Engine Oils

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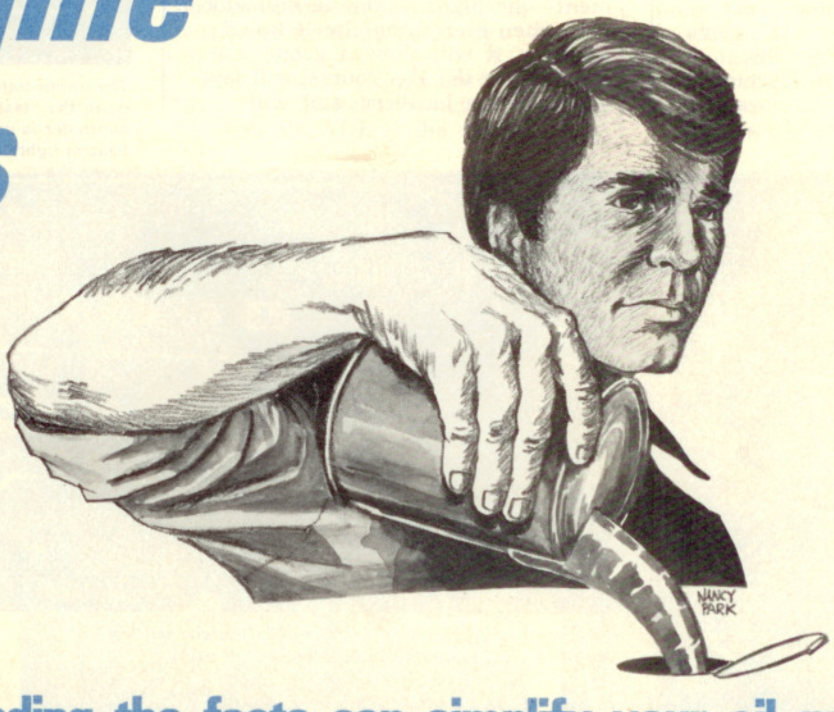
■■ Few aviation subjects are more controversial than engine oil. Questions such as "What name brand to use?" "What grades to operate with?", "When to change?", "What additives to use?", "What type of oil filters are best?", "AD or straight mineral?" are common among aircraft owners and mechanics. Some individuals accept and practice particular beliefs with bull-dog tenacity. How could something so simple as putting lubricating oil into an engine's oil sump become so complicated and confusing?

It ceases to be complicated and confusing once you possess the basic facts of the subject. To begin with, oil must perform five basic functions in the four-stroke-cycle aircraft and automotive engine:

- Lubricate (reduce friction between moving parts).
- Cool (transfer heat from interior engine parts not accessible to the regular cooling system).
- Seal (promote satisfactory piston ring to wall sealing).
- Clean (prevent contamination of engine interior with combustion by-products).



Understanding the facts can simplify your oil problems

- Preserve (protect all interior parts of engine from rust and corrosion damage).

Now let's examine each of these requirements as they specifically relate to the engine's needs.

There are many sliding surfaces inside the reciprocating engine that would quickly self-destruct without lubrication to keep them separated from each other. The pistons and rings slide back and forth along their respective cylinder walls at a considerable speed during normal operation. Although the normal oil film on the cylinder walls will be only approximately 2 mils (.0002 in) thick, it is sufficient to prevent these parts from actually contacting each other.

The pressure of combustion gasses, easily 1,000 psi or more, forces the piston rings hard against the cylinder walls. The oil film on the wall must not rupture under these conditions. There are other sliding parts such as valve stems, lifter bodies, and so forth, that impose high crush loads on the lubricating oil. The reciprocating aircraft engine has a considerable number of gears in its gear train and these gears impose severe crushing and shear loads on the oil.

At takeoff power, the pistons in a 520-cu-in engine exert a crushing force of 16,000 to 18,000 pounds on the connecting rod bearings and, since the crankshaft is also turning, the oil film undergoes a tearing or shearing action as well. Despite these mind-boggling crushing and tearing forces, the lubricating oil must at all times maintain a separating film and a slippery one at that. Essentially, this is lubrication.

To lubricate, the oil must absorb unwanted heat and convey this heat to some convenient point where it can be expelled. Friction produces heat and in the process of reducing friction the oil gets hot. Exhaust valves can experience temperatures of 1,650°F and some of this heat is transferred from the valve to its guide. Oil must remain on the hot valve stem and lubricate, or the valve will quickly seize in its guide.

