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High performance synthetic compressor oil: Targeting longer life and energy efficiency

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ExxonMobil Product Solutions – Synthetics
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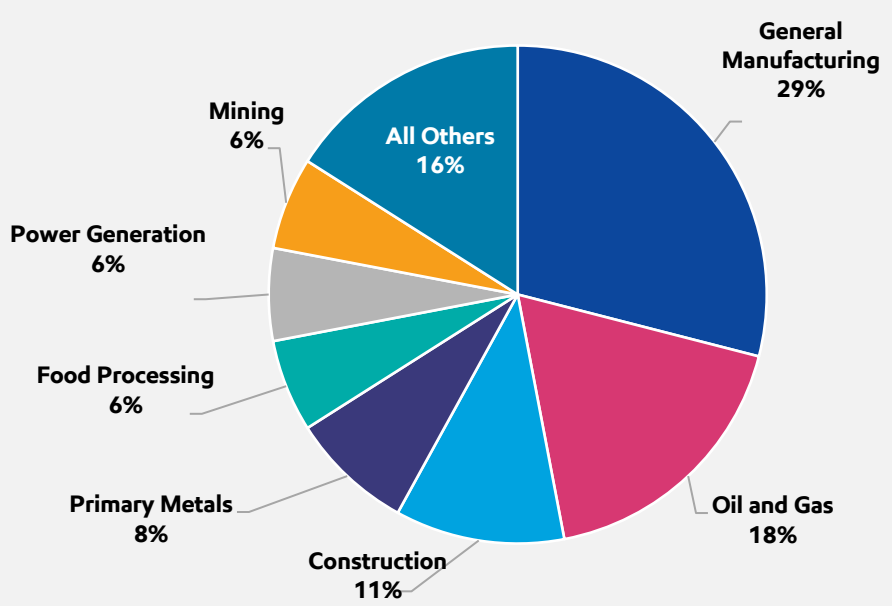
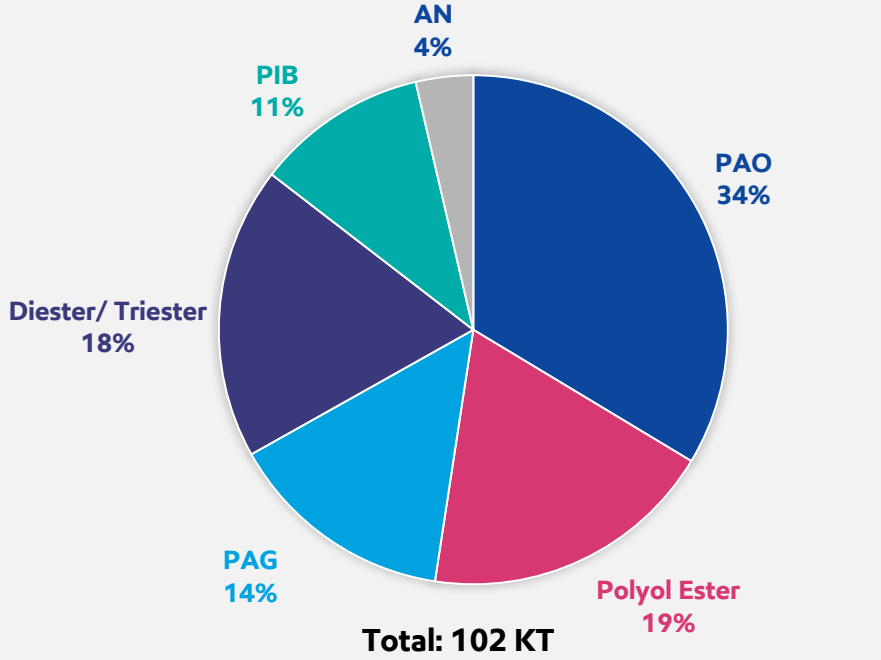
Global air compressor oil market trends (2023) & Synthetic segment outlook to 2029



Source: Kline + Company, Opportunities in Industrial Lubricants, 2024

- General manufacturing and oil & gas dominate the air compressor market
- Synthetic air compressor oil commonly used in food processing applications



Source: Future Market Insights (FMI)

- AN is used as co-base stock
  - Increasing oil life of compressor
  - Reducing varnish deposit
- PIB is used to increase base oil viscosity of synthetic compressor oil

Global synthetic compressor oil market: PAO and AN technologies drive longer oil life and cleaner performance

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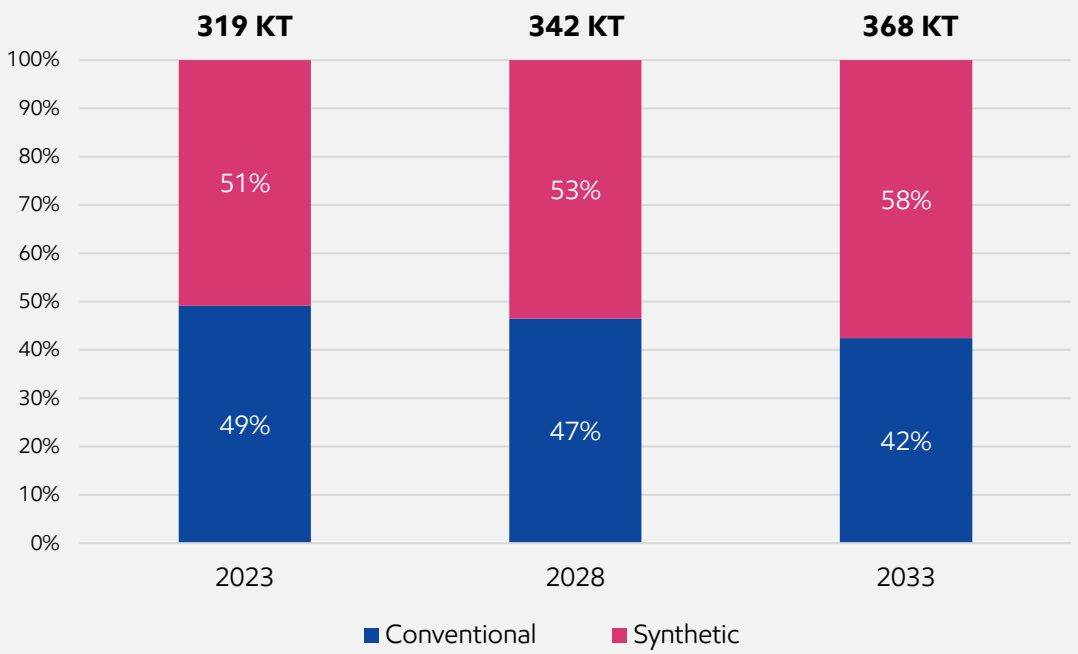
Compressor oil market, demand by operating hours and synthetic penetration

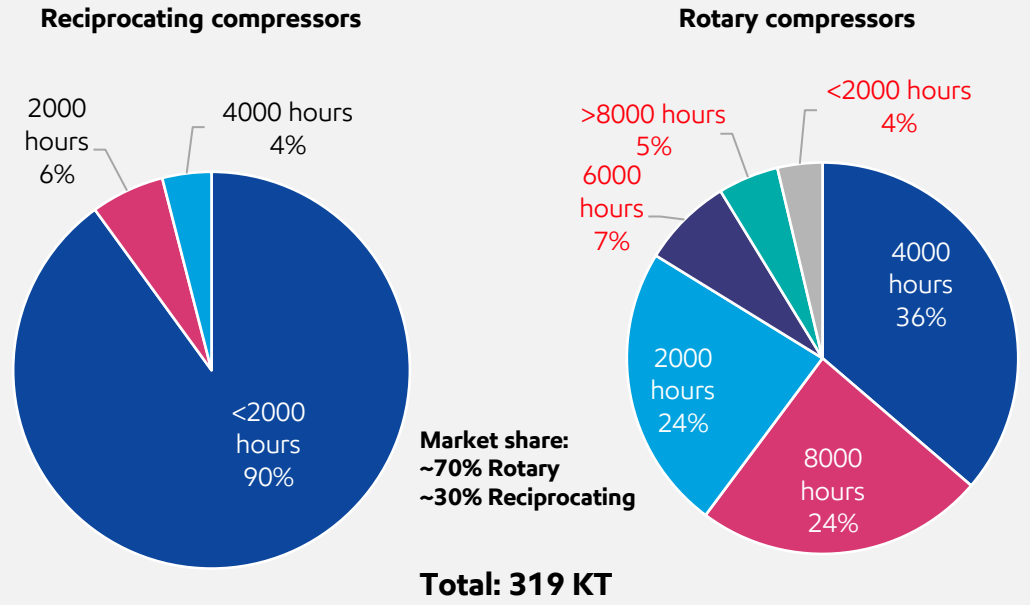
Synthetic compressor oil is projected to grow at an annual rate of 4.9 KT over the next decade

