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Passenger car engine oil

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Introduction and outline

- Formulation considerations for PCEO
- API SN PLUS, API SP and ILSAC GF-6
- JASO Automotive Gasoline Engine Oil Standard

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

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API SN PLUS, SN PLUS-RC

- Request from 10 automakers to come up with a supplemental standard to the current API SN gasoline engine oil spec to address low-speed pre-ignition (LSPI) problem in turbocharged direct injection gasoline engines.
- On November 9, 2017, API Lubricants Standards Group approved the adoption of SN PLUS.
- Addition of Sequence IX (Ford LSPI) test to API SN and modified API Donuts are the only direct changes.
- Oils satisfying API SN PLUS, SN PLUS-RC can also effectively lubricate engines calling for API SN, SN-RC or ILSAC GF-5

API SN PLUS, SN PLUS-RC

- API SN PLUS was implemented due to the repeated ILSAC GF-6 delays
  - It was a stop gap on the road to ILSAC GF-6
- API SN PLUS brought LSPI prevention to lubricant market
- API SN PLUS took center stage for the lubricant industry in 2018
- First Allowable Use: 1st May 2018

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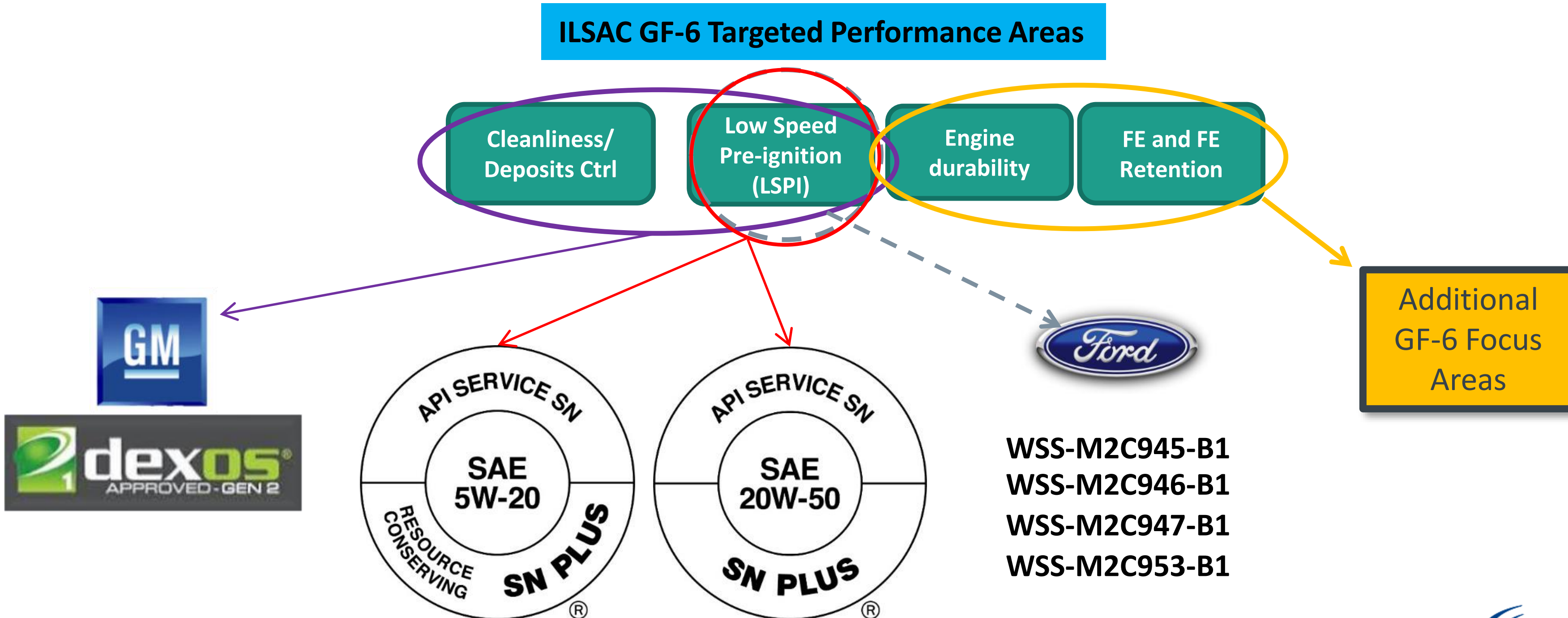
ILSAC GF-6: What are the drivers?