Cylinder wall temperatures are no evening breeze either. The top of the piston is subjected to the intense heat of combustion and would quickly fail if not adequately cooled. Contrary to a time-honored belief, all excess piston heat is not rejected to the cylinder wall cooling fins via the piston rings. It is the lubricating oil that performs this necessary function.

Some engines employ oil squirt tubes to increase the amount of oil directed to the underside of the piston for cooling. Oil contacting the underside of the piston crown (head) is subject to temperatures considerably in excess of 300°F.

The job of internal cooling is of such magnitude that oil coolers are necessary to nearly all high-performance aircraft engines. Thus, the lubricating oil absorbs unwanted heat from within the engine and transfers this heat to ambient air through the oil cooler or radiator.

The sealing function is quite important to engine efficiency. The excess oil thrown on the cylinder walls for lubrication and cooling is scraped off by the piston rings on the down stroke of the piston. Oil scraped from the cylinder walls flows under the piston rings and into drain holes drilled through the piston ring grooves. The presence of oil on and around the piston rings helps to form a better gas seal between the piston rings, their respective grooves on the piston and the cylinder wall.

Were it not for the sealing, considerably more combustion gas would blow by the piston rings and into the crankcase. Not only would this be undesirable from a loss of efficiency point, but from increased crankcase contamination, pressure and temperature as well. In performing this sealing function, the oil is lubricating and cooling the piston rings simultaneously.

At first glance, the engine appears to be well sealed, necessitating little cleaning. Indeed, most engines are sealed quite well. But, it isn't just the dirt from the outside that must be considered. During initial engine startup and shutdown, water vapor is condensed inside the crankcase. Depending on ambient conditions, this behavior can precipitate as much as eight tablespoons or more of water. Piston ring sealing is not 100% effective, especially during cold, initial starts. Consequently, raw unburned fuel from priming, along with combustion gas, blows by the piston rings and enters the crankcase to mix with the oil. This action produces sludge and corrosive agents that can cause damage.

Gasoline is a very complex hydrocarbon which breaks down into various other compounds during combustion. Among these compounds are at least five different acids, such as sulphuric, nitric, formic, and so on. Quite naturally, these acids become mixed into the oil and upon contact with water they become quite destructive.

There is also TEL (tetraethyl lead) from unburned fuel, lead salts, atmospheric dust and dirt, carbon and still other undesirable contaminants that find their way into the interior of the engine.

Once the engine reaches normal, in-flight, operating temperature, the water will be boiled off and passed out the crankcase breather tube as steam. The rest remains. Also, when the engine is shut down, crankcase condensation can produce more water which will remain until the next flight and, presto, more acid.

SAE GRADE	AVIATION GRADE	MILITARY GRADE
20 X 2 =	40 + 1000 =	1040
20W	----	------
30	60	1065
10W30	----	------
40	80	1080
50	100	1100
60	120	1120

Oil Grade Comparator

In addition to the rust and corrosion contaminants, the formation of sludge can restrict oil flow, and foul hydraulic lifters, constant-speed propellers and governors, turbochargers and their control systems, etc. If you had any doubts about the importance of keeping an engine clean internally, you shouldn't now.

The fifth function, preservation, is almost self-explanatory. A multitude of expensive parts exist within the interior of the aircraft engine and these parts must be protected from all of that rust and corrosion previously described. A film of oil will protect these parts from such damage as long as that film of oil remains and, of course, as long as the oil itself is reasonably uncontaminated.

Now let's examine the various oils and some of their essential qualities.

There are four basic sources, or origins, from which to derive lubricating oils: animal, vegetable, mineral, and synthetic. Of the four, only mineral and synthetic could even be considered for aircraft application and, since only mineral is presently approved by Lycoming and Teledyne Continental Motors, that leaves us with only one approved choice—to which we shall now confine our comments.

Petroleum-base oils originate from several different base stocks such as paraffinic, asphaltic, naphthenic, etc., but we can consider petroleum-base oils as being in either of two basic categories: straight mineral (not detergent or AD) and additive (detergent or AD types).

A straight mineral oil is one having a single viscosity index number such as grade 30. It is never a multi-viscosity oil such as 10W30. These straight mineral oils are sometimes defined as non-additive oils; however, such a definition is not really correct. Although these oils do not contain the super lubricants, carbon solvents, dispersants, etc., they do contain a host of special additives such as acid neutralizers, stabilizers, pour-point depressants, and so forth.

A straight mineral oil is simply a good lubricating oil of a single viscosity number, without the special additives found in the super oils. Incidentally, this type of oil is still recommended in many new, rebuilt and overhauled engines for the first 25 hours of operation. Since these oils lack the increased film strength of the super oils, they will promote the minute film ruptures necessary for initial piston ring to cylinder wall sealing.

