Engine Oil Impacts on SPI

Ashu Gupta, Ph.D.
CRC Workshop on Stochastic Pre-Ignition
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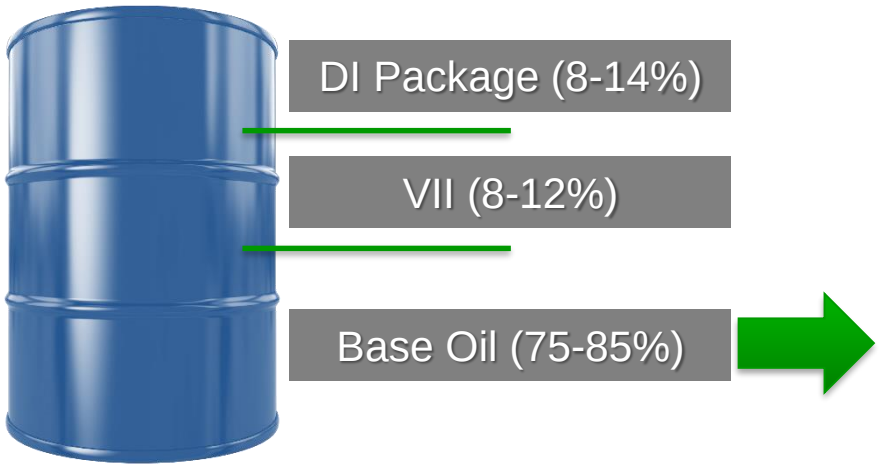
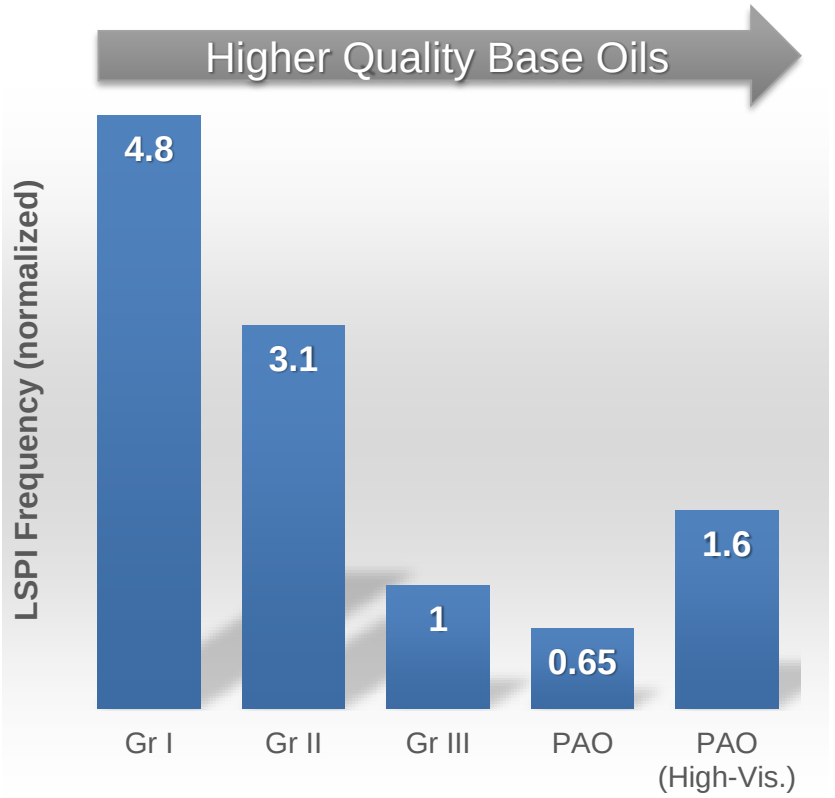
Aspects of Engine Oil That Impact SPI Performance

Typical Engine Oil Composition



DI = Dispersant Inhibitor (a multifunctional additive package)
VII = Viscosity Index Improver

