Advancing EV fluid development with next-gen base oils

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Market trends are driving electrification


Ford's wife EV, 1914-1930s


Horse drawn snow roller used till 1930s

CO_2 emissions

Energy efficiency

EV adoption

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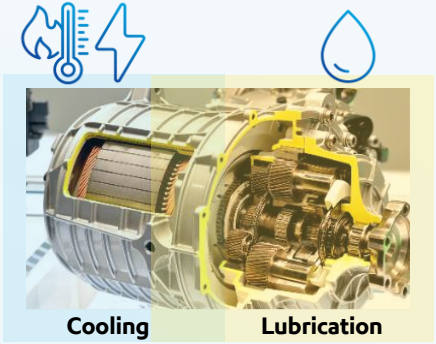
EV hardware design is evolving
Demand for superior oil formulation

Integrated e-modules

Single fluid



- Lubricating gears, bearings, etc.
- Cooling e-motor, electronics, potentially battery, etc.
- Direct cooling option

Interest in low viscosity base oils to improve energy efficiency

Base oil directly impacts:

- Energy efficiency (driving range)
- Heat transfer and thermal management

It can also contribute to oxidative stability, durability, wear protection, material compatibility, etc.

EV fluid innovation: synthetic base stock solutions

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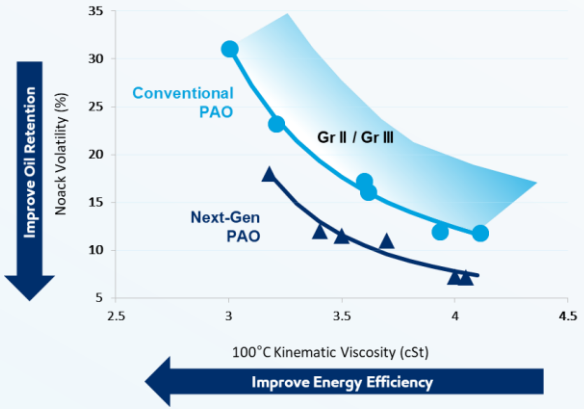
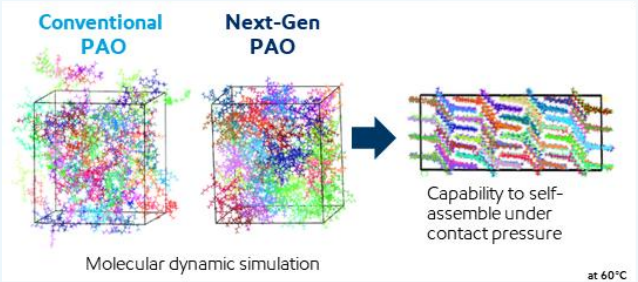
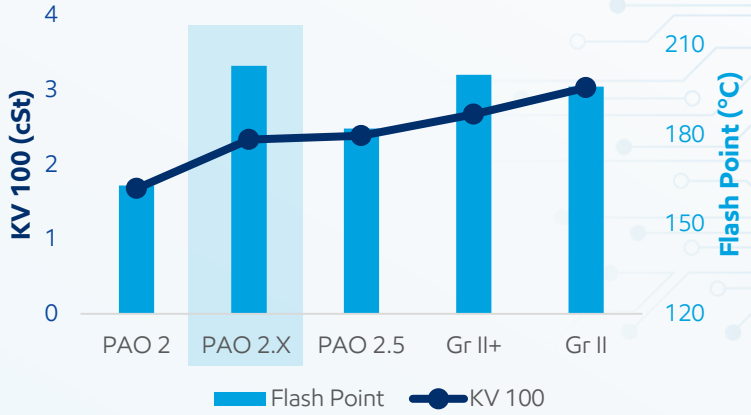
Low-viscosity next-gen PAOs deliver differentiated volatility/flash point





Property	Based on method	SpectraSyn™ MaX 3.5 PAO	PAO 2.X
KV @ 100°C, cSt	ASTM D445	3.5	2.3
KV @ 40°C, cSt	ASTM D445	14.2	8.2
Flash Point , °C	ASTM D92	234	203

The above molecules represent experimental next-gen PAO



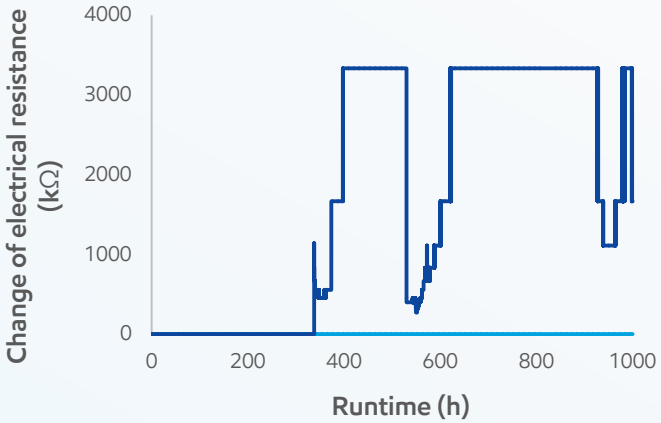
Copper corrosion

1000 hrs at 150°C
Two separate wires for vapor and oil phases

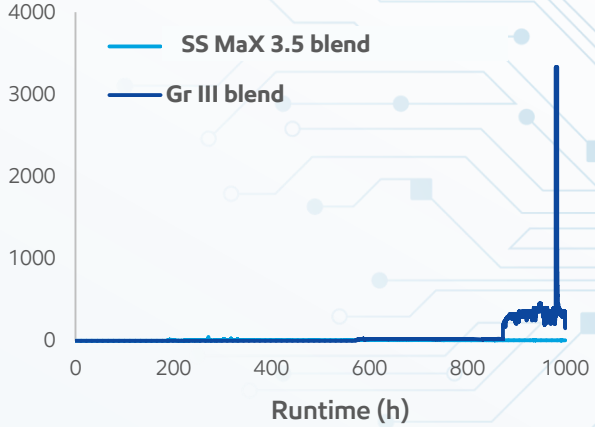
SS™ MaX 3.5 blend vapor phase

Gr III blend vapor phase

Oil phase



Vapor phase



SpectraSyn™ MaX 3.5 (SS MaX 3.5) PAO can improve copper corrosion

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Energy efficiency and driving range

