

*Engine Oil Specification Trends*  
*and*  
*Lubricants Technology*

**October, 2013**

**TOYOTA MOTOR CORPORATION**

**MINORU YAMASHITA**

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## 1. Engine Oil Specification Trends

**ILSAC GF-6**

**SAE J300**

## 2. Lubricants Technology

## 3. Summary

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## 1. Engine Oil Specification Trends

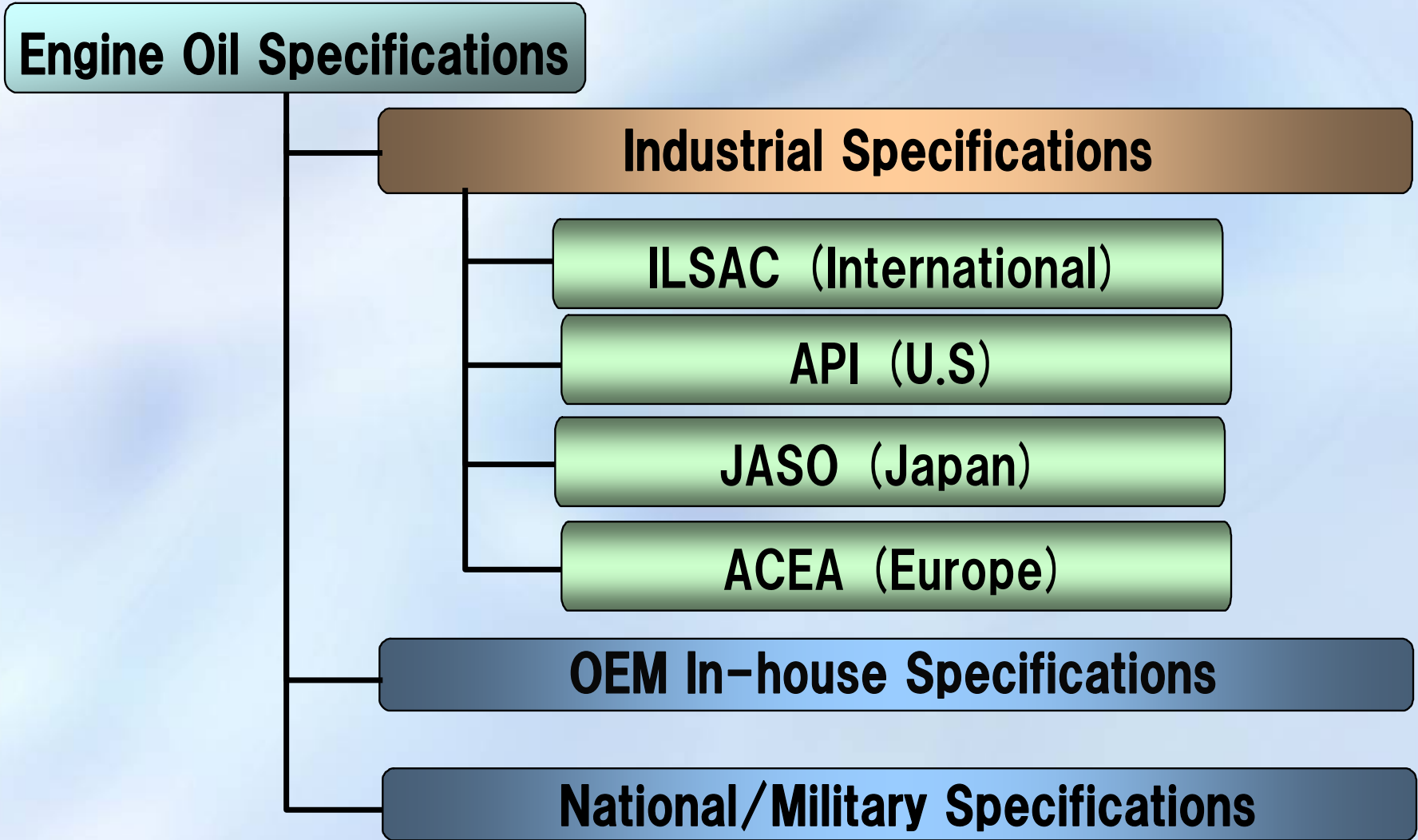
**ILSAC GF-6**

**SAE J300**

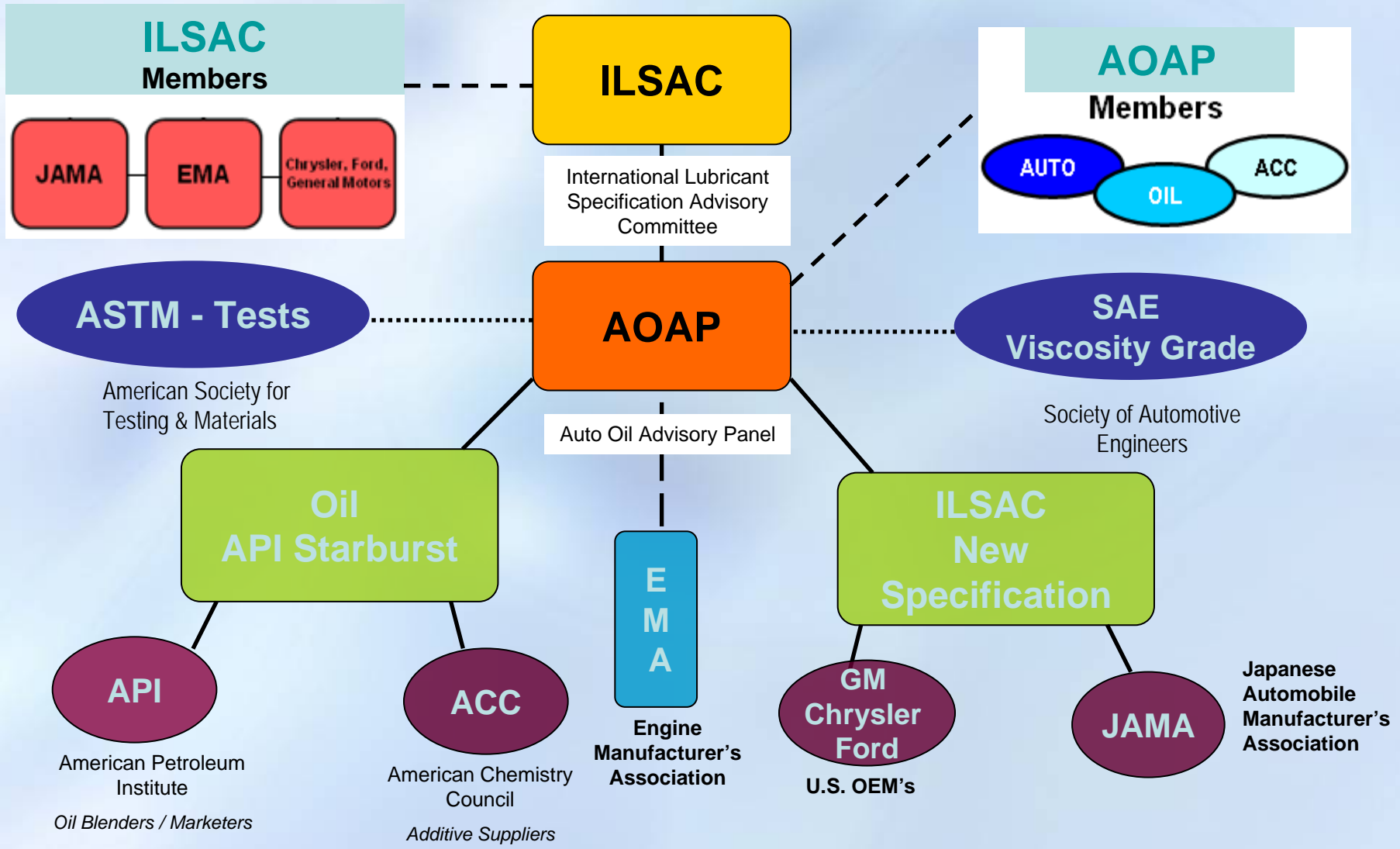
## 2. Lubricants Technology

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# Engine Oil Specifications



# ILSAC – Industry Structure



# API vs ILSAC

**API SN** with **Resource Conserving** is equivalent to **ILSAC GF-5**

## API SN

## Resource Conserving

## ILSAC GF-5



+

- Fuel Efficiency
- Emission System Protection
- Turbocharger Protection
- Ethanol-containing Fuels up to E85

=



*API Donut*

## Engine Robustness

- Detergency
- Oxidation Stability
- Wear Protection
- Rust Protection
- Corrosion Protection
- ⋮
- ⋮

