USING ENGINE OIL TO **IMPROVE FUEL ECONOMY**

EVERYTHING YOU NEED TO KNOW ABOUT HIGH TEMPERATURE HIGH SHEAR VISCOSITY

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Encouraged by government regulations worldwide, heavy-duty engine Original Equipment Manufacturers (OEMs) are working to achieve improved fuel economy and a reduction in greenhouse gas emissions. One of the ways that this can be partially achieved is through the use of lower High Temperature High Shear (HTHS) viscosity engine oils – but what is HTHS?

This white paper looks at:

1. What is HTHS?
2. Fuel Economy vs. Engine Protection
3. The Latest Heavy-Duty Oil Categories
4. Using Viscosity Index Improvers to Regulate Oil Viscosity
5. SAE J300 Table of Viscosity Grades for Engine Oils
6. Impact of "In Use" Oil Degradation on HTHS

WHAT IS HIGH TEMPERATURE HIGH SHEAR (HTHS)?

HTHS viscosity is the way we measure the ability of fully warmed (150°C/302°F) oil to flow within the narrow confines of fast-moving engine parts.

HTHS occurs in contact areas, such as the ring/liner interface, valve-train and gear contacts. Under SAE J300 Engine Oil Viscosity Classifications, this means under conditions of high shear between 1.0-1.4 x 106 sec-1, depending on the test method used.

HTHS viscosity is measured in milliPascal second (mPa·s) or centiPoise (cP).

Lower HTHS = Better Fuel Economy

When observed under normal operating temperatures (70 to 100°C/158 to 212°F), the HTHS viscosity of engine oil is inversely proportional to fuel economy performance.

Academic research has shown that a lower HTHS potentially improves fuel economy at a rate of 0.5% to 2.0% for each 0.5 cP reduction in HTHS, depending on the engine type and operating conditions.

Too Low HTHS and Durability can be Affected

Decreased oil film thickness can lead to increased friction and wear. It can also cause:

- Permanent loss of viscosity due to the high temperature shear conditions of the Viscosity Index Improver additive
- Lower oil pressure at idle with fully warmed oil

To Summarize

Lower HTHS viscosity tends to improve fuel efficiency, which lowers greenhouse gas emissions. However, higher HTHS viscosity affords better wear protection, so a careful balance must be found when formulating engine oil.

FUEL ECONOMY VS. ENGINE PROTECTION

Finding the Right Balance

Engine oil keeps the vital internal hardware protected and helps ensure that the engine operates with maximum efficiency. The lifeblood of the engine, heavy-duty engine oil is essential to the smooth running of a fleet, but it's important to find the right balance of protection and ease of movement – the oil needs to be thick enough to maintain the separation of critical parts, but thin enough to allow for fuel-efficient powering of the engine.

Sufficient HTHS viscosity creates a protective oil film between moving parts. This is critical for preventing engine wear in the ring/liner interface area.

HTHS viscosity is measured with ASTM test method number D4683. In this method, oil is introduced between a rotor and a stator at a prescribed temperature. For heavy-duty diesel engine oils, that temperature is set at 150°C (302°F). The rotor experiences a reactive torque caused by the oil's resistance to flow (viscose friction) and this torque response level is used to quantify the HTHS viscosity.

THE LATEST HEAVY-DUTY OIL CATEGORIES

The drive to improve fuel economy among engine manufacturers has been taking place for some time and to do this, the industry has been moving towards lower viscosity solutions, demonstrated by launch of API CK-4 and FA-4 oil categories in December 2016.

- API FA-4 specifies an HTHS viscosity between 2.9 and 3.2 cP
- API CK-4 specifies an HTHS equal to or greater than 3.5 cP

API FA-4 oils with lower HTHS offer potential increased fuel efficiency, but are be restricted to newer engines designed to run on these lower HTHS viscosity oils. This does exclude some older engines found in existing fleets as the oil was not designed for the older engine hardware.

Lower viscosity API FA-4 oils minimize frictional losses between moving components of the engine and reduce pumping and rotational losses, resulting in less viscous drag and improved fuel economy. This enables engines to run more efficiently and use less fuel, while still offering improved levels of wear protection by delivering oil more efficiently to moving parts within the engine.

Adopting Low HTHS Viscosity Oils

Engine manufacturers may have begun to adapt their engine design to FA-4 requirements and enable end users to achieve the greater fuel economy provided by low HTHS viscosity oils.

API CK-4 oils with a HTHS viscosity equal to or greater than 3.5 would cover the heritage fleet, plus any new engines requiring higher HTHS viscosity for wear protection (typically off-highway usage).

Between April 2013 and January 2015, the SAE incorporated three new viscosity grades to their J300 viscosity grade and classification standard for motor oils (see SAE J300 Table of Viscosity Grades for Engine Oils).

In pursuit of the higher fuel economy, they offer:

- SAE 16 – 2.3 mPa·s (min)
- SAE 12 – 2.0 mPa·s (min)
- SAE 8 – 1.7 mPa·s (min)

These viscosity grades with significantly lower HTHS are only applicable to passenger car hardware at present.