- **Fuel economy improvement**
  - Help meet higher MPG CAFE targets and provide best efficiency for consumers
  - Establish a second specification for lower viscosity oils (0W-16)
- **Replacement of old tests**
  - Running out of engine test parts
  - Need to address performance of modern engine hardware used today



ILSAC GF-6: A quick overview

ILSAC GF-6A	ILSAC GF-6B
SAE XW-20 and XW-30	SAE 0W-16
HTHS Viscosity >= 2.6 mPa•s	HTHS Viscosity 2.3-2.6 mPa•s
SAE 0W-20, 0W-30, 5W-20, 5W-30, 10W-30	SAE 0W-16 only

- ILSAC GF-6A and GF-6B have same performance requirements except for the fuel economy test – Seq. VIE for GF-6A; Seq. VIF for GF-6B
  - Seq. VIF utilizes a lower temperature than the Seq. VIE in 4 of the 6 stages
- Need to differentiate ILSAC GF-6A oils from GF-6B oils to avoid misapplication
  - ILSAC GF-6A oils will continue to contain current Starburst symbol; ILSAC GF-6B oils will contain Shield symbol

ILSAC GF-6: An unprecedented challenge

- ILSAC GF-6 contains 4 replacement engine tests and 3 new engine tests.
  - This was a historical level of change in a category, only the Seq VIII is unchanged
- This has placed a lot of strain on test labs and the rest of the industry, resulting in significant delays in test development and completion of category

ILSAC GF-5	
Sequence IIIG	1996 GM 3.8L
Sequence IVA	1994 Nissan 2.4L
Sequence VG	2000 Ford 4.6L
Sequence VID	2009 GM 3.6L
Sequence VIII	CLR Test 0.7L

ILSAC GF-6A/B	
Sequence IIIH	2012 FCA 3.6L
Sequence IVB	2010 Toyota 1.5L
Sequence VH	2013 Ford 4.6L
Sequence VIE/F	2012 GM 3.6L
Sequence VIII	CLR Test 0.7L
Sequence IX	2016 Ford 2.0L
Sequence X	2016 Ford 2.0L

BOI/VGRA guidelines in place

First Allowable Use: 1st May 2020

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API SP, SP-RC

- API has officially published the latest standards of API SP, SP-RC
- First allowable use: 1st May 2020
- API SP is backward compatible to API SN PLUS and earlier API S categories