Impact of Base Oil on SPI



Source: Reproduced from SAE 2012-01-1615

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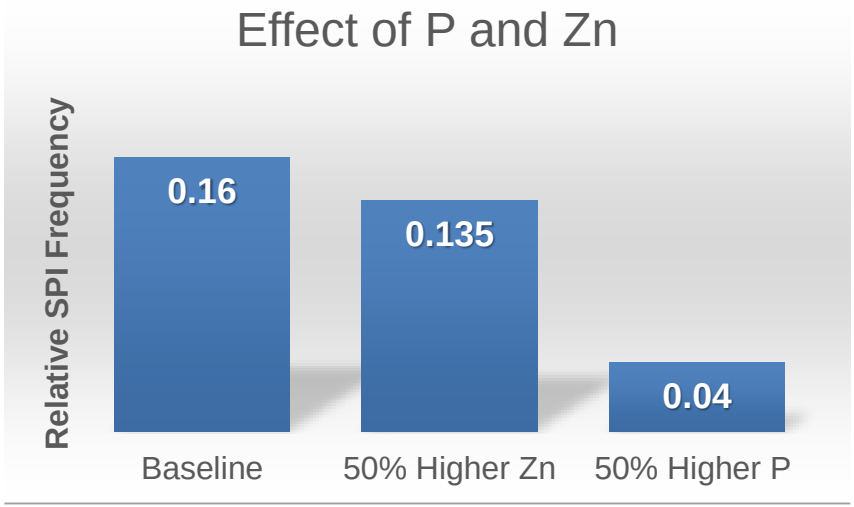
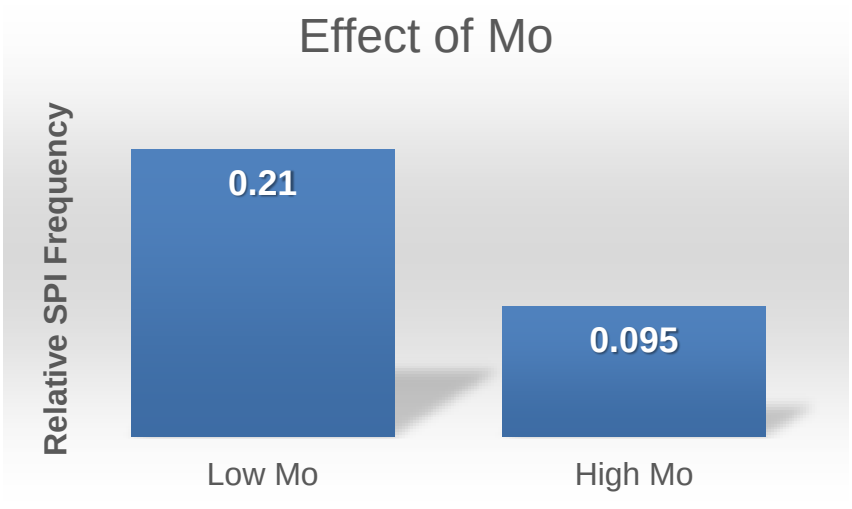
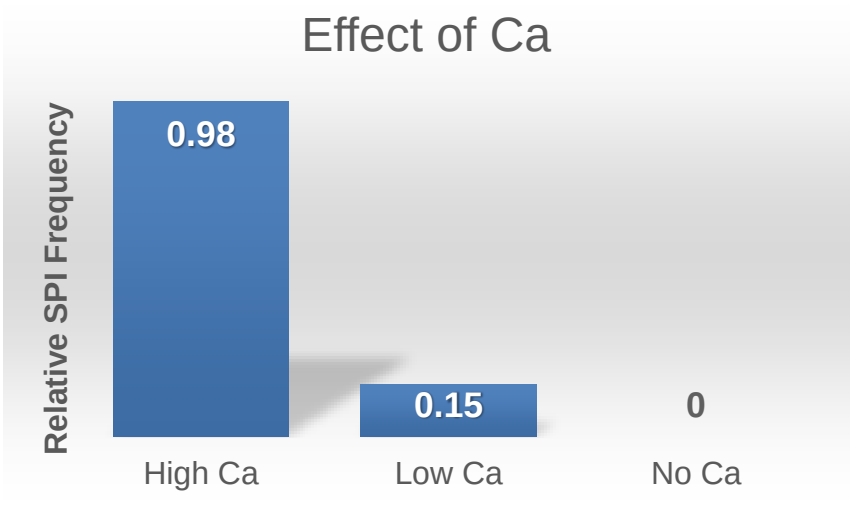
Inorganics present in Engine Oil known to impact SPI

- Additive packages contain a number of components (that contain inorganics) to provide a range of performance
  - ZnDDP: Anti-wear & Antioxidant
  - MoDTC: Friction Modifier
  - CaSulfonate: Detergent & Acid Neutralization
- These have also shown to impact SPI







