Understanding How Engines Consume Oil

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High consumption of engine oil is almost always a symptom or consequence of another condition of even greater importance. This article will address this issue from the standpoint of oil loss through combustion pathways (versus leakage). While the focus will be more on diesel engines used in industrial and commercial service, much of what will be discussed applies equally well to personal automobiles and natural gas engines.

By itself, oil consumption is a well-known source of harmful emissions to the atmosphere (see the sidebar on page 4). Unburned or partially burned oil is released through the exhaust path in the form of hydrocarbons and particulate contamination (soot). Additionally, motor oil anti-wear additives are known to poison or at least impair the performance of catalytic converters. The more oil consumed through the combustion chamber, the greater this poisoning risk/effect. This escalates the environmental impact further.

The causes of high oil consumption are many and complex. Because this consumption is symptomatic of other conditions, there is a need to be aware of changes in the oil consumption rate. These changes should be viewed in the context of other data and factors, including oil analysis, visual exhaust, engine service life (from last rebuild), boost pressures, running temperature, load/RACK, blow-by and operating conditions. Oil analysis will be discussed in terms of the correlation and meaning of common trends and how they might be useful for troubleshooting purposes.

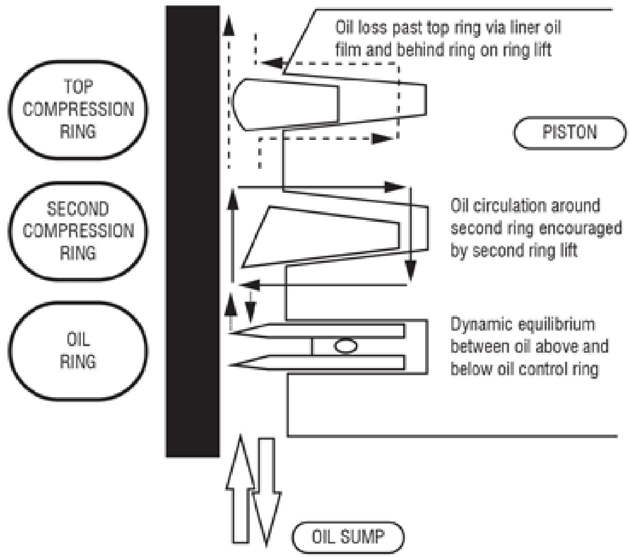

Figure 1. Piston ring-pack oil flow (Ref. Shell)

Causes of High Oil Consumption

Understanding oil transport mechanisms is necessary to prevent oil from going where it shouldn't. Loss of engine oil is influenced by the engine's design and the operating conditions. Oil consumption primarily occurs near or through the combustion chamber, either downward through valves or upward past the piston ring-pack.

Oil Mobility and Consumption Through Engine Valves

Oil collecting on the stems of intake valves is sucked into the combustion chamber during normal operation. Hot exhaust gases burn oil on stems of the exhaust valves. If there's too much clearance between the valve stems and guides, the engine will suck more oil down the guides and into the cylinders. This could be caused by valve guide wear and seals that are worn, cracked, missing, broken or improperly installed. The engine may still have good compression but will burn a lot of oil.

Oil Flow Through the Piston Ring-pack

Engine oil is designed to produce an oil film on the cylinder walls. While the oil control ring on the piston squeegees much of it off, a thin film will still remain. When the engine decelerates, high negative pressures suck oil in the combustion chamber and out the exhaust manifold.

The problem is more pronounced when rings or cylinders are badly worn or damaged, but it can also occur if the cylinders were not honed properly (out-of-round or surface finish defects) when the engine was built (or rebuilt) or if the rings were installed improperly.

Much of the oil that is transported through the piston ring-pack and along the liner usually occurs during the compression stroke. The oil control ring scrapes the oil from the cylinder wall. The scraped oil flows to the ring drain holes/cavities. Oil left behind on the cylinder wall is needed to lubricate the compression rings. Once oil moves past the compression rings, it is difficult for the oil to return to the sump. However, blow-by gases can provide a transport medium to help recycle the oil back to the sump (see Figure 1).

Piston Ring-pack Deposits and Movement

Piston ring-pack deposits can sharply reduce ring movement and flexing. Likewise, ring movement can greatly influence where deposits form and the lubricant motion (transport) within the ring-pack. This ring motion defines the residence time of the lubricant in the ring-pack, which in turn affects the rate of lubricant degradation and where deposits will form (see Figure 2). Ring-pack temperatures can range from 195-340 degrees C.

Collectively, these conditions can accelerate piston-ring-liner (PRL) wear, impair combustion efficiency, increase blow-by and reduce oil economy (more oil consumption). One way this happens is through carbon jacking. In this phenomenon, carbon buildup occurs in the ring grooves (fed by soot and oil degradation products). The corresponding ring movement restriction increases wear, blow-by and oil consumption with the rhythm of the piston.

