



Passenger car engine oil

Introduction and outline

1

The components
of a **PCEO**
additive package

2

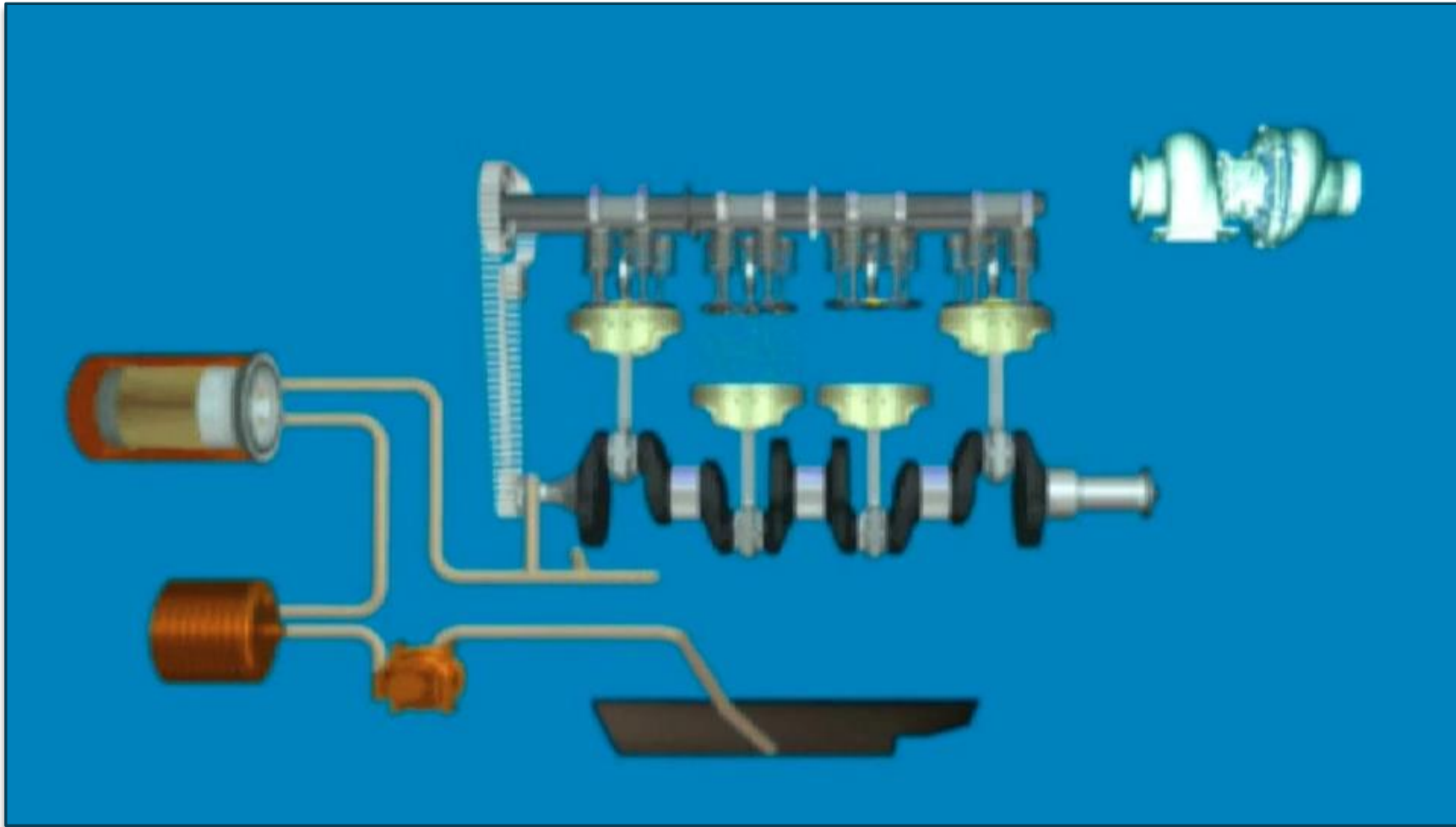
PCEO
specifications

3

The **PCEO**
market and
future **trends**



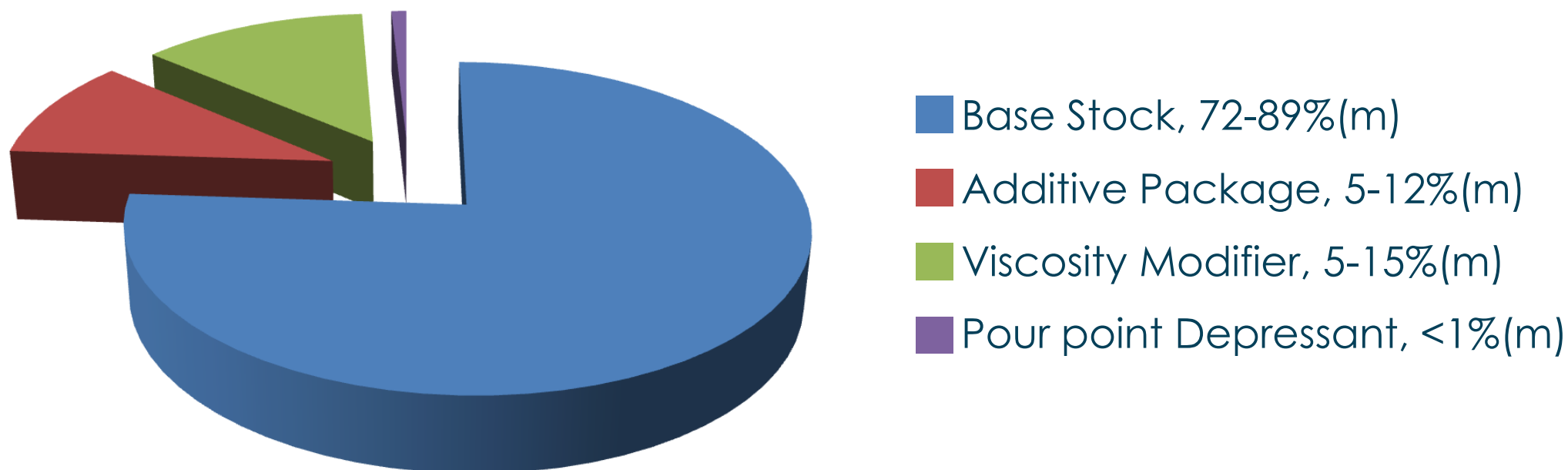
Oil flow through engine



Overarching formulation considerations

- ACC Code of Practice, ATC Code of Practice, API EOLCS guidelines, and ATIEL guideline
- Desired performance level or specifications
- Viscosity grade coverage
- Customer / oil company requirements
- OEM requirements including factory fill or service fill applications
- Base stock availability and quality
- Component and viscosity modifier (VM) technology

What goes into a finished PCEO?

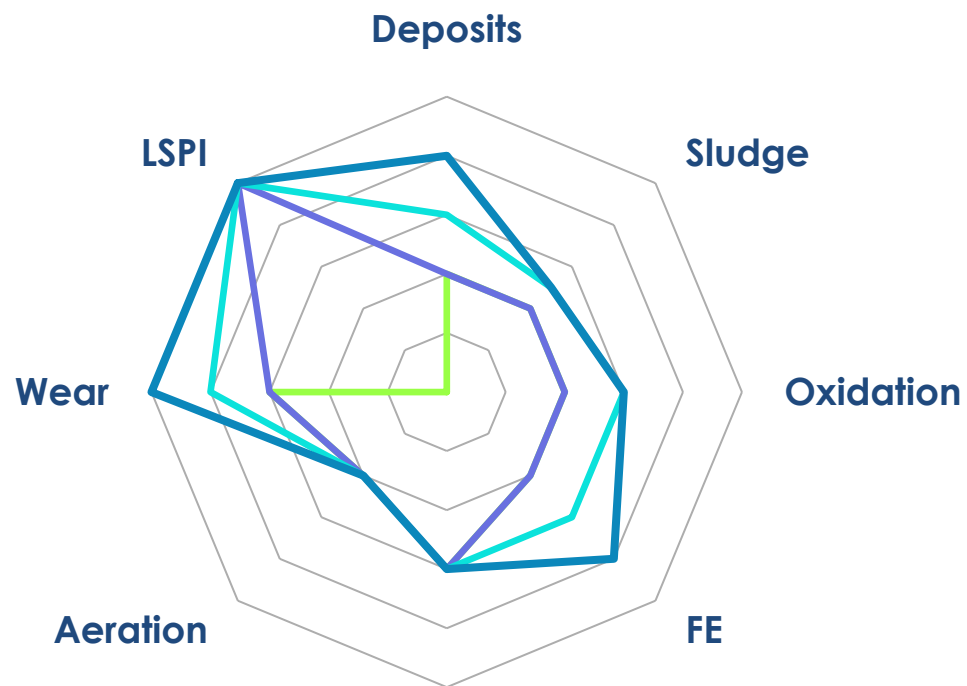


What goes into a PCEO additive package?