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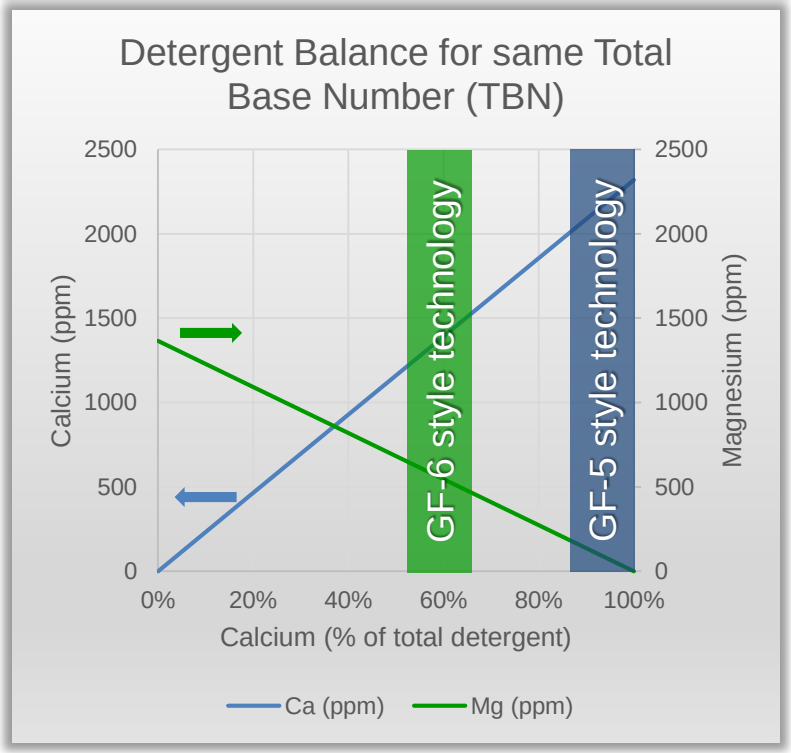
Practical Constraints in Improving SPI Performance

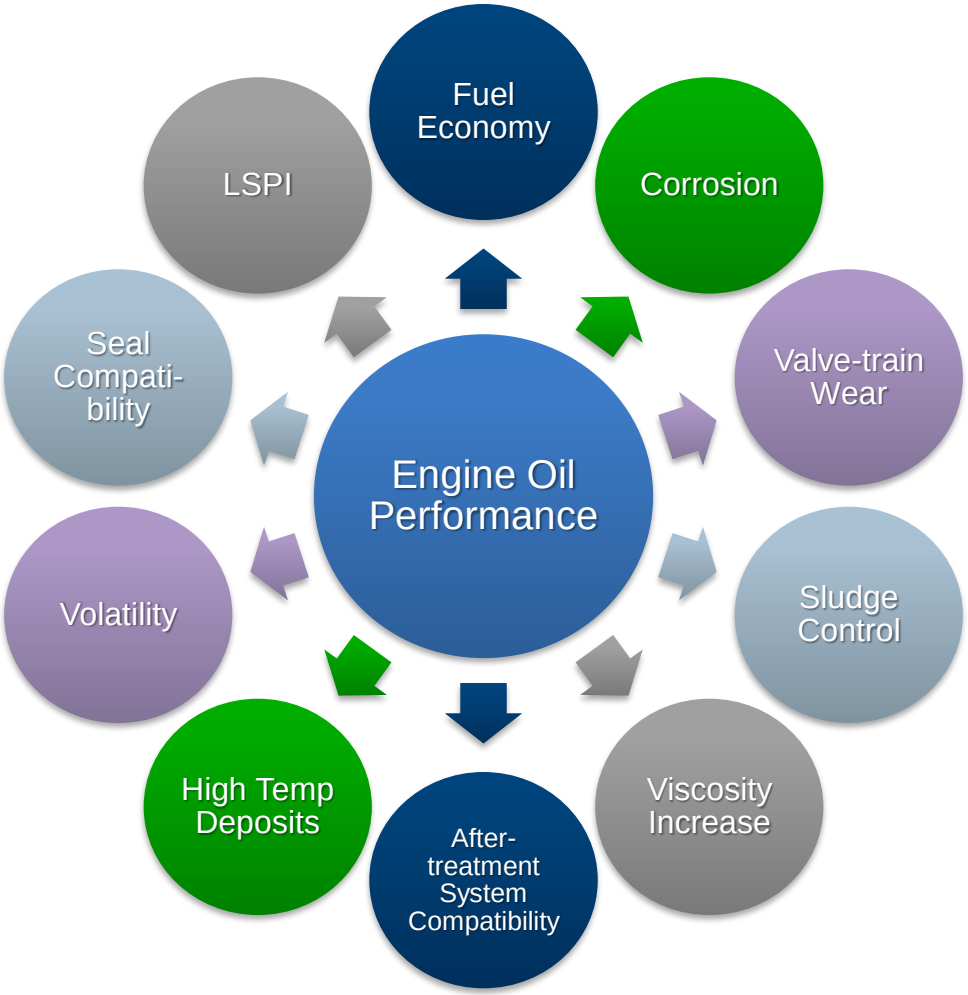
Component	Practical Constraints
Higher Quality Base Oil	Limited Supply Higher Cost
Increased ZnDDP	Potential impact of P on aftertreatment catalyst Increased Ash accumulation in GPF
Increased MoDTC	Increased Ash accumulation in GPF Potential increase in certain deposits Higher Formulation Cost