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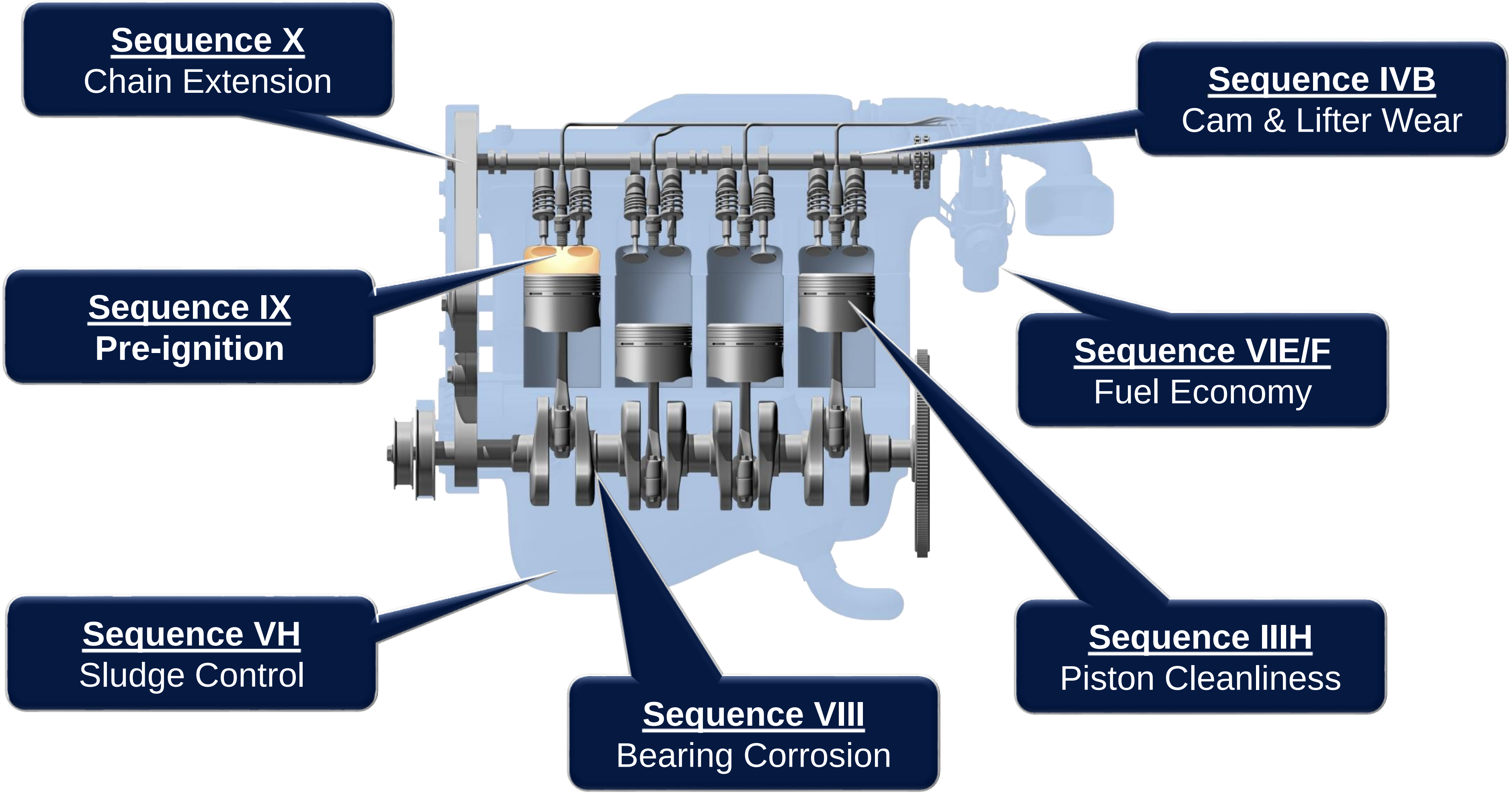
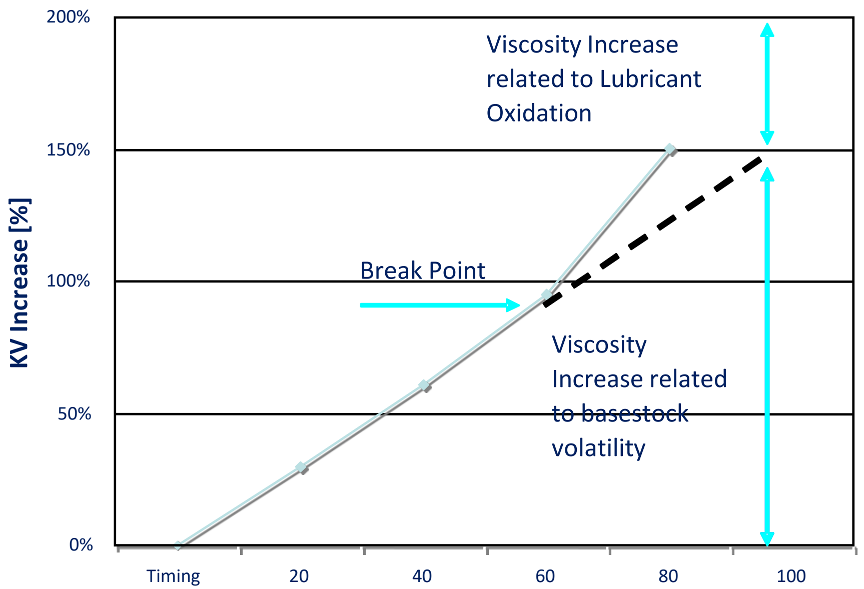
Engine map of ILSAC GF-6 tests



Sequence IIIH
Oxidation and deposit control

Evaluates viscosity increase and piston deposits during high temperature conditions



