TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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WIND-TUNNEL TESTS OF THE FOWLER VARIABLE-AREA WING

By Fred E. Weick and Robert C. Platt
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19

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SUMMARY

The lift, drag, and center of pressure characteristics of a model of the Fowler variable-area wing were measured in the N.A.C.A. 7 by 10 foot wind tunnel. The Fowler wing consists of a combination of a main wing and an extension surface, also of airfoil section. The extension surface can be entirely retracted within the lower rear portion of the main wing or it can be moved to the rear and downward. The tests were made with the nose of the extension airfoil in various positions near the trailing edge of the main wing and with the surface at various angular deflections. The highest lift coefficient obtained was $C_L = 3.17$ as compared with 1.27 for the main wing alone.

INTRODUCTION

The Fowler wing, developed by Harlan D. Fowler, is the result of an attempt to combine three different methods of increasing the maximum lift.

1. Increasing the area by means of an extension surface.

2. Increasing the effective camber by means of a flap.

3. Providing a slot to help maintain unburbled flow at high angles of attack.

The combining of these methods is accomplished by means of an extension surface, which is a sort of flap having an airfoil section. The extension airfoil is retracted into the lower rear portion of the wing when not in use but is extended to the rear and downward when high lift is desired. (Fig. 1.) The gap that is left between the main wing and the extension airfoil forms a slot to maintain unburbled air flow over the rear airfoil at the high angles of attack.

Previous wind-tunnel tests on models of 3-inch chord at both Massachusetts Institute of Technology and New York University, and full-scale flight tests have all shown exceptionally high lift coefficients with the Fowler wing arrangement. (Reference 1.) The present tests were made as part of a series on high-lift devices in the 7 by 10 foot wind tunnel of the National Advisory Committee for Aeronautics. The Clark Y airfoil section was used for both the basic wing and the extension airfoil and the tests were made to cover a range of slots and angular deflections of the extension airfoil.

APPARATUS AND METHOD

The Fowler wing model used in these tests consisted of a basic Clark Y wing with a 10-inch chord and 60-inch span, and a Clark Y extension airfoil having a chord 40 per cent that of the main wing. (See figs. 1 and 2 and Table I.) The extension airfoil and the forward portion of the main wing were constructed of laminated mahogany. The rear portion of the main wing, which followed only the upper contour of the Clark Y profile, was made of a 1/32 inch steel plate rolled to the proper curvature and stiffened by ribs spaced 5 inches apart. The extension airfoil was supported by means of five equally spaced metal plates attached to five of the ribs, and capable of adjustment to give different positions and angular deflections of the rear airfoil.

The extension airfoil could not be completely retracted into the model wing because of interference with the ribs; therefore, in the tests representing the retracted condition the main wing was fitted with a plate covering the rear 4 inches of the lower surface.

Tests were made with the nose of the extension airfoil in nine positions (shown in fig. 1) covering the range giving the best slots. At each of these nose locations the angular deflection of the extension airfoil was varied throughout the required range.

The 7 by 10 foot wind tunnel, which is of the open-jet type, is described in detail together with the balances and standard test procedure in reference 2. Because of the high lift obtained with the Fowler wing model, it was supported by a fine wire at each wing tip in addition to the usual center support.

The tests were made at an air speed of 80 m.p.h., corresponding to a Reynolds Number of 609,000. First the values of $C_{L\ max}$ were found for the various angular deflections at each location of the nose. Then complete lift, drag, and center of pressure tests were made for the six positions giving the highest maximum lift coefficients. Corrections were not made for tunnel wall effect.

RESULTS AND DISCUSSION

Curves of $C_{L\ max}$ (based on the area of the basic wing) against flap angle are given for each location of the nose of the extension airfoil in Figures 3 to 5. From the maximum values in these curves contour lines were prepared which show the various positions giving the same value of maximum lift. (Fig. 6.) The values in Figure 6 represent the deflection which gave the highest value of $C_{L\ max}$ at each location.

The highest value of $C_{L\ max}$, 3.17, was obtained with the nose of the extension airfoil in position 5. (See fig. 1.) This is the location suggested by Mr. Fowler. It is believed that the lift coefficient of 3.17 is the highest that has been obtained to date from a device readily applicable to normal airplane construction.

