Flight Measured Aerodynamics Of Wittman's Tailwind

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This paper was written with the express purpose of displaying to the members of the Experimental Aircraft Association the great value of the work they are doing. The experimental aircraft, because of their great variety of concepts, contain a vast store of basic aerodynamic information. By making measurements such as these on Wittman's Tailwind and other airplanes, designers will be enabled to project their new designs from known performance. Also having recorded the aerodynamic performance parameters of a plane one can evaluate the benefits of modifications which such measurements point out.

Performance Measurements - Brake Horsepower Required Curve

For small airplanes one uses the engine curves provided by the engine manufacturer in order to obtain the brake horsepower required at various airspeeds. For precise work both the tachometer and manifold pressure gauge should be calibrated.

In order to calibrate the airspeed one flies up and down wind over a fixed known course using section lines if possible.

The power required should be measured at as near standard sea level conditions as possible and in smooth air. This means flying early in the morning at near sea level or at night after the atmosphere has stabilized. The power required runs can be made over the course up and down at a number of airspeeds. In order to obtain the correct calibrated airspeed one must take the time on each leg and from the time compute the speed upwind and speed downwind. An average of these two speeds is the calibrated airspeed. A plot of the airspeed calibration for Tailwind (N5747N) is shown in Figure 1. Since cabin pressure was used for static pressure on the airspeed there is an error of 15 mph at 170 mph indicated; the calibrated airspeed being 155 mph at the indicated airspeed.

