Running through the Cold

By Steve Haffner

Southwest Research Institute uses a cold box to test for low-temperature engine oil performance. (Photo: Southwest Research Institute)

North America is still months away from winter, but lubricants being manufactured now will find their way into severe, cold weather applications. End users may take for granted the low-temperature engine protection that these products deliver, which is vital to the successful operation of all engines and equipment requiring lubricants operated in the cold.

"The lubricant industry has done a great job ensuring modern engine oils perform so consumers do not have to be concerned that the lubricant will do its job and properly flow, even at the coldest temperatures appropriate for the application," said Erika Vela, Infineum's global product manager for viscosity modifiers and pour point depressants.

Indeed, it's been a long time since vehicle engines cranked slowly on a cold day before turning over. It is well known to automakers and oil formulators that, once an engine starts to run, it is absolutely critical that the lubricant starts to pump and flow to protect the engine. Significant wear can occur at start-up before the lubricant warms sufficiently and flows freely, so the sooner that happens the greater the engine protection delivered.

Few may remember when some of Quaker State's engine oils had to be recalled in the early 1980s due to incidents of complete and sudden engine failure. These oils had passed the key mini-rotary viscometer low-temperature pumpability test that was run at that time for 16 hours (ASTM D3829), but it was later determined this test did not adequately simulate what happens to an oil that has been standing in the engine for a period of time. The current MRV test, ASTM D4684 "Standard Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature," takes about 48 hours to run.

An additional fresh oil test called the Scanning Brookfield Gelation Index was introduced for the ILSAC GF-2 passenger car motor oil specification, looking for gelation of the oil below 0 degrees Celsius. In its GF-4 specification, the International Lubricant Standardization and Advisory Committee introduced the Sequence IIIGA engine test for used oil pumpability to ensure that lubricants can protect engines for the full oil drain interval.

"Low-temperature performance and protection of lubricants has not lost any importance and remains crucial to assure the long life of an engine," said Boris Eisenberg, global product manager, engine oils with Evonik. With just one in-service incident, insufficient pumpability can lead to total loss of the engine due to starvation of lubricant.

"One of the most important functions of any lubricant is to flow at the lowest operating temperatures and ensure fast lubrication to the engine, especially given electronic ignitions on today's engines," stated Vela.

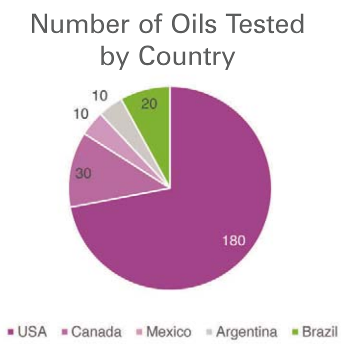
Barnaby Ngai, category manager with Petro-Canada Lubricants, noted, "For our customers globally, low-temperature performance of lubricants is very important. It is especially crucial for those customers working outside, as winter and plunging temperatures can pose real operational challenges. In the on- and off-road sectors specifically, low temperatures can wreak havoc on the health of heavy-duty vehicles, straining the engine's lubricant and its hardware."

"Lubricants have limits that dictate the acceptable temperature range in which they can perform optimally," he continued. "If the temperature falls into the 'critical' zone, lubricants can start to stiffen or become overly viscous, depending on their chemical composition. As a result, machinery can be improperly lubricated. This poses a significant risk to the equipment, which can lose stability and experience reduced performance, component wear and, in some cases, engine seizures or failure."

Wax molecules in the base stock can form gel-like particles at cold temperatures. The oil is then unable to flow to the oil pump's inlet tube as quickly as it is drawn up the tube, explained D.L. Alexander and S.W. Rein in SAE Paper 770632. This allows air to enter the pumping system and causes a partial loss of suction, a phenomenon known as air-binding. A different problem that can crop up at cold temperatures is flow-limited failure, which occurs when the oil is too viscous to be pumped into the engine quickly enough to maintain

Low Temperature Performance of North and South American Engine Oils

Oils are 2014 samples from the Institute of Materials database. TP-1 is an MRV test technique.



Country	TP-1 Viscosity	TP-1 Yield Stress	Gelation Index	Failing TP-1 and /or GI[2] (%)
Argentina	0	0	0	0 (0 %)
Brazil	2	3	2	4 (20%)
Canada	0[1]	1	0	1 (3%)
Mexico	0[1]	1	1	2 (20%)
United States	2[1]	2	9	9 (5%)
Total				16 (6.4%)

1 One additional sample was a borderline pass.
2 Samples often fail more than one test, so the number of fails may not be the total of the preceding columns.

Source: Evonik

necessary pressure.

"Field failures over the years related to high viscosity (flow-limited) or gelation (air-binding) of an oil continue to highlight the importance of low-temperature pumpability of a lubricant and its ability to flow at low temperatures, especially as oil drain intervals have increased and operating conditions have become more severe," observed Justin Mills, global product manager, pour point depressants at Evonik.

Can It Stand the Cold?

A lubricant's pour point is the temperature at which it can no longer flow. Pour point depressants modify the waxy structures in a base stock to maintain flow properties at lower temperatures.

PPDs interact differently with various base stocks, as well as detergent inhibitor and viscosity modifier additives. Vela pointed out that lubricant formulation is a balance. "Not all viscosity modifiers and pour point depressants perform the same way, and the right choice is critical to ensure compatibility with the base stock selected."