Component	Function	Typical type
Dispersant	Suspension of soot, sludge, and deposit precursors	PIBSA/PAM
Detergents	Prevention of rust, corrosion, and deposit adhesion	Calcium or magnesium based sulphonates, phenates, and salicylates
Antioxidants	Prevention of oxidation via radical traps and peroxide decomposition	ZDDP, diphenylamine, hindered phenols, metal and/or sulfur-based
Anti-wear agents	Prevention of surface microwelding and tearing	ZDDP
Friction modifiers	Reduction of boundary layer friction	Short-chain organic acids, 'solid' lubricants
Anti-foamant	Reduction in foaming tendency and stability	Polydimethylsiloxane

PCEO specifications

ILSAC category engine performance evolution



ILSAC GF-5



ILSAC GF-5 /
API SN Plus



ILSAC GF-6

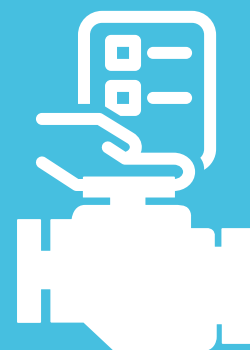


ILSAC GF-7



ILSAC GF-7 RAISES THE BAR VS. ILSAC GF-6 REQUIRING:

- Stronger piston cleanliness
- Even better fuel economy
- Improved chain wear performance
- Improved fresh oil MRV performance



NEW PERFORMANCE REQUIREMENTS:

- Aged oil low speed pre-ignition
- New variants of seals
- GPF protection
- Protection against gelation formation

ILSAC GF-7A/B performance requirements

PERFORMANCE AREA	TEST	ILSAC GF-6 LIMIT	ILSAC GF-7 LIMIT	CHANGE RATE	
FUEL ECONOMY	Sequence VIE/VIF, ASTM 8114, ASTM 8226	SAE 0W-16, ILSAC GF-6B FEI SUM ≥ 4.1 FEI 2 ≥ 1.9 after 125 hours aging	SAE 0W-16, ILSAC GF-7B FEI SUM ≥ 4.3 FEI 2 ≥ 2.1 after 125 hours aging	+4.9% +10.5%	0W-16
		SAE XW-20, ILSAC GF-7A FEI SUM ≥ 3.8 FEI 2 ≥ 1.8 after 125 hours aging	SAE XW-20, ILSAC GF-7A FEI SUM ≥ 4.3 FEI 2 ≥ 2.1 after 125 hours aging	+13.2% +16.7%	XW-20
		SAE XW-30, ILSAC GF-7A FEI SUM ≥ 3.1 FEI 2 ≥ 1.5 after 125 hours aging	SAE XW-30, ILSAC GF-7A FEI SUM ≥ 3.6 FEI 2 ≥ 1.8 after 125 hours aging	+16.1% +20%	XW-30
		SAE 10W-30, ILSAC GF-7A: FEI SUM ≥ 2.8 FEI 2 ≥ 1.3 after 125 hours aging	SAE 10W-30, ILSAC GF-7A: FEI SUM ≥ 3.0 FEI 2 ≥ 1.4 after 125 hours aging	+7.1% +7.7%	10W-30
AGED OIL LSPI	Sequence IXA, ASTM D8291 Appendix X2	n/a	Same as fresh oil LSPI limits: Average number of events 4 iterations ≤ 5 number of events per iteration ≤ 8		
FRESH OIL MRV	MRV, SAE J300 ASTM 4684	60,000 cP max	40,000 cP max	+33%	
PISTON DEPOSIT CONTROL	Sequence IIH, ASTM 8111	WPD ≥ 4.2 merits	WPD ≥ 4.6 merits for GF-7A, 4.2 merits for GF-7B,	+9.5%	
CHAIN WEAR	Sequence X, ASTM 8279	EOT elongation % increase 0.085 max	EOT elongation % increase 0.080 max		
GPF PROTECTION	SASH, ASTM D874	n/a	0.9% (mass) max	+5.9%	
PROTECTION FROM GEL FORMATION	EOGT, ASTM XXXX	n/a	Rate and report if test is available at licensing		
NEW SEALS MATERIALS	Seals, ASTM D7216	n/a	Rate and report		

Viscosity grades for industry claims

API 1509 - ENGINE OIL LICENSING AND CERTIFICATION SYSTEM

G.5 API SERVICE CATEGORY SP (AND RELATED CLASSIFICATIONS)

Table G-6—Requirements for API Service Category SP and API SP with “Resource Conserving”^a

	API SP		API SP with “Resource Conserving”
SAE Grades:	0W-16, 5W-16, 0W-20, 5W-20, 0W-30, 5W-30, 10W-30	Other Eligible Viscosity Grades	XW-20, XW-30, 10W-30, XW-16 Grades



Only “ILSAC” viscosity grades allowed for API SP-RC, no 5W-40 or 10W-40 allowed

API 1509 - ENGINE OIL LICENSING AND CERTIFICATION SYSTEM

Table H-8—ILSAC GF-7A Passenger Car Engine Oil Standard

Requirement	Criterion
Viscosity Requirements SAE J300	Oils shall meet all requirements of SAE J300. Viscosity grades shall be limited to 0W-20, 5W-20, 0W-30, 5W-30 and 10W-30. New Oil MRV: 40,000 cP max



Only “ILSAC” viscosity grades allowed:

- 0W-20, 5W-20,
- 0W-30, 5W-20, 10W-30
- 0W-16 covered by ILSAC GF-7B

API 1509 - ENGINE OIL LICENSING AND CERTIFICATION SYSTEM

G.6 API SERVICE CATEGORY SQ (AND RELATED CLASSIFICATIONS)

Table G-8—Requirements for API Service Category SQ and API SQ with “Resource Conserving”^a

	API SQ		API SQ with “Resource Conserving”
SAE Grades:	XW-16, 0W-20, 5W-20, 0W-30, 5W-30, 10W-30	Other Eligible Viscosity Grades	All Viscosity Grades Except 0W-8 and 0W-12



API SQ-RC allows for 5W-40 and 10W-40 viscosity grades!!

API SQ and ILSAC GF-7 Engine Tests



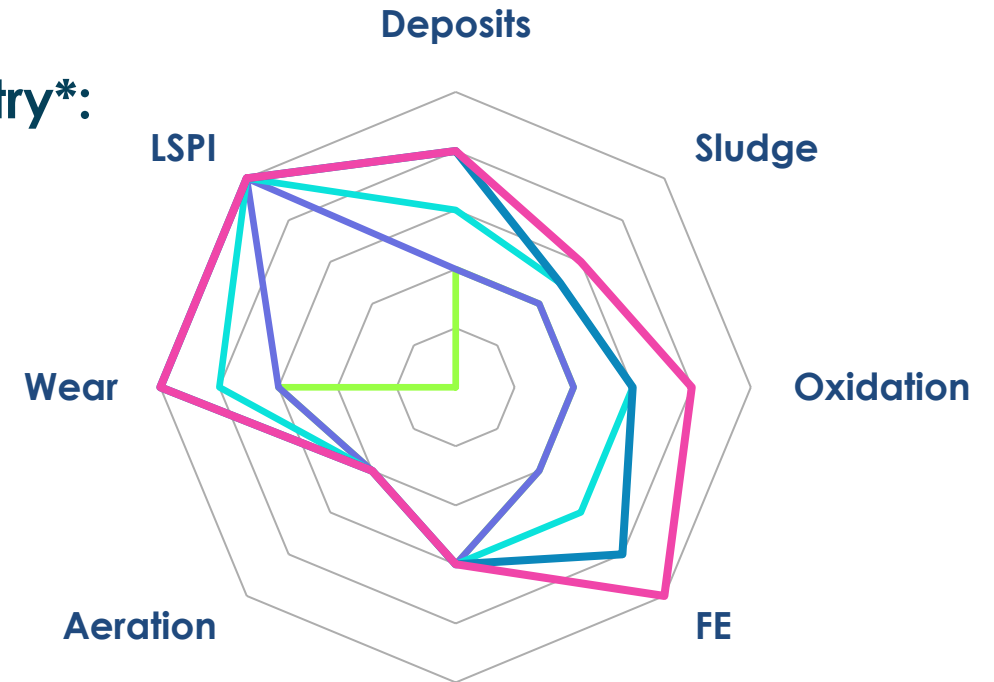
Test	Parameter	Engine description	Proposed Fate for ILSAC GF-8
Sequence IIH	Oxidation and deposits control	2012 FCA 3.6L PFI	Remanufacture Program
Sequence IIHA	Aged oil viscosity	2012 FCA 3.6L PFI Bench	Remanufacture Program
Sequence IIHB	Phosphorous retention	2012 FCA 3.6L PFI	Remanufacture Program
Sequence IVB	Wear control	2010 Toyota 1.5L PFI	Carryover
Sequence VH	Sludge and varnish control	2013 Ford 4.6L PFI	New Test: Sequence VH OR Remanufacture Program
Sequence VIE or Sequence VIF	Fuel economy performance	2012 GM 3.6L PFI	New Test: Sequence VIG
Sequence VIII	Bearing corrosion resistance and shear stability	CLR Test 0.7L	Carryover
Sequence IX and Sequence IX Aged	Low Speed Pre-Ignition protection	2016 Ford 2.0L GDI	Remove Sequence IX Carryover Sequence IX Aged
Sequence X	Cam chain wear protection	2016 Ford 2.0L GDI	Carryover

ILSAC GF-8 A/B

ILSAC GF-8 is being driven by a combination of **performance** and **engine hardware availability** needs.

