Afton CHEMICAL
Passion for Solutions®

Delivering More with Every Drop: A New Era for Heavy-Duty Engine Oils

The heavy-duty engine oil (HDEO) industry is on the brink of a transformative shift with the development of the new API Proposed Category 12 (PC-12), targeting first licensing by January 1, 2027. This upcoming category introduces advanced chemistries and next-generation formulations designed to meet evolving performance and regulatory demands.

Afton Chemical is leading the charge with HiTEC® 12330 and HiTEC® 12380 series of HDEO additives. These formulations are engineered to meet updated sulfated ash, phosphorus, and sulfur (SAPS) requirements while delivering enhanced performance in four key areas:

- Increased oxidation stability
- Lower high-temperature high-shear (HTHS) viscosity
- Wear protection
- Improved aftertreatment system (ATS) compatibility

PC-12: A Performance Leap Forward

PC-12 builds on the foundation of current categories—API CK-4 and API FA-4—and introduces two subcategories:

- PC-12A: Successor to API CK-4, maintaining traditional viscosity limits and backward compatibility.
- PC-12B: Evolves from API FA-4, retaining 2.9–3.2 HTHS for xW-30 grades and introducing 2.6 HTHS for xW-20 grades, pushing boundaries in fuel economy and emissions.

Formulating for the Future

Afton's R&D formulation team has been carefully selecting components and chemistries to optimize PC-12 performance without compromise. One key change driven by PC-12 sulfated ash, phosphorus, and sulfur (SAPs box) requirements is a reduction in phosphorus content—approximately 35%, as shown in Table 1. Traditionally, phosphorus in heavy-duty engine oils includes ZDDP, a common antiwear and antioxidant chemistry. Due to SAPs box limitations, the formulation team has strategically balanced antiwear and oxidation performance by leveraging synergistic chemistries to meet and exceed PC-12 standards.

Table 1: Proposed SAPS limit changes compared to API CK-4 (PC-11)

Parameter	API CK-4 PC-11	API "Cx-#" PC-12
Sulfated Ash	**1 wt.% max**	**0.9 wt.% max**
Phosphorus	**0.12 wt% max**	**0.08 wt.% max**
Sulfur	**0.4 wt.% max**	**0.3 wt.% max**

While the phosphorus limit is a change, it is not a challenge that cannot be addressed through a careful balance of chemistry. Part of the R&D work behind these low-phosphorus chemistries includes testing the limits up to 12% lower phosphorus content versus the minimum phosphorus level in PC-12. Current Afton PC-12 chemistries have been tested, Figure 1, to showcase performance in Cummins ISM and ISB wear tests and how oxidation performance, Figure 2, remains uncompromised.

Figure 1. Wear performance for HiTEC® 12330 and HiTEC® 12380 series at 0.07 wt.% phosphorus, showcasing greater than 20% performance reserve, significantly exceeding PC-12 wear limits.