ESTIMATED DEMAND FORECAST OF CONVENTIONAL AND SYNTHETIC OILS, 2023-2033



Source: Kline + Company, Opportunities in Industrial Lubricants, 2024

ESTIMATED DEMAND SHARE FOR COMPRESSOR OILS BY OPERATING HOURS, 2023

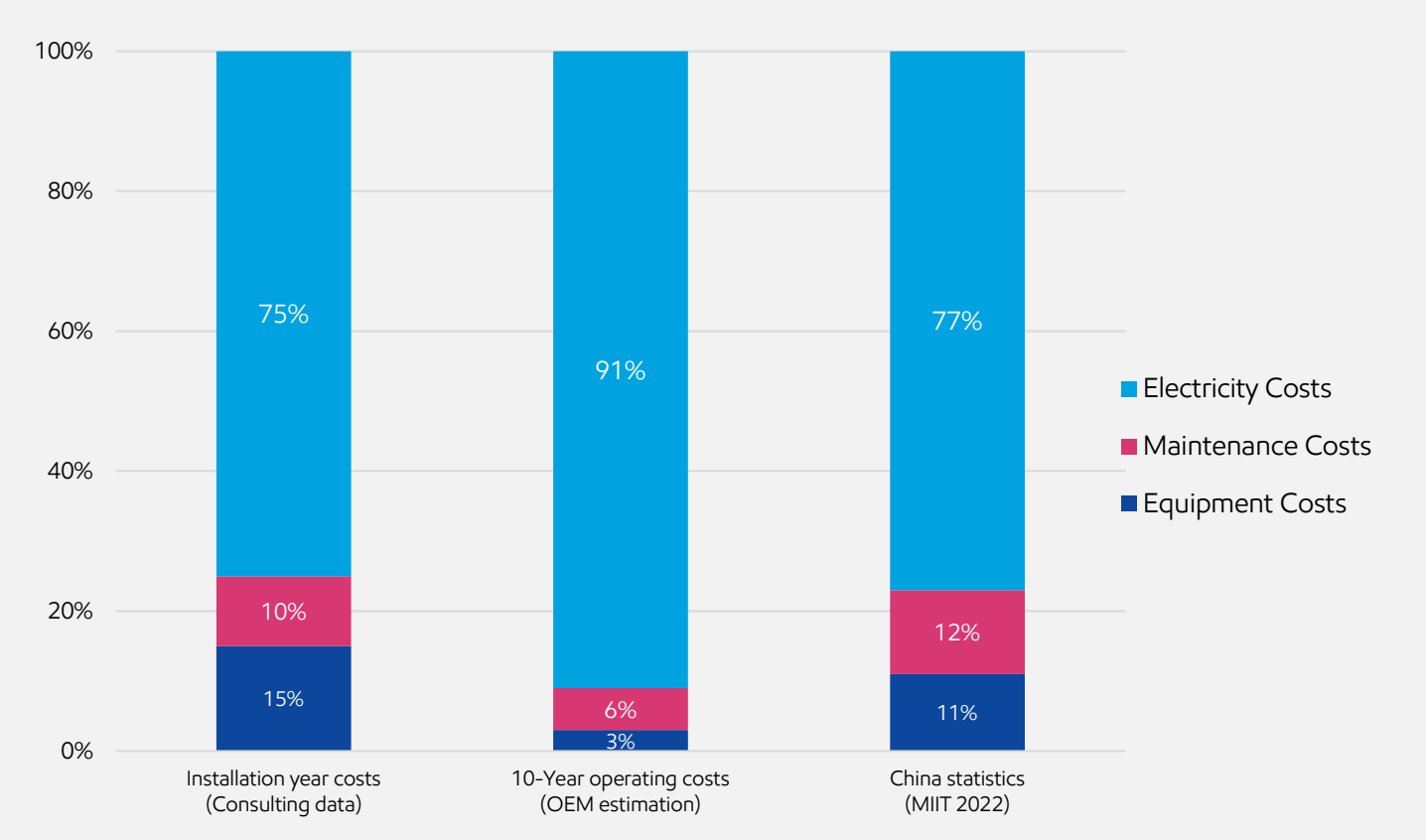


Source: Kline + Company, Opportunities in Industrial Lubricants, 2024

Demand for longer oil life and performance is driving 7% growth in synthetic compressor oil by 2033

Compressor efficiency: critical for managing electricity costs

The Chinese Ministry of Industry and Information Technology (MIIT) conducted an energy-savings air compressor study



Data Source: "Industry Energy Efficiency Improvement Action Plan" published in 2022 by MIIT

The electricity cost constitutes the major part of the operating cost for an air compressor

Over the lifespan of an air compressor:

77%

The cost of energy use

23%

The cost of the unit (equipment and maintenance)

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Potential benefits from synthetic compressor oil

Energy efficiency benefits when using synthetics vs. mineral oil in a plant with 57 air compressor units

Extension of oil drain interval from 6 to 12 months

$9,000

Approximate annual savings

Reduction of energy consumption by about 3%

$57,000

Approximate annual savings

Reduction of compressor air/discharge temperature from an average of

86°C to 82°C

Mobil Rarus SHC™ 1024 success story: Extend oil drain interval, increase energy efficiency and decreased operating temperature | Mobil™

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Key properties of synthetic base stocks enhancing air compressor energy efficiency

Advanced PAO technology – SpectraSyn™ MaX 3.5

SpectraSyn™ MaX platform – High efficiency technology

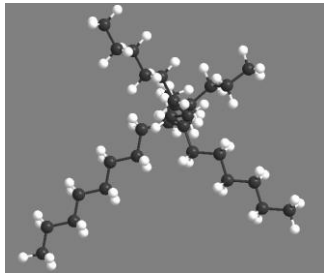
- Leverages unique PAO structure and proprietary manufacturing process
- Engineered, high molecular uniformity

Step-out performance in critical areas:

- Energy efficiency
- Low volatility
- Formulation flexibility
- Air release
- Thermal management
- Oil aging
- Durability
- Low-temperature

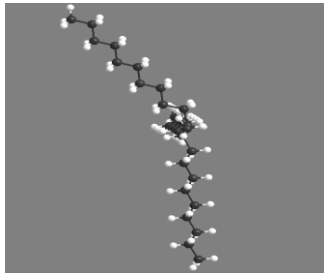
Uniform molecules align well under pressure, reducing molecular interactions during hydrodynamic film formation, improving efficiency and lowering friction

Conventional PAO



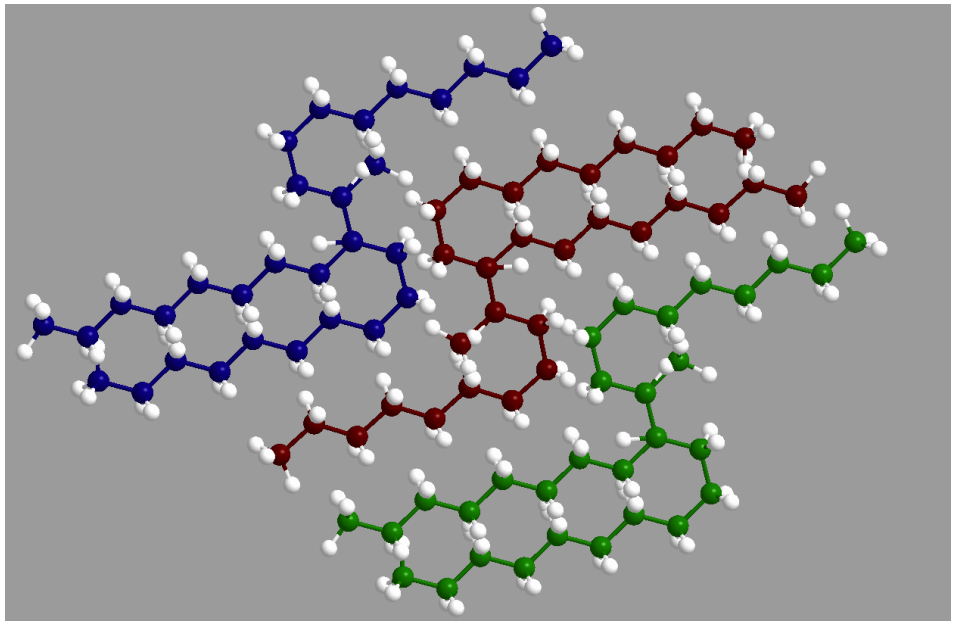
Improved uniformity

SpectraSyn™ MaX PAO



Combined SS MaX PAO

SpectraSyn™ MaX PAO (x3, visualization)



