

HEAT SHIELDS UP!



Protecting your cowl from excess heat.

BY ERIC STEWART

Regardless of whether your aircraft is metal, composite, or tube and fabric, quite a few homebuilts these days use composite fairings. Nowhere is this more true than the engine cowl—it's just not an easy shape to fabricate out of other materials. Unfortunately, for tightly-cowled installations, heat from proximity to exhaust

pipes (or a turbo) can be a problem. It's not uncommon for builders to find blistered—or even burnt—cowlings during Phase I testing, or after an engine swap or other firewall-forward modifications. If you are making your own cowl, use of a high-temp epoxy is an option, but for those of us working with kit-supplied

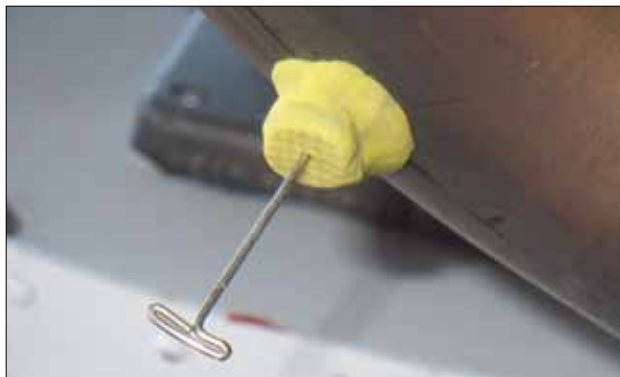
cowlings, some kind of a heat shield may be required.

What's My Clearance?

To find out what kind of clearance between cowl and exhaust pipes is typically necessary, we went straight to the exhaust master himself—Larry Vet-



Clay cone stuck to the exhaust pipe to check for clearance.



The impression left by the fiberglass cowl can be seen on the clay. The stick pin plumbs the exact clearance.

terman. Although Vetterman is now retired, his 27 years of experience manufacturing exhaust systems for Experimental aircraft have made Vetterman exhausts the gold standard among homebuilders. Vetterman flies behind his own pipes in an RV-7A.

To begin with, it's important to understand the heating and cooling of the pipes themselves. "What builders need to realize is that the pipes are hottest in two areas," says Vetterman. "First, because of valve overlap, the flame front in the pipes is about two inches from where the pipe flange bolts to the cylinder head. In cruise flight, this area of the pipe will actually be cherry red. You can see this in the discoloration of the pipes—when you look at the flange, you'll see that it stays a normal color at the cylinder but turns brown about two inches downstream. Incidentally, this is where your EGT sensors should ideally be located. The second location of high heat is the branch on crossover systems, since this is getting a double whammy of exhaust.

"On the other hand, we need to appreciate that the exhaust system is one of the best heat sinks on an air-cooled engine. The mass airflow coming past the cylinders continues to pick up heat as it passes the exhaust pipes." So, in addition to the thermodynamics of the exhaust gases cooling as they expand towards the pipe exit, cooling airflow causes the exit end of the pipes to be significantly cooler than the flange end. Therefore, one of the first steps in dealing with excess heat down by the pipes is to make sure your baffles

up top are well sealed to improve that mass airflow cooling.

And, if you've considered using automotive-style exhaust pipe wraps to manage under-cowl heat, think again says Vetterman. "Wrapped exhausts are a *serious* issue. I've seen numerous examples of pipe failure caused by wrapping. When I asked a metallurgist several years ago what was happening, he explained that if the surface of the pipe exceeds 1250° F, you see serious degradation of the metal as the chromium and other additive elements used to give Type 321 stainless its high temperature properties oxidize." In addition, wrapping the pipes is likely to put additional heat stress on the engine since their

function as a heat sink is compromised. Vetterman has seen no evidence that wrapping improves power or speed.

Finally, although this article is focused on keeping your cowl from getting toasted, Vetterman points out that it's extremely important to also protect fuel lines and control cables in the vicinity of hot exhaust pipes with heat shields mounted directly to the pipe.

