Advanced Polyalphaolefins

SpectraSyn Ultra™

ExxonMobil Chemical
What is SpectraSyn Ultra™ PAO?

• An unique molecular structure which results in improved high viscosity, high VI PAO basestocks

• Provide more stable viscosity / film thickness vs. temperature profile, excellent shear stability, and lower traction

• Opportunities for
  • Improved equipment protection at:
    • High load
    • High temperature
    • Low temperature
  • Reduced energy consumption from:
    • Viscous churning
    • Internal traction
## SpectraSyn Ultra™ Product Line

<table>
<thead>
<tr>
<th>SpectraSyn Ultra™</th>
<th>150</th>
<th>300</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic Viscosity @100°C, mm²/s (cSt)</td>
<td>150</td>
<td>300</td>
<td>1,000</td>
</tr>
<tr>
<td>Kinematic Viscosity @40°C, mm²/s (cSt)</td>
<td>1,500</td>
<td>3,100</td>
<td>10,000</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>218</td>
<td>241</td>
<td>307</td>
</tr>
<tr>
<td>Brookfield Viscosity @25°C, mPa-s (cP)</td>
<td>2,900</td>
<td>6,200</td>
<td>24,000</td>
</tr>
<tr>
<td>Pour Point, °C</td>
<td>-33</td>
<td>-27</td>
<td>-18</td>
</tr>
<tr>
<td>Surface Tension @24°C, mN/m</td>
<td>30.7</td>
<td>30.4</td>
<td>30.2</td>
</tr>
<tr>
<td>Specific Gravity @15.6/15.6°C</td>
<td>0.850</td>
<td>0.852</td>
<td>0.855</td>
</tr>
<tr>
<td>Flash Point, Open Cup, °C</td>
<td>&gt;265</td>
<td>&gt;265</td>
<td>&gt;265</td>
</tr>
<tr>
<td>Total Acid Number, mg KOH/g</td>
<td>&lt;0.10</td>
<td>&lt;0.10</td>
<td>&lt;0.10</td>
</tr>
</tbody>
</table>

Wide range of viscosities with high VI and improved pour point.
SpectraSyn Ultra™ Blends Offer a Wide Viscosity / Temperature Profile

- Viscosity ranges from ISO VG 32 - ISO VG 1500
- High Viscosity Indices, 160 – 220
- Very low pour points, -35 to -60ºC, when blended with low viscosity PAO
SpectraSyn Ultra™ PAO’s can provide shear stable ISO 22 Hydraulic Fluid with VI greater than 200.

SpectraSyn Ultra™ can provide very high VI / low viscosity lubricants by blending with SpectraSyn™ 2 PAO.
EHL occurs in rolling bearings, gears, and cams, where small contacts lead to very high local pressures (>1 GPa). Such high pressures cause the contacts to flatten elastically. In addition, lubricant viscosity increases exponentially with pressure and this allows a thin film (~1 µm) of lubricant to protect the surfaces.

Under very thin EHL film conditions, the unique molecular structure of SpectraSyn Ultra™ provides a film thickness boost which reduces metal-to-metal contact and protects against wear.
SpectraSyn Ultra™ Improves EHL Film Thickness

Significance of enhanced EHL film thickness:
- Delays transition to boundary lubrication in valve train contacts
- Protects against wear by reducing local surface contact
- May also reduce boundary friction and increase valve train efficiency

Lubricant film thickness as measured in a point contact (ball on disk) test rig demonstrates the benefits of SpectraSyn™ Ultra

SpectraSyn Ultra™ formulations provide additional film thickness thereby reducing friction, heat, and wear.
SpectraSyn Ultra™ Benefits Passenger Car Lubricants

SpectraSyn Ultra™ reduces wear by over 75% in key engine test.