Parameter	Units	GF-5 limits	GF-6 limits
KV40 increase	[%]	≤ 150	≤ 100
Avg. weighted piston deposits	[merits]	≥ 3.7	≥ 4.2
Hot stuck rings	[#]	= 0	= 0

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Sequence IVB
Valve train wear

- Evaluates valve train wear in a modern gasoline engine
- Low temperature test, with total test duration of 200hours
- Intake and exhaust bucket lifters are removed at the end of test to determine mass and volume losses

Parameter	Units	GF-6 limits
Average Intake Lifter Volume Loss	mm3	≤2.7
End of test Iron	ppm	≤400

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Sequence VIII
Resistance to bearing corrosion and shear stability

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

Parameter	Units	GF-5/6 limit
Bearing weight loss	[mg]	≤ 26
Shear stability		= stay in grade

PASS

FAIL

Sequence VH
Engine sludge and varnish control

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

Parameter	Units	GF-5/6 limits
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
Fuel economy

- Evaluates fuel economy improvement
- Procedure:
  - Fuel consumption is measured twice at each of 6 speed/load/temperature test conditions for SAE 20W-30 baseline oil (BL)
  - The candidate oil is introduced and aged for 16 hours at aging conditions. Fuel consumption is measured for each of the 6 test conditions
  - The candidate oil is aged for an additional 84 hours. Fuel consumption is measured for each of the 6 test conditions and followed by a repeat of the BL oil at the 6 test conditions. Candidate results reported relative to the BL

	GF-5 limits		GF-6 limits			
SAE Grade	FEI_2 Limit [%] Seq. VIE	FEI_{SUM} Limit [%] Seq. VIE	FEI_2 Limit [%] Seq. VIE	FEI_{SUM} Limit [%] Seq. VIE	FEI_2 Limit [%] Seq. VIF	FEI_{SUM} Limit [%] Seq. VIF
xW-20	≥ 1.5	≥ 3.2	≥ 1.8	≥ 3.8	-	-
xW-30	≥ 1.2	≥ 2.5	≥ 1.5	≥ 3.1	-	-
10W-30	≥ 1.0	≥ 2.2	≥ 1.3	≥ 2.8	-	-
0W-16	-	-	-	-	≥ 1.9	≥ 4.1

Sequence IX
Low speed pre-ignition

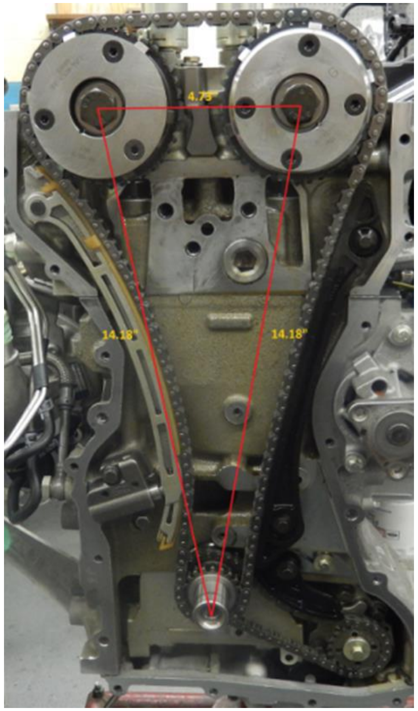
- Evaluates the ability of a test lubricant to reduce pre-ignition events
- Test sequence (each 175000 cycles) repeated for 4 test iterations
- LSPI events are defined as outliers of peak pressure (PP) and crank angle location of 2% mass fraction burned (MBF02) data.
- Limit on total number of LSPI events across all 4 cylinders averaged over 4 iterations

Parameter	Units	GF-6 Limit
Average number of LSPI events for 4 iterations	#	≤ 5
Number of LSPI events per iteration	#	8