Additive oils are better known as detergent and ashless dispersant (AD). These oils are truly the super-lubricating oils, first developed for the higher performance automotive engines built after World War II.

Basically, the detergent oil is a petroleum-base engine oil just as before, but now it contains EP (extreme pressure) additives that increase its film strength by at least two to three times over what it was. This oil is also treated to withstand higher normal operating temperatures. We used to be limited to a maximum of 225°F, but now it's up to 240°F.

Another valuable additive to detergent oil is the dispersant. A dispersant continuously repels contaminants from the oil. This behavior prevents contaminants from collecting in any particular area. This behavior also causes it to appear dirty shortly after it is put into the engine. Still another additive, known as an anti-precipitant, was included. This additive remains in suspension with the oil. Its purpose is to attract and hold contaminants repelled by the dispersant. Figure 1 illustrates the action of these two special additives.

Detergent oils also contain carbon and varnish solvents (phosphates). These solvents dissolve, and subsequently remove, "stick-on" types of contamination. Most of the contaminants that find their way into the oil mix with it in mechanical fashion only. Upon engine shutdown, these contaminants settle, or precipitate, out of the oil. In time, such action will result in sufficient accumulation to cause difficulties with various engine components, such as hydraulic lifters, governors or even oil passages.

With detergent oil, the contaminants continually remain in suspension and subsequently drain out with the engine oil. A common question at this point challenges the feasibility of having all this garbage flowing through the engine, as opposed to settling out each time. Keep in mind that much of the contamination is liquid and therefore not abrasive. Having these contaminants settle out and form sludge is much worse.

To some degree, piston-type aircraft engines encounter the same contamination problems as automotive engines—in some instances to an even worse degree. Consequently, it didn't take the aircraft industry long to adopt detergent oil for use in aircraft engines. For all practical purposes, aircraft detergent oil was basically heavier grade automotive detergent oil.

The Shell Oil Co. wasn't satisfied with that approach and subsequently developed a detergent-type lubricating oil exclusively for piston aircraft engines. This new oil was called ashless dispersant—AD. The term "ashless" originated from the substitution of different additives to replace certain metallic additives used in all detergent-type lubricating oils. Some of the oil on the cylinder walls is consumed during normal combustion.

Oils containing metallic additives were suspected of leaving a metallic ash residue that possibly might cause pre-ignition, when subjected to the higher operating temperatures of air-cooled aircraft engines. Considerable research in this area by the Shell Oil Co. prompted that firm to develop new additives

