'homebuilt' mooney

*Editor's Note: In November of 1980 we published an article by Brien Seeley on his work with inertially tuned exhaust systems. It initiated a great deal of experimentation by EAAers and the eventual adoption of a number of inertially tuned systems – Tom Hamilton in his Glasair, for instance. Much of the test work has involved homebuilts – VariEzes, Glasairs and the like – but Brien's chosen instrument has been his 1966 Mooney Super 21. As you will learn, the exhaust system was only a start. Subsequently, the airplane has been so extensively modified it is now referred to as "Brien's homebuilt Mooney". Actually, the **type** of airplane is irrelevant to the presentation he makes in the following article, because the modifications, at least in concept, can be applied to almost any airplane – most particularly homebuilts. Because of their potential benefit to EAAers in improving the performance and, thereby, efficiency of their aircraft, arrangements have been made to have Brien display his Mooney on the flightline at Oshkosh next month and be available to answer your questions. Be certain to look for them.*

With his demonstrated devotion to aircraft efficiency, it was almost a matter of course for Brien to conceive the CAFE 250 (400 this year) and to serve as its director for the past two years.

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IN 1976, THE year Roy Lopresti unveiled the Mooney 201 and Burt Rutan made "composite" a household word, I began dreaming of modifying an older Mooney for more speed using Lopresti's ideas and Rutan's methods. Naturally, I could save a lot of money by fixing up an older Mooney rather than buying a new 201. Boy, was I naive!

I researched the Mooney genealogy and decided that the '66-67 short fuselage 200 hp Super 21 would be the best model to start modifying. It had the late styling window pattern, flush wing inspection plates, the wide-deck engine, smooth tail feathers (not crenulated as on later models) and was supposedly 3-4 mph faster than the longer Executive.

In 1966, N6057Q left the Mooney factory as serial #892, a 200 hp Super 21. First owned by Beechcraft Corporation in Wichita, she was sold to W. L. McCallum of Topeka in 1976. In May 1979, McCallum offered her for sale in Trade-A-Plane, and, with a cashiers check in my pocket, I flew commercial jet from San Francisco to Kansas City to have a look at her. After a short demo flight to Topeka, I was sold. Taking the keys from Mr. McCallum, my great adventure began. Lyle Powell, my father-in-law, had accompanied me to Kansas to offer a second opinion before the sale. We flew her back to California together, and spent the return trip as a thorough flight test.

We determined that she would true out at 178 mph at 8000' with full throttle, ram air, 2700 rpm, all vents closed, and leaned for best power. This was about 10 mph below book. The airplane was loaded with IFR gear; 2 navcoms, DME, ADF, 3 axis autopilot, marker beacon, etc., and had the attendant antenna farm on her fuselage. This, in combination with somewhat oxidized original paint and other detail flaws, doubtlessly helped make the actual speed differ from book value.

The modifications began upon arrival back in Santa Rosa. By removing the IFR hardware, auto pilot, 4 antennae and entry step, I gained 3 mph and 50 lbs. of useful load.

Next I delivered the airplane to Paul Loewen and Lake Aero Styling in Lakeport, California. Paul is an AI who knows Mooneys backwards and forward and is a real enthusiast for modifying them. Paul and his shop crew did a first class job of installing aileron and flap gap seals, a new dorsal fin with tighter elevator root fairings, a "201" windshield, and also relocated the brake calipers to raise them out of the slipstream when retracted. All this yielded 10 mph more speed. Top cruise was now 191.

Next, I reduced the size of the cooling air inlet on the cowl from 205 in.^{2} to 55 in.^{2} and relocated the oil cooler and air cleaner inside the cowl. I made a Plexiglas cover to smooth over the landing light recess. The engine cooling baffles were sealed as thoroughly as possible. These modifications yielded another 4 mph. I had equaled the 201's 195 mph cruise.

Feeling now like the airlane was "finished" (little did I know), I had the paint shop strip off the original paint. I smoothed and filled the wings with Featherfill and used lightweight auto body filler around the windshield and on various draggy-looking lap joints. A pair of "231" wing root fillets were installed.