The following updates have been discussed by industry*:

- **Sequence IIIH:**
 - **Remanufacture program to extend life of Seq IIIH hardware**
 - **Tighter limit for oxidative viscosity increase**
- **Sequence VI: Fuel Economy**
 - **New Sequence VI (Seq VIG) with new procedure to extend life of Seq VI hardware**
 - **Tighter limits for higher fuel economy**
- **Sequence V: Sludge Protection**
 - **New Sequence V (Seq VJ) on new engine platform**
 - **OR Remanufacture program on current hardware**
- **Limits for engine oil gelation test and new elastomer materials**
- **Possible inclusion of corrosion bench test**



ILSAC GF-5



ILSAC GF-5 /
API SN Plus



ILSAC GF-6

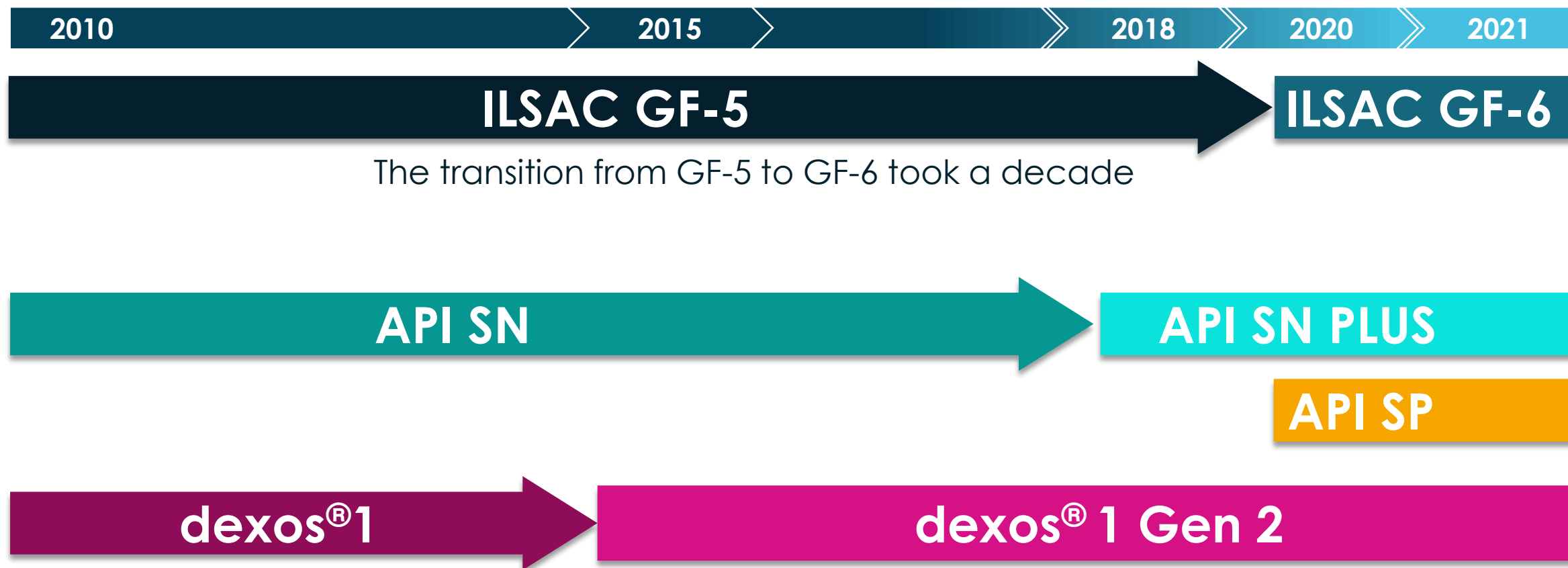


ILSAC GF-7

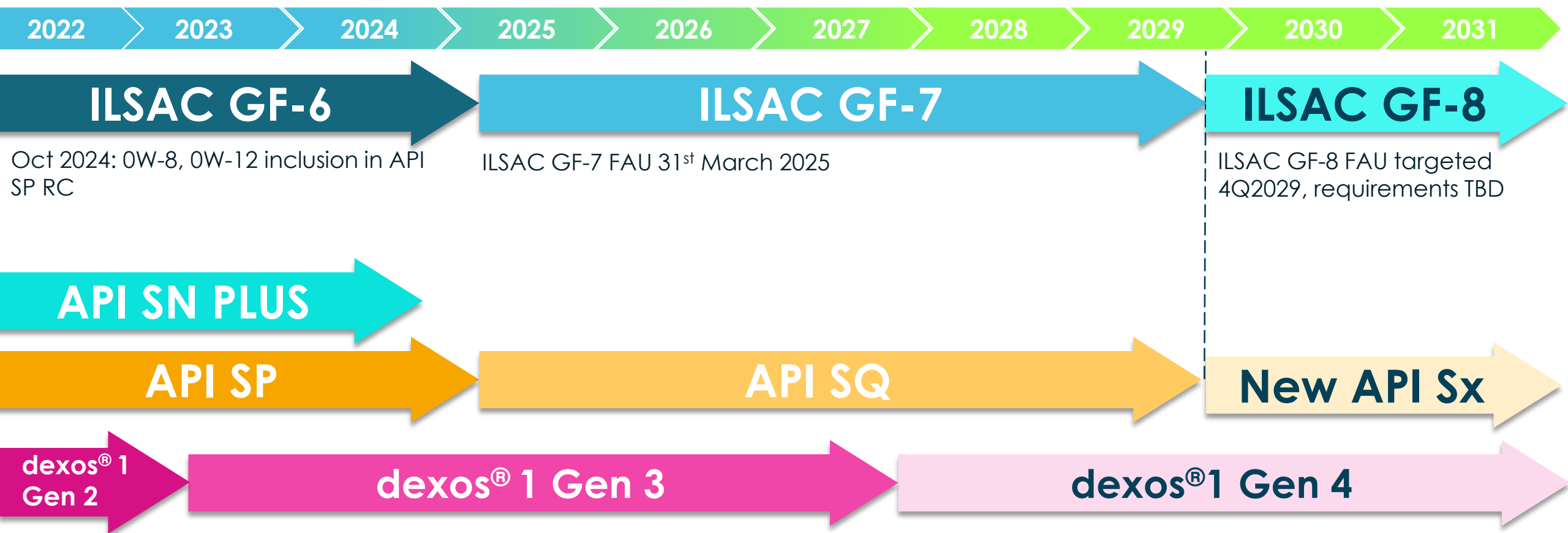


ILSAC GF-8

North America specifications landscape



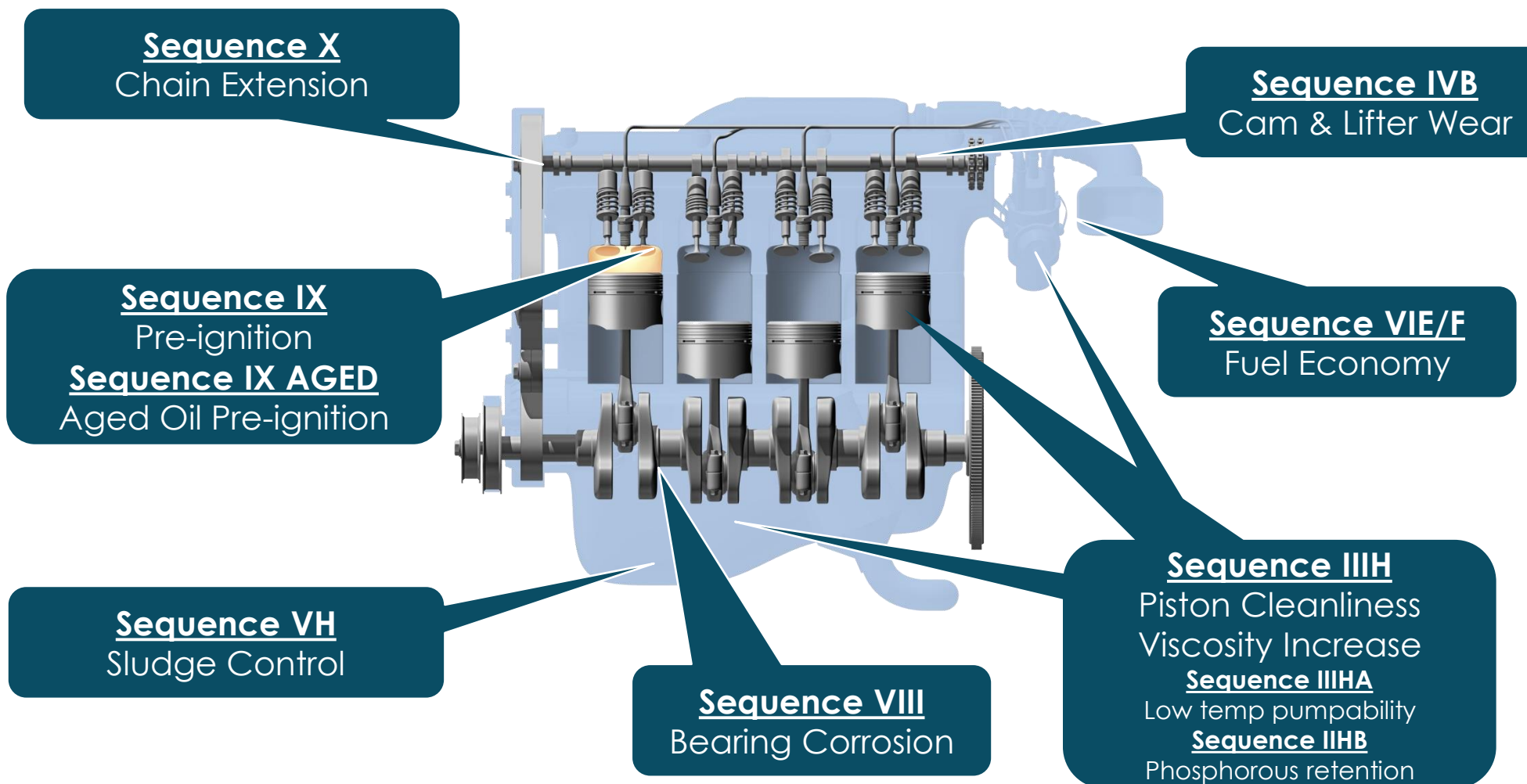
North America specifications landscape



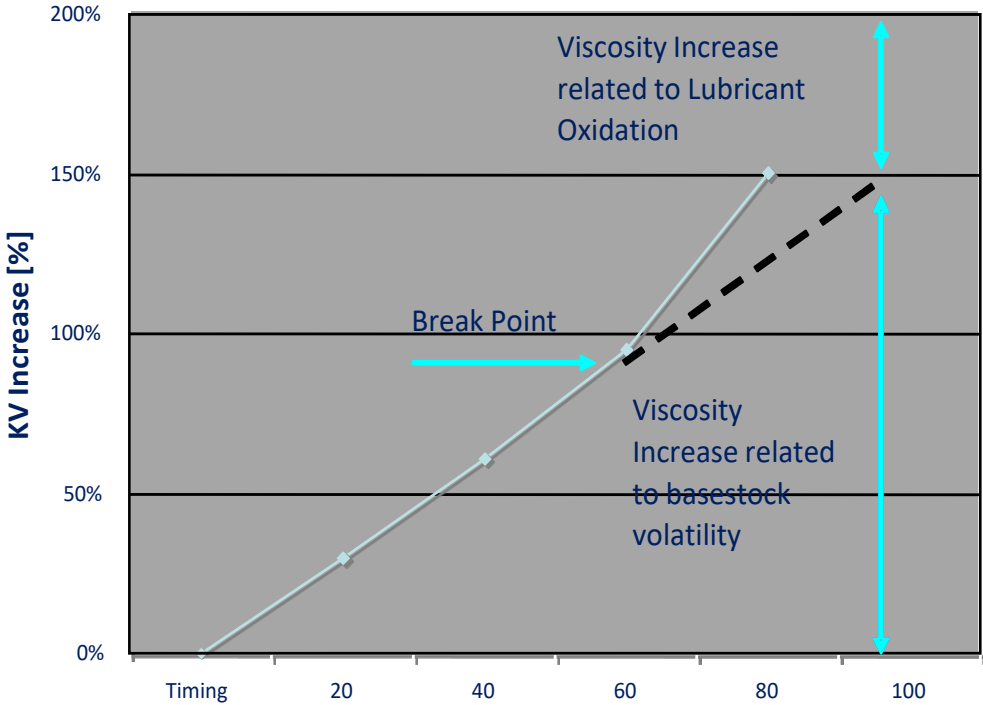
FAU = first allowable use

Engine tests