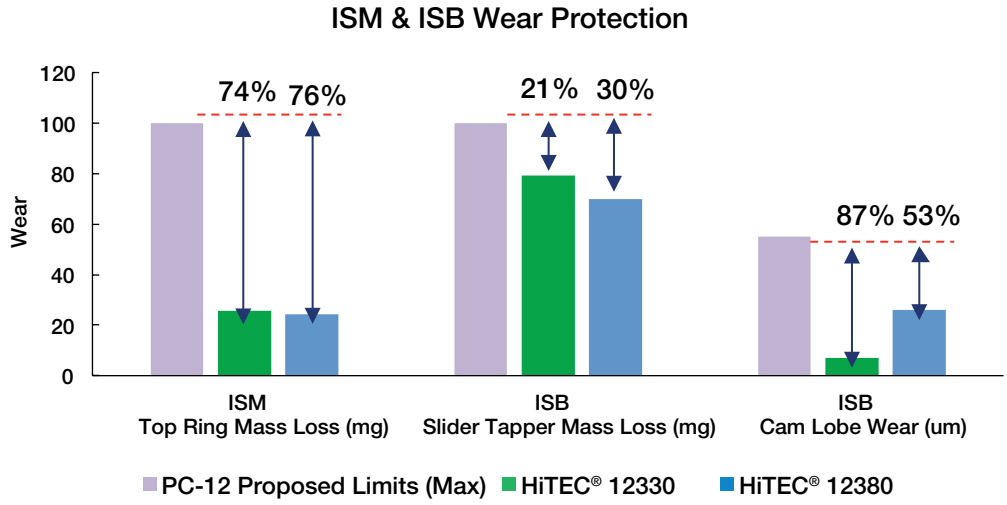
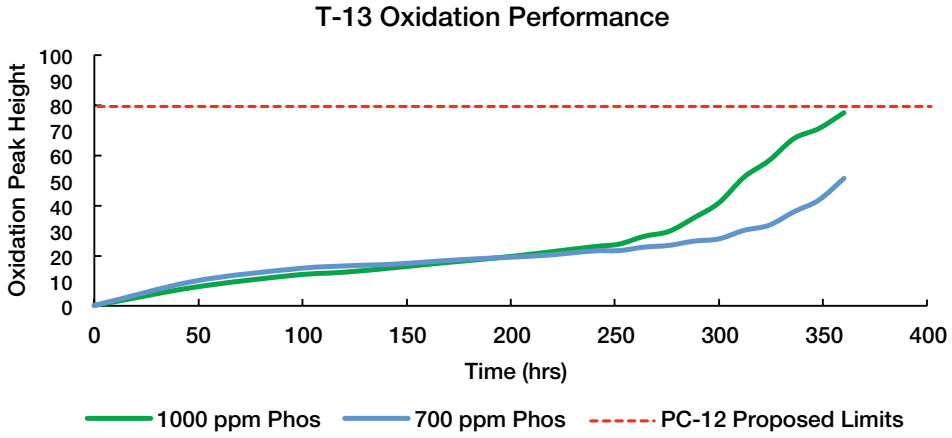


Figure 2. Afton 0.07 wt.% PC-12 chemistry T-13 oxidation performance versus API CK-4 at 0.10 wt.% phosphorus.



Exploring Low HTHS Viscosity Grades

Moving to lower HTHS, it becomes imperative to address parts protection. The new PC-12B category is introducing low HTHS SAE XW-20 viscosity grade. While this viscosity grade is not meant to replace the most common viscosity grade today, SAE 15W-40s, Afton R&D is ensuring there is a fundamental and real-world understanding of how low HTHS can impact parts protection and ways to address potential performance challenges. Afton developed an experimental SAE 5W-16, 2.4 HTHS, 0.06 wt.% phosphorus prototype (25% below the minimum PC-12 phosphorus limit) as a potential worst-case scenario and tested for wear performance on ISM Wear (Figure 3). The results allowed the formulation team to gain an in-depth understanding of wear mechanisms and ways to address this potential challenge in the future.

Subsequently, an SAE 5W-20 2.6 HTHS prototype was developed and field tested (Figure 4), with no field or performance issues over the duration of the field trial—550,000 miles.

Figure 3. SAE 5W-16 2.4 HTHS, 0.06 wt.% PC-12 prototype exceeds PC-12 proposed limits for Cummins ISM Wear.