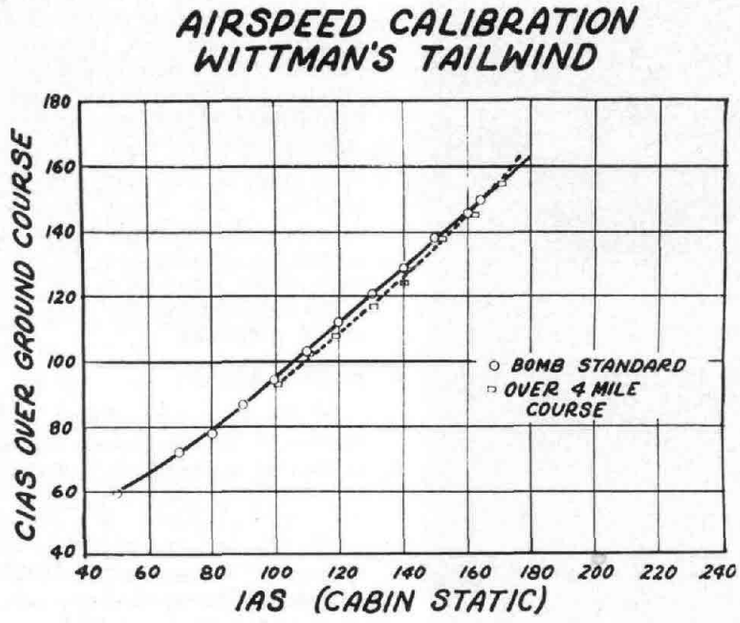


Figure 1 —

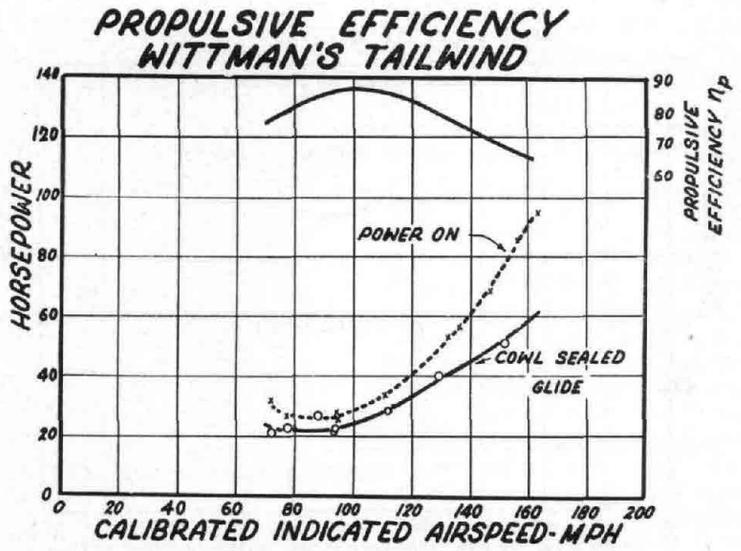


Figure 2 —

Thrust Horsepower Required Curve

While a lot of information can be gleaned from a brake horsepower curve, it is not sufficient to allow a separation of the aerodynamics and propulsion of the airplane. However, if a measurement of thrust horsepower is made by means of glides at various airspeeds one can determine the true airplane drag curve and the propulsive efficiency of the airplane.

The technique for doing glide measurements consists of removing the propeller, installing a glider release on the prop shaft and towing the airplane with a suitable towplane to at least 10,000 feet ASL. The sinking speed at various airspeeds is measured accurately by taking time readings at altitude intervals of 100 or 200 feet. The airspeed must be held accurately and the air should be stable. From air temperature taken on the climb one can reduce the sinking speed to sea level conditions. From the sinking speed and gross weight one computes the thrust horsepower which is being lost at each airspeed. This is also the thrust horsepower required to fly level at that speed.

In Figure 2 are shown the results of measurements made on Tailwind. Note that at 140 mph calibrated indicated airspeed the little plane requires only 60 brake horsepower. This power requires 5 gallons of fuel per hour which comes out to be 28 miles per gallon.

If the ratio of thrust horsepower obtained in glide to brake horsepower is computed for each airspeed there results a curve of overall propulsive efficiency. For Tailwind at 100 mph this efficiency reaches a peak value of 85% which is indeed excellent when compared to other airplanes (Reference 1). However, the curve drops off rather rapidly to 70% at 142 mph. It would be an excellent experiment for one of the Tailwind builders to try to move the peak propulsive efficiency to a higher speed. This may entail a loss in take off acceleration unless a variable pitch propeller is used.

Cooling Power

If the glide measurements are made with the cowl sealed so that no cooling air flows through the engine cowl and with the cowl open as in normal flight, one can obtain the power required to move the cooling air through the cowling as well as the drag of the cooling air as it leaves the cowl opening. The effects of heat from the engine are not included in such a measurement. However, the results are useful for analyzing various cooling arrangements when tested by this method. In Figure 3 is shown the cooling power required for the Tailwind. At cruising speeds above 120 mph the cooling power amounts to exactly 10% of engine power. Some reduction of this power might be made with an efficient augmentor.

Drag Polars

From the power curves and the wing loading the drag coefficient can be computed. When this is plotted with lift coefficient squared vertically and drag