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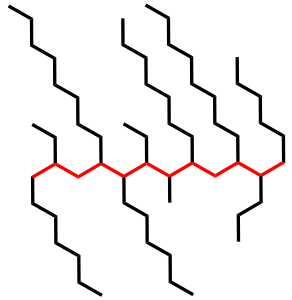
Source: ExxonMobil data

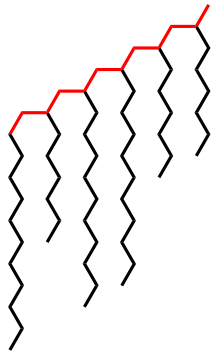
SpectraSyn Elite™ metallocene PAO molecular modelling

C_{60} Conventional PAO



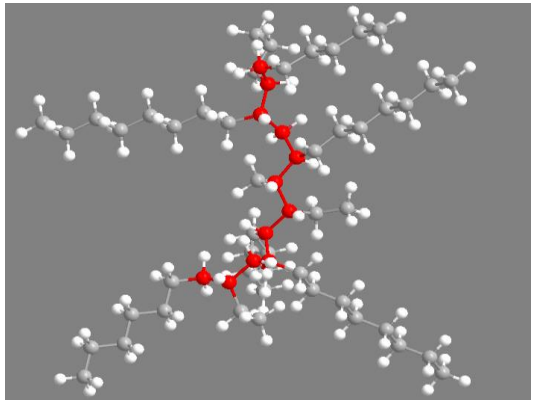
- Prominent "backbone"
- Isomerization prevalent, random side-chain orientation, more carbons in the main chain
- More extended with more chain interactions - greater sweep volume

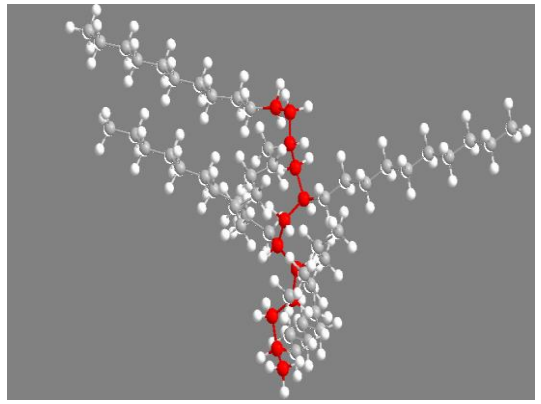
C_{60} Metallocene PAO



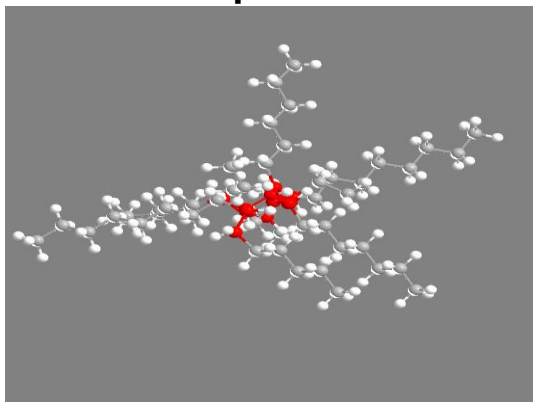
- Uniform, bottlebrush structure with absence of short side chains
- No isomerization, more carbons in the branches
- High viscosity with narrow molecular weight distribution, smaller molecular volume
- More compact with few chain interactions

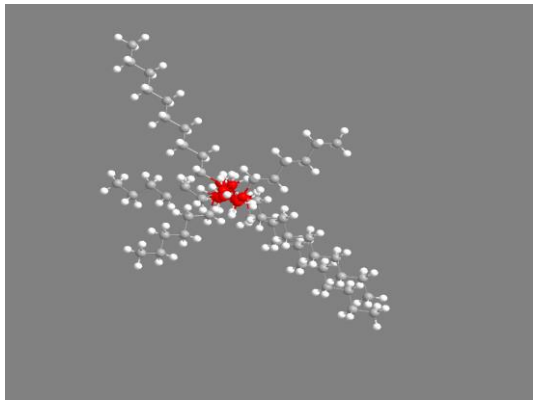
Side view





Top view





Key performance advantages of Metallocene PAO in comparison with conventional PAO are:
high VI, enhanced oxidation stability, superior low-temperature properties

Source: ExxonMobil data

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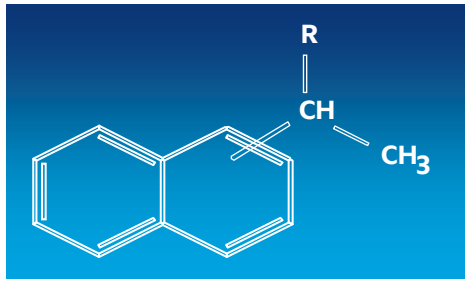
Alkylated Naphthalenes | Performance

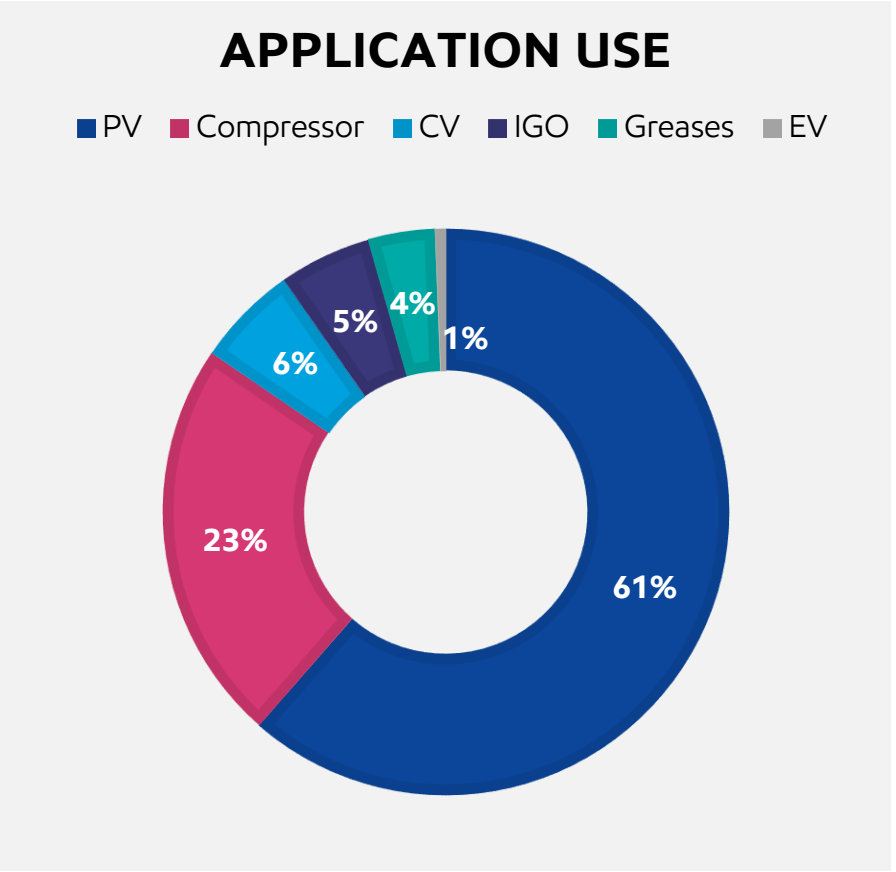
Alkylated Naphthalene extends oil life of compressor, PV and CV oils



