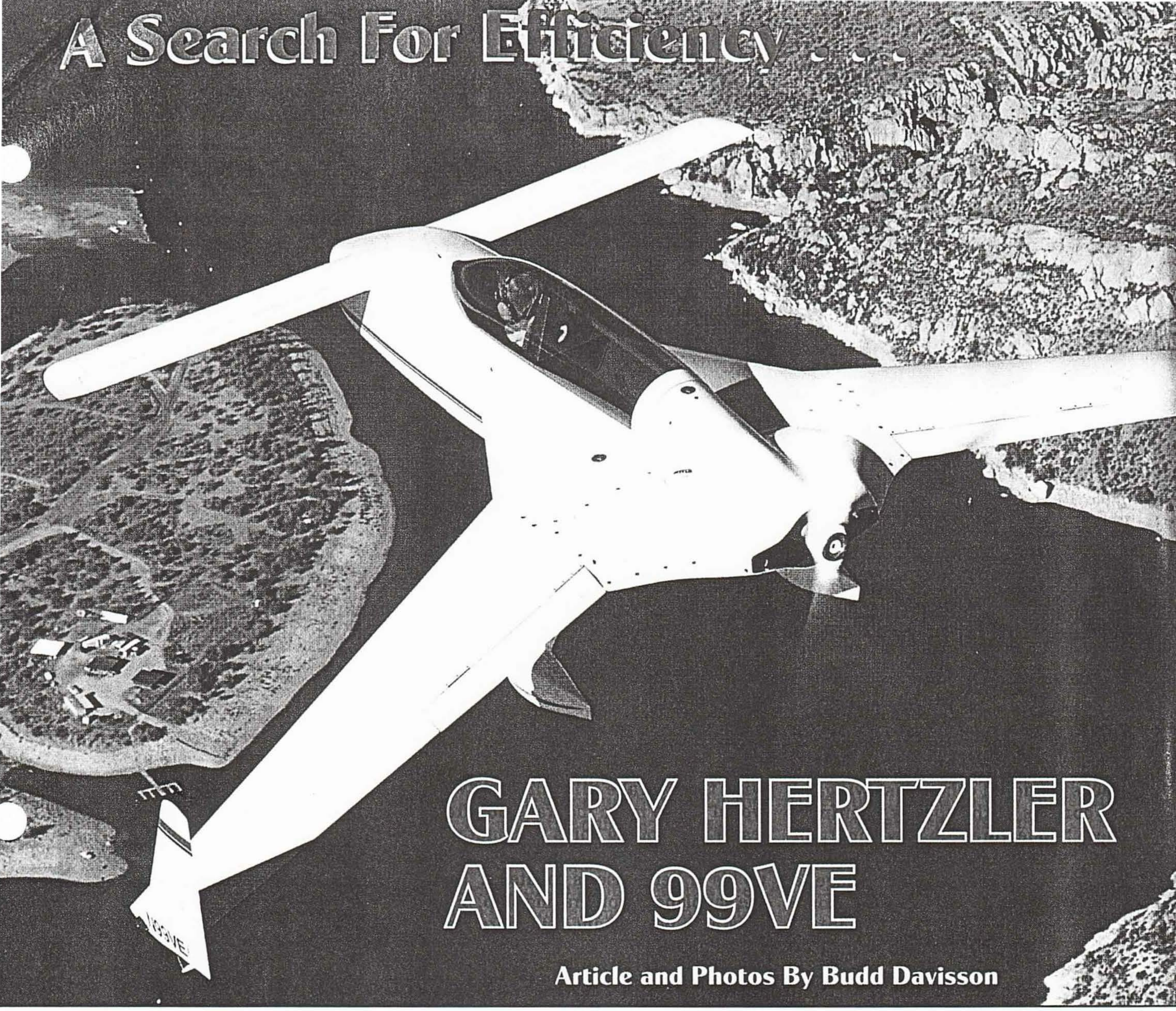


A Search For Efficiency . . .

GARY HERTZLER AND 99VE

Article and Photos By Budd Davisson

The question among devotees of efficiency racing is: By replacing the little A-80 Continental in his VariEze with a monster motor, has Gary Hertzler, oftentimes winner of his class in the CAFE 400 and holder of the C1a speed distance record, copped out? Has he forsaken his ". . . do as much with as little as possible" credo? Has he been caught up in the race in which price and performance is driven by horsepower?