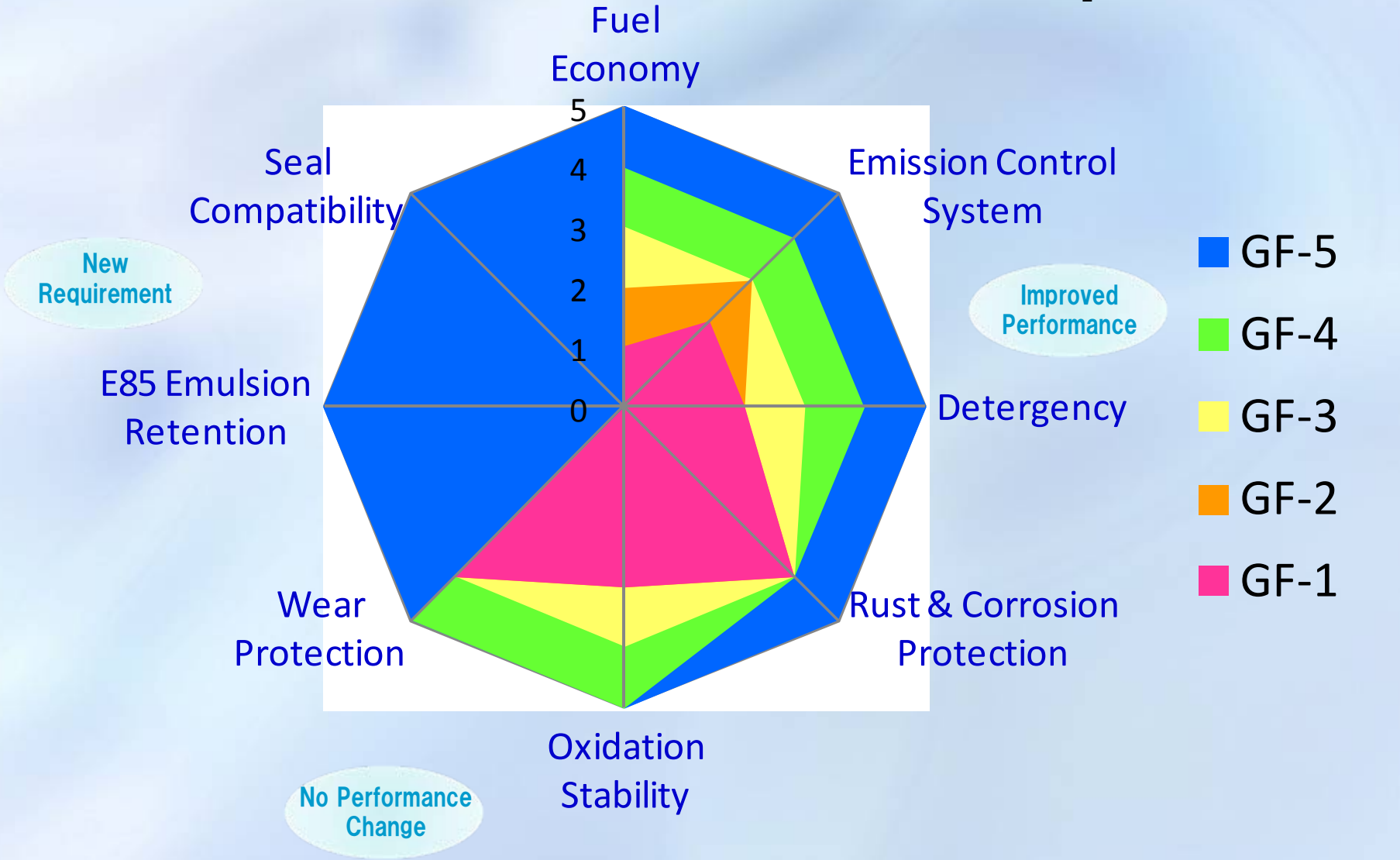


*ILSAC Starburst*

Note: All viscosity grades

Note: Viscosity grades are limited to SAE 0W, 5W, and 10W multigrade oils.

# GF-5 Performance Relative to the past GF-X



# ILSAC GF-6 Direction

- **Improved fuel economy and fuel economy retention**
  - Higher FEI in Sequence VID (or equivalent test)
  - Longer oil aging, equivalent to 8,000 to 10,000 miles
- **Improved engine oil robustness and wear protection required to protect engines in all global markets**
  - Improved IIG, IVA and VG (or equivalent tests) performance
- **Not cause low speed pre-ignition**
- **Viscosity requirements will reflect changes to SAE J300 viscosity grades**
- **Timing: First License Date January 2017**
  - Will coincide with introduction of replacement Sequence Tests presently under development



# GF-6 Engine Test Availability Issues

- Four engine tests are being replaced or updated for GF-6

<b>Test</b>	<b>Description</b>	<b>Sponsor</b>
<b>Sequence IIIH</b>	— Oxidation Stability & Piston Deposit Test	<b>GM</b> <b>Chrysler</b>
<b>Sequence IVB</b>	— Valve Train Wear Test	<b>Toyota</b>
<b>Sequence VH</b>	— Sludge & Deposit Test	<b>Ford</b>
<b>Sequence VID</b>	— Fuel Economy Test	<b>GM</b>
<b>New Test</b>	— Chain Wear Test	<b>Ford</b>
<b>New Test</b>	— Low Speed Pre-Ignition Test	<b>Ford</b>

# About Pre-Ignition

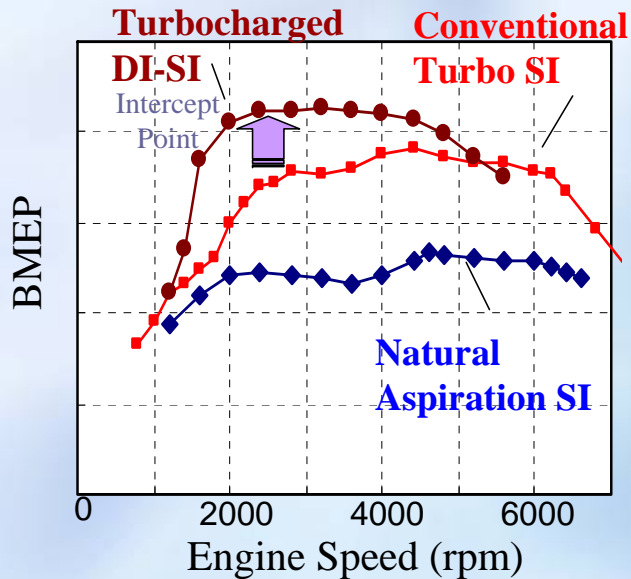


Fig.1 Turbocharged DISI Engine Torque Curve

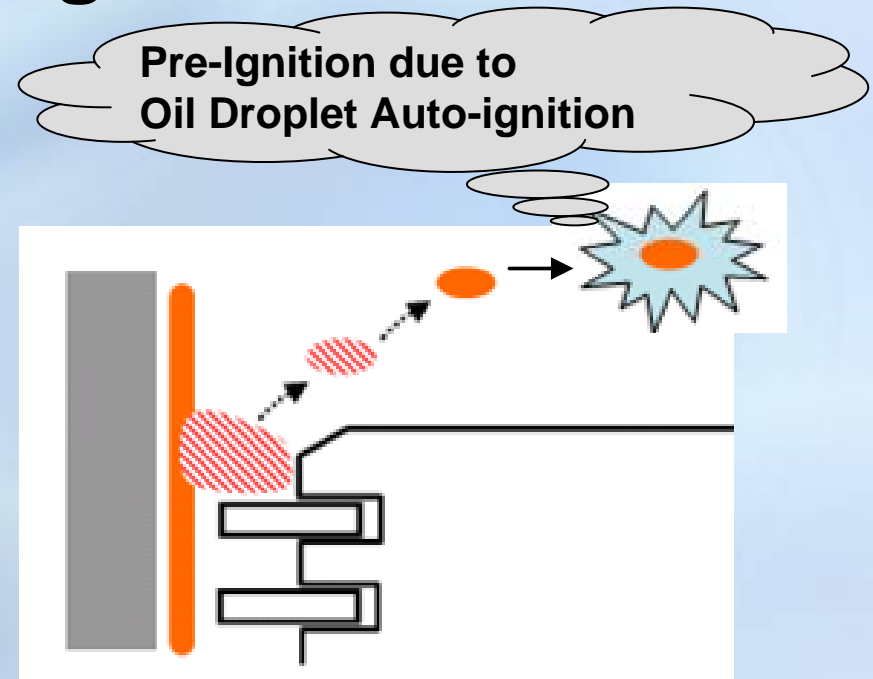


Fig.2 Possible Mechanism of LSPI

- Downsized SI engines equipped with turbocharger and direct-injection system have been increased for better fuel economy performance
- LSPI (Low-speed Pre-ignition) restricts low-speed torque improvement significantly
- LSPI is considered to begin at oil droplet auto-ignition