**Synthetic 0W30 Sequence VE Wear Test**

<table>
<thead>
<tr>
<th>Max</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>415</td>
<td>189</td>
</tr>
<tr>
<td>28</td>
<td>18</td>
</tr>
</tbody>
</table>

**Sequence VE Wear Test**

- 288 hour gasoline engine test involving 72 cycles
- Simulates moderate-temperature taxicab service, delivery service, and job commuting service
- Fuel-injected Ford 2.3 liter gasoline engine with overhead camshaft, **slider follower design**
- Engine oil category specifications for this test include:
  - API SG, SH, SI
  - ILSAC GF-1, GF-2, GF-3
  - MIL-L-21260D, MIL-L-46167B

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Tests indicate **20-30% wear reduction** in heavy duty engines from using SpectraSyn Ultra™ 150 with Group I and Group II formulations.

This Roller follower wear test is the GM 6.5L engine test and is part of: API CG-4, API CH-4, API CI-4 specifications.
Scuffing Hypothesis:
Scuffing occurs when Frictional Power Intensity (FPI) exceeds critical limit.

\[ FPI = \frac{(Traction) \times (Power) \times (V_2 - V_1)}{2 \times A \times \lambda} \]

Note: Maximum shear stress is the maximum traction force divided by the contact area.

SpectraSyn Ultra™ PAOs have lower traction.

SpectraSyn Ultra™ - low traction may increase allowable gear loading / reduce scuffing & improve gear durability.
SpectraSyn Ultra™ PAO can increase HTHSR Viscosity while maintaining nearly constant kinematic viscosity and CCS.

- Increases hydrodynamic bearing lubricant film thickness under load
- Reduces wear
SpectraSyn Ultra™ based Hi VI ISO VG 220 Gear Oil

High VI

Viscosity Index

KRL % Viscosity Retained after 20 hours

Good Shear Stability

SpectraSyn Ultra™ high VI industrial gear oils provide more consistent viscosity over wide range of temperatures with good shear stability.
SpectraSyn Ultra™ based Hi VI ISO VG 220 Gear Oil

Excellent Low Temperature Viscosity

SpectraSyn Ultra 150
SpectraSyn Ultra 300
PIB
PMMA

Outstanding Pour Point

SpectraSyn Ultra 150
SpectraSyn Ultra 300
PIB
PMMA

SpectraSyn Ultra™ provides significant low temperature advantages compared to alternative high viscosity modifiers.
SpectraSyn Ultra™ PAOs Have Low Surface Tension

Low surface tension of SpectraSyn Ultra™ results in less foaming.
SpectraSyn Ultra™ Provides Good Air Release

Air Release Screener Test Results of ISO VG 220 Blends (PAO6 base)
SpectraSyn Ultra™ Has Lower Foaming Tendency

Mixmaster Foam Test Results at Room Temperature (No defoamant)

Foaming is an undesirable characteristic of lubricants. Excessive foaming can lead to lubricant escaping from reservoir.
SpectraSyn Ultra™ Maintains Low Foam Capabilities Over Time

Mixmaster Foam Test Results for ISO VG 460

Aged lubricants continue to have lower foaming tendency when formulated with SpectraSyn Ultra™.
Key Benefits of SpectraSyn Ultra™ High VI PAO

Wide Viscosity Range Blends Possible
• ISO VG 32 to ISO VG 1500

Low Pour Point Blends
• -60° C to -35° C

High Viscosity Index
• 160 - 220 VI basestocks
• Improves high temperature film thickness

Excellent Shear Stability
• 95% viscosity retention @ 20 hour TRB (ISO VG 220)

Excellent Low Temperature Fluidity
• Brookfield Viscosities < 100,000 cP @ -40° C (ISO VG 220)
• Reduces low temperature viscous drag losses

Low Traction
• ~ 30% lower traction at high contact stress than conventional PAO
• May help reduce
  - Scuffing
  - Micro-pitting
  - Load dependent losses

SpectraSyn Ultra™ High VI PAO - Synthetic lubricant basestocks for the next generation industrial lubricants