Yes, he has . . . at least he has if you consider a Lycoming O-235 a monster motor. And very few of us do. And, yes, he copped out on the efficiency thing, if you consider it foolishness to combine airframe mods with a bigger engine to lower the fuel consumption at his original record speed of 157 mph (for 2490 miles) from 2.68 gallons per hour to 2.4 gallons per hour. That's over 50 mpg!

Just what manner of beast is Gary Hertzler's VariEze? It is obviously something other than your classic glassbackwards foambuilt. And Hertzler is something other than a lead footed airplane racer.

What drives Gary to spend a huge amount of time squeezing everything he can out of his airframe and making every single horsepower count in the quest for speed and economy?

"Basically, I'm always looking for value," he says. "Even with my cars it is a game with me to see how much performance I can get on the least amount of gas."

And how far is that? In establishing the record in October of 1993, he made four round trips from Chandler, AZ (Phoenix) to a VOR next to Palm Springs, CA, a total of nearly 2,500 miles, on 42 gallons of gas. His elapsed time was 15 hours, 45 minutes at 157 mph. Yeah, it looks like he really is a cheap kind of guy. A fast cheap kind of guy!

Gary is a mechanical engineer by trade and spends his days as part of the engine design team at AlliedSignal Aerospace in Phoenix. They spend hours splitting hairs to make their turbo-fan engines as efficient as possible. Then Gary goes back to his work shop and continues splitting hairs to make his VariEze as efficient as possible.

Basically, an airplane is an ongoing battle in which thrust (horsepower) tries to move an airplane forward while drag tries to slow it down. Granted, this is reducing aerodynam-

Gary Hertzler is a propulsion design engineer for a major aerospace company and holder of several world records for speed and distance in his class.

ics to a coloring book level, but it really isn't any more complicated than that. So Gary's search for speed and efficiency couldn't concentrate in just one area. Pure horsepower may help make an airplane go faster, but, all other things being equal, the faster it goes, the less efficient it gets. Each new mile per hour will cost an increasing amount of horsepower because drag builds up as per the square of the speed.

So the obvious move is to get the airplane so slick it really doesn't take much horsepower to make it slide through the air. One way to look at it is to view drag as if it is negative horsepower that has to be canceled out with positive horsepower. So, the fewer negative ponies there are pulling backwards, the fewer that are needed to pull forward. Or in Hertzler's case, push forward. Cut down the number of ponies needed to pull the airplane through the air and just that many less need to be fed. More speed, lower feed bill. That's Hertzler's magic but hardly original formula.

This is all pretty basic stuff which everyone knows. So what is Hertzler's secret? That is also pretty basic.

"Details," says Hertzler. "I'm not inventing anything new or coming up with any great new technology. I'm just doing everything I can think of to decrease drag while doing engine mods that increase efficiency without costing reliability."

The last comment, about engine mods, is important because horsepower is secondary in his mind. The trick is to make the engine generate its horsepower on less fuel. His original solution to the low fuel burn question was to use a tiny engine on a super clean, super light airframe.

Gary didn't originally build his airplane to go racing or set records. he says he originally built the VariEze because it looked like an airplane that would satisfy his urge to go fast with little horsepower. His old more-for-less way of thinking picked the VariEze. That and the fact it looked like an airplane he would finish.

In the 1960s he had started a metal bird, but didn't complete it.

"For me, metal was just too tooling intensive," he says. "But the plans for the EZ were so good and the material so easy to work with, the project moves along quickly and you don't lose interest."

Even so, it took three years, until 1980, before the airplane was flying. When he got it flying, it turned out to be one of the lightest VariEzes around. With the A-80 (actually an A-65 with A-80 pistons), it weighed in at 610 pounds. Asked how he got it so light, the same basics come to light.

He repeats himself, "Details, strictly details. If the airplane doesn't have it, the engine doesn't have to carry it. In the first place, all of the foam cores should be as perfect as possible, so no filling needs to be done to true them up. all the lay-ups should be as dry as practical. It doesn't make sense to carry around filler and resin that isn't needed."