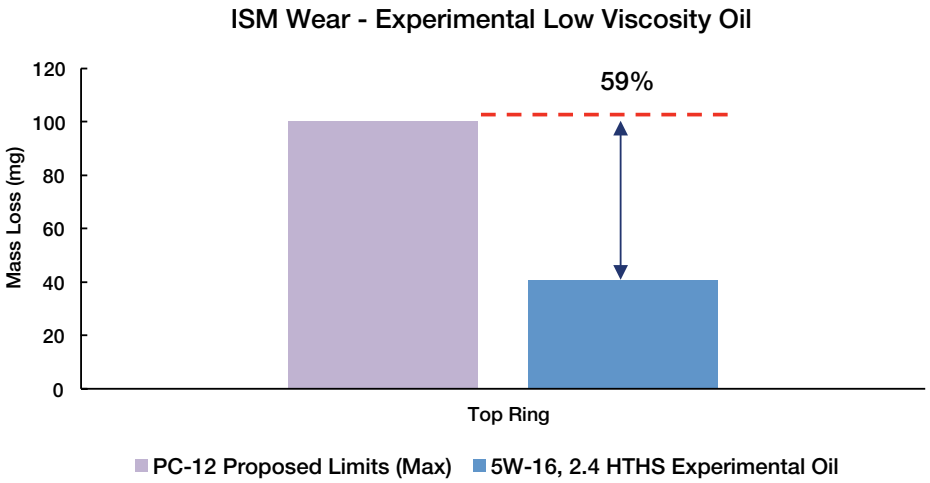


Figure 4. SAE 5W-20 2.6 HTHS parts protection proof of performance field testing. Over 550,000 miles accumulated on Freightliner DD15 with no issues, clean pistons (rear of engine piston #6) with minimal wear on rod bearings.

Enhancing Aftertreatment System Compatibility

While previous category upgrades have also focused on oxidation and wear protection, a key differentiator for PC-12 is the emphasis on aftertreatment system (ATS) compatibility—particularly for on-highway class 8 vehicles. PC-12 addresses aftertreatment system chemical compatibility via the SAPS box (Table 1). However, under the EPA's 2027 NOx regulations, emission warranty (EW) and emissions useful life (EUL) requirements for ATS are anticipated to increase significantly versus current requirements (see Table 2).

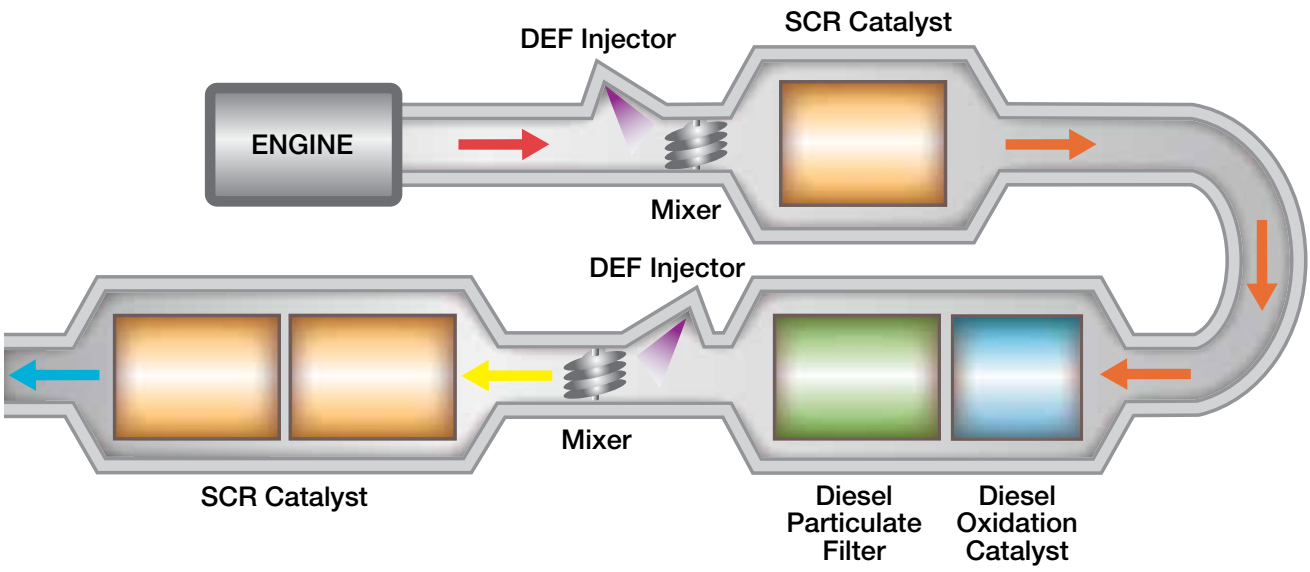
Table 2. ATS durability (mileage) requirements for these devices increase by over 50%.

