The Facts and Follies About Avgas

If you use it right, 100LL may not be as bad for your engine as you think

by KEN GARDNER / AOPA 132319

■■ There was a time when the owner of a grade 80 fueled airplane could taxi up to the pumps at just about any airport in this country and be assured of a plentiful supply of that particular fuel. Not anymore. Many such owner today is singing that more familiar tune, the "Blue Gas Blues."

At first the hapless owner only had to contend with a dwindling supply of grade 80 fuel, but then as always, there arose doomsday prophets who predicted dire consequences for all who use the forbidden grade 100 in their engines designed for grade 80. They warned the owner that his bird's flying days would soon be over and that he would not be able to sell or trade his flying machine.

Now, if that sounds like some kind of fairy tale, it is. The situation isn't now, nor ever was, as grim as it has been made to seem. In the course of my lectures at various pilot clinics around the country I am inevitably asked about the avgas situation. Indeed, most aircraft owners are confused by the mass of conflicting information disseminated on this subject. My experience has been that most owners are interested in the answers to three basic questions and they are:

- What really is the present avgas situation?
- What damage will grade 100 do to my engine?
- What can I do about the situation?

It would be great if we could just give, "Never better," "None," and "No concern necessary" as answers to those questions—however, it isn't quite that simple. There is one simple solution I can offer, and its truth is inevitable: Most individuals can solve their problems adequately if they are sufficiently informed. That statement holds the key to most of our problems and certainly to the one we are about to examine.

Now, what really is the present fuel situation? To begin with there is a fuel shortage problem regardless of what some choose to believe. If you could compare the number of holes from which it comes, to the number into which it goes you wouldn't have any problems believing. Continuously rising costs from inflation, federal government imposed regulations and requirements, exploration and drilling, liability cost from law suits, and so on, have forced the petroleum industry to seek cost reductions in areas just as distasteful to them as to their customers.

For example, the cost involved in producing 100 low lead (100LL) is considerably greater than for regular grade 100, due in part to replacing the lead normally used with more expensive anti-knock compounds. In a manner of speaking you paid taxes to increase the price you pay for gasoline. Be it right or not right, that's what it amounts to. Consider as well that one careless person refueling a grade 100 airplane with grade 80 fuel opens the liability doors to all manner of law suits. Guess what that does for the price of avgas, and it does happen.

Presently there are four aviation gasolines available in various parts of the U.S.: 80 octane, 100LL, 100, and 115. Under the ultimate plan there will eventually be only one general purpose avgas and that will be 100LL. That is the present avgas situation and it can be livable.

What damage will grade 100 do to my engine? The answer to that question can vary according to operating procedures and maintenance practices; therefore, it will be necessary to understand some basic rudiments about gasoline, tetraethyl lead (TEL), and their subsequent behavior under various operating conditions. Gasoline, by weight, is the most powerful of all the fossil fuels. It is by comparison 5.25 times more powerful than TNT, the king of World War II explosives. Even in our most powerful engines we have not yet fully realized the energy potential of gasoline. Without the use of TEL even this progress would not be possible on a practical basis. (There are numerous other anti-knock compounds, but none so economical as tetraethyl lead.)

Perhaps the most rewarding of the various ways employed to increase horsepower of a reciprocating engine is to raise the compression ratio. The more we compress the fuel-air mixture, the more power we can get from the same amount of gasoline. It is basically TEL that makes this possible because it prevents detonation. Exactly how it does that remains a mystery even to those most knowledgeable about its behavior. Thinking about that for just a minute, you may arrive at the question, "If TEL is such a mystery, by what authority speak those who tell you that TEL will surely ruin your engine?"

Another time-honored myth about gasoline is that "high octane gasoline burns hotter than a lesser octane number." That simply isn't true. The heating value of gasoline is approximately 19,000 BTU's per pound plus or minus a few hundred between different grades of crude. This difference isn't enough to be of any significant consequence to your engine. The amounts of anti-knock additives have absolutely no bearing on the fuel's heating value.

Perhaps you have heard that, "grade 100 fuel is more powerful and will strain your engine's structural limitations." The heating value is the power factor and if it remains unchanged by additives, how could that statement be so? Furthermore, it was stated earlier that it is the compression ratio that determines the degree of power extraction from the gasoline.

There is also the myth, "Grade 100 fuel burns hotter than grade 80." Even if this were factual, the time difference would be in micro seconds and subsequently too minute to be sensed by your engine. Therefore, the only noteworthy difference between grade 80 and grade 100LL is the amount of TEL and other anti-knock additives.

