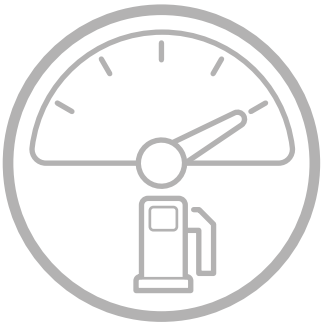
USING ENGINE OIL TO **IMPROVE FUEL ECONOMY**

Everything you need to know about **HTHS viscosity**



Brian Humphrey, OEM Technical Liaison - HD Driveline, Petro-Canada Lubricants

PETRO-CANADA™
LUBRICANTS
Beyond today's standards.™

CONTENT OUTLINE

WHAT IS HTHS?

New global government vehicle regulations demand better 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 HTHS viscosity engine oils – but what is HTHS?

High Temperature High Shear (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 10^6 sec^{-1}, depending on the test method used.

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. According to many published papers, 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 boundary lubrication 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 GHG emissions. However, higher HTHS viscosity affords better wear protection, so a careful balance must be found when formulating engine oil.

USEFUL INFORMATION

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

FUEL ECONOMY VS. ENGINE PROTECTION

FINDING THE RIGHT BALANCE

Imagine trying to swim through molasses, you'd use up a lot of energy and not get very far. Equally, swimming through a liquid that was too thin would affect your buoyancy. What is needed is the right balance of support and ease of movement. It's the same in an engine – the oil needs to be thick enough to maintain the separation of critical parts, but thin enough to power the engine in a fuel-efficient manner.

Sufficient HTHS viscosity creates a protective oil film between moving parts. This is critical for preventing engine wear in the ring/liner interface area. One method used to measure HTHS viscosity is with the ASTM test method number D4683. In this method, oil is introduced between a rotor and a stator at the test temperature of 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.

HTHS viscosity by ASTM D4683 has been found to relate to viscosity, providing hydrodynamic lubrication in light duty and heavy duty engines.

NEW HEAVY DUTY OIL CATEGORIES

The new heavy duty diesel engine oil categories have come into effect in North America in December 2016. PC-11 is divided into 2 categories based on HTHS values of the engine oil:

- An HTHS viscosity between 2.9 and 3.2 cP (API FA-4)
- An HTHS equal to or greater than 3.5 cP (API CK-4)

API FA-4 oils with lower HTHS will offer potential increased fuel efficiency, but would be restricted to newer engines designed to run on these lower HTHS viscosity oils. This may exclude many older engines found in existing fleets. Engine manufacturers are evaluating their hardware to see if engine durability, especially for ring and liner scuffing, is an issue with low HTHS viscosity oils.

Taking advantage of these new oils would enable companies to meet new US Environmental Protection Agency and National Highway Traffic Safety Administration requirements.

ADOPTING LOW HTHS VISCOSITY OILS

Engine manufacturers may have to redesign their engines to enable end users to take advantage of the potential fuel savings 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
- SAE 12 – 2.0 mPa·s
- SAE 8 – 1.7 mPa·s

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

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 deliver the required viscosity performance in both low shear and high shear operating conditions, while being exposed to a wide range of lubricant temperatures – very cold to very hot.

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

LOW TEMPERATURES

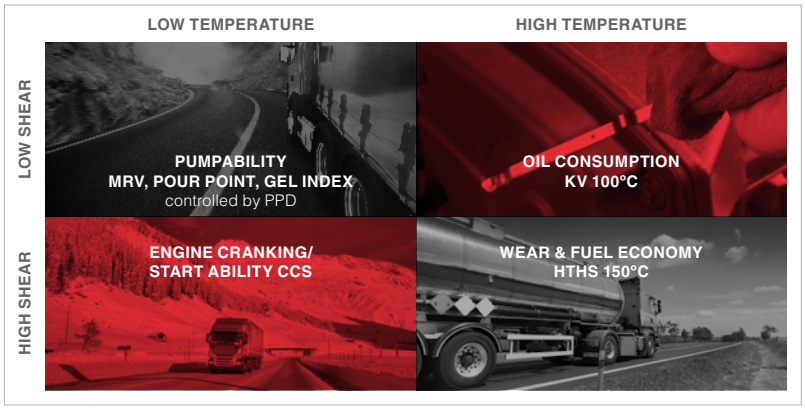
When low shear is encountered, such as in the oil lines and the sump, oil that is too thick can cause oil starvation. When high shear is encountered, for example in the engine bearings, oil that is too viscous can cause too much resistance to the engine cranking, resulting in a failure to start. VIIs must deliver the much needed viscosity control.

HIGH TEMPERATURES

Measured in terms of kinematic viscosity at 100°C (KV 100°C). This defines the oil's SAE high temperature grade (example, the "30" in 10W-30). 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

It measures viscosity and indicates how thick the oil film is likely to be during severe high-speed operations in the bearings and cams etc. 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.



PETRO-CANADA™
LUBRICANTS
Beyond today's standards.™

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 mm^2/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.

PETRO-CANADA™
LUBRICANTS
Beyond today's standards.™

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.

WHAT DO HEAVY DUTY MANUFACTURERS SAY?

All Original Equipment Manufacturer (OEM) positions and official recommendations on using API FA-4 oils with lower HTHS viscosity are still being evaluated at this time - they will be shared as they become known.

Cummins and Detroit Diesel are likely to introduce 2 new specifications, one aligned with API CK-4 and one aligned with API FA-4. Although Cummins has announced that it has certified its 2017 engines without requiring API FA-4 low HTHS viscosity oils.

Sources-

1. Lubrizol HDEO article - High Temperature High Shear Viscosity of Engine Oils http://pceo.com/ViscosityModifierPart3.htm
2. Oronite website - https://www.oronite.com/paratone/viscositybasics.aspx
3. SAE International - SAE J300 - Engine Oil Viscosity Classification

PETRO-CANADA™
LUBRICANTS
Beyond today's standards.™

LUB3431E (2016.12)