She continued, "This performance must also be maintained as the lubricant ages, and we have found that amorphous polymers tend to perform best over the life of the lubricant and with a higher safety factor than some non-amorphous polymers."

To ensure that oils are formulated properly, additive companies and marketers develop products using a variety of tools to ensure the right mix of additives and base stocks.

Mills explained that the mini-rotary viscometer and Scanning Brookfield Technique each employs a different, but slow, cooling rate to mimic conditions observed in the field. Both cooling rate and shear rate have a profound impact on the way waxes crystallize and are preserved for measurement. "The MRV and SBT methods are considered critical to ensure adequate low-temperature protection, and as a consequence are required for engine oils as specified in SAE J300 and ILSAC GF-5," he said.

"Evonik developed the ROBO [Romaszewski Oil Bench Oxidation] test and introduced it to the industry in 2009 as a cost-effective alternative to the Sequence IIIGA engine test for evaluating the low-temperature performance of an aged oil," Mills noted. The test was incorporated into ILSAC GF-5 in 2010. "With the obsolescence of the Sequence IIIGA, we expect the ROBO to be a critical test in ILSAC GF-6, as well as the newly introduced API SN Plus category."

During product development, some formulators conduct testing that goes beyond industry standards. Infineum has simulated cold start-up conditions in cold boxes large enough to fit a Class 8 semi-trailer truck. Properly formulated oils in this test will see the lubricant flowing almost immediately,

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An MRV test is run at Evonik's lab in Darmstadt, Germany. (Photo: Evonik)

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while others can take well over 5 minutes to become warm enough to start lubricating the engine and prevent wear from occurring.

Field testing and other bench tests, including European Automobile Manufacturers' Association (ACEA) tests such as the CEC L-105 used oil aging test as well as some proprietary component tests, are used in addition to standard SAE J300 requirements.

Will Low-vis Oils Chill PPDs?

Some industry players speculate that with SAE 0W-XX viscosity grades gaining market share, the importance of pour point depressants is being reduced along with pumpability issues. This may be true to a degree, but Vela noted that "both viscosity modifiers and PPDs remain critical, if not more critical, as industry moves towards lower viscosity grades for improved low-temperature protection and to provide maximum fuel efficiency at all temperatures."

"This is especially true in SAE 0W-30 viscosity grades that may be seen in heavy-duty formulations in the near future," she continued. "In light-duty applications, the impact on low-temperature [performance] is reduced as viscosity targets are lowered, which reduces the amount of viscosity modifier needed."

"PPDs will remain a vital component in SAE 0W-XX oils," stated Evonik's Eisenberg. "Most of these oils are formulated with high-quality API Group III base stocks. While these oils can show pretty good low-temperature performance, they still require a PPD as an enabler, as typically base stocks can still contain too much wax to perform adequately on their own. This is especially true when combined with certain viscosity index improver or detergent inhibitor package chemistries."

Mills noted, "The low-temperature requirements of an SAE 0W-XX engine oil are more demanding than an SAE 5W-XX. SAE J300 requires a lubricant to have a maximum pumping viscosity of less than 60,000 millipascal-seconds at -35 degrees Celsius for SAE 5W-XX and -40 C for SAE 0W-XX. While 5 degrees may seem like a minor difference in temperature, it often has a large, negative impact on the viscosity of a fluid due to natural viscosity increase and wax crystallization."

Looking further into the future, new products such as SAE 0W-16 or even SAE 0W-8 oils will require lower amounts of viscosity modifiers or possibly none at all. There is a common misconception that Group III base oils do not require PPD, Mills said. However, MRV, SBT and pour point test results still benefit from the use of PPD.

He continued, "As the level of viscosity index improvers declines in SAE 0W-16 and

SAE 0W-8 formulations, friction modifiers will play a larger role. PPDs are often necessary to disrupt the association of these components at low temperatures."

Industrial Applications

Cold temperature protection is crucial in engine oils, but there are many industrial lubricants for which it is also important.

Low-temperature viscosity issues manifest themselves in different ways depending on the application. "As an example," said Mills, "hydraulic fluids will exhibit lower efficiency, sluggish performance, rough movement or cavitation in extreme cases. Transmission fluids could have rough shifting, poor lubrication and lower fuel economy—and, like in engines, inadequate lubrication can lead to premature failure." One common theme to all applications is that if left untreated, high viscosities caused by low temperatures will lead to equipment damage or failure.

Ngai explained that Petro-Canada's grease products "are used for 24/7 mining and on-road applications that experience extremely low temperatures in Canada, the northern United States and globally, so low-temperature performance of the lubricant is critical. These operations rely on lubricants and greases to handle heavy loads under even the coldest temperatures, where downtime is not only costly but also can present safety concerns. In the construction and mining sectors, cold weather can also reduce productivity and threaten equipment life if the proper hydraulic fluid isn't used. All-season capability provides increased equipment precision and responsiveness."

Don Smolenski of Strategic Management of Oil LLC and former General Motors engineer summed things up: "Low-temperature engine protection will always be a concern and a key design consideration. A marginal wear oil may not exhibit a problem for many thousands of miles, but a pumpability failure will be immediate. Low-viscosity oils such as SAE 0W-20 have reduced the concern, but not all cars are there yet."

"All lubricants need to be formulated properly to ensure low-temperature operability over the life of the oil and in any equipment requiring smooth operation in low-temperature climates," he emphasized. ∎

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