Alkylated Naphthalenes are engineered high-performance molecules

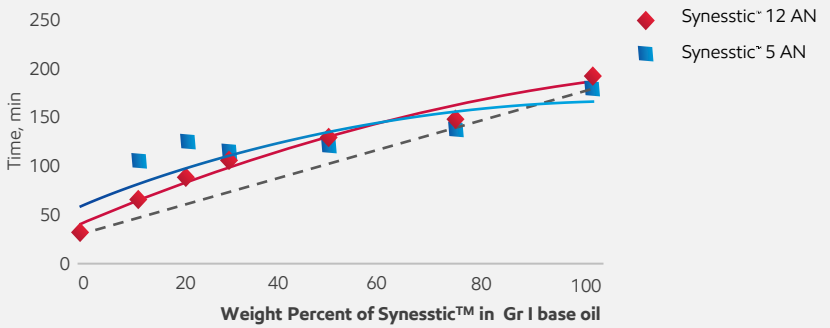
Synesstic™ 5 AN
Synesstic™ 12 AN

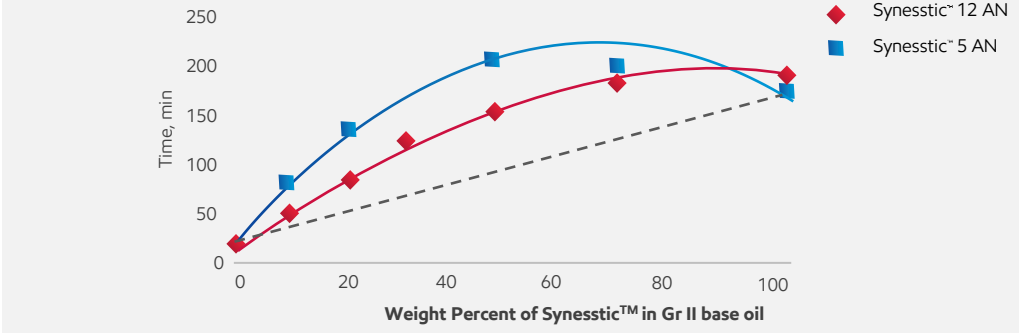
- Low volatility
- **High thermal & oxidative stability**
- Excellent **hydrolytic stability**
- Boosts **oxidation resistance**
- Capability to improve seal swell
- Capability to improve solubility of additives in formulation
- **Potential to improve additive response**

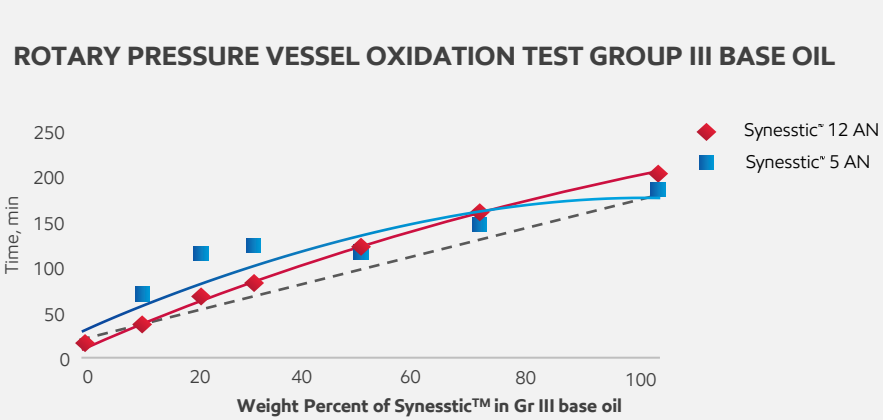


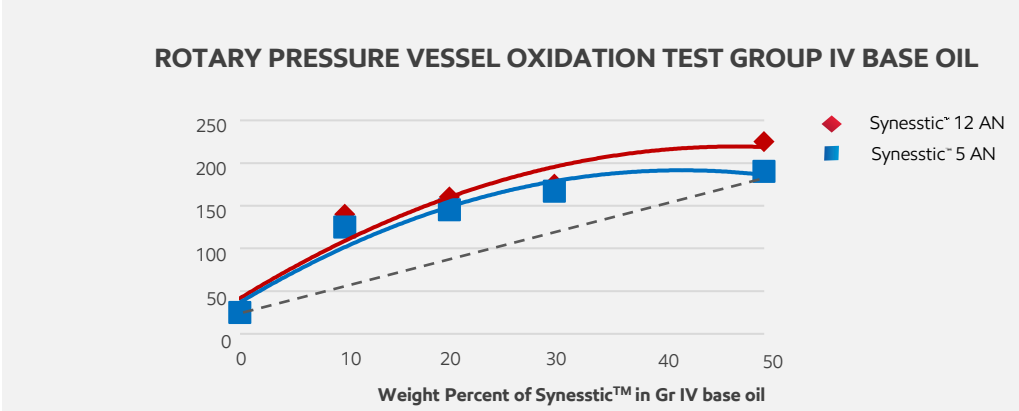
Data source: ExxonMobil published information

Synesstic™ AN can improve oxidative stability in Gr I / II / III / IV Base Oils









Source: ExxonMobil internal testing data

All chart test data generated using ASTM D2272 RPVOT oxidation method test

Spot data measured, results may vary over time

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Synesstic™ 5 AN improves oxidative stability of blends with Gr II / III / IV Base Oils

Synesstic™ 5 AN inhibits acid buildup, sludge/deposit formation, and viscosity increase for a range of base stock blends

BULK OIL OXIDATIVE STABILITY TEST (Modified ASTM D 4636)

Sample description	Synesstic™ 5 (AN)	Group II	Group II / AN	Group III	Group III / AN	Group IV	Group IV / AN
Evaporation Loss, wt %	1.9	3.6	3.0	2.5	2.2	3.3	1.7
Total Acid Number Change, mg KOH/g	0.5	6.3	4.4	7.4	6.4	5.0	0.9
Kinematic Viscosity @ 100 C Change, %	3.8	35.8	18.5	99.7	25.8	23.7	4.2
Sludge Content, mg/100 ml oil	0	427	< 5	< 5	< 5	< 5	< 5

Blends are 50 : 50 wt % with 0.50 wt % antioxidant
Test: 175 °C (347 °F), 4 days, 5 liter/hrs dried air In the presence of Al, Ag, Cu, Steel, & Mg coupons

[1]Source: ExxonMobil internal testing data

* * Spot data measured, results may vary over time

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Compressor oil blends with Synesstic™ AN and API Group III oil

Component, wt. %			ISO VG 32	ISO VG 46	
Gr III 4 cSt			41.1	7.3	
Gr III 8 cSt			41.5	74.8	
VI improver			0.5	1	
Additive Package *(contains 15% Synesstic™ 5 AN			16.9	16.9	
Property		Test Method	ISO VG 32	ISO VG 46	Limits
Kv@40°C, cSt°		ASTM D445	32.7	43.8	ISO VG +/- 10%
Kv@ 100°C, cSt		ASTM D445	6	7.3	
Viscosity Index		ASTM D2270	133	130	
Pour Point, °C		ASTM D97	-42	-39	<-20
Flash Point °C		ASTM D92	232 (>210)	241 (>231)	Shown in brackets
Tan, mg KOH/g		ASTM D974	0.4	0.4	<0.6
Ash Content %		ASTM D874	<0.05	<0.05	
Conradson Carbon, %		ASTM D189	0.03	0.05	
Air release, minutes		IP313	1.5	2.5	
TOST, hours		ASTM D943	8269	6250	>400
Demulsification, time to 40-40-0, minutes		ASTM D1401	4.5	4.8	<30
Demulsification	water in oil, %	ASTM D2711	0.1	0.15	<1
	Total free oil, ml		88.2	87	>60
	Emulsion, ml		0.1	0.15	<1
Foam	Sequence 1, ml	ASTM D892	0/0	0/0	<50/0
	Sequence 2, ml		20/0	0/0	<50/0
	Sequence 3, ml		10/0	0/0	<50/0
Copper corrosion, 3h @100°C		ASTM D130	1b	1b	1b
Rust test		AST D665B	Pass	Pass	Pass
RPVOT, minutes		ASTM D2272	1885	1956	
FZG visual (A/8.3ms-1/90°C		ASTM D5182	12 Fail	11 Fail	>11 Fail
4 ball wear, ASTM D4172, mm(40kg/1200 rpm/60 mins/75°C)		ASTM D4172	0.34	0.39	<0.4

*Additive package meets the requirements of DIN 51506 VDL; DIN51524 HLP, GM ; SAE MS1003.
The test results are typical and are not intended to be specifications
Source ExxonMobil and models

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Energy efficient compressor oil formulations using: SpectraSyn™ MaX PAO 3.5/Synesstic™ 5 AN/SpectraSyn Elite™ PAO 150