Curves of C_L, C_D, and c.p. are given in Figures 7 to 12 for the best positions of the extension airfoil and are compared with similar curves for the case with the extension airfoil retracted. The maximum lift coefficient obtained with the plain wing was 1.27 as compared with 3.17 with the best extended position.

The minimum drag coefficient for the retracted condition was 0.0156. (No external flap supports were in place for this test.) The speed range ratio $C_{L\ max}/C_{D\ min}$, the maximum lift coefficient being taken with the flap down at the best location and the minimum drag coefficient with the flap retracted, was 203 as compared with 87 for the main Clark Y wing alone.

At angles of attack above 0° the center of pressure with the extension airfoil extended was about 25 per cent of the chord behind the center of pressure for the plain Clark Y. Although this difference may seem excessive, it is not likely to lead to great trouble in connection with the balance of an airplane because the downwash is substantially greater with the surface extended, which increases the download on the tail.

To investigate the possibility of reducing the motion of the c.p. caused by extending the surface, a complete test at the best position of the nose of the extension airfoil was made with a reduced flap angle (25°). The curves for flap angles at 25° and 40° (fig. 11), however, show very little difference in c.p. for the two settings.

Effect on airplane performance.- If the wing of an average parasol monoplane were modified to include the Fowler extension airfoil arrangement, the gross weight being assumed unchanged for simplicity, the present tests indicate that the minimum gliding speed would be decreased to less than 2/3 of the original value. If the extension device required no external supports or mechanism, the high speed would of course remain the same.

If the original landing speed were desired and the original gross weight maintained, the basic Fowler wing could be reduced to 40 per cent of the original area, and the high speed would be increased somewhat (in the neighborhood of 5 per cent for an average present-day airplane).

CONCLUSIONS

1. With the extension airfoil in the best position a maximum lift coefficient of 3.17 was obtained for the Fowler wing model as compared with 1.27 for the basic wing.

2. To obtain the high maximum lift coefficients of which this combination is capable, the extension airfoil must be located within close limits of the best position.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 12, 1932.

REFERENCES

1. Fowler, Harlan D.: Variable Lift. Western Flying, November, 1931.

2. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 412, N.A.C.A., 1931.

