Tests made by author indicate that automotive fuel can be used in some aircraft engines without adverse effects. He warns, however, that 'it is very dangerous' to do so 'without complete knowledge of the factors involved.' It's also illegal to use fuels other than those specified by aircraft engine manufacturers

by AL HUNDERE / AOPA 42710

Autogas For Avgas?

EDITOR'S NOTE: An often-asked question in general aviation is, "Why can't a good grade of automotive gasoline be used as fuel in aircraft engines?"

This question is not new; it has been asked for years. The answers have been varied, but they usually boil down to this: automotive gasoline will ruin the aircraft engine and likely will cause an accident. The admonishment, "You will be risking your neck if you try to substitute autogas for avgas in your engine," has caused most pilots to take heed—as they should. However, we have all heard of a few who have used automotive fuel in their flying and gotten away with it. We also have heard of other pilots who met up with the predicted catastrophe.

The PILOT took this intriguing question about fuels to one of the country's leading authorities on combustion engines and their fuels—Al Hundere, president of Alcor, Inc., of San Antonio, Tex., who has been involved in aviation fuel research and testing for many years. We asked for his opinion and findings. This comprehensive article is his report. He also gives some recommendations for the future, among them being a common fuel for both automobiles and aircraft.

Mr. Hundere believes that automotive fuels can be used in aircraft engines under controlled conditions. He points out that some engines respond better than others and that some gasolines give better performance than others. He warns that the substitution of any fuel other than the kind specified by the manufacturer of the aircraft engine is "very dangerous" without full and complete knowledge of the factors involved. The PILOT joins in that warning.

Publication of this article is not meant to inspire pilots to go out and fill up their tanks with gasoline from the corner filling station, or to start testing on their own. "Autogas For Avgas?" is considered by The PILOT—and we hope by our readers, also—as a progress report on investigations being made on matters of considerable importance to pilots and aircraft owners. Other tests are being made by the manufacturers of fuels and engines. It would appear that there are developments yet to come.

Meanwhile, remember that it is both risky and illegal for the individual pilot to use fuel not specified by the manufacturer of the engine involved. Bob Bornarth discussed the legal aspects of this situation in his Answers For Pilots department in the September issue of The PILOT (page 142).

■■ Since the publication of my PILOT article, "How Good Is Aviation Gasoline?" [June 1967], a number of pilots have asked about using the same fuel that they use in their car (automobile gasoline, or autogas) in place of aviation gasoline (avgas). My answer is that there is absolutely nothing wrong technically in doing so if one has the necessary know-how. I say "technically" because legally one is required to use only fuels approved by the engine manufacturer.

If automotive fuel could be used in place of avgas, several advantages could result. First would be a saving in one's fuel bill. In my area, regular autogas now sells retail for 13 cents less than Grade 80/87 avgas. In 1,000 hours of flying an airplane, averaging 12 gallons an hour, this would result in a saving of $1,560. This difference of 13 cents is based on service station versus airport retail prices for the same brand, and it is recognized that there is a difference in markups. This same company has posted bulk prices of 16.1 cents and 23 cents for regular autogas and 80/87 avgas without tax. This difference of 6.9 cents in 1,000 hours at 12 g.p.h. would result in a fuel bill saving of $828.

The second possible advantage in using autogas for avgas would be that of convenience in certain cases. If you keep an airplane in your backyard and you maintain a gas pump for refueling your automobiles and trucks, as ranchers and farmers often do, it is an advantage to be able to taxi your airplane up to the same gas pump.

A third reason for considering the use of autogas would be in the event of an emergency. I recall a case in Brazil where I used—in an emergency—a clear fluid, and my only basis for assuming that it was suitable for my airplane was that it smelled and felt like gasoline. The editor of The PILOT told me of an emergency he had experienced in Brazil, where he had to use 80 octane gasoline in his *Twin Comanche*, for which 100 octane is specified. If 80 octane avgas had not been available, he could as well have used autogas.

I would like to stress that it is very dangerous to use any other fuel than that specified, without full and complete knowledge of the factors involved. The purpose of this article is to provide this knowledge, which can be most valuable when one must use automotive gasoline in case of an emergency. In my opinion, consideration should be given to having an aviation grade of regular automotive fuel replace the present Grade 80/87 avgas. Until such a grade of autogas becomes available and is approved by the engine manufacturers, it is recommended that automotive fuel only be used when avgas is not available. The use of automotive gasoline has caused a number of fatal accidents resulting from engine power loss due to vapor lock, which will result from using an autogas that has too high a vapor pressure for the temperature involved.

