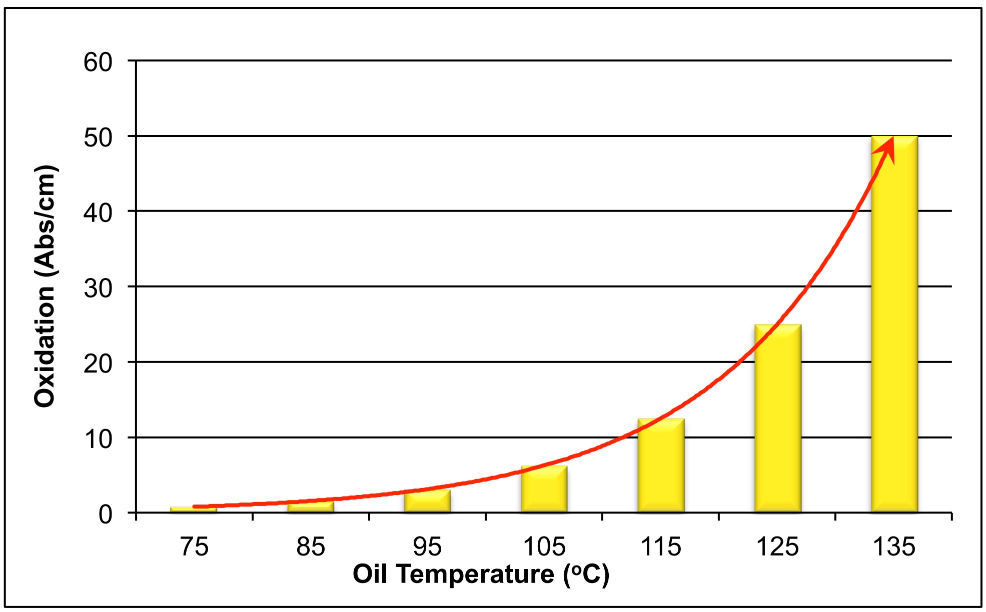
The New Oxidation Standard for Next-Gen Heavy-Duty Diesel (HDD) Oils

Today's on road equipment is designed to be more aerodynamic with smaller engines putting out higher horsepower in an effort to decrease fuel usage. These design changes are causing less airflow and hotter running engines. The increased temperatures stress the oil more and will increase oxidation rates. Unless the oil being used is formulated for higher temperatures and strong oxidative stability, normal use of the engine will lead to shorter oil life and could lead to shorter engine life. Consider the Arrhenius Rate Rule that says, 'the oxidation rate doubles for every 10°C (18°F) increase in temperature', it's easy to see why improved oxidation stability is critical (Graph 1).



Graph 1
Arrhenius Rate Rule

Temperature is the main factor controlling the rate of reaction, but it's not the only culprit. Driving conditions and loads on the engine contribute to increased oxidation rates and can cause oil temperatures to vary by 8° to 10°. Original equipment manufacturers (OEMs) are understandably concerned about their engines maintaining durability in everyday situations let alone harsh environments.

Why oxidation is bad

Oxidation disrupts oil's ability to lubricate properly and maintain performance. That's bad for the oil, and it leaves the engine vulnerable when it needs the most protection.

When oil is exposed to oxygen and accelerants like heat, water and wear metals, it undergoes a chemical change. The oil thickens and doesn't flow as easily to lubricate and cool critical engine parts like bearings, pistons, springs, and rollers. Some components may suffer from oil starvation because the oil can't properly lubricate those surfaces. The engine is subjected to excess friction and heat, and eventually experiences metal fatigue and failure.

Oxidation products react at a chemical level and result in the formation of sludge and deposits. Over time, the sludge and deposits build on surfaces and obstruct oil flow. This buildup can cause wear and damage to critical metal surfaces as they move against one another. In addition, the deposits can harden and flake off, resulting in solids in the oil that can cause further wear issues and filter blockage.

To prevent these issues from occurring, the lubricant should be changed before high levels of oxidation emerge. While changing the oil is the right thing to do to prevent oxidation related problems, it is not desirable from an operation and cost perspective.
Oil can be costly when multiplied across an entire fleet, and downtime for maintenance means less time on the road and less revenues the equipment could otherwise be making. That's why the lubricant industry and OEMs develop tests and specifications to ensure acceptable levels of oxidation performance are met.

Oxidation is measured in one of two ways:

Increase in viscosity as the oil ages in the engine.

Oxidation can be quantified by infrared spectroscopy.

Oil chemistry to slow down oxidation

As oxidation is a spontaneous chemical reaction that occurs between the oil and the air, it begs the question: What can be done to slow the reaction? First, we need to understand how engine oil is made.

