some thoughts on vapor pressure in AUTO FUEL

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THE EAA IS very much involved in testing automobile gas as a fuel for small aviation engines. Our company has been involved in manufacturing petroleum pumps for almost 40 years. Based on observations over these years, we have gathered information which may be useful to any proposed use of auto gasoline in aircraft.

There are two important items which must be considered: (1) vapor pressure of the fuel and (2) the fact some major oil companies manufacture three types of auto fuel — winter, spring and fall, and summer gasolines.

Let's discuss vapor pressure first. Vapor pressure is the pressure at which the liquid transforms from a liquid to a gas. This pressure may be expressed in either pounds per square inch or feet of head. In this discussion we will use feet. Because we may be lifting the liquid from a wing tank to the engine fuel pump, vapor pressure is important.

As noted above, major oil companies, depending on the part of the country in question, may produce fuel designed to meet climate conditions. Winter fuel is compounded to give quick starts, summer fuel to prevent vapor lock. Vapor lock is simply caused by fuel reaching its vapor pressure due to heat and vacuum.

Chart "A" shows vapor pressure of various liquids at different temperatures. Note difference between winter and summer gasoline at 90° F. Notice the much lower vapor pressure of aviation fuel. A lower vapor pressure is much to be desired, as we shall see.

When we want to determine how far we can lift liquids, water is used as the standard of comparison. One important word to remember is "vacuum". Whether it is a soda straw in your mouth or an airplane fuel pump, all we do is create a vacuum in the suction line and atmospheric pressure pushing down on the liquid forces liquid up the straw or fuel line. At sea level there is 14.7 pounds of atmospheric pressure. If we had a perfect vacuum, this atmospheric pressure would force water up the pipe 33.9 feet vertically (1 pound equals 2.31 feet: 14.7 x 2.31 equals 33.9 feet). However, no one has yet created the perfect vacuum, so the practical suction lift of water is 25 feet at 40° F. sea level.

In theory, it is possible to lift petroleum products higher than water because their specific gravity is less and, therefore, they weigh less than water. Theory is one thing, practice is another, and over the years we have found it a lot more practical to be conservative when dealing with petroleum products.

Let's look at Chart "B" which shows how far we can lift various liquids at sea level with a temperature of 40° F. Note we come very close to our 25 feet on water. How did we get this figure? As shown on Chart "A", vapor pressure of water at 40° F. is .28 feet. Rounding this off to .30 and subtracting from 25.0' gives us our suction lift of 24.7'.

Using the same method of computation on winter auto fuel, our maximum suction lift would be 13.9' (vapor pressure 11.1 subtracted from 25.0' equals 13.9'). This causes us no problems because our fuel tank is only 1.5' below the engine, so a wide safety margin exists.

Now summer arrives and we still have winter fuel in our 500-gallon tank at the airstrip. We are in trouble. Chart "C" shows vapor pressure of our winter gasoline at 90° F. has risen to 28.9'. 28.9' is higher than our suction lift capabilities of 25.0', so no fuel can be pumped from the lower wing tank. As we create a vacuum with our fuel pump, the fuel vapor locks. It changes from a liquid to a vapor as the fuel pump creates a vacuum. Some bright person may remark at this point that all of the above is of no concern to him because he has a gravity flow system in his high wing airplane. Be sure to point out the tank must be at least 4' above his engine or he won't be getting any fuel either. This may sound far-fetched for a high wing airplane, but it is true. As we crank over our engine, a vacuum is created by pistons pulling air into cylinders. With the high vapor pressure of winter auto fuel at 90° F., the vacuum created will cause vapor lock even in a high wing airplane.

Remember, all of the above information is based on sea level operation. As we move up to 5,000', our practical suction lift decreases because atmospheric pressure is less the higher we go. While our suction lift capabilities at sea lvel might be 25', at 5,000' they decrease to 17'. See Chart "D".

Chart "E" shows operation at 5,000' at 70° F. We are unable to use **winter gasoline** unless our tank is at least 3' above the engine. If we take off from Denver and climb at 8,000', our tank must now be almost 5' above the engine (See Chart "F").

Take a good look at Chart "F". Note some real good problems developing. Not only will winter and spring/fall fuels be out of the question, but we are approaching upper limits of summer fuel.

Some conclusions. There are many limitations on use of auto fuel in aircraft. Special note of altitude/temperature combinations must be made. From charts, your local conditions can be computed. Gravity flow from high wing tank with ample sized fuel line is preferred. Vapor pressure of each batch of fuel should be determined. Fuel with vapor pressure greater than summer auto gas should be avoided.