# Engine Oil Impact - Base Oil -

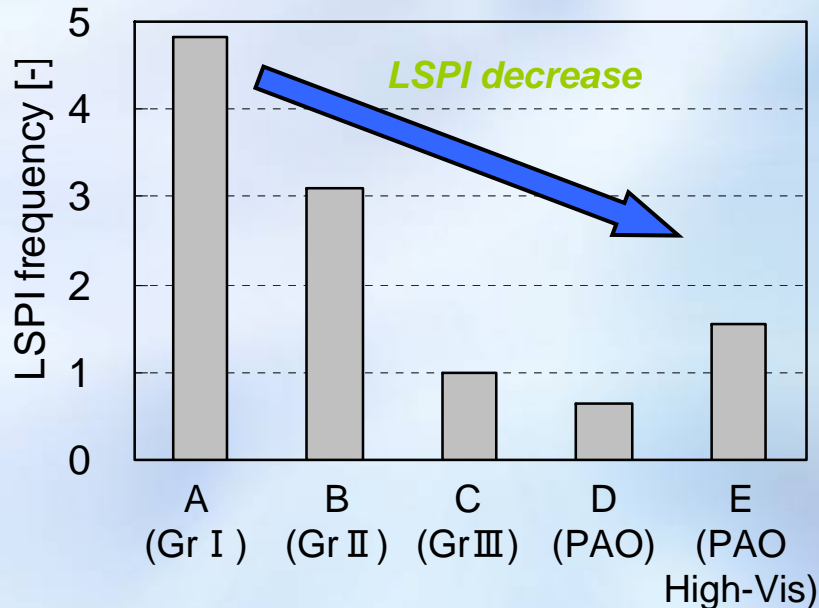


Fig.3 Base Oils Effects on LSPI

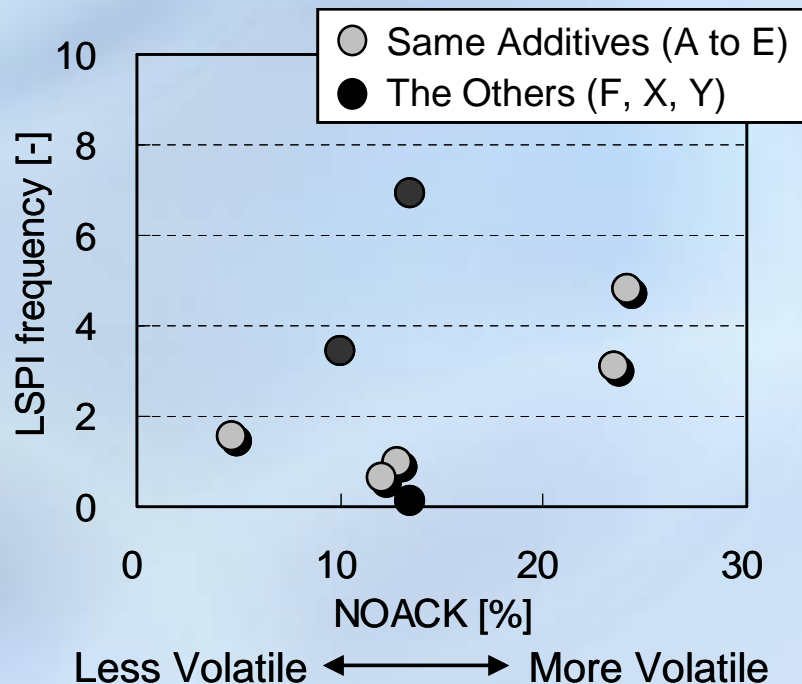


Fig.4 Volatility Effects on LSPI

- Base oil types affect significantly on LSPI frequency (Fig.3)
  - Base oil volatility is not effective property on LSPI frequency (Fig.4)
- LSPI frequency depends on base oil oxidation reactivity, not on base oil volatility

# Engine Oil Impact - Additive -

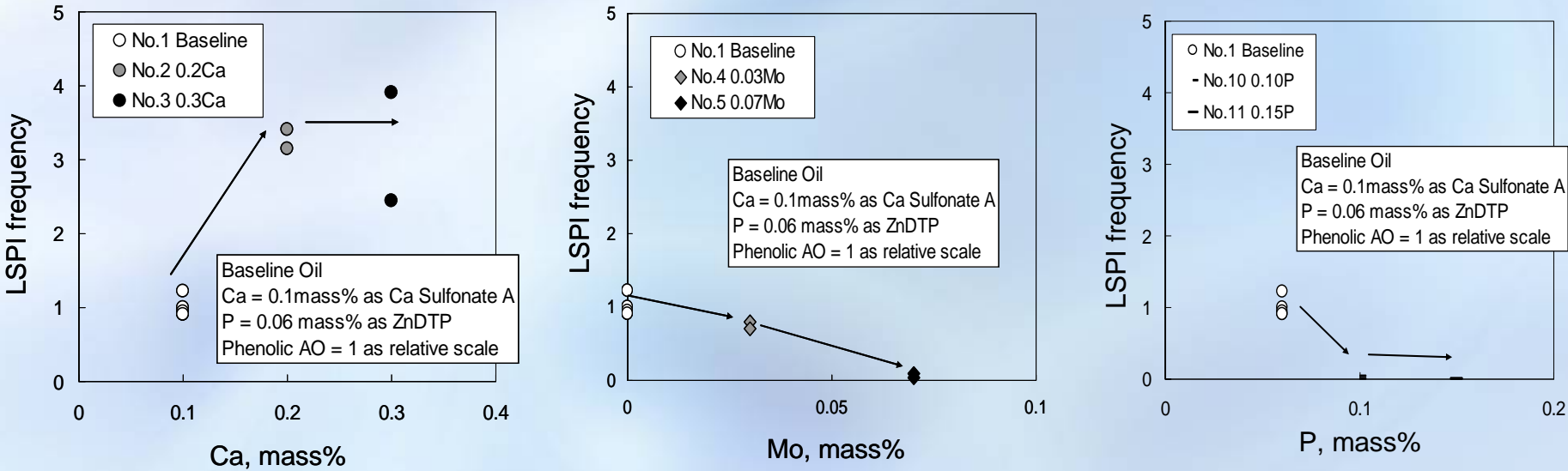


Fig.5 Additive Effects (Ca, Mo, P) on LSPI

Additives have a significant effects on LSPI frequency  
Ca-detergents promote LSPI, whereas ZnDTP and MoDTC inhibit LSPI

# New SAE J300 Low Viscosity Grade

SAE J300 Viscosity Specification was revised in April of 2013.

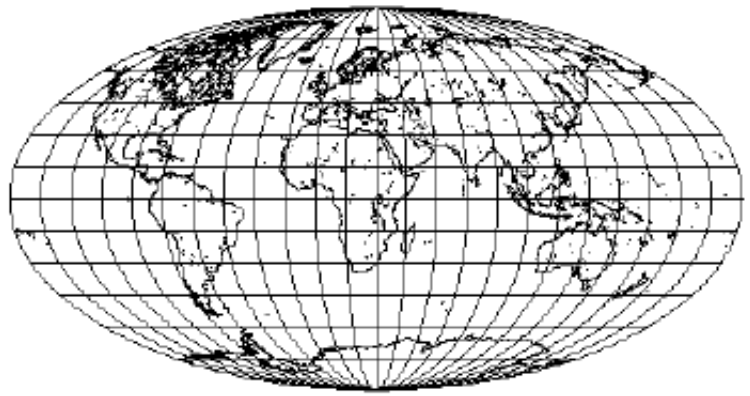
SAE 20 Grade is revised 6.9 min from 5.6min.

SAE 16 grade is added.

SAE Viscosity Grade	Low-Temperature (°C) Cranking Viscosity <sup>(3)</sup> , mPa·s Max	Low-Temperature (°C) Pumping Viscosity <sup>(4)</sup> mPa·s Max with No Yield Stress <sup>(4)</sup>	Low-Shear-Rate Kinematic Viscosity <sup>(5)</sup> (mm <sup>2</sup> /s) at 100 °C Min	Low-Shear-Rate Kinematic Viscosity <sup>(5)</sup> (mm <sup>2</sup> /s) at 100 °C Max	High-Shear-Rate Viscosity <sup>(6)</sup> (mPa·s) at 150 °C Min
0W	6200 at -35	60 000 at -40	3.8	—	—
5W	6600 at -30	60 000 at -35	3.8	—	—
10W	7000 at -25	60 000 at -30	4.1	—	—
15W	7000 at -20	60 000 at -25	5.6	—	—
20W	9500 at -15	60 000 at -20	5.6	—	—
25W	13 000 at -10	60 000 at -15	5.6	—	—
16	—	—	6.1	<8.2	2.3
20	—	—	6.9	<9.3	2.6
30	—	—	9.3	<12.5	2.9
40	—	—	12.5	<16.3	3.5 (0W-40, 5W-40, and 10W-40 grades)
40	—	—	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40 grades)
50	—	—	16.3	<21.9	3.7
60	—	—	21.9	<26.1	3.7

# ILSAC GF-6B

INTERNATIONAL LUBRICANT SPECIFICATION  
ADVISORY COMMITTEE



**ILSAC GF-6A RECOMMENDATIONS FOR  
PASSENGER CAR ENGINE OILS**

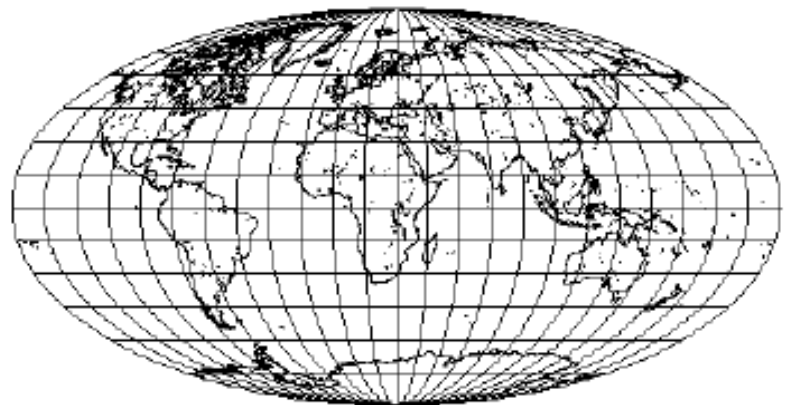
DRAFT November 6, 2012

1. FRESH OIL VISCOSITY REQUIREMENTS

1.a SAE J300

Viscosity grades shall be limited to SAE 0W-20, 5W-20, 0W-30, 5W-30 and 10W-30 multigrade oils. Oils shall meet all of the requirements of SAE J300.