The suggestion of using autogas as avgas is not new. In 1943, the U.S. Army seriously considered operating all combat vehicles, including liaison aircraft, on the same general-purpose automotive gasoline, which was of very poor quality compared to today's autogas. After the Army gained considerable experience with the use of automotive gasoline, the idea was abandoned for various reasons, including "loss of pilot confidence." In 1946, Dr. D. P. Barnard, then director of research for a major oil company, in an article, "Where to Refuel?" stated, "This writer believes that the usefulness of private-owner aircraft should be materially increased by employing the existing motor gasoline servicing facilities and, possibly, operating such aircraft on motor gasoline." Incidentally, Dan Barnard (when he retired from his oil company job about 10 years ago) became consultant to our Department of Defense on aviation fuels and lubricants, and is still active as a private pilot. When I discussed the subject article with him, he told me that he had just purchased a new Cessna *Skylane*.

Presently, the engine manufacturers admonish against the use of autogas, as evidenced by an engine manufacturer's bulletin, dated 1964, which states:

"It is not permissible in any instance to use an automotive fuel in aircraft engines, regardless of its octane or advertised features. The difference in the properties and composition of automotive gasoline and aviation gasoline makes automotive fuels unsafe for use in aircraft. The main differences between automotive and aircraft fuels are as follows:

"1. Automotive fuels have a wider distillation range than aircraft fuels and this promotes poor distribution of the high anti-knock components of the fuel. Further, the octane ratings of automotive and aircraft fuels are not comparable due to the different methods used to rate the two types of fuel. This would result in an appreciable difference in actual knock rating for two fuels which have the same octane number. This difference could lead to destructive preignition or detonation.

"2. Automotive fuels are more volatile and have higher vapor pressure which can lead to vapor lock. Also the greater volatility increases the fire hazard.

"3. Tetraethyl lead in automotive fuels contains an excess of chlorine and bromine whereas aviation fuels contain only the chemically correct amount of bromine. The chlorine is very corrosive and under severe conditions can lead to exhaust valve failures.

"4. Automotive fuels are less stable and can form gum deposits. Gum deposits can result in valve sticking and poor distribution.

"5. Automotive fuels have solvent characteristics not suitable for aircraft engines. Seals, gaskets and flexible fuel lines are susceptible to attack."

Such statements have undoubtedly discouraged most pilots from considering the use of autogas even in an emergency. In my opinion, all of the above reasons against the use of automotive gasoline are mostly not justifiable for today's autogas. Also, I believe that such views against the use of automotive gasoline are a carryover of experience dating back 20 or more years when autogas was of rather poor quality.

Its quality has improved greatly over the last 20 years. Twenty years ago, the anti-knock quality of the average *premium*-grade motor gas was less than minimum-grade 80/87 avgas. Today, it would be difficult to find a *regular*-grade automotive gasoline that doesn't have anti-knock quality exceeding the minimum required for Grade 80/87 aviation gasoline. The vast majority of today's regular-grade motor fuels considerably exceed the anti-knock quality of minimum-grade 80/87 avgas. Why is this? It is simply because the constituents that previously went almost exclusively into aviation fuels have been going into automotive fuels in ever-increasing percentages.

Automotive gasoline and aviation fuels are both composed of hydrocarbons plus additives and impurities. As will be shown later, automotive gasoline contains many more larger-size, as well as smaller-size, hydrocarbons than avgas. This is normally referred to as automotive fuel having a wider distillation range. Automotive fuel uses a slightly different additive to reduce the formation of lead deposits in the combustion chambers, but the maximum lead content for automotive fuel is less than for the higher grades of avgas. Also, automotive fuel contains special additives such as TCP (a phosphate) to reduce spark-plug fouling from lead deposits, and it may contain detergents to reduce deposits in the carburetor and induction system. These special additives are present in very minute quantities, and it is my opinion that they can do the same good in aircraft engines as claimed for your car engine.

Let's examine each of the above claims against the use of automotive gasoline for avgas, with regard to their applicability to today's autogas.

Composition

First is the claim that "the difference in the composition of automotive gasoline and aviation gasoline makes automotive fuels unsafe for use in aircraft." If one lines up by size the hundreds of different hydrocarbons that make up both avgas and automotive fuel, then the cut for aviation gasoline would represent the center portion, plus concentrating on the higher-octane hydrocarbons for the higher grades such as 100/130 and 115/145. The hydrocarbons that are excluded from aviation gasoline, but that are used in autogas, are basically the same as those used in avgas, except for size. One advantage of automotive fuel that results from this difference is that of more miles per gallon—an average of about 3%—because of the greater heat energy per gallon.

