Falco Construction Note 61001-1

S-P-E-E-D

This Falco Construction Note replaces Advanced Builder Memo "Chapter 48 S-P-E-E-D"

Since everyone is interested in speed, this is a summary and discussion of all of the things that you can do to make your Falco go faster. First, some basic physics.

For an aircraft in unaccelerated level flight, the thrust of the plane is equal to the drag of the plane. Since thrust is equal to horsepower x propeller efficiency, the equation can be expressed as: horsepower x propeller efficiency = drag. Thrust and drag are expressed in pounds or kilograms, and while you can't measure these directly, they can be calculated. At 75% power, the Falco engine and propeller will produce about 200 lbs of thrust. The airplane will settle down at a speed where the drag of the airframe is also 200 lbs.

We all know that if you increase the thrust, decrease the drag, or do both, the airplane will go faster, but you may not be aware of the mathematical relationship between power, drag and speed. *Power required increases with the cube of the speed.* Another way of saying the same thing is that *speed increases with the cube root of the power increase*. The math is easy. Let's say your airplane goes 190 mph on 160 hp, and you want to know how fast it will go with 180 hp. The power increase is 1.125 (180 ÷ 160). Now, take the cube root of 1.125, and you will get 1.040, the speed increase. Thus, the airplane will go 197.6 mph (190 x 1.040). The simple reality is that you do not get much speed by increasing the power.

Drag increases with the square of the speed. If you put your hand out of your car window, you will feel the wind pushing your hand back. Let's say at 60 mph, the pressure on your hand—the drag—was exactly 5 lbs. If you increased the speed of the car to 180 mph, that's three times the speed (180 ÷ 60 = 3), so the drag would be 45 lbs (5 lbs x 3^2). Drag reduction is the single best way to get additional speed, and the faster the airplane, the more important each little improvement becomes.

The Wing

Typically, a wing constitutes 50% of the drag of an aircraft. The Falco has a laminar flow airfoil, and if you achieve laminar flow, the drag decreases by about 20 percent. This is an enormous reduction! Achieving laminar flow on the wing is the single most effective way to increase the speed of an aircraft. Laminar flow is possible only on the front of the wing. Thus, you should concentrate your efforts on the leading edge and the front of the wing.

Laminar flow is tripped up by any irregularities or bumps on the wing. A small bug smashed on the wing will cause a V-shaped wake of turbulent flow behind it. Aft of the point of maximum thickness, the air flow will become turbulent. A smooth surface will make the airplane faster, but the big payoff from laminar flow is gone.

Once you have built your Falco and the wing is painted, there is not much you can do except keep the wing clean and polished. So let's go into the little things you can do to get more speed.

Skinning the cove ribs. Most Falco builders have skinned the "cove" ribs—the little ribs right in front of the aileron and flap. The production Falcos did not have those ribs skinned. The natural inclination is to make everything on the outside of the airplane as smooth as possible. This does not make sense in this case, because the fastest aircraft will have no flow of air up through the slot. The most desirable condition is to stop the flow of air through this slot, not to increase it. The reason most builders skin the area really has to do with neatness and appearance.

The only reason to skin the cove ribs is to facilitate a curtain aileron or flap gap seal. By itself, it appears that skinning the cove ribs would make the airplane slightly slower. The difference in speed is probably too small to measure.

Flap gap sealing. In flight, high pressure air on the bottom of the wing will flow up in front of the flap to the top of the wing. This causes drag and can be eliminated by sealing the slot. The easiest way is to install a strip of soft, 1/4"-wide adhesive-backed foam on the wing so that it closes the gap with the leading edge of the flaps. This will give you an automatic speed increase.

The Falco's slotted flaps depend on the flow of air in the slot when the flaps are lowered. This gives the flaps additional lift. The foam seals do not prevent the functioning of this slot. Karl Hansen and others have used the adhesive foam strip method of sealing the flaps with success.

Luciano Nustrini sealed his flaps with a curtain of "plastic paper" attached to the wing and to the flap leading edge with double-sided tape. This converts the slotted flaps to plain flaps, thus increasing the landing and takeoff speed. We do not recommend this method as a result.

Aileron gap sealing. Sealing the aileron gap should give you a speed increase, just like the flaps, but the increase will be smaller due to the twist of the wing. The outer portion of the wing does not generate as much lift as the inner portion. Aileron gap seals can be expected to do more for you at economy cruise speeds than at the top end.

Sealing the ailerons is not as simple as the flaps—there are a number of things you should consider. The ailerons are just like the flaps in that they use the slot for air flow when the ailerons are down, thus the ailerons are really slotted flaps when they are down. Stop the flow of air in the slot, and you will decrease the rate of roll. The slot also provides clearance for the free movement of the ailerons and allows for a build-up of dirt, bugs or airframe ice. Ice is potentially the biggest danger. If you closed up the gap to a tiny slot, you could have the ailerons lock in position if you did an extended turn in icing conditions. This could be fatal.

Remember too, that the ailerons must go up and when they do, the gap between the wing and the aileron becomes smaller.

Karl Hansen sealed his ailerons with the same adhesive foam strip method he used on his flaps. Our principal concern with the adhesive foam strip method is the potential danger of binding at with the aileron leading edge at up-aileron. He took them off after the CAFE 400 race and said he didn't notice any change in speed.

Luciano Nustrini sealed his ailerons with a curtain of "plastic paper" attached to the wing and the aileron leading edge. He installed the aileron gap seals only for races since they reduce the rate of roll. Conceptually, we like the idea of a curtain seal although attachment methods aren't that easy. Nustrini attached his aileron gap seals with double-sided tape. He skinned the "cove ribs" in front of the ailerons and flaps, and this is really required if you want to install the seals. The curtain forms an upside-down "U", and the curtain is installed by sticking the curtain to the wing with the aileron leading edge up and then sticking the curtain to the aileron leading edge with it down. The curtain must be long enough to allow free movement of the ailerons.

The air pressure will hold the curtain in position as an upside-down "U", but any inverted manuevers could cause the curtains to tear loose and jamb the controls, thus no inverted flight should be attempted with the seals installed.

Luciano Nustrini reported that the aileron and flap gap seals make a dramatic difference in the speed—6 to 10 mph—but he installed his seals only for races since they increase the landing speed and hurt the rate of roll.

Aileron and flap end gaps. There is a gap at each end of the aileron and flap. Like the slot in front of the flap and aileron, high pressure air from below the wing will flow through these gaps. This causes drag.