The wing inspection plates were removed and reshaped on form blocks so that they did not distort the wing skin. I rigged the ailerons to both ride 2 degrees high at the trailing edge, and adjusted the flaps so that they rode as high as possible, ½ degree up.

Finally, it was all painted with Imron. I refused to allow the coarse gritty wing walk to be applied to the door entry area. After waxing, I tried her out at 8000' again, and was amazed to see another 5 mph increase, cruising at 200 mph.

The speed comparisons were always run at 8000' with full throttle, ram air, 2700 rpm, 12.6 gph, all vents closed, full fuel and me alone aboard. Since 1-2 mph increments are not reliably measured without elaborate equipment, I've had to lump the modifications together to see significant gains. I used an Alcor true airspeed indicator with its built-in altimeter and temperature bulb servos to obtain all the true airspeed readings. It was calibrated to the certified FAA boom-mounted airspeed indicator and revealed near zero instrument error with a 3 mph pitot installation error (most Mooney pitots are about 3 mph optimistic at the top end). Thus, all the speeds discussed in this article are about 3 mph above calibrated airspeeds. The fuel flows were measured using a digital DAV-TRON flow meter which has proven accurate to within ± 1%. Level flight was maintained accurately by monitoring an accelerometer-biased Teledyne IVSI, a super instrument with no lag.

Lyle and I next designed and built the tuned exhaust system described in the November 1980 *SPORT AVIATION*, and it delivered a big improvement in climb and BSFC as well as 4 mph more cruise . . . 204 mph.

Lyle was an ever helpful and analytical force in my Mooney project. The angle of attack indicator he designed was installed on my left wing and works beautifully. (See Diagram)

Roy Lopresti, whose ideas I copied without shame, was always willing to discuss my project in detail, and has such an intuitive talent for drag reduction, that it seemed there was no end to the gains to be made.

By then, I was totally obsessed — I couldn't stop modifying! Only with an angel for a wife could I have continued and so I did.

Roy suggested a flush door handle and flush riveting the bottom skin of the flap trailing edge. I did. I closed off 1 of the 2 cabin air inlets and 1 of the 2 outlets with flush skin patches. A new door seal, removal of the belly bilge vents, removal of the battery box vents (using a sealed battery), removal of tie-down rings, relocating the cabin vent water drain; I even flush mounted the baggage door key lock. The old pitot tube strut under the left wing had to go and the pitot in the wing leading edge proved more accurate at high speed.

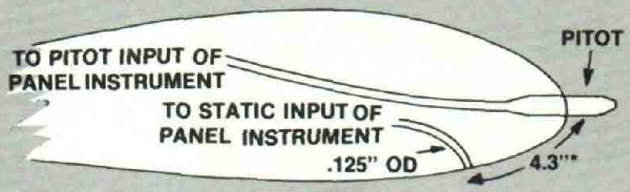
I replaced 2 large removable fuselage belly access panels with one large composite one which incorporated a flush Nav antenna like the one Jim Weir designed for the VariEze. And it works! So I was then able to remove the old stainless rod Nav antenna off the vertical fin. Now she would cruise at 206 mph.

I designed some additional landing gear doors to cover the gaping wheel wells in flight, but the extra doors created too much airload during retraction for the electric retraction motor. Paul Loewen installed the bigger landing gear drive motor of the "201" and I beefed up the actuator rods to be sure the system would tolerate the greater air loads. A 3rd gear door was needed for each main wheel and had to cycle shut-open-shut during the retraction cycle (a la Bonanza system). Paul came up with an ingenious linkage system using the stock idler arm in the gear well to actuate the 3rd door. It worked great and finally the system completely covered the gear wells in flight. The gear door project was worth about 5 mph more cruise speed, giving 211 mph.

