Speed Modifications to Improve Efficiency

International Comanche Society

2002 Annual Convention

Reno, Nevada

Hans D. Neubert

ICS 7685

BSME, MSAE, FAA Structures DER

PA-30 N7331Y

Seminar Presentation Topics

- Drag Basics
- Drag Reduction Fundamentals
- Oil Smear Testing Performed
- Tuft Testing Performed
- Speed Modifications Incorporated
- Propeller Efficiency
- Cooling Drag
- Cowlings
- Conclusions/Recommendations

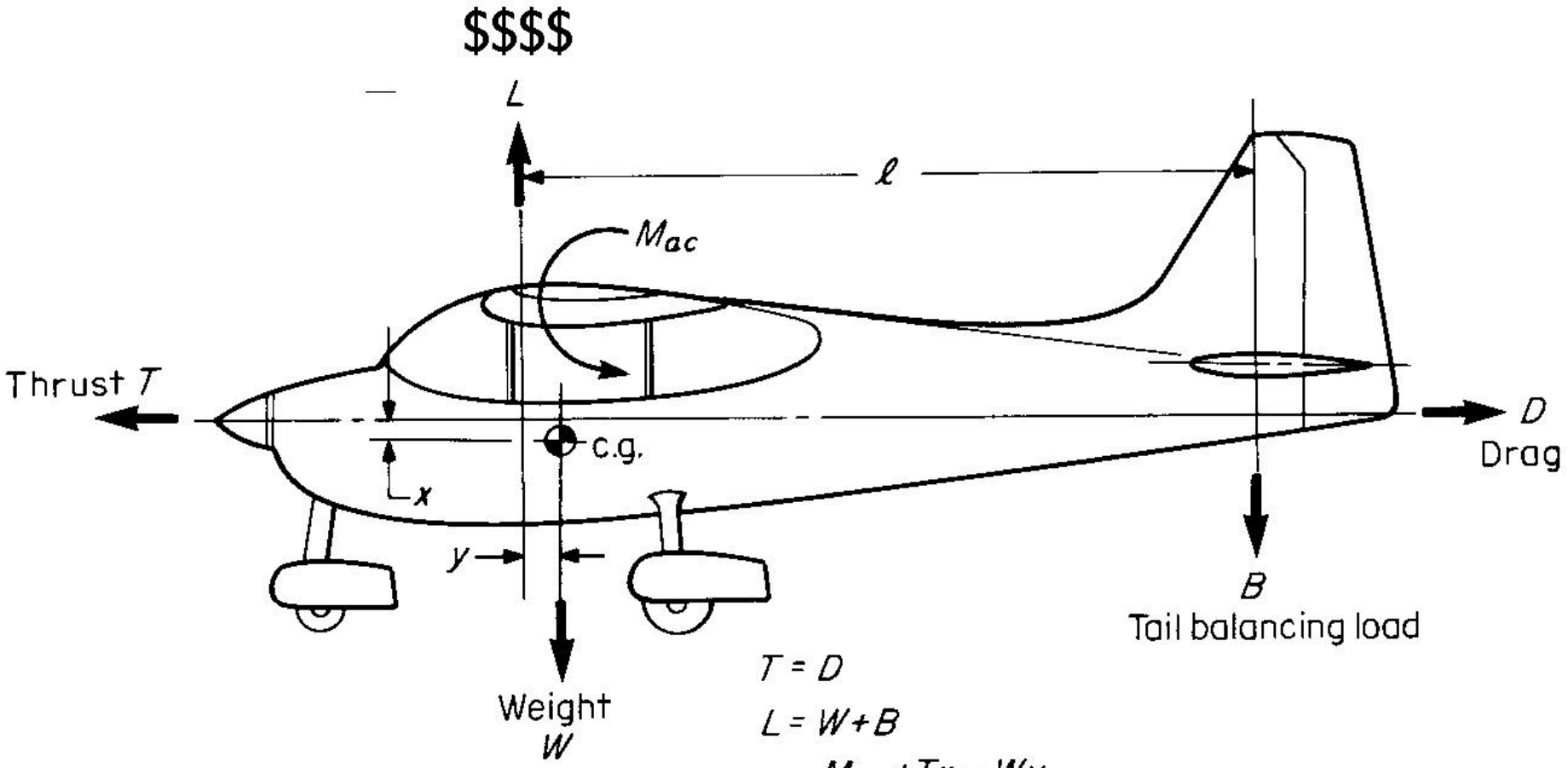
Definitions

- Dynamic Pressure
  - Air Density times Velocity Squared
- Reynolds Number
  - Velocity times Characteristic Length divided by Kinematic Viscosity of air
- Drag Component
  - Drag equals Dynamic Pressure times Drag Coefficient times Characteristic Dimension

Drag Components

- Total Drag equals Parasite Drag plus Induced Drag
- Parasite Drag has 5 Main Components
  - Skin Friction Drag
  - Pressure Drag (or Form Drag)
  - Interference Drag
  - Trim Drag
  - Cooling Drag
- Induced Drag
  - Results from the generation of lift
  - Increases with altitude and during climb

Aircraft in Static Equilibrium - Level Flight



$$T = D$$

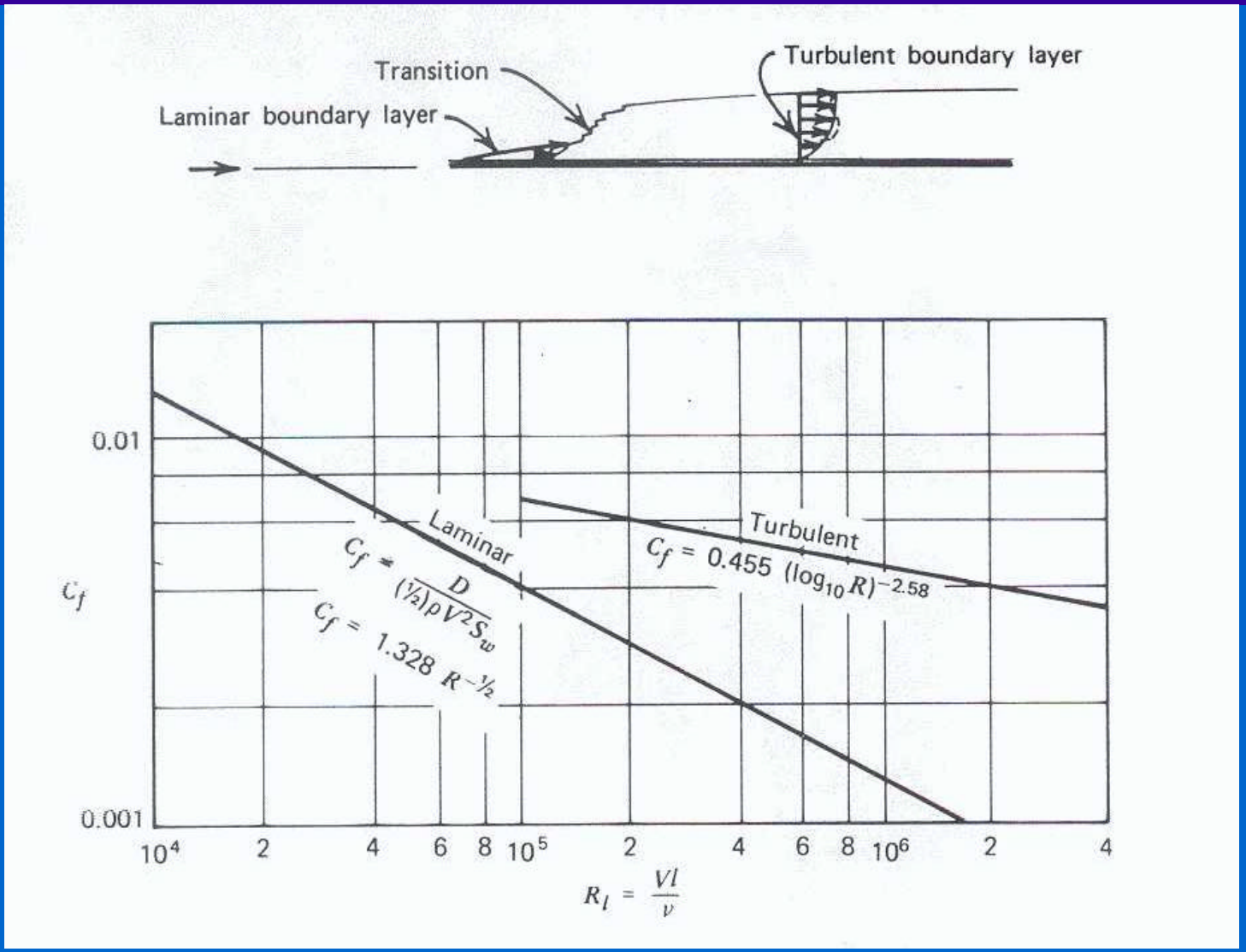
$$L = W + B$$

$$B = \frac{M_{ac} + Tx - Wy}{\ell}$$

Balance of Thrust and Drag

- In Steady, Level Flight - Thrust equals Drag
- Thrust equals Hp times Prop Efficiency divided by Velocity (corrected for units)
- Drag equals all drag components added together. Parasite Drag can also be expressed as an equivalent drag area having a drag coefficient of one multiplied by the wing area
- Units are: pounds thrust = pounds drag