Synthetic Compressor oil		ISO 46	ISO 46	ISO 46	ISO 46	ISO 32	ISO 32	ISO 22	ISO 22
Formulation components wt. %									
SpectraSyn™ Max 3.5		**20%**	**30%**	**20%**	**20%**	**20%**	**20%**	**40%**	**40%**
SpectraSyn™ PAO 8		47%	32%					40%	
Gr III 6 cSt				43.5%		54%			
Gr III+ 8 cSt					46%		57%		40%
Synesstic™ 5 AN		**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
SpectraSyn Elite™ 150		13%	17.5%	16.5%	14%	6%	3%		
AdPack (2% to 4%)									
KV @100^{0}C, cSt	ASTM D 445	8.08	8.37	7.92	8.36	6.24	6.27	4.89	4.94
KV @40^{0}C, cSt	ASTM D 445	46.36	46.86	43.83	46.09	32.82	32.92	24.24	23.62
VI	ASTM D2270	148	156	154	159	143	144	127	138
BV @ -26^{0}C, cP	ASTM D 5293	2935	2772	3861	3566	2646	2360	1081	1007
BV @ -40^{0}C, cP	ASTM D 5293	14151	12596	26033	22799	17780	18514	5857	5447
NOACK Volatility, wt.%	CEC L-40-A-93	7	7	6	6	8	6	9	8

Using SpectraSyn™ MaX PAO 3.5 and SpectraSyn Elite™ PAO 150 in compressor oils can provide excellent low temperature properties and high viscosity index

Source: ExxonMobil internal data

Formulations shown are intended to be starting points for formulation evaluations. Lubricant blender is responsible for obtaining appropriate approvals and licensing of all formulations.

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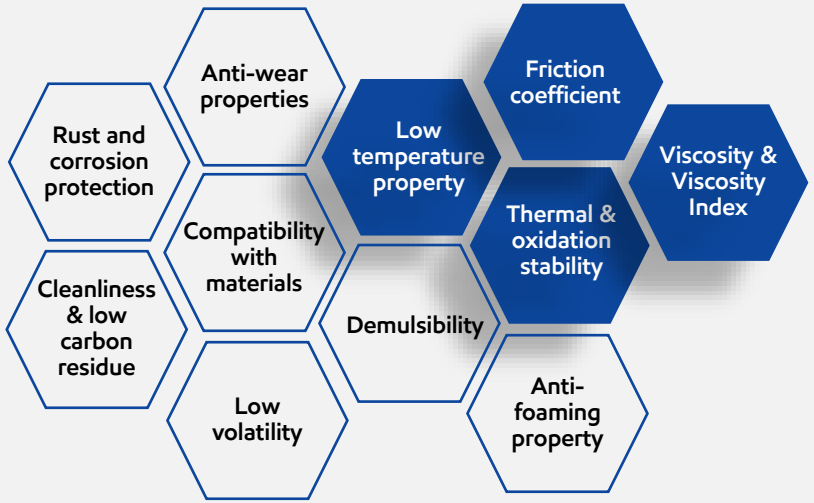
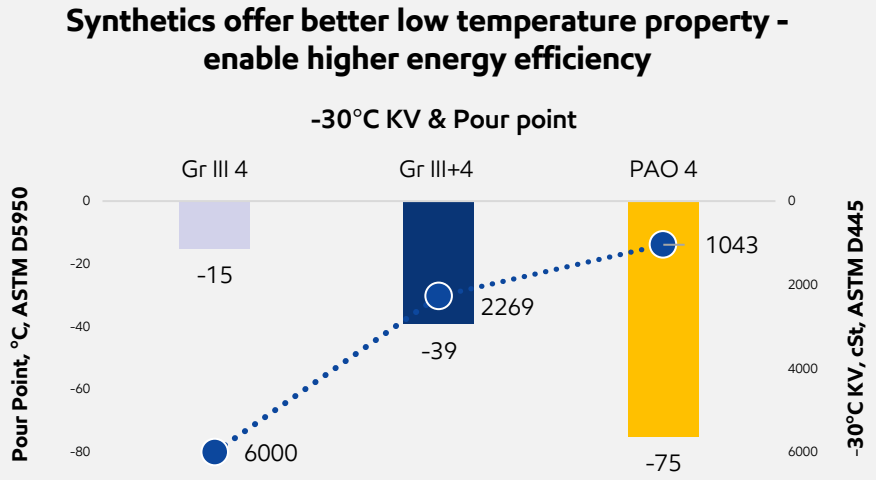
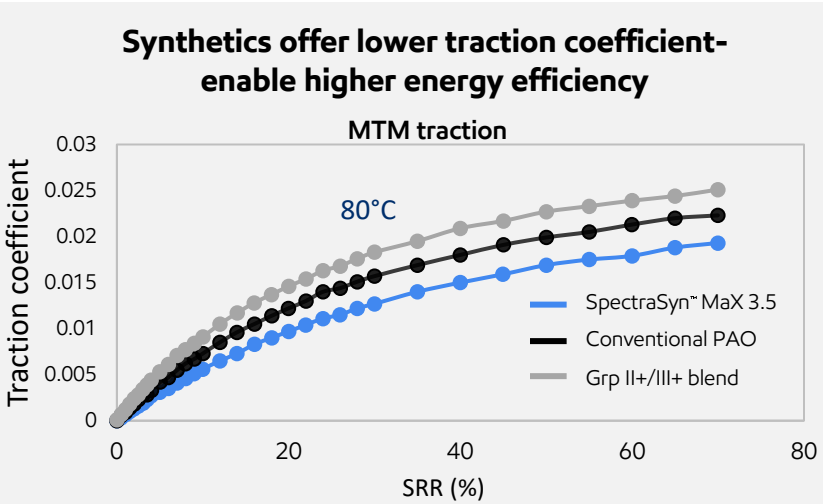
Performance evaluation of synthetic air compressor oils

Key properties of synthetics contributing to energy efficiency

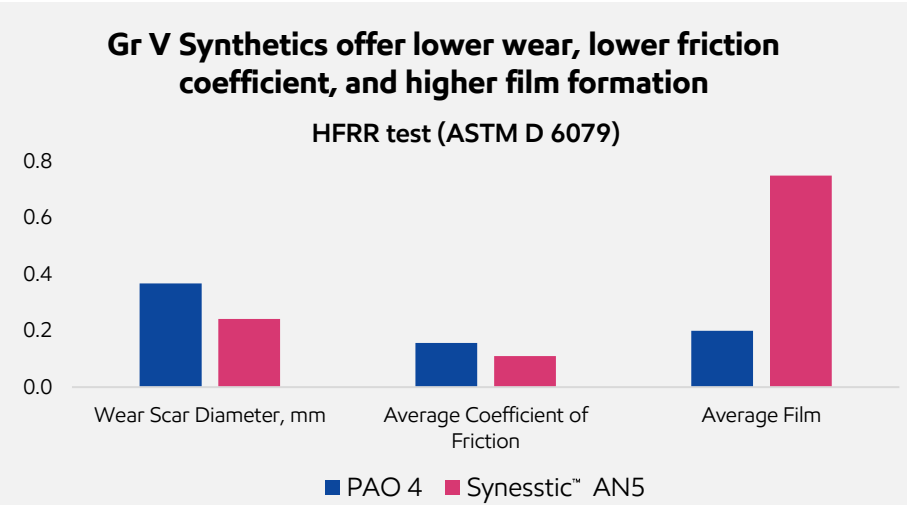






(All oils tested at Load 30N, speed 2 m/s, SRR 0-70%)