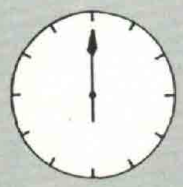
I still wasn't satisfied with the cooling drag and cowling shape. Also, I wanted a bigger diameter prop which could turn slower to increase the blade L/D and thrust efficiency. To accomplish this, I took on a major project; installing the 200 hp Lycoming IO-360 A1B6 engine with its counter-weighted crankshaft combined with an extended hub 77" Hartzell propeller (HCE-2YR-1BF). This combination was certified after a vibration study at Hartzell and could be operated continuously at any rpm between 2000-2700. The prop blade is a latter-day design (F84-67-7R) that I hoped would be more efficient. The hub extension moved the blade centerline more than 9" forward of the crankshaft flange, and required a new cowling shape. The prop's 77" diameter compares with 74" on the original prop, and Lopresti warned me that at 2700 rpm and high airspeed, tip mach number would begin to hurt my top speed. Nevertheless, I had to try it.

In November 1980, Lyle and I visited Tom Hamilton at the Glasair skunkworks and after hours of discussion we evolved a cowling design that ends up being a close copy of that on my

ANGLE OF ATTACK INDICATOR ON LEFT WING OF MOONEY N6057Q



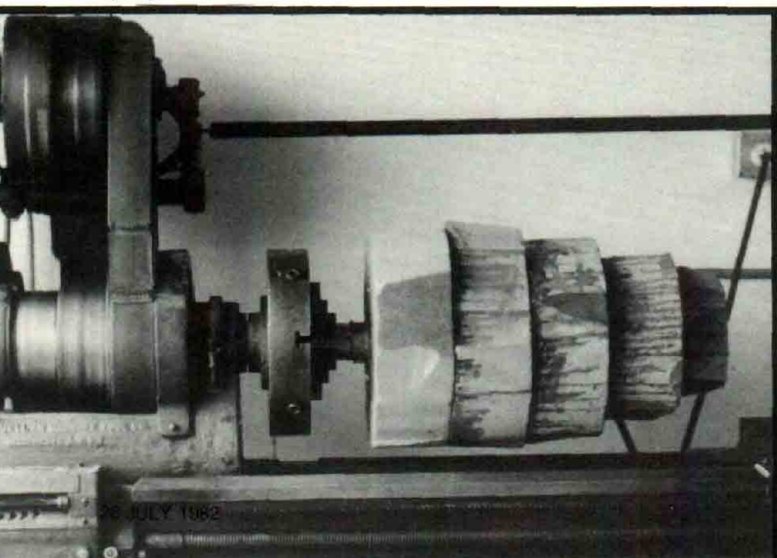
***This dimension is CRITICAL and will vary depending on airfoil section. It is more aft than you think (the stagnation line at stall angle of attack). The orifice must be perfectly flush to the wing skin.**



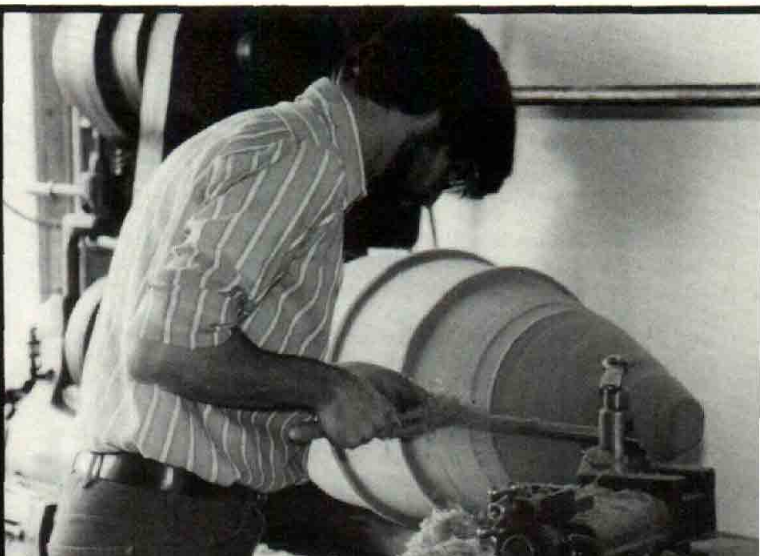
Panel instrument. 0-200 mph airspeed indicator with repainted "clock" face. Calibrate by test flight. EG —
2 o'clock = Approach
12 o'clock = Stall
6 o'clock = Best Rate Of Climb

Note: This instrument will show nearly zero lag relative to the marked lag in airspeed indication. Try it!