Also, from the composition standpoint, there is the claim that "automotive fuels have solvent characteristics not suitable for aircraft engines." Any validity to this claim must date back about 30 years when there was considerable difference between autogas and avgas with respect to composition. The difference in solvency between today's automotive fuel and aviation gasoline is due to the difference in aromatic content. Aromatics are added to both autogas and avgas to increase the upper grade number, or octane number. The maximum aromatic content for avgas is limited to about 25% by the heating value specification, which is on a weight basis; however, one can find automotive fuels with aromatic contents as high as 40%. The higher the aromatic content, the more miles per gallon for the same mixture setting on an EGT basis.

The only aircraft problem I have ever heard of that has resulted from fuel solvency was the result of using avgas with an aromatic content that was not too high, but too low, causing insufficient rubber swelling, resulting in fuel leakage around the seals.

Anti-Knock Quality

Anti-knock quality is one of the two most important properties to consider in using automotive fuel as avgas; the other is vapor pressure. Anti-knock quality is that property of the fuel that determines whether a given fuel can be used without knock, also called detonation. Any pilot who has, by mistake, used Grade 80/87 in an aircraft for which 100/130 is required, knows fully the meaning of using fuel of insufficient anti-knock quality. In this case, severe detonation usually results, which leads to preignition and engine failure from one or more burned pistons and/or cracked cylinder heads. Each engine is designed for a given grade of fuel, say Grade 80/87, which means that the engine will be free of detonation with a fuel of the specified grade, even under conditions of maximum rated power and maximum allowable engine temperature. There is no advantage in using a fuel of higher anti-knock quality or grade number than that specified. As to how much the anti-knock quality can be lowered below that specified without getting into detonation, this depends on the operating conditions and the anti-knock margin built into the engine.

As you may know, anti-knock quality is expressed in octane numbers, like 80 and 87 octane for Grade 80/87, and performance numbers above 100 which one can consider to be the same as octane numbers. While it is not factual to

Table I - Anti-Knock Quality

	Min.	Avg.	Max.
Avgas, Grade 80/87	80.0/87.0	82.6/88.2	86.6/90.7
Autogas, Regular	81/87*	85.4/91.4*	89/95*
Autogas, Premium	89/95*	91.3/97.3*	95/101*
Avgas, Grade 100/130	100/130	109/131	121/136

* Second grade number for autogas not from Bureau of Mines reports but obtained by adding six numbers to first grade numbers.

say that "the octane ratings of automotive and aircraft fuels are not comparable due to the different methods used to rate the two types of fuels," it is true that the octane numbers that oil companies use in their advertising of automotive fuel are not the same as either of the grade numbers used for avgas. However, two octane ratings are made on autogas: the Motor Method and the Research Method. The former, or Motor Method, is identical to the first number in the aviation gasoline grade number, and the government specification for avgas permits the use of the Motor Method for the first grade number. Any reputable oil company can supply the Motor Method octane number for any grade of their automotive fuel. Normally, they cannot, however, supply the octane number by the Supercharged Method, which is the second number in the avgas grade. For all practical purposes, one can assume for the better brands of automotive gasoline that the second grade number is six numbers above the first. For example: if you know the Motor Method octane number of a particular automotive gasoline is 86, then for aircraft use, the anti-knock quality can be considered to be Grade 86/92.

What are the grade numbers for today's automotive gasolines? Motor Method octane numbers are published annually by the Bureau of Mines for every area of the country, with over 5,000 samples from over 80 oil companies. Table I presents a comparison between automotive fuel and aviation gasoline with respect to grade numbers. Note that the average regular-grade automotive fuel is Grade 85.4/91.4 and that the premium-grade automotive gasoline is 91.3/97.3. Note also that the maximum grade number for premium autogas is 95/101.

The statement "automotive fuels have a wider distillation range than aircraft fuels and this promotes poor distribution of the high anti-knock components of the fuel," etc., could imply that knock or detonation can result because of the wider distillation range. I know of no substantiation of this for our present-day light aircraft engines, and do not believe it can be substantiated. The reason for this opinion is that poor distribution to the individual cylinders is largely a low-temperature problem, whereas knock or detonation is a high-temperature problem. Another way of saying this is that under the severe operating conditions where detonation is of concern, the temperatures are sufficiently high that distribution to the individual cylinders should not be significantly different between automotive gasoline and avgas.

Vapor Pressure

Yes, it is true that most "automotive fuels have higher vapor pressure which can lead to vapor lock," and vapor lock is very dangerous because it results in loss of engine power. But vapor lock can readily be avoided with proper knowledge.

Vapor pressure is that property of a fuel that defines its tendency to form fuel vapors. The higher the vapor pressure, the greater the tendency to emit vapor and cause vapor lock. Vapor lock occurs when the fuel vapor formed in the fuel system is sufficient to restrict the flow of liquid fuel and interfere with normal engine operation.