The largest single component found in engine oil formulations is base oil, which is refined from crude oil (Figure 1).

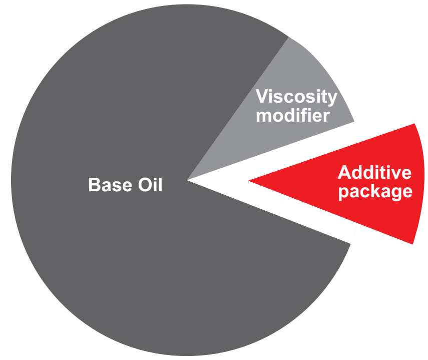
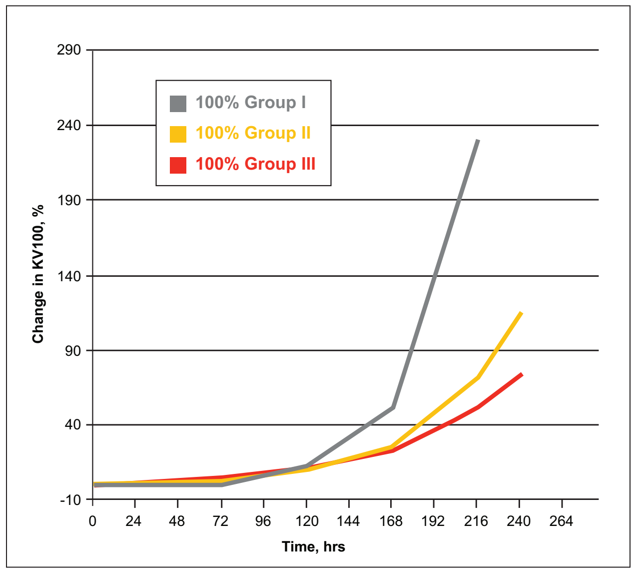


Figure 1
Typical engine oil makeup.

The chemical composition of the base oil can vary based on the degree of refining; this has a big impact on oxidative performance. The American Petroleum Institute (API) has five base oil classifications; Group I, II and III are based on the amount of saturates and the viscosity index (VI) of the oil. Group IV is all polyalphaolefins (PAO) and Group V includes all other base oils. These distinctions are based on the level of processing during manufacturing.

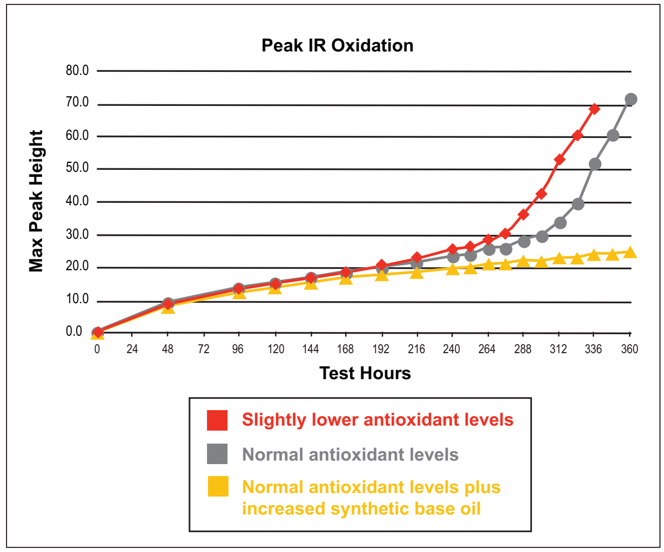
The amount of saturates is a key distinction. This difference in the oxidation stability can clearly be seen in bench testing when comparing mineral Group I and synthetic Group III oils by looking at the viscosity increase (Graph 2). Oils formulated with additional PAO provide even greater viscosity and oxidation stability.



Graph 2
The choice of base oil has a significant impact on performance in oxidation tests. Same pattern observed in both Daimler (bio and non-bio tests) and CEC oxidation tests.

Engine oils also feature antioxidants in their additive package to slow the rate of oxidation. Oxidation reactions are self-accelerating, which can lead to rapid increases in oxidation. To understand how antioxidants work, think of a drag strip with speed bumps. Rather than allow the continuous increase in speed, the speed bumps, or in this case, antioxidants, keep the speed low. Once the antioxidant is used up, there's a rapid rise in oxidation, known as breaking.

Graph 3 illustrates how a small decrease in antioxidant level can cause the oil to break much sooner – refer to the red line. The Mack T-13 corresponds to real-world operation to ensure adequate protection of the engine throughout the oil's life.