Note: All samples shown are pure base oils or blends of base oils



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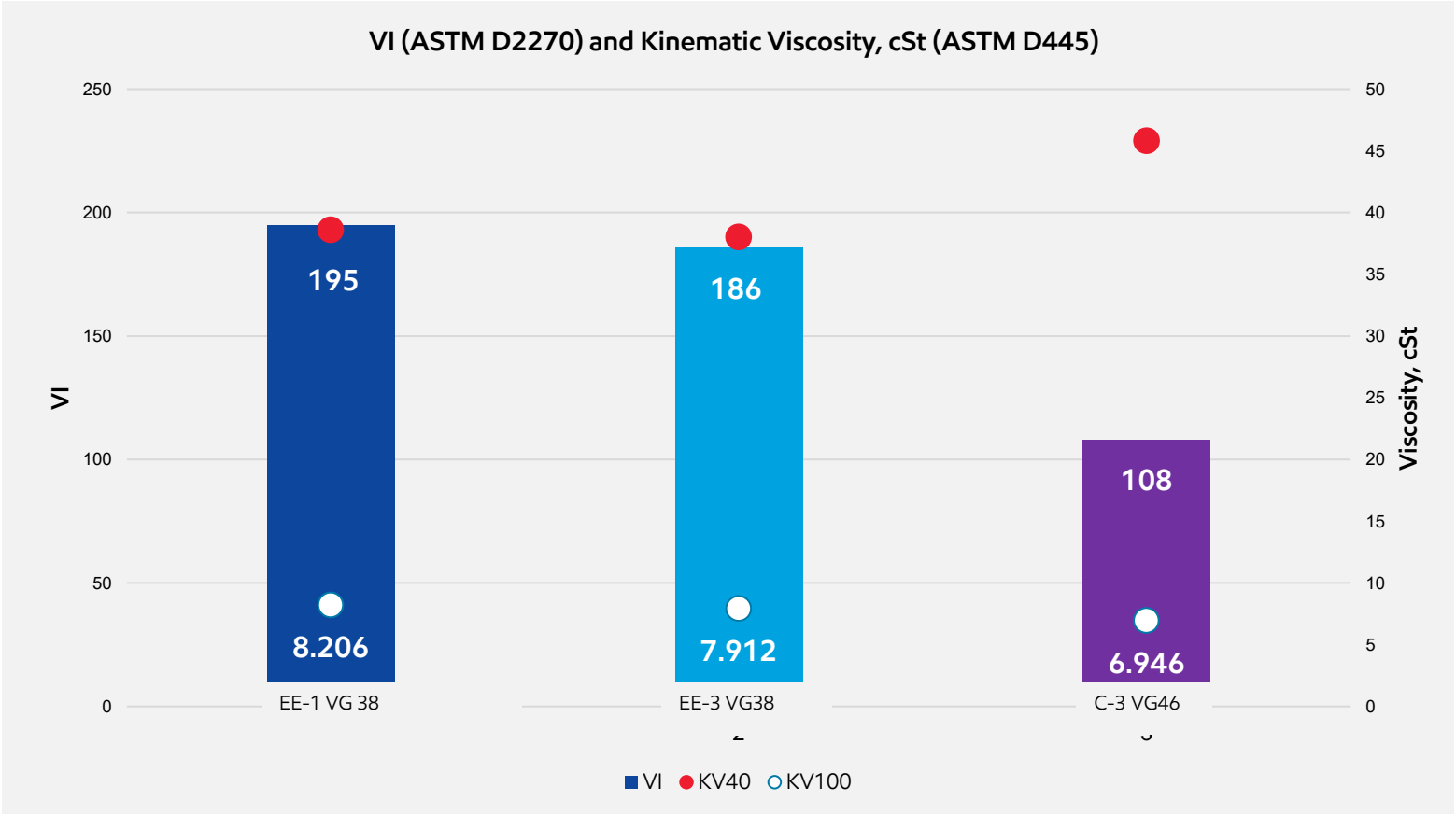
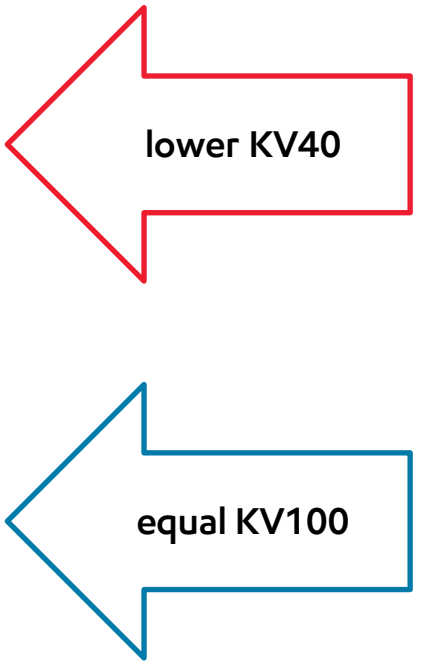
Source: ExxonMobil data

Low-viscosity lubricants, enabled by high VI, better energy efficiency

High Viscosity Index air compressor lubricants may contribute to improved energy efficiency



EE-1 VG 38	EE-3 VG38	C-3 VG46
Gr III+ with SpectraSyn™ MaX PAO 3.5/ **& Esterex™ Esters NP343 of 15%**	Gr III+ with SpectraSyn™ MaX 3.5/ & **Synesstic™ 5 AN of 15%**	Ref Sample: Commercial air compressor oil sample



EE-1 & EE-3 blends are formulated blends with the same additives

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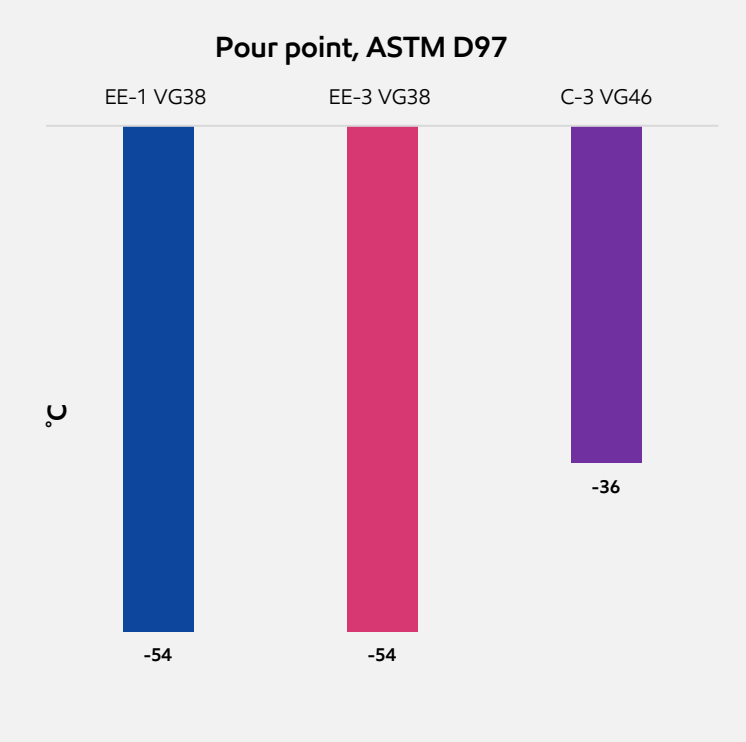
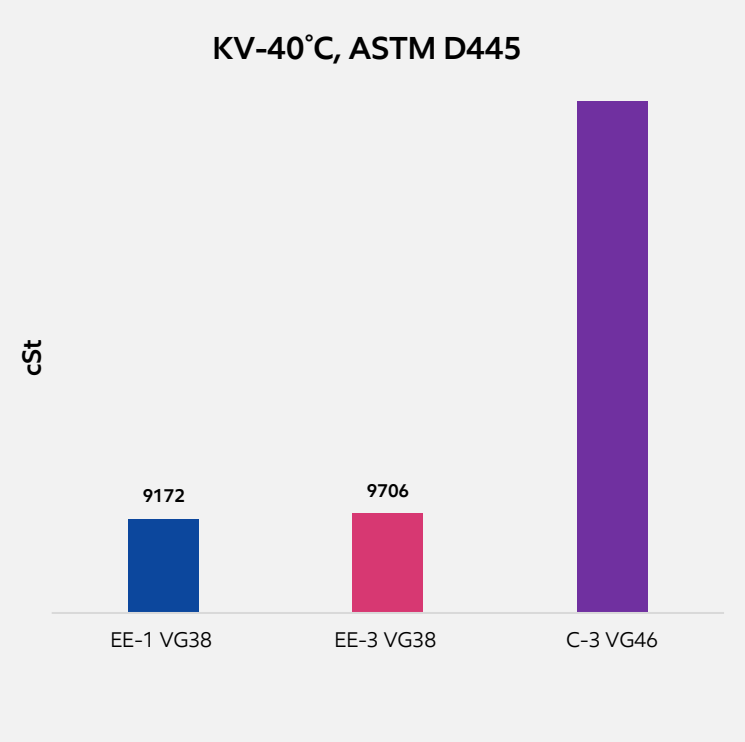
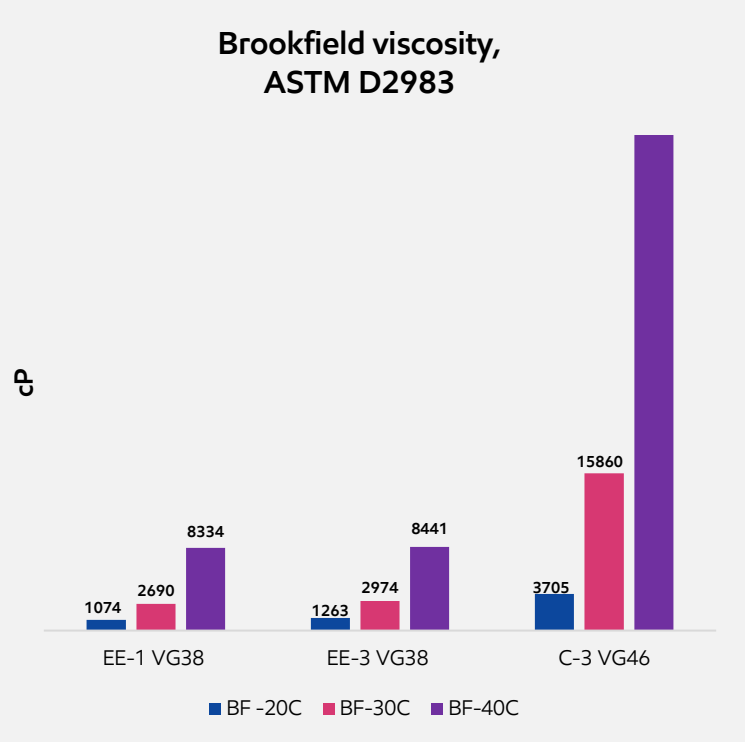
Source: ExxonMobil data