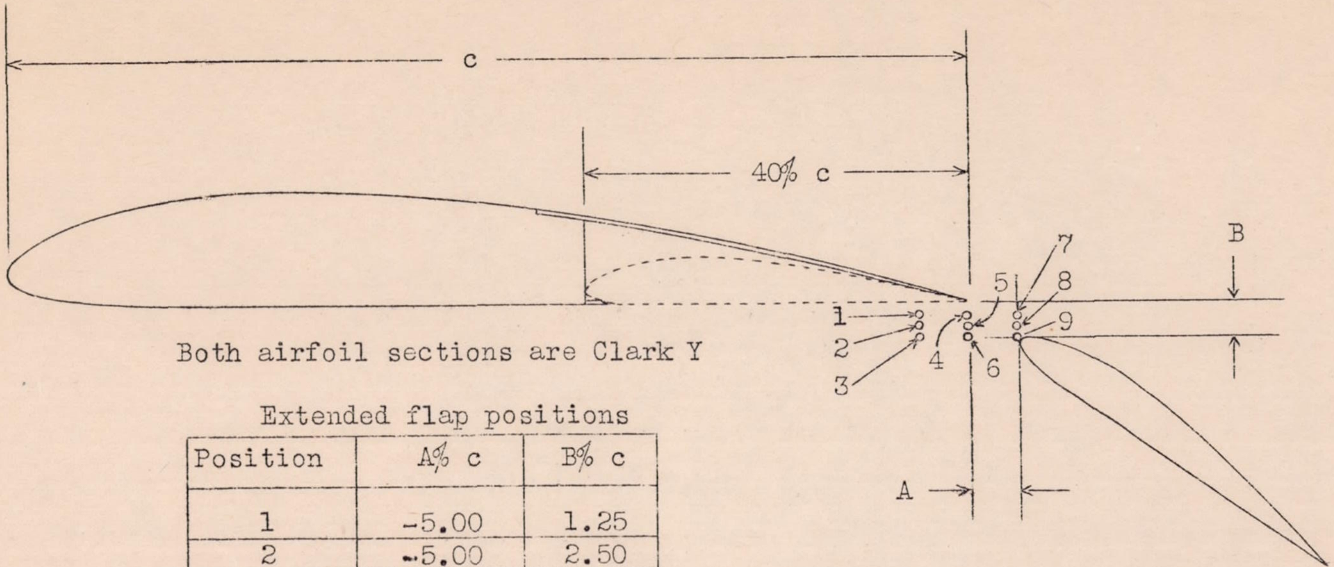
TABLE I

AIRFOIL ORDINATES

(All values in per cent airfoil chord)

Clark Y		
Station	Ordinate Upper	Ordinate Lower
0	3.50	3.50
1.25	5.45	1.93
2.50	6.50	1.47
5.00	7.90	.93
7.50	8.85	.63
10.00	9.60	.42
15.00	10.69	.15
20.00	11.36	.03
30.00	11.70	0
40.00	11.40	0
50.00	10.52	0
60.00	9.15	0
70.00	7.35	0
80.00	5.22	0
90.00	2.80	0
95.00	1.49	0
100.00	.12	0

Leading edge radius = 1.50



Both airfoil sections are Clark Y

Extended flap positions

Position	A% c	B% c
1	-5.00	1.25
2	-5.00	2.50
3	-5.00	3.75
4	0.00	1.25
5	0.00	2.50
6	0.00	3.75
7	5.00	1.25
8	5.00	2.50
9	5.00	3.75

Fig.1 Section of Fowler wing.

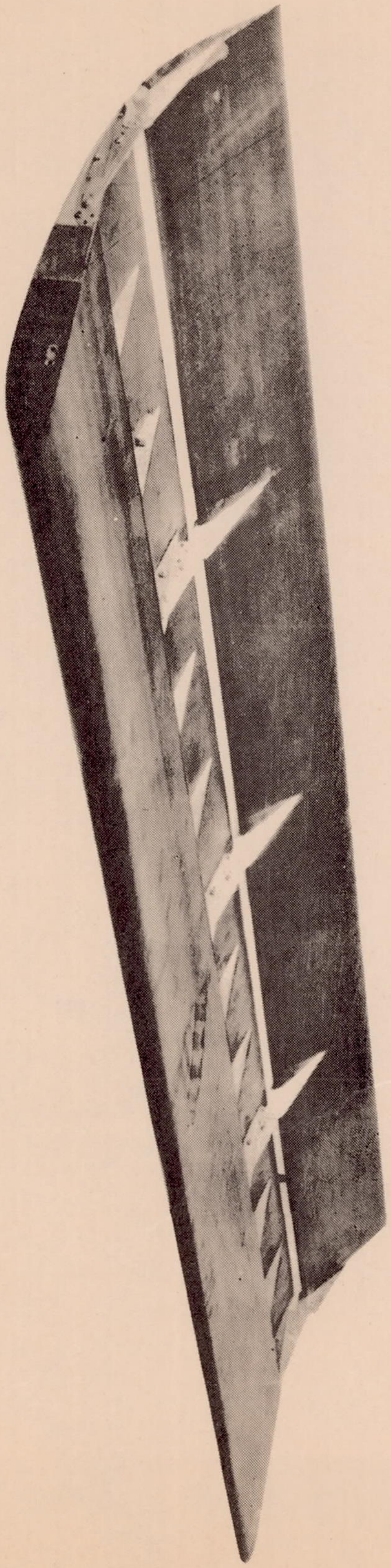


Fig.2 Wind tunnel model of Fowler wing.