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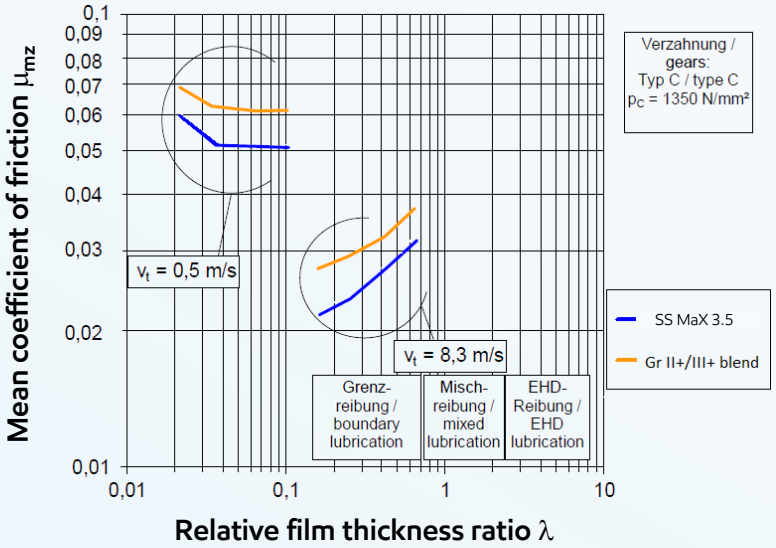
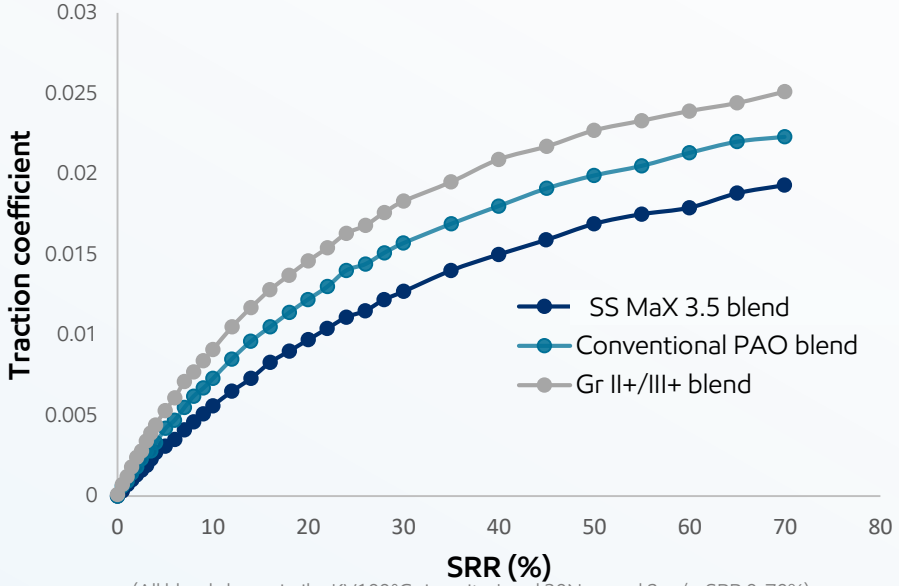
Improved energy efficiency

FZG test – FVA 345



Better

MTM traction 80°C



(All blends have similar KV100°C viscosity, Load 30N, speed 2 m/s, SRR 0-70%)