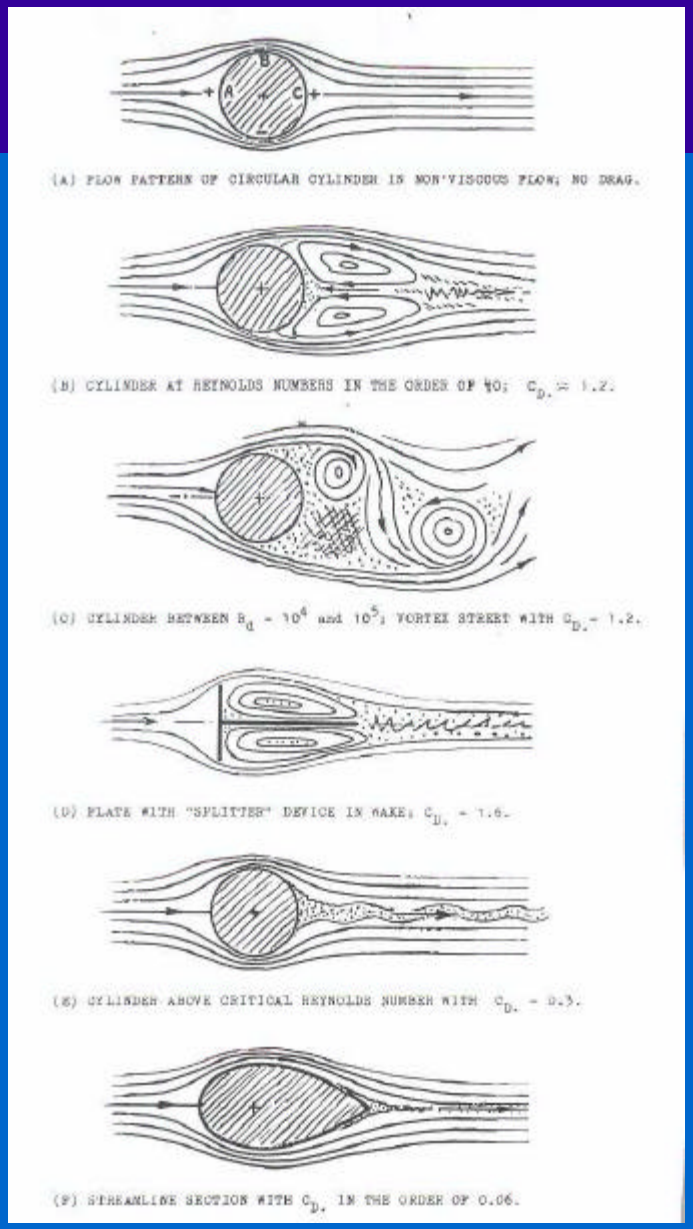
Skin Friction Drag



Pressure (Form) Drag

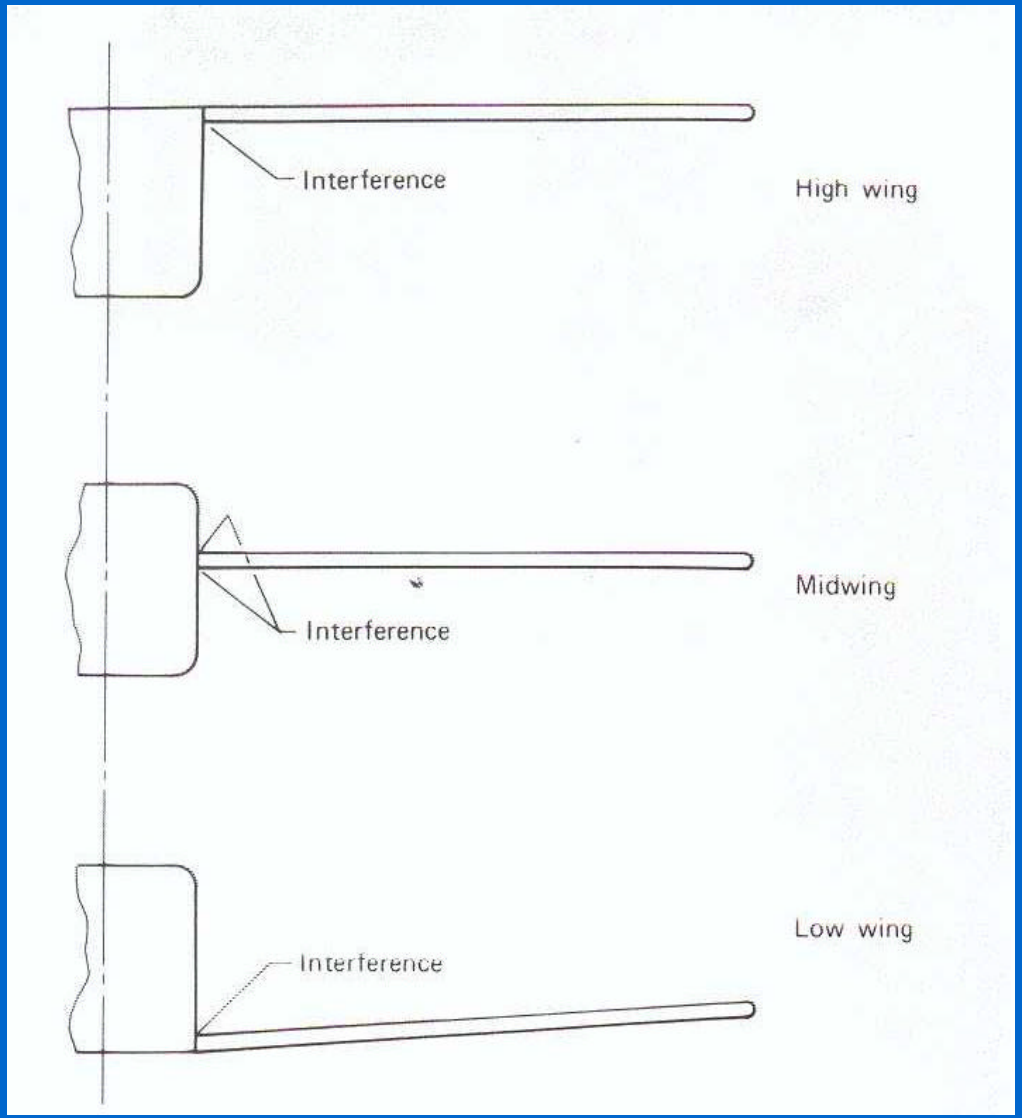
Form drag on shapes is very difficult to predict. Wind tunnel testing is the usual method for obtaining drag coefficient vs. Reynolds number.

Form drag is the integral of pressure over the entire surface area.

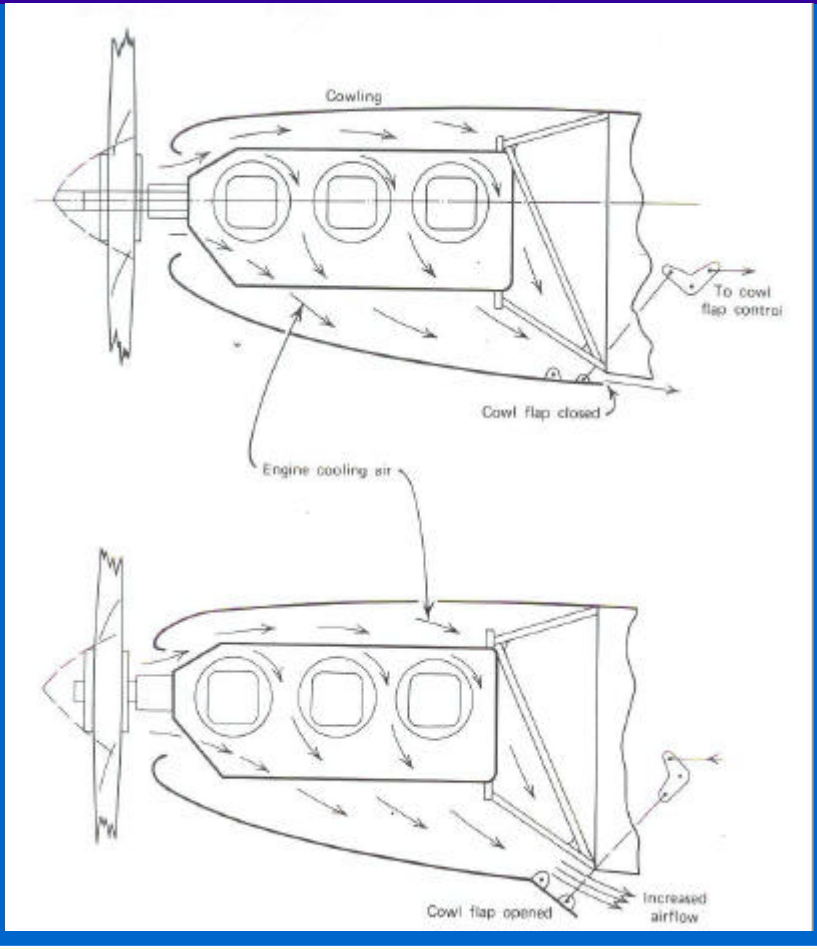


Interference Drag

When two shapes intersect or are in proximity, their pressure distribution and boundary layers can interact, resulting in a net combined drag that is higher than the sum of the separate drags.



Cooling Drag



Outside air enters upper plenum, air velocity converts to increased pressure, air absorbs heat from cylinder fins, and heated, higher pressure air leaves lower plenum creating thrust.