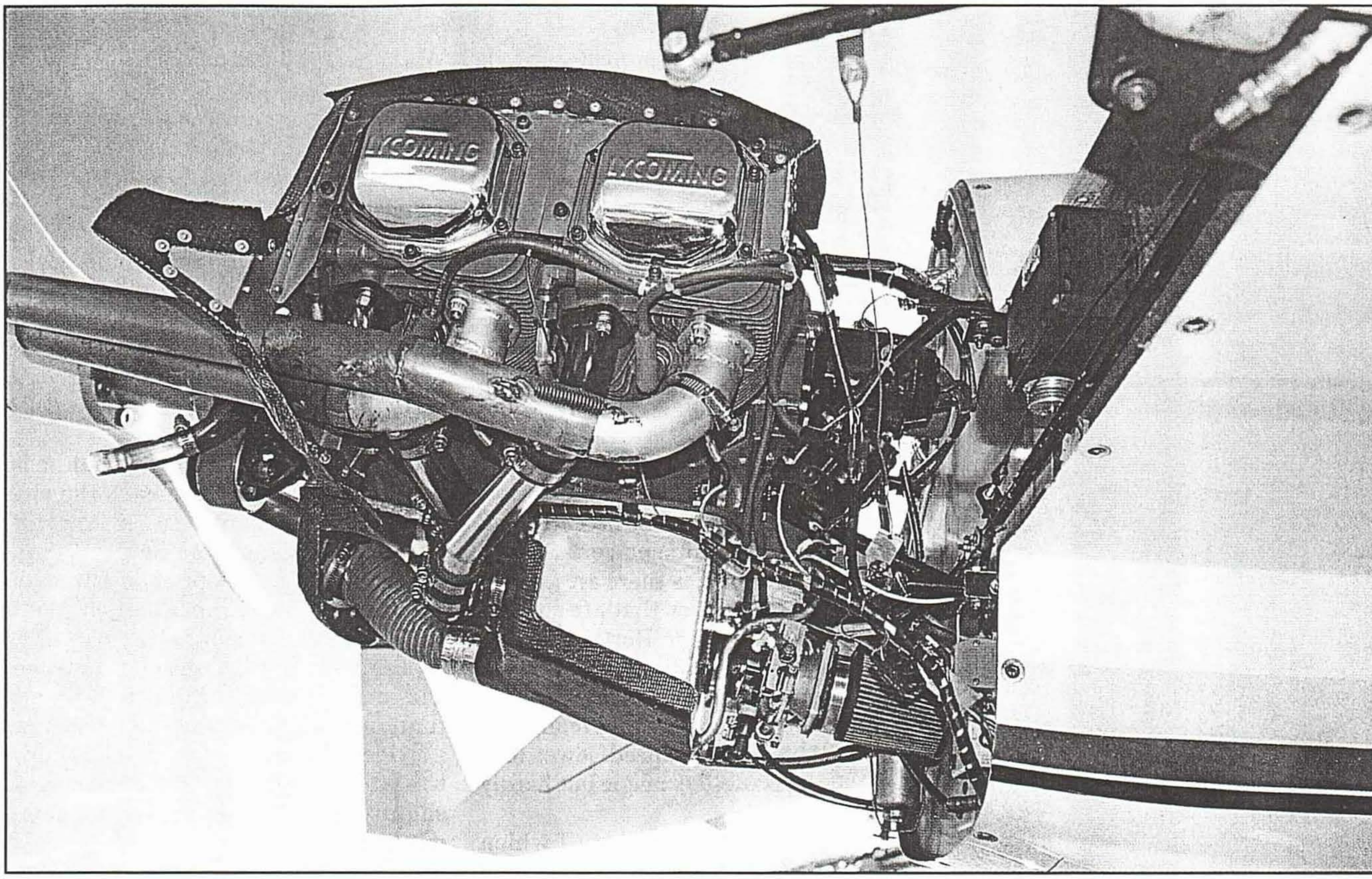
Without saying as much, what he is saying is extra weight means the airplane must generate extra lift to carry it. The lift means more induced drag. Which means more horses are needed. And those ponies must be fed. Isn't this where we came in?

