.840	0.842	0.846	0.846	
Flash Point, °C	236	236	239	240	Deduce viels of invition
Fire Point, °C	268	270	271	268	Reduce risk of ignition
Pour Point, °C	-57	-51	-45	-39	Good low temperature performance

* Examples of basestock combination only. Will require appropriate additives and testing.

SpectraSyn[™] High Viscosity PAO can be formulated into wide ISO grade industrial gear/compressor oils that have high VI, high flash/fire points, and good low temperature performance.





Other Key Features of PAO

- Low toxicity
- Hydrolytically stable
- Excellent additive response
- Compatible with mineral oils, Esters and Alkylated Napthalene
- All SpectraSyn[™] grades are registered worldwide
- Meet FDA Requirement under 21 CFR 178.3620(b) Technical White Mineral Oil
- Can be used to formulate lubricants for incidental food contact
 - Kosher approved
 - Halal approved
- NSF Approval For Incidental Food Contact (USDA H1)(except SpectraSyn[™] 5)
- Listed in the NSF White Book (http://www.nsf.org/usda/Listings.asp)





PAO Typical Applications

					sions	6	6	5	Oresso		<u>ک</u>	uic
EMCC Product Names	Gasoline	Engines	Industric Transmisse	Hydrs. alla unons	ndus 'alic 'sh	Rolary A:	Combressor Res. H. Ssor	Chige ation Cond	Turbin Millin	hear _{7.}	Automotic Fluid	Mist Lutos aulic
SpectraSyn 2™		•	•	•			•	•		•	•	
SpectraSyn 4™	•	•	•	•		•	•	•	•	•		•
SpectraSyn 5™	•		•	•			•		•	•		
SpectraSyn 6™	•		•		•	•	•	•	•			•
SpectraSyn 8™	•		•	•	•	•	•	•	•			•
SpectraSyn 10™			•	•	•	•	•	•	•			•
SpectraSyn 40™			٠				•					•
SpectraSyn 100™												•
SpectraSyn Plus™ 3.6							•	•	•			
SpectraSyn Plus™ 4			٠				•	•	•	•		•
SpectraSyn Plus™6	•		٠			٠	•	•	•			•
SpectraSyn Ultra™ 150	•	•	•	•	•			•				•
SpectraSyn Ultra™ 300	•				•			•				
SpectraSyn Ultra™ 1000												



Most common application uses

Less commonly used



SpectraSyn[™] PAO Product Line Summary

Description	Product	kV@100°C	kV@40°C	VI	Pour Point °C	COC Flash point °C
	SpectraSyn™ 2	1.7	5	-	-66	157
	SpectraSyn™ 4	4.1	19	126	-66	220
Low and high viscosity PAO with excellent	SpectraSyn™ 5	5.1	25	138	-57	240
oxidative & thermal	SpectraSyn™ 6	5.8	31	138	-57	246
stability, low volatility and low temperature	SpectraSyn™ 8	8.0	48	139	-48	260
performance	SpectraSyn™ 10	10.0	66	137	-48	266
	SpectraSyn™ 40	39	396	147	-36	281
	SpectraSyn™ 100	100	1240	170	-30	283
Low viscosity PAO with	SpectraSyn Plus™ 3.6	3.6	15.4	117	-65	224
enhanced volatility and low temperature fluidity	SpectraSyn Plus™ 4	3.9	17.2	126	-60	228
	SpectraSyn Plus™ 6	5.9	30.3	143	-54	246
Very high viscosity PAO with high viscosity	SpectraSyn Ultra™ 150	150	1500	218	-33	≥ 265
index, good shear stability, improved low temperature properties,	SpectraSyn Ultra™ 300	300	3100	241	-27	≥ 265
enhanced oil film thickness & lower traction	SpectraSyn Ultra™ 1000	1000	10000	307	-18	≥ 265





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