Estimates of Stock Comanche Total Drag

	Total Drag Breakdown		
Item	250/260 Single		Twin
Total Drag	420 lb		500 lb
Induced Drag	30 lb		40 lb
Parasite Drag	390 lb		460 lb
Equiv. Flat Plate Area	4.53 sq.ft.		4.46 sq.ft.
Airframe Drag (Skin friction)	245 lb		265 lb
Airframe Drag (Form)	54 lb		60 lb
Interference Drag	42 lb		68 lb
Cooling Drag	39 lb		55 lb
Trim Drag	10 lb		12 lb
Assumptions:			
Max. Speed at SL, Max. HP, Aft CG.			
Gross Weight, Stock Configuration			

What Can You Do to Reduce Parasite Drag

- Skin Friction Drag
  - Essentially nothing - Keep Leading Edge clean to maintain Laminar Flow
- Pressure (Form) Drag
  - Essentially nothing - Controlled by airplane shape & configuration. Some speed mods deal with Form Drag.
- Interference Drag
  - Judicious application of Speed Mods & airflow enhancements
- Trim Drag
  - Maintain Aft CG using payload or baggage weight
- Cooling Drag
  - Maintain seal between upper and lower plenums - no leaks

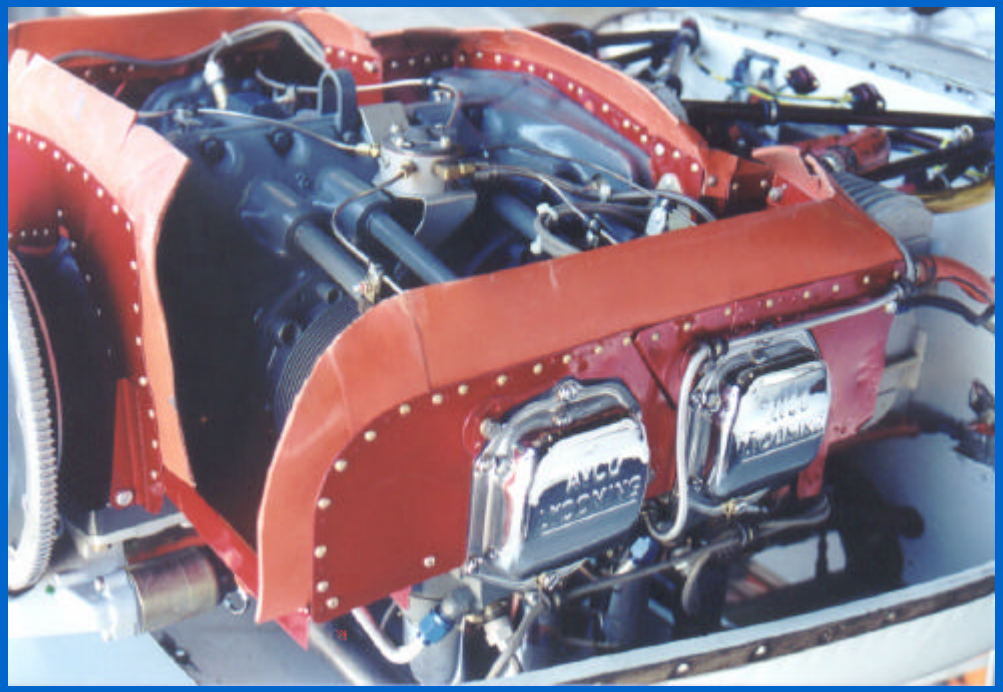
Prior to Any Speed Modifications

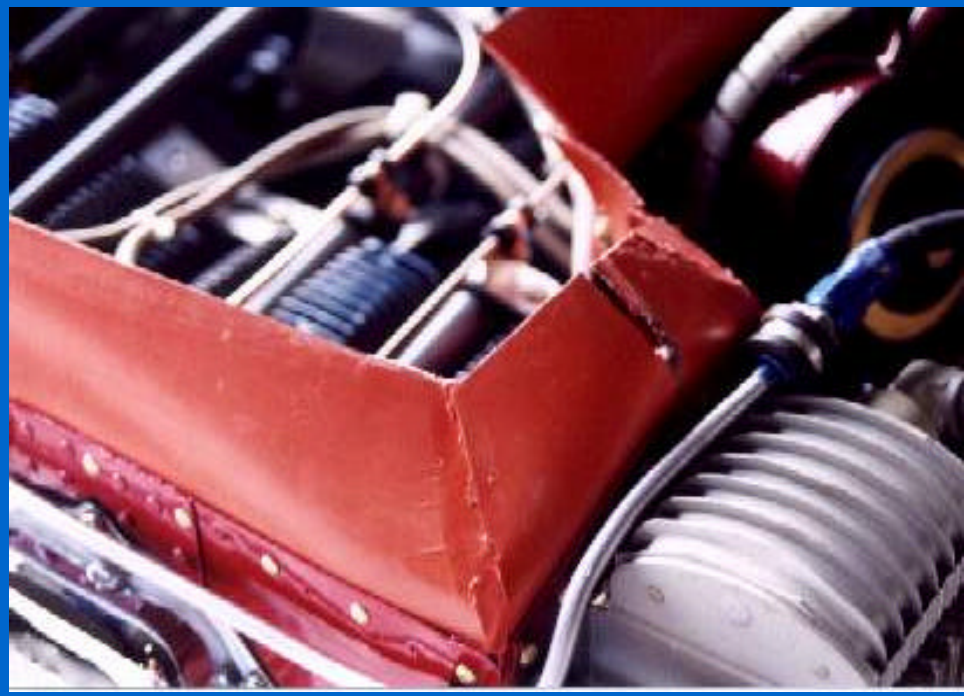
- Rig Airplane for Maximum Speed
- Verify Gear Retraction and doors per Service Manual
- Seal Cowling to Minimize Internal Leaks
- Remove Unnecessary Antennas and Protuberances
- Service Propeller for Nicks and Dings - Paint Backside

Gear Door Adjustment Test

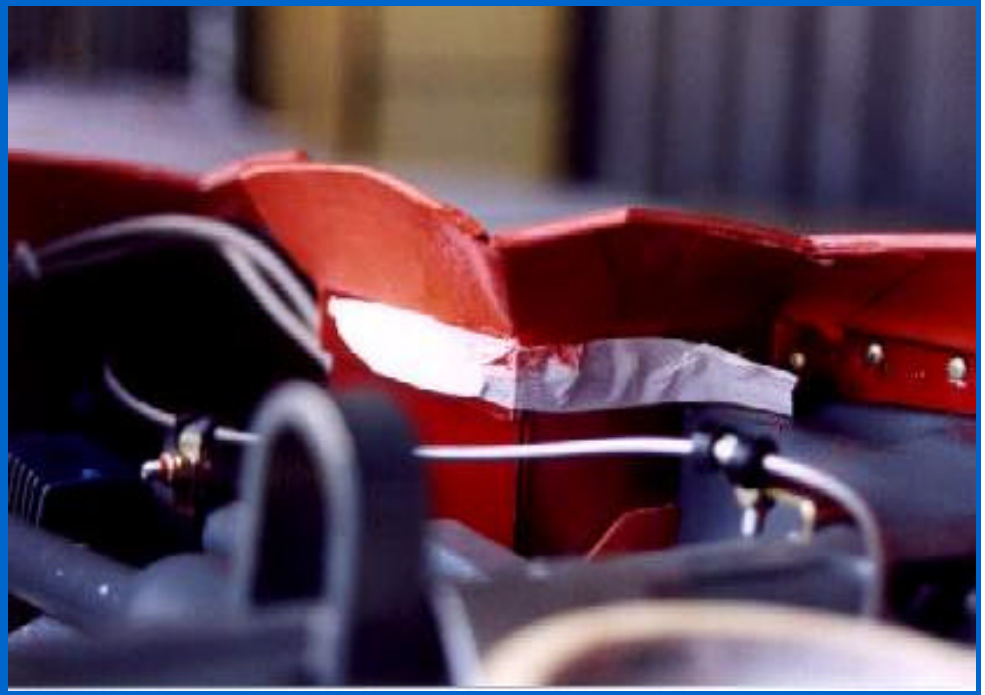
9 lb. weight at center of gear door - 1/8” door deflection