Sequence X
Chain wear protection

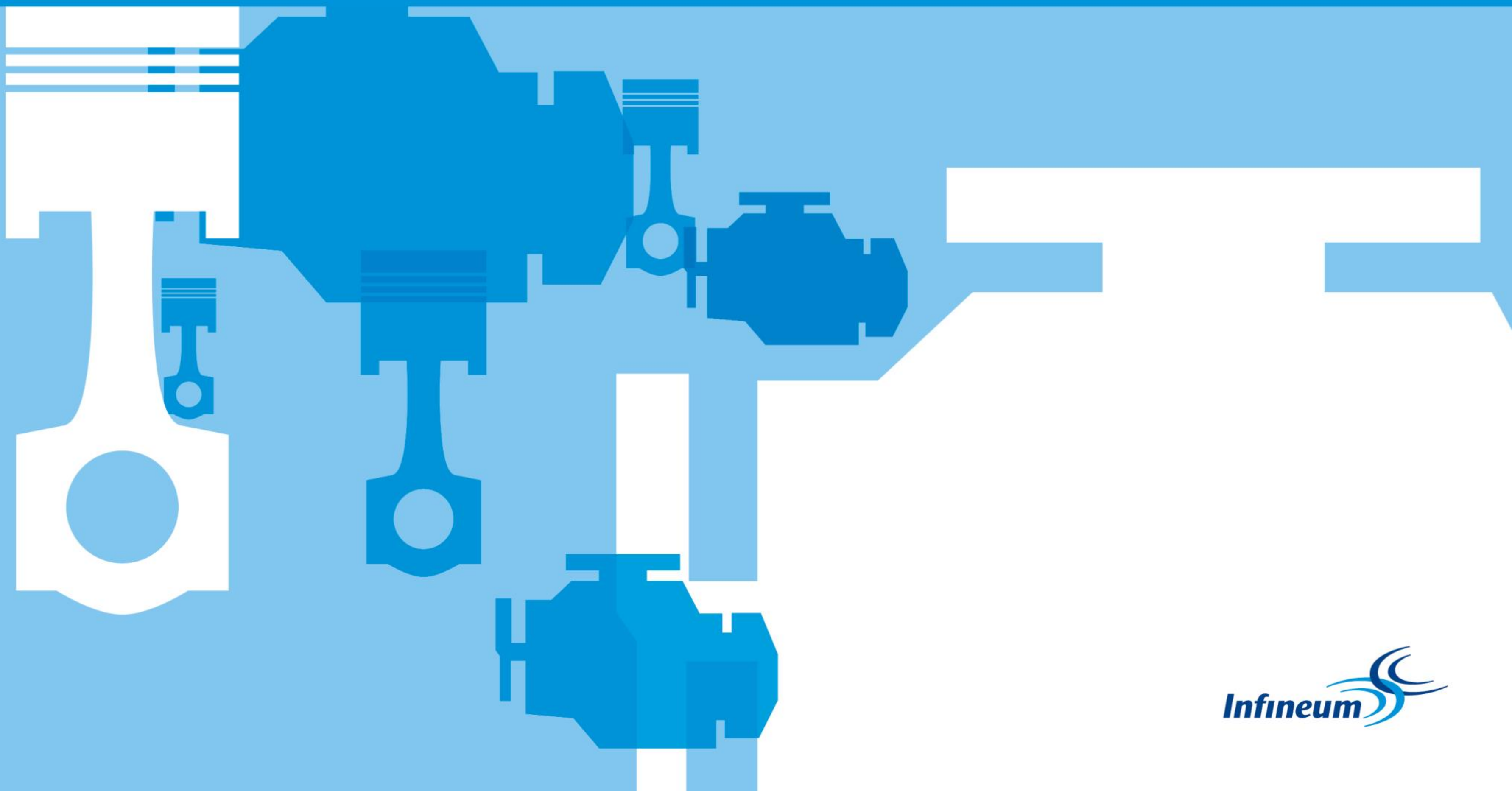
- Evaluates the ability of the lubricant to reduce timing chain wear
- Total duration 216 hours
  - 8hour break-in schedule before main test cycle
- Timing chain is measured prior to installation, after break-in and at the end of test
- Timing chain is replaced after every test

Parameter	Units	GF-6 Limit
End of test Chain stretch	%	≤ 0.085



Performance you can rely on.