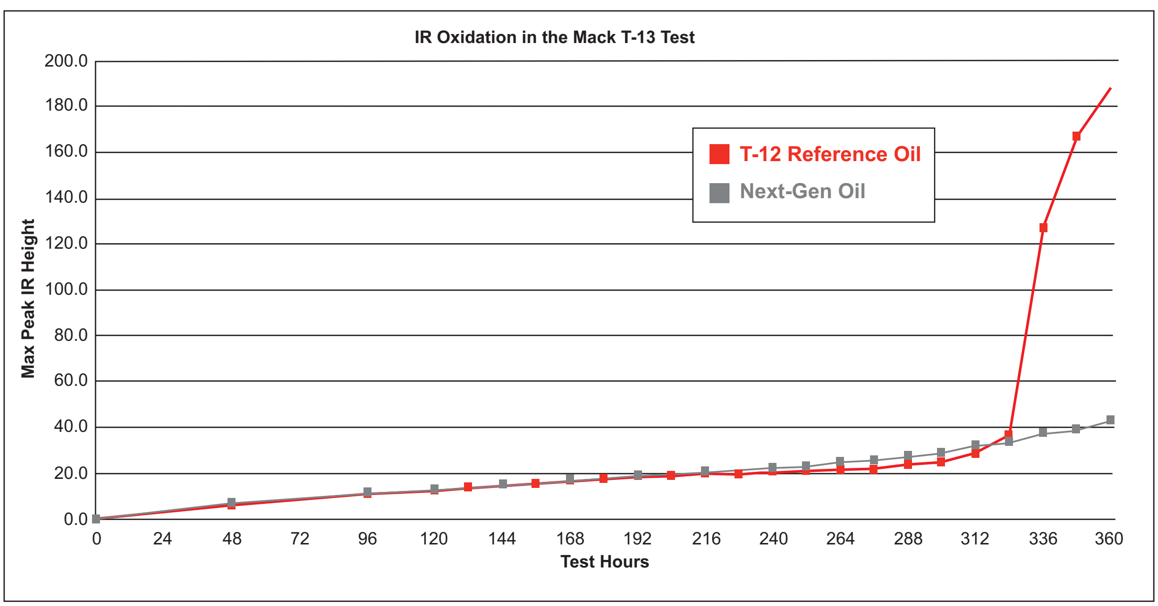


Graph 3

A Closer Look at the Mack T-13

As changing engine designs push the limits of engine performance, so too must the oxidation standards push the limits of engine oil.

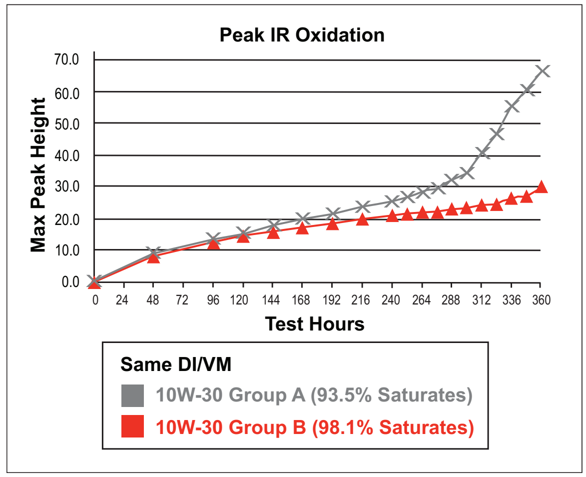
The Mack T-13 engine test was introduced to ensure API CK-4/FA-4 oils deliver improved oil oxidation stability over past oils. Higher temperatures and longer duration are key. The Mack T-13 test is 10°C hotter and 60 hours longer than the previous Mack T-12 test used with API CJ-4 oils. The difference with the previous base line oil (T-12 test reference oil) and the next generation oils run in the Mack T-13 is shown in Graph 4. The T-12 reference oil breaks hard as measured by Max Peak IR once it passes 312 hours.



Graph 4

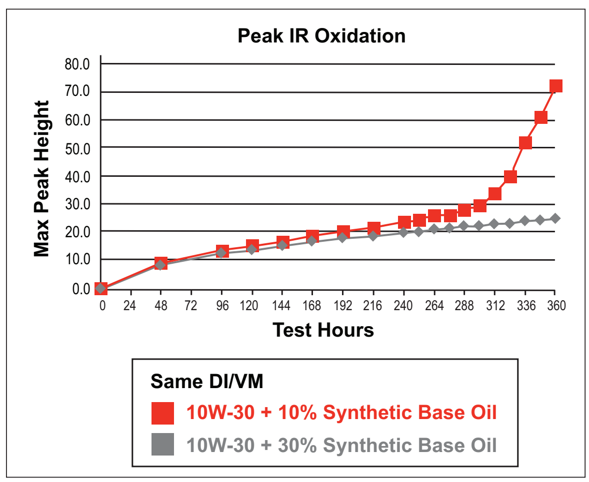
Also shown in Graph 4, a Next-Gen HDD oil with much better oxidative stability can essentially flat-line (no break in the oxidation of the oil) the Mack T-13 out to 360 hours (end of the test length). Base stocks higher in saturates contribute to the improved performance and oxidation stability.