Engine Baffle Seal

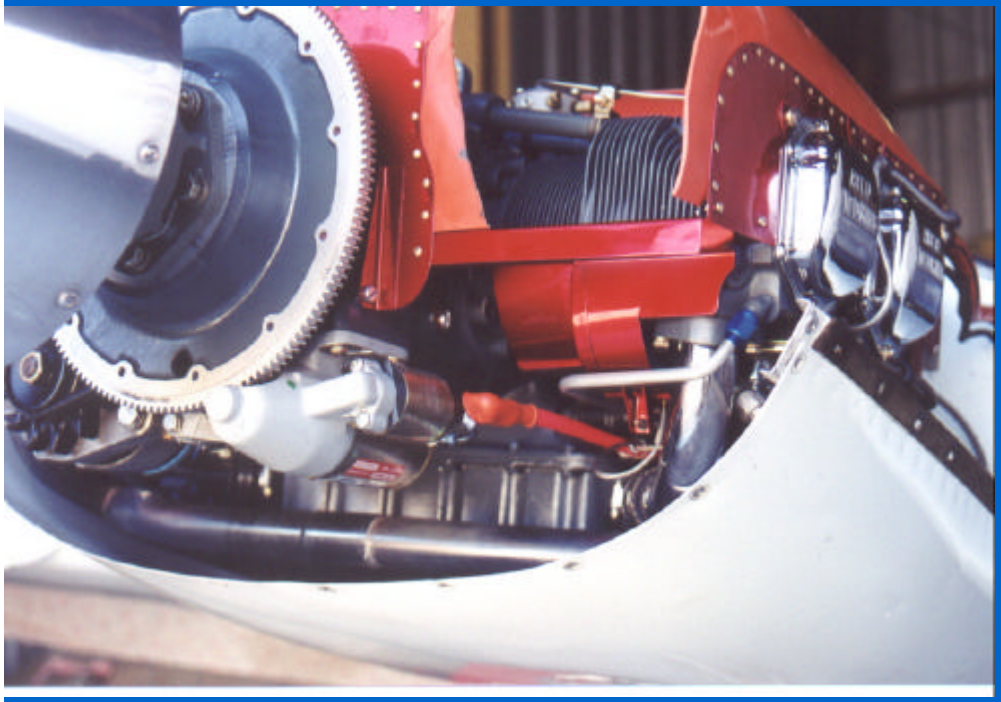




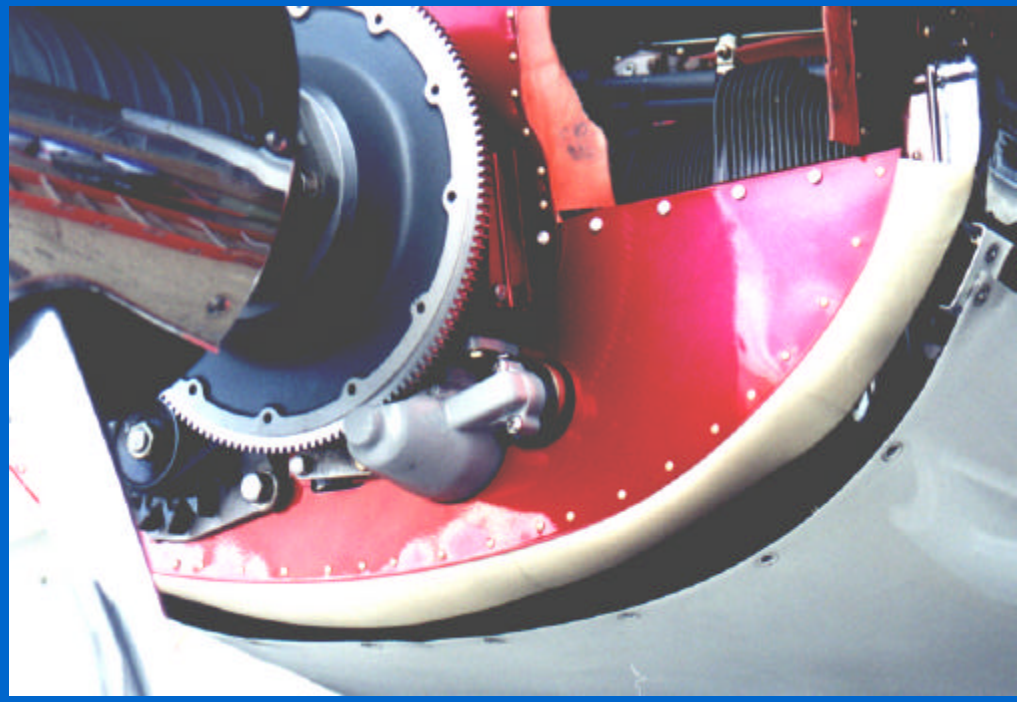
Engine Baffle Seal



Maintain Cowl Airflow in Aft Direction



Before - Stock Configuration

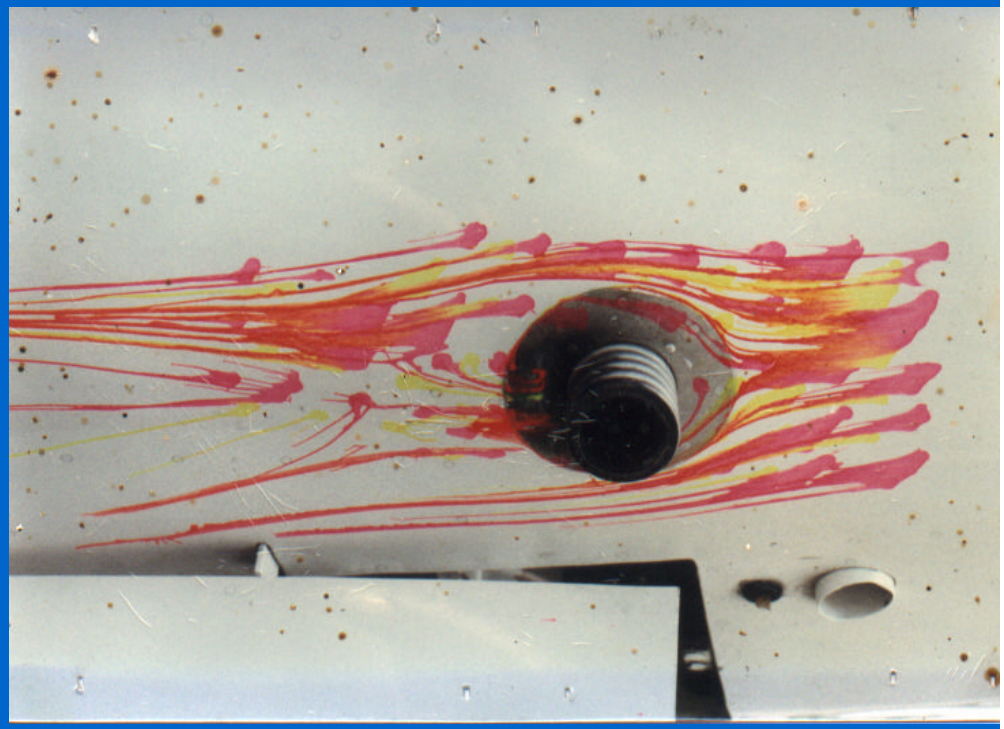


After - Added Lower Seal

Things I Have Done to Minimize Drag

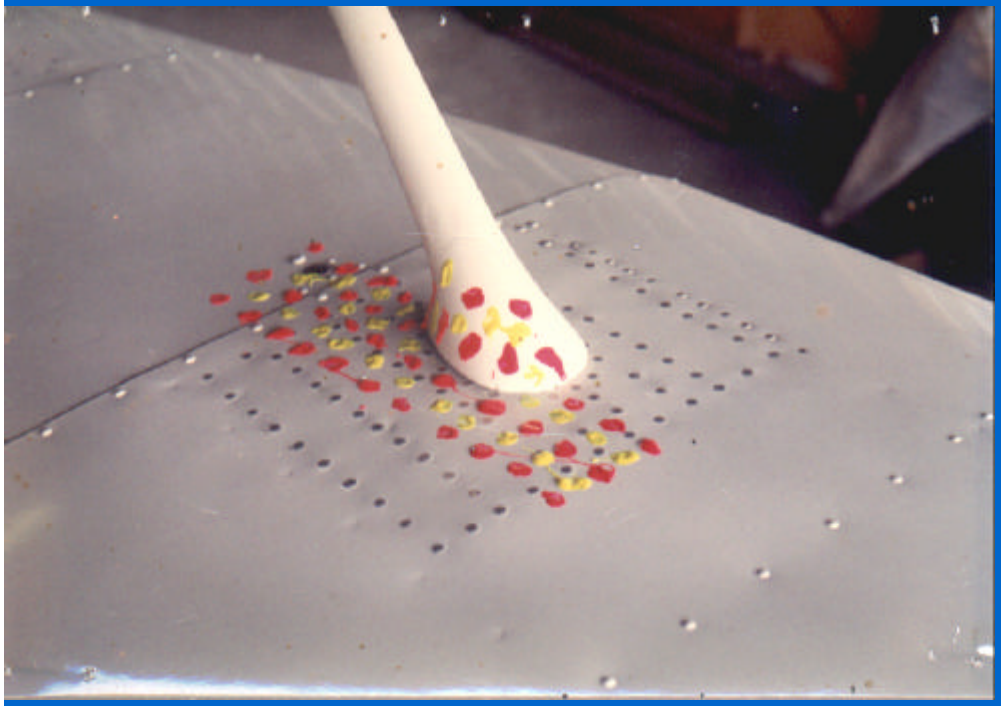
- Oil Smear Studies
  - Mix Engine Oil with Fine Powder (Use Two Colors)
  - Dab on Plane in Hex Pattern
  - Take Photos Before and After Short Flight
- Tufting Studies
  - Contrasting Yarn Taped to Plane
  - Take Photos (Video or Still) From Cabin or Chase Plane
- Eliminated Sharp Edged Airflow Areas
  - Engine Induction Air Intake
  - Cowl Exit Air Outlet
- Fab'd or Purchased STC'd Airflow Enhancement Fairings