The first indication of vapor lock is leaning of the mixture. Shortly after World War II, I conducted flight tests on four single-engine aircraft, low and high wing, 85 to 185 h.p., using fuels of vapor pressures up to 13 pounds, with outside air temperatures up to 100°F. For the condition of a 100°F day, it was found that the maximum permissible vapor pressure for three aircraft tested varied from 8.0 to 10.0 before encountering incipient vapor lock, i.e., the first indication of mixture leaning due to vapor formation. These data should be applicable to today's aircraft because there have been no significant changes in the design of the fuel systems used. One airplane tested gave incipient vapor lock on a 7.0-pound fuel on a 100°F day. However, after modifying the fuel system, the tendency to vapor lock was reduced to the point that a 13.0-pound fuel gave no more than incipient vapor lock.

Table II presents vapor pressure data from the Bureau of Mines reports. Note that the average summer grade automotive fuel has a vapor pressure of 9.0, and the winter grade, 11.7. For some areas, the vapor pressure deviates considerably from the average; for example, in the southern mountain states, more than 50% of the summer automotive gases are below 8.0 pounds. This means that autogas presents minimum danger of causing vapor lock in aircraft use if the autogas is utilized in the area where it is sold, at the time when it is sold. The major danger stems from taking winter-grade automotive gas from a frigid area and using it in a high-temperature area.

Table II - Vapor Pressure

	RVP* In PSI		
	Min.	Avg.	Max.
Avgas, Grade 80/87	5.5	6.6	7.0
Autogas, Summer	5.3	9.0	11.2
Autogas, Winter		11.7	14.9
Avgas, Grade 100/130	5.5	6.5	7.0

*Reid Vapor Pressure

Excessive vapor formation is a temperature and altitude problem. The relationship between fuel temperature and vapor formation is shown in Figure 1, for sea level and a 7,500-foot altitude. The maximum allowable fuel temperature for this chart is based on the formation of sufficient vapor to have a 50-50 combination of vapor and liquid fuel. Some aircraft can tolerate much greater quantities of fuel vapor. The maximum allowable outside air temperature shown in Figure 1 is based on the fuel temperature at the carburetor inlet being 20°F above the OAT. This temperature increase, however, can be as much as 40°F for a poorly designed fuel system. The fuel temperature increases approximately 1°F for each degree of increase in outside air temperature.

What does Figure 1 mean? It simply means that the higher-vapor-pressure autogas can be safely used in aircraft if the temperature is sufficiently reduced to compensate for the vapor pressure involved. For example, if one has a 10.0-pound fuel and it is an 87°F day, the vapor formation will be no more than with a 7.0-pound fuel on a 105°F day. Likewise, if one has a 13.0-pound fuel and it is a 74°F day, the vapor formation will be no more than with a 7.0-pound fuel on a 105°F day. Another way of saying this is that the maximum allowable OAT is decreased approximately 6°F for each pound increase in vapor pressure.

Note also in Figure 1 that vapor formation increases with altitude. If one were taking off from Mexico City at 7,500 feet with a 13.0-pound fuel, the maximum allowable fuel temperature would be 82°F, compared to 94°F at sea level.

It should be pointed out that the tendency for vapor lock not only increases with altitude, but also with the rate of climb. For example, a turbocharged aircraft with a high rate of climb might not have a vapor-lock tendency with a high-vapor-pressure fuel during takeoff at the limiting OAT for the fuel, but could easily encounter a vapor problem if it climbed so rapidly to altitude that the tank fuel had minimum chance to cool.

Referring to the above claim that "the greater volatility [of automotive fuel] increases the fire hazard," the only basis that would make this claim valid would be the case of fuel spillage. Under this condition, one probably couldn't tell any difference between avgas and a 13-pound motor fuel except on an extremely cold day. The greater vapor formation of autogas under this condition would have an offsetting advantage by making engine starting easier.