The gap at the inboard end of the flap is the easiest to seal, since the flap goes down only. During construction, you could build the airplane for a tight fit, if only by adding to the wing with foam and fiberglass. You can extend the bottom of the flap inboard and the top of the wing outboard so that the flap "seats" into the wing and this could be sealed with an adhesive foam strip. Except for possible binding by debris or ice (which would only be an inconvenience) we can see no problems with closing this gap.

Jambing the ailerons would be quite serious, of course. Many Falco builders have closed up the gap on each end of the aileron for clearance of about 1.5mm. If you do this, add foam and fiberglass to the outboard end of the flap and to the inboard side of wing rib No. 14. Don't add to the aileron. Ensure that the aileron will have free movement and check the ailerons on each preflight for free movement and anything that could cause binding of the controls.

Reflexed flaps and ailerons. Luciano Nustrini reflexed his ailerons and flaps, raising the trailing edge 15mm at the inboard end of the flaps and 12mm at the tip of the aileron. To do this, he completely rebuilt the control surfaces. If you attempt to do this with your controls, you will slow the airplane down since the leading edge of the ailerons and flaps will stick down below the lower contour of the wing. This modification increased the speed of the airplane by 6-7 mph at sea level, but hurts the airplane at altitude.

We strongly recommend against any such attempt. Since Nustrini was intent on winning races at very low altitude, this made sense for him, but it makes no sense for anyone else.

You can simply reflex the flaps slightly by diddling with the adjustment of the control arm. A number of Falco builders have done this, and it appears at lower altitudes that you can get an extra mph or so, but you will pay a price at 12,000 feet or so.

Flap and aileron hinge fairings. Everyone should install fairing in front of the flap and aileron hinges. What you are looking for is the smallest smooth shape which will divert the blast of air *completely* around the hinges and hinge bolt. The rough shape of a bolt is a terrible drag-producer. Air doesn't mind smooth shapes, and the size of the fairing is of much less consequence than having the end of a hinge bolt protruding into the air stream. Be sure all hinge fairings also fair the stream of air over the hinge bolts.

It is not enough to simply fair the air stream over the hinges. The air on the bottom of the wing is high pressure air and will attempt to go up into the hinge opening if it can. Karl Hansen reported a substantial increase in speed when he first installed fairings on the inboard flap hinge—if felt, he said, "like you took the brakes off." The air curves up and hits the front of the flap and aileron spar. All efforts to stop this from happening have produced additional speed.

Downstream hinge fairings. The SF.260 has fairings on the aft side of the hinges for the flaps, but not on the ailerons. Luciano Nustrini had downstream fairings of foam and fiberglass glued permanently in place. It is difficult to say how much good these do—we don't know. There can be little harm in installing such a fairing on the inboard hinge of the flap, but you should be very cautious about installing such fairings on the ailerons for reasons of aileron balance and flutter. Always re-weigh and balance your flight controls after doing such work. Flutter is a terrible phenomenon, and it can kill you. Treat it with respect.

Other hinge fairings. Karl Hansen and others have installed a tight-fitting aluminum fairing plate on the top of the aileron at the control arm. The piece of aluminum fits tightly around the control arm and the pushrod.

Karl Hansen and others have installed an aluminum fairing on the bottom of the flap at the outboard hinge opening. This fairing effectively extends the bottom of the leading edge of the flap to the hinge. Karl Hansen and others have install the same kind of aluminum fairing on the bottom of the flap at the inboard hinge opening. This keeps the high pressure air from coming up and hitting the forward face of the flap spar. This was one of Karl Hansen's first 'speed mods', and he said it made a noticable change in performance.

Flush fits. All wing access panels and the pitot tube mast should be rabbetted into the plywood for a flush fit with the skin. There is no way of knowing how much speed this gives, but it certainly does not hurt. All of the very fastest Falcos are built this way, if only because they are built by compulsive perfectionists.

Flat head screws. Again, it is difficult to access the benefit of using flat head screws on the pitot tube mast, all access panels, wing tip lenses, etc., but a number of the fastest Falcos have nothing but flat head screws installed.

Paint stripes. If you paint stripes along the leading edge of the wing, you are going to have inevitable ridges in the paint. Any such imperfection will trip the laminar flow and slow the airplane.

Wing walks. The production Falcos had a metal strip along the front of the wing walk, and the wing walk itself was a strip of rubber with a rough surface. One owner told us he got 5 mph by removing the wing walk. Owners of such aircraft have mostly removed these wing walks and installed wing walks of 3M Company's non-skid material. This is a sandpaper-like material with an adhesive back.

It's difficult to say how much speed it costs to have a 3M wing walk, probably less than 1/2 mph. Nustrini did not have a wing walk. Karl Hansen did not have one at first, but he had one installed when he flew the airplane to 232 mph at full throttle at a density altitude of 6,000 feet. Karl intentionally installed the wing walk about 40% aft of the leading edge, because there's no hope of laminar flow aft of that point. Karl said he didn't notice any change in speed. Our advice is to install a wing walk and get your speed from other things—but it's a free country!

Wing trailing edges. Most builders have used a blunt trailing edge by gluing the plywood to each side of the trailing edge strip and then sanding the trailing edge to a radius. Karl Hansen built his wing so all of the trailing edges were to a sharp point. He did this by scarfing one skin and then gluing on the other. Karl says that he finds the sharp trailing edges pretty, and that "you want a lady to be as dainty as possible." There are others who will argue that sharp edges are an invitation to hangar rash.

A blunter trailing edge is actually superior for maneuvering, so a blunt trailing edge on the aileron will result in a marginally higher rate of roll.

Karl Hansen says that he asked his nephew—who has a masters degree in aeronautical engineering at M.I.T.—about critical drag areas on laminar flow devices, and he said "smooth laminar flow area and thin, clean, trailing edges." Karl points out that if you look at a computerized flow pressure chart, you will see a high pressure line just in front of the trailing edge. Karl reports that he showed Mr. Frati the trailing edges and that Mr. Frati said "That's the way I designed them."

We don't claim any knowledge on this. Our instinct is that the speed increase would be very small, but we could well be wrong.

Flush fuel vents. Most of the faster Falcos have the fuel vents out of the air stream, installed so that they drain at the inboard flap hinge area.

Talcum powder. No discussion of speed mods would be complete without mention of Luciano Nustrini's bizarre technique of dusting the leading edge of his wing with talcum power before a race. Nustrini said it gave him two to three mph. There is, in fact, a rational basis for this. Sailplane pilots have long ago discovered that a lightly sanded leading edge is better for laminar flow than a polished finish. Nustrini tried sanding the leading edge, but it was always dirty, so he developed the talcum powder technique instead.

