HOW GOOD IS AVIATION GASOLINE?

by AL HUNDERE / AOPA 42710

■■ For many years the public gave no thought to the connection between cigarette brands with regard to tar content. Ignorance is bliss in a similar manner with regard to aviation fuels. All fuels of a given grade, say 80/87 or 100/130, are not the same.

When I made this statement at last year's AOPA Plantation Party, great interest was expressed in the differences between brands of a given fuel and how one can tell the best brand. Every year from 1952 to 1964, the Bureau of Mines published inspection data on about 100 samples of aviation gasolines representative of all the U.S. manufacturers' production. These data were submitted by the manufacturers as being representative of their production at the time so their poorest quality produced could easily have escaped these reports. The samples are coded in these reports with no information on suppliers or their locations.

Why did the Bureau of Mines discontinue their reports on the quality of aviation gasoline which were made as a cooperative agreement with the American Petroleum Institute? Since the Bureau of Mines is continuing and expanding their reports on jet fuel quality, it can be concluded that the avgas reports were dropped because of inadequate interest in the quality of avgas. When the Bureau of Mines initiated their avgas reports, the airlines were

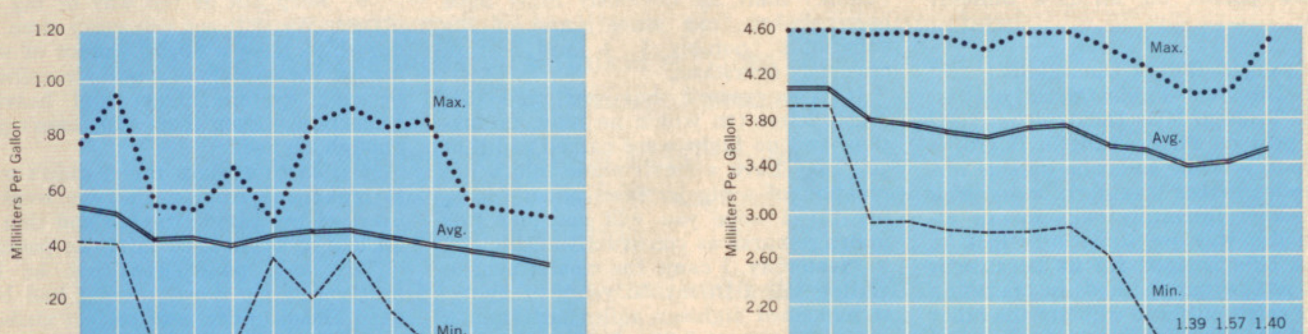


FIGURE 1. Variation in tetraethyl lead content of Grade 80/87 and 100/130 aviation fuels.

Quality is not the best, says combustion expert. Interest in maintaining high quality of avgas has declined since most air carriers have switched to jets. Bureau of Mines has dropped its reports on avgas quality and now is concentrating on jet fuels

keenly interested in the quality of avgas and they demanded quality because their expenditure for fuel is a major item making up their operating costs. This airline interest has now disappeared because of their switch to jets and jet fuels. This leaves only general aviation to be interested in the quality of avgas but no general aviation organization to date has pressed their interest to the point of having any influence.

What quality are we talking about?

When you purchase avgas, the only quality information that you are given is that the antiknock quality equals or exceeds the designated grade. Antiknock quality is expressed in octane numbers like 80 and 87 octane for grade 80/87, and performance numbers above 100 which you can consider to be the same as octane numbers. When you purchase fuel you might obtain, by chance, a tank full of avgas with a big extra bonus in antiknock quality, and the Bureau of Mines' reports show some very high values, such as 121/130 for Grade 100/130. The extra 21 numbers will do you absolutely no good unless by mistake your tank is topped with 80 octane.