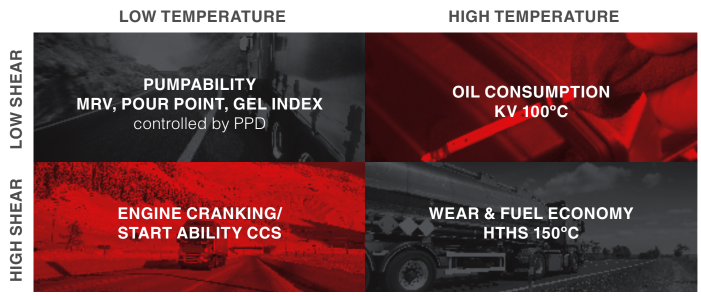
The demand of higher fuel economy is only going to continue and as such, lubricant manufacturers are continually striving for lower HTHS viscosity oils. At Petro-Canada Lubricants, we're asking 'how low can we go?' and testing oils at an HTHS viscosity below 2.9 cP. It's still important to consider the balance between protection and ease and movement, but if we can demonstrate that a 0W-20 oil can protect as well as a 10W-30 or a 15W-40 and still provide the fuel economy benefits, it could be a real step forward in the future of engine oils.

USING VISCOSITY INDEX IMPROVERS TO REGULATE OIL VISCOSITY

All oils must enable engines to perform through a wide range of temperatures while minimizing wear. To achieve this, engine oil formulators rely on Viscosity Index Improvers (VII) to lessen temperature effects on viscosity and deliver the required performance in both low shear and high shear operating conditions. VIIs help regulate viscosity characteristics to ensure an appropriate balance between oil flow and oil film thickness.

VIIs are compositionally polymeric and can be sheared under stress via mechanical forces. This shearing is the main source of viscosity loss in an engine oil.

The automotive industry has adopted several tests to quantify engine oil's performance over a broad range of temperature and shear conditions.



Low Temperatures

At low temperatures, VIIs work to resist the thickening of an oil, ensuring appropriate flow to and through an engine as designed. VIIs must be able to both improve cold flow characteristics as well as resist breakdown due to shearing. Low shear is encountered with oil flow in the lines and in the sump. When high shear is encountered, for example in the engine bearings, VIIs must deliver the much needed viscosity control to ensure adequate oil flow and protection to vital engine componentry.

High Temperatures

At elevated temperatures, VIIs work to resist the thinning of an oil, ensuring appropriate film thickness and boundary lubrication throughout an engine. VIIs must be able to both improve high temperature viscometrics as well as resist breakdown due to shearing. At high temperatures, low shear conditions are seen in leak paths (oil seals, behind piston rings) and having too low a viscosity can affect oil consumption.

The HTHS Viscosity Test

This test measures viscosity and indicates how thick the oil film is likely to be during severe high-speed operations in critical componentry. Oil that is too thin under these conditions may not provide the needed lubricant protection, which could result in significant wear to critical engine parts.

SAE J300 TABLE OF VISCOSITY GRADES FOR ENGINE OILS

Caution: kinematic viscosity ranges for SAE 8 to SAE 20 viscosity grades partially overlap. How to assign a single viscosity grade to an engine oil satisfying the kinematic viscosity specifications of more than one grade is covered in Section 6 of the SAE J300 Engine Oil Viscosity Classification Standard.

SAE Viscosity Grade	Low-Temperature (°C) Cranking Viscosity[3], mPa-s, Max	Low-Temperature (°C) Pumping Viscosity[4], mPa-s Max with No Yield Stress[4]	Low-Shear-Rate Kinematic Viscosity[5] (mm^2/s) at 100 °C, Min	Low-Shear-Rate Kinematic Viscosity[5] (mm^2/s) at 100 °C, Max	High-Shear-Rate Viscosity[6], (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	9.3		
8			4.0	<6.1	1.7
12			5.0	<7.1	2.0
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

1. Notes-1 mPa·s = 1 cP; 1 mm2/s = 1 cSt.
2. All values, with the exception of the low-temperature cranking viscosity, are critical specifications as defined by ASTM D3244.
3. ASTM D5293: Cranking viscosity - The non-critical specification protocol in ASTM D3244 shall be applied with a P value of 0.95.
4. ASTM D4684: Note that the presence of any yield stress detectable by this method constitutes a failure regardless of viscosity.
5. ASTM D445.
6. ASTM D4683, ASTM D4741, ASTM D5481, or CEC L-36-90.

IMPACT OF "IN USE" OIL DEGRADATION ON HTHS

During normal operating cycles, oil viscosity is impacted by a number of physical and chemical processes, which in turn impact the HTHS value over time:

- Reduction in apparent viscosity due to mechanical shear down of the VII polymer
- Contamination by incomplete combustion – soot can agglomerate into larger particles and increase apparent viscosity if not properly dispersed
- Thermal oxidation can increase the oils apparent viscosity
- Fuel dilution can reduce viscosity

Well-formulated engine oils will minimize the change in viscosity and maintain a more stable HTHS viscosity value over the full drain interval.

AUTHOR AND SOURCES

About the Author

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Sources

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