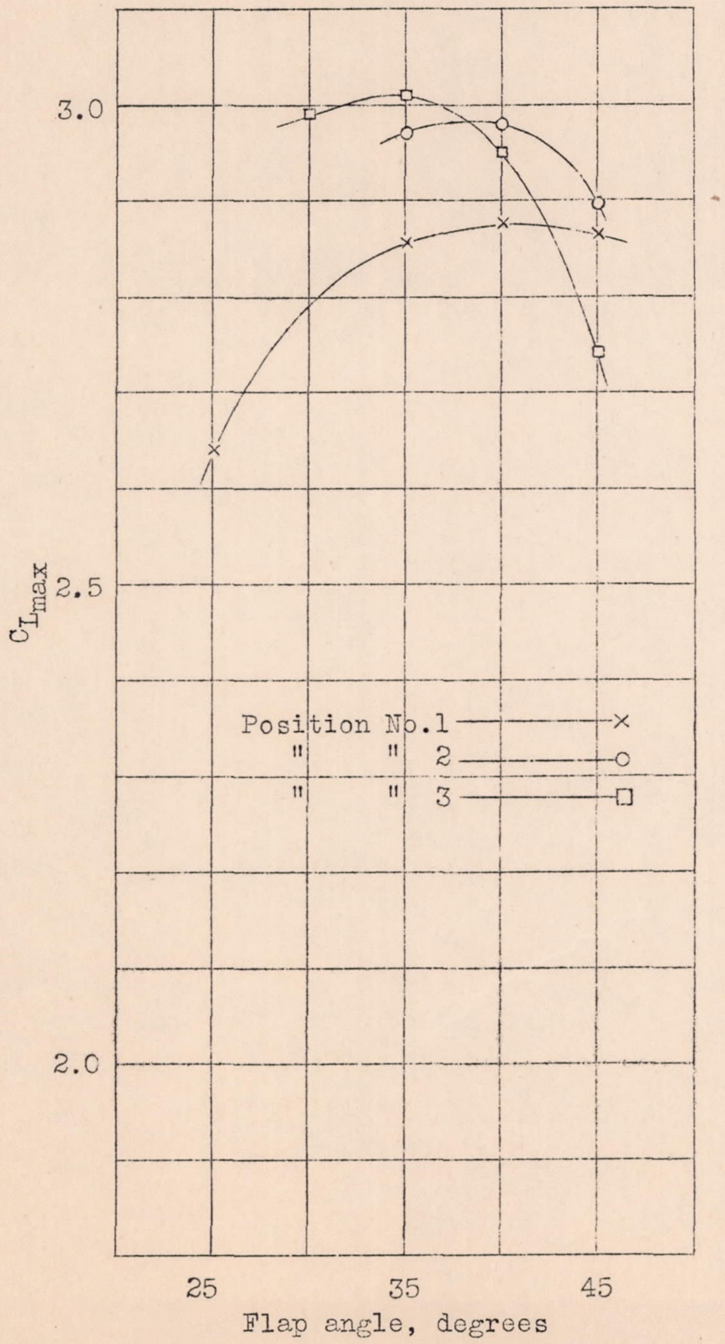


Fig.3 Variation of $C_{L_{max}}$ with flap angle.