There are, however, other differences that do affect engine performance and maintenance. Lead content is such a property, with a variation of three-to-one for Grade 100/130, based on Bureau of Mines' reports. Lead is the main contributor to combustion chamber deposits and spark plug fouling. It is added to the fuel in the form of tetraethyl lead (TEL) to give antiknock quality because it is the lowest cost means for obtaining "octane numbers." TEL consists of 64% lead and 36% carbon and hydrogen and has a boiling point of 388° F, at which temperature it decomposes. If one removed the metallic lead from four gallons of Grade 100/130 fuel of maximum lead content, it would be sufficient to make a one-ounce lead sinker. Figure 1 shows the variation in TEL content for both Grade 80/87 and Grade 100/130.

These data are from Bureau of Mines' reports. Normally, the lower the lead content, the more costly the fuel is to produce, and a 100-octane fuel can be produced with zero lead content. In the manufacture of fuel, an effort is made to keep the TEL from forming engine deposits by adding a lead scavenger, which is ethylene dibromide. This is only partially effective and, as a result, when the lead content is increased, the amount of lead deposit is increased. This is illustrated in Figure 2 showing the spark plugs from a six-cylinder, horizontally opposed, carburetor aircraft engine after two 100-hour tests, one with 2.0 ml (milliliter) TEL and the other with 4.6 ml TEL per gallon. The same fuel was used for both tests except that additional lead was added for the high lead test and therefore the only variable was lead content. These tests were conducted under carefully controlled conditions simulating a typical flight with a 4¼-hour cruise period at 5,000 feet with no mixture leaning. The 4.6 TEL content used for these tests is the maximum lead content permissible for Grade 100/130 by military specifica-