Tail Group

The tail group is a repeat of the techniques used on the wing. With a wing, we give the top of the wing the bulk of our attention simply because it is the side we can see without bending over. As it turns out, it is also the side of the wing which *should* get the most attention since air on the low pressure side is more easily tripped to turbulent flow. With the horizontal tail, the low pressure side is the bottom. Just as with the wing, the leading edges and surfaces of the fin and stabilizer should be smooth and clean back to the point of maximum thickness if laminar flow is to be achieved.

Elevator gap seals. Most builders construct their Falcos with such a tight fit between the stabilizer and the elevator leading edge that there is no space or need for a gap seal. The object of any seal would be to stop the flow of high pressure air on the upper surface of the horizontal tail to the lower surface. It appears to us that the simplest method is an adhesive-backed foam strip along the centerline of the stabilizer spar. Make very sure that any such seal does not bind the controls.

Rudder gap seal. Because the rudder is normally in a trail position, there is little or nothing to be gained from installing a rudder gap seal. If you would like to do so, install an adhesive-backed foam strip along the centerline of the main fin spar. Make very sure that any such seal does not bind the controls.

Elevator trim tab gap seal. The gap at the hinge line of the elevator trim tab is best sealed with a piece of plastic tape. Select a piece of the same color as your airplane and make sure it will flex when the trim tab is moved. For most Falcos, the trim tab spends its life between the trail position and with the trailing edge of the trim tab about 5mm above the trailing edge of the elevator. Thus, the high pressure air, if any, would be on the lower side of the elevator trim tab.

Hinge fairings. The hinge fairings for the elevator and rudder are detailed in the construction drawings. Perfectionists may install flat head screws.

Canopy and Windshield

We are often asked about the speed improvement of the Nustrini canopy. Falco owner Hans-Heinrich Kühne installed the Nustrini canopy on his Series IV Falco. Dr. Kühne thinks the canopy improved the indicated airspeed by about 3 knots, but he did not keep careful notes. The speed increase is not so much from the lower height but from the smoother transition from windshield to canopy. Another Falco owner in Germany told us he tuft-tested his Falco and found the (standard) canopy, top of the tail cone and much of the vertical tail was bathed in turbulent flow.

(It would be very interesting to see a tuft test of a Falco with each type of canopy. This is easily done, you just tape knitting yarn to the fuselage and canopy with masking tape. Cut the yarn off in 3-4 inch lengths and then fly the airplane. It's best to have another plane fly with you to photograph the test. The tufts will behave differently at different angles of attack.)

Windshield installation. The production Falcos were built with their windshields installed with strips of aluminum over the plexiglass and with screws through all of this. Most of the fastest Falco have flat head screws with Tinnerman washers and then with fiberglass over the screws. It makes for a beautiful installation, and it is clearly the best way to go for speed—but Lord help the builder if he ever has to replace the windshield!

Windshield/canopy fit. Obviously, a smooth fit of the canopy with the windshield is important for low drag as well as looks. Many Falcos have a tight fit between the fairing on the canopy with the fairing strip around the windshield.

Canopy leaks. Sealing up all air leaks around the canopy is important for many reasons—dry, quiet cockpits—including drag. Air leaking in or out of the canopy will slow the plane down.

Flat head screws. Karl Hansen and others have replaced the canopy screws with flat head No. 6-32 machine screws installed with Tinnerman washers under the heads. Speed increase is unknown. The Tinnerman washers are a must to distribute the load on the plexiglass. Karl used Loctite on the threads to make sure they don't loosen since you can't tighten them very much. The sheet metal screws wedges into the threads, but tapped threads are free and could loosen.

Fuselage

There is little opportunity for speed mods on the Falco fuselage. Obviously a smooth finish is important, and you can used flat head screws on all access panels.

Flat head screws in the cowling. Some Falco builders have installed their cowlings with flat head screws. Some countersink the fiberglass and install the screw, while others have used Tinnerman washers. Obviously, a screw that is completely flush with the surface will produce less drag than a round head screw, but our advice is *don't do it*. Fiberglass does not tolerate pin fasteners well and flat head screws are an invitation to trouble. There is a lot of vibration in the cowling and over time this is likely to cause the cowling to crack around flat head screws. Flat head screws installed with Tinnerman washers are less likely to crack because the washers spread the load into the fiberglass, but we have to wonder if the washers don't produce as much drag as the round head screws. Luciano Nustrini, by the way, has round head screws on his cowling.

Landing light lens. Pay particular attention to getting a perfectly smooth fit and installation of the landing light lens. Many cowlings have laminar flow and any turbulence caused by this lens would be detrimental.

Gear Doors

Gear doors are always controversial. There are many fast airplanes—SIAI Marchetti SF.260, Cessna Citation, Bellanca Skyrocket II—that do not have them. The decision to install doors on a production aircraft has a lot to do with production costs and marketing decisions. Truth be known, most gear doors are not worth the expense (often $5,000 to $10,000) involved with a production aircraft. The rationale offered for or against doors often has more to do with whether doors are currently installed on this year's model.

But on the Falco, it is easier. Doors are not terribly expensive. Doors always give additional speed, and only the main gear wheel well doors involve any significant complexity. All of the fastest Falcos have full gear doors all around. Everyone installs the main gear doors, so we will consider that a standard part of the design.

Warning

One of the more tempting things do to with a Falco is to bring the landing gear up as much as possible. *This is an extremely dangerous thing to do!* The problem is with the nose gear retraction mechanism. When the nose gear is up in its correct position (exactly horizontal), the nose gear lower drag strut is under considerable tension. If you bring the gear up more, the load on the nose gear lower drag strut increases at an astonishing rate, so it is quite easy to double and triple the load on this part by bringing the gear up more, because of the lower drag strut's very shallow angle to the trunnion's "hinge line". For this reason, Luciano Nustrini's Falco had the nose gear retraction linkage fail, and the airplane ended up on its nose. Nustrini's Falco is not the first to do this, nor will it be the last if homebuilders follow this dangerous practice.

Remember that a smooth bump on the nose gear or main gear wheel well doors is extremely insignificant. Smooth bumps create very little drag.

The nose gear door is important for two reasons. Without it, the engine runs too cool since the fairing for the nose gear functions as an extractor, pulling air out of the cowling. This is one very powerful extractor—causing the CHT to run a full 100°F cooler than the production Falcos.

The main thing about the doors is that you should make sure that they fit well and do not pull open. This will involve a certain amount of flight testing, observation from another aircraft, and adjusting.