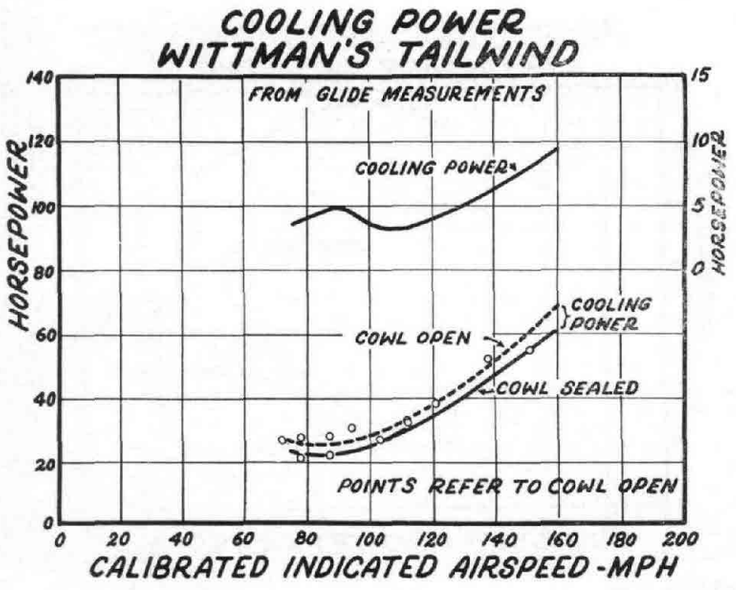


Figure 3 —

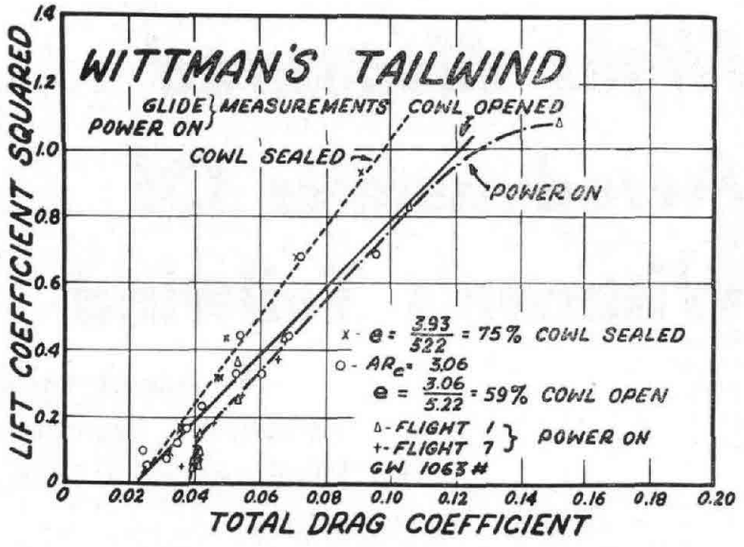


Figure 4 —

coefficient along the horizontal the resulting curve is called the linearized drag polar. If the airflow around the airplane is having normally the drag polar is straight line having a slope proportional to the effective aspect ratio of the airplane. Where the drag polar starts bending the airflow is separating from the surface resulting in high pressure drag and low lift. A series of drag polars for the various flight modes of Tailwind are shown in Figure 4. The power-on polar clearly shows the bending of the polar above a lift coefficient equal to one.

Since the slope of the linear portion of the drag polar yields the effective aspect ratio, it is easy to obtain the span efficiency factor which is the ratio of effective aspect ratio to the geometric. The span efficiency factor is indicative of the induced drag of the airplane compared to that of a minimum induced drag wing. In general the span efficiency factor should be around 90% for a high wing airplane with a good intersection between wing and fuselage. The fact that Tailwind has a span efficiency in the clean configuration of 75% is indicative of a region of separated flow.