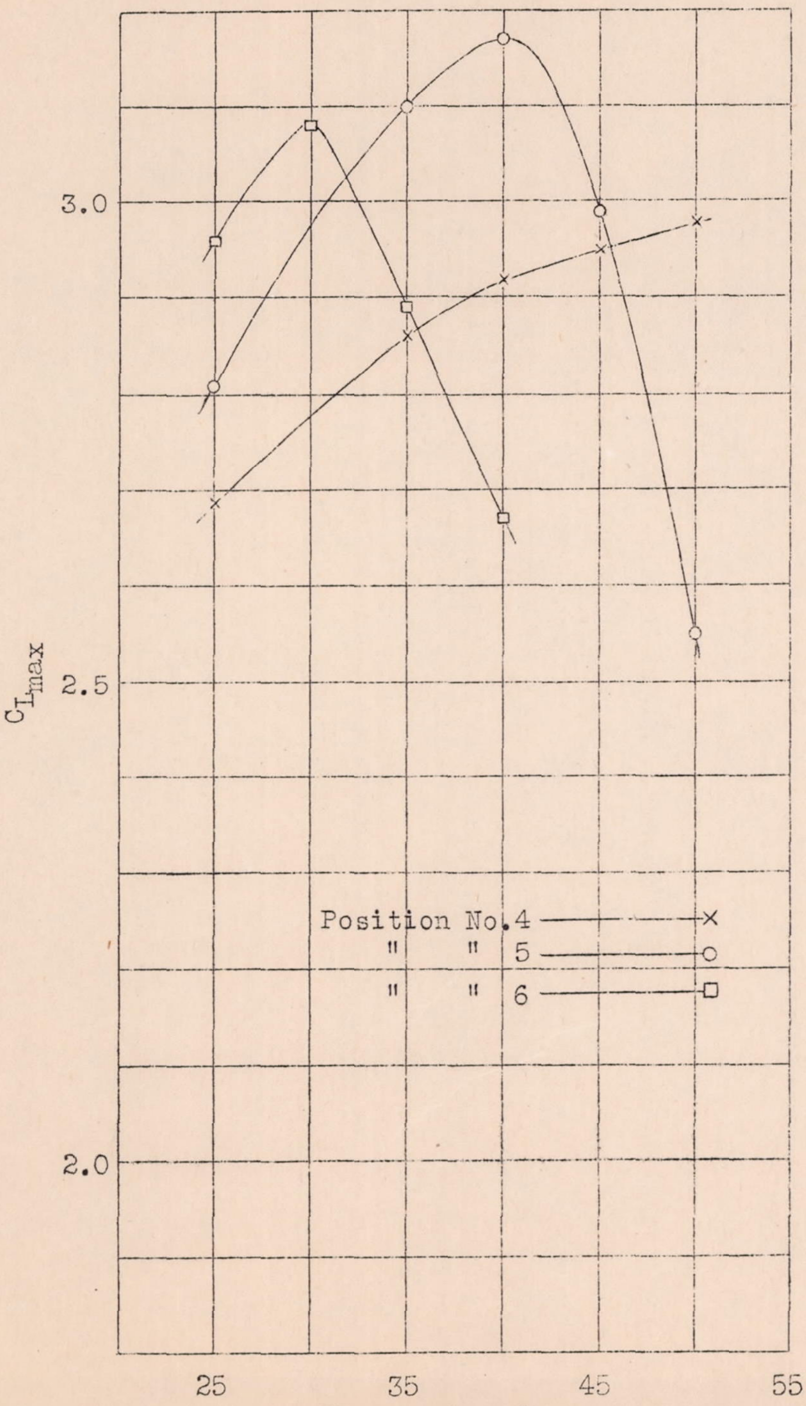


Fig.4 Variation of $C_{L_{max}}$ with flap angle.