JASO Automotive Gasoline Engine Oil Standard



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JASO GLV-1 specification

- JASO TF developed a new specification for ultra low viscosity grade oils; SAE 0W-8 and SAE 0W-12
- JASO M364:2019 Application Manual (JASO GLV-1) was officially released in June 2019 and can be downloaded from JALOS website
- First effective date for JASO On-File: 1st October 2019

JASO GLV-1 specification

- Fuel economy test: to be passed in either JASO FE tests
- Valve train wear: to be passed in either Sequence IVA or IVB test
- Seq IX (Ford LSPI) not required as there is no interest to use SAE 0W-8 and 0W-12 oils in turbocharged engines among JAMA members

JASO GLV-1		
Firing FE test **or** **Motored FE test**	Toyota 2ZR-FXE 1.8L (JASO M366) or Nissan MR20DD 2.0L (JASO M365)	1.1% min. or 0W-8: 2.0% min. 0W-12: 1.7% min.
Sequence IIIH	2012 FCA 3.6L	GF-5 Limits
Sequence IVA **or** **Sequence IVB**	1994 Nissan 2.4L or 2010 Toyota 1.5L	GF-5 Limits GF-6 Limits
Sequence VH	2013 Ford 4.6L	GF-5/6 Limits
Sequence X	2016 Ford 2.0L	GF-6 Limits

Summary

- PCEO formulation requires careful component and base stock selection to achieve balanced performance in combination with engine and bench tests defined by a specification
- API SN PLUS will address automakers' concerns about low speed pre-ignition problem in turbocharged direct injection gasoline engines
- ILSAC GF-6 will deliver improved fuel economy and more robust engine protection, similar to its predecessors
- JASO GLV-1 will address the future needs of ultra low viscosity grade oils

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Appendix

Detergents

Background	Many configurations available including: • Salicylates, phenates, and sulphonates • Neutral and highly overbased • Magnesium and/or calcium
Formulation considerations	1. Mixture of detergents generally used to provide an balance of attributes 2. Neutral provide detergency for piston cleanliness while overbased provide a source of alkalinity reserve 3. Sulfonates more effective at lower temperature (piston skirt) while phenates more effective at higher temperature (piston crown) 4. Salicylates provide detergency and antioxidant protection, and their low sulfur content enables greater flexibility in restricted formulations 5. Metal variety can affect wear performance 6. Source of ash, a restricted parameter in some applications

Dispersants

Background	Many configurations available including: • High and low molecular weight • Chloro or thermal • Borated or non-borated
Formulation considerations	1. Concentration and type chosen to provide: • Sludge and filter plugging control • Piston and engine cleanliness • Control of soot-induced oil thickening 2. Contributes significantly to additive package and finished oil viscosity, so high treat rates can be detrimental to fuel economy performance 3. Detrimental to CCS viscosity 4. Chloro-dispersant contains residual chlorine, a restricted parameter in some applications 5. May be detrimental to compatibility with certain elastomers 6. Borated dispersants are beneficial in wear and elastomer compatibility, at the expense of sludge control efficiency

ZDDP

Background	Many configurations available including: • High or low molecular weight • Primary or secondary
Formulation considerations	1. Provide dual-functionality as both an antioxidant and antiwear component 2. Lower molecular weight provides better wear protection while higher molecular weight provides better thermal stability 3. Secondary provides better wear protection while primary provides better thermal stability 4. Source of ash, a restricted parameter in some applications 5. Contribute phosphorous, a controlled parameter for emissions system protection 6. Highly efficient and cost-effective

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Antioxidants and Friction Modifiers

Antioxidants	
Background	Several options available beyond ZDDP including: • Aminic and phenolic • Metal – and/or sulfur-based
Formulation considerations	1. Response of oil to oxidation varies significantly by engine test, so a combination of antioxidants typically used to achieve performance

Friction Modifiers	
Background	Several options available including: • Organic • Inorganic
Formulation considerations	1. Some are highly surface active and can detrimentally impact wear performance 2. Organic FMs may cause stability issues in the additive package or finished oil

Viscosity Modifiers

Background	Many options available including: • OCP, PMA, styrene/isoprene copolymer • Functionalized (dispersant) or non-functionalized
Formulation considerations	1. Exhibit different degrees of temporary and permanent viscosity loss in high-shear operating conditions 2. Exhibit different contributions to low temperature performance 3. Typically detrimental to engine cleanliness 4. Selection of VM may benefit fuel economy 5. VM diluent contributes to finished oil volatility

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