Ca and Mg Based Detergents in Engine Oils

Detergents are vital to engine oil to ensure performance

- Suppression of formation of deposits
- Prevention of corrosion through neutralization of acids formed due to combustion





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Detergents are Known to Affect Fuel Economy

- The GF-6 Sequence VIE test measures fuel economy performance of engine oils
- Industry standard test for Fuel Economy
- Measures Brake Specific Fuel Consumption at 6 different conditions to represent real-world operation
- A weighted-average Fuel Economy is then calculated for the whole test
- An All-Ca and an All-Mg oil were evaluated in the test

Stage	Engine Speed (rpm)	Torque (Nm)	Oil Temp (°C)	Coolant Temp (°C)	Stage Weight
1	2000	105	115	109	0.300
2	2000	105	65	65	0.032
3	1500	105	115	109	0.310
4	695	20	115	109	0.174
5	695	20	35	35	0.011
6	695	40	115	109	0.172

3.6 L GM LY7 engine

Oil	Detergent Composition	
	Ca (%)	Mg(%)
Oil A	100	0
Oil B	0	100

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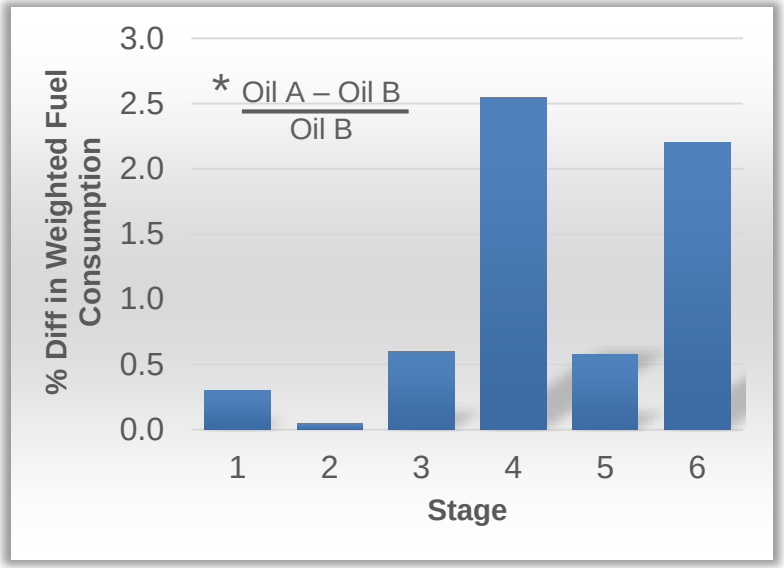
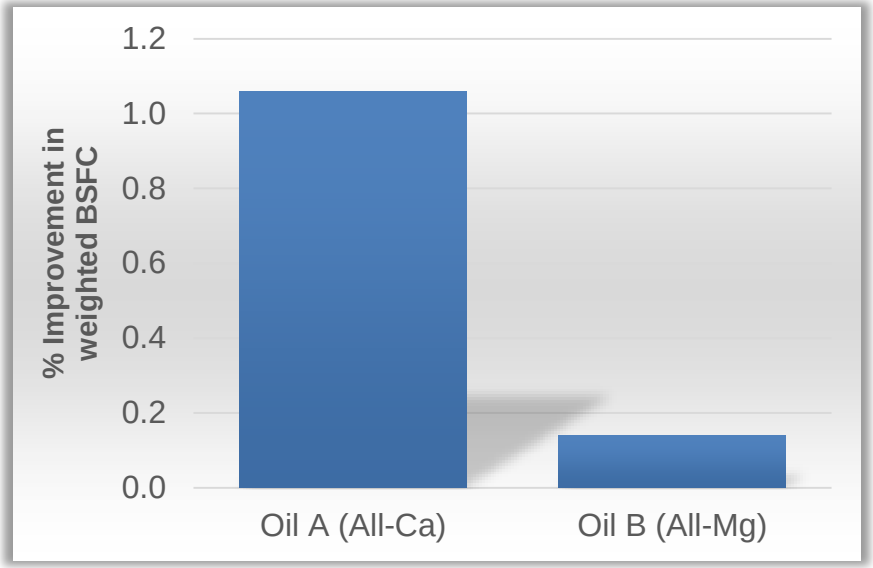
Effect of Detergent System on Fuel Economy