(Photo by Brien Seeley)
The spinner mold started out as a wedding cake of 6" foam blocks stacked on a 3" steel tube and bonded together with epoxy.



(Photo by Brien Seeley)
A master at work, Cris Hawkins used extreme care to carve the foam spinner.





(Photos by Gail Rathbun)
Retraction sequence, showing the gear doors developed by the author.

friend Lloyd Hamilton's Hawker Sea Fury. The next 2 days were spent carving a foam plug for a Glasair cowling mold. The mold was finished and the first "hose-nose" Glasair cowling was shipped to Lyle for testing.

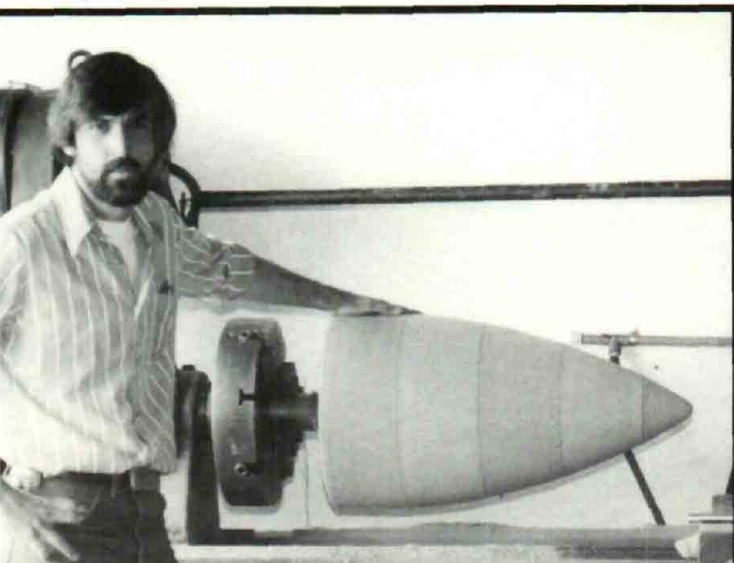
Meanwhile, I began carving my own version out of polyurethane foam which was applied right over my Mooney's existing cowling, engine, prop, and all. What a mess! (See Photo)

The idea of this cowling was to take the cooling air in through an open ring around the spinner and, using a large spinner, thus have very gently rounded external cowl shoulder for the lowest possible C_d and possibly to produce some forward thrust. The idea is not new; annular inlet cowls abound — Gulfstream I, DC-6, DC-7, etc. It was important to have fairly uniform curvatures in every meridian off of the ring (like radial engine nacelles) to avoid uneven circumferential pressures and flows. Thus, the roof of the Mooney cowl had to be 3" higher than stock and now actually covers the bottom 3" of my windshield. On the Glasair, this roofline created a broken nose shape resulting in a "Great White Shark" appearance, which some felt was ugly. For this reason, the Glasair probably won't use this cowling.