Engine map of ILSAC GF-7 tests



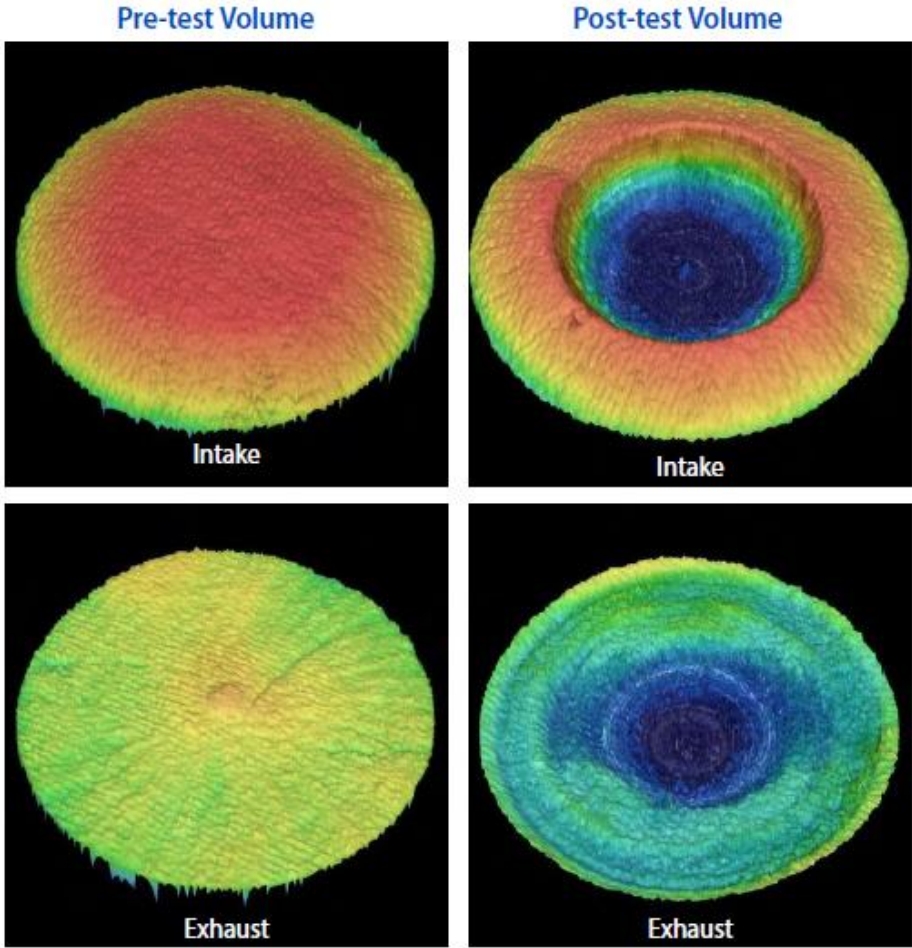
Evaluates oxidative viscosity increase and piston deposits during high temperature conditions



Parameter	Units	Seq. IIH Limits	
		GF- 7A	GF- 7B
KV40 increase	[%]	≤ 100	≤ 100
Avg. weighted piston deposits	[merits]	≥ 4.6	≥ 4.2
Hot stuck rings	[#]	= 0	= 0



Sequence IVB



Evaluates a lubricant’s performance in resisting valve train wear and control of iron concentration

Parameter	Units	GF-7 Limit
Average Intake Lifter Volume Loss	[μm]	≤ 2.7
Fe Content at EOT	ppm	≤ 400

Sequence VH

Evaluates a lubricant's ability to prevent sludge and varnish formation

Parameter	Units	GF-7 limit Seq. VH
Engine sludge, average	[merits]	≥ 7.6
Rocker cover sludge, average	[merits]	≥ 7.7
Engine varnish, average	[merits]	≥ 8.6
Piston skirt varnish	[merits]	≥ 7.6
Oil screen sludge	[%]	Report
Hot stuck compression rings	[#]	= 0
Cold stuck rings	[#]	Report
Oil screen clogging	[%]	Report
Oil screen debris	[%]	Report