% Difference* in Fuel Consumption at Different Stages



% Fuel Economy Improvement over Seq. VIE Baseline Oil



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- Detergent System significantly affects Fuel Economy
  - More than 80% reduction in FEI for All-Mg detergent system
  - Consistent with measurement of performance in boundary-friction and thin-film friction regimes (measured using bench tests)

Forcing an elemental limit for Ca will handicap lubricant industry from delivering better fuel economy performance

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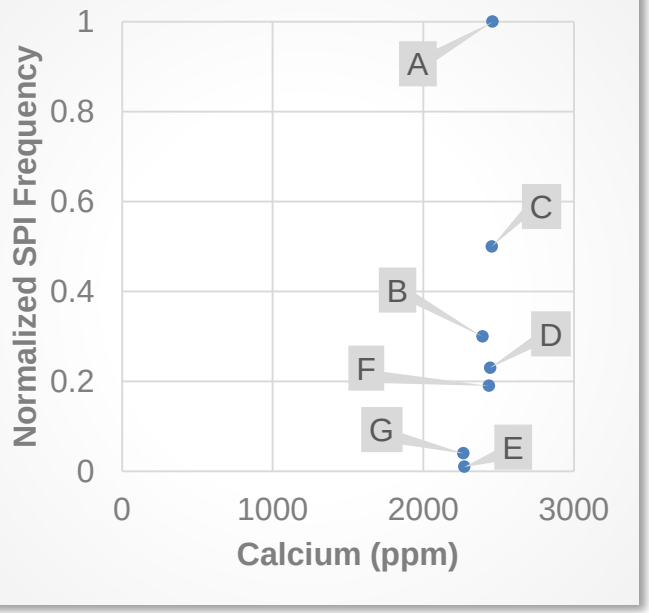
Robust SPI Performance is Possible with High Ca Oils

SPI Performance[1] for different oils with High Ca



Oil	A[2]	B	C	D	E	F	G
Ca ppm	2460	2393	2454	2444	2273	2435	2265
Mg ppm	8	9	8	7	11	8	9
Zn ppm	837	834	831	828	779	852	771
P ppm	760	748	759	752	701	766	696
Mo ppm	82	82	83	82	75	83	73
Normalized LSPI Frequency	**1**	**0.30**	**0.5**	**0.23**	**0.01**	**0.19**	**0.04**

1: LSPI tests run on GM LHU engine using SwRI P3 Test Cycle
2: Representative of NA Commercial GF-5 style formulations

An elemental limit on Ca will hinder commercialization of innovative formulations that deliver robust LSPI performance as well as fuel economy

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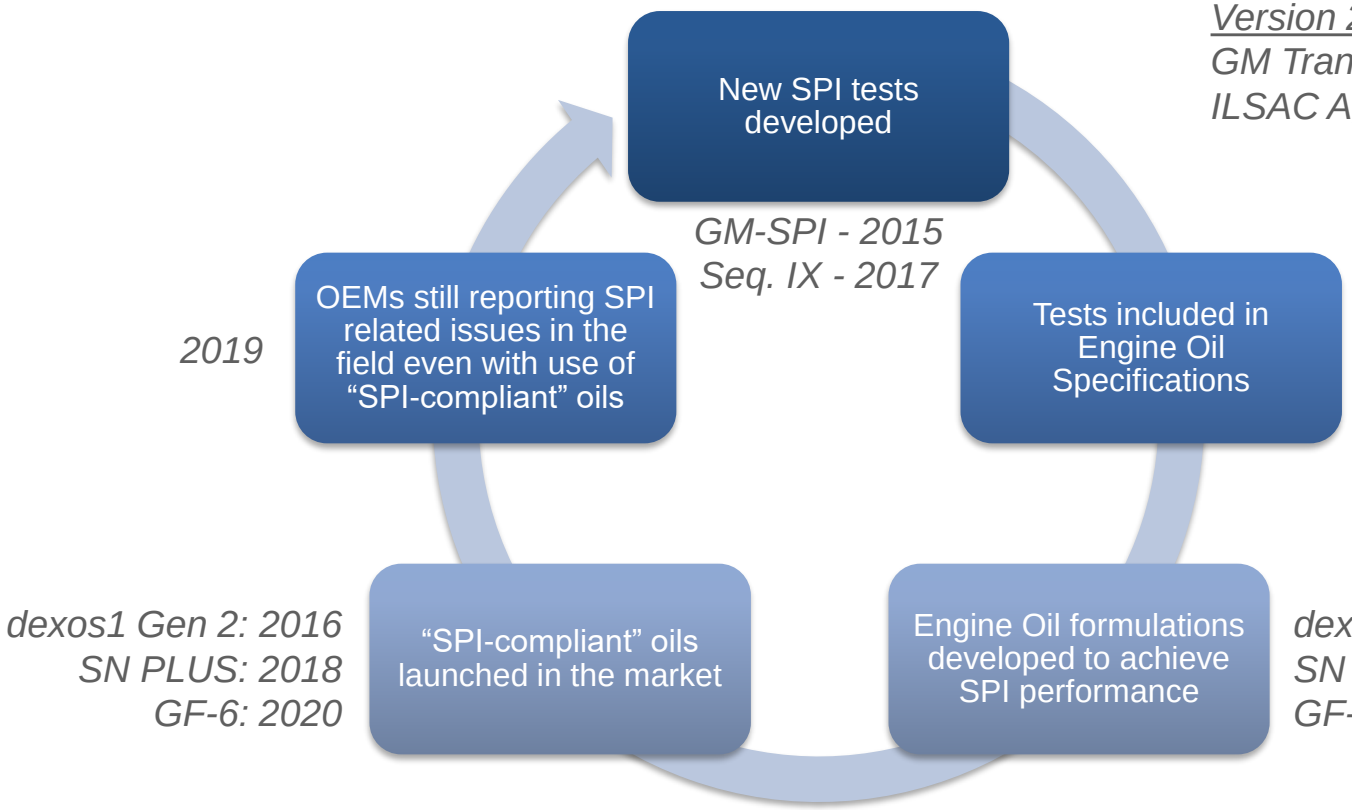
Industry SPI Test Development Cycle