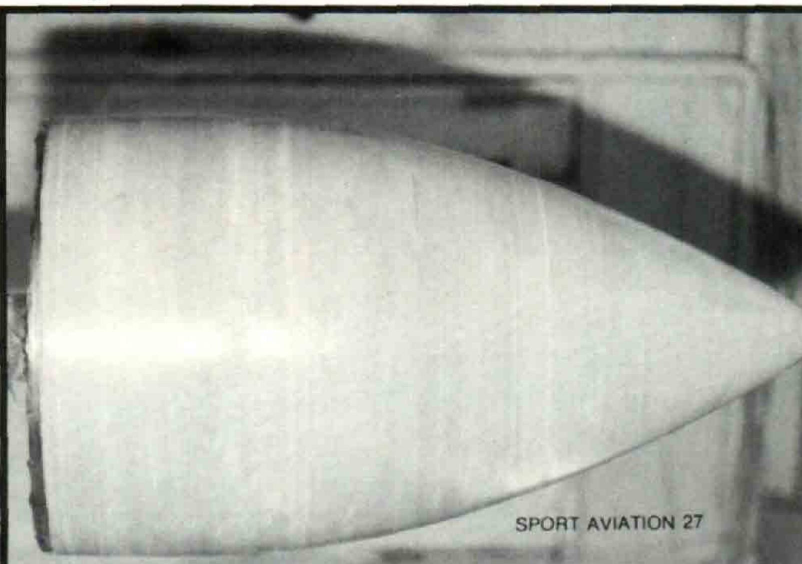
The Mooney's annular inlet cowling was expected to minimize disturbances in propeller blade root passage by avoiding the irregularity of the usual slab roof and nostril cooling inlets. Again, we hoped better prop efficiency would result.

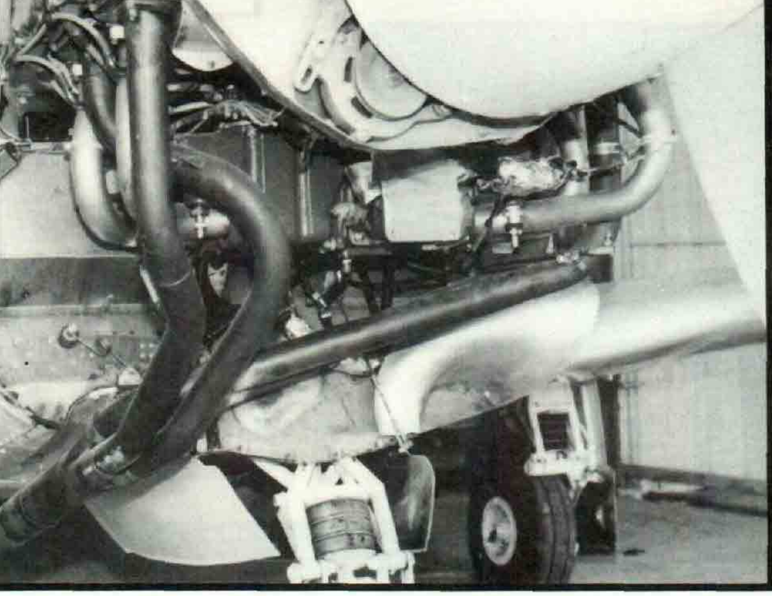
Unlike conventional cooling systems which inhale air from stagnation regions by slowing the air down before it enters

(Photo by Brien Seeley)
The foam spinner and Cris Hawkins after carving and before fiberglassing.



(Photo by Brien Seeley)
The finished, polished spinner mold. 3/16" thick "Bondo" over glass and foam.





(Photo by Brien Seeley)
The lower right firewall has an exponential horn-like airflow guide. Note tuned exhaust and small Honda alternator.

(Photo by Lyle Powell)
The new Mooney cowl was made from a female mold after a foam plug was carved on top of the new engine/prop/spinner.

the cowling, this cowling, I hoped, would have lower drag by inhaling air at velocities closer to freestream with little or no viscous drag due to external standing waves or reflux drag. Once inhaled, good pressure recovery would be achieved by smoothly decelerating the air in an annular diverging duct as on the Sea Fury. A skirt extension on the spinner was used to create the inner wall of this duct. (See Photos) The extra length of the prop extension afforded the necessary room for the deceleration duct forward of the engine.

Lopresti surmised the possibility that the spinner would develop negative skin pressure near the ring and might actually suck extra air into the inlet to enhance the cooling efficiency.

Every opportunity was taken to create a large cavernous plenum chamber on top of the engine to further enhance pressure recovery. The raised cowl roofline greatly increased this plenum volume.

The new cowling's belly was faired into a new smooth, tight-fitting pair of nose gear doors which were part of the new cowling mold. An internal horn was built on the firewall to smoothly reaccelerate the exiting cooling air.

