TECHNICAL NOTES

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WIND TUNNEL TESTS OF FUSELAGES AND WINDSHIELDS

By Edward P. Warner
Massachusetts Institute of Technology

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Introduction

The tests described herein were made in 1918, in the old four-foot wind tunnel at the Massachusetts Institute of Technology and at the request of the Engineering Division of the U. S. Army Air Service. The results were given circulation only in official circles at that time. The interest of the work appears sufficient to justify its wider distribution even at this very late date.

Object and Method

The primary object in planning the tests was the securing of data on the effect of windshield form on the total resistance of a fuselage of a good streamline shape. Secondarily, it was anticipated that some information might be obtained on the degree of protection afforded the pilot by the windshield.

Tests were made in the ordinary manner, the model being supported rigidly on a spindle. The resistance and interference of the spindle were allowed for by measurement of the effect of a dummy spindle, and the final figures of fuselage resistance should be correct within .0010 lb. Relative values, or differences between the several figures, are of course much more accurate than that, and are therefore given to four decimal places.

The resistance of each fuselage-windshield combination was measured with the cockpit empty and also with the heads of the pilot and gunner, modeled from plasticine, in their proper places. It is probable that the interference of the heads of the crew on the fuselage is very small, and the difference between the two resistances can therefore be taken as a satisfactorily approximate indication of the total air pressure on the heads of the crew and so of the mean velocity with which the air strikes them. When this difference is large it of course points to inefficiency of windshielding. So far as the pilot is concerned, the difference in effectiveness of the several shields is likely to be even larger than the direct comparison of the resistance figures suggests, for when the total force on the heads of the crew is large most of it falls on the pilot, while the small force correspondent to an efficient shield bears principally on the gunner, the air stream being directed completely over the pilot's head.

All runs were made at a wind speed of 30 M.P.H.

Description of Model

In the windshield tests the U.S.A.-C2 fuselage was used, the model being made to 1/12 scale. The U.S.A.-C2 was to have been a two-seater fighter, the rear seat fitted with a gun ring, and to carry the Liberty engine. The design called for a nose radiator, but one of considerably smaller area than that commonly used in later years, and the streamlining of the nose was therefore comparatively good, the height of the flat portion being only about what it is, for example, on the DH4. The sides of the fuselage were flat, the top and bottom curved in section.

Five windshields of as many different types and forms were tried in front of the front cockpit, and a test was also made with no windshield at all. The six cases are shown in Fig. 1 (A), representing the unbroken outline. Of the other five cases, (B) and (D) include shields running the full width of the body, (C), (E), and (F) being narrowed in by varying amounts. The several shields also differ markedly in their slope as seen in profile, the angle being very abrupt for case (F), a little less so for cases (D) and (E), and still gentler for cases (B) and (C). Case (E) represents most closely that form of shield which would be considered typical of modern design.

The U.S.A.-C1 model, on which a few supplementary tests were made, was a fuselage of the same general type but designed for a free-air radiator and a geared engine. The form of the nose was therefore much smoother and more symmetrical than on the C2. Both fuselages are shown in Fig. 2.

Results of Tests

The results are best expressed in tabular form.

Cases	Resistance, cockpits empty	Resistance, 2 men in place	Change of resistance by addition of men
A	.0376	.0451	.0075
B	.0401	.0401	0
C	.0409	.0411	.0002
D	.0402	.0371	.0031
E	.0410	.0413	.0003
F	.0388	.0423	.0035

All forces stated in pounds on 1/12 scale model at 30 M.P.H.