INTERNATIONAL LUBRICANT SPECIFICATION  
ADVISORY COMMITTEE



**ILSAC GF-6B RECOMMENDATIONS FOR  
PASSENGER CAR ENGINE OILS**

DRAFT November 6, 2012

1. FRESH OIL VISCOSITY REQUIREMENTS

1.a SAE J300

Viscosity grades shall be limited to SAE 0W-16 and 5W-16 multigrade oils. Oils shall meet all of the requirements of SAE J300.

# ILSAC GF-6 Timeline

First license date is Jan 1<sup>st</sup>, 2017.

GF-6 "A" <i>DRAFT</i> TIMELINE	2013												2014												2015												2016												2017												2018		
<b>AOAP Committee Work</b>	[Timeline grid with blue shading]																																																														
<b>TEST DEVELOPMENTS AND MATRIX PREPARATIONS</b>	[Green shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
1) GM Oxidation Test	[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
2) Chrysler Oxidation Test	[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
3) Toyota Sequence IVB Test	[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
4) Ford Sequence VG/H MY2013 Engine Replacement	[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
5) GM Sequence VID/E MY2012 Engine Replacement	[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
6) Ford Timing Chain Wear Test	[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
7) Ford Low Speed Pre-Ignition Test	[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]												[Blue shading]		
Introduce New Calibration Oils for Carryover Tests	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		
Funding of Precision, BOI/VGRA Matrices	[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]		
Design of Precision, BOI/VGRA Matrices	[Purple shading]												[Purple shading]												[Purple shading]												[Purple shading]												[Purple shading]												[Purple shading]		
MOA Established and Signed by all Parties	[Red shading]												[Red shading]												[Red shading]												[Red shading]												[Red shading]												[Red shading]		
<i>Test In or Out?</i>	[Red shading]												[Red shading]												[Red shading]												[Red shading]												[Red shading]												[Red shading]		
RUN PRECISION, BOI/VGRA MATRICES	[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]		
ANALYZE MATRIX DATA FOR ACCEPTANCE	[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]												[Yellow shading]		
ASTM TEST ACCEPTANCE	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		
ACC REGISTRATION BEGINS	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		
TECHNOLOGY DEMONSTRATION	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		
AOAP APPROVE GF-6 SPEC	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		
API MANDATORY WAITING PERIOD	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		
API FIRST LICENSE DATE = January 1, 2017	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		
API MANDATORY USE DATE = January 1, 2018	[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]												[Green shading]		

This time period now factors in all preparation for precision matrices, including test stand installations at matrix laboratories, matrix test stand verification testing, matrix hardware procurement and drafting test procedures.

This is a non ASTM test. Procedure and test conditions are still under development. Tests are running. Precision matrix planned for Q1 2014.

Procedure and test conditions are still under development. Tests are running. Test stands needs to be installed at IAR.

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2.0L not producing sludge. Switching to MY2013 4.6L for VG/H. Timing chain wear, using 2.0L, will be a separate test. Determining if VG will carry over with MY2013 4.6L or if procedure and test condition changes are needed (i.e. VH).

Aging length and oil charge have been determined. Procedure is being drafted. Premature exhaust valve leakage and compression loss with the MY2012 engine is being investigated.

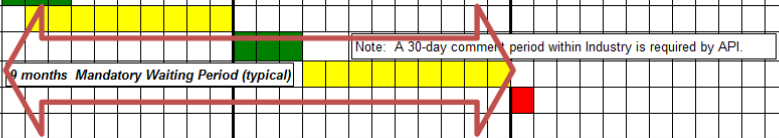
Test stand setup, procedure and test conditions are being re-developed for a timing chain wear only test. Testing is about to start.

Test stand installation and shakedown, and combustion analysis equipment installation and training have been completed at SwRI and IAR. Initial test condition development has started. Testing about to start.

Desire is to have calibration oils from "GF-6 technology" so older tests will utilize GF-6 lubricant technology. New calibration oils will be coming from the BOI/VGRA Matrix TF. Use in carryover tests will be studied by each SP. TF to be formed when tests are available.

Desire is for companies to secure this funding in their 2012/13 budgets for use in 2014 matrix. TF outcome in June was that ~50 tests are needed per test. This estimate is to be used as a placeholder for 2013 company budgets.

This includes obtaining matrix oils, blending & homogenizing by TMC. TF recommended ~50 tests needed per test at the June 2012 AOAP mtg for planning and budgetary purposes. Have plenty of base oils to choose from and working on how to select the best for this task. Mtg Sept. 18 in Richmond.



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## 1. Engine Oil Specification Trends

**ILSAC GF-6**

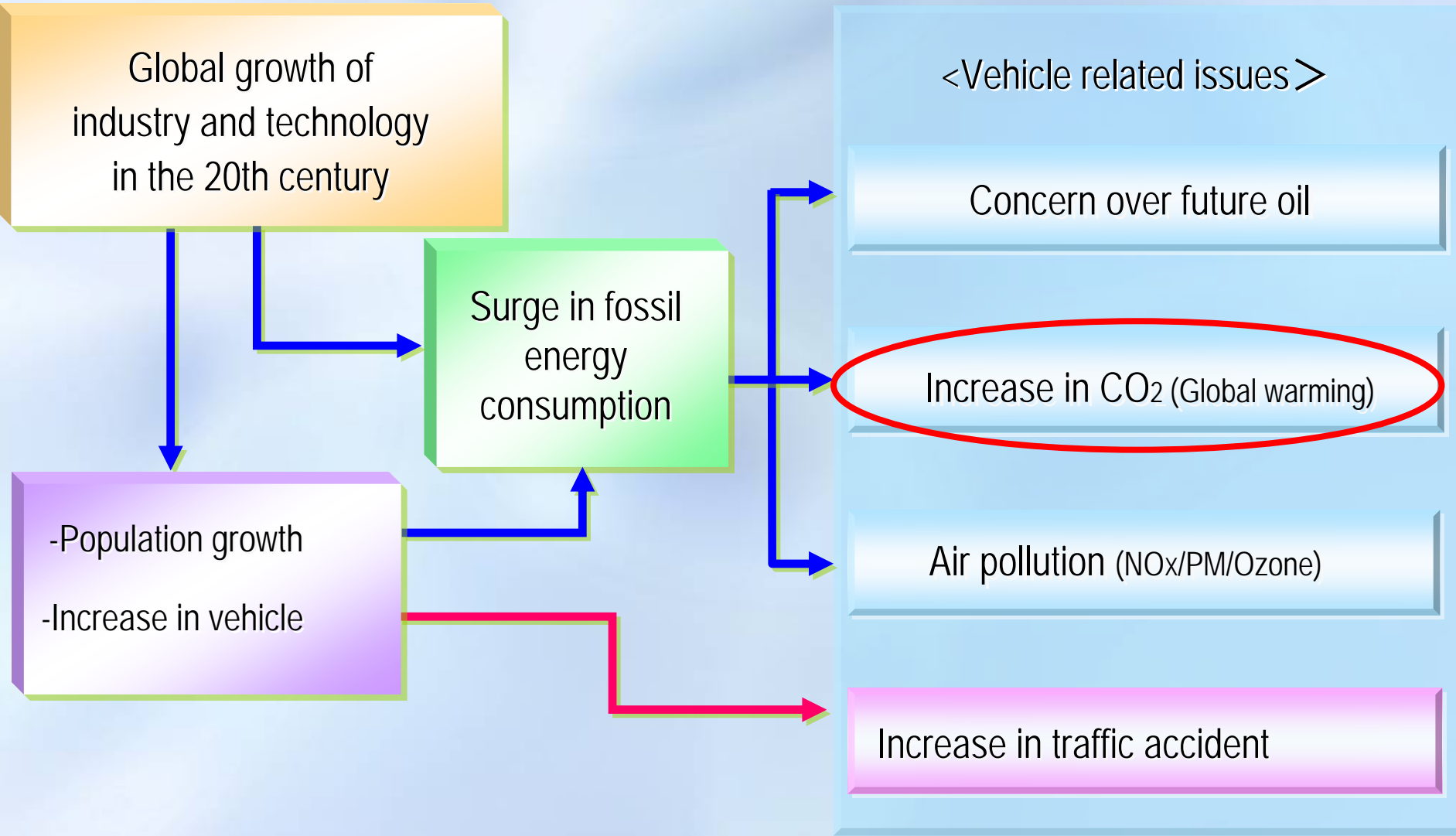
**SAE J300**

## 2. Lubricants Technology

## 3. Summary



# Issues of Vehicle



# Fuel economy Regulations in Asia

- Many countries in Asia are investigating to revise or introduce FE/CO2 standard from the viewpoint of economy, energy security and CO2 reduction

	2012	2013	2014	2015	2016	2017	2018~
Australia	Fuel Consumption Label						
				CO <sub>2</sub> emission standards (Light vehicle)			
Viet Nam							
Singapore	Mandatory Fuel Economy Labeling						
Philippines	Labeling Program (in NEECP)						
Indonesia							
Malaysia							
Thailand	Labeling Program						
Taiwan	Fuel Economy Standards for PC						
PR of China	Limit of fuel consumption, Fuel Consumption Label						
India	Fuel Consumption Label						
Korea	K-CAFE (phase-in until 2015, average fuel economy 17km/L or 140 CO <sub>2</sub> g/km)						
Japan	Top Runner Program (Target fiscal year: 2015)						
	Top Runner Program (CAFF Target fiscal year: 2020)						