	Current EPA Emission Requirements	EPA 2027 Emission Requirements
NOx	0.2	0.035
ATS EUL	435,000 miles	650,000 miles
ATS EW	100,000 miles	450,000 miles

A potential solution to meet the new NOx emissions and ATS requirements is to position the SCR (Selective Catalytic Reduction) closer to the engine to utilize the engine's heat to increase the NOx conversion process (see figure 5). However, this would expose the SCR to the engine-out emissions first, where increased levels of SAPS are expected.

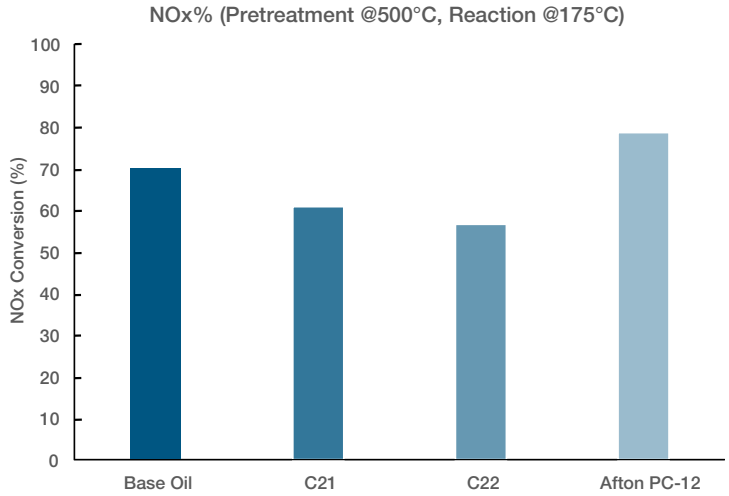
While SAPS is a critical parameter to consider when discussing ATS compatibility, it's important to note that it's not just the level of SAPS, but rather the nature of SAPS. Published industry papers, including Zhu et al., have studied the effects of alkaline components and found that sodium (Na) and potassium (K) coming from the detergents used to formulate a heavy-duty engine oil can have an adverse effect on the SCR, affecting NOx conversion.

Figure 5. Placement of SCR closer to the engine helps with NOx conversion efficiency; however, it may increase the risk of catalyst poisoning by increased exposure to less optimally formulated oils.



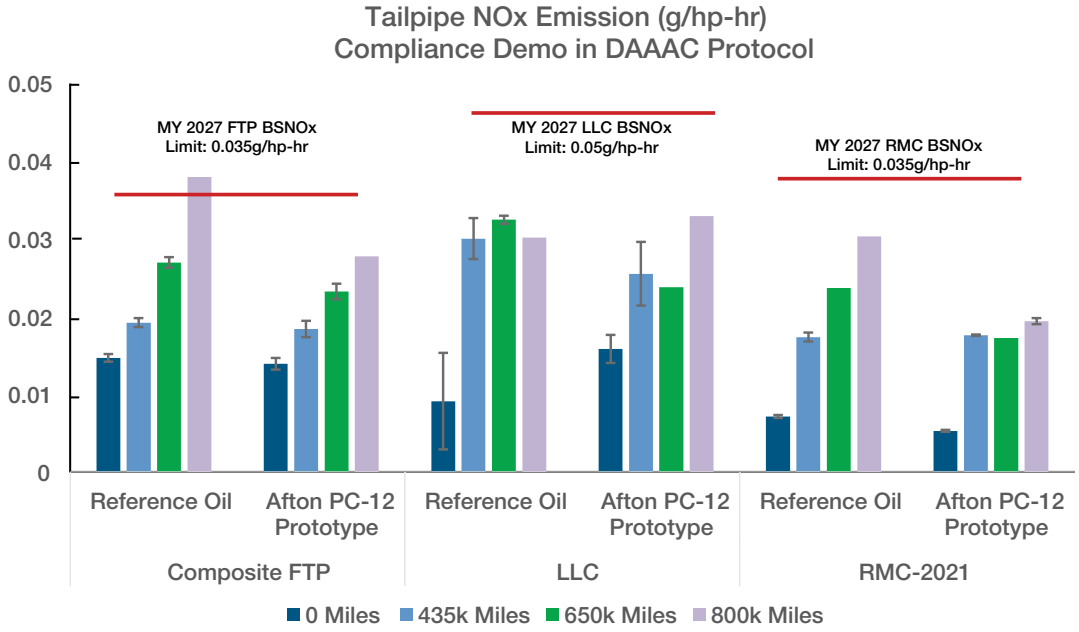
Afton's comprehensive research has focused on understanding and addressing potential chemistry risks, testing risks, and real-world performance challenges by partnering with industry experts across the ATS supply chain to deliver robust solutions that meet tomorrow's ATS needs. Beginning with fundamental research into formulation and catalyst compatibility, we were able to screen formulation impacts and define the best possible candidate for ATS compatibility, as shown in Figure 6.