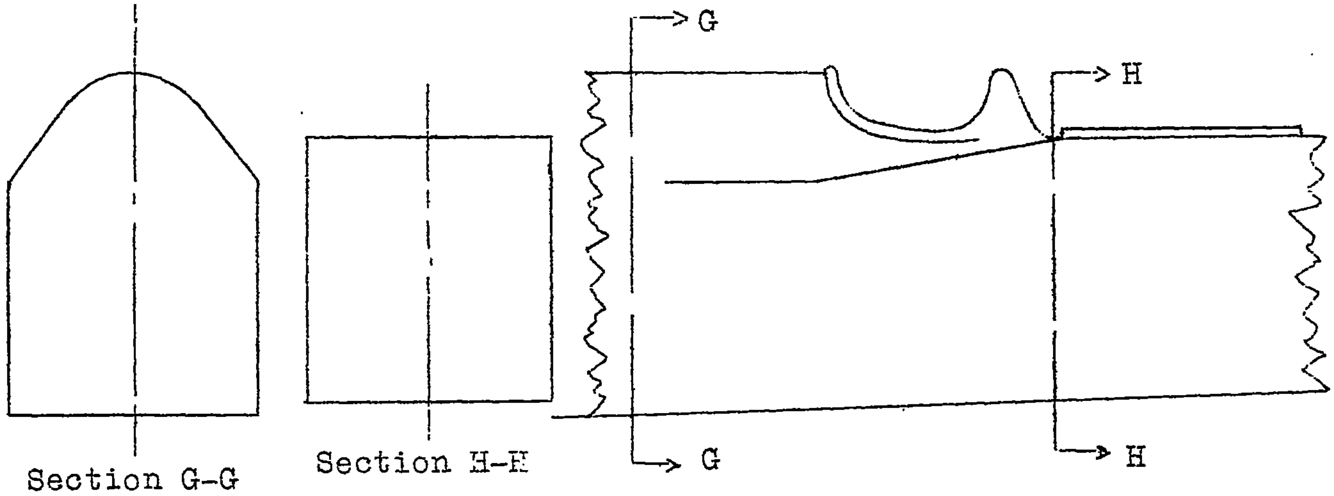
The resistances with the cockpits empty are of course of little interest in themselves. Comparing the figures in the next column, it is apparent that the resistance is lowest when the windshield extends over the full width of the fuselage and breaks upward from the smooth surface at a fairly sharp angle (at least 30°). The advantage of this form in keeping the resistance low is tied up with its very effective shielding, shown by the figures in the last column of the table, for if the windshield does not direct the air away from or over the pilot the resistance of his head may be an important part of the total parasite drag of the fuselage. From the point of view of drag, it would be practicable and indeed desirable to decrease the angle of rise of the shield if it were extended farther forward so that its highest point would more nearly reach the level of the top of the pilot's head. There are, of course, practical limitations on form and dimensions, for airplane windshields are ordinarily at least semi-opaque, and they must therefore be small enough so that the pilot can look around or over them without serious difficulty.

The shortest, narrowest, and steepest of the five shields tried, case (F), gave the largest resistance. The difference between the best and worst was .0052 lb. on the model, or 12 lb. on the full-sized airplane at 120 M.P.H., equivalent to a change of 3.8 in the horsepower required for flight at that speed. The resultant change in speed, in a typical Liberty-engined observation airplane, would be less than a mile an hour. It is therefore safe to ignore the effect of windshield form on performance within the limits of the probable range of alterations of shape and size, and to proportion the shield with reference only to the pilot's comfort and field of view. On the first count it would appear, so far as variation of resistance can be used as a guide, that any of the five shields except the smallest would be satisfactory.