# Emission Regulations in Asia (Light-duty vehicles)

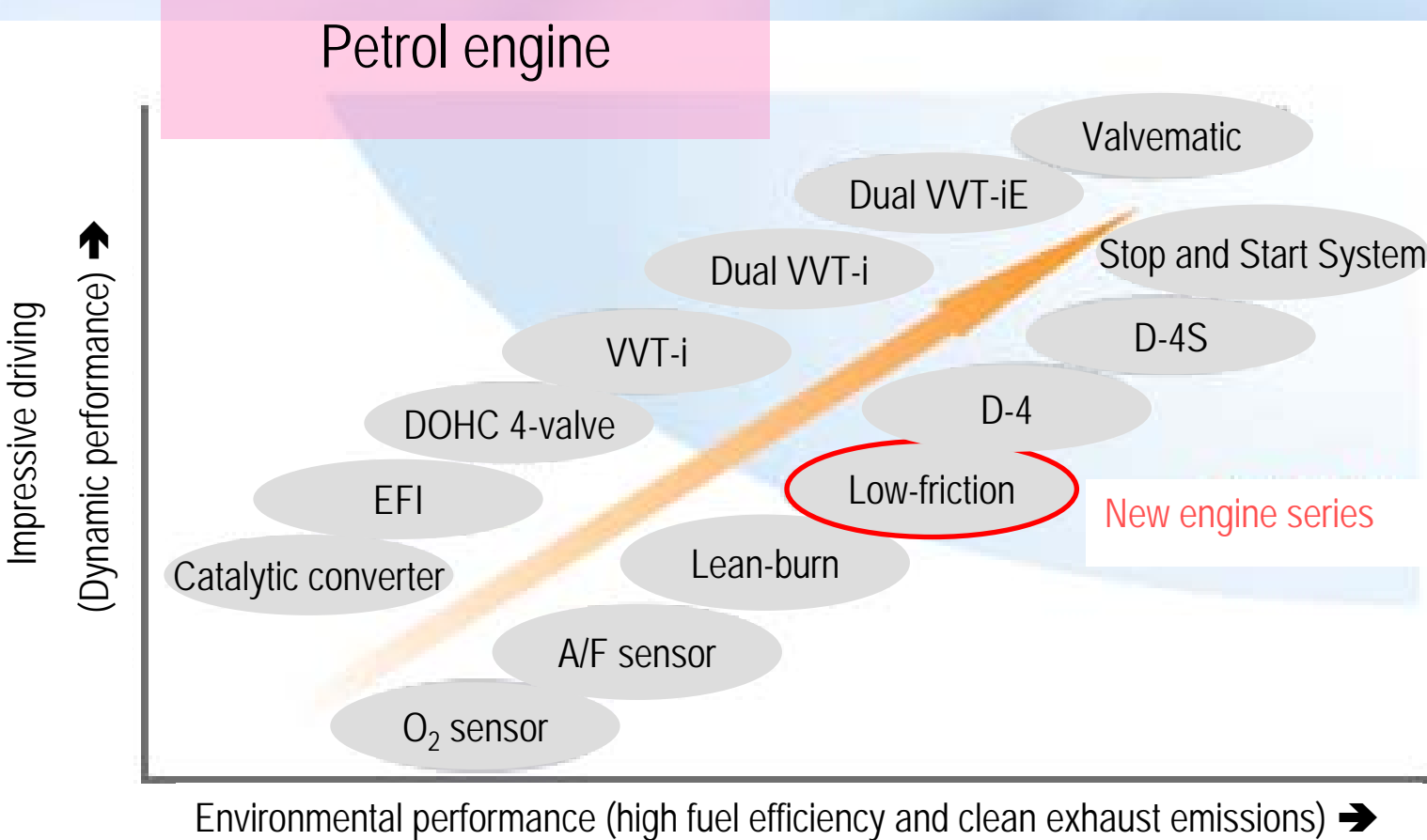
- Generally Asian countries are moving to Euro 4/5 or equivalent by 2013. However, some countries still remain on Euro 2 even after 2015.

	2012	2013	2014	2015	2016	2017	2018~
Australia	Euro 4		Euro 5			Euro 6	
Viet Nam	Euro 2					Euro 4	(Euro 5 : 2022~)
Singapore	Euro 2						
Philippines	Euro 2			Euro 4			
Indonesia	Euro 2						
Malaysia	Euro 2	Euro 4					
Thailand	Euro 4						
Taipei, China	US Tier 2 (Equivalent to Euro 4)						
PR of China	Euro 4						
Beijing	Euro 5						
India	Nationwide Bharat stage III (Euro 3)						
Delhi and 11 cities*	Bharat stage IV (Euro 4)						
Korea	LEV 2 (phase-in until 2015)						
Japan	Post new long-term						

\* Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Secunderabad, Ahmedabad, Pune, Surat, Kanpur and Agra

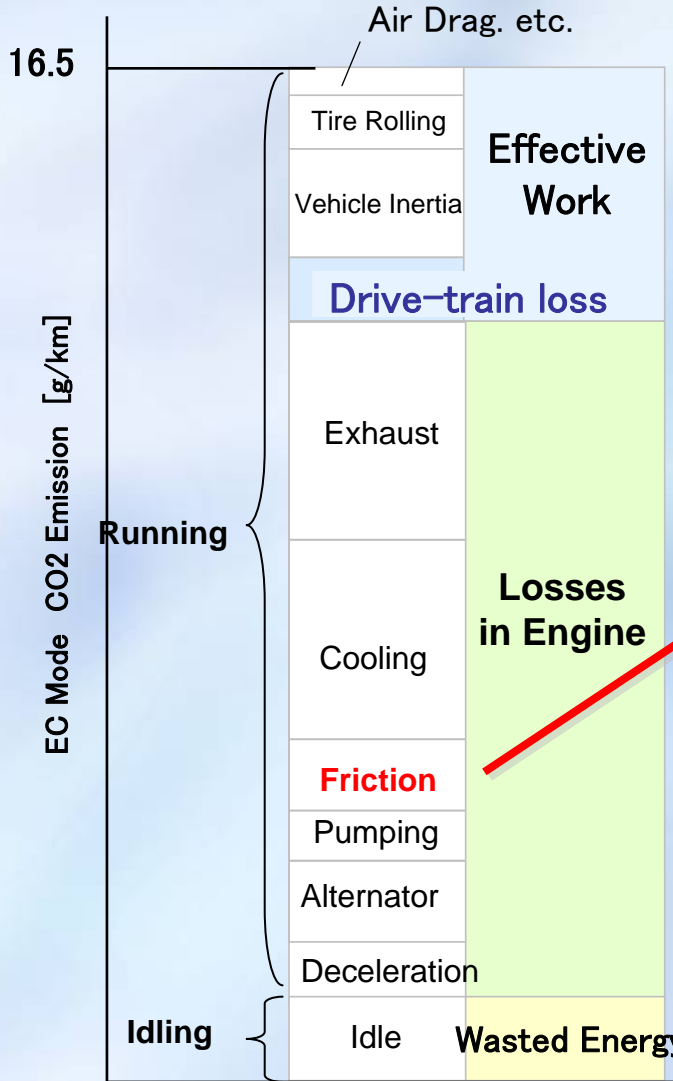
Emission Standards for New Light-Duty Vehicles (as of April 2009), Available : [http://www.cleanairnet.org/ca/asia/1412/articles-58969\\_resource\\_1.pdf](http://www.cleanairnet.org/ca/asia/1412/articles-58969_resource_1.pdf)  
 Worldwide Emission Standards Guide for 2010/2011, DELPHI, Available : <http://delphi.com/pdf/emissions/Delphi-Passenger-Car-Light-Duty-Truck-Emissions-Brochure-2010-2011.pdf>

# Power Train Trends

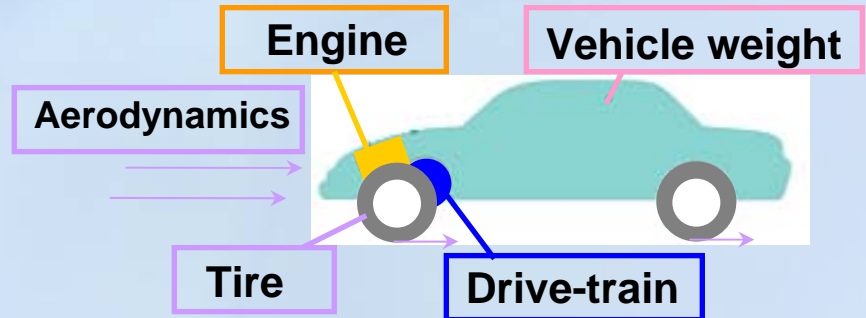
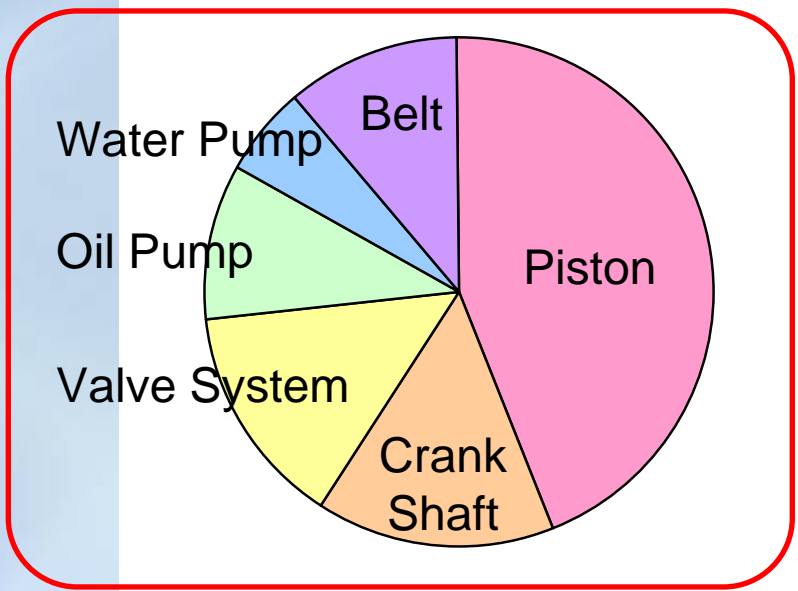