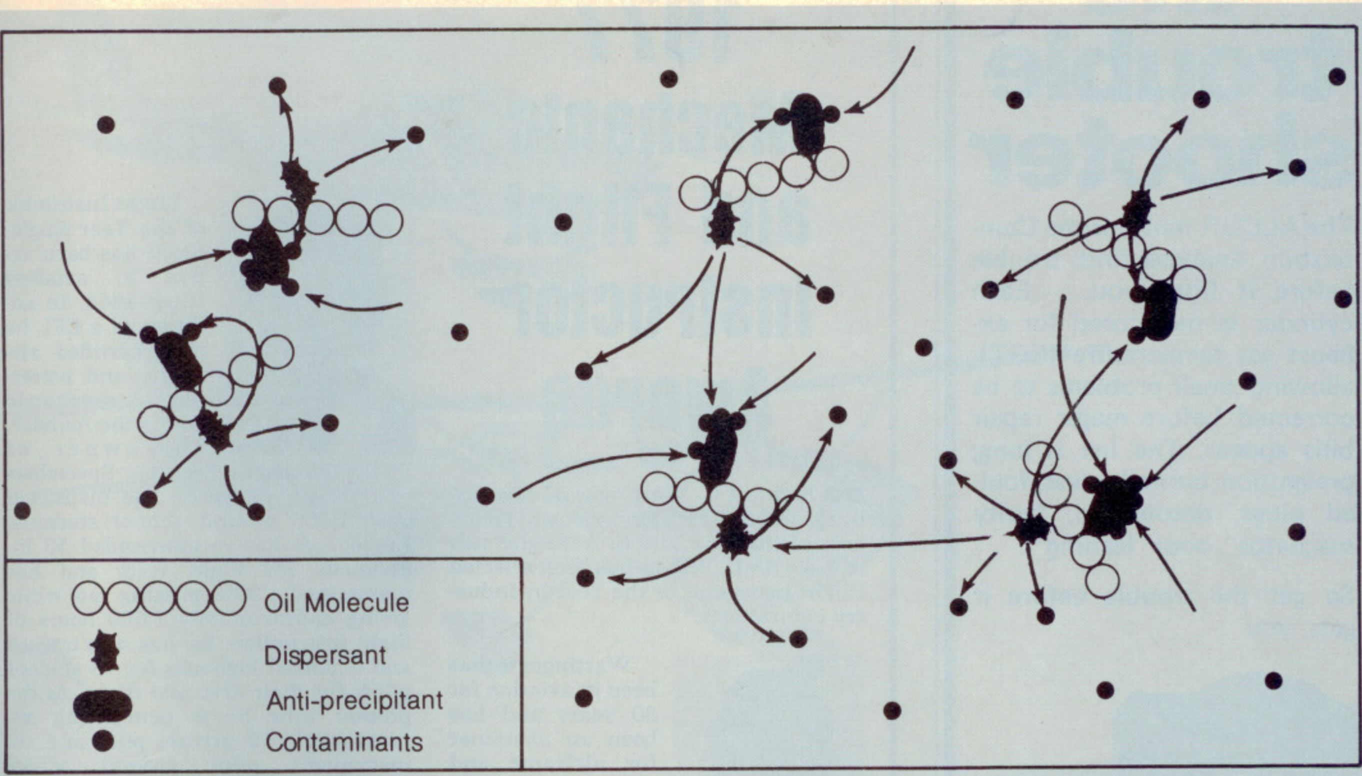


Figure 1

as replacements for those thought to be undesirable for aviation use. Since this new oil was not the same as the regular detergent, Shell named it for what it accomplished—"ashless," because it eliminated the previous metallic ash residue, and "dispersant," because it retained the dispersant qualities of detergent oil. Today there are only a few detergent aircraft oils available. Most aviation engine lubricating oils are either straight viscosity or AD. The AD lubricating oils retain all the advantages of the original detergent oils plus being compounded especially for the special needs of the aircraft piston engine.

Another area of disregard that can cost the owner plenty is extended oil changes. One of the chief purposes of dispersant lubricating oils is to keep your engine clean internally. It can do that only as long as the antiprecipitant additive is able to hold contaminants in suspension. Once this additive becomes saturated contaminant precipitation begins.

How can you know when that occurs? Short of chemical analysis you can't. However, you can be reasonably certain by following the engine manufacturer's recommended change intervals. Such intervals are based on average conditions; consequently, the change period may need to be more frequent under extreme dirt and temperature conditions.

Prior to the invention of the electron microscope, it was an accepted fact that oil did not wear out, it simply became dirty. Thus, if used oil was cleaned, it would be as good as new. Despite this conclusion, which was even backed by a government bulletin, strange and unexplainable changes occurred in used lubricating oil.

Armed with an electron microscope, researchers were able to see an oil molecule for the first time. New and unused lubricating oil molecules appeared as the chain illustrated in Figure 1. When used oil was viewed through the electron microscope, many of these chain-like molecules appeared to be divided, as if cut in two.

Indeed they were and the destructive process of molecular shear was verified. The high crushing and tearing forces described previously literally tear the oil molecule apart. Thus, in addition to becoming saturated with undesirable contaminants, the oil in your engine is damaged by heat and pressure.

No discussion on lubricating oil would be complete without some mention of oil filters. The most frequent questions in this regard are, "Will an oil filter extend the life of my engine?" and "Can I extend the change period with installation of an oil filter?" With regard to the first question your engine can hardly fail to benefit from the reduced contamination possible with a good oil filter. Therefore, it would seem a safe presumption that engine life would be increased. In accepting an answer to the second question you must consider all of the changes that have taken place with the lubricating oil.

Most oil filters are designed to remove damaging particulate matter and, of course, that is a definite plus for your engine. One filter manufacturer claims water, as well as particulate matter, removal. That could be another plus, especially with frequent short flights in extreme, cold-weather operation where all of the oil in the engine may not be sufficiently exposed to the normal "boil-out" temperatures.

But what about heat and shear damage? These two minus factors are just as real as particulate and liquid contamination. It would appear that an approved oil filter definitely aids in engine well being, but that's about all.

What about additives? Do the original engine manufacturers recommend that you treat your lubricating oil with supplements or additives? They certainly do not. Buying any name-brand engine lubricating oil is quite like going to the drug store to have a doctor's prescription filled. When the druggist hands it to you it's all there. You need not take it home and add to it. Likewise, that can of engine oil represents the engine manufacturer's prescription for your engine's lubricating needs—filled by a petroleum industry equally sensitive to those needs. More than that is hardly necessary. □