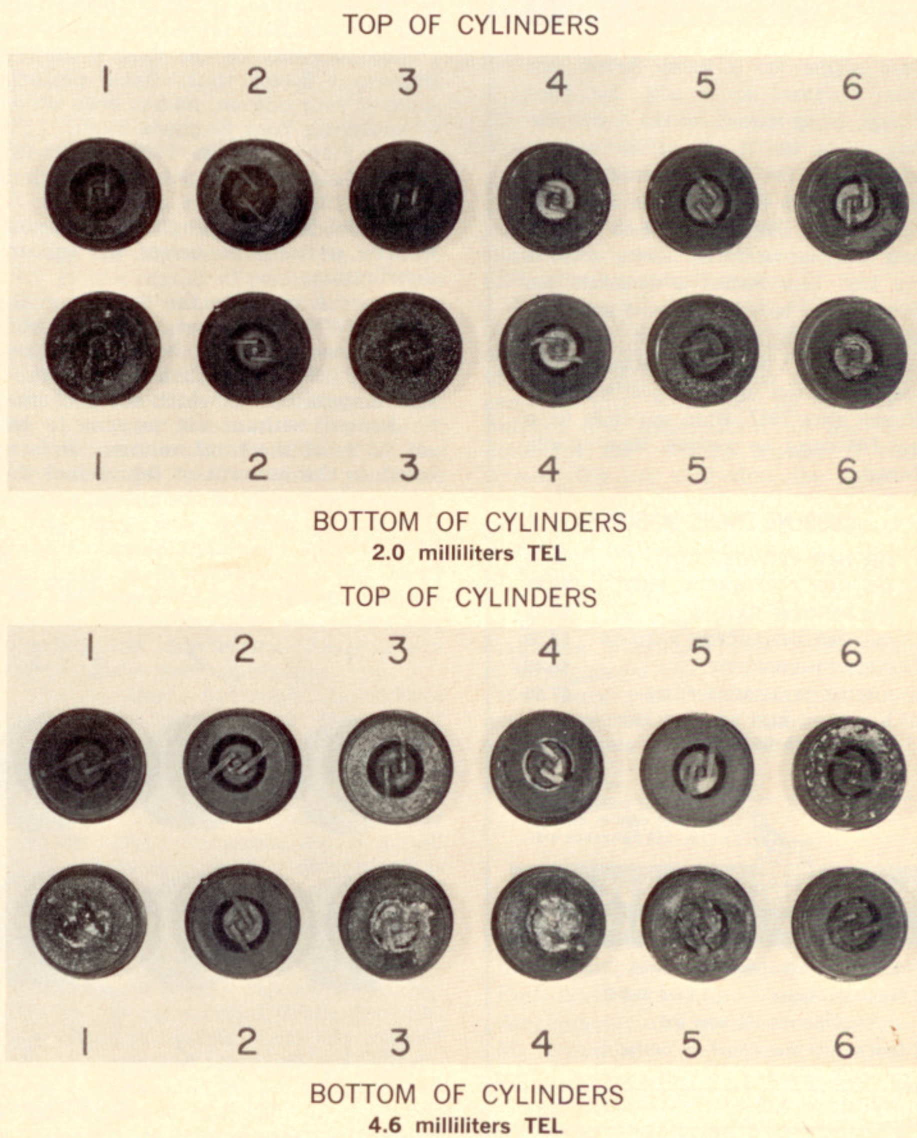


FIGURE 2. Spark plugs after 100 hours of operation under identical conditions, except for tetraethyl lead content of fuel.

tion. The Bureau of Mines' reports show that for 1963, 30% of the Grade 100/130 fuels had a lead content below 3.0 ml TEL, but in 1964, the percentage was reduced to 15%. This would indicate that the lead content is increasing with time which is to be expected if there is no change in the incentive for the continued production of low lead content fuels.

How much lead an aircraft engine can digest without causing lead deposit problems, such as spark plug fouling, is dependent on the degree of mixture leaning, power output, cooling, type of spark plugs, and engine design factors. One thing is certain: if your operation is one where you have spark plug fouling from lead deposits or any other lead problem, reducing the lead content will reduce the problem. Mixture leaning is the most important variable influencing spark plug fouling from lead deposits. Figure 3 shows the improved condition of the spark plugs when the 4.6 ml TEL test, shown in Figure 2 was repeated with the mixture leaned to peak EGT for the leanest cylinder for cruise at 65% power and 100° F lower EGT for all higher powers.

The volatility of the fuel is another important factor that affects performance of your engine. As has been shown ("Analyzing Your Engine's Health," The AOPA PILOT, August 1966, page 48), the fuel-air mixture going to the individual cylinders varies greatly even for most fuel injection engines. The more volatile a fuel, the better the mixture distribution.

Figure 4 presents the data from Bureau of Mines reports on the 90% distillation point for both 80/87 and 100/130. The 90% distillation point is the temperature to which the fuel must be heated without air present to boil off 90% of the total volume. It is related to the amount of liquid fuel that covers the inside of the intake pipes of an engine, thereby contributing to poor mixture distribution. Of course, if a fuel is too volatile, it will cause excessive fuel vapor to form in the fuel system before it leaves the carburetor or injectors and is brought into contact with the air. When this type of vapor formation is excessive, it is called vapor lock. The vapor pressure (Reid) is limited to seven pounds per square inch. A 100-octane fuel can be produced with seven pounds vapor pressure that would have a 90% distillation point of only 154° F, which is about half the maximum 90% point shown in Figure 4. Such a fuel, however, would be prohibitively expensive.

What other properties are specified for an aviation fuel? The most important are as follows:

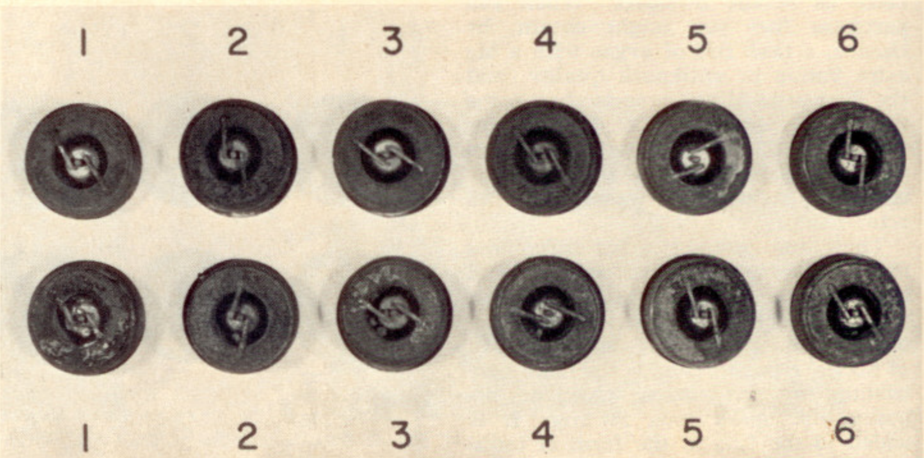
1. *Distillation.*—In addition to the 90% point, the 10, 40, and 50 and end point (100%) are specified, plus the sum of the 10% and 50% points. In the distillation test, the residue and loss are also measured and specified.

2. *Gum Content*—This is a measure of the residue left after evaporation under specified conditions. Gum is the major contributor to induction system deposits of an engine and if sufficiently great, they can reduce air flow and power as well as cause intake valve sticking. The Bureau of Mines reports show a range from zero to two milligrams per 100 milliliters of fuel. Up to three milligrams are considered acceptable by current specifications.

3. *Potential Gum*—This is a measure of how much gum might form after storage for an extended period. The Bureau of Mines reports show a range from zero to three, with 10 considered acceptable.

4. *Sulphur Content* — The sulphur content of avgas is much lower than motor fuels, and is limited to 0.05%, with the Bureau of Mines report showing a range from 0 to 0.04.

TOP OF CYLINDERS



BOTTOM OF CYLINDERS

FIGURE 3. Spark plugs after repeat of 4.6 milliliters TEL test shown in Figure 2 but with mixture leaned to peak for 65% cruise.

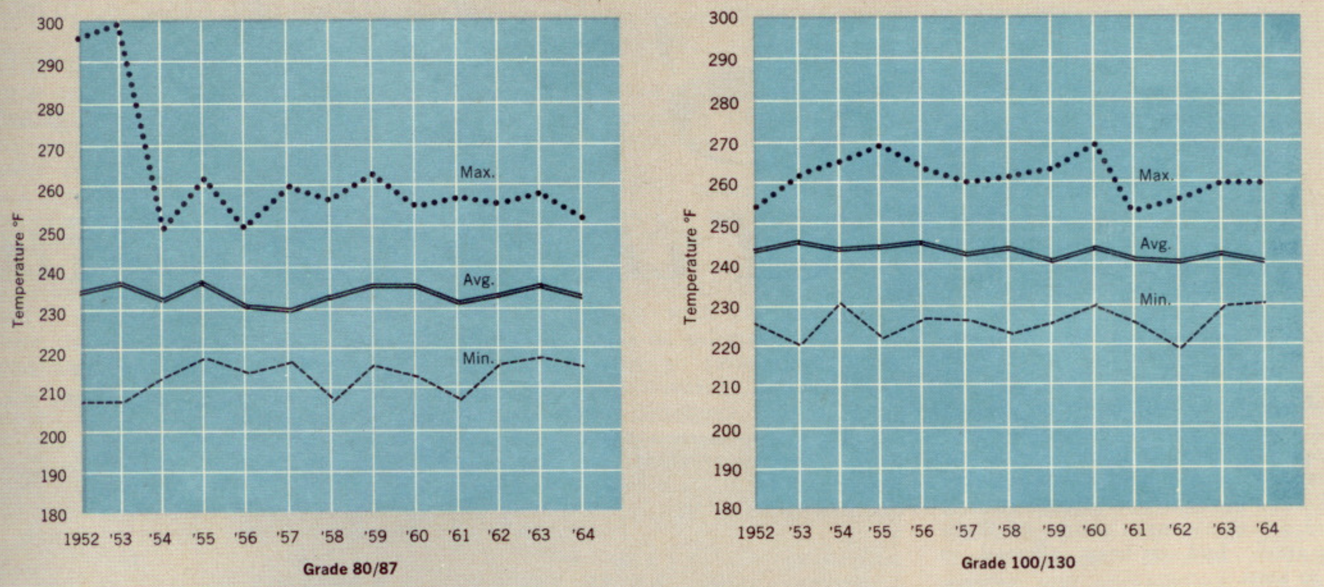


FIGURE 4. Variation in volatility of Grades 80/87 and 100/130.