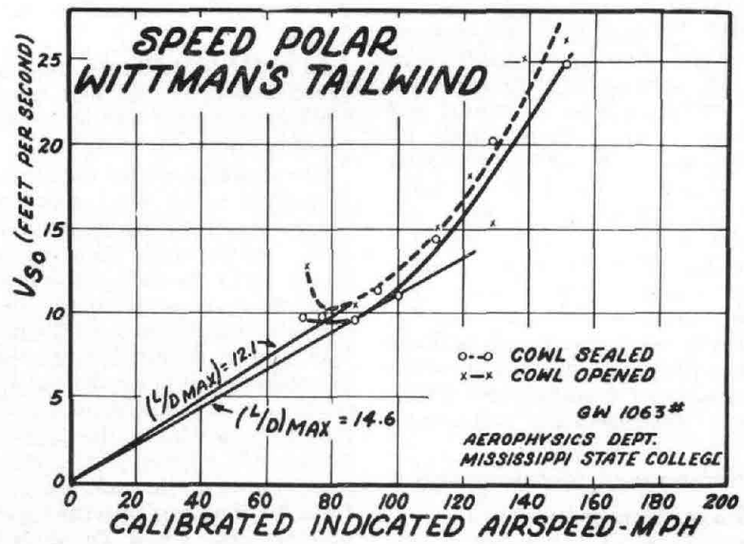


Figure 5 —

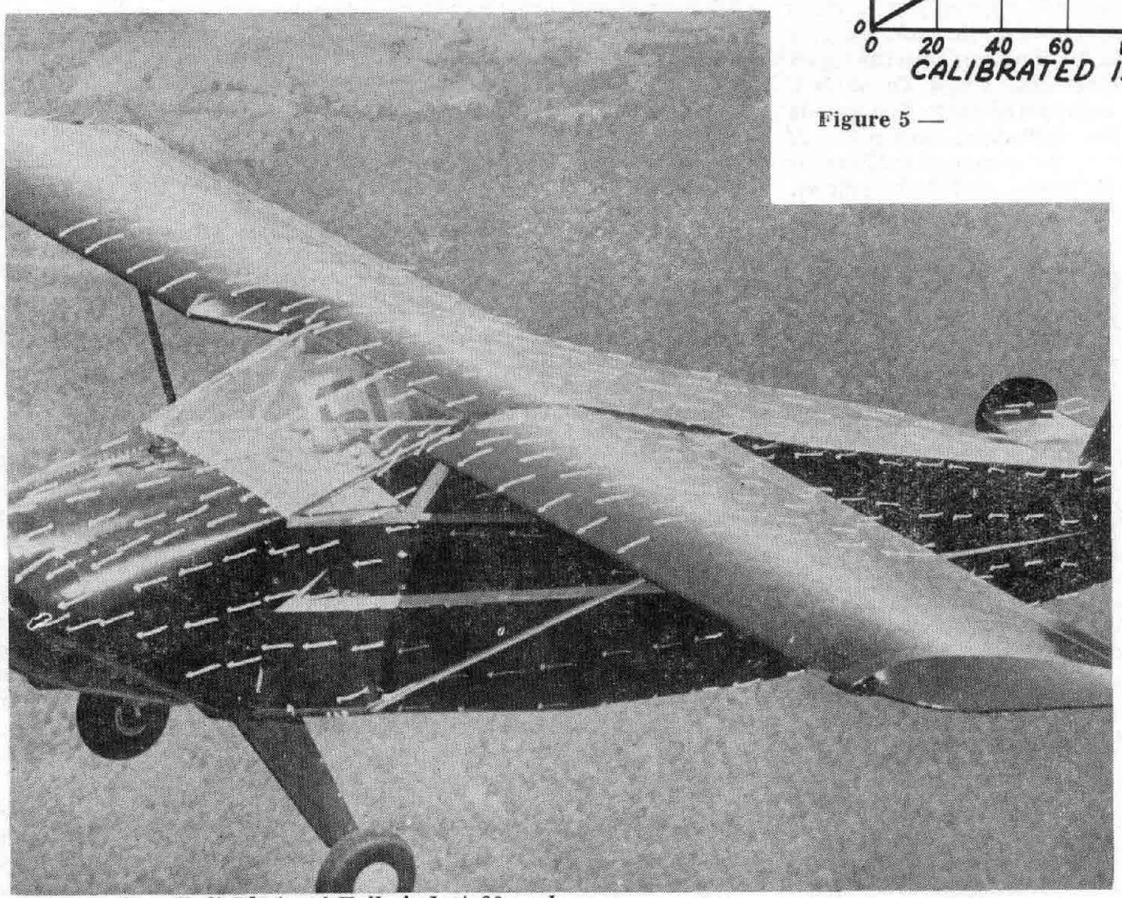


Figure 6 — Tuft Photo of Tailwind at 60 mph.

At high speeds (low lift coefficients) the linear portion shows a bending which indicates separation occurring on the bottom of the airplane or on the bottom of wing as the angle of attack decreases.

Sinking Speed

In Figure 5 are shown the curves of sinking speed versus calibrated airspeed of Tailwind for the cowl sealed and cowl open arrangements. The minimum sinking speed occurs at 80 mph. This is also the point where minimum power would be required for level flight.