All of the doors seem to be in a place where the air is trying to rush out of the wheel well. The leaking of air causes drag.

Nose gear door seals. Karl Hansen sealed between the nose gear door and the cowling by using strips of rubber sheet, like we use for the engine baffling. He fastened the strips to the cowling so the door would come up against the seal and the air pressure would hole the seal closed. Karl used Plio-Bond—which he reported is unaffected by oil or gas—and then used rivets to make sure it stayed in place. Karl reports that you can see chafe marks on the rubber where it contacts the door and concludes that it must be sealing tightly from air pressure.

Nose gear bay doors. The nose gear bay is an aerodynamically dirty opening of nearly one square foot. Installing the doors will give you about 10 knots at top speed and 7 knots at cruise. The air tends to rush out of the nose gear bay. At the hinge line, buckskin seals could be cemented to the doors, and the air pressure would push an extended flap of the seal against the nose wheel bay walls.

At the centerline, the situation is more difficult. If one door consistently closes first, then a simple overlaping flap on one door would do the job. Failing that, it seems like the simplest thing to do is to put a rubber P-strip on each door so that the P-strips touch when the doors are closed.

Main gear doors. The piano hinges can be sealed with a strip of buckskin cemented in place. The pressure of the air rushing out will push the soft leather in place to seal the hinge.

Around the door, it looks like the best thing is to glue a strip of adhesive-backed foam to the wall of the gear well. The foam should stick out a little—say 1mm—so that it will seal and compress slightly when the door closes.

Main gear wheel well doors. Same as above. These doors have a tendency to pull open at the outboard trailing edge at high speeds. We see this as a matter of door stiffness and adjustment. You will usually find that you cannot get the doors to seal tightly when the gear is up and down. The important thing is that the doors be tight when the gear is retracted. If the doors hang down a half-inch or so when the gear is extended—don't worry about it! The doors are strong enough to withstand cycling the gear, and this puts no greater load on them. Luciano Nustrini's gear doors are not a tight fit when the gear is extended.

The Engine Compartment

Now it is time to give our attention to the air that passes through the engine compartment. This air follows a tortuous path into the cowling, over the cylinder fins and out the bottom of the cowling. Some of it goes through the oil cooler, and smaller quantities go to the cabin heat system, to cool the alternator, and to cool the magnetos. There are several basic principles in minimizing the cooling drag: (1) smooth out the flow of the air for the least drag, (2) seal all leaks so the air that enters the cowling is used for cooling and is not wasted, (3) reduce the amount of air allowed to pass through the cowling.

When the air enters the cowling, it quickly slows down as it packs into the "upper deck"—the high pressure side of the engine cooling system. As the air leaves the cowling at the bottom, it is accelerated once more. Smooth surfaces are more important at these areas of high speed air flow.

Starter ring seal and fairing. Air entering the cowling slows down, and the pressure increases. The pressure increase comes not only from the ram effect of the air, but from a property of air explained by Bernoulli's theorem. Remember in a venturi, the high-speed air at the narrowest point has the lowest pressure, thus as the air leaves the venturi the air slows down and the pressure increases. Think of the inlet of the cowling as the aft end of a venturi. The inside of the cowling expands to slow the air down and to increase the pressure of the air. The first object is to admit this air with the least possible resistance.

As it is supplied, the inside of the intakes are a smooth airfoil shape—similar to the Mooney 201. This shape joins the upper inside surface of the upper cowling at the forward edge of the door. At the inboard side of the inlet, the inlet fairing stops. You can reduce the drag by extending these fairings down to the baffling.

These fairings should also be joined together by extending them across the engine to completely seal the upper deck from the lower deck. Although it will have little effect on the operation of your engine, this is an extremely important thing to do for additional speed. Without this sealing, a lot of air is allowed to pass down around the starter ring. This is a terrible waste of energy and the air spilling out behind the spinner is re-circulated back into the engine.

Remember that the engine moves around quite a bit. We provide about 1/2” between the baffling and the cowling. This extension of the upper cowling inlet fairing should also have rubber seals at the bottom.

Glue a piece of foam (say 1/2” thick) so that it is in line with the aft ends of the inside inlet fairings, and goes straight across the engine (at right angles to the crankshaft). Fit the foam piece to the engine so that it clears by 1/2”. Cover the foam with fiberglass and epoxy or polyester resin. Install a rubber seal on the aft edge so that it seals against the engine crankcase.

If you wish, this inlet fairing can be extended back a couple of feet so that it forms a complete streamlined shape with the spinner, and you would use this “reverse spinner” to seal against the engine. Many fast airplanes seal around the starter ring with a simple blunt shape for easy construction. The air inside the cowling is slowed down and swirls in many directions, so the general thinking is to not bother with aerodynamically clean shapes.

Cowling inlet fairings—outboard. At the inlets, there is a little drag which can be eliminated by installing fairings on the baffles. The cowling inlets are rounded, while the baffling are squared off at the front. Glue some foam on the baffles and sand so that it continues the shape of the cowling inlet. This is easy to do on the right front. On the left front, this sort of fairing will cover up the screws for the oil cooler support. You could provide a small hole and cover it with tape. It is also possible to remove the oil cooler with the forward oil cooler support in place, so fanatics might want to try that.

Cowling hinge seals. The cowling hinge is something of a sieve. Take a look through the cooling intake of the cowling at the amount of daylight that shines through.

Seal the hinge with a strip of buckskin glued to the cowling support angle and with part of the strip covering the bottom of the hinge. The air pressure from below will push it tightly shut. The soft deer skin does a beautiful job of sealing—it is light, seals well, and doesn’t harden.

Glue the buckskin in place with Plio-Bond. Experiments with contact cement proved that it was useless in the engine compartment.

Sealing the engine baffling. There are a number of little holes in the baffling created in the process of manufacturing. These occur in corners and are easily sealed with silicone rubber RTV compound.

Stiffening the baffling seals. The baffling seals are made of 1/16” nylon-reinforced neoprene gasket material. For most airplanes, this is just right, but you will find if you get over 190 knots indicated the baffling will push back. Karl Hansen had this problem in one place on the left aft baffling, and Kim Pearson had the same problem in the SF.260 he used for airshows. We think you should do nothing until you find this happening on your airplane. When you find a baffle seal pushing back, stiffen it by cementing on an extra piece of rubber gasket material. A double-thickness of the rubber should be stiff enough to solve the problem.

Intercylinder baffles. Check the intercylinder baffles. Karl Hansen found that his did not fit well and had a half-inch space for air to spill through. He sealed this up with a piece of aluminum.