Version 2.0 LSPI tests:
GM Transient SPI - 2020
ILSAC Aged Oil LSPI - 2021

dexos1 Gen 2: 2015
SN PLUS: 2018
GF-6: 2019

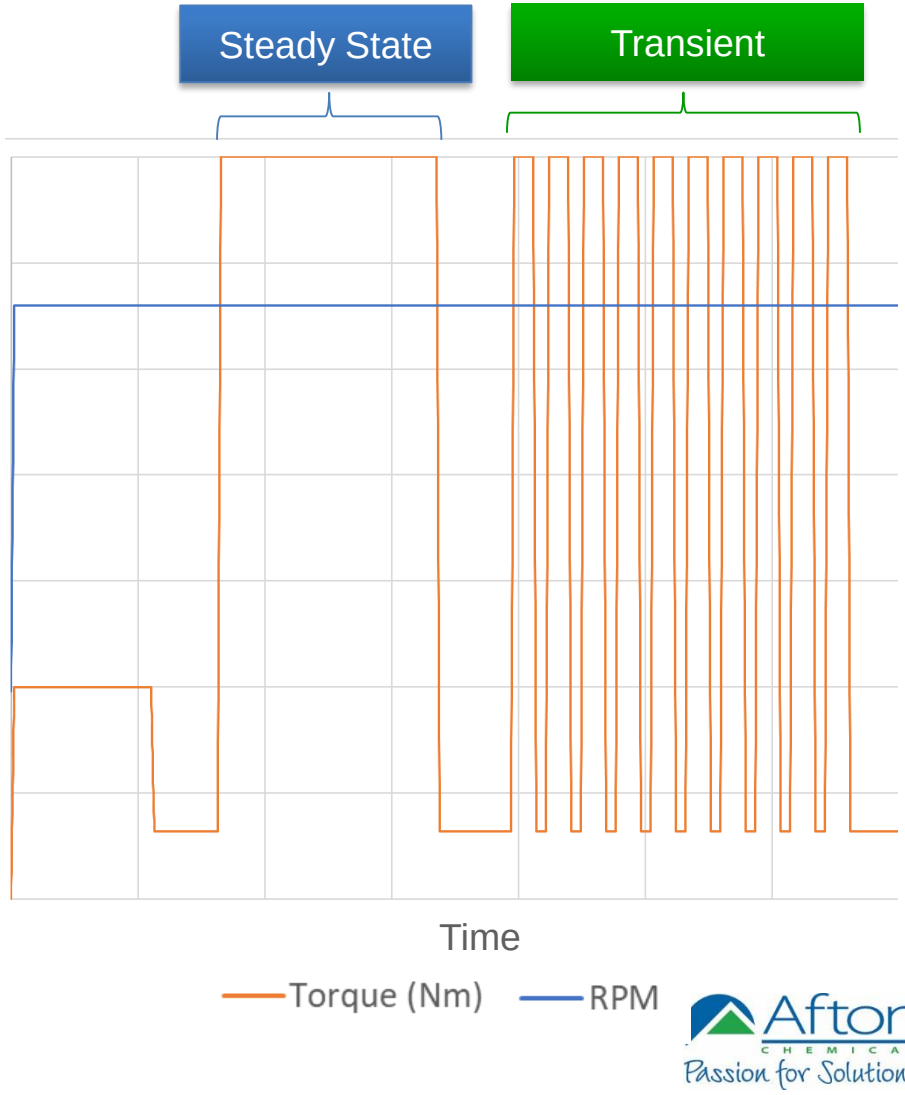
dexos1 Gen 2: 2016
SN PLUS: 2018
GF-6: 2020

OEMs reporting SPI related issues even after adoption of oils that pass current industry SPI tests. Reason for deviation not known. New SPI tests being developed.