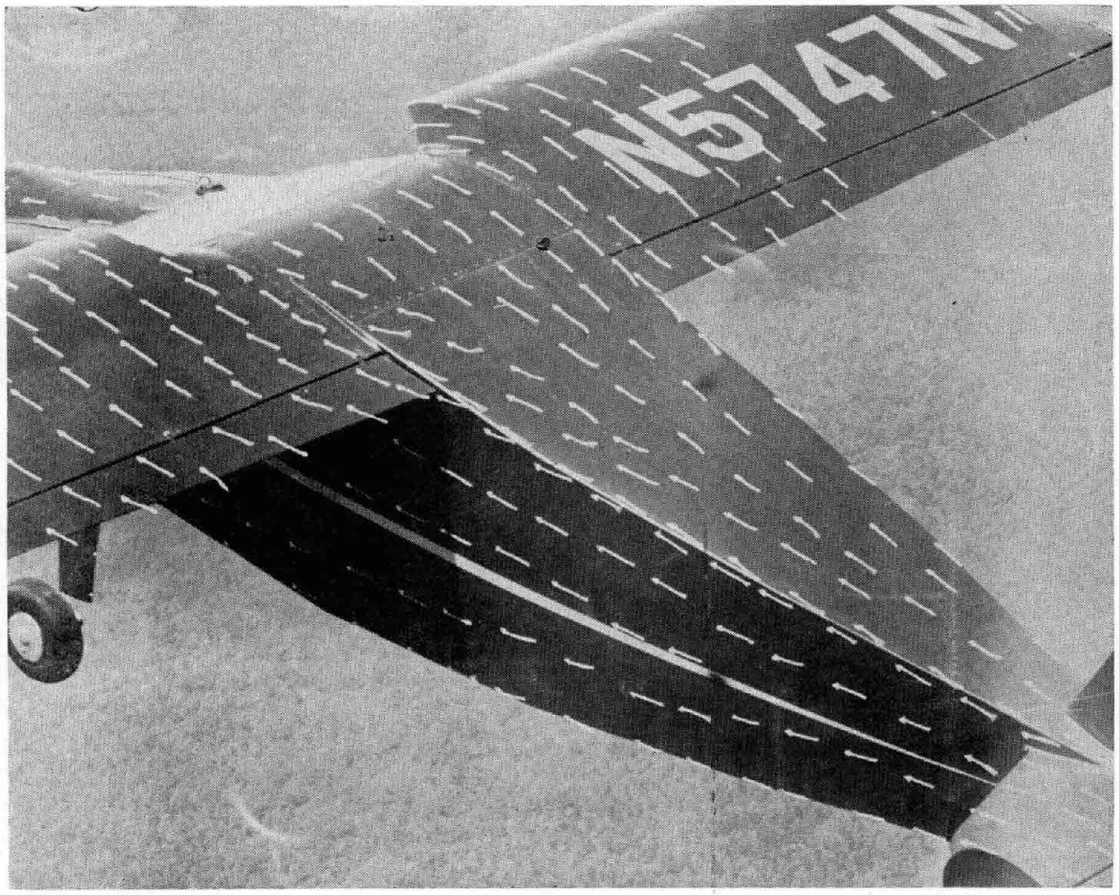


Figure 7 — Tuft Photo from Rear of Tailwind at 60 mph.

Flow Visualization

In order to locate areas of flow separation the airplane was tufted with nylon yarn and photographed at various airspeeds from another chase plane. A telephoto lens was used on the camera so that the airplanes were not required to fly at close spacing. Figure 6 shows a tuft photo taken at 60 mph indicated. (The speed is shown on the card inside the cabin.) The flow around the sharp corner of the windshield is clearly seen to be vorticular. It is this separated vortex which flows over the center section resulting in high induced drag and low lift.