Twin Heater Exhaust



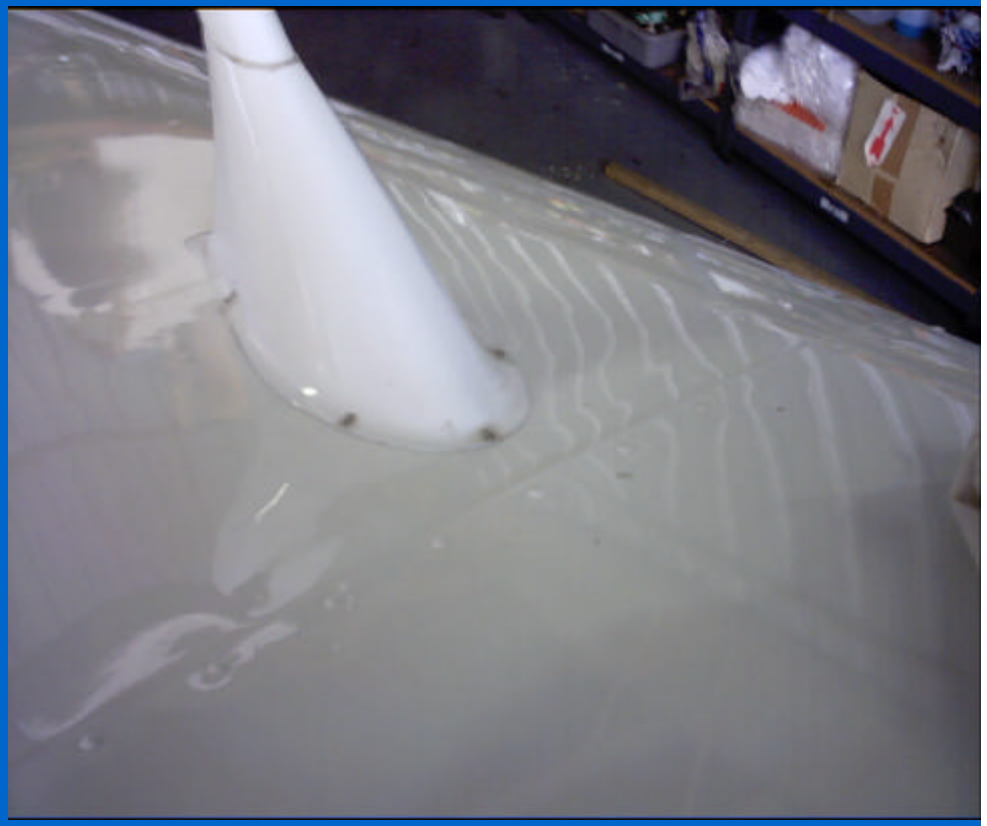
Heater Exhaust Fairing

Blade Comm Antennas

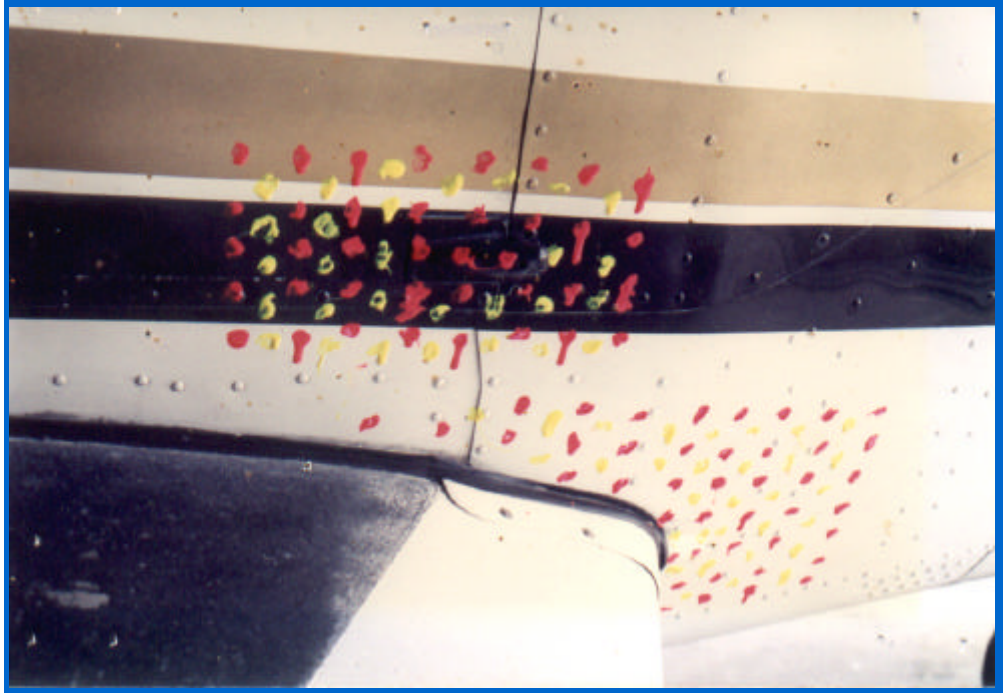


Blade Comm Antennas

Blade Comm Antenna Fairing

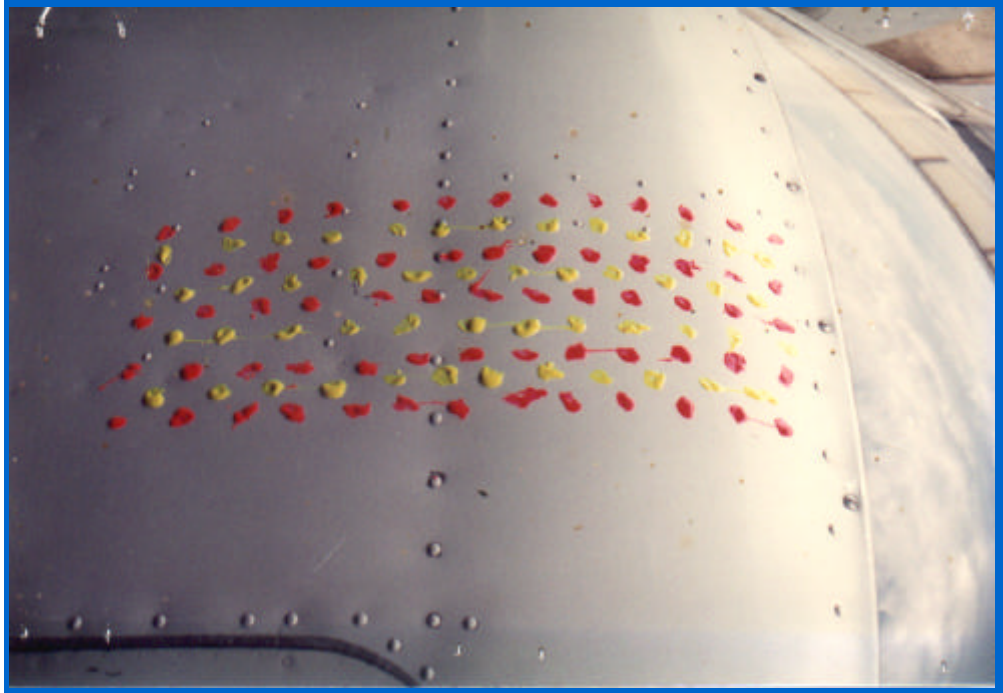


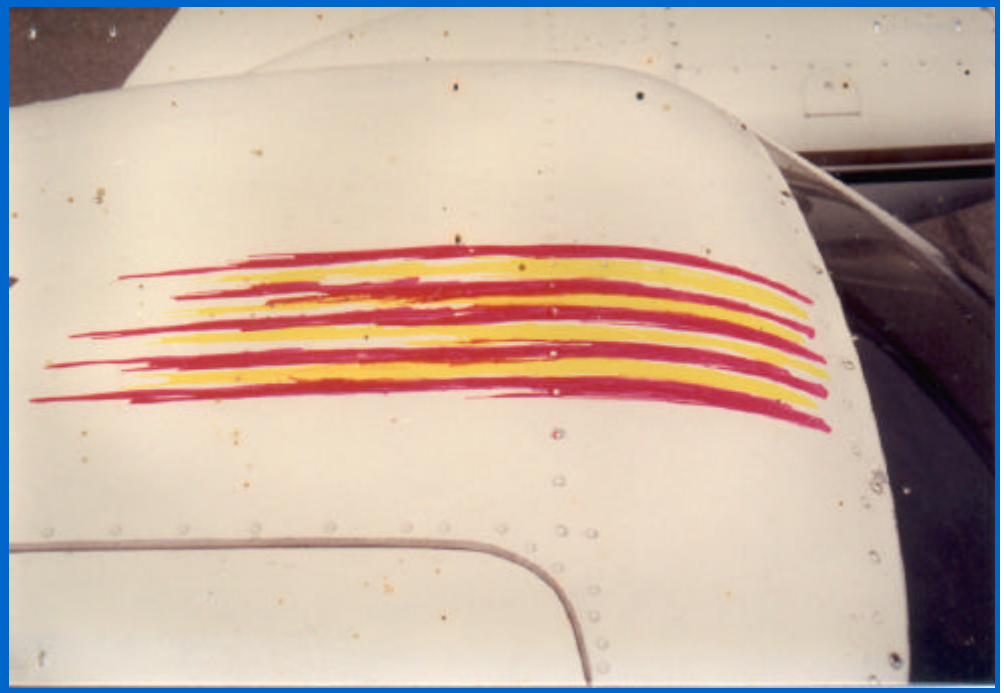
Wing Root and Door



Wing Root Fairing

Windshield - Cabin Junction



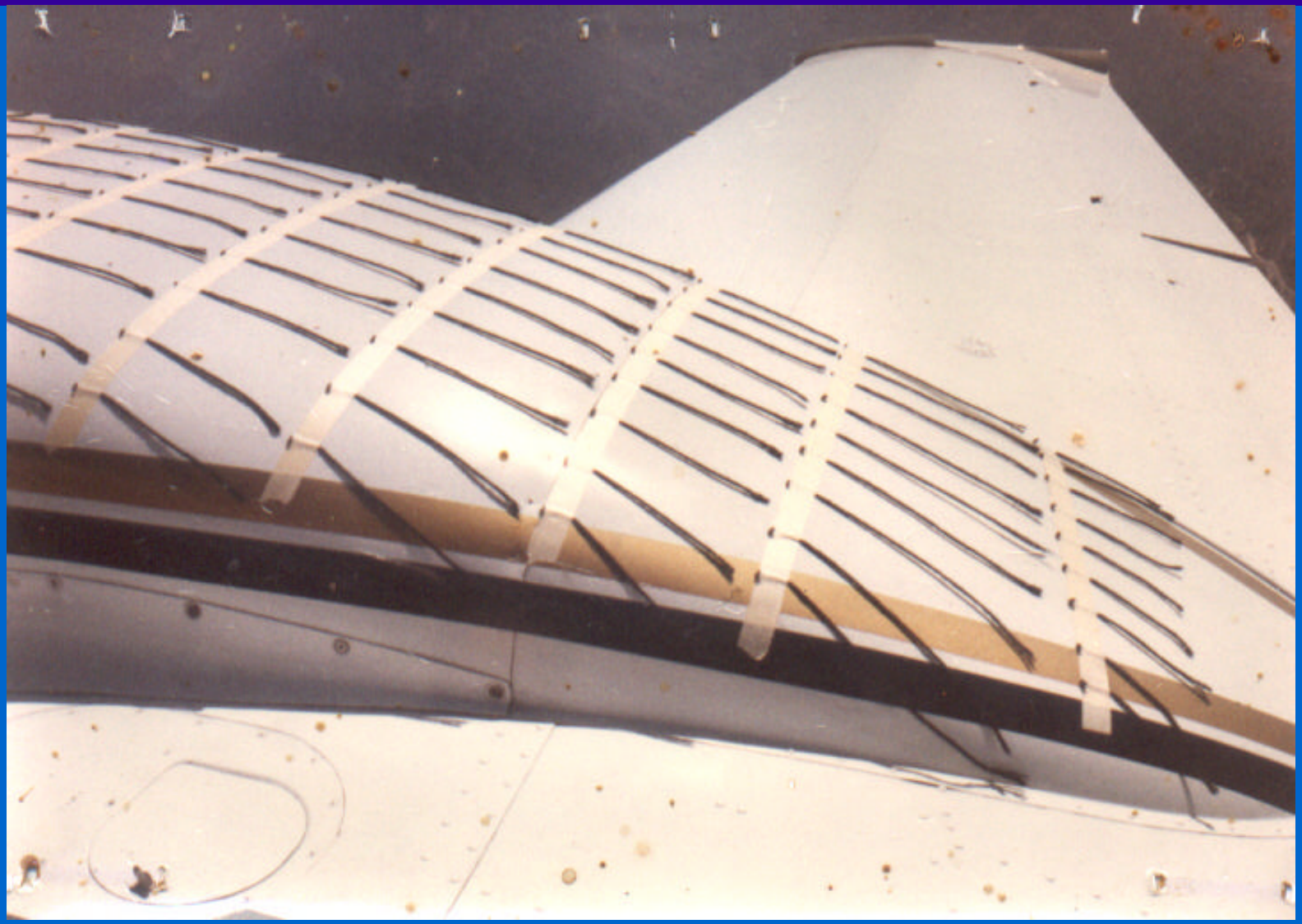


Airflow over windshield to cabin roof appears normal - Vortex generators not req'd

Wing - Fuselage Trailing Edge

Adverse airflow not observed - No action taken

Airflow on Nacelle



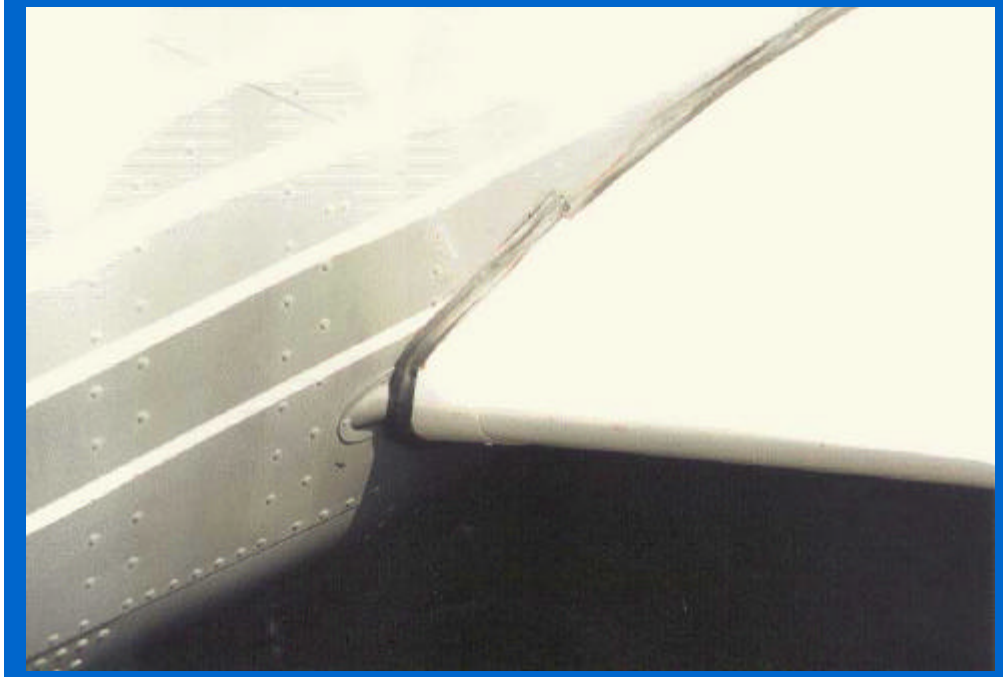
Wing at Stall - 18” & 2100 RPM

Wing in Landing Configuration (15° Flaps)

Purchased STC'd Speed Modifications

- Consider Speed Modifications based on value and historical customer satisfaction
- Value = Buck Spent per MPH gained (my criteria)
  - $100 - $200 / mph gained = good deal
  - $200 - $300 / mph gained = acceptable deal
  - $300 - $400 / mph gained = marginal deal
  - > $400 / mph gained = unacceptable deal
- ***Keep in mind speed modification claims for speed gain are not additive - As interference and form drag are reduced and plane goes faster, skin friction and pressure drag increase, resulting in a smaller, if any, net gain.***