Figure 2. The sequence of piston ring-pack deposit formation

Cylinder Wall Oil Evaporation

As much as 17 percent of total oil consumption is associated with liner wall evaporation. The more distorted (out-of-round) and rough (surface finish) the cylinder liner, the more oil film that will remain on the liner after the power stroke. High liner surface temperatures (80-300 degrees C) will cause a loss of this oil by misting and evaporation. Light oil molecules are more prone to evaporation. These light molecules are the first to deplete, and as a result, there is less evaporative loss toward the end of the lubricant's service interval.

Not all oils of the same viscosity are equal from the standpoint of volatility (risk of evaporative loss). Some lubricants may exhibit as much as a 50-percent greater loss from volatility than others. This is influenced by the base oil's molecular weight distribution.

Of course, temperature plays a key role. A low liner temperature translates to a low evaporation rate. Liner temperature is influenced by load, combustion efficiency and cooling. Approximately 74 percent of vaporization occurs during intake and compression strokes (no speed effects have been found).

Blow-by from Ovaloid Cylinder Bores

Ovaloid cylinder bores are usually caused by machining issues as well as thermal and pressure distortions. Piston rings can conform to out-of-roundness cylinders to a certain extent. Still, reverse blow-by gases and oil mist can follow the pathway across these cylinder bore distortions by moving more easily against the ring's running face. Oil mist is carried with reverse blow-by gases into the combustion chamber and outward with the exhaust.

High Ring Float Conditions

Researchers have found that lower oil viscosity can reduce the oil control ring's "float" conditions. "Float" basically means there is too much film thickness between the oil control ring and the cylinder wall. Consequently, this excessive viscosity fights the ring's ability to squeegee (downscrape) the oil sufficiently from the cylinder wall and return it to the sump. As a result, too much oil is left on the cylinder wall that then can move toward the compression rings or remain adherent to the liner, increasing oil loss through misting and evaporation.

How Oil Consumption Influences Tailpipe Emissions and Health

As engines age and wear, they become greater consumers of crankcase oil. Solid contaminants combined with soot and other oil suspensions influence engine wear, deposits and oil economy (oil consumption rate). When oil is consumed, it enters the combustion chamber, burns with the fuel and is pushed out with exhaust gases as particles and volatile hydrocarbons.

Fresh new lubricants have more volatile light-end molecules and are more prone to hydrocarbon emissions. As the oil ages, the hydrocarbon emission levels off but can pick up again if the oil becomes contaminated with fuel (fuel dilution), such as from short run times or long idles. However, in general, the service life of the oil has no significant influence on carbon monoxide and nitric-oxide emissions.

The level of exhaust emissions can increase considerably over time, corresponding to engine wear and deposit formation. This leads not only to greater exhaust particulates but also to a higher percentage that are hydrocarbon, which is a byproduct of oil consumption. It has been observed that lubricating oil is a significant contributor to the particulate emissions signature as the engine ages, especially with diesel engines. The obvious strategy to control/reduce hydrocarbon emissions is to decrease oil consumption. This, in large part, is accomplished only by controlling combustion efficiency, wear and deposits (especially through good lubrication and filtration practices).

Nitrogen oxides (NOx) consist of nitric oxide (NO) and nitrogen dioxide (NO2). These ozone precursors also lead to smog when exposed to hydrocarbon gases and sunlight. As a health hazard, NOx can potentially cause irritation and damage to lung tissue as well as paralysis. Because of regulatory requirements and environmental protection pressures to lower both particulates and NO2, increased pressure has been placed on lubricant formulation, engine design and filter performance.

It is worth noting that too little viscosity induces a plethora of dangers as well. The optimum reference viscosity (not too low or high) is always desired. This "optimum" is pushed and pulled by numerous engine design and operation factors, including the desire to mitigate oil consumption.

Oil Change Interval Effect

Extended oil drains are an ever-growing trend. While there are clear advantages (lower oil change costs, higher productivity, environmental benefits, etc.), there are also engine life risks, fuel economy risks and oil economy penalties. A recent study on the effects of the oil change interval on miles per quart of oil is shown in Figure 3. Three different engines (Class 8, long-haul service) at different oil change intervals show a clear relationship between oil health and oil consumption. One can conclude that as oil ages, the effects of aging (high soot, loss of dispersancy, additive depletion, insolubles, viscosity-index shear, dirt load, etc.) impair the ability of the engine to retain the oil during service.