Until more positive evidence is available as to the suitability of auto fuel in airplane engines, use aviation fuel. I don't know how you feel about it but to me, my life is worth more than the few dollars saved. It is very true Dick Wagner flew the Cuby to 20,000' during the 1976 convention but he had several things going for him. The day was cool and a gravity flow condition existed. The story might have had a different ending if the test had taken place during the 1975 convention heat wave with a low wing airplane.

SOME CONTRARY THOUGHTS ON VAPOR PRESSURE IN AUTO FUELS

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THE ARTICLE IN the January *SPORT AVIATION* talking about vapor pressure in auto fuels calls for some very prompt and corrective comment. First, the article contains much excellent information, but one particular conclusion is quite erroneous because the author apparently misapprehends the nature and function of the naturally aspirated reciprocating engine/carburetor combination.

Reciprocating engines are nothing but air pumps producing an excess of power over that required to pump the air. The amount of power produced is controlled by a throttle on the inlet side which, when partially closed, develops the vacuum mentioned in Mr. Gorman's article. But this throttle is **downstream** of the carburetor and fuel system, and here is where he goes astray.

Let us assume a gravity fed float carburetor system. The entire system senses only ambient air pressure and temperature, modified perhaps by a little ram effect. It knows nothing of pressures and temperatures existing in the engine intake manifold or cylinders because that all occurs on the other side of the throttle which is downstream of the carburetor venturi. At the risk of boring some of you we will review the mechanism of this system. Briefly, the fuel flows by gravity into the carburetor float bowl where the level is controlled by the float valve (and these are a bit touchy with minimum fuel heads). The fuel level in the float bowl is slightly lower than the jet in the venturi throat, but fuel flows in response to the pressure differential produced by the venturi suction, and the quantity is in proportion to the volume of air going through the venturi. This proportion is empirically established to give a combustible fuel/air mixture. To cancel out the effect of ram pressure differentials, the aircraft carburetor float bowl is vented to the carburetor throat just above the venturi.

Because the carburetor meters on air volume and net density the system naturally runs richer at altitude than at sea level, hence the use of the mixture control. During the big war, the Air Corps produced an automatic carburetor with temperature and pressure sensors which automatically adjusted (more or less) the mixture for altitude conditions. This was required because they could train a pilot in about 200 hours, but it takes maybe ten years to get an engineer to understand it. And partly because a fighter pilot has much better things to do with his time than fool with a mixture control as he zooms through the blue trying to survive.

Thus, for our postulated case, fuel does **not** flow in response to vacuum in the engine cylinders but only in response to gravity head and pressure differential in the carburetor venturi. And once in the moving air stream the fuel flows willy-nilly in that stream slightly gasified, somewhat vaporized and in various size globs most of which struggle into the cylinders rather inefficiently producing the power to run the air pump with some left over for the propeller. Your garden variety Continental A-65-8 engine has a thermal efficiency of about 22-24 percent.

But what about proof in the pudding? Part of my experiment with MacBird has been almost exclusive use of auto gas. Of 130 hours so far, over 100 has been with auto gas, part of it over the hot sands of the Mojave desert and part over the green fields of Ohio. The last 50 hours or so has been with no lead auto gas which has simply eliminated concern for mag drop and plug fouling.

Getting back to vapor pressure, the contents of my fuselage tank are not all useable because the outlet is at a lower level than the carburetor. However I have flown this bird at 5000 ft. on auto gas with 2 inches, yes **two inches**, head between the fuel level in the tank and the carburetor float level; of course raising the nose a tad causes the engine to start stumbling. The tank does have a ram vent of some indeterminate effect which is very important because you don't want the fuel trying to run uphill against the ram effect in the carburetor air inlet. So it is not at all mysterious that the Cuby could, would and did fly at 20,000 ft. on auto gas.

But let us not kick Mr. Gorman around too much, let us not throw out the baby with the bath water. He has a very valid point which should be taken very seriously. If you have a tightly cowled engine running hot under the collar, pumping gas through long lines from a low wing tank, please don't try this auto gas thing unless you have carefully instrumented your system, have maybe 30 years of experience with aircraft engine installations and stay within gliding distance of an airport. I, like others, have had the experience of something like a Cessna 210 with fuel injection — shut down on a hot ramp; boil the avgas in the lines and just try to get it started. I also had one quit just as the wheels touched down at Flagstaff.

In Macbird, the cylinders stick out in the breeze, the carburetor and gascolator get a blast of ambient air so I know the fuel system is almost as cool as the prop spinner. As a parting thought, if you really don't know what you are doing, or have no good point of comparative reference, don't take the chance with auto gas. If you don't want to fight the lead in LL-100 in your old Continental, put in a pint of Alcor TCP with about 20 gallons, it helps a lot.