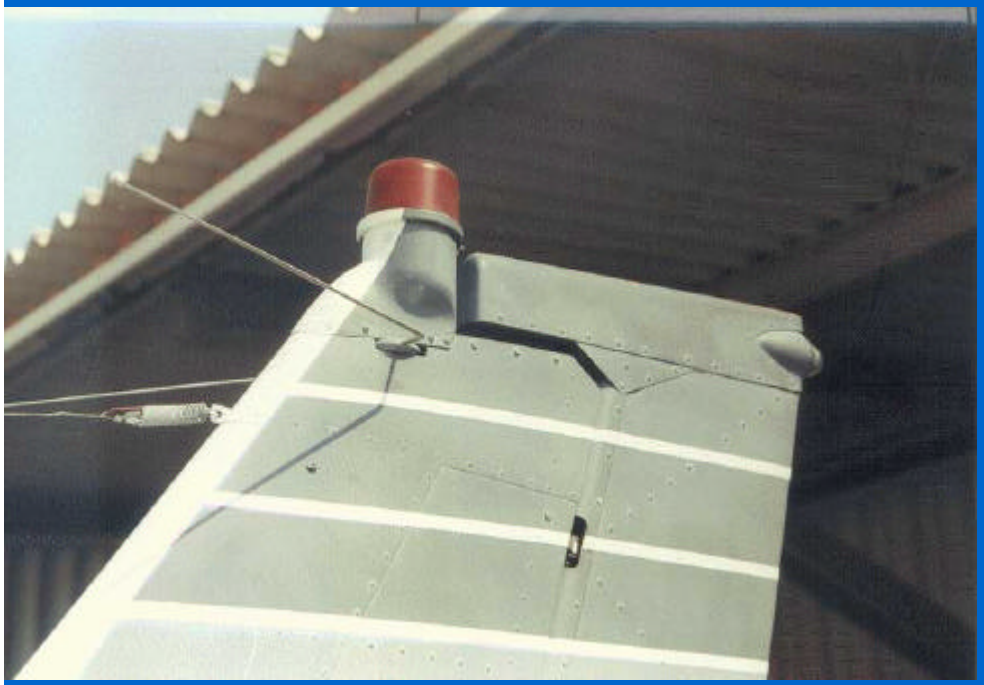
Wing Root Fairing



Stock Configuration

K2U Wing Root Fairing

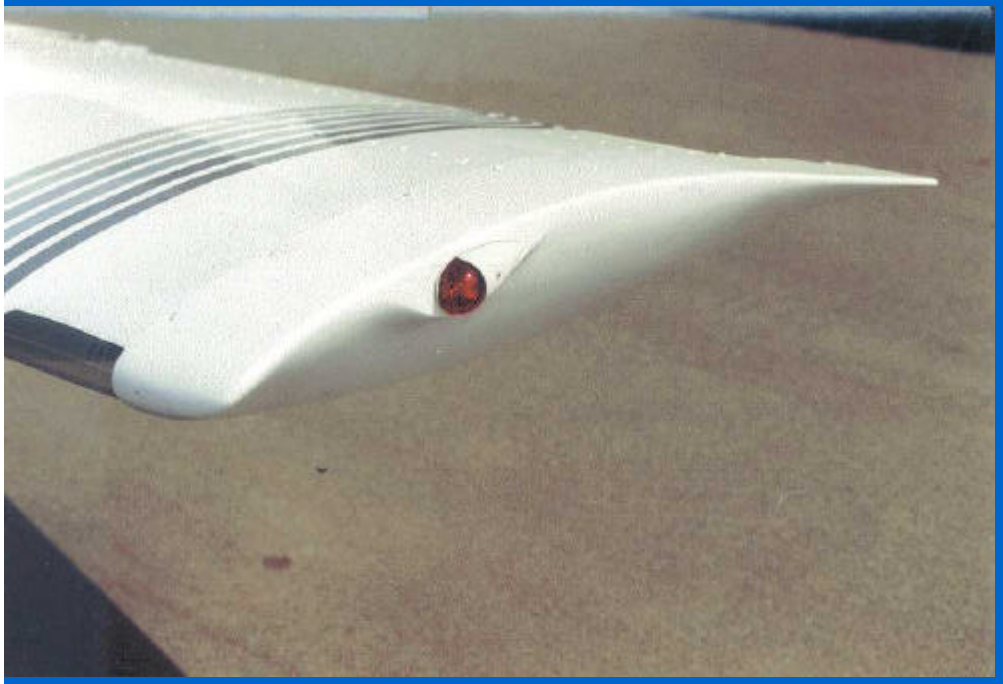
Remove Things that are Round



Standard Grimes Strobe

K2U Fin Cap - Strobe in Rudder

Improved Airflow Wing Tips



MetCoAir Wingtips with External Light

Johnston Wingtips with Enclosed Lights

Landing Gear Afterbody Fairings

Stock Configuration

K2U Gear Lobe shown

Lopresti Speed Spats similar

Flap and Aileron Gap Seals

Stock Configuration

K2U Flap & Aileron Seals

Flap Track Bracket Fairings

Stock Configuration

Lopresti Speed Splitters

Windshield Cowler

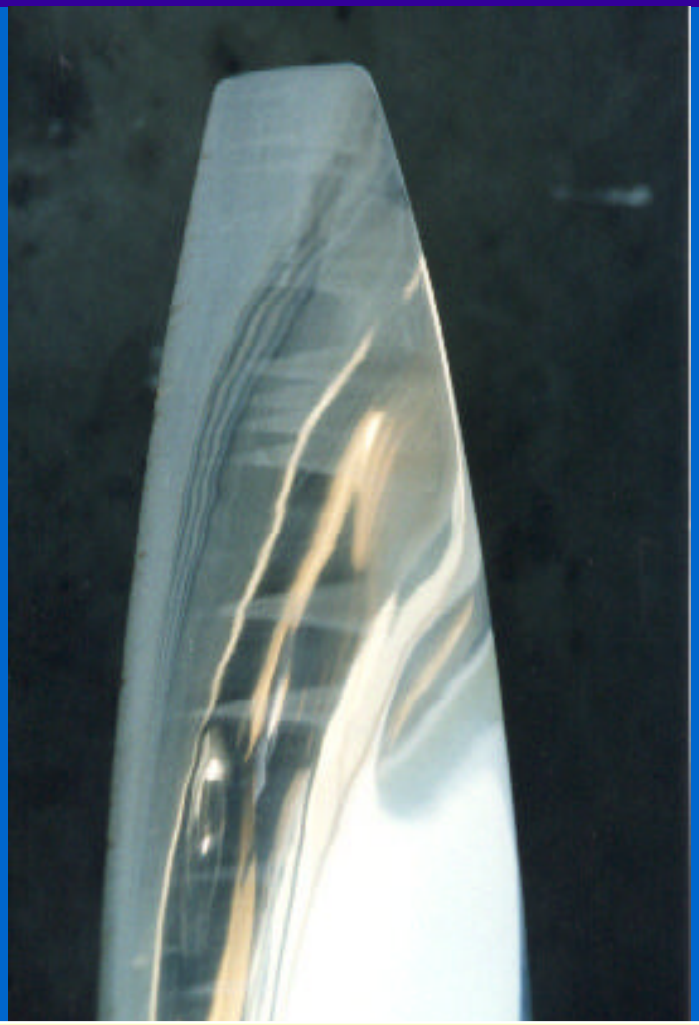
Stock Configuration

K2U Windshield Cowler

Brake Reversal

Requires a cutout on rib at WS 33.06. Cutout reinforced with Doubler + Stiffener. Swap wheel and brake caliper Left to Right, and re-route brake line. Split hubcap is optional.

Propeller Cleanliness for Maximum Performance

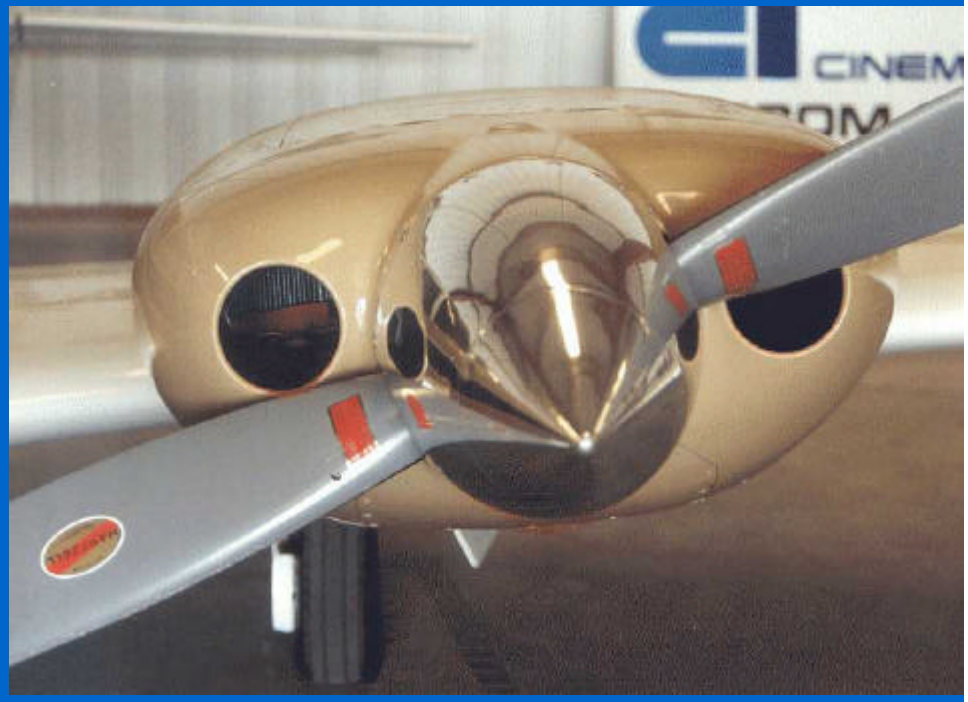


Pictures show effect of laminar vs. turbulent flow caused by leading edge imperfections

Nose Bowl - Singles

Nose Bowl - Twin

Stock Twin Inlet = 64 sq. in.



Lopresti Twin Inlet = 38 sq. in.

Similarity of Twin to Nemisis Cowl

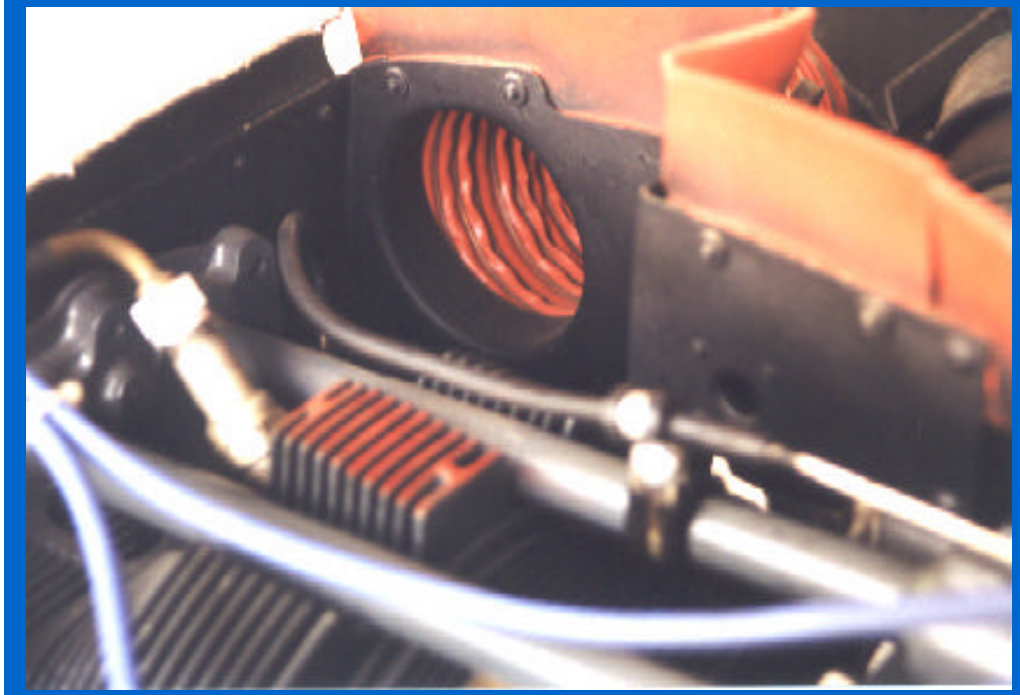
Long Prop Extension - Angled Air Inlets - Controlled Expansion into Cowl Plenum - Complete Seal around Engine

Nosebowl Idea That Did Not Work

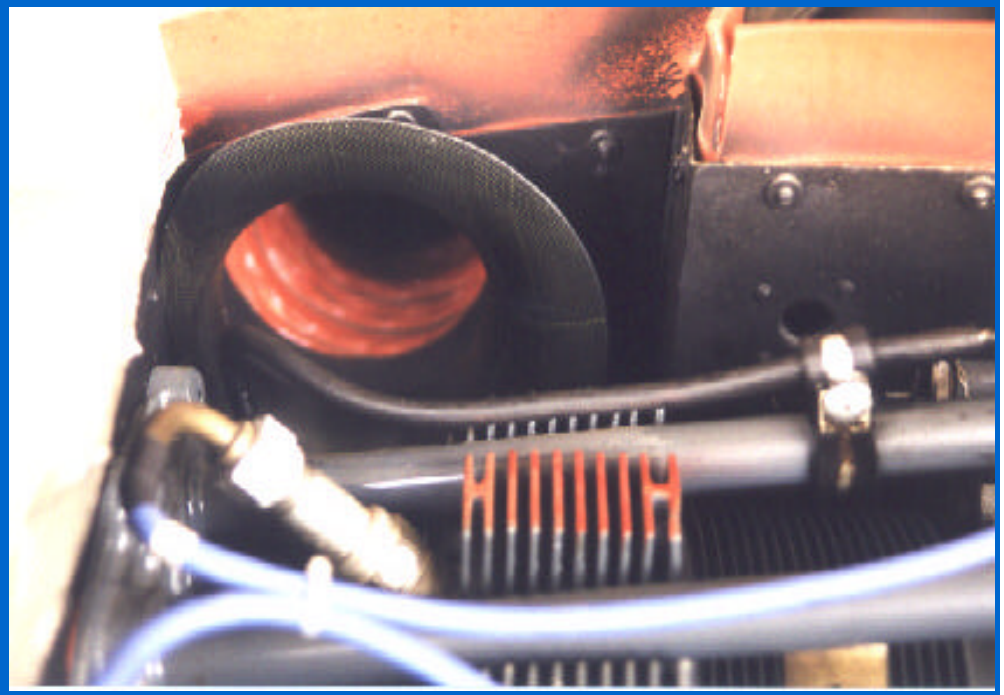
Reduce Inlet Area by 20 sq. in.