Engines and transmissions revamped through ongoing incorporation of new technologies

# Friction Loss in Power Train

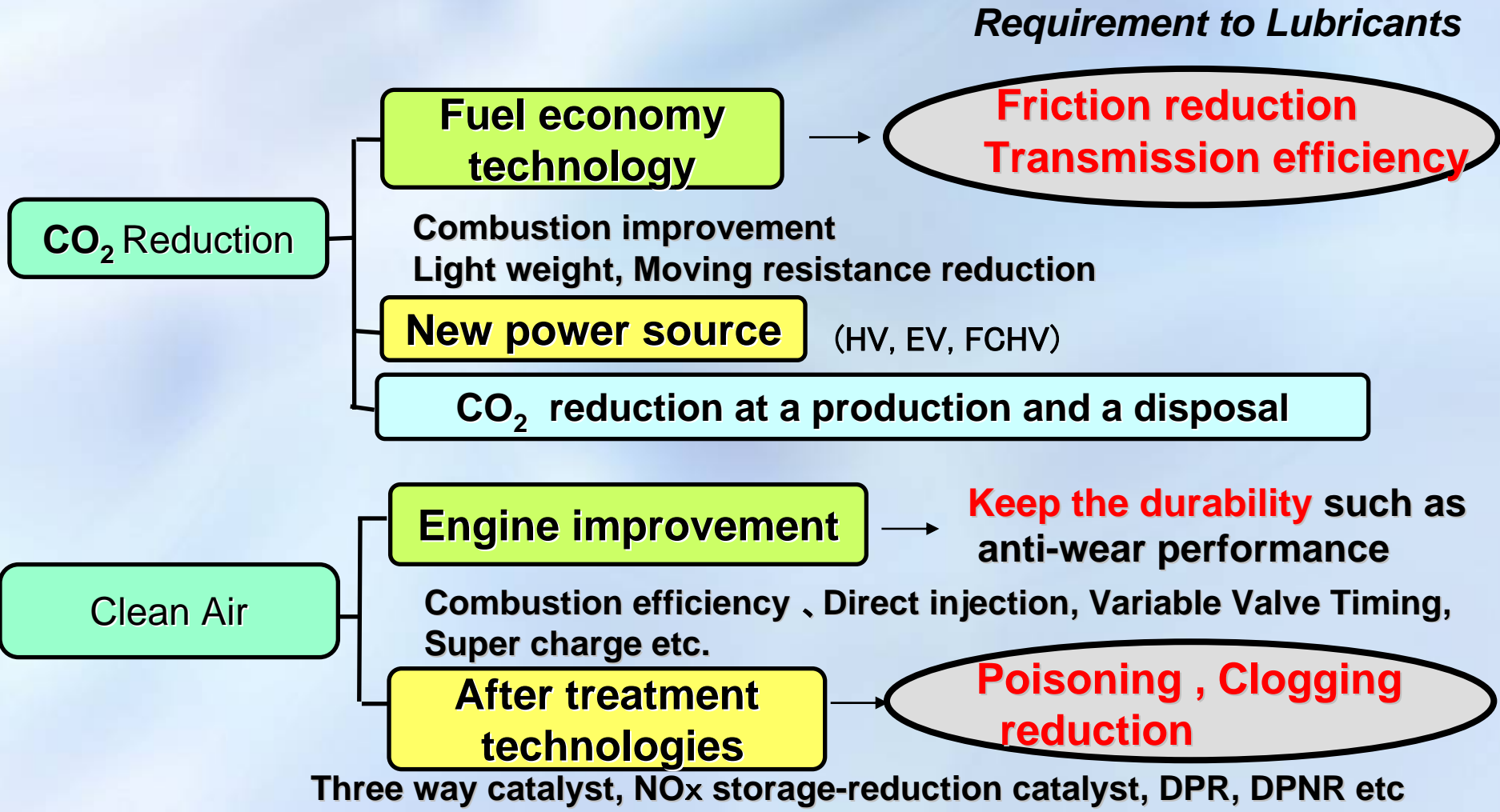


Friction Loss (7 ~ 10%)



Breakdown of Energy Consumption in Entire Vehicle (2.0L x 4AT @ EC Mode)

# Development of lubricants for the environmental protection



# Tribological Parts in Automobile

## Engine

- Piston
- Piston Ring/ Cylinder Bore
- Bearing, Seal
- Cam/Cam Follower
- Valve/Valve Guide
- Valve/Valve Sheet
- Oil

## Steering

- Joint, Gear, Bearing,
- Power Steering Pump

## Fuel Pump

- Pump Body
- Commutator,
- Bearing

## Differential

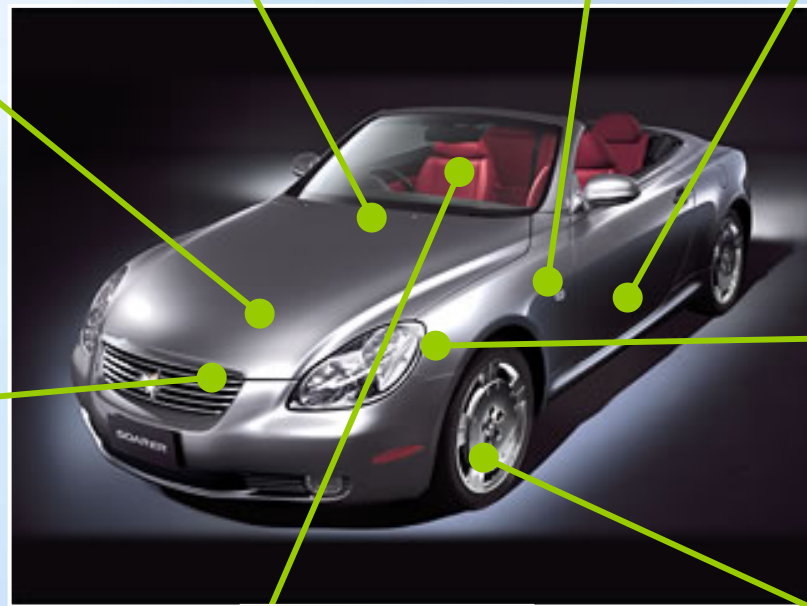
- Gear, Bearing, Oil
- LSD
- Viscous Coupling Plate

## Auxiliary

- Belt/Pulley
- Water Pump
- Alternator
- Compressor
- Electromagnetic
- Clutch
- Seal/Bearing

## Transmission

- (AT, CVT, HV)
- Wet Clutch, Gear,
- Bearing, Seal, Oil
- (CVT)
- Belt, Pulley
- (MT)
- Dry Clutch, SNR,
- Gear, Bearing, Seal, Oil