There is one more area we need to examine before approaching a satisfactory answer to questions two and three. Along with its beneficial qualities, TEL has a few "not so beneficial" habits. For one thing it has a tenacious tendency to remain in the combustion chamber and all over the parts therein. If this condition was allowed to endure unabated, combustion chamber deposits would reach an undesirable level in very short order. To prevent this situation a scavenging agent known as ethylene dibromide is added to the fuel in relative proportions to the TEL as a scavenging agent. During normal combustion the TEL and the ethylene dibromide become gaseous. In this state they will combine to form another compound. In this combined state the TEL loses its tenacious behavior and readily passes from the combustion chamber with the other spent gases. Nothing wrong here so long as normal combustion is occurring. If the TEL and/or its scavenger fail to gasify, they will not combine and you lose the scavenge effect. The results will then be lead deposits in the combustion chamber.

The chemical combination of TEL and ethylene dibromide during normal combustion produces still another chemical compound that is often defined as "lead salts." During normal engine operation these lead salts are in an anhydrous (dry) state and while in that state pose no cause for concern. However, when the engine is at rest for prolonged periods (seven days or more), especially in high humidity conditions, these lead salts can become quite corrosive.

While most of the lead salts are continuously expelled through the exhaust, a residual amount will remain in the exhaust system and combustion chambers. If activated by moisture these salts can, on contact, damage any and all metal parts subject to corrosion. Fortunately this isn't much of a problem with engines that are active. So, what the higher amount of TEL in 100 LL means to the owner of a grade 80 fueled engine is the possibility of a noticeable increase in the effects of lead salts and combustion chamber deposits.

Now let's examine the effects of these two factors on engines designed for 80 octane. Engines infrequently operated are subject to increased corrosion possibilities when operated on higher leaded fuels. Even a grade 80 fueled engine operated on grade 80 is not free from the damaging effects of rust and corrosion if infrequently operated. Thus, proper and frequent operation will keep any engine in better health despite operation on higher leaded fuels.

The second factor involving increased lead deposits is the greatest detriment to spark plugs and valves, especially the intake valves. Carbon deposits from lubricating oil and very rich mixtures tend to burn off in high power conditions. The lead does not burn off and therefore its accumulation must be prevented. The procedures employed to burn out a "mag drop" caused by carbon fouled spark plugs will not work with lead fouling, and nearly always make the situation even worse. Most lead fouling results from undesirable operating conditions. Once you have learned how this lead fouling occurs you should have no difficulty in avoiding the conditions that induce it.

Here is how it happens. To begin with, avgas does not evaporate as readily as its nearest cousin, automotive gasoline. This lower volatility is necessary to provide sufficient protection from vapor locking, especially at higher altitudes. But, it also makes cold-weather starting less easy. The volatility of TEL and ethylene dibromide is even lower than avgas.

Also, gasoline will not burn until it is converted to a gaseous state. The carburetor or other fuel metering equipment begins this conversion process by breaking the liquid fuel into tiny droplets. This atomization process, as it is called, helps to hasten the conversion but it is actually heat that accomplishes this process. Under normal operating conditions, heat from the engine is quite adequate. However, during initial start up, the only heat usually available is atmospheric. Consequently, the lower ambient temperatures become, the less heat there is for vaporization and the more difficult the process becomes.

With initial start-up under these conditions not all of the fuel reaching the cylinders has vaporized. The fuel that is still in the wet or droplet stage will condense back to a liquid upon contact with the cold metal parts within the combustion chamber. The TEL that requires still higher vaporization temperatures will also condense on the cold metal parts and especially the intake valves. Once the cylinder fires, the heat of combustion quickly vaporizes much of the excess liquid fuel and now the mixture in the cylinder goes from excessively lean to excessively rich. The resulting incomplete combustion produces combustion chamber deposits. As the engine warms up this condition will abate.

Upon application of full power for takeoff the carbon deposits start burning off. The lead does not, but instead bakes into a rock-hard deposit, especially on the intake valves. Thus, any mode of engine operation that results in excessively rich mixture or incomplete combustion will increase chamber deposits. Now add a higher leaded fuel to this kind of operation and you multiply the effects.

At this point you know what lead fouling is and how it occurs. Now let's examine the problems it could cause. While the lead does not actually harm the engine, its presence in the form of deposits can cause trouble. First, and in the most likely order of occurrence, is spark plug fouling. This situation can result in the need for from more than usual cleaning to ultimate failure of the plug to fire. Severity of spark plug fouling depends considerably on the degree and extent of operation under the fouling conditions previously described.

Next in order is sticking valves and piston rings. If the engine is continuously operated beyond the recommended oil change intervals, especially with

"The situation isn't now . . . as

grim as it has been made to seem."

higher leaded fuels, sticking valves and piston rings are likely to result. Lead gets into the lubricating oil by way of blow-by past the piston rings and valve guides. Consequently, excessive lead content in the oil can result in baked on deposits in such high-temperature areas as valve stems and piston rings. This process will eventually reduce the necessary clearance these parts require and they will begin to stick.