Keeping the weight down reduced the induced drag, but Hertzler's attention to the airframe drag goes far, far deeper than that. He found, for instance, holding both rudders slightly out of line (they are independent on most canards) generated a noticeable drop in speed. He theorized the rudder displacement was making reflex that was already in the winglets much more pronounced and that apparently generated a sizable amount of drag. That being the case, Gary reasoned the reflex already in the winglet airfoils probably was generating drag all by itself.

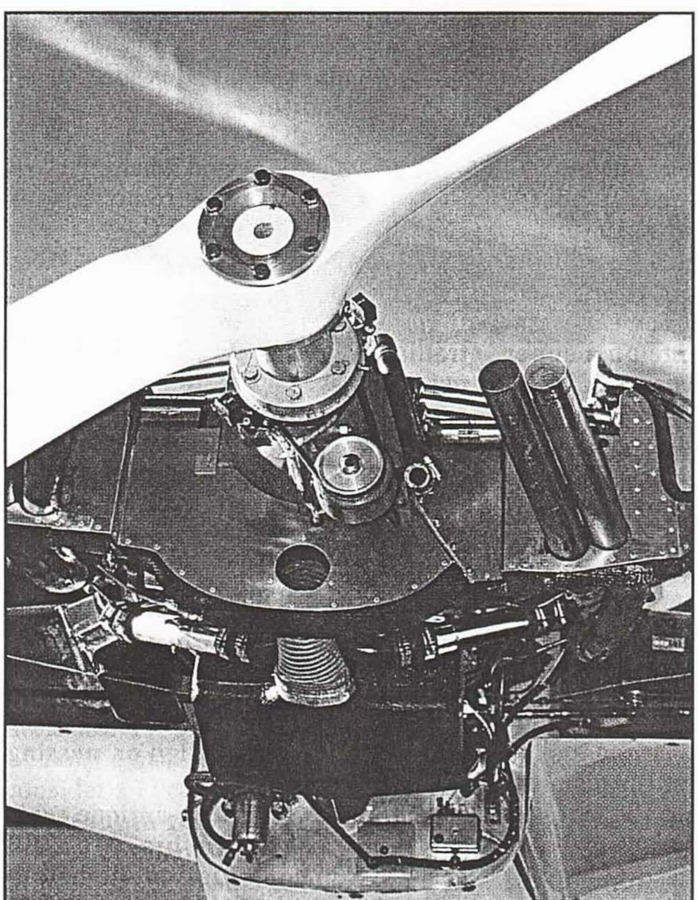
The only way to find what effect all that reflex had was to remove it, so the final winglet airfoil Gary is now flying has a nearly straight curve from the point of max thickness to the trailing edge. This meant moving the trailing edge slightly inboard, but the net result was a speed increase of at least three mph. At the same time, however, he says his low speed stability was slightly compromised. Nothing is free in aerodynamics.

Gary is very serious about the possible problems folks can run into when modifying airplanes and doesn't condone his type of program. "I'm almost afraid to talk about the changes I've made because not all of them have worked and it's possible to get into trouble changing a design or messing with the engine."