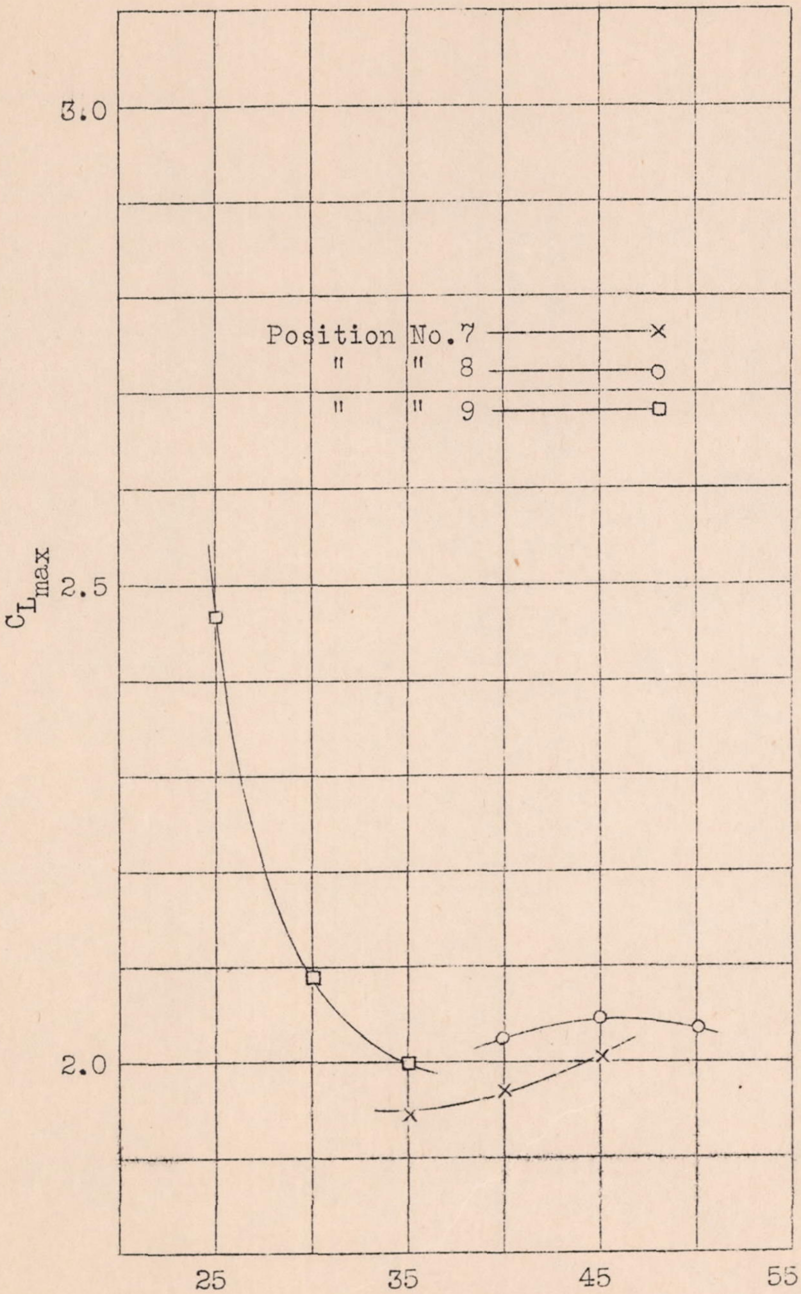


Fig.5 Variation of $C_{L_{max}}$ with flap angle.