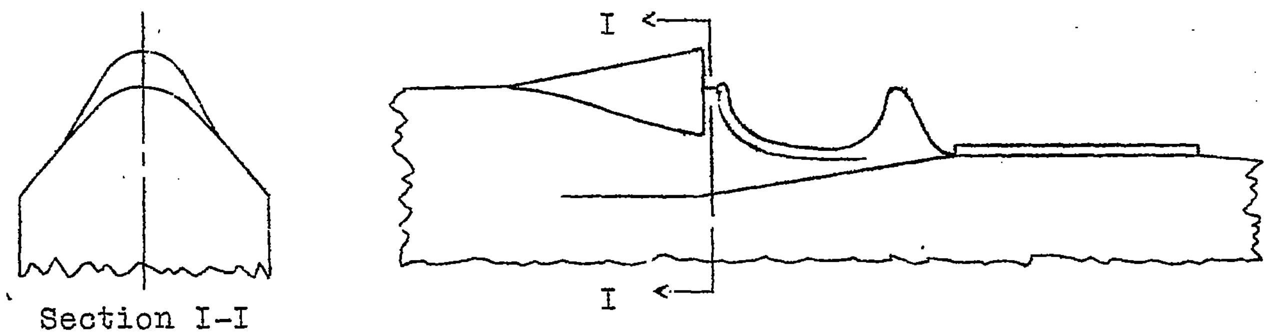
Results of Tests in Yaw

Both the U.S.A.-C1 and C2, the latter with the windshiled of case (D), were tested at various angles of yaw ψ the drag and cross-wind force being measured. The results are plotted in Figs. 3 and 4, whence it appears that, as might have been expected, the flat-nosed C2 has a considerably higher resistance than the C1, with its obviously better streamline form. It is a little more surprising to find the better of the two forms far less sensitive to angle of yaw than the poor one, 4° of yaw increasing the resistance of the C2 7 per cent, that of the C1 only 3. The effect of the turbulent flow around the badly-shaped nose evidently becomes aggravated when the object is presented to the wind unsymmetrically.

Cross-wind forces are largest on the C2, presumably because of its flatter sides. In both cases, but especially for the C2, the curves of cross-wind force against angle of yaw show a consistent upward curvature, the slope increasing as the angle increases, much as the lift curve is sometimes found to bend upward for a very thick airfoil section.



(A)



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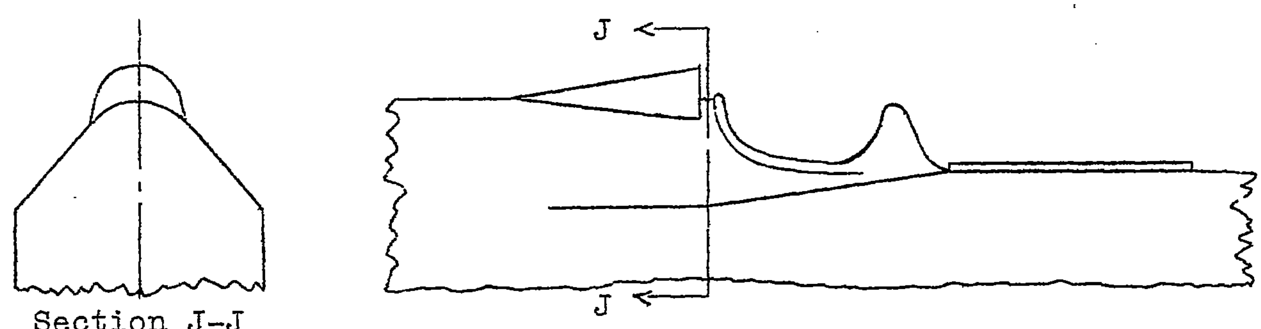
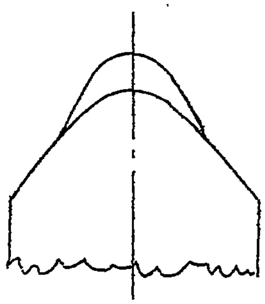


(C)

Fig. 1

(Continued on next page)