By calculation, a tiny 2.5 in.^{2} ram air engine induction inlet would be just big enough to maintain a high inlet velocity at 75% cruise and would avoid reflex spillage drag. It is the little smile shape under the spinner in the photos.

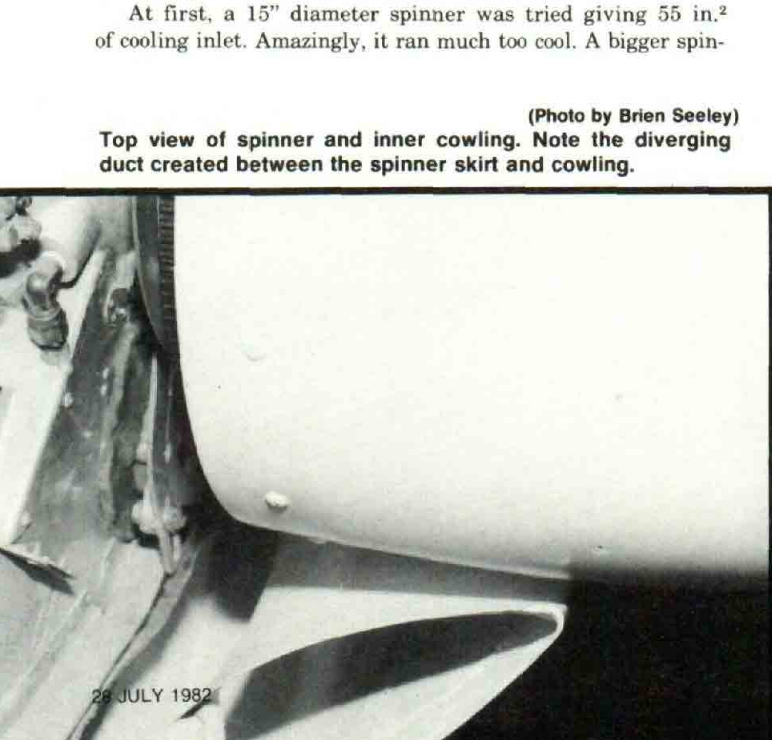
At first, a 15" diameter spinner was tried giving 55 in.^{2} of cooling inlet. Amazingly, it ran much too cool. A bigger spinner was needed. It also wanted a spinner with tight blade cutouts like Larry Kinder's, flush screw fasteners to keep the boundary layer thin and an integral flow skirt. The only alternative was to build it.

Enter Cris Hawkins, machinist par excellence, Mooney enthusiast, and good friend. Cris and I built a foam and fiberglass plug covered with Bondo and used Hal Kenyon's 22" lathe to turn and polish it. A very large 16.1" spinner male mold was created. The mold had circumferential grooves cut at the bulkhead locations so the fiberglass and graphite spinner would be extra thick overlying the bulkheads, and thus flush fasteners could be used. Two computers were used to derive the spinner shape (one in Chris' skull and one in mine). Every time I walk by this spinner I fondle it.