PASS



FAIL



Sequence VIE/VIF

Evaluates the effect of engine oil on the fuel economy of passenger cars and light-duty trucks

- Seq VIF run only for 0W-16 viscosity grade with different procedure than Seq VIE

	ILSAC GF-7A		ILSAC GF-7B	
SAE Grade	FEI ₂ Limit [%] Seq. VIE	FEI _{SUM} Limit [%] Seq. VIE	FEI ₂ Limit [%] Seq. VIF	FEI _{SUM} Limit [%] Seq. VIF
xW-20	≥ 2.1	≥ 4.3		
xW-30	≥ 1.8	≥ 3.6		
10W-30	≥ 1.4	≥ 3.0		
0W-16			≥ 2.1	≥ 4.3

Sequence VIII

Evaluates a lubricant's performance in resisting copper-, lead-, or tin-bearing corrosion and measures shear stability

Parameter	Units	GF-7A limit
Bearing weight loss	[mg]	≤ 26
Shear stability		= stay in grade

PASS



FAIL



Sequence IX

- Fired engine dynamometer lubricant test which evaluates the ability of a test lubricant to reduce pre-ignition events
- Test sequence (each 175,000 cycles) repeated for 4 test iterations
- LSPI events are defined as outliers of peak pressure (PP) and crank angle location of 2% mass fraction burned (MBF02) data.
- Limit on total number of LSPI events across all 4 cylinders averaged over 4 iterations

Parameter	Units	GF-7 Limit
Average total number of LSPI events	#	≤ 5
Number of events per iteration	#	≤ 8

Sequence IXA

- Fired engine dynamometer lubricant test which evaluates the ability of an aged test lubricant to reduce pre-ignition events
- Limit on total number of LSPI events across all 4 cylinders averaged over 4 iterations for aged oil is the same as the limit for fresh oil:

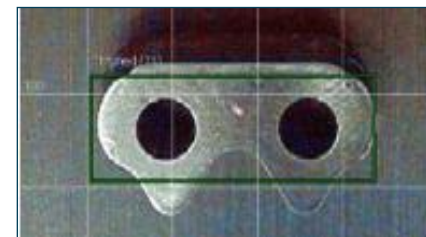
Parameter	Units	GF-7 Limit
Average total number of LSPI events	#	≤ 5
Number of events per iteration	#	≤ 8

Sequence X

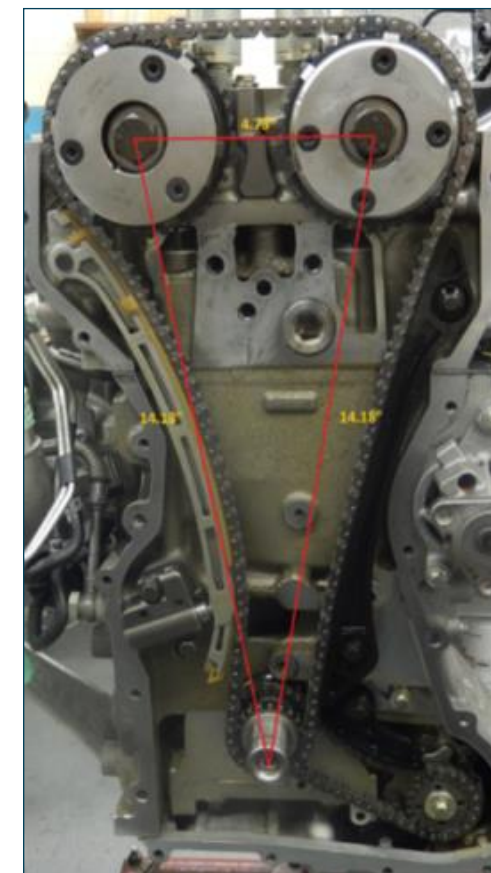
- Sequence X Ford Chain Wear test designed to induce wear on timing chain
- Elongation occurs over time, which can lead to potential misfires and loss of power