Last in order is the problem caused by deposits within the combustion chamber. Within normal operation the exhaust valve can reach temperatures in excess of 1,600° F during its cycle. Upon recontact with its seat the valve must quickly dissipate most of this heat because the cycle can occur more than 20 times per second. Much of the heat picked up by the valve is transferred to the valve seat insert and dissipated by the cylinder head. Under normal conditions this arrangement is quite satisfactory. However, should excessive deposits accumulate on the valve it creates the same effect as increasing the mass of the valve. Now each time the valve heats up there will be more mass to cool. Since the heat transfer capacity of the seat insert remains the same, the valve will be hotter when it opens again. Under such circumstances the valve will get hotter than it normally would during its open cycle.

As more deposits accumulate the situation gets worse. Eventually the valve may exceed its designed temperature range and this will result in premature replacement. Fortunately, the high normal operating temperatures experienced at full and high cruise power tend to burn off much of the deposits accumulated at lower operating temperatures. Thus, failure of exhaust valves from lead deposits can be reduced by proper procedures.

Unfortunately it is a different story for the intake valve. This valve is usually the first component encountered by the fuel-air mixture as it enters the cylinder. Inevitably it gets the heaviest contact with those "wet" mixtures during initial start and warm-up, and also during long power-off descents. During normal combustion the intake valve will get hot enough to bake these deposits, but since it never operates at the high temperatures encountered by the exhaust valve, these deposits have no way of burning off. Consequently, they continue to accumulate. In time such deposits can elevate the operating temperature of the intake valve above its maximum level and this will ultimately lead to early replacement. The cure for intake valve deposits is prevention, so care must be exercised in this respect.

At this point the answer to the second question should be obvious. Neither the fuel nor the lead actually damage an engine, but careless operation with higher leaded fuels can cause trouble eventually.

As for question number three, yes, there are steps you can take to prevent the problems previously described. Here are some of the really important ones:

- Take care to avoid over-priming, especially during cold-weather starts. Excess fuel is a principle factor in deposit accumulation. Once the engine has started, try to hold the speed to approximately 1,000 rpm. Lesser engine speeds require longer warm-up periods and add considerably to deposit fouling.
- If the ambient temperature is +40°F or higher, start taxiing out just as soon as the oil pressure has stabilized after engine start up. (Stabilized means needle steady and not over the top end red line.)
- Avoid low engine speed during taxi operations. While this is sometimes easier said than done, low rpm is a heavy contributor to deposit fouling.
- Complete your preflight runup just as soon as you reach the runup apron or area.
- Make every effort to take off as soon after preflight runup as possible.
- Always open the throttle full for all takeoffs and keep it full until you are at least 400 feet agl. Remember, high power burns off those deposits.
- When forced to hold for takeoff, head into the prevailing wind if possible and operate your engine at 1,000 to 1,200 rpm. If your delay exceeds 10 minutes, gently accelerate your engine to approximately 1,800 rpm for 10 seconds or so, then gently reduce speed to your original setting. This practice will help prevent deposit build up. In extremely hot weather (90°F or more) you may have to settle for a hold speed of 800 rpm. This will depend on how well your engine cools under these conditions.
- If your takeoff delay has exceeded 10 minutes, advance the throttle slowly until at least 2,000 rpm during the initial takeoff roll. For short runways, hold the aircraft in position with the brakes and slowly advance to 2,000 rpm. This technique provides the time necessary to permit the lead to burn off and clear the combustion chamber. A very rapid opening of the throttle will cause the lead deposits to become molten before they can burn off. Once this happens the lead becomes a permanent resident of the spark plugs and combustion chamber.
- Adjust your mixture properly for climb-out above 5,000 feet density altitude and check your climb mixture every 2,000 feet during the ascent. Proper and precise mixture trimming during cruise will do wonders in keeping the combustion chambers clean.
- Lean your mixture any time the carburetor heat is used during cruise flight. This will restore some of the lost power and prevent those very over-rich mixtures attendant with carburetor heat.
- Properly lean for descent and maintain a clean mixture all the way to the level where power will again be added. Long, power-off descents with rich mixtures are one of the worst offenders of combustion chamber fouling.
- Upon landing, taxi into the parking area without delay and again avoid low engine speed as much as possible.
- When landing at high altitude (5,000 feet density altitude) airports, lean the mixture for ground operation.
- Drain lubricating oil at the intervals recommended by the engine manufacturer and don't use additives in your oil.
- Use the correct spark plugs for your engine and replace them when it becomes necessary. Faulty spark plugs misfire frequently and that contributes immensely to deposit accumulation.
- Do not operate your engine on automobile gasoline. There are many valid reasons, all to your advantage, as to why not. You may discover that your insurance is not valid if you do. Neither Lycoming nor Teledyne Continental Motors recognize automotive fuels as suitable for operation in their aircraft engines.

If you practice the recommendations just described, your flying will become more professional, your engine will be much happier and you won't have near the troubles you have heard about. Oh yes, if you happen to be flying with an engine designed for 100 octane, you are even better off than before. The new blue grade 100LL has less TEL than the original green grade 100. Excepting the increased price, life got better for you. □