Figure 6. Bench test evaluation of catalyst compatibility. Higher NOx conversion is desired, indicating better catalyst compatibility.



Once we established our fundamental understanding of the formulation effects in ATS durability, we followed with a compliance demonstration utilizing the Diesel Aftertreatment Accelerated Aging Cycles (DAAAC) protocol. This protocol was developed at SwRI to simulate long-term ATS operation over the expected life of the system and is used to determine compliance with 2027 emissions targets. We ran our PC-12 formulation beyond the 2027 EUL target of 650,000 miles to a simulated 800,000 miles and still met 2027 NOx emissions targets, Figure 7, per the pre-determined durability cycles.

Figure 7. Compliance demonstration in the DAAAC protocol. Afton's PC-12 formulation showed 2027 Emissions compliance even to extended operation of 800k+ miles, exceeding EPA's 650,000 miles Emission Useful Life requirements.



Field-Proven Performance: Going the Extra Mile

Over the past five years, Afton Heavy Duty R&D, Marketing, and Field Engineering team have been working with several fleets to understand their needs, operation pinch points, and hear directly from them how a lubricant can help improve their overall operation. The feedback and opportunity resulted in four simple words: keeping my vehicle running. In April, Afton delivered on that promise with a PC-12 prototype that achieved three consecutive 90,000-mile oil drain intervals (ODIs), plus the standard 60,000-mile ODI—totaling over 500,000 miles without issues. The proof of performance field trial tested a Freightliner fleet equipped with DD15 engines operating on average at 6.7 mpg. The PC-12 prototype technology, SAE 10W-30 API FA-4, was formulated in 100% Group II base oil. This same prototype is now being tested to accumulate over 100,000 miles on a single ODI, with the first milestone ODI expected to be completed at the end of the year. This is a demonstration, Figure 8, on how the proper formulation, combined with a deep understanding of wear mechanisms and engine testing, can help deliver longer ODIs while keeping engines clean and fleets running.

Figure 8. API FA-4 SAE 10W-30, 500,00 miles of field performance at low HTHS with no engine issues (rear of engine piston #6). The inspection showcased Afton's PC-12 technology and its ability to deliver parts protection and engine cleanliness.

Delivering Passion for Solutions®

At Afton, we are committed to Passion for Solutions® by delivering more with every drop of heavy-duty engine oil and leveraging the new API category to set a new standard. Afton PC-12 family of products, HiTEC® 12330 and HiTEC® 12380 series, are not only being tested against the industry standards but also put to the test in real-world demonstrations. We are committed to you and assurance that we are not only engine testing our products to meet a standard, but field proofing their performance to exceed your expectations.

Want to learn more about PC-12?

Contact your Afton Chemical Sales representative today and discover how our next-generation solutions can help your customers go further, cleaner, and more efficiently.

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