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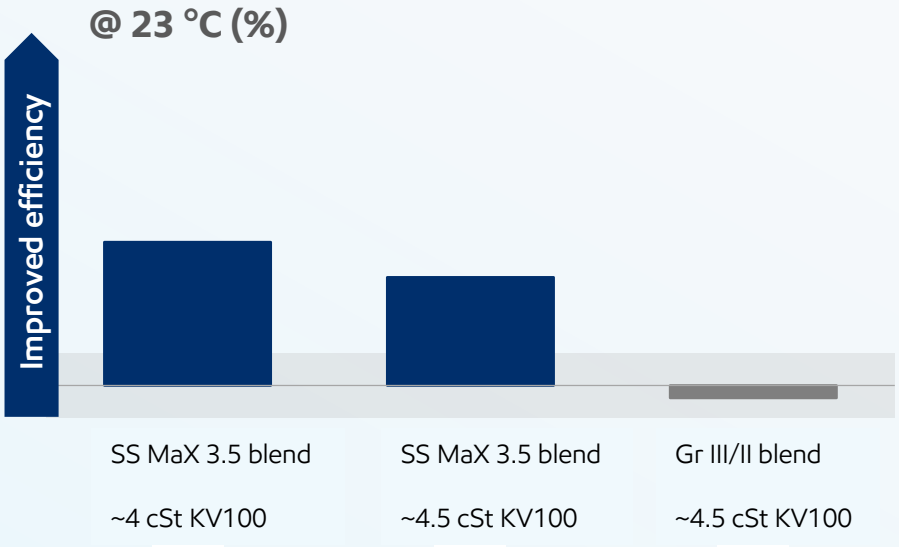
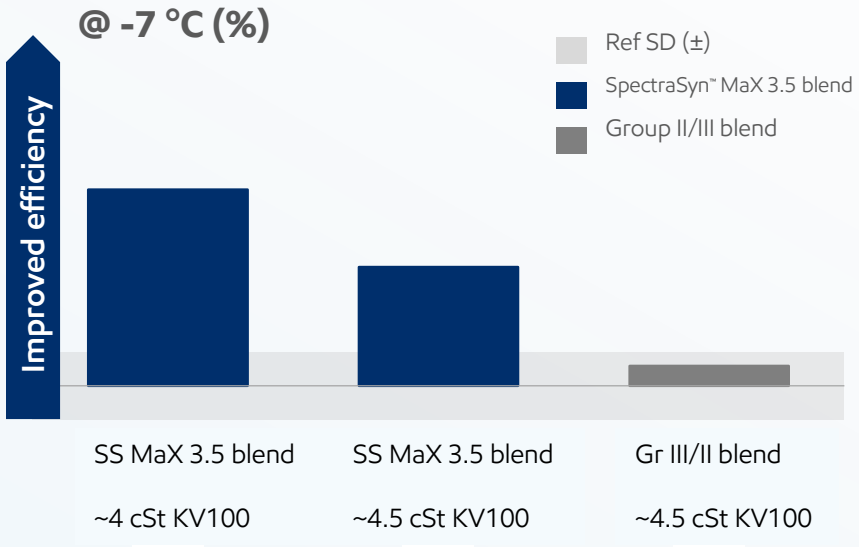
Improved energy efficiency extends driving range

VW ID 4 Drive-Unit WLTC testing
Energy efficiency gains/losses vs ref. oil (~6 cSt KV100)





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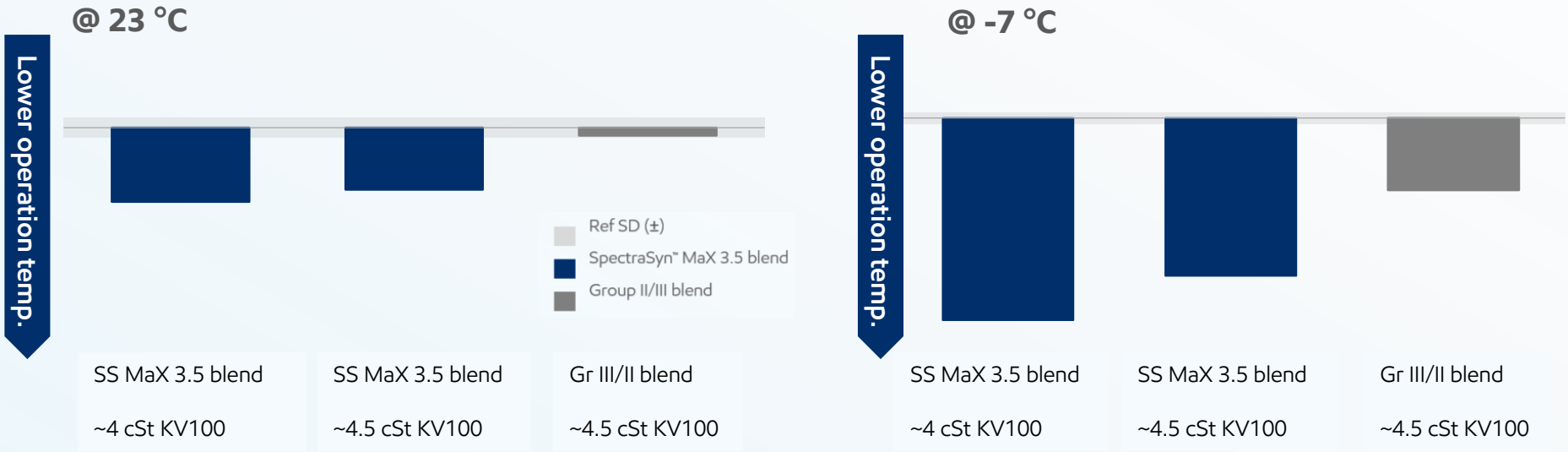
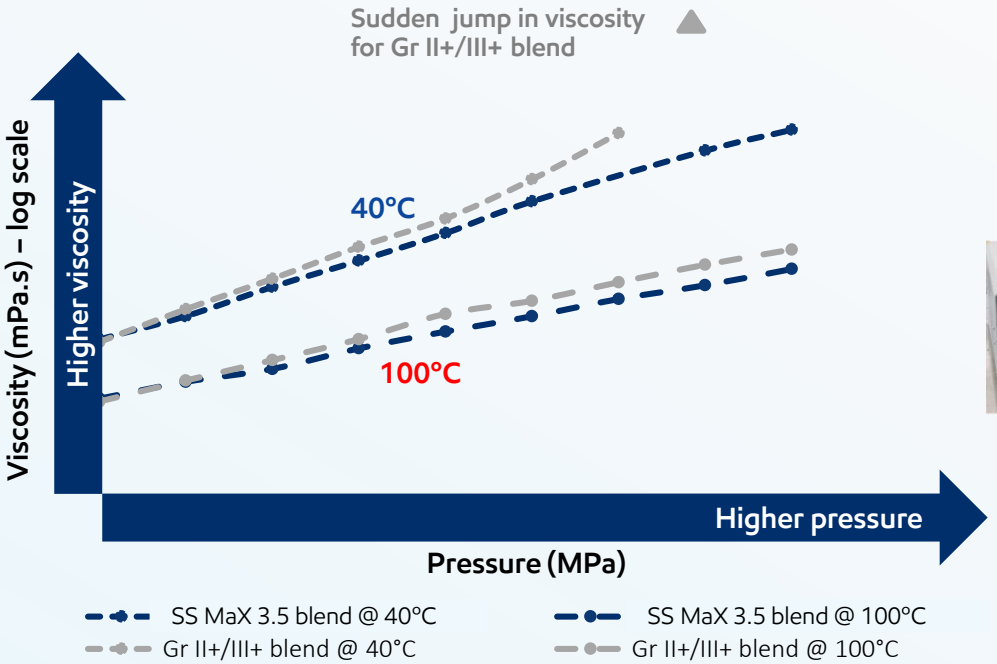
Reduced operating temperature extends oil longevity