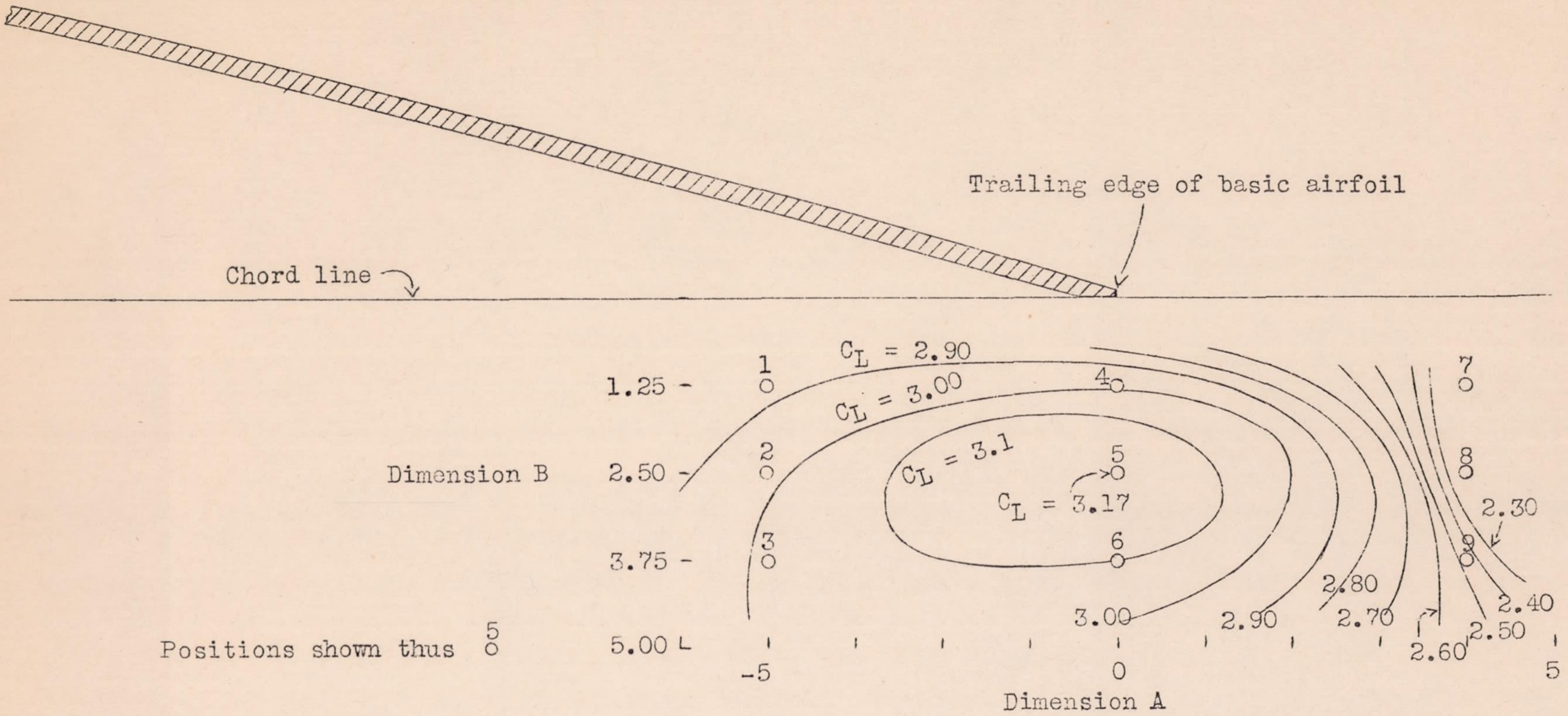


Fig.6 Contours showing variation of $C_{L_{max}}$ with position of nose of extension airfoil.