Figure 7 shows a rear overhead view of the tufts at 60 mph. Note that the tufts along the wing joint indicate cross-flow and appear to be in a weak flow. The flow over the rear of the left corner of the fuselage is disturbed by the same cause, viz. the sharp corner on the windshield.

At high speeds (140 mph) the flow over the sharp windshield corner appears to bend around to the side resulting in a vortex intersection (Figure 8). This may be the cause of the drag rise at higher speeds.

In addition to tufts there is available also the sublimation technique for examining the flow in the boundary layer. If a dry coat of naphthalene dissolved in white gasoline is sprayed on a wing and then flown for a few minutes one finds after landing a picture such as shown in Figure 9. The white coat of naphthalene will remain where the flow has low shear and will sublime completely where the shear is high. In a turbulent boundary layer the shear is high and in a laminar boundary layer low. Therefore on the outer portions of the wing one can see how much laminar flow exists at the cruising speed at which the run was made 150 mph. The wedges of turbulent flow where the coating is completely gone are wedges of turbulent flow caused by a little speck of dirt or a small abrasion in the skin. The large wedge behind the pilot clearly shows the drag coat of protruberences sticking out of the leading edge.

On the cutout portion of the wing the flow in the boundary layer is more complicated. First there is a white streak along the cutout. This is a laminar bubble. Then there is a black region (turbulent flow) and then again a white region of extensive proportions. This is a region of separation of the turbulent boundary layer. Such a region results in very high drag.

A photo (Figure 10) of sublimation on the lower surface shows that there is a large extent of laminar flow on the bottom surface. On the strut fairing there is evident a region of separated flow.

From the greatest extent of laminar flow as shown by the sublimation it is possible to compute the minimum profile drag of the airfoil. This was done for the Tailwind. The profile drag coefficient came out to be 0.0063 which is nearly as low as was obtained in low turbulence tunnel measurements of this airfoil It is evident, however, from the sublimation picture that not all of the wing possesses this low drag. Smoothing (2) the leading edge should yield a considerable gain in wing drag reduction.