Additional intercylinder baffle. We designed the Falco baffling with the idea that each cylinder should “see” the same air, thus each of the two front cylinders have deflectors. The baffles are the same for each cylinder—with one exception. Note that the baffling wraps under the right aft cyliner and deflects air toward the exhaust port. This is done for the aft left cylinder and the right front cylinder, but is not done for the other two because their exhaust ports are "between" the cylinders. It seems to us that the cooling air will flow through this area more rapidly as a result and that some experimentation with installing little baffles might be in order.

Reducing oil cooler air. After you are flying, you may reduce the flow of air through the oil cooler if your oil temperature is low. Karl Hansen simply put a piece of duct tape across a couple of rows of the cooler. The engine will develop more power with hotter (i.e. lower viscosity) oil, and the airplane will be faster because of less cooling drag.

Cabin heat system. If you do not have a cabin heat system installed, you should cover the two-inch diameter hole with duct tape. All cabin heat valves for aircraft are designed for a constant flow of air through the system—the theory being that simply stopping air would cause the heat muff to get very hot and something could burn. An aluminum heat muff would not be damaged, but the red Aeroduct silicon rubber tubing rated up to only 400 to 500°F (as we recall) and would not tolerate taping off the cabin heat inlet. If you wish to do that, remove all parts that will not stand the high temperatures.

Insulating the exhaust pipes. Karl Hansen came up with an unusual idea. He insulated his exhaust pipes by wrapping them with Fiberfrax insulation, then with heavy aluminum foil, then with aluminun foil tape (from Aircraft Spruce) and finally laced the whole thing in place with stainless steel safety wire. This accomplishes several things. First, it keeps the exhaust gases hot until they are expelled from the tail pipe. Because the gases are hot, they have not contracted, so the exhaust produces more thrust. Second, the exhaust pipes do not heat the lower deck air. If the insulation were not installed, the air would be heated, it would expand and a greater volume of air would have to be exhausted from the cowling. Third, the insulation keeps things cooler. Some builders have found that their cowling paint will blister at a close spot with the exhaust. Others have had problems with vapor lock in their fuel system. The insulation will help all of these things. Fourth, it probably makes the airplane a little quieter.

The only negative consideration is that insulating the exhaust pipes will cause them to run hotter, and it is possible that there could be some problems with cracking. Turbocharged engines frequently require Inconel exhaust systems since stainless steel will not hold up at the temperatures. So far, Karl Hansen has had no problems with the insulated exhaust system, but one aircraft with 150 hours is too small a sample to be definitive. We think this is an intriguing idea and probably worth doing, but the system should be monitored closely for cracks.

Exhaust port horns. We designed some exhaust port horns for the Falco engine installation. The theory is that it is always better to have air go around a smooth corner. Karl Hansen has installed these horns on his Falco. We have no definitive proof that they make the airplane faster, and no way of knowing if they are worth the trouble.

We do know that the parts are very difficult to make of aluminum! We have now had two shops attempt to make the horns and each has failed. We expect to go ahead and make the damned things out of fiberglass in the near future.

Sealing around nose gear screwjack. Karl Hansen blocked the flow of air into the nose gear bay by installing rubber seals around the nose gear screwjack. The seals were made of the same rubber gasket material we use for the baffling seals. Karl held these in place with two half-ovals of aluminum, screwed into place. The seals are two pieces of rubber, and they overlap in the center of the hole. The screwjack pushes between the seals. Karl cut a hole in the two pieces to fit the screwjack in the gear-up position.

Sealing on both sides of the nose gear. Karl Hansen blocked the flow of air into the nose gear bay by installing aluminum plates on both sides of the nose gear. He cut two pieces of aluminum for a good fit between the nose gear and the upper drag strut supports. The top of the sealing plates were bent 90° and screwed to the bottom of the fuselage frame. This prevents air from entering the nose gear bay. Strut side clearances must be carefully observed.

Breather line to exhaust. Homebuilders are adopting a practice first introduced on the Swearingen SX-300 of dumping the engine breather line into the exhaust. It has the advantage of keeping the bottom of the airplane from being covered with oil. We can't think of any reason to object to this practice. It has obvious merit and only time will tell if there are any negative consequences of this installation. From the standpoint of cooling drag, this has the very slight benefit of removing the breather tube from the cowling exit, and the airplane will definitely be faster with no oil on the belly. It is impossible to quantify such improvements, but tiny drag reductions always help.

Sealing around nose gear cowling door. We covered this earlier, but you should install seals between the nose gear door and the cowling to keep air from leaking out.

Baffling adjustments. Adjust the intercylinder baffles so that each cylinder has the same opening at the bottom. The key to even cooling is to have each cylinder "see" the same amount of air.

Advanced Techniques for Cooling Drag Reduction

Aircraft designers say that an airplane is a group of compromises flying in close formation. This is certainly true of the engine cooling system. The inlets and exits for the Falco cowling were developed for the original production Falco, and we did not change the areas on our cowling. By smoothing out the inlets, we have probably increased the amount of air which enters the cowling. The same is true of the exits, since the exhaust port horns eliminate a sharp corner and because we have two exhaust tailpipes instead of the four used originally.

As we supply it, the Falco cowling is used by pilots who install 160 hp or 180 hp engines, and these are used by some pilots for high speed cross-country flying only, while others use their aircraft for extensive aerobatics. When an airplane is flown in aerobatics, the power setting is frequently high, and the airspeed fluctuates wildly. You cannot expect a cowling optimized for high speed to cool an engine during aerobatics.

If you want to get the maximum speed possible out of your airplane, you can get some additional speed by restricting the flow of air through the cowling. Less air going through the cowling will mean less cooling drag, and the engine will develop more power at higher temperatures. Theoretically, the ideal engine requires no cooling, since cooling carries off energy that might otherwise be used to develop engine power. The temperature limitations of an engine are imposed by the oil and metal in the cylinder head.

Opinions vary on the ideal temperature for an engine. High Performance Engines preferred to see an engine operate at a CHT of ???-??? for the best flame front in the cylinder. Increased oil temperatures are generally desirable since the oil has lower viscosity when hot, heats the induction air better, and uses less energy to cool the oil. Increased cylinder head temperatures are desirable primarily because less temperature is lost to the cylinder head. The limiting factor for most engines is the ability of the exhaust valves to tolerate extremely high temperatures.

For certification, aircraft cooling systems are designed and tested for a "100°F day", meaning that the engine can be operated on such a day and stay within the engine manufacturer's temperature limiations. If you live in Norway or Alaska, this may be of little concern to you, but don't forget that you have to leave a temperature margin for those hot days.