Inner Guide Link Plates

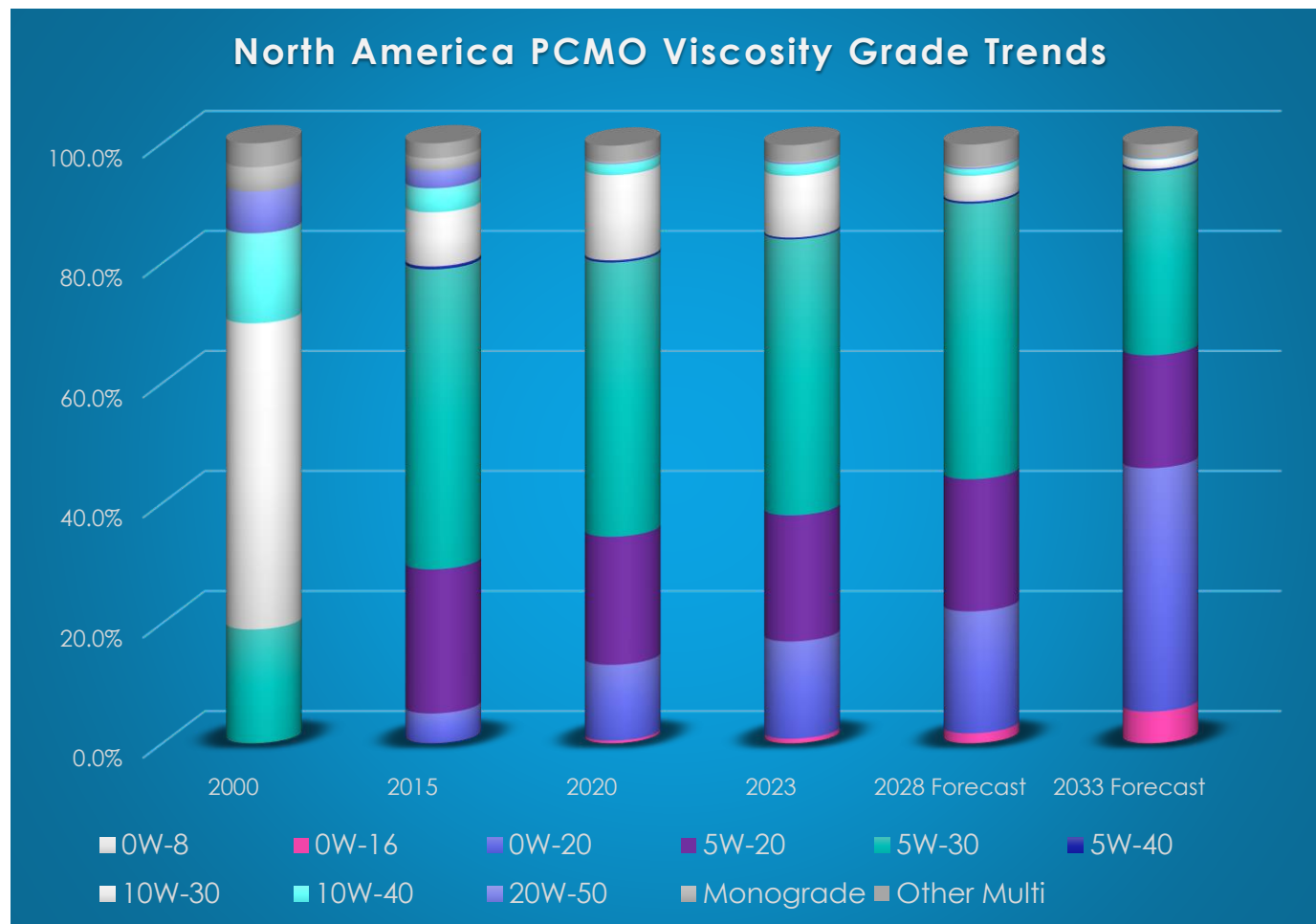


Parameter	Units	GF-7 Limit
Chain stretch	%	≤ 0.080



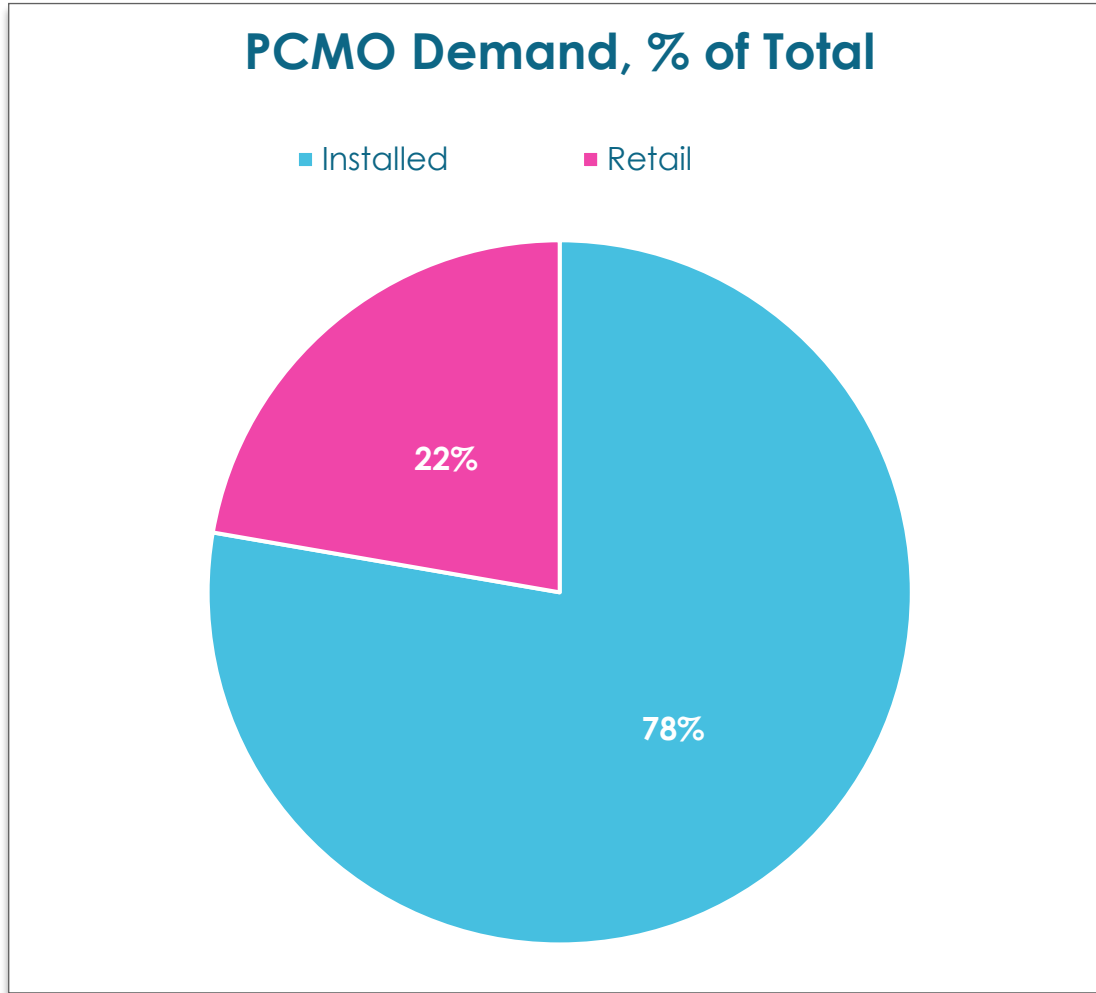
The PCEO market and future trends

Passenger car engine oil trends in North America



- Current market environment is dominated by 5W-20 & 5W-30 viscosity grades.
- The transition to lower viscosity grades will continue as most OEM recommend 0W-20 oils or lower in support of their drive for enhanced fuel economy.
- 40% of the NA PCMO market will be 0W-20 by 2033.
- Although 0W-16 remains niche, its market share is expected to grow supported by Japanese OEMs
- 0W-8 volumes are expected to remain marginal even until 2033

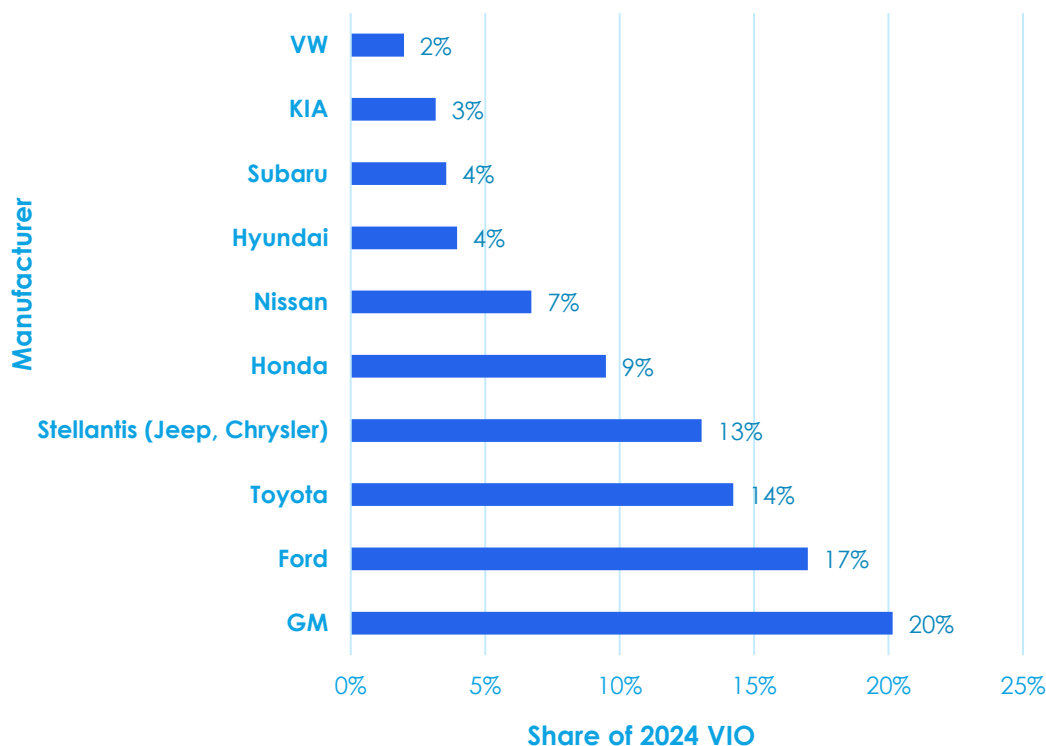
Estimated PCMO Demand by Channel, 2025



- Installers account for an estimated 285 million gallons, or 78% of PCMO demand.
- The balance is sold through such retail outlets as auto parts stores and big box stores.

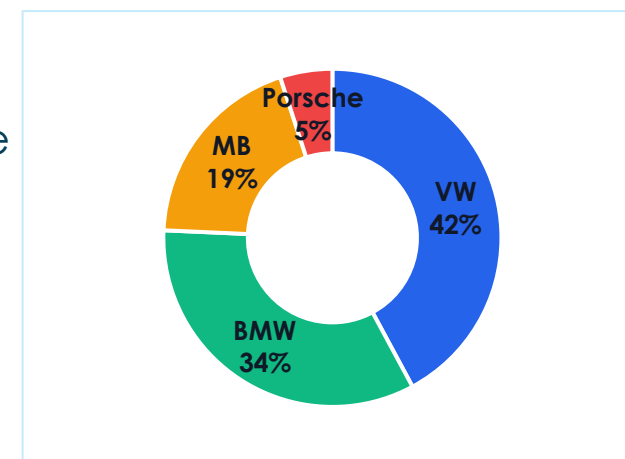
The North America vehicle park continue to be dominated by NA and Japanese OEMs