Faired Inlet - Foam Expansion Ramp Shape Internal

Cowl Internal Airflow - Induction Velocity Stack

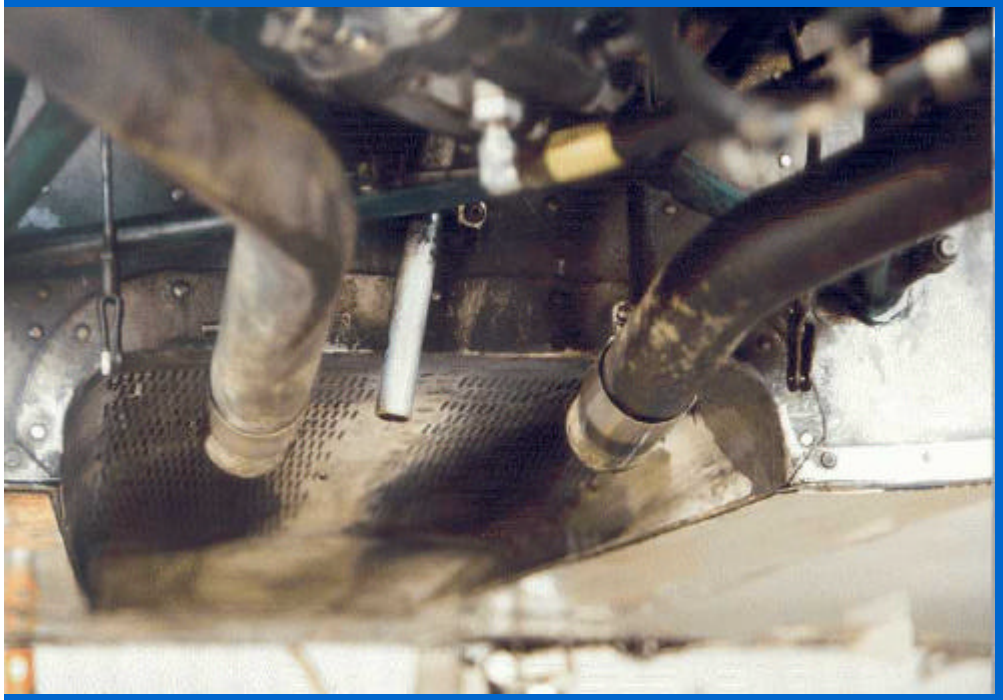


Induction Inlet - Stock

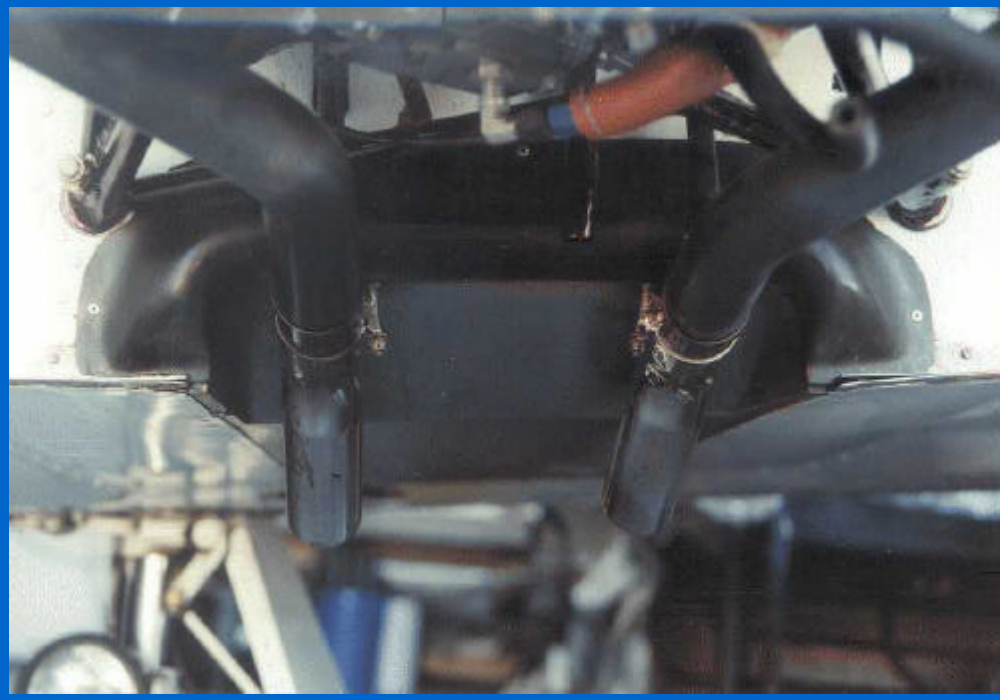


Induction Inlet with Velocity Stack

Cowl Internal Airflow - Exit Air Fairing

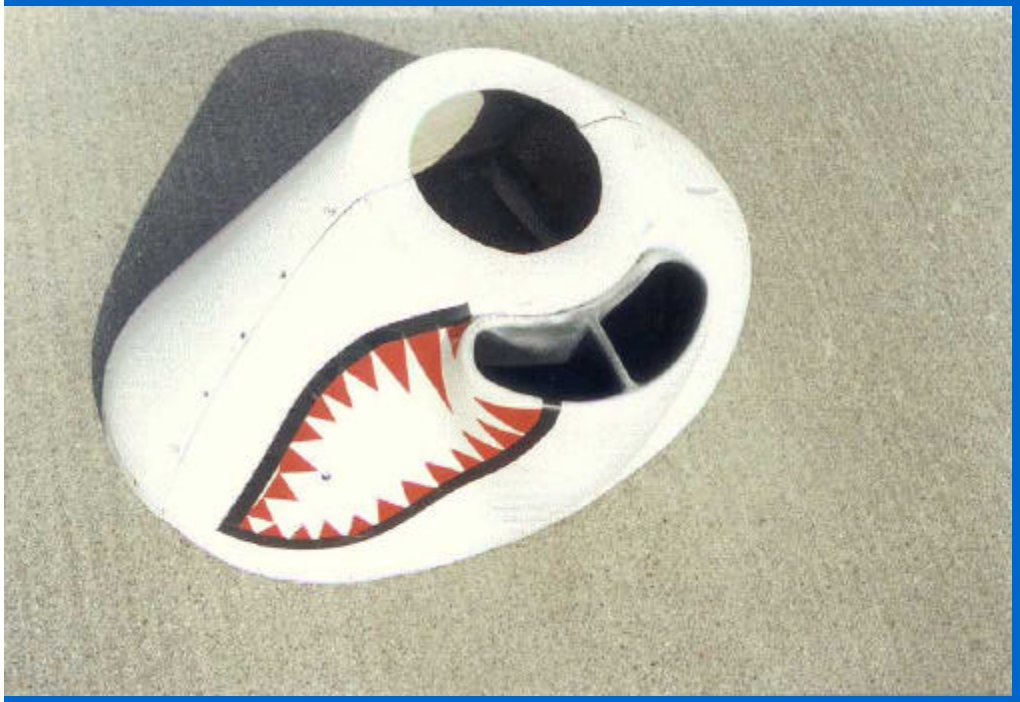


Exit Tunnel - Stock



Firewall Exit Fairing with K2U Exhaust Fairing

New Twin Nosebowl - Neubert Version



New Twin Nosebowl - First Flight

Measured Cowl and Engine Temperatures

			Temperature °F	
Location		Cowl Door Open		Cowl Door Closed
Outside Air Temperature	61°F			
Air Temperature at Induction Inlet		70 °F		73 °F
Cylinder Head Temperature (Average)		360 °F		403 °F
Left Magneto (at Data Plate)		147 °F		152 °F
Right Magneto (at Data Plate)		129 °F		139 °F
Vacuum Pump (at Data Plate)		168 °F		174 °F
Fuel Pump (on Stem)		161 °F		174 °F
Exit Air at Cowl Door		140 °F		158 °F
Conditions:				
5000 Ft, 24 Square, 8.2 GPH, 165 KIAS				

New Nosebowl - Flight #1

Speed Mods in Action

Antenna Fairing, Gear Lobes, Flap Track Fairing, Ailerons Reflexed Up, Exhaust Pipe Ext.

Recommendations
Incorporate Low Cost Speed Mods First

- Perform initial rigging, gear check, engine seal first
- Brake Reversal with Hub Caps on Dual Fork Models
- Reflex Ailerons up 3 Degrees (see Tips Special)
- Blade Nav and Comm Antennas in lieu of wire
- Digital Thermometer with small probe
- Aileron + Flap Gap Seals
- Eliminate round things (if possible)
- Maintain weight in baggage compartment for aft CG

Summary

- ***Keep in mind speed modification claims for speed gain are not additive - As interference drag is reduced and plane goes faster, skin friction and pressure drag increase, resulting in a smaller, if any, net gain.***
- ***Keep in mind that aircraft performance and engine power are greatly influenced by density altitude.***
- ***Select Speed Mods based on value.***
- ***Keep propeller and wing leading edge clean at all times.***
- ***Pay attention to detail.***
- ***Be realistic in your expectations.***