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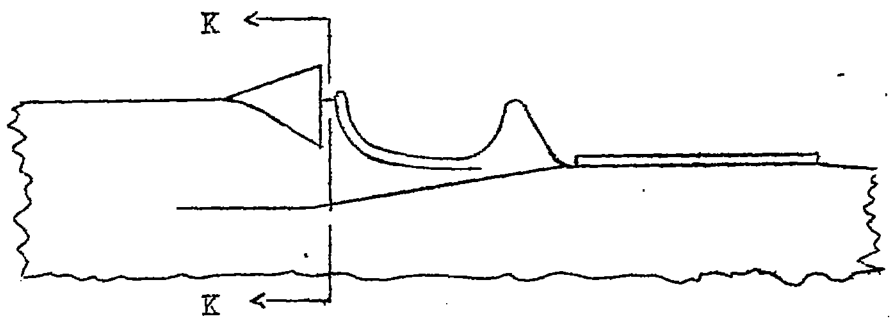
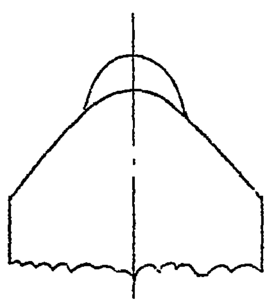


(D)



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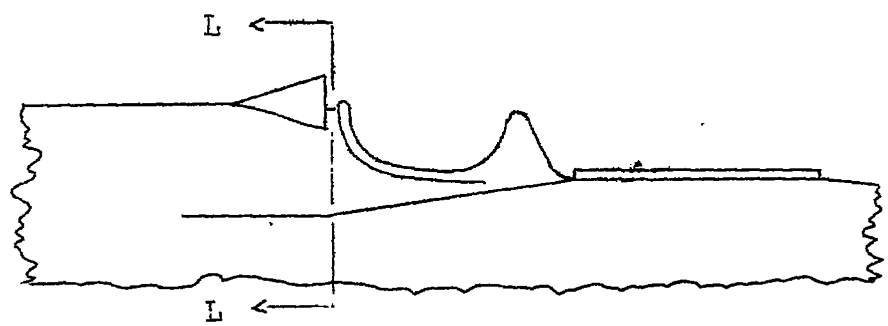
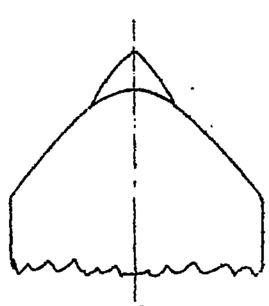
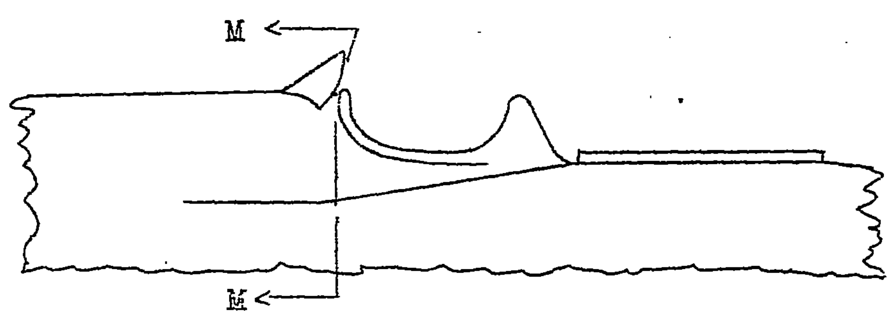


(E)