Low temperature properties enable performance gains

Compressor oil containing SpectraSyn™ MaX PAO 3.5 and either Esterex™ Esters NP343 or Synesstic™ 5 AN show better low temperature properties vs commercial oil*, which may contribute to higher energy efficiency performance







EE-1 VG38	EE-3 VG38	C-3 VG46
Gr III+ with SpectraSyn™ MaX PAO 3.5/ **& Esterex™ Esters NP343 of 15%**	Gr III+ with SpectraSyn™ MaX 3.5/ & **Synesstic™ 5 AN5 of 15%**	Commercial air compressor oil sample (Mineral oil base formulation)

EE-1 & EE-3 blends are formulated blends with the same additives

* Commercial oil made with mineral base stocks

Source: ExxonMobil data

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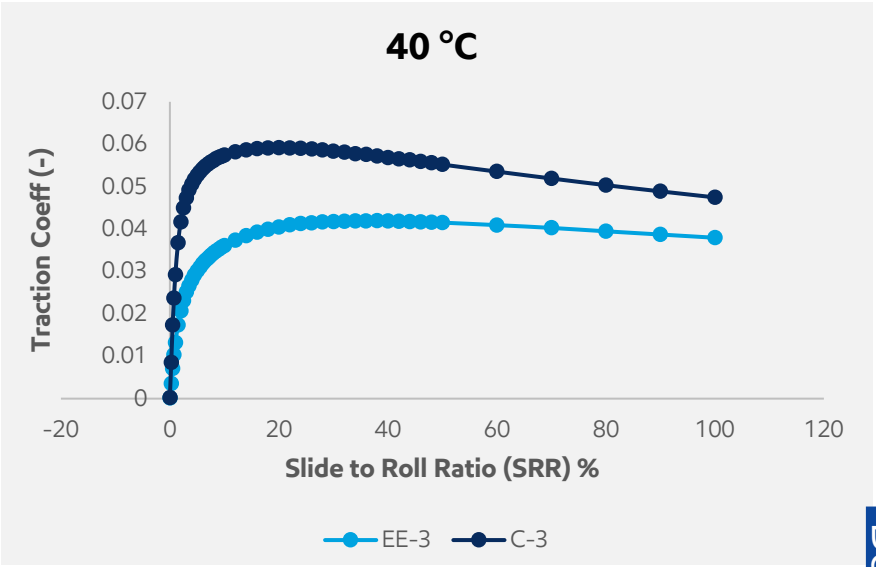
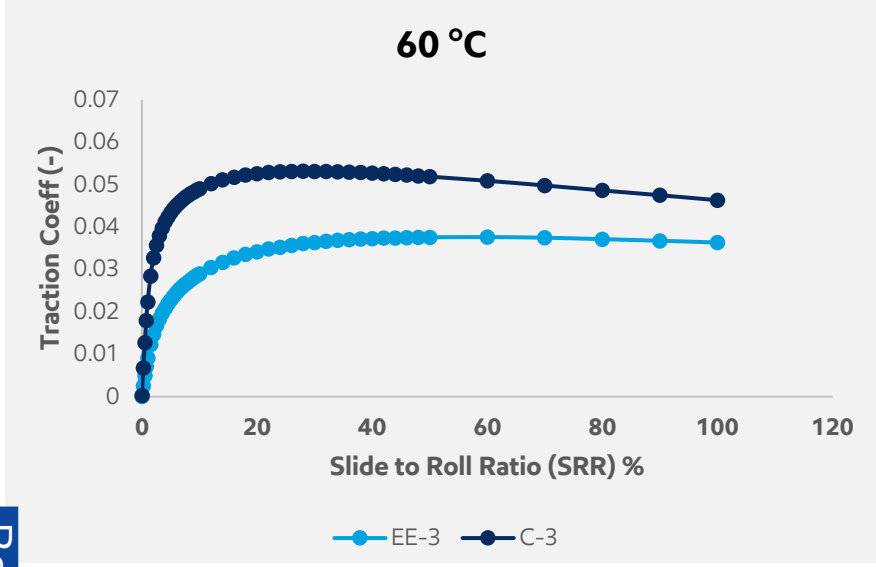
MTM traction synthetics vs mineral compressor oils

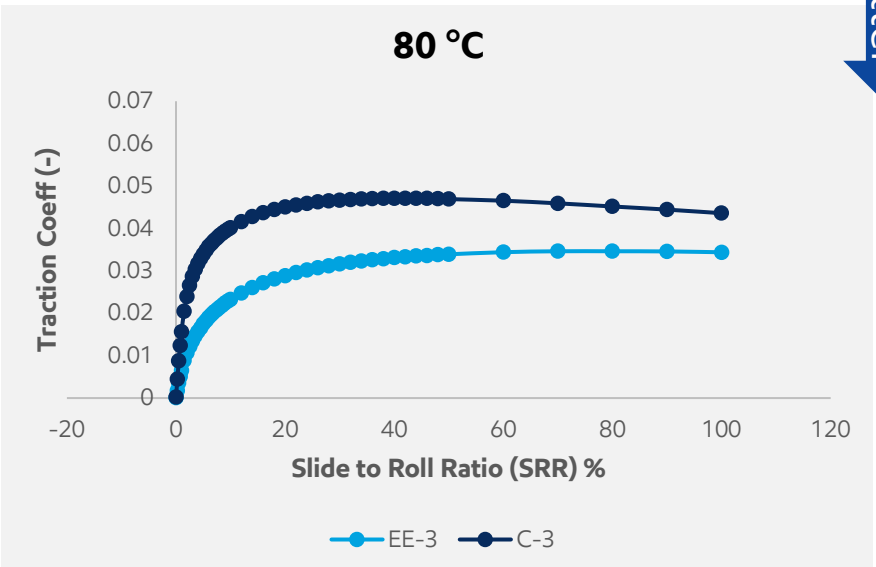
Compressor oil sample with SpectraSyn™ MaX PAO and Synesstic™ 5 AN show lower traction compared to a commercial compressor oil, potentially boosting energy efficiency.