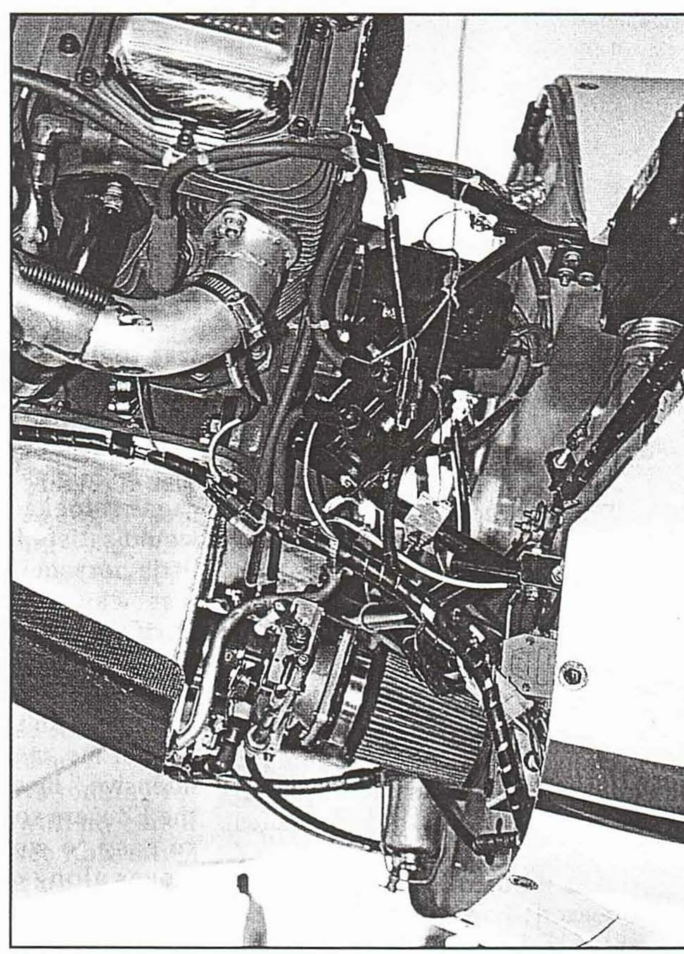
With only 170 nearly-antique cubic inches available in his A-65/80 case/piston combination, he had to make those inches work as efficiently as possible. Since thermodynamic efficiency is a function of compression ratio, he opted to do something about



The O-235-C1 has L2C pistons and Ellison throttle body. Light Speed Engineering electronic ignition is at upper right. Note hand made oil sump with induction tubes running around it, rather than through. Dark air scoop on bottom of sump holds air against it for cooling.



Low pressure draws oil sump cooling air through Scat hose on rear baffle. Prop is Hertzler's own composite creation over wood core.



Details of rear of sump. Note use of automotive aftermarket exhaust elbows to build induction and exhaust systems.

the 7.5:1 ratio of the original engine. He wanted to go to 9:1 but with newer technology pistons and rings.

It was the compression ratio mod that almost got him in trouble, hence his comments about careful experimentation. He didn't want to go with a set of stock Continental pistons, even though they could get him up to 9:1 with little effort. Stock pistons were heavy and of an old design. Being a designer, Gary sat down with his calculator and designed a set of pistons which were lighter and, therefore, more efficient. He then came up with a combination of automotive rings that would seal much better, making the engine even more efficient. He had the pistons made by a custom automotive manufacturer.

The pistons looked good on paper, but they had this one little problem. When hot, they were larger than the cylinders in which they ran. Proving once and for all that even the best designers in the world can't foresee all the unknowns, he found a combination of tight design tolerances and loose manufacturing tolerances had produced pistons that grabbed the cylinder walls and wouldn't let go.

But he didn't know that until the engine seized solid at 250 feet over a citrus grove on takeoff!

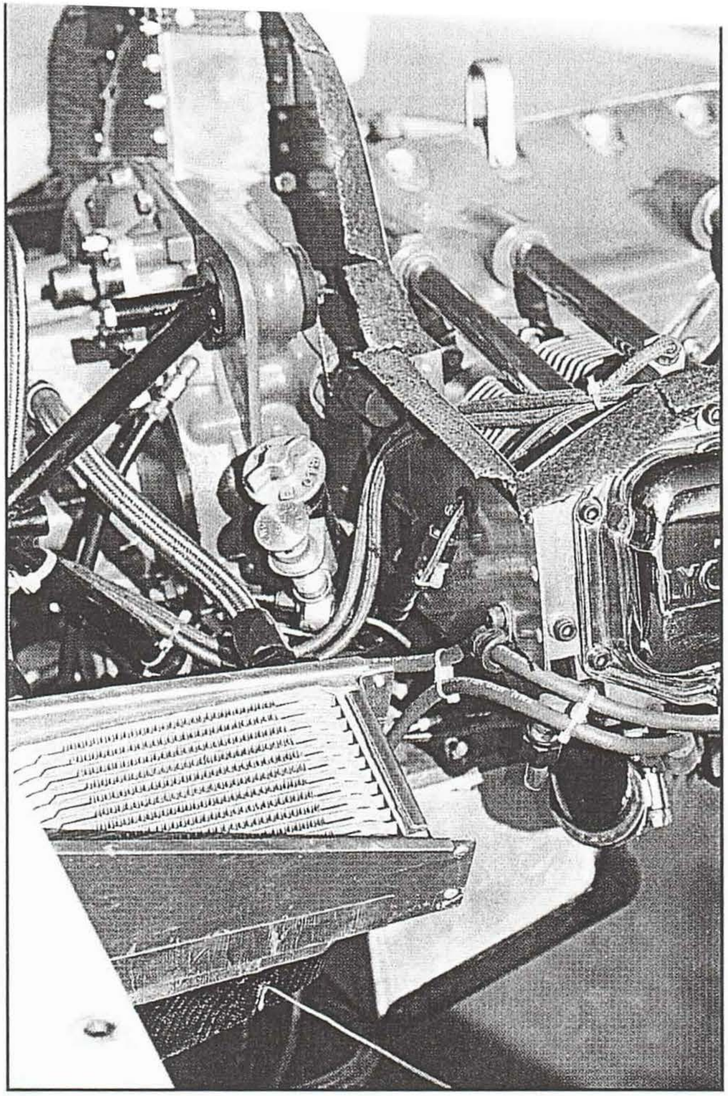
"Nothing but an EZ, a light EZ at that, could have made it back from that position," Gary says. He also admits his part in the problem, but the next set of pistons ran trouble free for nearly 800 hours.