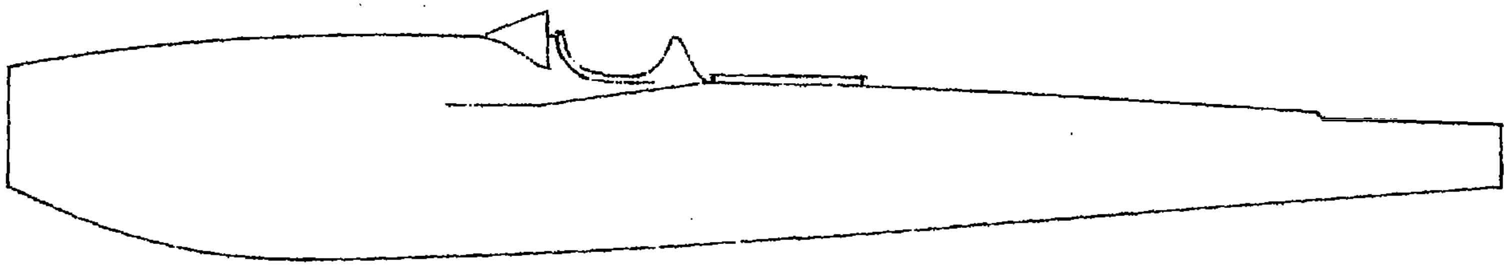


Section M-M

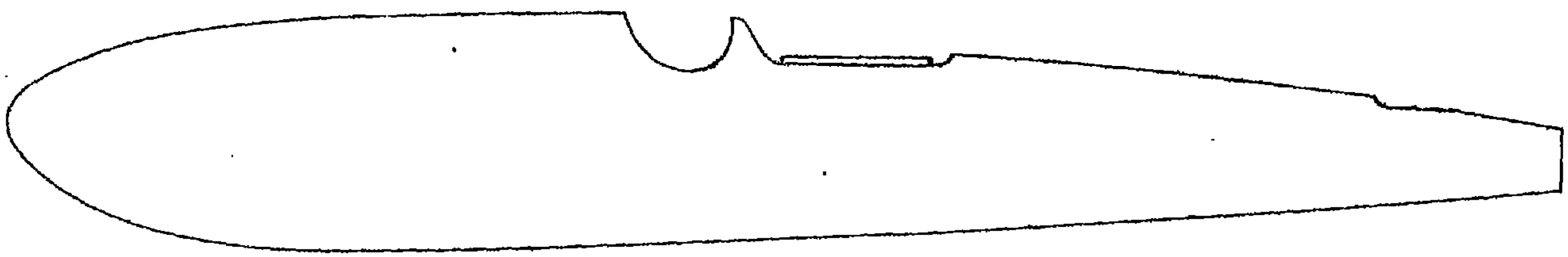


(F)

Fig.1 continued.