GM Transient SPI Test (dexos™ 1 gen 3)

- Current industry SPI tests are effectively steady state only, which is not representative of real-world driving
- Inclusion of transient segments (with fast ramp ups and ramp downs) could potentially make an SPI test more representative

Please Note:
- What is depicted on this slide is only a representative test cycle consisting of steady state and transient segments, meant for illustrative purposes
- The official GM Transient SPI test is proprietary



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ILSAC Aged Oil LSPI Test

- Ageing of the engine oil during service could potentially deteriorate SPI performance
- The ILSAC Aged Oil LSPI test (in development) has developed and demonstrated a 2-step test procedure:

DRAINED EOT OIL

Step 1: Age oil in a 'mule' engine*

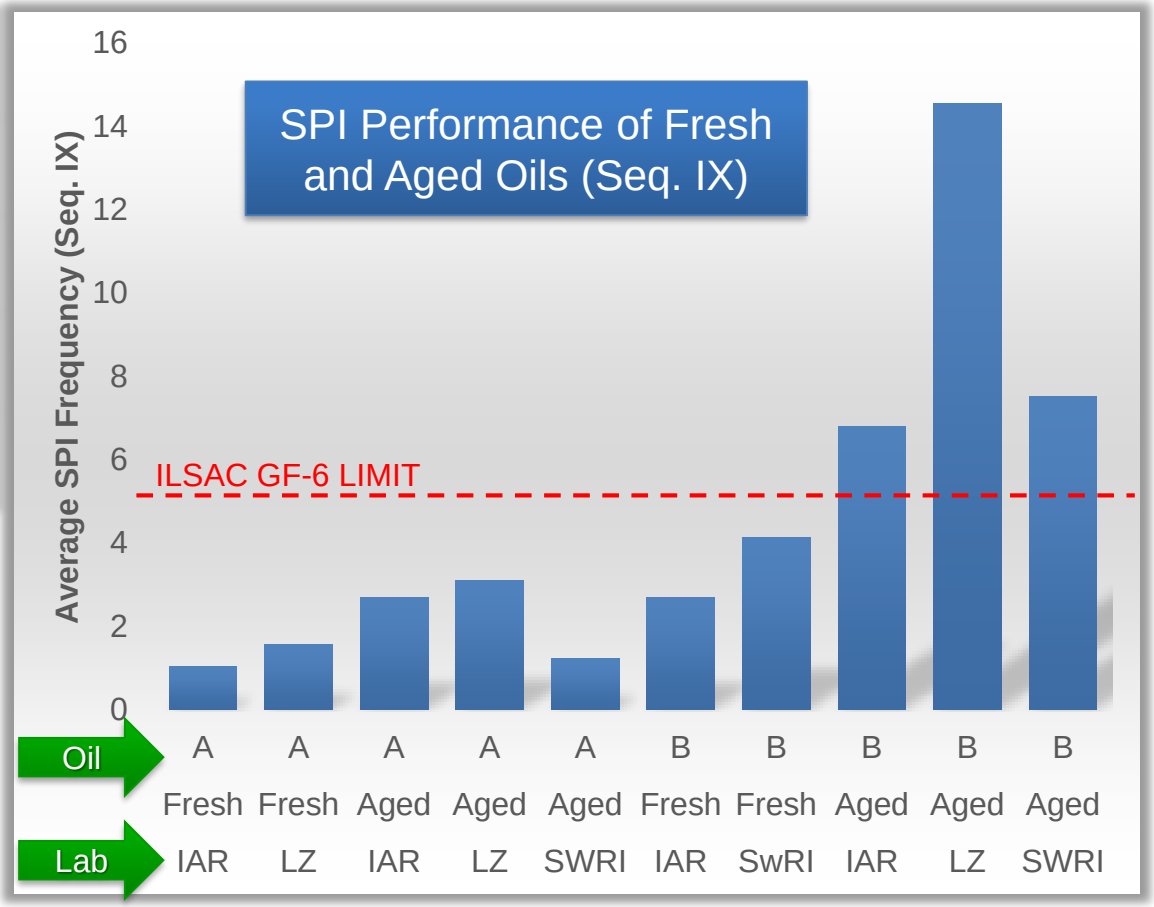
Step 2: Evaluate SPI performance of the aged oil in a standard Seq. IX LSPI test