If you are going to optimize your engine cooling, you should have a 4-cylinder CHT gauge installed. This is very important since it will allow you to carefully monitor the temperature of each cylinder, and you can never make any assumption on which cylinder is the hottest.

Ideally, you should install plastic tubes to the upper and lower deck so that you will know the "delta P" or the difference in air pressure across the cylinders. This will help you determine whether to reduce the inlet area or exit area.

Uninformed homebuilders have a natural tendency to reduce the air inlet size as the first step. This is wrong. It is best to seek a proper balance between the induction and extraction of cooling air. The size and shape of the inlet determines the ability to admit air, but it does not control the volume of air that is admitted. The volume of air is controlled by the friction of the air passing over the cylinder heads and by the "delta P". The "delta P" is a function of airspeed, the pressure increase on the upper deck and the extraction on the lower deck.

Many amateur homebuilt designs depend entirely on the pressure of air passing through the cowling inlets to push the air through the engine, and the air is allowed to exit where it will. This is not a good situation. The Glasair, for example, actually has a *reversal* of air flow through the oil cooler at certain airspeeds!

Properly designed, the inlets will admit enough air to cool the engine in a full-power low-speed climb. This occurs momentarily at takeoff, and on the Falco the open nose gear door gives additional extraction. With the gear up, the airplane should be capable of climbing on a 100°F day without the engine overheating. Design goals are different for different aircraft. Some designers want the ability to climb at full power at a cruise-climb speed on a 100°F day, while others want to do this on 75% power. If the CHT reaches red line temperatures during such a climb, there is no margin for error.

The choice is up to you. If you mainly do cross-country flying with occasional loops and rolls, our recommendation is that you decrease the flow of cooling air so the cylinder head temperatures go about halfway into the yellow band—to 460°F—on a full power 90 knot climb on a 100°F day. You may assume that all temperatures are additive, thus if the CHT reaches 400°F on a 40°F day, you can assume that a 60° warmer day will result in a 60° increase in CHT.

(Karl Hansen, by the way, reported that he has never seen more than about 390°F cylinder head temperature, even in the CAFE 400 with multiple climbs in 100°F heat, and that he had no engine trouble even climbing at lean mistrue settings at 73% power, indicating 150 kts and climbing at 500 fpm.)

Since inlets are designed for takeoff and climb, they are always too large at cruise. Excess air flows around the cowling. This is the reason for the large radiuses on the cowling inlet—tight radiuses do not handle the variable angle of air flow well. Tight radiuses are appropriate only if the inlet is precisely sized for a specific speed.

The best designers begin by calculating the cowling inlet areas with equations, rules of thumb, and experience. Once the airplane is flying, they just fiddle with the design until they get it right. To do it right, you should have specific goals for cylinder head temperature, oil temperature, upper deck pressure, lower deck pressure and the difference—“delta P”. Lycoming’s specifications call for a “delta P” of (6 to 8?) inches of water across the heads.

Since we have adequate extraction, you should start by reducing the inlet area to optimize your Falco for high speed cruising. Reduce the inlet size slowly until the cylinder head temperatures are just a little cooler than desired, then make final adjustments to the exit area.

We think the best approach is to make a temporary cuff of foam, fiberglass and bondo for the outer part of the cowling inlet. This cuff can be added to gradually as you flight test the reduction. Once you have what you want, you can install a permanent piece, or you can make a nice-looking part that can be removed whenever you want.

With each decrease in the inlet area, check the cooling of the engine in climb as well as inlet area. We repeat—a 4 cylinder cylinder head temperature gauge is essential! A water manometer to measure the “delta P” is a good idea, but not essential.

A few notes on inlet and outlet areas. It is difficult to measure the inlet area exactly, but using the plane that we used to draw the inlet, each calculates out to 45.2 square inches per side, so that’s 90.4 square inches total. Somewhere in our design notes we have it that Dave Thurston’s calculations showed we needed 80 square inches for a 180 hp engine and 72.6 square inches for the 160 hp engine and that we had 75.5 square inches with a one-inch band eliminated. Dave Thurston considers the first inch of air out from the spinner as “dead air” which cannot be calculated for cooling purposes. Because of these calculations, we were worried that the engines might run hotter than the production Falcos. As we all now know, the engines run cooler since our inlet and outlets are more efficient. The outlet area is 21 square inches per side for 42 square inches of total available opening. A four pipe exhaust system reduces the net exit area to 32.36 square inches, while a two-pipe system reduces the net exit area to 37.19 square inches. For the calculations of the inlet and exit areas, see Falco Powerplant Installation below.

For comparision, the Lopresti Sharkfire homebuilt had a total inlet of 38 to 39 square inches total and Curt Lopresti said the engine cooled well—although the plane only flew a couple of times and the cooling was probably never tested in a full power 90 knot climb or a 100°F day. This airplane had a 160 hp Lycoming, and had two seats in tandem. The exits were at the aft end of extended cheeks, and they were located in a low pressure area. George Pereira’s 200 hp GP-4 has 42 square inches total of cooling air inlet.

One method of controlling the cooling is to install cowl flaps. Some of the best aircraft designers do not use cowl flaps and yet have achieved extremely fast aircraft. Ted Smith designed the Aerostar without cowl flaps, and Stelio Frati has not used them on the SF.260, Falco, Nibbio, Picchio and many other aircraft. The argument has always been that if you design the engine installation right, you don’t need cowl flaps. Piper executives even *ordered* the design engineers to install cowl flaps on the Aerostar—after all, don’t all real airplanes have cowl flaps?—and discovered that they did nothing for the airplane!

We like the Ted Smith/Stelio Frati approach. Usually the best design work is the simplest, and we think this is true in this situation. We cannot identify a problem worthy of a “solution” of the complexity of cowl flaps.

But if you do everything we say and feel that there could still be some speed available by using cowl flaps, the approach that we would suggest is to use “internal cowl flaps”. Do something to control the flow of air out the cowling exits. There are any number of ideas, none of which we have explored. To actuate the device you can use one of the cabin-heat cables to control a torque tube mounted on brackets backed up the the rudder pedal supports’ bolts. But, remember, our advice still is to pursue all alternatives first.

Propeller and Spinner

Closing up the space behind the spinner. If you wish, you may want to seal between the cowling and the spinner. The space provided is large by some standards, but you should remember that the Falco is an acrobatic airplane. During acrobatics, the engine will move around a surprising amount. Early Pitts aircraft, which had the cowling installed close to the spinner, had problems with the spinner contacting the cowling. When the spinner touched the cowling—boom!—no more cowling! For this reason, we provided enough room for clearance during acrobatics.