U.S.A.- 02



U.S.A.- 01

Fig. 2

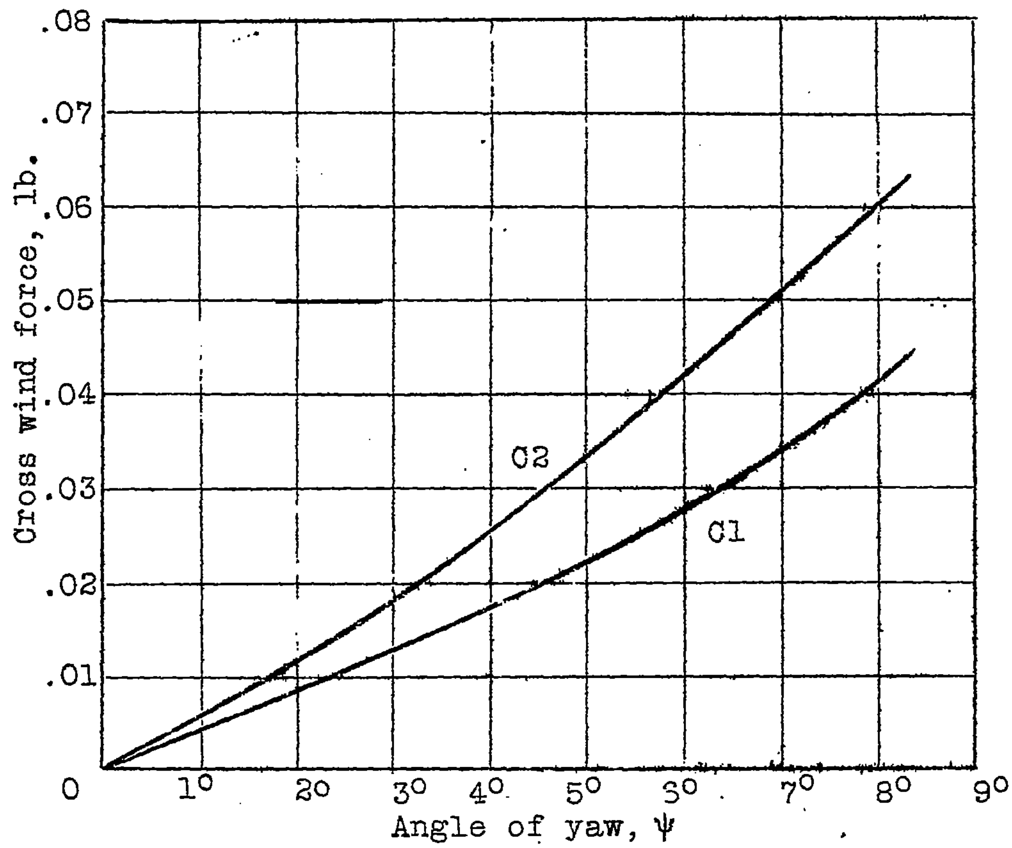

.08
.07
.06
.05
.04
.03
.02
.01
0
Cross wind force, lb.
C2
C1
1°
2°
3°
4°
5°
6°
7°
8°
9°
Angle of yaw, ψ

Fig.3

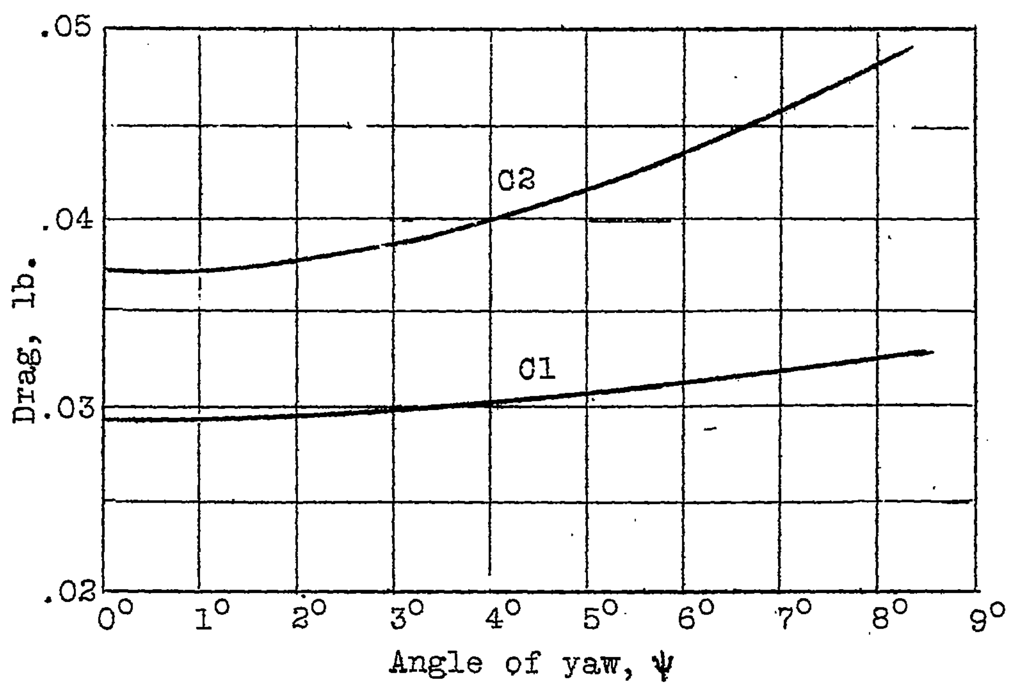

.05
.04
.03
.02
Drag, lb.
C2
C1
0°
1°
2°
3°
4°
5°
6°
7°
8°
9°
Angle of yaw, ψ

Fig.4