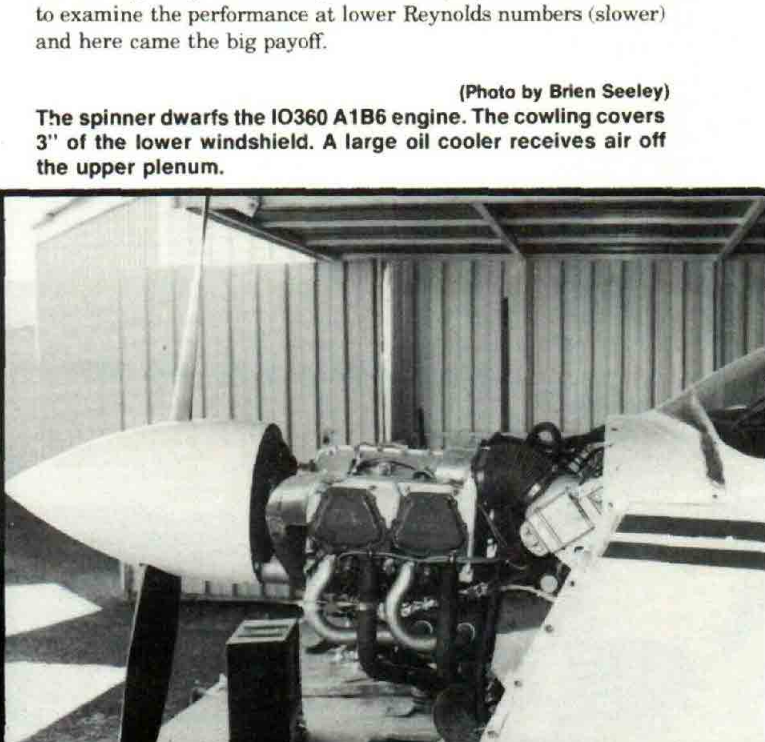
The spinner bulkheads were custom spun by Tom Hamilton's sub-contractor, and after Cris fastidiously mill drilled for the fasteners, the spinner was mounted. It tracked true with a run-out of only .005".

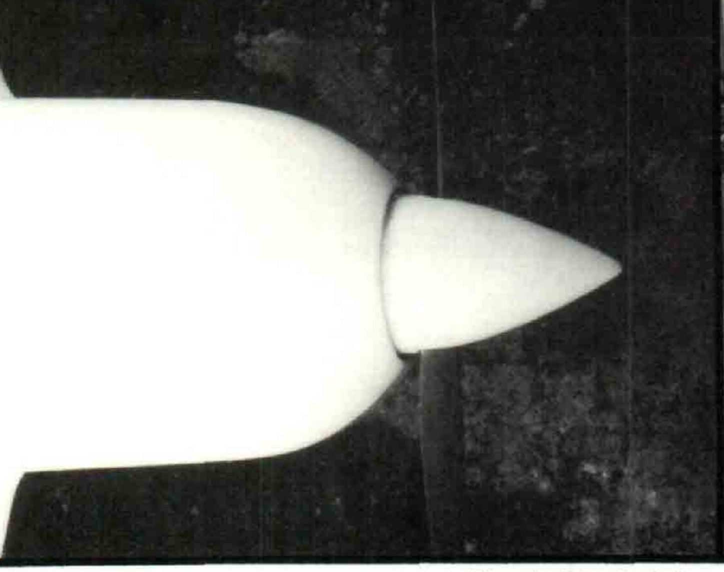
Now with only 34 in.^{2} of cooling inlet (the 201 uses 72 in.^{2}), this Mooney still runs cool. With the new engine, prop, spinner, and cowl, it was able to cruise at 216 mph at 8000'. It was disappointing to only see 5 mph from all that work. Maybe the prop tip mach limit was holding me back as Lopresti predicted. Maybe the cooling drag had already been nearly optimized. I decided to examine the performance at lower Reynolds numbers (slower) and here came the big payoff.

(Photo by Brien Seeley)
Top view of spinner and inner cowling. Note the diverging duct created between the spinner skirt and cowling.



(Photo by Brien Seeley)
The spinner dwarfs the IO360 A1B6 engine. The cowling covers 3" of the lower windshield. A large oil cooler receives air off the upper plenum.





(Photo by Brien Seeley)
Top view of new cowl shows the gently rounded shoulder contours and uniform shape encountered by prop blade root.

(Photo by Lyle Powell)
A large 50 in.^{2} cowl flap was built in the midline, but is seldom needed.

	TAS MPH	GPH	RPM	MP"	MPG
Original	178	12.6	2700	21.6	14.1
	*216	12.6	2700	21.6	17.1
	200	9.3	2400	21.6	21.5
	188	8.0	2100	22.0	23.4
	181	7.0	2100	21.0	25.7
	163	5.3	1850	15.0	30.2

*All mph measured per stock pitot. CAS would be about 3 mph slower.

I haven't yet tuft tested or manometer tested the airplane, but I feel these values can be bettered by more fine tuning. It would be fun to bolt on the shorter prop and compare performance.