At the other end of the spectrum, the GP-4 aircraft of George Pereira has an opening of only about .030” between the spinner and the cowling. This is wonderful for speed, but could lead to an unsafe condition if something went wrong.

Karl Hansen closed up this space to about 3mm using foam and microballoons, and he reported that this created a significant increase in speed. The hope is that if the spinner does hit the cowling, the frangible microballoons will grind away. So far, with cross country flying and some mild acrobatics, the spinner has not touched. John Harns did the same thing and reports that the spinner has not touched yet and he has pulled 4 gs. SF.260 owner Gary Fritzler has closed up the space on his airplane to about 5mm and has not had any problems.

The speed benefits of this modification are undeniable, but we still remember the experience of the Pitts losing their cowlings. This is no laughing matter, folks! The loss of a cowling is a violent event. Tony Bingelis had his spinner come loose, and it chewed up the front end of his cowling—fortunately Tony was still on the ground.

Let’s remember that there are three types of engine mounts. The conical engine mounts are quite stiff and do not allow the engine to move about very much. The two-inch dynafocal are softer. The three-inch mounts are very soft and the amount of engine movement is large.

The rubber isolators are made by Lord Kinematics, whose installation drawings provide an indication of the amount of engine movement to be expected. The wording on the drawings is “Provision for the following displacements of the engine should be allowed to prevent breaking external lines, binding controls or transmitting vibration....” We have listed below the displacements for the three types of isolators.

Conical Mounts (Lord J-6230-1)		
lateral and vertical translation:	±.24"	
fore and aft translation:	±.040" at 150% thrust	
torsional roll:	+2° 20', –1° 10'	
pitch or yaw rotation:	±1° 10'	
Two-Inch Dynafocal (Lord J-7402-24)		
torsional roll (from vertical centerline):	±0° 40' normal	±2° maximum
pitch or yaw about E.C. axis:	±0° 25' normal	±2° maximum
thrust or displacement:	±.027" normal	±.110" maximum
vertical displacement of C.G.:	±.070" normal	±.280" maximum
Three-Inch Dynafocal mounts (Lord J-9613-40)		
At 1g plus takeoff torque and thrust:		
gravity:	.13" at C.G. plus 0° 18' nose down pitch	
torque:	1° 5' counter clockwise rotation	
thrust:	.03" at C.G.	
Maximum motions:		

torsional roll (from vertical centeline):	±2° 51'
pitch rotation:	±1° 10'
yaw rotation:	±1°
lateral displacement:	±.20" at C.G.
thrust displacement:	±.16" at C.G.
vertical displacement:	+.64" at C.G. plus 1° 30' nose down pitch
	–.32" at C.G. plus 0° 45' nose up pitch.”

The C.G. is located 10.53" aft of the propeller flange. Thus, at about one-third of the way back, the displacements at the propeller are about a third again greater.

By our calculations, this means that the propeller will go down about .85”, up about .42” and will move fore and aft about 3/16”. We don’t think you should take too much comfort in these numbers if you plan to do acrobatics. It may be true that the engine moves in a conical fashion in loops, rolls and simple manuevers, but a violent snap roll would probably cause the engine to exceed even Lord’s specifications—remember, this stuff is *rubber*.

We are quite worried about all of this and look forward to getting reports on the experience of Falco builders who push the limits. We are also worried about what will happen in icing conditions. We recommend treating the propeller with healthy respect and let *someone else* be the first to lose a cowling. If you plan to do lots of acrobatics, our strong recommendation is to leave the space as designed. It may be a little excessive, but the spinner is not going to hit the cowling. If you do close it up, we recommend you at least leave enough room for the movement specified by Lord.

One method used to seal up this space on production aircraft have installed brush-seals. These are brushes installed in an aluminum extrusion. They have to be specially formed to the round shape of the spinner. The brush-seal is installed on the cowling with the bristles contacting the spinner. The spinner quickly wears the nylon bristles to that they clear.

Sealing the back of the spinner plate. The spinner is mounted on a plate of aluminum that is mounted to the back of the propeller hub. This plate has two half-moon shaped holes. Karl Hansen put a piece of aluminum sheet over these holes to keep air from entering the spinner from the aft end. This was part of the work he did while closing up the space between the spinner and the cowling. We have no idea if this does anything for speed or not.

We presume these holes are for lightening. If you do this, it appears that the risk of contributing to an out-of-balance condition is the primary concern. Karl reports that he was very careful to weigh the plates and screws on a postage scale and could detect no vibration when flying. The plates are close to the hub and don’t have much moment. Karl cautioned to put Loctite on the screws—you don’t want the plates rolling around in your nose cone.

Flat head screws. John Harns installed flat head screws in his spinner. Spinners are weird things, and they can develop cracks easily. Until we hear of others who have done this and have found that it works well over time, we do not recommend installing flat head screws in the spinner.

By the way, in recent years a method of “dynamic balancing” has been developed. The relatively inexpensive process balances the engine/propeller combination for a specific rpm by recording the vibrations of the engine/propeller and then adding washers under the spinner screws. It can substantially reduce the vibration level of the airplane. If you have installed flat head screws in the spinner, you will not be able to dynamic balance your engine/propeller. One engine balancing company is Gaar-Lamb Aero, Box 105, Brodhead, Wisconsin 53520. Telephone: (608) 897-8014 or 897-8459—ask for Gene Lamb. Gaar-Lamb is unusual in that their balancing is a byproduct of their main business of vibration analysis—by monitoring and plotting the frequency and amplitude of all engine vibrations, they can pinpoint potential problems in the engine before they become evident.

Smooth leading edges. More of a maintenance matter than a speed mod, but don’t forget to keep the leading edge of the propeller smooth. CAFE racers are very careful to buff these smooth.

Don’t. We probably don’t need to mention this, but some homebuilders seal up the space between the spinner and the propeller blades. That is probably all right with a fixed pitch propeller, but don’t do this with a constant speed propeller!

Engine Power

As mentioned earlier, speed increases with the cube root of the increase in power. As you get additional speed, one way to keep track and congratulate yourself is to calculate the amount of power you would have needed to accomplish the same thing. The math is very easy. If you increase the top speed from 190 to 210 mph, then you have increased the speed by 1.105 (210 ÷ 190). Cube that (1.105 x 1.105 x 1.105) and you get 1.349. Thus the speed increase of 10.5% is the equivalent of a 34.9" power increase. If you were going 190 mph on 160 hp, then that is the equivalent of adding 55.4 horsepower.