VW ID 4 Drive-Unit WLTC testing
Peak oil temperature vs ref. oil (~6 cSt KV100)



High-pressure viscometer helps differentiate lubricant performance



High-pressure viscometer has been semi-automated, to improve operation and precision

Thermal management

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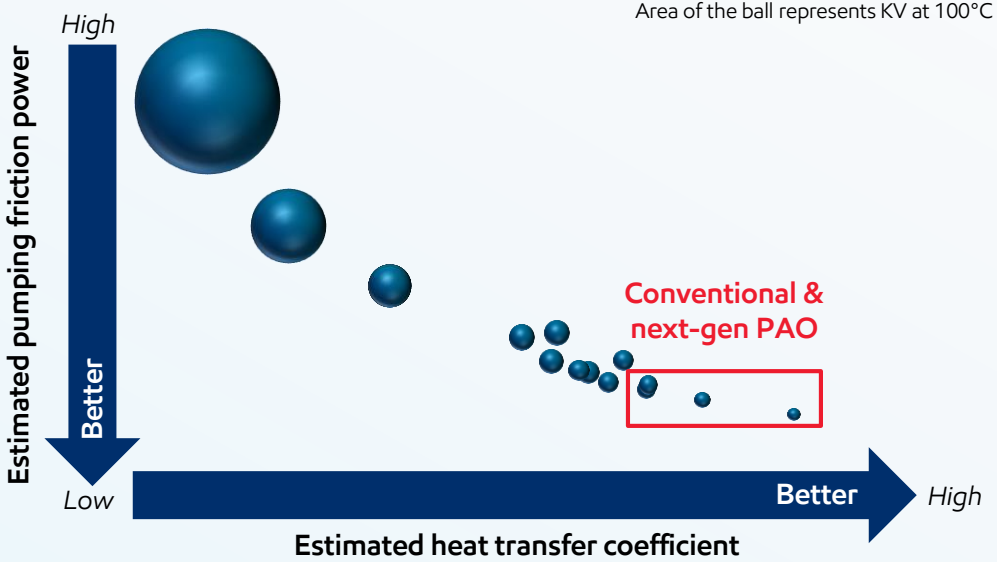
High thermal efficiency to enhance direct cooling



- Improve heat transfer and reduce pumping power
- Preferred dielectric properties
- Enable direct and efficient cooling

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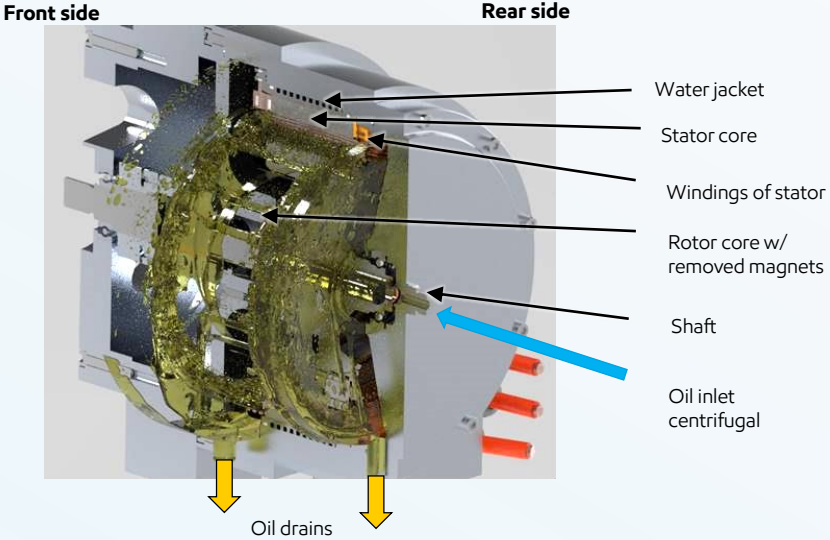
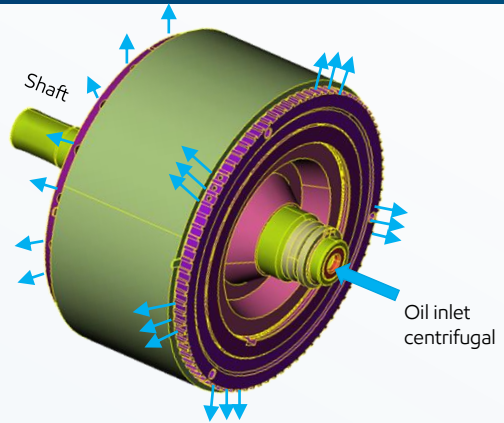
E-motor oil thermal management simulation



Photos source: FEV



Cooling simulation condition:

- Rotational speed 1000rpm
- Centrifugal oil inlet 3 lpm, 50°C
- SpectraSyn™ MaX 3.5 vs. Gr III (base oil only)
- Leveraged CFD analysis

CFD simulation preliminary results: Oil distribution

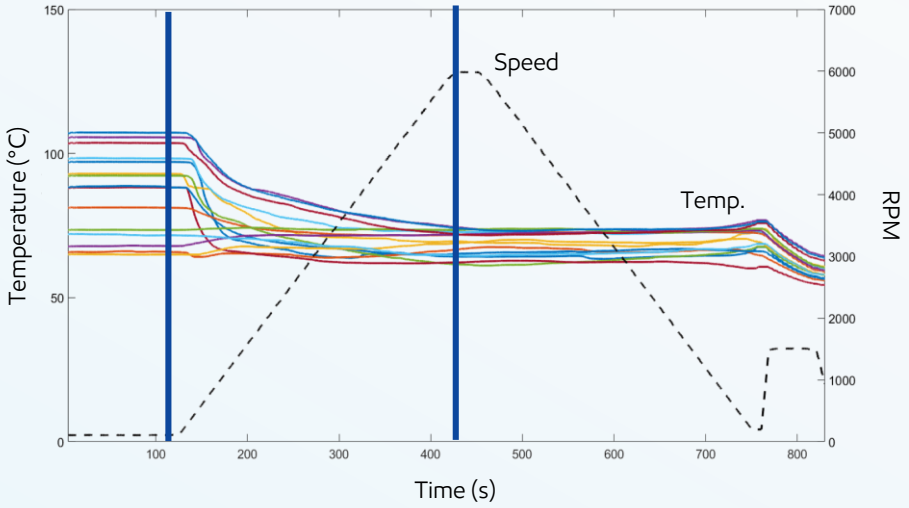
Estimated oil distribution using Gr III oil

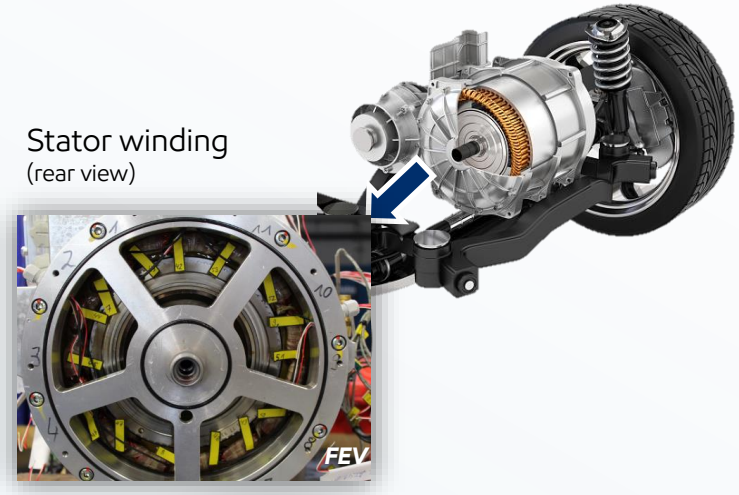
Estimated oil distribution using SpectraSyn™ MaX 3.5 oil

Initial analysis suggests, SpectraSyn™ MaX 3.5 PAO:

- Improve oil distribution
- Reduce frictional losses (drag torque)
- Reduce winding temperature and average operating temperate