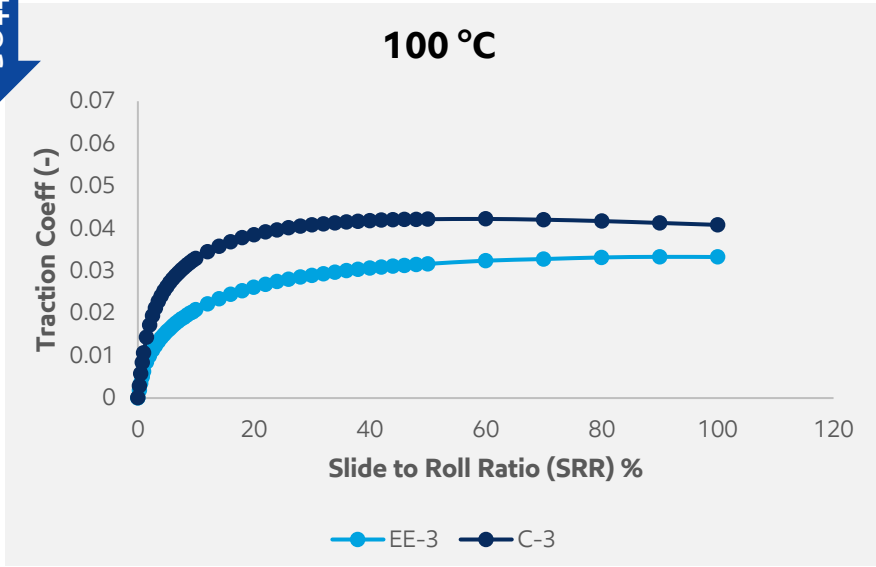
EE-3 VG38
Gr III+ with SpectraSyn™ MaX3 PAO.5/ & **Synesstic™ 5 AN of 15%**
C-3 VG46
Commercial air compressor oil sample





Better





MTM condition:
Loads: 1.25 Gpa
Speeds: 2.00 m/s

Source: ExxonMobil data

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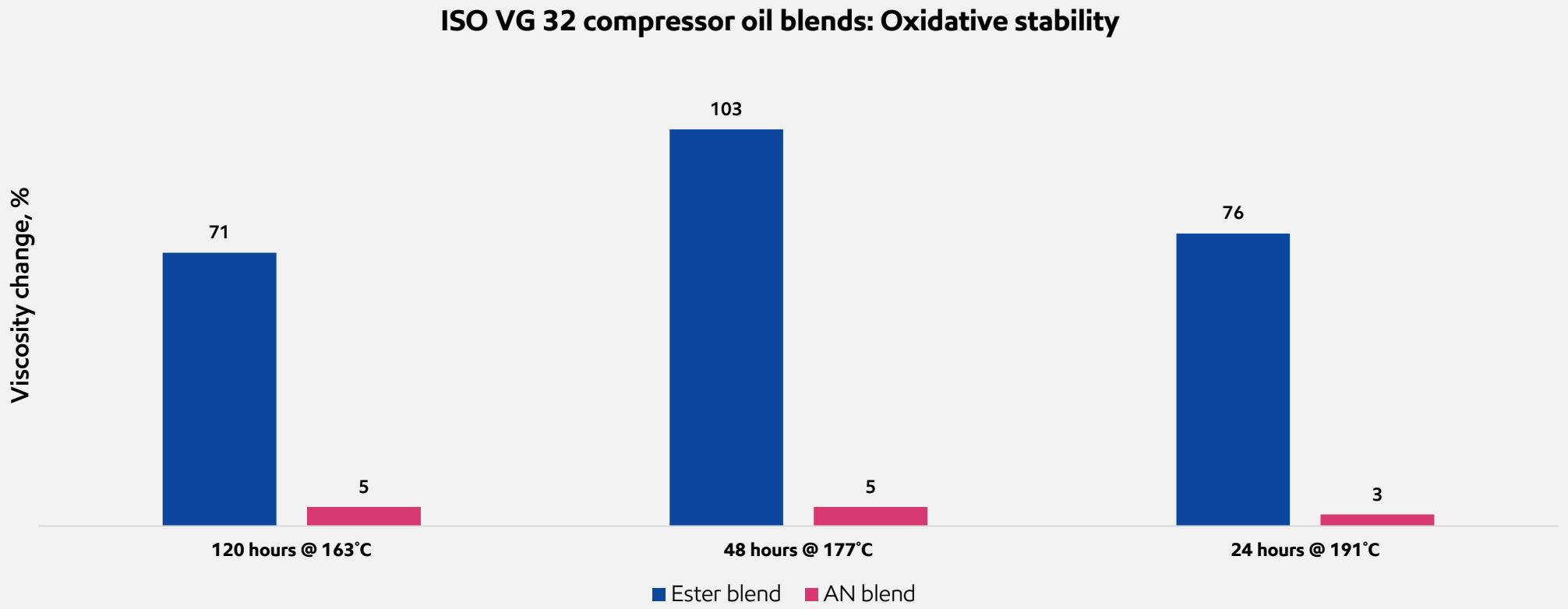
High thermal & oxidative stability – key performance drivers

Synesstic™ 5 AN improves the oxidative performance of PAO-based formulation compared to adipate ester



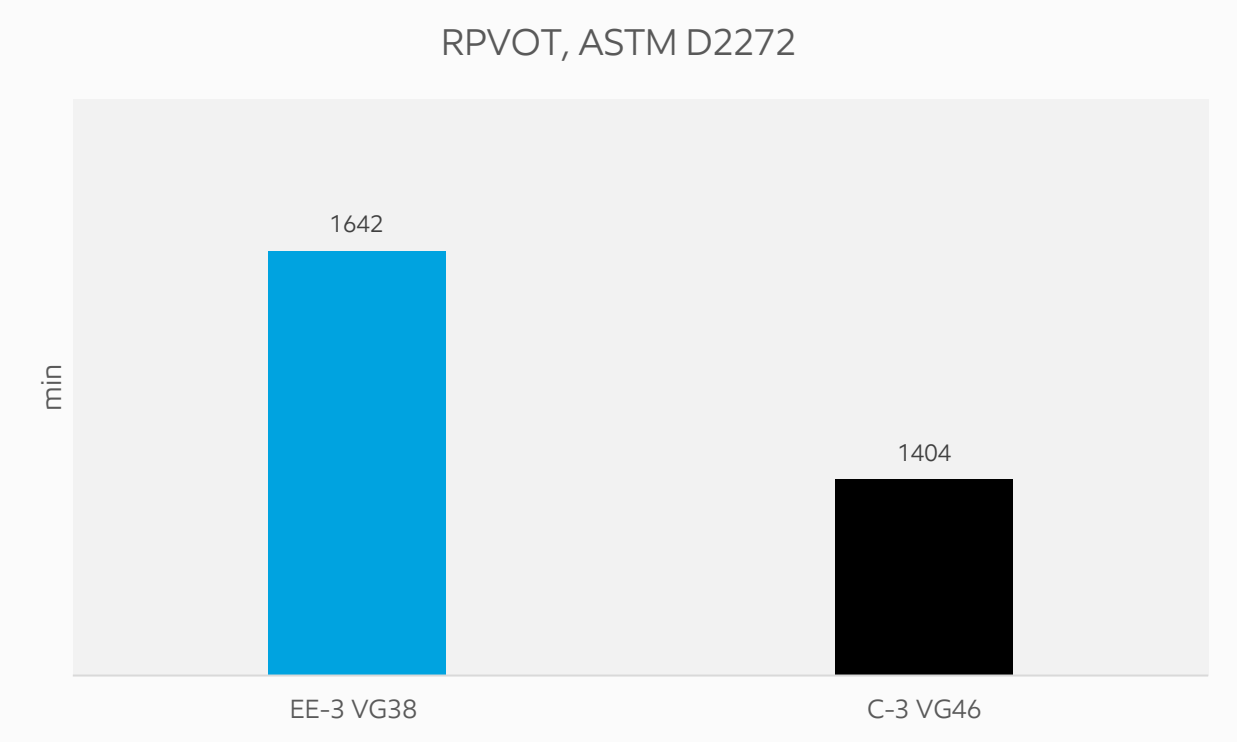
- Ester blend: 73% PAO + 25% Adipate ester + additives
- AN blend: 73% PAO + 25% AN5 + additives

Test method: modified in house Oxidation-Corrosion Test in the presence of air and metal coupons

Source: ExxonMobil data

Higher oxidation stability reduces varnish and deposits

Compressor oil samples with SpectraSyn™ MaX PAO and Synesstic™ 5 AN show longer RPVOT, potentially extending oil life.



EE-3 VG38	C-3 VG46
Gr III+ with SpectraSyn™ MaX3.5/ & **Synesstic™ 5 of 15%**	Commercial air compressor oil sample (fully formulated oil in Gr II, without AN)

Varnish deposit example

End of test rotors from **Proprietary rig test**:

Synthetic compressor oil with AN5 at 2460 hours

Reference compressor oil at 2460 hours

Source: ExxonMobil data

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Conclusion:

Compressor oils formulated with synthetic base stocks such as SpectraSyn™ PAOs, Synesstic™ AN and/or Esterex™ can provide:

- Excellent low temperature properties
- Higher oxidative stability* for extended oil life
- High viscosity index
- Low traction* for improved energy efficiency

The use of synthetics base oils can improve reliability and cleanliness of the compressors while providing potential cost savings.

* Compared to conventional mineral compressor oil

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Thank you!