He also completely replaced the induction and ignition systems, all of which have formed the basis for the mods to his current engine, the not-so-monster O-235.

The ignition was a combination of a magneto with fixed timing and an electronic unit from Light Speed Engineering. This has an electronic processor and sensor which reads manifold vacuum and adjusts spark advance up to a maximum of 17 degrees above the normal setting. This allows matching the ignition set-up to conditions that exist at high altitude. Gary says when he's at altitude and switches from the mag to the electronic ignition and back, there's a 50 rpm drop caused by the difference between the full advanced setting of 43 degrees and the nominal setting of 25 degrees.

Much of Gary's work has been aimed at truing up the airframe. One of those areas was in the landing gear. He went through at least three different iterations of cowling and cooling design starting out with Rutan's original P-51 type belly scoop and progressing towards his current cowling that brings the bottom of the firewall up and allows a tight, continuous curve from the belly right up to the prop.

Although that mod eliminates just about every scoop that sticks out into the airstream, it has the downside of changing the curvature of the fuselage where the gear legs enter. The intersection becomes much more acute and creates a spot that loves to tear at the air. To make matters a whole lot worse, the gear legs sweep forward which give them an effective positive angle of attack, when compared to the rest of the airplane.



Oil cooler is very necessary in Arizona temperatures.

Since Gary's airplane is about two degrees nose high at cruise speed, this means the gear legs present the wind with a surface which has a significant angle of attack all its own. Gary's solution was to create a square around the gear legs whose edges paralleled the relative wind. Then he simply airfoiled that square and made a fairing in that shape. That was good for nearly three mph.

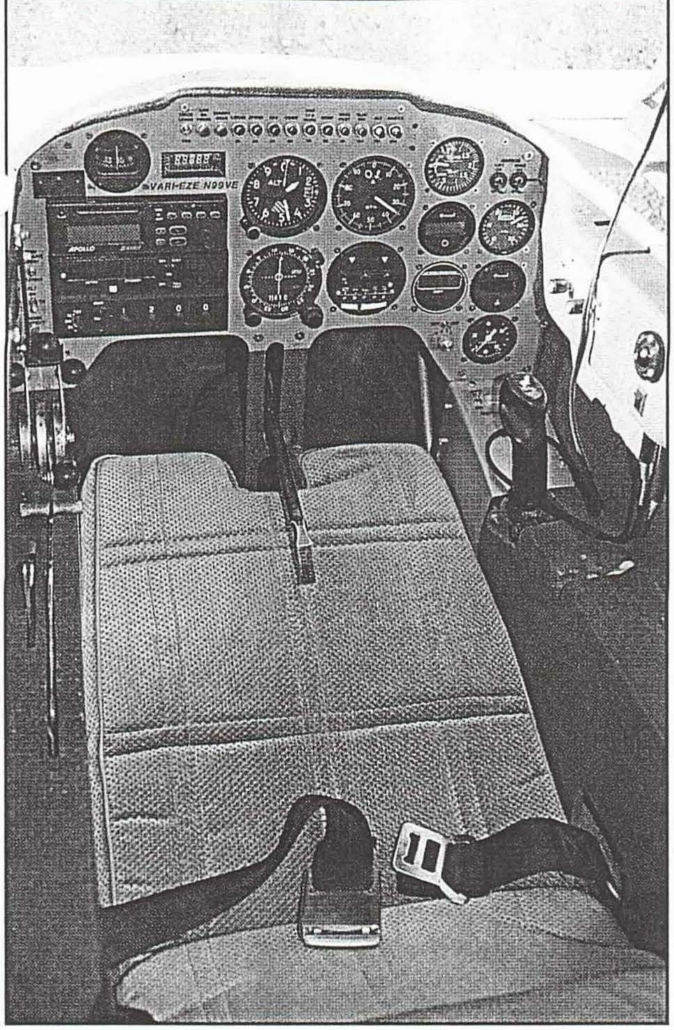
The wheel pants on Gary's airplane are more than simply wheel pants. Most of us visualize pants as something that makes the air think a wheel isn't a wheel. Anything is better than dragging a wheel through the air so most are satisfied with any kind of wheel pant.