E-motor thermal management

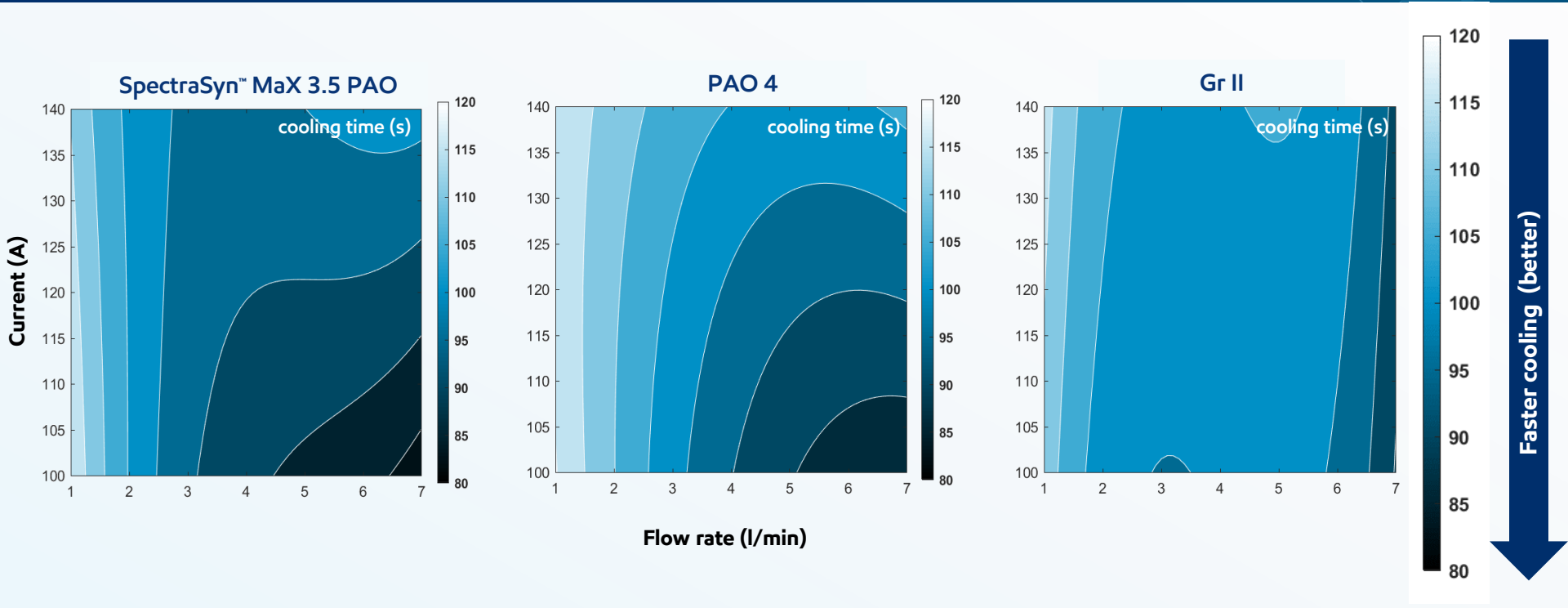




Testing condition

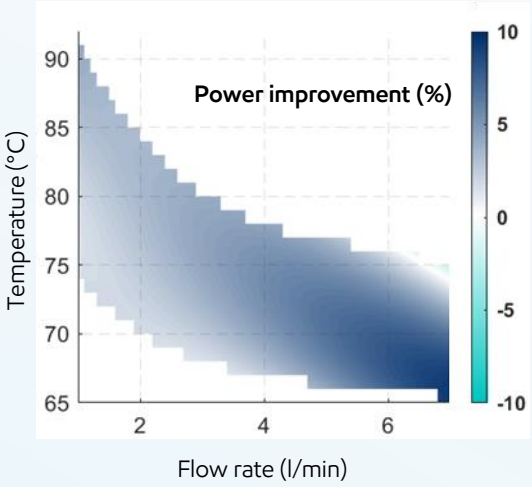
- Current: 80, 100, 120 and 140, 150 A
- Flow rate: 1, 2, 3, 5, 7 l/min
- Centrifugal cooling at 30, 50, 80°C

Thermal efficiency in an e-motor, “cooling time”

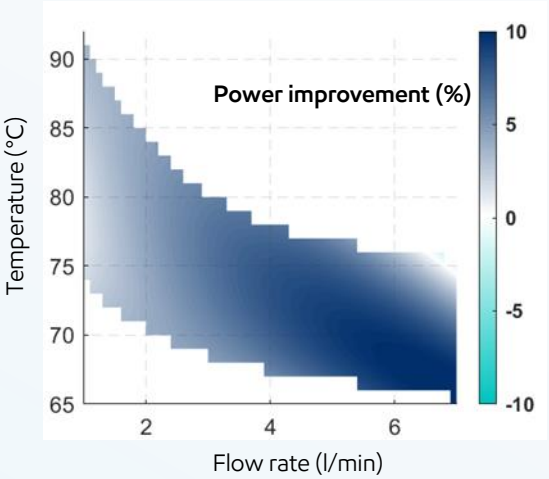


E-motor cooling and "power improvement"

SpectraSyn™ MaX 3.5 PAO vs. PAO 4



SpectraSyn™ MaX 3.5 PAO vs. Gr II



SpectraSyn™ MaX 3.5 PAO can result in:

- Faster cooling
  (i.e. reduce cooling time)
- Lower operating temperature
- Improving power and efficiency of the e-motor and system
- Reduce pumping power

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Innovating products with sustainability benefits

Advancing climate solutions across the value chain

Building sustainability into Major facilities

KEY ENABLERS

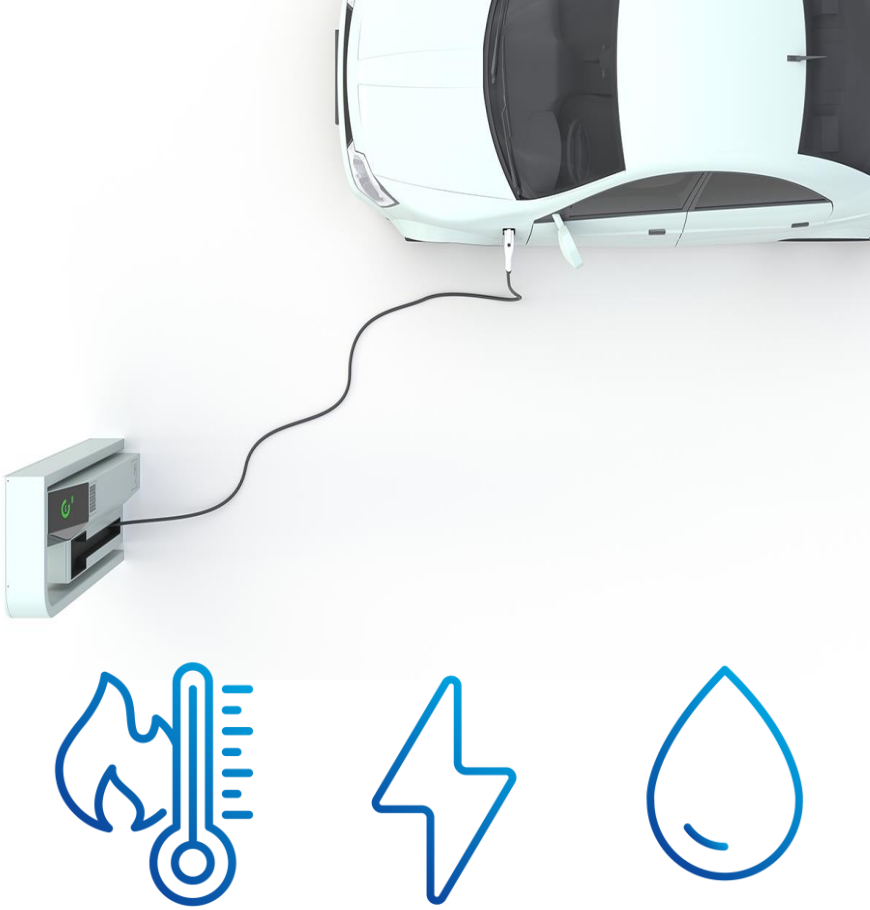
People **Innovation** **Collaboration**

Summary

EV e-module design and performance targets continue to evolve; trends toward single fluid to deliver both lubrication and cooling