The heavier engine and prop required ballast in the tail, and the new Gates sealed lead-acid battery cells were used. Taking the 22 amp-hour "6-pak" battery and putting 3 cells in the original battery box and 3 cells at the vertical stabilizer shear web cured the CG problem. Incidentally, this little battery is sensational — no vent required, three times the cold cranking power of the ordinary 22 ah aircraft battery, no maintenance, and three times the useful life.

A non-certified 35 amp Honda alternator weighing 6.7 lbs. was used to save 6 lbs. up front. The new 3.7 lb. alternator developed by Bill Bainbridge to fit on the vacuum pump drive may be adopted. At 8 amps output, it is adequate for a simple VFR airplane, especially with the Gates sealed battery. Bainbridge deserves a lot of credit for developing a solution to a chronic homebuilder problem.

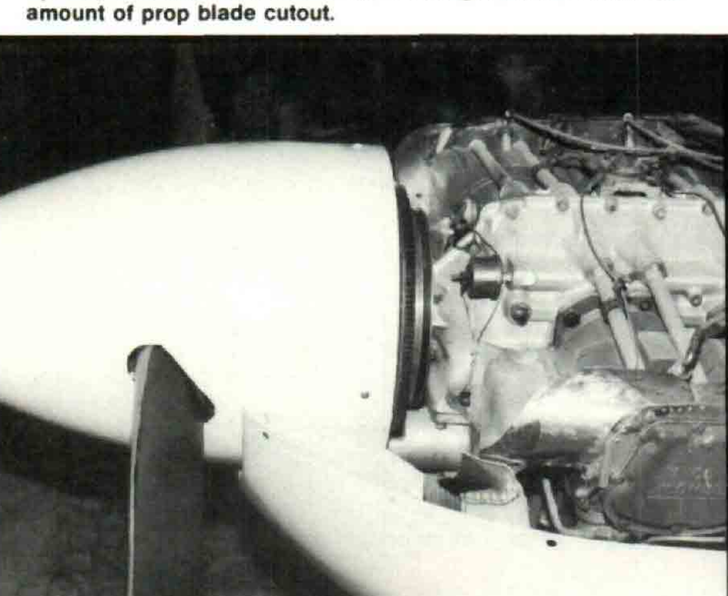
Future modifications for my Mooney will probably include a com antenna hidden in a fiberglass tail stinger (Jim Weir says it can be done), further sealing of leakage drag, elevator root fillets, 231 wing tips, and lots and lots of family trips. I promise, dear.

A word about the FAA certification of all this. Every modification must meet FAA engineering and CAR 3 standards and has to be type certificated. This is a big undertaking in itself. I have found the engineering people at the FAA's Western Region Los Angeles offices to be very reasonable and helpful, as long as you present a well-built, well-functioning, and well-documented modification. Al Strickfaden and Lyle Davis, in particular, have both been totally professional and very patient with my obsession with this airplane.

This project may have started out as an attempt to create a poor man's Mooney 201, but I hope from the foregoing story that it is apparent that this is no way to save money. If you see a hose-nosed Mooney at Oshkosh with a guy fondling the spinner, be sure to say hello.

I'd like to also thank Bob Walters at Lycoming West Coast, Gil Howe and Dick Ettinger at Hartzell, Bruce Malcolm, Don Lee and Bill Wheat at Mooney, Andy Marshall and Ron Jenkins for advice on composite methods, Mark Rusin for fireproof resin research, Dick Hunt for the spinner project, Al Stone for electrical help, Phil Steiner for help and support of all kinds, Gail Rathbun, Bob Walling, Jim Horn and Paul Loewen for air to air photography, and most of all, my wife, Anne.

(Photo by Brien Seeley)
Spinner extends well inside the cowling, and has minimal amount of prop blade cutout.



(Photo by Brien Seeley)
Lloyd Hamilton's Hawker Sea Fury annular inlet cowl uses a spinner flow skirt and inner cowl wall flow horn.