Top 10 Manufacturers by 2024 Share



- GOEM represents ~6% of the total vehicle parc in NA

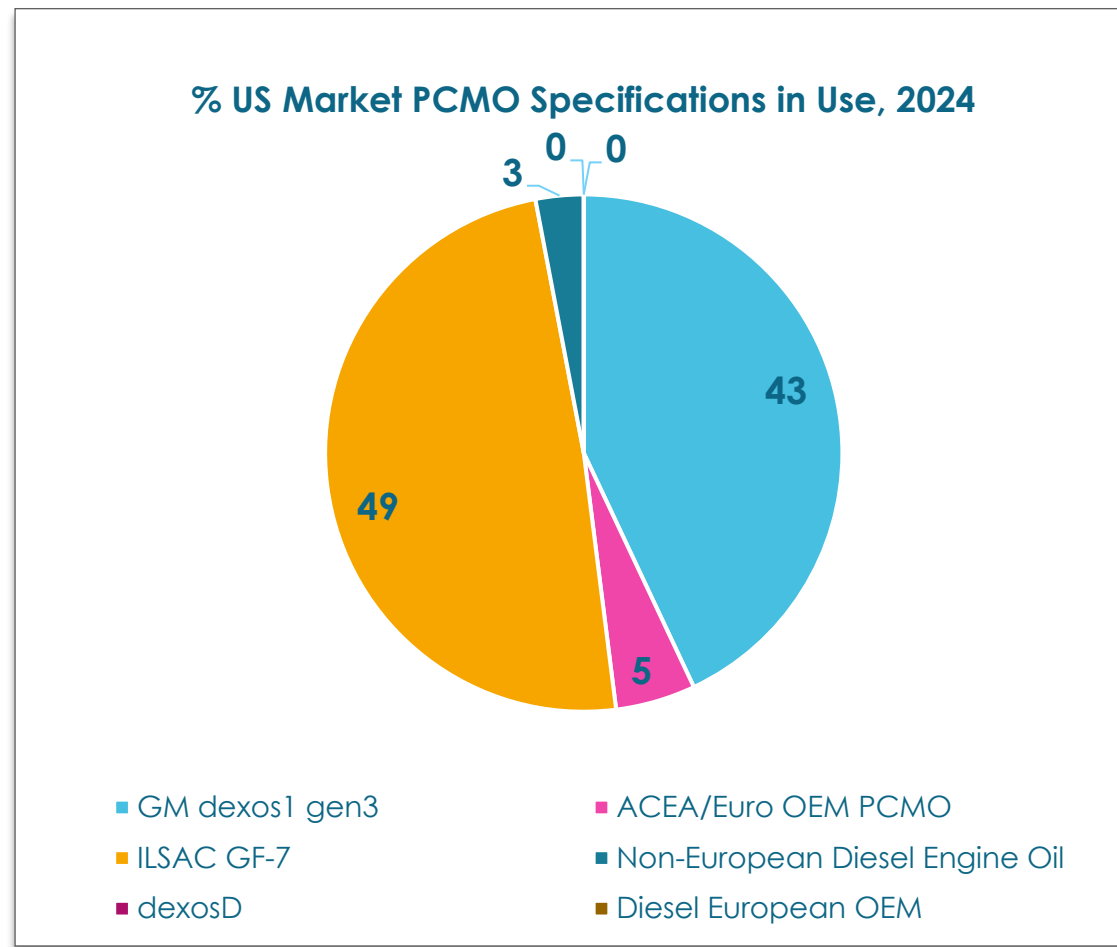
- Of that vehicle parc, VW and BMW dominate



- The average age of cars in the US is 12.5 years and growing
- The average age of GOEM cars in the US is about 10 years

PCMO Specifications Overview for U.S. Market, 2024 basis year

- **ILSAC GF-7** dominates the U.S. market as the underpinning specification.
- **Dexos 1 Gen 3** rapid growth in SAE 0W-20 and introduction of 0W-16 oils for GM vehicles, expected to account for 20% **technical** demand of Vehicles in Operation (VIO).
 - *Actual use of GM dexos1 oils in the market closer to 43%, driven by convenience and the trend toward synthetic oils in the PCMO market*
- **European OEM Specifications** have small share, reflecting the presence of German and other European vehicles in the U.S. market.
- Segments such as **European/non-European Diesel Engine Oil** and **dexosD** have minimal presence in the NA market except with specialized European OEM applications



General motors and Dexos™

Passenger Car Gasoline Engines:

GM dexos®1 Gen 3 is designed to outperform ILSAC GF-6

- Specification shares many of the Sequence tests needed for ILSAC claims and features tighter limits for the Seq VH for better sludge protection
- GM maintains a set of OEM tests that further validate a candidate oil's fuel economy performance, deposit protection, pre-ignition protection, and aeration performance among other performance areas

GM dexos®1 Gen 4 is expected to outperform in cleanliness & protection against wear and corrosion

- Specification target date is Q4 2027, specification release expected to be concurrent with FAU
- Expect updated hardware and improved performance, especially in the area of cleanliness
 - Several new test developments including Gasoline Direct Injection GMOD

Light Duty Diesel Engines:

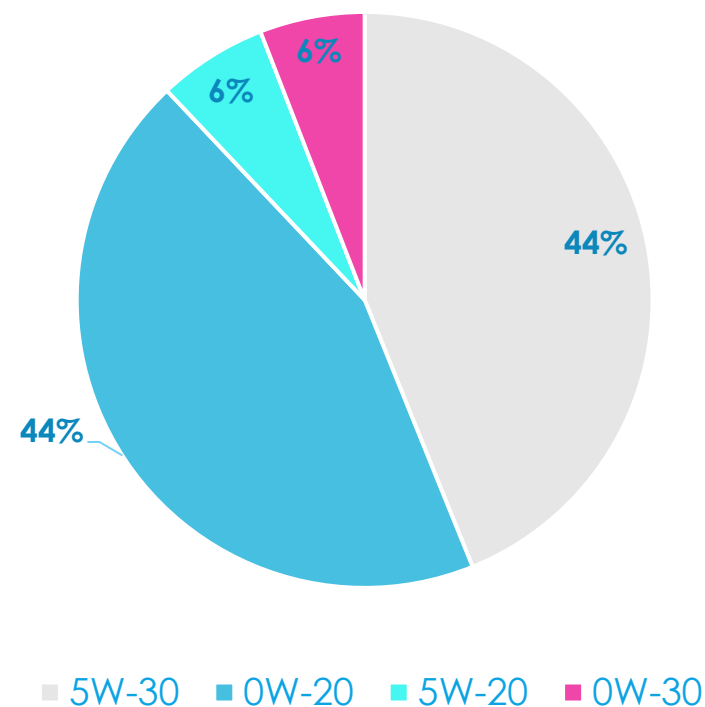
- GM dexos®D is a lubricant specification designed for light duty diesel engine and includes 0W-20 and 5W-30
- GM dexos®D meets or exceeds requirements of GM dexos®2

U.S Market Dexos® 1 Gen 3, 2024 year basis

Trend Toward Lower Viscosity Oils in New GM Vehicles

- Dexos 1 Gen 3: New GM vehicles require 0W-20 viscosity, with growing demand.
- Aligned with broader shift toward lower viscosity grades to improve fuel efficiency and reduce emissions.
- Market Shifts:
 - 0W-20: Stable demand.
 - 5W-30 and 5W-20: On the decline
 - 0W-30 has limited use, but demand could increase in the future

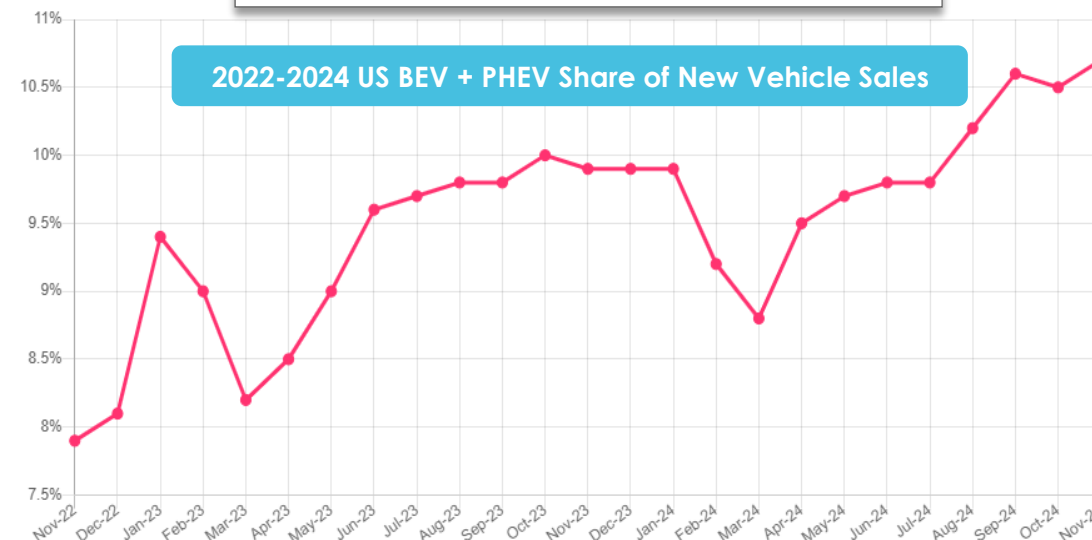
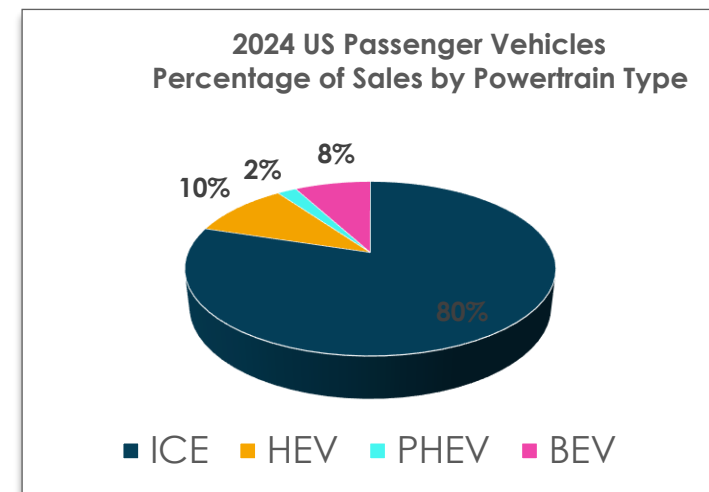
US dexos1 gen3 Viscosity Grades, 2024