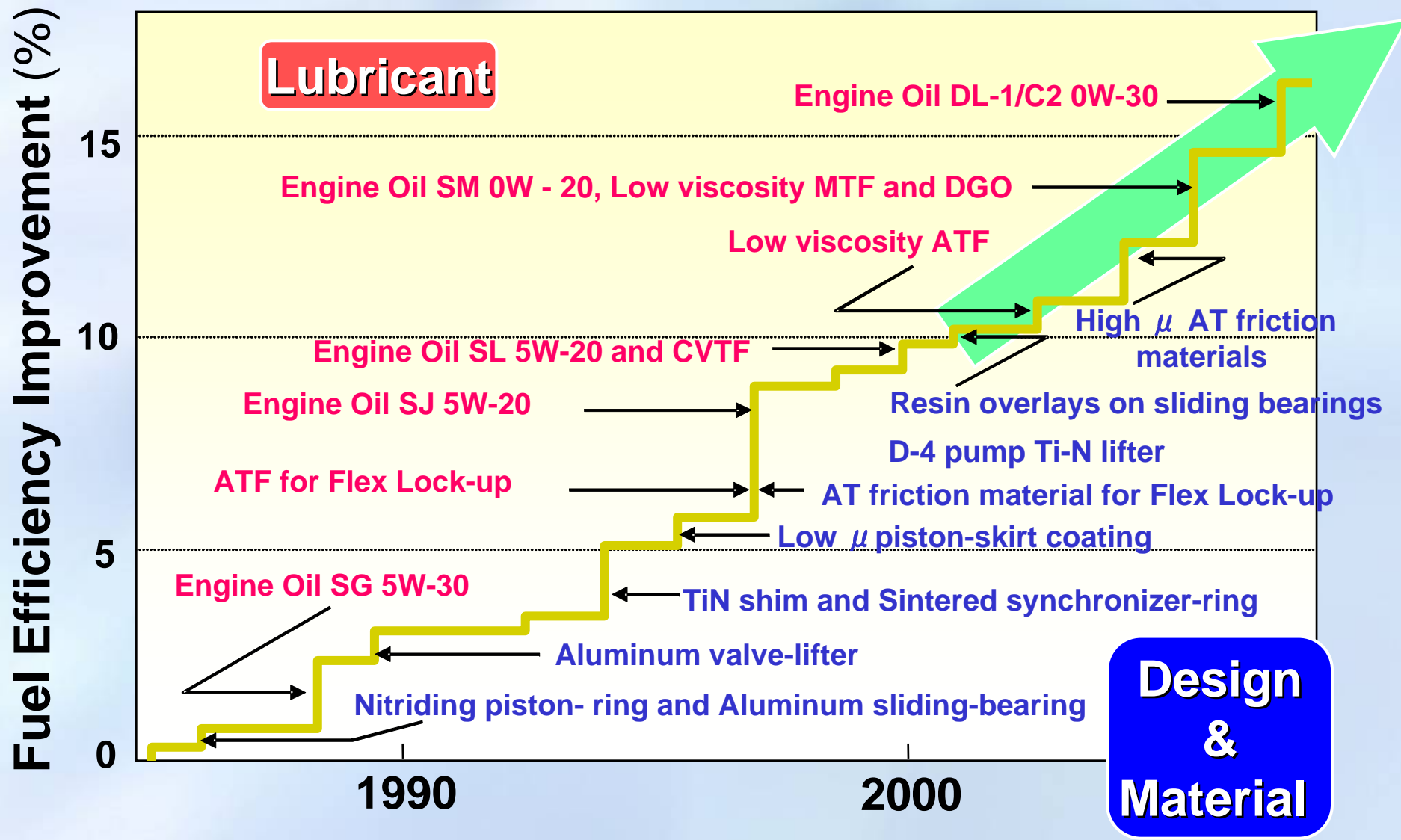


## Seat

- Fabric

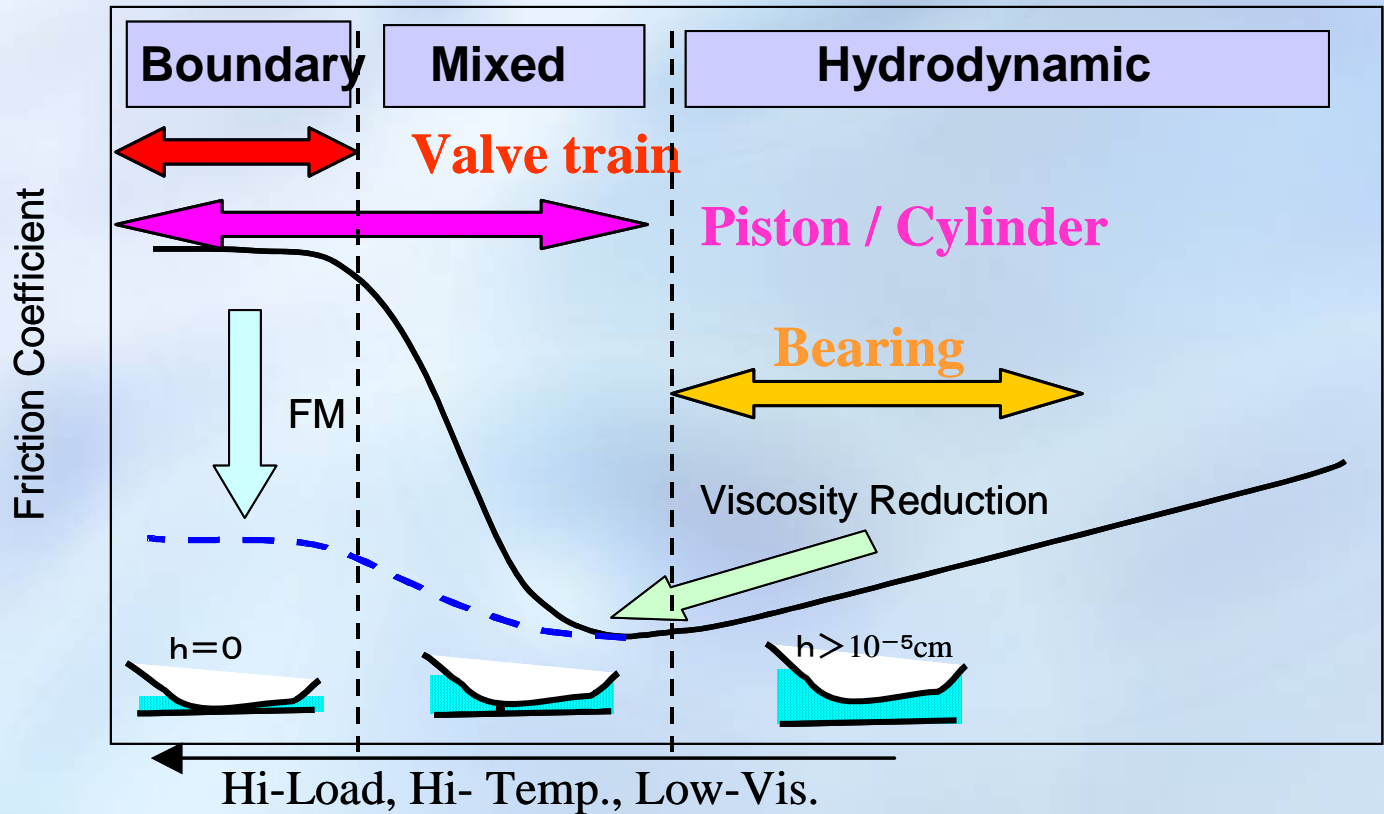
## Brake

- Pad/Disc,
- Piston/Cylinder
- Seal/Cylinder





# Concept of Friction Reduction on the Streibeck Curve



**Striveck Curve**

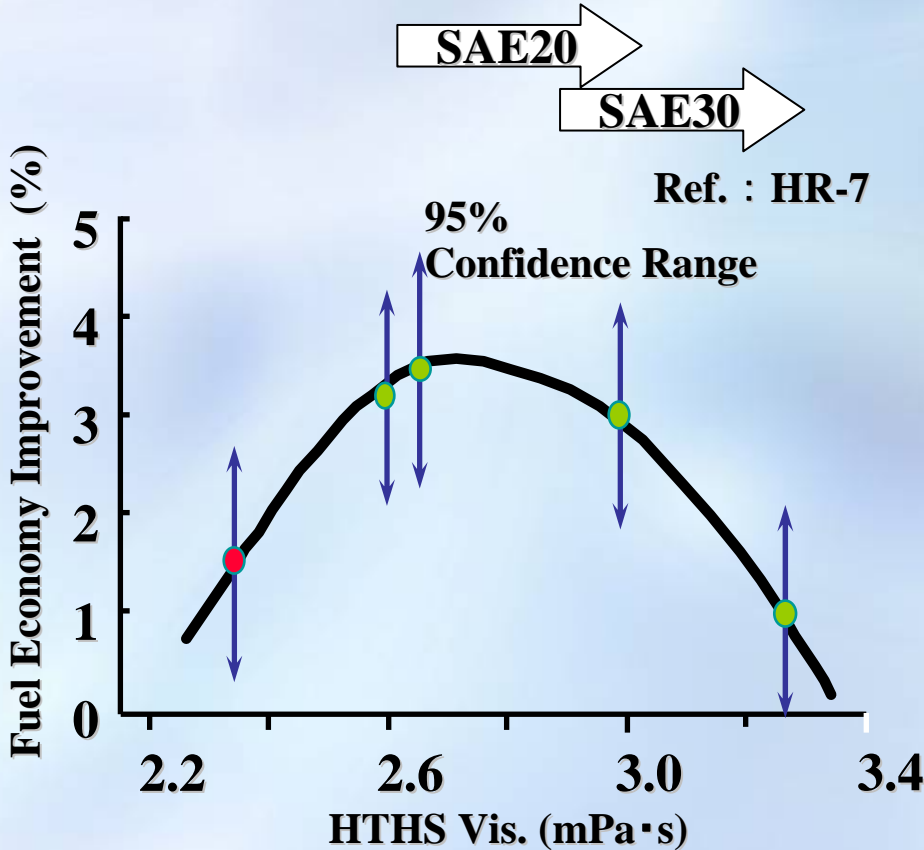
**Friction reduction technology must be applied that pertain specifically to each lubrication condition**