Determining Actual Clearance

So, what kind of clearances does Vetterman recommend? "For unprotected fiberglass, I would recommend not less than 1½ inches of clearance. For fiberglass with either foil or silver paint, you can reduce that to ¾ inch." The addition



Here's what you'll need (clockwise): Laminating epoxy, adhesive-backed foil, Fiberfrax and a straightedge, a half pint of Plasti-Bond adhesive, modeling clay, a sharp X-Acto knife for trimming the foil, a Sharpie for template layout, an acid brush to seal the edges of the foil with epoxy, a window-tint applicator, and paint.

of an insulator like Fiberfrax will provide additional protection.

These numbers of course represent a rule of thumb and Vetterman stresses the importance of airflow in keeping things cool. In that sense then, an area of static airflow is of greatest cause for concern. In determining your own cowl's hot spots, it also helps to find someone else with a similar installation and compare notes. If you want to be truly scientific, you could use something like Omega temperature labels (www.omega.com) and make a temperature map.

In order to determine the exact cowl clearance from the exhaust pipe at any particular point, roll a bit of modeling clay into a cone slightly greater in height than the estimated clearance. Stick the cone to the pipe in the region of interest, and carefully assemble the cowl. Give the cowl a light tap in the region of the cone, then remove. The cowl will have made an impression on the clay which you can then "plumb" with a stick pin to determine the precise clearance. You may want to subtract another $\frac{1}{8}$ to $\frac{3}{8}$ inch from this measurement to allow for vibration of the cowl, engine or pipes themselves.

Level 1 Protection/Rare: White Paint

At a minimum, simply painting the interior of the cowl white or silver will help to reflect radiant heat, as well as



Here we can see the Fiberfrax, which has already been glued to the inner cowl with Pliobond, being covered with the adhesive foil.

highlight oil leaks. Some builders fill and smooth the interior of their cowls just as they would an exterior surface, since a smooth surface facilitates easy clean up and is aesthetically pleasing. However, this is not necessary, and it does add weight and build time.

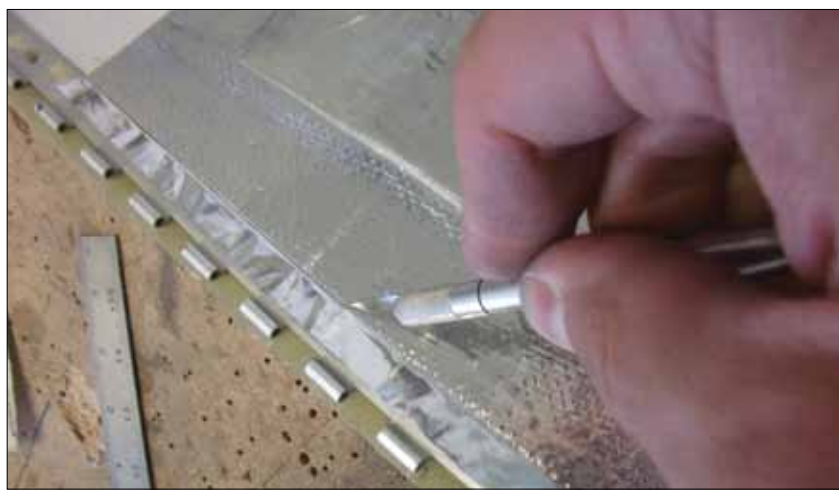
Before painting, it is recommended that you at least seal the entire inner cowl with a nice fuel-proof coat of laminating epoxy. (Laminating epoxy is much less viscous than structural epoxy and therefore easier to apply; I recommend West Systems 105 Resin and 206 Hardener.) This helps keep oil and gas from soaking into pinholes or core material, which can add weight and compromise the strength of the cowl. And as Vetterman points

out, if you need to repair the fiberglass in the future, it will be impossible to do so if it has been contaminated with oil. Some builders thin the epoxy with acetone, but I don't find this necessary—simply paint on a single thick coat with a brush and wipe the excess off with a rubber squeegee. Let cure and follow with your choice of paint. Even if you plan to put down additional heat barrier layers, you'll still want to seal everything with epoxy as a kind of base coat.