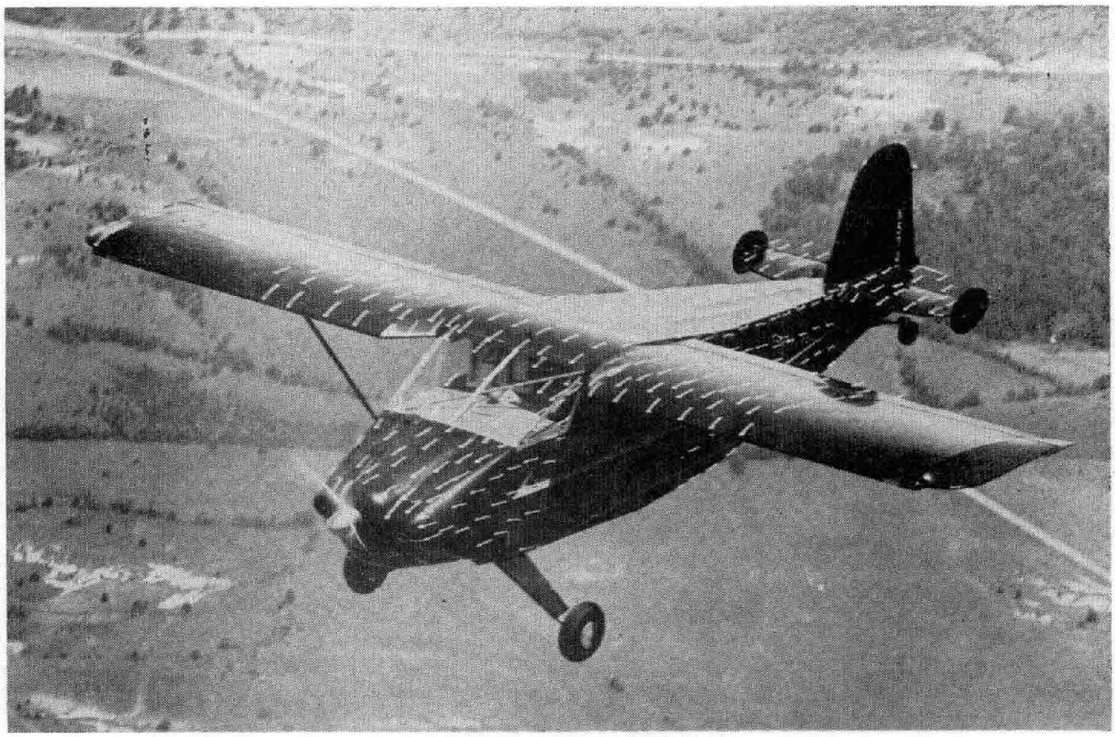


Figure 8 — Tuft Photo of Tailwind at 140 mph.



Figure 9 — Disturbance of pitot tube

Note: Separated flow over triangular cutout. (no wedges).

Conclusions

These measurements in themselves may not appear too meaningful until more airplanes of this type are measured and published (3, 4). However, one can compare this airplane with a few existing side-by-side two seaters in Table I.

TABLE I

Airplane	Minimum Drag coefficient gliding Prop-off, Cowl open
Tailwind	0.025
AG-14 Pusher	0.040
Cessna 120	0.035

Since the minimum drag coefficient is based on wing area the comparison tends to favor the airplanes with larger wing areas. However, in the end the quality of the design of an airplane is really a complex relation between its many parameters. Therefore it is important that in order to further the progress of light plane design that each airplane be analyzed just as has been the Tailwind herein. From the individual parameters one may then synthesize a new design projecting that parameter which shows possible improvement.

It has been the author's pleasant lot to have the wholehearted cooperation of Steve Wittman who provided the airplane and his excellent piloting skill for these measurements. The author also gratefully acknowledges the inspiration for this paper which his reception by the EAA has engendered.

References

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2. *Swartzberg, M. B. "Technique of Smoothing Leading Edges of Airplanes." Aerophysics Department. Mississippi State College, May 17, 1954.*

3. *Raspet, August "Application of Sailplane Performance Analysis to Airplanes." Institute of Aeronautical Sciences, August, 1954.*

4. *Raspet, August Determination of the Drag Polar of the Cessna 120 Airplane in Gliding Flight." The Journal of the Aeronautical Society of India. Vol. 4, No. 4, November 1952.*

Specifications Corben Baby Ace

Wing Span	34 ft.
Wing Chord	5 ft.
Length	18 ft. 9 in.
Height	6 ft. 6 in.
Weight (empty)	630 lbs.
Stalling Speed	30 mph.
Cruising Speed (Cont. 65)	95mph.
Wing Area	184 sq. ft.
Airfoil	Clark Y
Angle of Incidence	2 degrees
Dihedral	2 degrees
Wing Loading	6.2 lbs. per sq. ft.

PRPA NEWS....Race Results

INTERNATIONAL AIR MEET AND RACES
OSHKOSH, WISCONSIN AUG. 4-5, 1956

QUALIFYING TRIALS — August 4, 1956 — 1 Lap 2¼ Mile Course

Place	Race No.	Owner	Pilot	Elapsed Time in Seconds	Speed	Net Prize Money
1	111	T. K. Cassutt	Same	40.9	198.05	
2	1	S. J. Wittman	Same	41.85	193.55	
3	92	W. F. Falck	Same	41.9	193.32	
4	16	Ohm & Assoc.	R. V. Ohm	43.25	187.28	
5	46	Pack & Assoc.	C. E. Bishop	47.5	170.53	
6	9	Luther Johnson	M. H. Stickney	47.7	169.81	
7	14	James Miller	Same	(Arrived too late to qualify)		
FIRST SEMI FINAL — 10 Laps 2¼ Mile Course						
*1	92	W. F. Falck	Same	464.85	174.25	$147.84
2	46	Pack Assoc.	C. E. Bishop	483.2	167.63	137.28
†3	111	T. K. Cassutt	Same	509.72	158.91	126.72

*Penalized the average time for completion of one lap for cutting #2 pylon on 1st lap.

