#438
$.16

SOME THOUGHTS ON FUELS AND THEIR EFFECT ON FUEL SYSTEMS AND PERFORMANCE.

Art Bianconi
EAA Designee # 1216

One of the characteristics of engines used at Bonneville for record attempts was exceptionally high compression. Seventeen to one ratios were typical and made necessary because the "Flats" are almost a mile above sea level. The lower density of the air demands that it be compressed just to compensate for the loss of volumetric efficiency and related power losses. The ability to really squeeze the mixture this much was made possible because of the fuel used which was predominantly methanol alcohol with varying degrees of water plus an oxidizing agent. The latter was usually in the form of nitromethane. The water cooled the valves and the "nitro" provided the extra oxygen that the engine needed to burn the extra fuel.

To give you some idea of how the high compression effected these engines mechanically, the amount of free volume left in the combustion chamber at Top Dead Center was so small that if the engines were not turned backwards by hand each morning <u>before</u> they were started for the first time, the overnight accumulation of condensation in the cylinders was sufficient to cause hydraulic lockup; the engine would be totally destroyed before it even finished its first complete revolution! The engines of today will tolerate a great deal more abuse than those we used in the sixties but the principles, the problems and the solutions are essentially unchanged. Especially the problems associated with running fuels containing alcohol.

The popular carburetor of the sixties was the Stromberg model 97 and a factor contributing to its popularity was its adaptability to a wide assortment of fuels and mixes by simply changing the main jets. This made it possible to race weekends on a variety of fuels and still operate on gasoline during the week. On racedays you could, in a matter of minutes, re-jet the carburetors with larger main jets and run a methanol mix. Presto! Instant power increase and, with it, a host of other consequences, some of which weren't so nice.

Because alcohol has a high specific heat, it draws off surrounding heat more readily than gasoline thereby helping to prevent detonation in high compression engines. However, alcohol does not produce as much energy by volume as gasoline. That was why we had to go to the larger main jets when racing: to provide the extra volume of fuel needed to offset the reduced thermal output. This placed a demand on the fuel delivery system since it had to work harder to provide the supply. No problem as there were plenty of ways to get the pump to do its job of drawing fuel from the tank. Right? Wrong! Engines started blowing like mad and it took a mistake in plumbing before one guy discovered that we should be pushing alcohol from the tank, not pulling it. We were getting vapor lock. How ironic: the engines were running lean and experiencing detonation because of the very same fuel characteristic that normally prevented it! Vaporized fuel was forming bubbles in the fuel line and the pump couldn't cope with it. So, we installed high volume electric pumps right next to the tanks and pushed the stuff through fuel coils wound inside of cans filled with ice just before the race. Some "stock" car huh?!

After about one season of this we started having engine failures again. The engines were blowing for the same reason as before: detonation. I pulled some spark plugs from other, undamaged cylinders and found tell-tale signs of lean mixtures. Lots of people tried lots of tricks but it wasn't until one guy found particles of rubber in his carburetor float bowl that someone started getting suspicious of the lines. A timed volume test was performed and when the fuel system failed to provide the expected volume, a section of armored rubber fuel line was sacrificed to a hacksaw. The inside of the line was found to be slimy with black goo and the inside diameter had shrunk down to one third of the original size. Other cars were checked and we got the same results. The only common denominator?: methanol fuel mixes. The problem had been found: the fuel line was both swelling and desolving and in so doing, it was cutting off the fuel supply. Soon thereafter, everyone went to steel lines wherever possible and replaced the short flex lines once a month, just to be sure.

These scenarios never happened to street cars whose diets were exclusively gasoline and since alcohol cost more compared to gasoline, it hardly was likely that anyone would use alcohol as a substitute for gasoline except in some isolated Latin American countries with an abundance of wood and the stills needed to ferment the harvest. This logic disappeared, however, with the Arab fuel embargo of 1973. Gasoline got really expensive, much more so than alcohol. Now some recent events have made it increasingly likely that autogas will have alcohol mixed in with it: Federal law is restricting the use of tetra-ethyl lead compounds and many states are taxing it's use more heavily. Since alcohol is not only less costly now but also provides the needed anti-knock properties and burns cleanly, it's universal use in gasoline appears inevitable.

I personally do not have a problem putting the stuff in the resin lined fuel tanks of a Long-Eze. My own tests have failed to indicate any of the softening problems that are often rumored. However, I am a bit uncomfortable with it's effect on high altitude performance and on the integrity of flexible fuel lines. While the most popular of Bert Rutan's designs have pump redundancy, it's important to remember that the Long-Eze's electric unit doesn't push fuel. Rather, it is an alternate source of drawing fuel from the tanks in the event the engine driven pump is unable to provide sufficient fuel volume and pressure. HOWEVER, IF THE REASON THE MECHANICALLY DRIVEN PUMP FAILED IS BECAUSE OF VAPOR LOCK, THE EFFECTIVENESS OF THE ELECTRIC PUMP WILL ALSO BE SERIOUSLY COMPROMISED!

How much? That's difficult to say. It would depend on the Reid Vapor Pressure of the fuel (that would vary according to the amount of alcohol present) and the size of the bubbles blocking the fuel flow. Fortunately, the composite construction of the fuel tanks and the light paint colors mandated by RAF helps quite a bit in cutting down the effect of sunlight on fuel temperature. On the negative side, however, are two factors: 1. the effect of low density altitude and 2. the amount of plumbing the Long-Eze has for feeding fuel from the tanks, up to the selector valve and back to the engine compartment.