** Oil aging is also conducted in a Ford EcoBoost 2.0L TGDI engine, using a modified Seq. X test cycle on the Seq. X test stand.*

The ILSAC Aged Oil Test is Able to Discriminate for SPI Durability Performance

Elemental Composition	Conc. (ppm)	Oil A	Oil B
	Ca	1444	2004
	Mg	808	0
	Mo	0	800
	P	770	771

- Results from round robin testing indicate Oil A (mixed metal detergent system) has robust Aged Oil SPI performance
- Mixed metal detergent system meets current GF-6 limits, even after ageing



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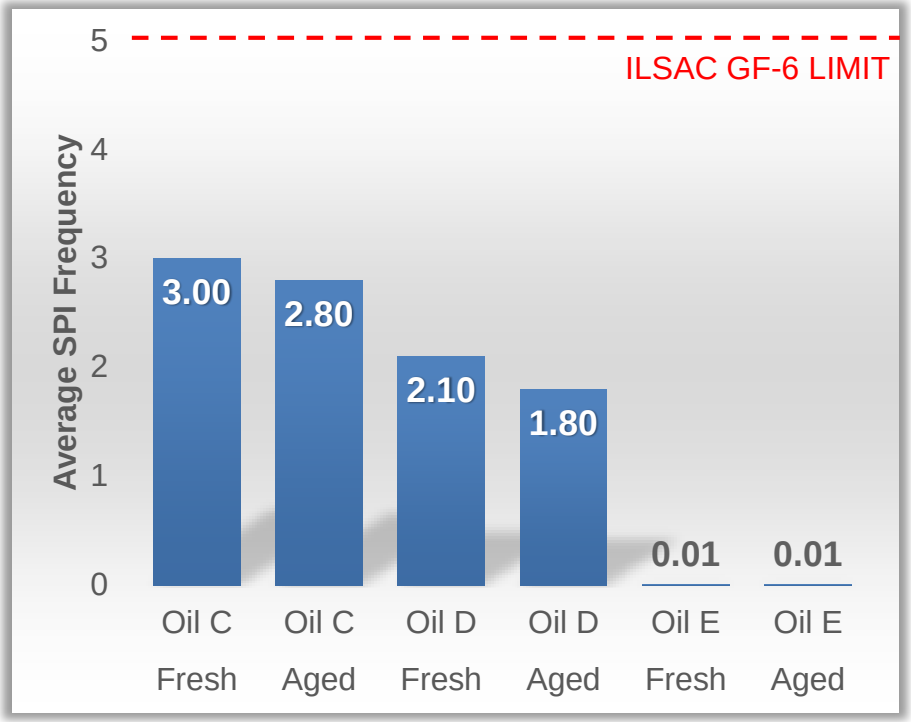
Robust and even ‘Zero’ SPI performance (Fresh and Aged) is achievable for commercial formulations

Elemental Composition	Conc. (ppm)	Oil C	Oil D	Oil E
	Ca	1073	1309	983
	Mg	651	568	576
	Mo	87	79	79
	B	195	231	189
	P	759	772	772

Certain formulation styles appear to be durable and do not show an increase in SPI frequency after ageing

SPI Performance of Fresh and Aged Oils (Seq. IX) for three Commercial NA formulations



Engine Oil formulations that offer holistic performance, including robust SPI, Fuel Economy and all other performance requirements are achievable and available commercially.

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Quick Recap / Summary

- Base oil and elemental composition drive SPI performance for engine oils
- There are practical limits (performance and commercial) associated with these components
- Eliminating/imposing strict limits on Ca may incur large Fuel Economy penalties, and inhibit innovation
- Industry is developing new LSPI tests to better represent real world LSPI performance
- Robust and even ‘Zero’ SPI performance (Fresh and Aged) is achievable for commercial formulations

Open Questions / Food for Thought

- Why are industry SPI tests diverging (e.g., Transient vs. Oil Ageing) if it's the same exact phenomena we are trying to suppress?
- What drives real-world SPI performance? Why do current industry SPI tests not correlate well with real-world performance?
- Do we expect future TGDI engines (either in hybrids or pure-ICEs) to operate in SPI-prone regions of the engine map?
- The lubricants industry has already reduced SPI frequency by 80-95+% (vs. GF-5/dexos™ 1 gen 1 levels). Does improving fuel quality now offer a greater opportunity for further reduction in SPI?

Thank You!

Ashu Gupta, Ph.D.
Ashu.Gupta@AftonChemical.com

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