No More Exhaust Streaks!

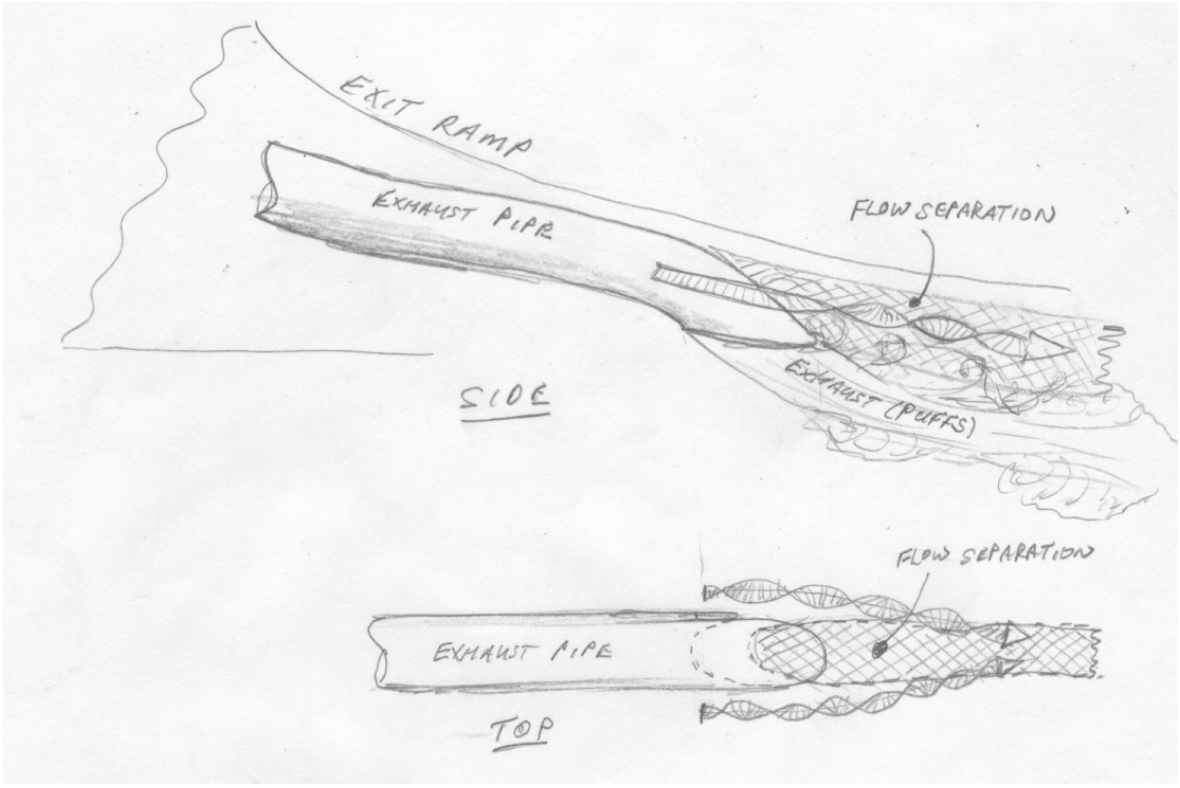
Fred Moreno, Dec. 2008

If your exhaust pipes do not stick a LONG way below the fuselage, the result is probably ugly exhaust streaks from near the firewall to the tail, and in some cases, perhaps even blistered paint near the exhaust pipe exits. Attempts to eliminate the streaks usually involve exhaust pipe extensions (more weight, ugly), turning the pipes downward substantially (reduced thrust, more drag, more ugly), or deflectors attached to the exhaust pipe and pointing down for more drag and locally higher ambient pressure at the exhaust pipe exit, right where you do not want it.

Causes

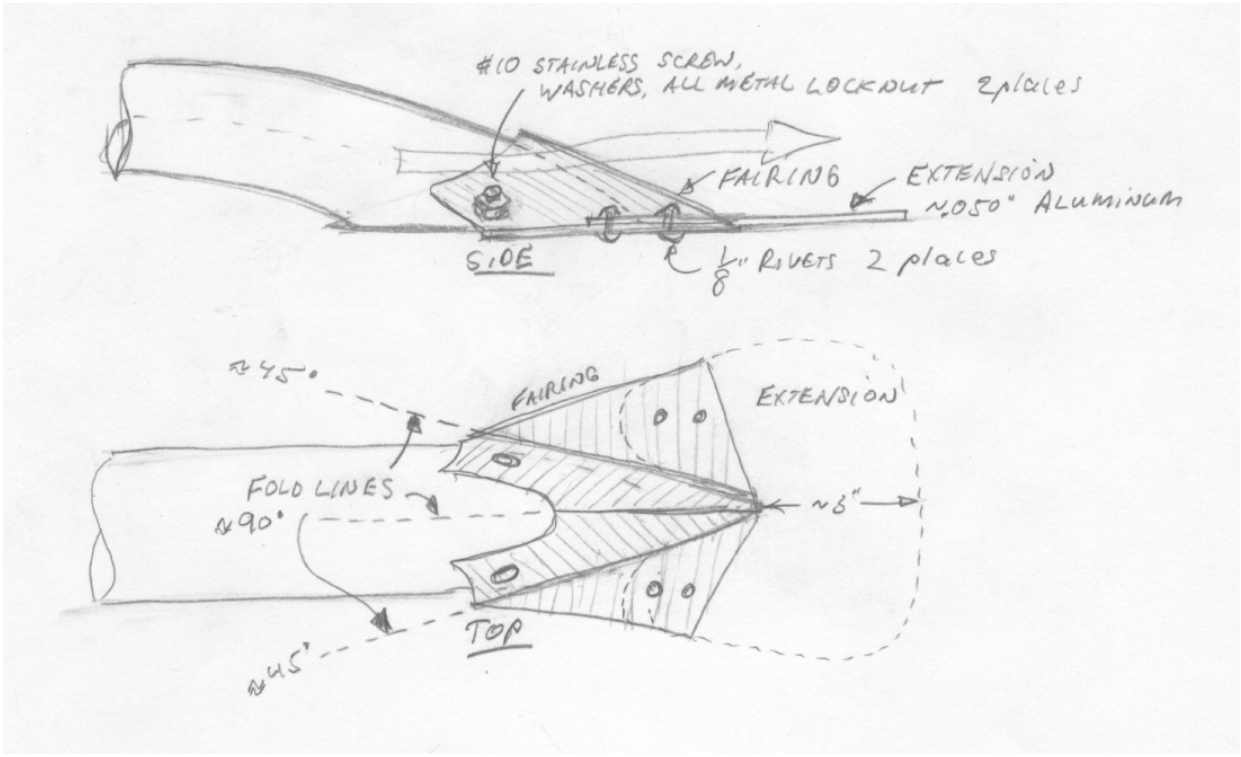
There are three contributing factors to the exhaust hitting the fuselage. (See figures below.)