†Penalized the average time for completion of two laps for cutting #2 pylon on 1st and 2nd laps.

SECOND SEMI FINAL — 10 Laps 2¼ Mile Course						
1	1	S. J. Wittman	Same	419.0	193.32	$147.84
2	16	Ohm & Assoc.	R. V. Ohm	452.2	179.12	137.28
3	9	Luther Johnson	M. H. Stickney	503.3	160.94	126.72
4	14	James Miller	Same	506.4	159.95	116.16
CONSOLATION RACE — 10 Laps 2¼ Mile Course						
1	111	T. K. Cassutt	Same	429.8	188.46	$142.56
*2	14	James Miller	Same	477.4	169.67	96.23
3	9	Luther Johnson	M. H. Stickney	494.5	163.80	117.61

*James Miller won second place, but because he did not appear before the close of the official qualifying time, was awarded 3rd place prize money.

S. J. WITTMAN TROPHY RACE — 12 Laps 2¼ Mile Course						
1	1	S. J. Wittman	Same	493.8	196.84	$704.00
2	92	W. F. Falck	Same	494.1	196.72	440.00
3	16	Ohm & Assoc.	R. V. Ohm	515.8	188.45	286.00
4	46	Pack & Assoc.	C. E. Bishop	545.5	178.19	198.00

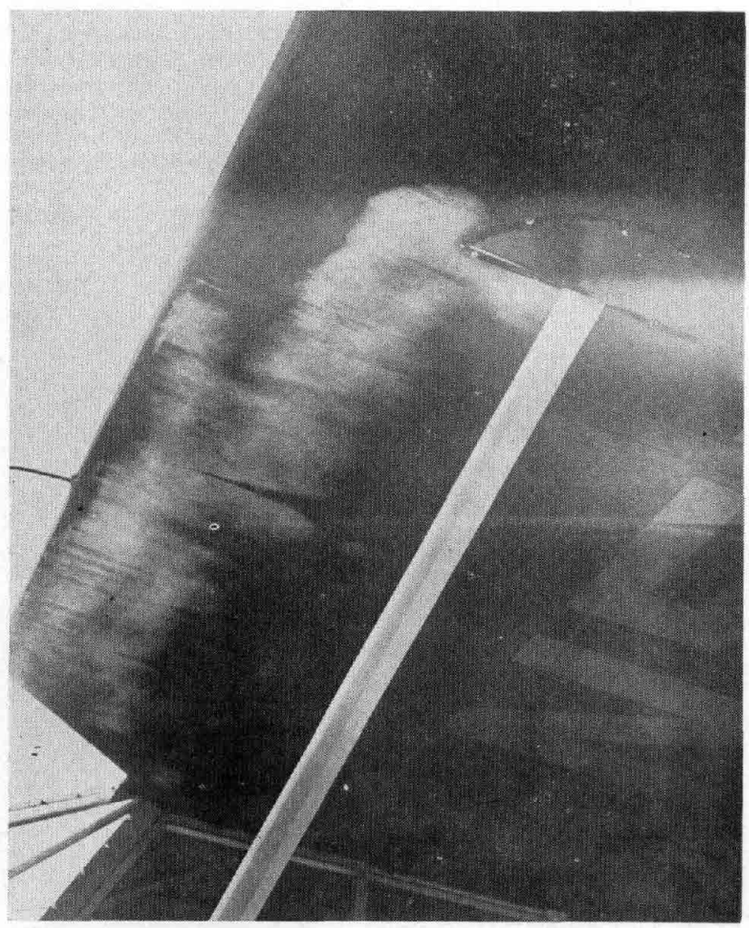


Figure 10 — Tailwind

Sublimation 150 mph — bottom of wing.