Next-gen PAOs can enable superior EV fluids with improved energy efficiency and thermal management for safer and longer operation

Low-viscosity low-volatility next-gen PAOs exhibit step out performance in EV fluids and other applications like PCMO, HDMO and grease



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Backup slides

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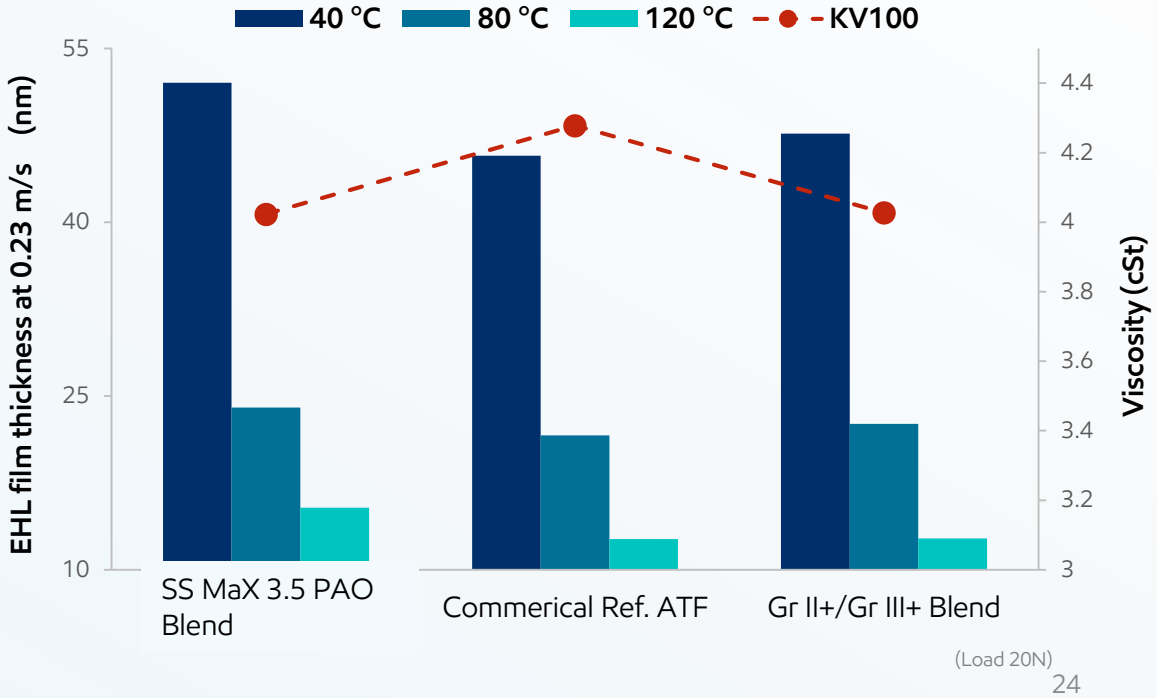
Excellent wear protection in mechanical systems

FE-8 bearing test

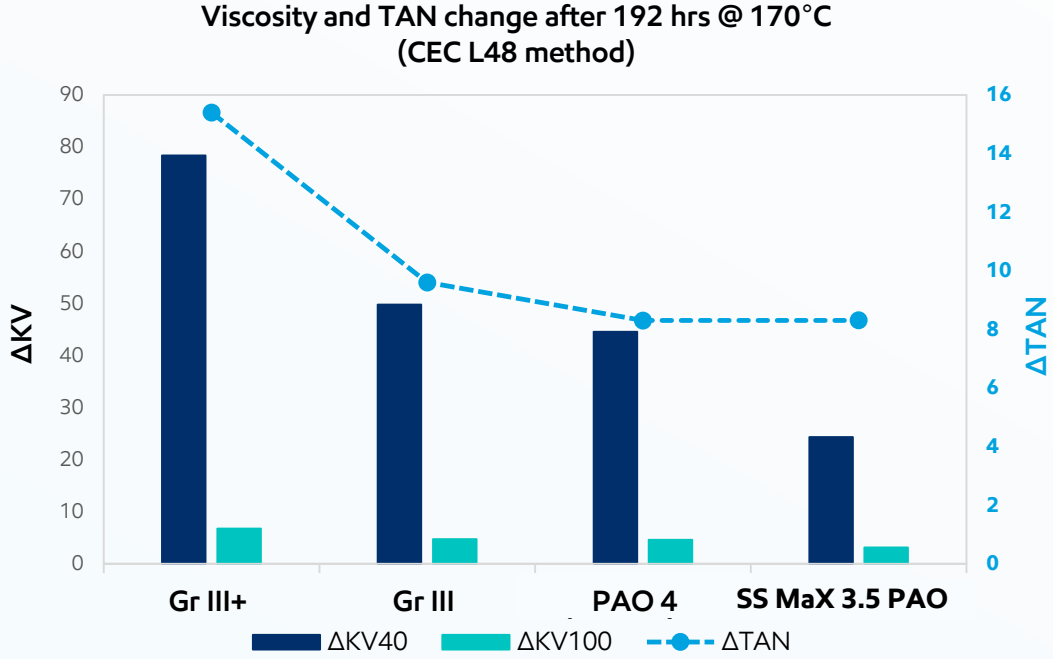
- Load 100 kN
- Speed 7.5 rpm
- Temperature 80°C

wear of roller set for 50% probability for PAO 3.X blend:

m_{w50} = < 2 mg



Next-gen PAO molecules can improve oxidative stability



(All molecules have TAN value of 0.1 mgKOH/g before oxidation)