1) The exhaust comes out in strong "puffs" as each exhaust valve opens, less so in turbo engines, more so with higher power settings in non-turbo engines. These puffs exit at higher than ambient pressure and higher than free stream velocity. The result is that the exhaust stream is not a smooth cylinder as seen behind a jet engine, but a series of turbulent "balls" that form almost immediately aft of the exhaust pipe. Want proof? Look at a close-up photo of an aerobatic plane trailing smoke during a high power manuver. The puffs are readily evident, and the "puff out" in diameter is also a puff up onto the fuselage.
2) The exhaust pipe is angled cross ways to the air flow exiting from the cowl and in the free stream. If this angle is large enough or with enough flow blockage between the exhaust pipe and exhaust ramp wall, the result is flow separation. A highly turbulent region of air forms behind the exhaust pipe that is not moving very fast but is extremely chaotic with a lot of churning. This churning carries exhaust from the exhaust pipe plume up to the fuselage bottom.
3) The angled exhaust pipe also generates a bit of lift as it deflects the air flow downward. Like a wing, one consequence of lift is the formation of counter rotating vortices on either side of the exhaust pipe ("wing tip vortices"). They drift aft and move closer together carrying exhaust plume gases into the separated flow region and up to the fuselage skin.



The Solution

I tried various types of vortex generators in the cowl exhaust air duct, deflectors, and fairings in pursuit of a low visibility, low drag, but effective solution. It took about seven tries, but I have something that seems to work. It consists of a combined fairing (to reduce or eliminate the flow separation behind the exhaust pipe) and extension trailing behind the exhaust pipe exit to block the strongest part of the exhaust puffs from rising toward the fuselage until some energy has dissipated. The fairing is fabricated from 0.050 (1.25 mm) aluminum sheet folded in a vise with a hammer and block of wood to which the flat extension is riveted on with four squeeze rivets as shown below. The fairing is attached with 10-32 stainless steel screws (head inside the exhaust pipe) and all-metal lock nuts. Photos which follow will help clarify.



How to Make It

I used thin cardboard from a cereal box combined with scissors and did some cut and try until I got something that fit and looked about right. The fairing has three folds: one 90 degree fold down the middle, and then two 45 degree folds the opposite direction leaving two flat and parallel "tail paddles." All three folds intersect at the trailing edge which starts out as a straight line, but which become angled after all the folding.

I fit this over the trailing edge of the exhaust pipe, and then had to cut out a U-shaped large relief area on the top to provide clearance from the exhaust ramp. I kept trimming until I got a shape that hugged the exhaust pipe along the fairing leading edge. When I was satisfied with the cardboard, I transferred the pattern to a piece of 0.050" aluminium sheet metal. A bit of hammering for curvature helped the sheet metal to wrap around the exhaust pipe better. I then held the aluminum in place, and drilled two holes through the exhaust pipe and aluminium to clear a 10-32 stainless screw.

Once satisfied with the fit and attachment, I cut a second cardboard pattern for the deflector extension shown in dotted lines above. This flat sheet was riveted with four squeeze rivets to the fairing piece, and the assembly then fastened in place. Your goal is to get the flat portion of the deflector/extension roughly parallel to the bottom of the fuselage, extending downward far enough to permit air to pass between the extension and fuselage, but not so far that it becomes highly visible and distracting.

Raised Eyebrows?

Aluminum sheet bolted to a hot exhaust pipe, you ask? The exhaust temperature is higher than the melting point of aluminum, no? Yes. But the saving grace is 1) there is a huge blast of cooling air always present, and 2) stainless steel is a lousy conductor with a thermal conductivity about 1/8 of aluminum and a third of steel. While heat is carried up the stainless screw from the hot exhaust stream, the outer portion of the screw and all metal lock nut in the air stream are very well cooled. Where the aluminum sheet touches the exhaust pipe, I used some Unobtanium high temperature metal sintered felt from a prior life. A better solution (because the felt is fairly soft) is to put in a couple of stainless washers. The contact resistance between pipe and washer, washer to washer, and washer to deflector is enough when combined with the high velocity cooling air blast to keep the aluminum cool enough.

The photos below should help with the visualization.