# Impact of the engine oil viscosity on fuel economy

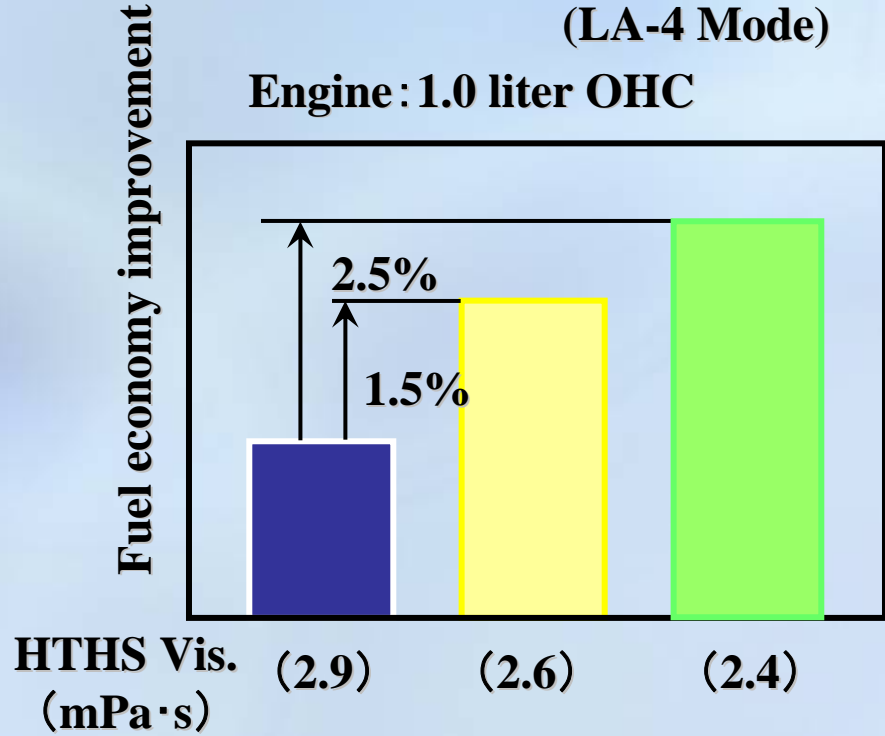
HTHS Viscosity@150C

(Valve-train;Bucket Type)

(Roller-follower Type)

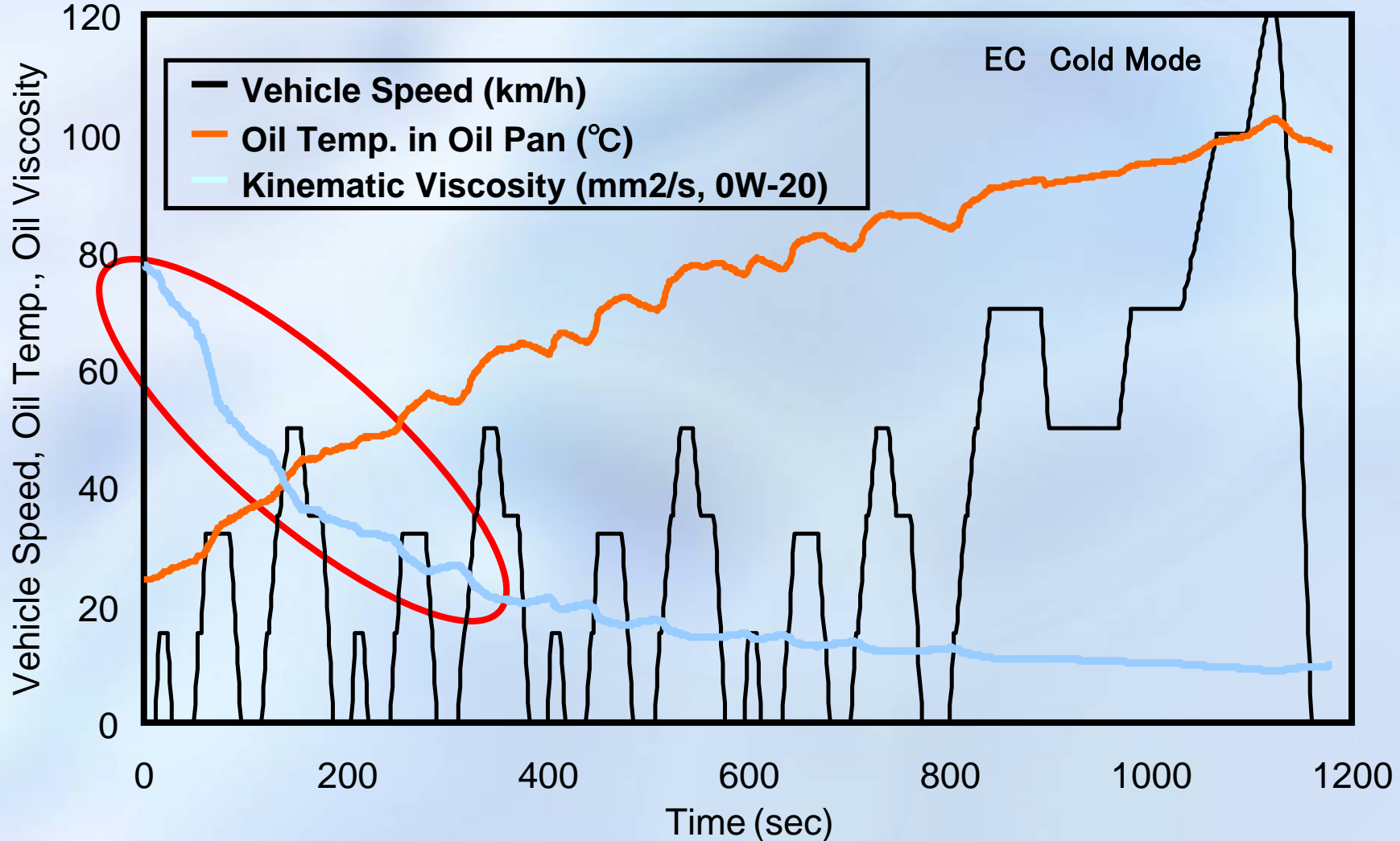


(Toyota; SAE982506)



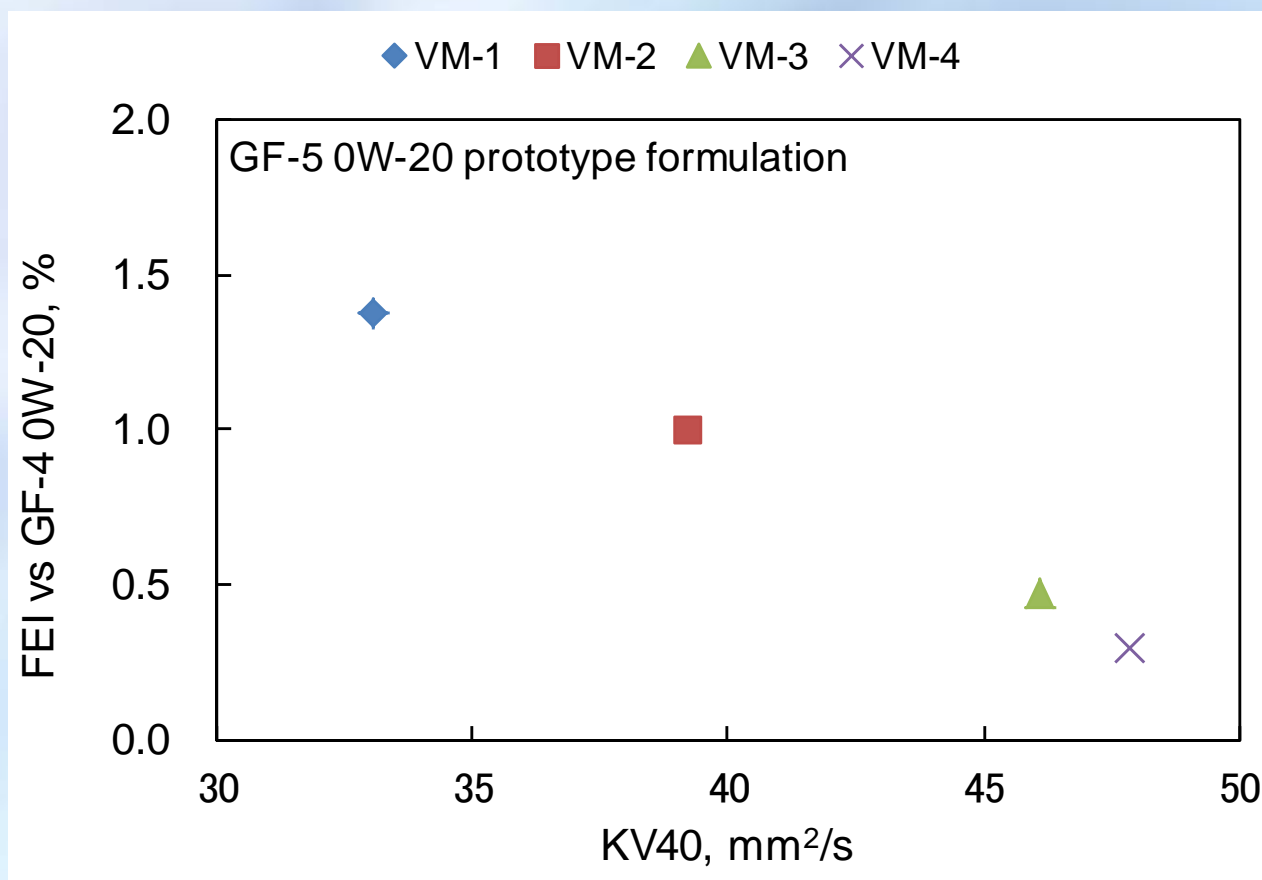
(Honda; SAE1999-01-3468)

# Fuel Economy Test Driving Cycle



**Test Mode Including Cold Start**  
⇒ High Oil Viscosity Increases Friction under Hydrodynamic Lubrication

# Lower-KV40 Effect



**Lower KV40 (Kinematic Viscosity at 40°C)**

**⇒ Significant Improvement in Fuel Economy Engine Test under Low Temperature**

# Summary

## [Specification]

ILSAC GF-6

First license date : January 1st 2017.

New engine test : LSPI, Chain wear

GF-6B : XW-16.

## [Lubricants Technology]

Lowering the viscosity at low temperature is effective in fuel economy improvement for cold start mode.

*Thank you for kindly attention*