If you wish to increase the engine power, then the standard methods are porting and polishing. High Performance Engines specializes in this work, as do a few others.

You can also increase the engine power and fuel efficiency by increasing the cylinder head temperatures and oil temperatures, but you must of course keep within the operating limitations of the engine manufacturer.

For racing, you can increase the power of the engine by eliminating the power loss of accessories. Turning off the alternator is always an option, although hardly a sensible thing to do for cross country flight. The vacuum pump consumes a small amount of power.

For maximum engine life, we prefer to see an induction filter installed, but you can get a slight increase in manifold pressure (about a half inch of MAP) if you eliminate the induction filter.

One very small way you can reduce cooling drag is to paint the rocker arm covers black. This will increase the radiant heat given off by the rocker arms—even in the dark!—and will take a very small burden off the oil cooler.

Falco Powerplant Installation

(For those of you interested in reducing the cooling drag, you may be interested in this analysis by Dave Thurston in December 1983.)

A.

1. Falco 180 hp climb speed = 90 mph.
2. Cooling air required (Lycoming spec. No. 2525)
   Lycoming 0-360-E1AD 180 hp @ 2700 rpm, C.S. propeller = 2.3 #/sec @ 100°F inlet temp, S.L.
3. 2.3 #/sec = 2.3/.0712 = 32.3 ft^3/sec @ 100°F S.L. Std.
   d = .0756 #/ft^3 @ S.L. std
   d = .0712 #/ft^3 @ 100°F @ S.L. std
4. @ 90 mph climb
   V = (90 x 88)/60 = 132 ft/sec
5. Assuming .7 entrance coefficient,
   cowling inlet area = 32.2/(132 x .7) = .3485 sq ft required
6. Oil cooler area (20 sq in cooler face) = 20/(144x.7) = .1984 sq ft
   therefore: total area required (100°F @ S.L.) = .55 sq ft = 79 sq in
   80 sq in = 40 sq in/side
7. Cowl inlet area for engine cooling per Sequoia drawing: 75.5 sq in total (taken 1" out from spinner radius).
   Marginal for 180 hp.

B.

8. Airflow required to cool 160 hp Lycoming
   Lycoming spec. No. 2403, page 6: 2500 cfm (IO-320-B1A)
   Lycoming spec. No. 2497, page 14: curve 13242A: 1.9 #/sec @ 100°F (IO-320-F1A)
   Lycoming spec. No. 2283-F, page 15: curve 13242A: 1.9 #/sec @ 100°F (O-320-D1B)
   Lycoming spec. No. 2284-C, page 8: 2500 cfm (150 hp O-320-E1A)
9. @ 1.9 #/sec = 1.9/.0712 = 26.7 ft^3/sec @ 100°F S.L. Std.
10. @ 85 mph climb
    V = (85 x 88)/60 = 124.7 ft/sec
11. Required cylinder air = 26.7/(124.7 x .7) = .306 sq ft
12. Oil cooler inlet area = .198 sq ft (Item 6 above)
    therefore: total area required (100°F @ S.L.) = .504 sq ft = 72.6 sq in

13. Conclusion: The active (engine and oil) cooling area is marginal in climb for a 100°F standard day @ sea level, but probably acceptable. (Note: a radius band extending about 1" beyond the spinner is not effective as inlet area.) Inlet area is marginal because of greater diameter spinner.

C. Exit area
14. Exit area per Sequoia drawings = 28 sq in total when nose wheel well is fully enclosed.
(*Dave Thurston is mistaken here, the actual gross area is 42.00 sq in gross, 37.19 net of two exhaust pipes.*)
15. Exit area in climb @ 90 mph (132 fps) assuming 100°F temperature rise on 100°F day:
Inlet pressure = 14.6 psi = P_1
Outlet pressure = 14.1 psi = P_2
Inlet temperature = 100° + 460° = 560°R = T_1
Outlet temperature = 100° + 100° + 460° = 660°R = T_2
At same inlet and outlet flow velocity, relative inlet and outlet areas may be compared directly rather than comparing areas bease on flow volumes.
V_2 = outlet area required = K x V_1
V_1 = inlet area
16. $(P_1 \times V_1) / T_1 = (P_2 \times V_2) / T_2$ or
$(P_1 \times A_1) / T_1 = (P_2 \times A_2) / T_2$
therefore
$A_2 = (P_1 \times A_1 \times T_2) / (P_2 \times T_1)$
$A_2 = [(P_1 \times T_2)/(P_2 \times T_1)] \times A_1$
$A_2 = [(14.6 \times 660)/(14.1 \times 560)] \times 80$ (see Item 6 for 80)
A_2 = 98 sq in outlet area for 90 mph climb with 180 hp Lycoming at full power
17. The revised cowling design does not meet this outlet area. (end of Thurston report)

Note that the actual exit area is larger than Thurston assumed, but still it is substantially smaller than he calculated it needed to be.

We did not follow Dave Thurston's advice to change the inlet or outlet area for several reasons. First, we hoped that the "dead band" around the spinner would be effective for cooling and we based this hope of the experience of the Mooney 201 and Mike Smith's Bonanza, which had similar inlets and cooled well. The small exit area was more worrisome, but Luciano Nustrini had been flying with nose gear doors installed, and he had no cooling problems. We reasoned that if more exit area was needed, we planned to open a slot between the cowling and the nose gear door to pull more air out.

For additional information, obtain the following:

SAE Paper 730325 "The Development of Reciprocating Engine Installation Data for General Aviation Aircraft" by Frank Monts, Lycoming Div., Avco Corp. Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096

SAE Paper 790609 "Determination of Cooling Air Mass Flow for a Horizontally-Opposed Aircraft Engine Installation, by S. J. Miley, E. J. Cross, Jr., N. A. Ghomi, P. D. Bridges, Department of Aerospace Engineering, Mississippi State University. Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096

SAE Paper 770467 "An Investigation of the Aerodynamics and Cooling of a Horizontally-Opposed Engine Installation" by S. J. Miley, Department of Aerospace Engineering, Mississippi State University. Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096

SAE Paper 810623 "Full-Scale Study of the Cooling System Aerodynamics of an Operating Piston Engine Installed in a Light Aircraft Wing Panel" by V. R. Corsiglia and J. Katz, Ames Research Center, NASA, Moffet Field, CA. Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096

Design for Flying by David B. Thurston. McGraw-Hill, 1978. See page 151 for calculations for engine cooling.

"Installation Design for Engine Cooling" Avco Lycoming Corporation.