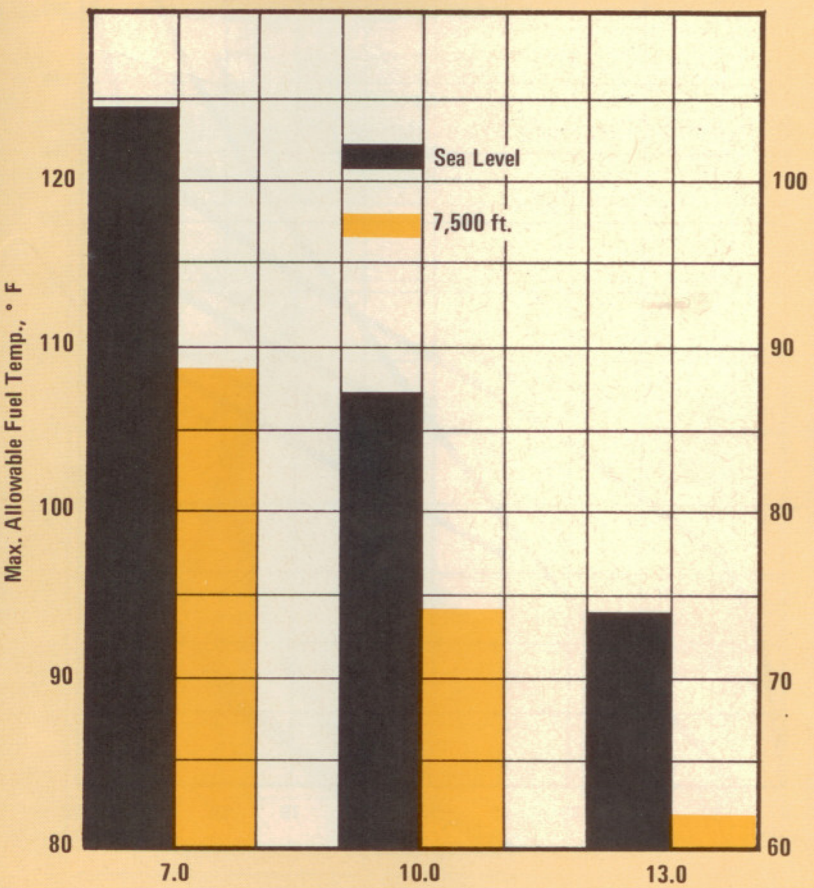
Table III - Tetraethyl Lead Content

	Milliliters per gal		
	Min.	Avg.	Max.
Avgas, Grade 80/87	0.0	0.3	0.5
Avgas, Grade 100/130	1.4	3.4	4.6
Autogas, Regular	0.4	2.04 (2.16)*	4.0 (4.23)
Autogas, Premium	0.0	2.66 (2.81)	4.0 (4.23)

* Figures in brackets are lead content in grams lead per gallon as normally used in expressing lead content for Autogas.

Effect Of Vapor Pressure On Maximum Allowable Temperatures

Figure 1



Lead Content

Yes, it is true that the average autogas has a higher lead content than Grade 80/87 avgas. The effect of lead content on aircraft engine performance was covered in my article, "How Good Is Aviation Gasoline?" [June 1967 PILOT].

Table III presents a comparison between autogas and avgas with respect to lead content. Note from Table III that the average regular-grade autogas contains about 1.5 milliliters (ml) of TEL (tetraethyl lead) more than the maximum for Grade 80/87 avgas, but 1.4 ml less than the average for Grade 100/130 avgas. In considering the significance of this difference in lead content, keep in mind that practically all engines for which Grade 80/87 avgas is specified are also approved for operation on Grade 100/130. One often has to operate on this higher-grade fuel when 80/87 is not available. It is interesting to note from the Bureau of Mines reports on automotive fuel that there is available a premium autogas of zero lead content of sufficient anti-knock quality to satisfy my *Travel Air*, for which Grade 91/96 avgas is specified.

Let's examine the claim that the "tetraethyl lead in automotive fuels contains an excess of chlorine and bromine whereas aviation fuels contain only the chemically correct amount of bromine. The chlorine is very corrosive and under severe conditions can lead to exhaust valve failures."

Yes, there is a difference in the type and amount of lead scavenger used. By lead scavenger, we mean an additive that is added with the lead to aid in its removal from the combustion chamber after combustion. The lead scavenger used with the TEL of avgas is 1.0 theory of ethylene dibromide, whereas automotive fuel TEL has 1.5 theory of a mix-

Table IV - Comparison Of Motor And Aviation Mixes Of TEL In O-290-C Lycoming Engine

	Motor Mix	Aviation Mix
TEL Content	3.0	3.0
RVP, PSI	7.6	7.6
90% Point	325	325
Test Duration, Hrs.	110	110
Hours Full Power	50	50
Test Results		
Valve Heads	Severely Etched	Severely Etched
Valve Seats	Good	Good
Valve Sticking	None	None
Combustion Chamber Deposits, Grams	77.0	124

Reference: R. V. Kerley, SAE Transactions, April, 1947

ture of ethylene dibromide (0.5) and ethylene dichloride (1.0).

As to whether this difference in lead between autogas and avgas can cause exhaust valve failures, I have only verbal reports to this effect. The only available actual test data that I have been able to locate are presented in Table IV.