5. *Heat of Combustion*—The amount of heat obtained in the combustion of a fuel is of utmost importance because it is directly related to the range obtained with the fuel. However, the Bureau of Mines' reports show a very small difference between fuels, 18,720 to 19,102 BTU's per pound or 111,800 to 110,600 BTU's per gallon, or about a 1% variation.

6. *Water Intolerance*—Avgas specifications require that the fuel shall neither gain nor lose in volume when shaken with water. The Bureau of Mines' reports show a water tolerance range from 0 to 1 with 2 being specified as maximum.

7. *Freezing Point*—Although specifications call for a minus 76°F maximum freezing point, all fuels are well below this limit, and this property is of little interest except for rare exceptions.

8. *Color*—Avgas is dyed red, blue, green, brown and purple to indicate 80/87, 91/98, 100/130, 108/135, and 115/145, respectively.

9. *Contamination*—This property is presently not specified but is very important. Contamination is the amount of foreign material, such as rust, dust, etc., that gets into the fuel by the time it gets into your tank. Part of this you observe when you drain your fuel tank sumps and filters but indications are that a considerable amount is getting into some aircraft engines, as evidenced by the analysis of spark plug deposits; in fact, possibly enough to contribute to preignition from combustion chamber deposits.

Why don't all the fuel manufacturers provide the highest quality fuels possible? It is a matter of economics. What sells avgas is not the quality of the fuel but sales promotion. When you land at an airport where several brands of fuel are available, you will probably select the one that has the biggest sign, the most eager line-man to flag you in, the prettiest truck, is closest to the restaurant, the one for which you have a credit card, etc.

The only way general aviation is going to obtain maximum quality aviation fuels is to demand it. But how? The only way is to follow the procedures used by the airlines for years—writing specifications and testing. Let's take a look at these two approaches:

Specifications—Although the airlines in the past have done a fine job of writing specifications for avgas, demanding maximum quality consistent with cost, these specifications are not in use for the avgas used by general aviation. The commercial aviation fuel specification most widely recognized is that of ASTM (American Society for Testing Materials) and designated D910-57T, which calls for a maximum of 3.0 ml TEL/gallon for 100/130 but the Bureau of Mines' reports show that 60% of our commercial Grade 100/130 fuels don't meet this limit but instead meet the military specification (MIL-G-5572C) which calls for a maximum lead of 4.6 for Grade 100/130.

Therefore, if general aviation is going to obtain the highest possible quality fuel via the specification route, some general aviation organization has to demand it. You would then select only those brands of avgas that met the general aviation specifications.

Testing—All the major airlines have laboratories to conduct complete tests on fuel samples from all their sources of supply. Although each plane owner can't do this, what can be done is to publish test information as has been done for the various brands of cigarettes. We are told that the sales of cigarette brands with low tar content have greatly increased since the publication of test data showing tar content by brand name. This raises the question as to whether you would buy the brands of avgas with low lead content if this magazine published this information. It is suggested that you let The AOPA PILOT have your views on this if you are interested in obtaining the best aviation fuels for your money. □

THE AUTHOR

Al Hundere, author of "How Good Is Aviation Gasoline?" is president of Alcor Aviation, Inc., of San Antonio, Tex., and is engaged in engine-fuels-lubricants research, test method development and product evaluation. Mr. Hundere is a frequent contributor of articles in this general field to The AOPA PILOT, the last such article being "Analyzing Your Engine's Health," which appeared in the August 1966 issue.