Deposit formation after CEC L48 test

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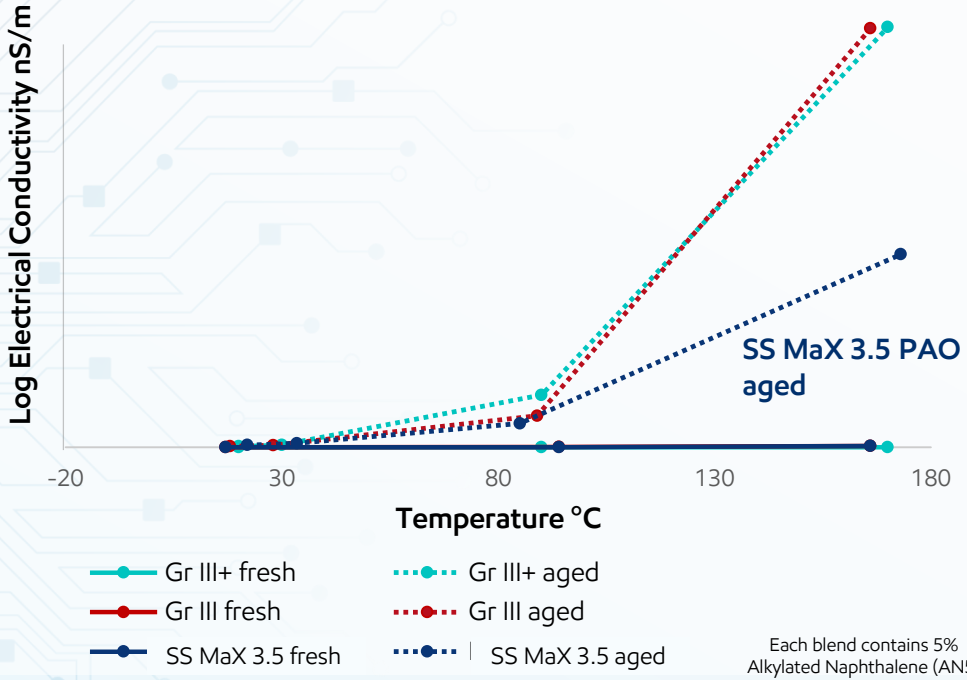
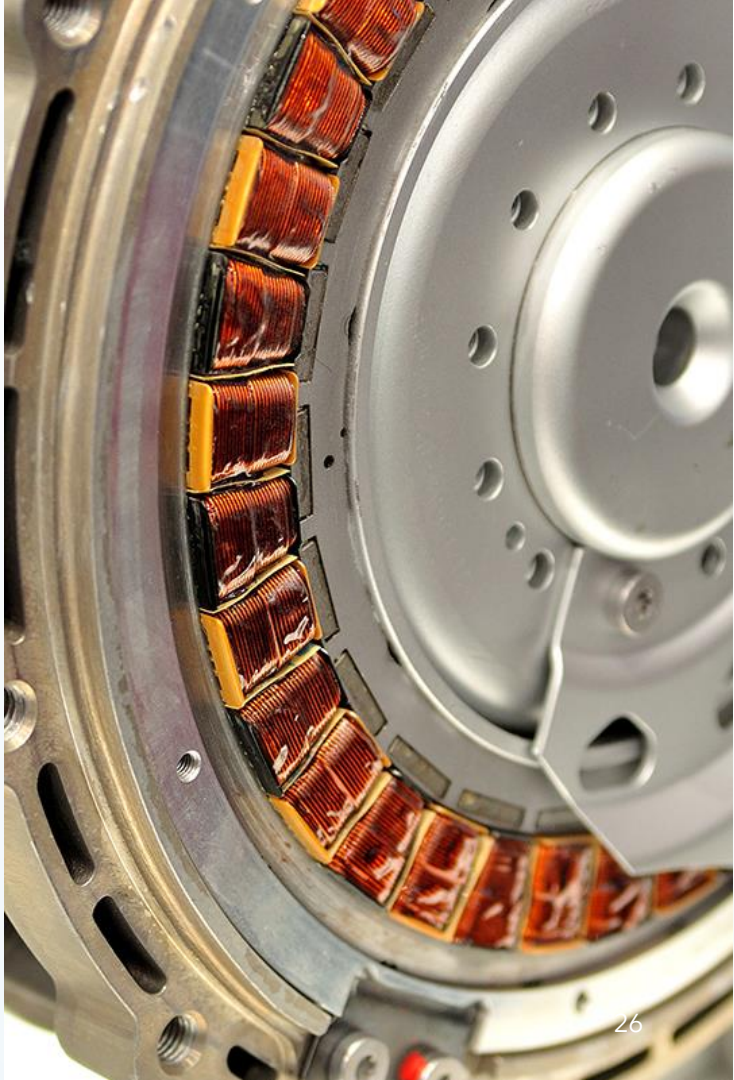
Next-gen PAO blend provides more stable dielectric properties over time



Each blend contains 5% Alkylated Naphthalene (AN5)



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