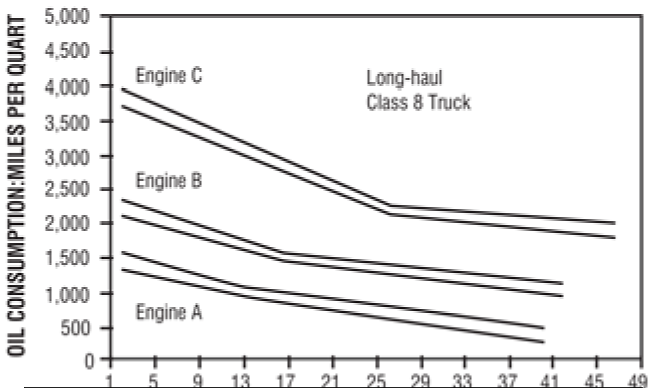

Figure 3. Effects of the oil change interval on miles per quart of oil (Ref. Carver, Exxon)

Oil Consumption Issues Revealed by Oil Analysis

Monitoring oil levels and makeup rates offers a reliable indication of oil consumption and relative oil economy. If oil consumption is low, it can be assumed that while many things could be going wrong, they are not going wrong simply because engine oil consumption is within a normal and safe range. Therefore, it is logical to track oil levels and makeup oil consumed between scheduled oil changes.

OIL ANALYSIS AND OTHER REPORTABLE CONDITIONS	WHAT IT COULD MEAN	WAYS IT CAN CAUSE HIGH OIL CONSUMPTION	WAYS HIGH OIL CONSUMPTION CAN CAUSE IT	WAYS IT CAN OCCUR CONCURRENT WITH HIGH OIL CONSUMPTION
Low base number/high acid number	High blow-by, water contamination, distressed base oil, high sulfur fuel	Corrosion of piston-ring-liner (PRL), piston ring-pack deposits	Low oil level prematurely depletes overbase detergents and antioxidants	High blow-by gas ingestion due to poor compression/combustion efficiency
High oil viscosity	High soot load, wrong oil, glycol in oil, hot oil, extended oil drain, oil oxidation	High ring float, piston ring-pack deposits	Fractional evaporative light-end oil loss	High blow-by (soot) due to poor compression/combustion efficiency
Low oil viscosity	Fuel dilution, wrong oil, VI improver shear	Evaporative light-end oil loss, PRL wear		Incomplete combustion and blow-by (fuel dilution)
High soot load	High blow-by, extended oil drain, exhaust gas recirculation (EGR), long idle, etc.	High ring float from elevated viscosity, piston ring-pack deposits, PRL wear	Low oil level concentrates soot	High blow-by (soot) due to poor compression/combustion efficiency
Low soot dispersancy	Water contamination, high soot load, fuel dilution, extended oil drain, coolant leak	Piston ring-pack deposits	Low oil level depletes dispersant prematurely	High blow-by (soot) due to poor compression/combustion efficiency, incomplete combustion and blow-by (fuel dilution)

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Water contamination	Coolant leak, short intermittent operation, cold temperature	PRL corrosion		High blow-by and short intermittent operation
Sludge and oxide insolubles	Extended oil drain, base oil oxidation, poor dispersancy, depleted detergency	Piston ring-pack deposits, PRL wear	Low oil level raises sump temperature and prematurely depletes antioxidants	
Fuel dilution	High blow-by, PRL wear, extended oil drain, injector issues, overfueling/lugging	PRL wear and blow-by, premature base oil oxidation (piston-ring deposits)		Incomplete combustion and blow-by (fuel dilution)
Coolant (glycol) contamination	Coolant leaks from defective seals, cavitation, corrosion, damaged cooler core, head gasket leak, etc.	High ring float from elevated viscosity, PRL corrosion, PRL wear, piston ring-pack deposits		High blow-by gas ingestion due to poor compression/combustion efficiency
Dirty oil (silica) and other solid contaminants	Dirty air induction, defective oil filter, dirty fuel, dirty new/backup oil, wear and corrosion debris	PRL abrasive wear causes high oil consumption	High oil consumption carrying particles causes excessive PRL abrasive wear and more particles	High blow-by gas ingestion brings in induction air dirt and fuel dirt

The table above not only details how high oil consumption might accompany certain reportable oil analysis conditions but also provides examples of what these conditions may mean.

Understanding how engines consume oil is still a work in progress and is the subject of ongoing research by many organizations. It is important to slow down or arrest the problem as much as possible. Undoubtedly, much progress will be made in the years to come. In the meantime, it will be beneficial to use the current knowledge to its fullest extent. The strategies described in this article offer several plausible ways that this can be achieved.

About the Author

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Jim Fitch, a founder and CEO of Noria Corporation, has a wealth of experience in lubrication, oil analysis, and machinery failure investigations. He has advise... Read More

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