Gary did some dirty-oil flow testing of the wheel pants and decided they needed some serious work.

The final shape was arrived at by making the planform that of a 25% 65 series laminar airfoil. The 25% was picked because that offers the 4:1 taper ratio which is usually considred to be optimum for an aerodynamic shape. Also by selecting a known airfoil, the airflow was possible to predict.

Then the pant's side view was carefully laid out. The side view was developed in such a way there was a constant pressure distribution at each station down the pant. This required that the angle the top and bottom of the pant made with the waterline be the same as the angle which the left and right side make with the line of flight. This not only maintains laminar flow but stops migratory airflow which in turn keeps the pants from throwing off any drag-producing vortices of their own. Gary says the pants' modifications alone accounted for just under 6 mph!

The canard is basically stock except for the down-swept tips which change airfoil section as they sweep to soften the vortex. Gary isn't sure which had the most effect, the down sweep or the shape, but he says a long piece of yarn attached to the tips of the original square canard would whip around in a three foot circle so fast it disappeared from sight. With the new tips the same yarn lazily rotates in a circle



Flight deck is neat and tidy.

that's only about a foot in diameter, which to Gary says there was a lot of energy being wasted in generating vortices.

With this super clean airframe and fuel-sipping little A-80 pushing it, Gary took six(!) out of nine CAFE 400s with his elbow-to-elbow racing buddies, Klaus Savier and Gene Sheehan, taking the rest. Then, however, the 400 was dropped in favor of the CAFE Challenge. The Challenge isn't a race so much as it is a challenge in which individual pilots pit themselves against a performance level that has been pre-established. The goal is go beat that datum point. This is no mean feat since the performance standard set was by Dick Rutan flying Burt's Cat Bird.

Basically, the airplane leaves Santa Rosa, CA, goes out 250 miles in any direction, as recorded by a high-tech GPS system, and returns. The hooker is that the aircraft has to be at 10,000 feet by the time it hits a line which circles Santa Rosa 25 miles out. That is a fairly steep climb gradient and makes it nearly impossible to do it in a cruise-climb configuration.

With the original A-80, the only way Gary could hit the 10,000 foot level in time was by circling in the climb. There is a limit to what lightweight and clean aerodynamics can do. At that point, horsepower has to take over. With a fixed pitch prop and only 170 cubic inches, Gary was stuck.

The old hotrod axiom "the only substitute for cubic inches is more cubic inches" fits here.

Gary needed more motor. But, he wanted an efficient bigger motor. Not one that simply generated horsepower. He went with a 108 hp, O-235-C1C Lycoming, one of the more popular VariEze powerplants. But, rather than hot rodding it beyond all recognition, he opted to do exactly the same things he had done to the old A-80: increase the compression ratio (using factory L2C pistons this time), clean up the fuel distribution and install a better ignition system.

Anyone familiar with airplane engines at all have to walk around the rear of Hertzler's VariEze and wonder how he got all the normal engine stuff in that incredibly tight cowling. There is obviously room for the engine, but what about those other gadgets, like carburetors and induction tubing that usually hang down.