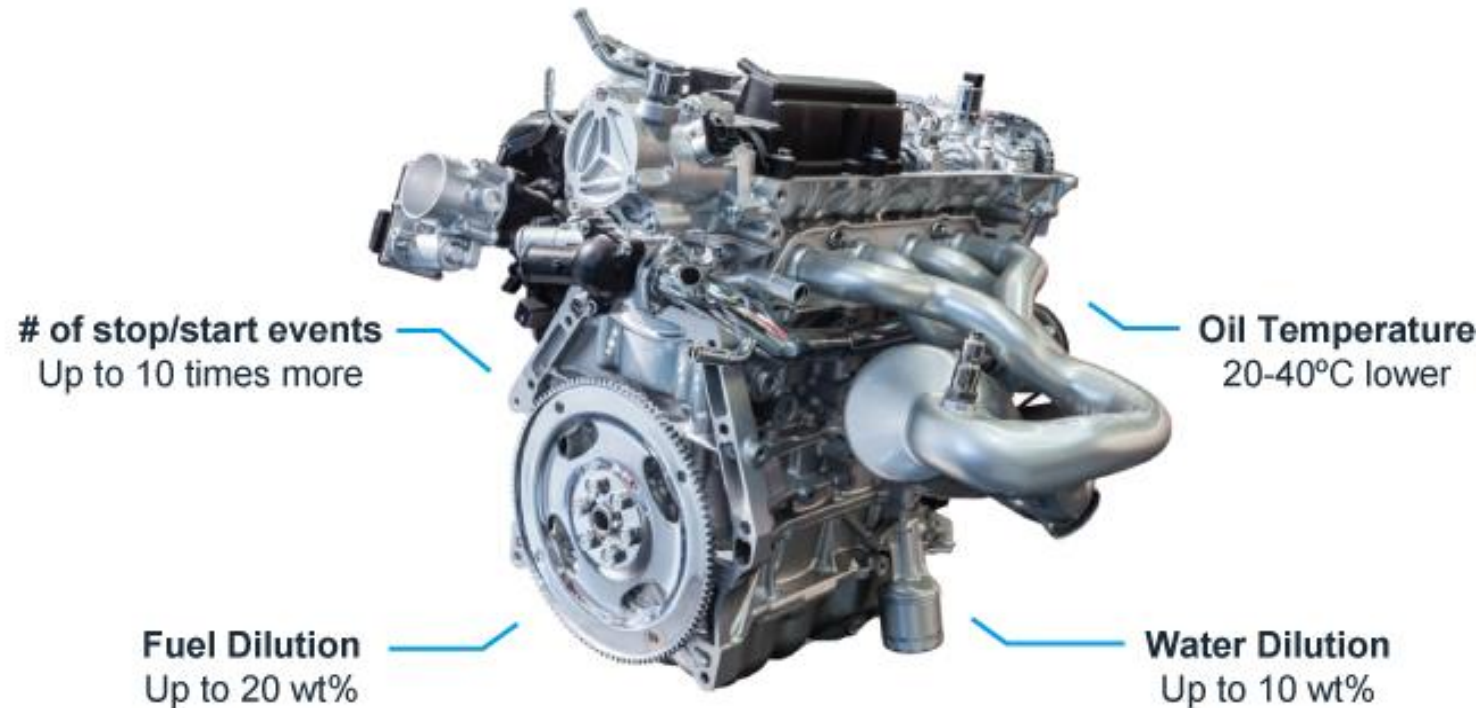
Source: Infineum Commissioned Report, 2025-2026

U.S. hybrid/electric vehicle sales trends

- Depressed Sales due to expiring tax credit for EVs in Sept 2025: US EV sales were a drag on the overall market (~1.3 million units sold in 2025, 8% share of new vehicles sold), declining ~2% YoY
- Price Comparison: Average EV price ~\$58,000, ~\$8000 higher than ICE vehicles.
- Market Adjustments: Slower growth than forecasts; automakers idling plants and delaying decisions
- Consumer Shift: Preference moving towards hybrids vs BEV due to affordability and existing infrastructure



Hybrid operating conditions vs traditional ice



ICE spends less time running during drive cycle → lower average oil temperatures
→ less water/fuel evaporation from oil
→ accumulation of water/fuel in oil

- **Water dilution**

- Increased Corrosive wear
- Potential oil starvation

- **Fuel dilution**

- Oil can fall out of viscosity grade
- Increased mechanical wear due to lower viscosity/oil dilution

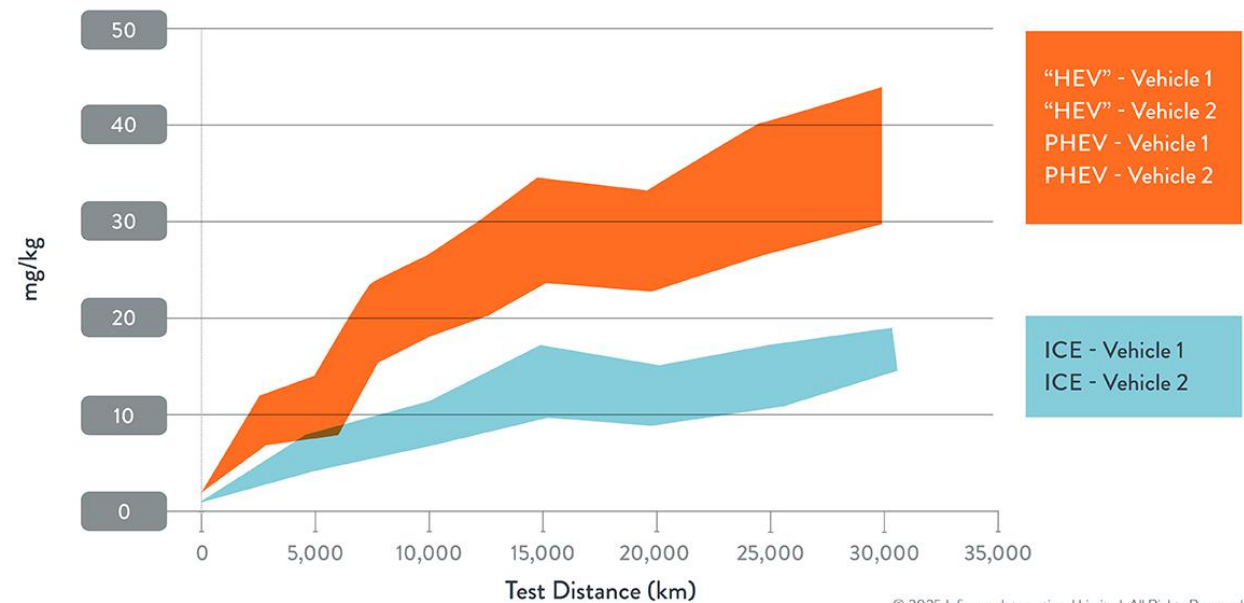
- **Greater # of start/stop events**

- Increased mixed/boundary friction between metal surfaces
- Increased propensity for wear

Numbers are intended to be indicative only and can vary depending on drive conditions and cycles

Hybrid operating conditions vs traditional ice

IRON, ASTM D5185



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CON-ROD BEARING WEAR IN ICE AND PHEV VEHICLES

Vehicle Type	ICE Vehicle	PHEV Vehicle
Test Distance (km)	45,000	30,000
Con-rod Bearing, lower half		

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- Infineum conducted severe hybrid field trial* as part of a greater project to build hybrid understanding
 - Oil in hybrid vehicle engines accumulated more water/oil than oil in ICE only engines
 - More wear occurred in hybrid vehicle engines than ICEs, as demonstrated by:
 - Wear metals in used oil analysis and wear observations of bearings at end of test

Hybrid vehicle engine oil performance

There are currently no industry or OEM specifications dedicated to qualifying the performance of lubricants intended for use in hybrid vehicle engines



Hybrid performance continues to be a potentially valuable area of differentiation for oil marketers in the absence of standardized hybrid specifications

- API work group formed at the end of 2024 to assess the need to create, and the potential performance requirements of an industry hybrid specification
- However, API work group was disbanded earlier this year and work towards dedicated API hybrid spec has been indefinitely postponed

Summary

1

**PCEO
formulation
requires careful
component and
base stock
selection**

To achieve
balanced
performance in
both engine and
bench tests defined
by a specification

2

**ILSAC GF-7
delivers improved
fuel economy and
more robust
protection for the
engine and after
treatment**

ILSAC GF-8 is being
developed,
targeting FAU in Q4
2029

3

**The NA market is dominated by
demand for ILSAC GF-7 and dexos 1
Gen 3 approved oils**

Trend towards lower
viscosity grades
continues and
consumers are
tending to
choose HEVs
over BEVs



Thank you



Formulating tomorrow together

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