Level 2 Protection/Medium-Rare: Adhesive-Backed Foil

The next level of protection is adhesive-backed aluminum foil. Both Aircraft Spruce & Specialty Co. and Van's Aircraft, Inc. sell foils. (Van's is happy to sell many of their products to all homebuilders, not just those who have purchased their kits.) The Van's product is 30 inches wide and adheres very well; I highly recommend it. You'll want to make templates for the area of application (better to waste template material than foil) and to get an idea of how many linear feet of foil you'll need to order. I find the $\frac{1}{16}$ -inch thick closed-cell foam often used for packing material these days perfect for templates, since it is slightly rigid, but still conforms nicely to compound curves—like the foil itself.

The foil cuts easily with either scissors or an X-Acto knife and straightedge. It is extremely sticky, so make sure you have it positioned exactly where you



Here we can see the 1.5" perimeter anchor of adhesive-backed foil over a layer of $\frac{1}{16}$ -inch Fiberfrax. The foil is squeegeed to the edge of the cowl hinge pin, trimmed with an X-Acto knife, then the edge sealed with laminating epoxy to prevent lifting.



Finished product: Entire inner cowl was sealed and painted, followed by application of Fiberfrax and aluminum foil in areas of close proximity to exhaust pipes.

want it before laying it in the cowl. This is another reason to put down a layer of epoxy—the adhesive backing sticks best to glossy surfaces. I prefer to work from the middle outward, as this seems to minimize the number of creases on compound-curved surfaces. Use the felt edge of a window-tint application tool, available from a car parts store, to smooth the foil as you go. Once finished, mix up some laminating epoxy and paint the edges of the foil with an acid brush. This will prevent oil seeping under the foil as well as the foil lifting.

Level 3 Protection/Well-Done: Ceramic Blanket

If your clearances are minimal, you'll want to consider adding an insulator. Aircraft Spruce sells a variety of insulating blankets. We encourage you to do your own research, but try not to get carried away with high-tech multi-layered blankets that promise to deflect space shuttle-magnitude heat rays. For most builders $\frac{1}{16}$ -inch Fiberfrax is more than adequate ($\frac{1}{8}$ -inch is also available). Fiberfrax is a ceramic blanket that can be laid under the aluminum foil to greatly slow heat transfer.

As with the foil, first make templates of the region you want to protect. Cut out the Fiberfrax, and attach it to the cowl with Pliobond contact cement. Use regular Pliobond—VOC compliant isn't nearly as effective. Now, using your original template, cut a sheet of

aluminum foil whose edges extend one or two inches beyond the Fiberfrax. This extension will serve to anchor the foil around the perimeter of the Fiberfrax. Peel the backing and lay this directly over the foil, again working from the center outward. Finish up by sealing the edges with laminating epoxy.

Level 4 Protection/Charbroiled: Firewall 2000

The nuclear option of heat barriers is a product like Firewall 2000, a quarter inch of insulator sandwiched between aluminum foil on one side and stainless steel on the other. Unless you have a glowing turbo an inch from your cowl, avoid the "bigger is better" temptation.

This is pretty substantial stuff. It is quite heavy at 9.5 ounces per square foot, versus less than 1 ounce per square foot for either $\frac{1}{16}$ -inch Fiberfrax or Van's adhesive-backed aluminum. Due to the sandwich construction, it doesn't conform to compound curves as well as the thinner materials, and it relies on rivets or glue to be held in place. In addition, due to the open edge construction, you'll definitely need to anchor the perimeter with aluminum tape to keep the blanket from getting oil-saturated.

Where to Start?

While some builders apply foil to the entire inside of their cowl, this probably isn't necessary. Unless you have extremely close tolerances from the get-go (i.e., less than $\frac{1}{2}$ inch), I'd probably take the first step of epoxy seal/white paint, then go fly. During Phase I, you'll be pulling the cowl off quite a bit anyway to make sure everything is secure, and if you are toasting the cowl, the paint will tell you pretty quickly. However, once you've got your base layer of epoxy and paint, applying the Fiberfrax and aluminum won't take more than a few hours and will add less than a pound of weight, so don't be afraid to take a preventative approach. Given how much many builders hate fiberglass work (and how expensive cowls are), this is one case where an ounce of foil is worth a pound of Bondo. Good luck, and stay cool! ✚



Close-up of Fiberfrax/foil barrier adjacent to an exhaust pipe. (Pipe hidden behind intake runner.) Epoxy to seal the edge has not yet been applied in this picture.

Riveting.



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