This table presents the results of two identical aircraft engine tests, one with motor-mix TEL and the other with aviation-mix TEL. (The TEL used in autogas is called "motor mix.") These tests were conducted by the Ethyl Corporation under very carefully controlled conditions. Although the exhaust-valve heads were badly corroded due to the very severe operating conditions, it was not possible to tell any difference between motor and aviation mixes of TEL. It will be noted from Table IV, however, that the motor TEL mix gave only 62% of the combustion chamber deposits obtained with the aviation TEL mix. This is probably the result of the motor-mix TEL's containing 50% more scavenger.

Distillation Range

Let's go back to the claim that "automotive fuels have a wider distillation range than aircraft fuels and this promotes poor distribution of the high anti-knock components of the fuel." Figure 2 shows the average boiling range for autogas in comparison with avgas. Note that to boil off 50% of the average autogas, it must be heated to 207°F, compared to 221°F maximum for avgas. Likewise, to boil off 90% of the average autogas, it must be heated to 325°F, with the maximum being 373° and the minimum 275°—the latter being also the maximum for avgas.

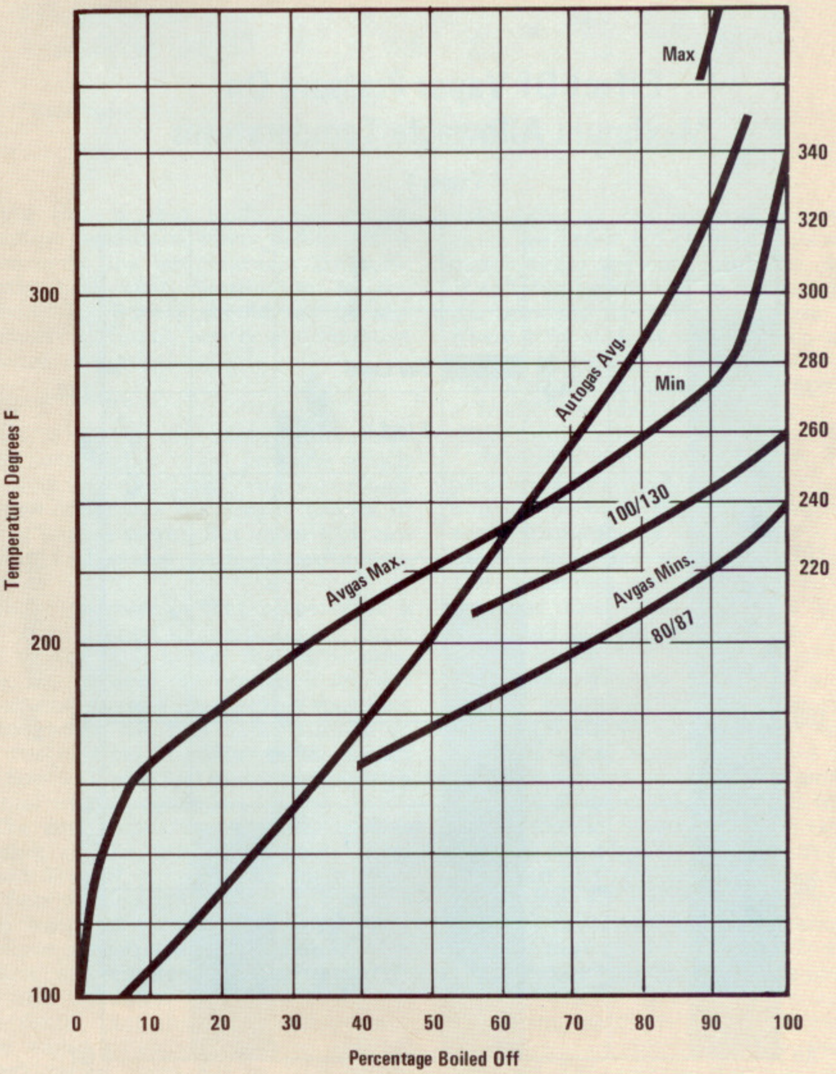
How will the wider distillation range of autogas affect aircraft engine performance? It is true that the higher 90% point and end point of autogas can contribute to poorer fuel distribution to the individual cylinders—which, as pointed out above, is a low-temperature problem, with the degree of the problem being a function of the engine design. Even under minimum temperature conditions of the most critical engines, the problem is not considered serious.

There are some beneficial effects of the wider distillation range of autogas. First, the problem of carburetor ice may be reduced, because fuel vaporization is spread over a greater distance in the induction system. A second benefit is that of easier starting on a cold day because more of the autogas will vaporize during starting.