It isn't until the cowling is dropped that the true extent of Hertzler's quest for aerodynamic cleanliness and engine efficiency comes to light. Nothing hanging from either the bottom of the case, nor the bottom of the jugs is stock.

As with most carbureted aircraft engines, the O-235 mounts its carburetor on the bottom of the oil sump and routes all the induction tubes through the sump. Not Hertzler's. The original sump is gone, replaced by one completely fabricated by Gray from aluminum plate. The carburetor has been replaced by an Ellison throttle body which is mounted on the back, er, magneto end, of the engine. The incoming fuel mixture is routed through the sump to a distribution spider featuring an entirely new batch of induction tubes which hug up against the bottom of the cylinders. The tubing work on the engine shows what can be done using the exhaust elbow page out of J. C. Whitney's latest catalog.

Incidentally, Gary says the Ellison is one of the most important contributing factors to his engine's efficiency. He says the normal carburetor doesn't atomize the fuel nearly well enough at the low throttle settings he is often running. At those flow rates the throttle butterfly is basically stalled which totally disrupts the flow and allows the heavier droplets to take the path of least resistance. This causes distribution problems with the near cylinders running rich and the far ones leaning out. The Ellison gives the ability to lean far past what a normal carburetor can and the longer induction runs give more time for the mixture to equalize between the cylinders. Gary credits the Ellison for at least 10% increase in fuel efficiency.

The bottom plugs don't have clearance so have been replaced by automotive units which are fired by one of Klaus Savier's electronic ignition systems. Gary says the electronic system works better with automotive plugs anyway, but he would have put them on top, rather than the bottom, if he didn't have clearance problems.

The oil pan has a composite scoop running its entire width leaving about a half inch of clearance for holding the cooling air up against the pan's lower surface. The front end (as determined by where the airplane's front end is) is open while the back flows into a two inch tube that exits on the baffle face right in front of the propeller. Gary says the system depends on the negative pressure area at the back of the cowling to pull cooling air across the pan. He also admits the oil system, which also employs a traditional oil cooler, still needs some tweaking to cope with Arizona's summers. But then, at 115°, practically every oil cooling system in Arizona has troubles coping.

Every bit of air the engine needs to breathe and cool itself comes in through a hand sized armpit scoop under each wing. Gary says the first time he ever saw that type of inlet was on an EZ belonging to Charles Airesman from Cumberland, MD. He says his airplane is not only beautiful, but is - along with his and Klaus Savier's -

among the fastest in the country. This type of scoop works in high pressure air and leaves the belly completely smooth and clean. However, Gary says the performance gains over the NACA inlet are minimal, especially when put against the huge amount of work involved. It does, however, make for a much nicer looking cowl which flows better up to the propeller.

The estimated 118 hp pushes the airplane through a propeller that is basically a Hertzler original. Although the core is that of an aftermarket wooden propeller, it has been completely reshaped and reconfigured using fiberglass and carbon fiber. It is the same prop Gary used for his record flight, but he changed the pitch from 64" to 76". The basic airfoil is built up using glass, which is overlaid by carbon fiber uni-cloth running tip to tip and overlapping in the middle. It is 14% at the root and tapers to 10% at the tip, so it is fairly thin. He says it lets him turn 2,350 rpm static and is giving him about 3,000 rpm flat out.

Did the extensive mods as the result of the engine installation work? Well, Gary broke the Cat Bird's mark by 5% (as calculated by the CAFE efficiency-based formulae) and found he had actually overcompensated for the climb. He hit 10,000 feet only 18 miles out. Using a flatter, faster climb or a different pitch, he would probably have bettered his mark.

Of course, there's always that one final question everyone who isn't into efficiency - which is practically everyone - asks: How fast is it? In a recent 120 mile, closed course race among VariEze owners, he clocked 228 mph at a density altitude of 5,000 ft. As originally built, the airplane did 176 mph, so he's added 52 mph to its speed!

What's next for Gary? Remember that 228 mph run? Amazingly, he wasn't the fastest! Klaus did it at 235 mph.

"Yes, I do have a few more ideas." He hesitates for a second before continuing, "But, I think I'll keep those to myself." ◆