High density altitude means lower ambient pressure and as this goes down, the size of vaporized fuel pockets goes up. Bigger bubbles make the pump efficiency drop and when they get really big and enter the pump itself, the pump can cavitate: the vapor just sits inside the pumping chamber. It can't compress enough to open the outlet valve so it just sits there going no-where. Some pumps can be ruined by this sort of treatment: pump temperatures go up because the liquid gasoline that was cooling it is no longer available to do so. This is the worst case scenario however, as usually, the pump can't pull hard enough to get that bubble into the chamber and the engine runs out of fuel first which renders the whole subject of fuel pump survival academic.

The way the fuel gets to the engine on a Long-Eze can add difficulty too. Remember: the fuel is being pulled through this maze, not pushed. Why did they choose this set up? I can only guess: the integrity of a fuel system is usually more severely tested under pressure than under vacuum and with all those lines running through the cockpit, a leak under pressure obviously would leak fuel into the cockpit a lot faster than one where fuel is being sucked through. Why did they run all those lines to the pilot seat? Again, I can only speculate. Here's some history that might explain it: horror stories by Vari-eze owners of trying to change fuel tanks via torque tubes to the aft mounted valve suggest that the Long's excess plumbing was an attempt to give the pilot direct access to the valve. That the problem of stiff fuel valves still wasn't solved until the availability of a special and very expensive grease must be asource of some frustration to the pilots as well as RAF.

Recently I had occasion to work with some U.S. Coast Guard engineers who had adopted computer aided design (CAD) software. Since my wife Betty and I are sailing enthusiasts too it was inevitable that I would get drawn into a discussion on boats, power plants, etc. What surfaced out of the discussion is worth noting: the Coast Guard and the SAE have issued a new standard (J-1527) for rubber hoses. This standard replaces J-30 and all boat owners using gasoline engines are cautioned to examine fuel lines for deterioration due to exposure to gasoline containing alcohol! Apparently, the problems I chronicled earlier are now happening to members of the boating community plus one more: hardening and cracking of the rubber fuel lines. I did some more investigating and here's what surfaced:

Gasoline containing a 10% mix of methanol will permeate the walls of a rubber line as much as 400% faster than straight gasoline if the line is constantly exposed to the fuel. Some lines will actually start to sweat fuel through the walls within minutes! The chemist explained that the reason for this is that the alcohol displaces the plasticizers that are part of the rubber compound (I forgot to ask him what the plasticizers do but I suspect that these keep the line flexible through temperature extremes). The line eventually swells up and gets real soft. Aside from the obvious sweating of raw fuel, the ability of such lines to contain any pressure or resist collapsing under suction is lost.

The other problem is hardening of the hose. Some others report that when the line is only occasionally filled with a gas/alcohol blend, the plasticizers don't leach out but instead are broken down at which point the line becomes brittle. Cracking is the most likely possibility here and the result is worse: a fire hazard and at 15,000 feet, you can hardly jump overboard!

It would be wonderful if the problem could be stopped here by simply changing all your hoses to the new SAE specs. Unfortunately, you can't change the float in your carburetor or the diaphragm in your fuel pump(s) as easily as that. It also doesn't address the vapor-lock problem.

Alcohol has an affinity for water and if allowed to stand for long periods of time, will absord moisture from the surrounding environment. Accumulated water in an alcohol fuel is not necessarilly bad. You've been adding "dry-gas" for years each winter to do just that so the water wouldn't freeze. However, long exposure to moisture, even moisture that is in suspension, can corrode metal parts including those aluminum fuel lines and those aluminum screens you've put in the bottom of your tanks.

Because they provide such outstanding fuel economy, the RAF family of homebuilt aircraft are hardly likely to cause an owner to anguish over fuel bills. If we assume an average yearly usage of 100 hours and an average power setting of 6.5 G/P/H, the consumption will be about 650 gallons for the whole year. If the difference in the price between autogas and avgas is 75 cents per gallon, then you are talking about a monthly difference of about $40.oo. Granted, I'd rather spend the money on someone or something else but, given my experience...........

If after all this you still wish to consider running autogas in your plane, here's a simple yet effective way of testing for alcohol before making a purchase: Get a simple glass jar with a tight fitting metal cover. I like the graduated Skippy peanut butter jars (I also happen to like chunk style Skippy peanut butter!) Put in equal amounts of water and gasoline, cover and shake the jar vigorously. Allow the contents to settle and seperate completely. (About the length of time it takes to eat a peanut butter sandwich) If no alcohol is present, the ratio of water to gasoline will stay as it was: equal. However, if there is alcohol present to any degree, it will absorb some of the water. This will manifest itself as a perceived increase in the amount of gasoline at the bottom of the jar and an equivalent decrease in the amount of water floating on top (this is where the graduations on the side come in handy).

If you think this jar business is funny, you should see what we do with small fruit juice bottles!

KEEP IT SIMPLE, KEEP IT LIGHT!
DON'T WORK WHEN YOU'R TIRED!
WHEN IT STOPS BEING FUN, STOP FOR A WHILE!