Before leaving the subject of fuel distillation range, I would like to point out that far more can be done to improve mixture distribution by improving carburetor air heating systems than anything the fuel manufacturer can do. It has been my observation that carburetor air heating systems on all our light aircraft are designed solely to melt ice, with no concern for using the heat to improve mixture distribution. I have flown several light aircraft equipped

Distillation Ranges Of Autogas And Avgas

Figure 2



with Alcor EGT Engine Analyzers, and in every case the mixture distribution has been poorer with the carburetor air heater full-on than full-off. Typical data are presented in Figure 3 for a *Super Cub* with O-320 engine, along with data from a 12-cylinder Rolls Royce Merlin engine. The "spread in EGT" is the EGT of the leanest-running cylinder, minus the EGT of the richest-running cylinder. Note for the Merlin engine that the higher the mixture temperature, the better the mixture distribution. However, for the *Super Cub*, a small amount of heat improves the distribution, but further heat has a harmful effect. In my opinion, the *Super Cub* could have an improvement in mixture distribution, as shown by the dashed line, if proper attention were given to the design of the carburetor air heating system.

Gum and Sulphur Content

Next, let's examine the claim that "automotive fuels are less stable and can form gum deposits. Gum deposits can result in valve sticking and poor distribution." It is true that gum deposits are definitely undesirable, but today's automotive gasolines are relatively low in gum content compared to what has existed in the past; in fact, if you purchase your autogas from the better oil companies, the gum content is not significantly different from that of avgas. Of more concern than gum content is sulfur content. The average autogas has a sulfur content 3.5 times as high as the average avgas, and the poorest quality of autogas has a sulfur content 18 times the average for avgas. The average avgas has a sulfur content of only 0.01%, but the maximum is about the average for autogas.

Recently I conducted flight tests on a 1964 *Super Cub* at Imperial Valley, Calif., to compare regular-grade autogas with the specification-grade 80/87 avgas. This airplane has the Lycoming O-320 engine rated at 150 h.p. The equivalent aviation grade of the autogas was 86/92, and the gas was purchased directly from automotive service stations. The operation on autogas totaled nine hours, and the data obtained are summarized in Table V. Each data point is the average of three or more tests. The power output was compared by determining the time to climb from −128 to 3,000 feet. (Brawley Airport in Imperial Valley is 128 feet below sea level.) The climb temperatures were measured 30 seconds after takeoff. The cruise temperatures were all determined at an engine speed of 2,400 r.p.m. The EGT values are in degrees Fahrenheit from the reference (*).

It was concluded from these tests that there is no measurable difference between autogas and avgas for the conditions involved. The differences shown in Table V are well within the repeatability from test to test with either fuel; for example, the 3.5-second difference in the average time for climb is insignificant compared to the 10-second (4%) variation from test to test.

After completing the tests on the *Super Cub*, I flew my *Travel Air* on regular-grade autogas, but with Texas's fuel rather than California's. Again, the equivalent aviation grade was 86/92. The fuel specified for my O-360 engines is Grade 91/96 avgas. I wanted to see how much manifold pressure I could use before encountering detonation. At 6,500 feet altitude, cruising with 2,300 r.p.m., I was able to lean out to peak EGT at full throttle (23.0 inches Hg) without encountering detonation. This might not have been true if the outside air temperature had been maximum

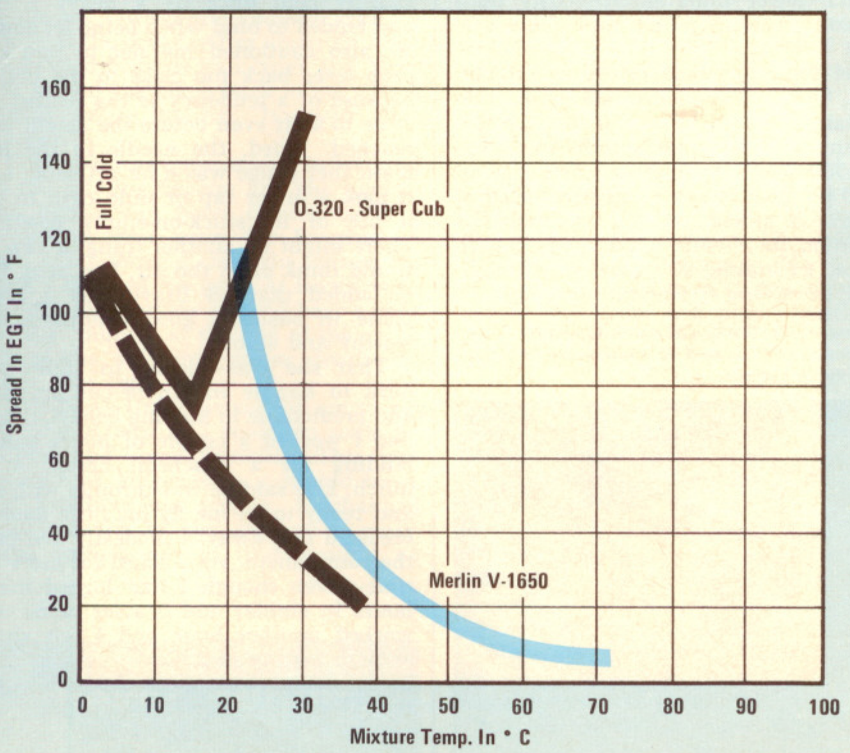
Table V - 1964 Super Cub Flight Test Results