Graph 5 illustrates how an increase in saturates level (use of a better quality base oil) improves performance in the Mack T-13 engine oxidation test. Notice how the Group B oil with higher saturates level flattens out the curve and continues a steady slope without breaking.



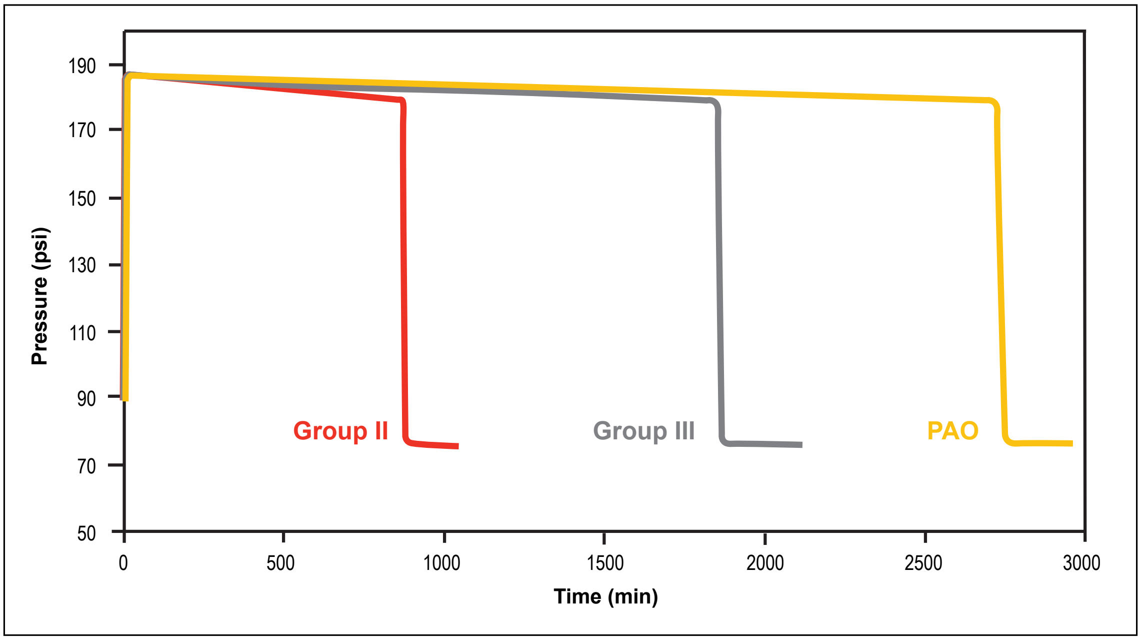
Graph 5

Furthermore, as shown in Graph 6, an increase in synthetic oil content drastically improves the oxidative stability of the heavy-duty diesel oil in the Mack T-13. As the synthetic content increases, the tendency for the oil to break is removed and the curve is flattened allowing for extended drain intervals and better oxidation control. Using oil with the right synthetic base oils, paired with PAO, and antioxidants can improve oxidation time and prolong lubricant life.



Graph 6

One way to differentiate between Group III and Group IV synthetic base oils is the use of the Rotating Bomb Oxidation Test (RBOT), which is now known as the Rotating Pressure Vessel Oxidation Test (RPVOT). In this test, a measured amount of oil, oxygen and copper catalyst are inserted in a rotating pressurized vessel. The vessel is heated to 150°C, and the test is run until there is a decrease in pressure.



Graph 7

As the oil oxidizes, the oxygen reacts with and becomes incorporated into the base oil. RBOT reports the time it takes for the base oil to react with the oxygen – the longer the time, the greater the oxidation stability of the base oils. PAO base oils are superior to Group II and Group III base oils (Graph 7).

Conclusion

In order to meet the increased demands of new engine designs, next-gen HDD oils must be formulated with high quality base oils (incorporating synthetics) and strong antioxidant technology. Oxidation stability is critical to extending engine and oil life. For more information on how engines can achieve their full potential and avoid the costly damages that can arise from inadequate oxidation protection, visit www.schaefferoil.com.

www.schaefferoil.com
800-325-9962
info@schaefferoil.com