	Avgas*	Autogas*
Avg. time to climb from -128 to 3,000 ft. full T., FR, 80 mph, 68°F OAT @ G.L..	250.0 sec.	253.7 sec.
Climb Temperatures, °F		
CHT, Average	426	424
Max. -Min.	67	64
EGT, Average	-159	-145
Max. -Min.	81	84
3,000 Ft. Cruise Temperatures, °F (55°F OAT)		
CHT, Average	428	433
Max. -Min.	70	72
EGT, Average	-44	-48
Max. - Min.	63	78
6,500 Ft. Cruise Temperatures, °F (40°F OAT)		
CHT, Average	417	415
Max. - Min.	73	71
EGT, Average	-92	-83
Max. - Min.	85	82

*Avgas - Grade 80/87; Autogas - Regular Grade

Effect Of Mixture Temperature On Mixture Distribution

Figure 3



rather than 40°F. Keep in mind, however, that the fuel used was regular-grade automotive fuel. As for mixture distribution during this test, the spread in EGT from richest to leanest cylinders was slightly more favorable with autogas, being 70°F, as compared to 78°F for avgas.

Conclusion and Recommendations

My conclusion is that today's autogas is satisfactory for use in aircraft engines providing the autogas selected has the necessary anti-knock quality and is utilized within the limitation imposed by its vapor pressure. It is recommended that autogas be utilized only when avgas is not available. In such a case, I recommend that you select a reliable oil company that can supply in writing the typical inspections and limits for their autogas, so that you will be assured of valid information on Motor Method octane number and vapor pressure. Don't rely on verbal information from salesmen.

I suggest that consideration be given to abandoning the present Grade 80/87 avgas and in its place substituting "aviation-grade" autogas. This fuel should have specifications written around the better regular-grade automotive gasoline produced, plus proper vapor-pressure limits such as seven for summer and ten for winter, with each grade being of a different and distinct color to easily tell the two grades apart.

Also, why not go all the way and carry out Dan Barnard's 22-year-old suggestion of having landing strips at the back door of some of our automotive service stations, say along our interstate expressways, to use the same refueling equipment as used for our automobiles? Crazy? Maybe not. If this were accomplished, would the aviation-grade autogas be marketable to the automotive trade? My opinion is that it definitely would be, because the oil companies could advertise it as aviation quality at regular automotive gasoline prices, to make it very much in demand. □

THE AUTHOR

Al Hundere is president and research director of Alcor, Inc., of San Antonio, Tex. He has made a career of research and development in the field of engines and their fuels. After being awarded bachelor's degrees in science and mechanical engineering by Oregon State College, he attended Yale University and there qualified for a master's in engineering. Prior to joining Alcor in 1957, he was connected with some of the country's leading research organizations in the engine and fuel field. He has written several articles for The PILOT, *among them being the popular article, "Accurate and Consistent Mixture Control," which has been reprinted several times.*

Teal Amphibian's New Elevator Control

Thurston Aircraft Corporation of Sanford, Me., recently announced that the new Controllex elevator trim system has been certified for its *Teal* prototype amphibian aircraft. The system is designed to eliminate, through its push-pull control, the stretch and resulting undesirable surface deflection associated with some actuation systems.

The Controllex, basically a linear ball-bearing in a flexible-tubing envelope, was chosen for the *Teal,* said Thurston officials, "because it permits a direct input/output connection to the elevator control surface. Control is smoother and more directly responsive." It is also expected that the ball-bearing system will provide lower maintenance costs than the conventional pulley and cable systems.

The Thurston *Teal,* priced at $16,550 f.a.f., is a two-place, all-metal amphibian, powered by a 150 h.p. Lycoming engine. The plane climbs in excess of 1,000 feet a minute at gross load of 1,850 pounds. It has a cruising speed of 108 m.p.h. at sea level and is capable of operation in 30-mile winds and 18-inch waves, including 90° crosswind conditions, according to the manufacturer. □

A significant design feature of Thurston Aircraft Corporation's Model TSC-1A Teal amphibian aircraft is the Controllex elevator trim tab and linkage. It is said to eliminate much of the hardware required with conventional pulley and cable systems.