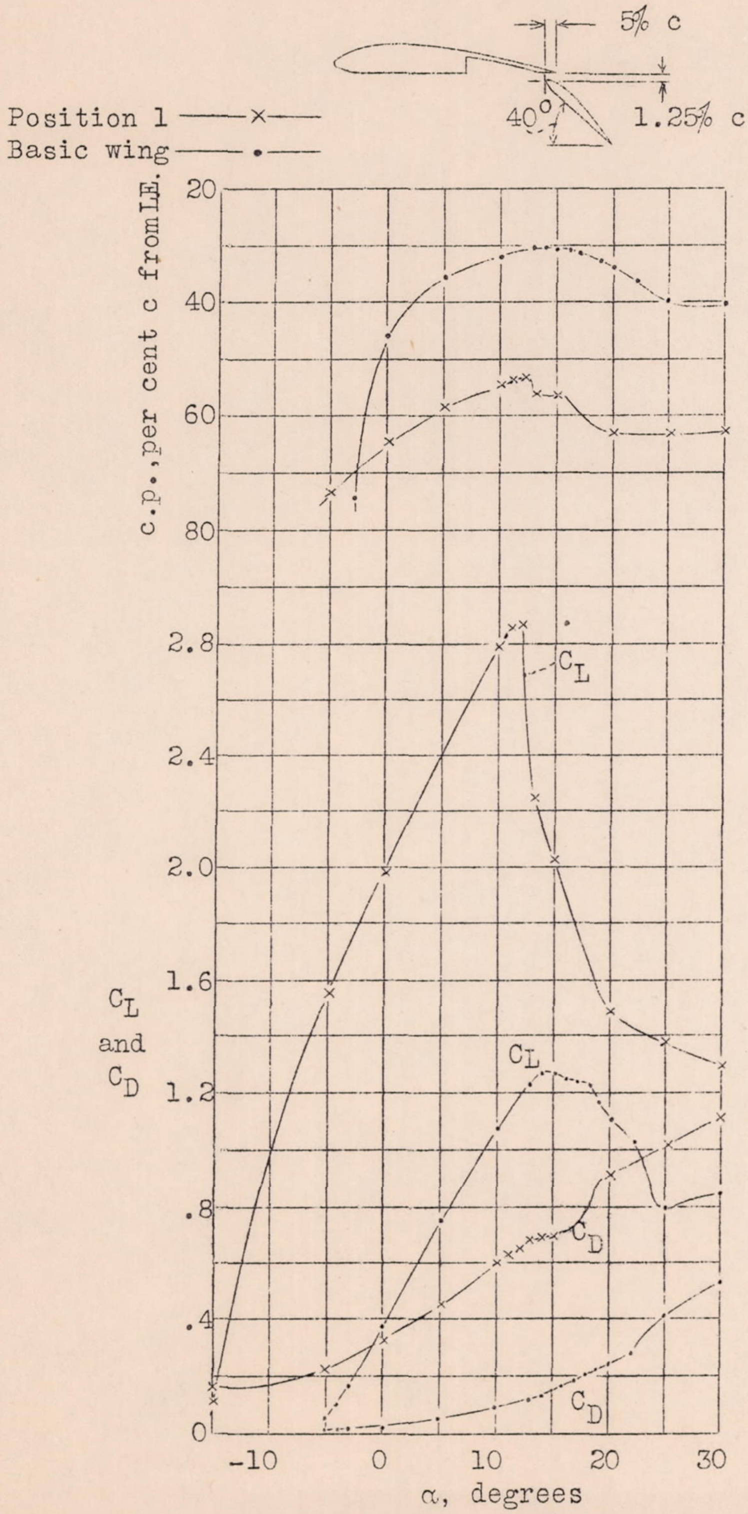


Fig.7 C_L, C_D and c.p. curves for position 1.

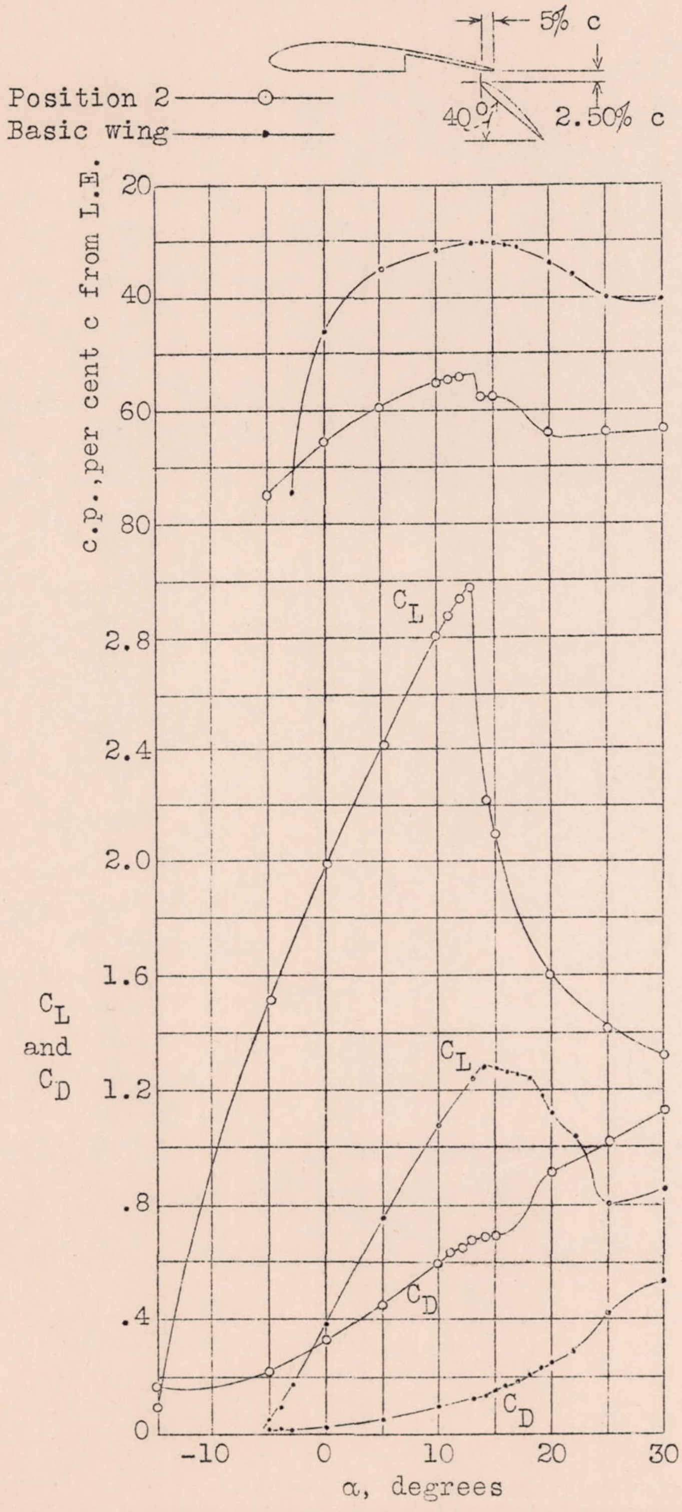


Fig.8 C_L,C_D and c.p. curves for position 2.

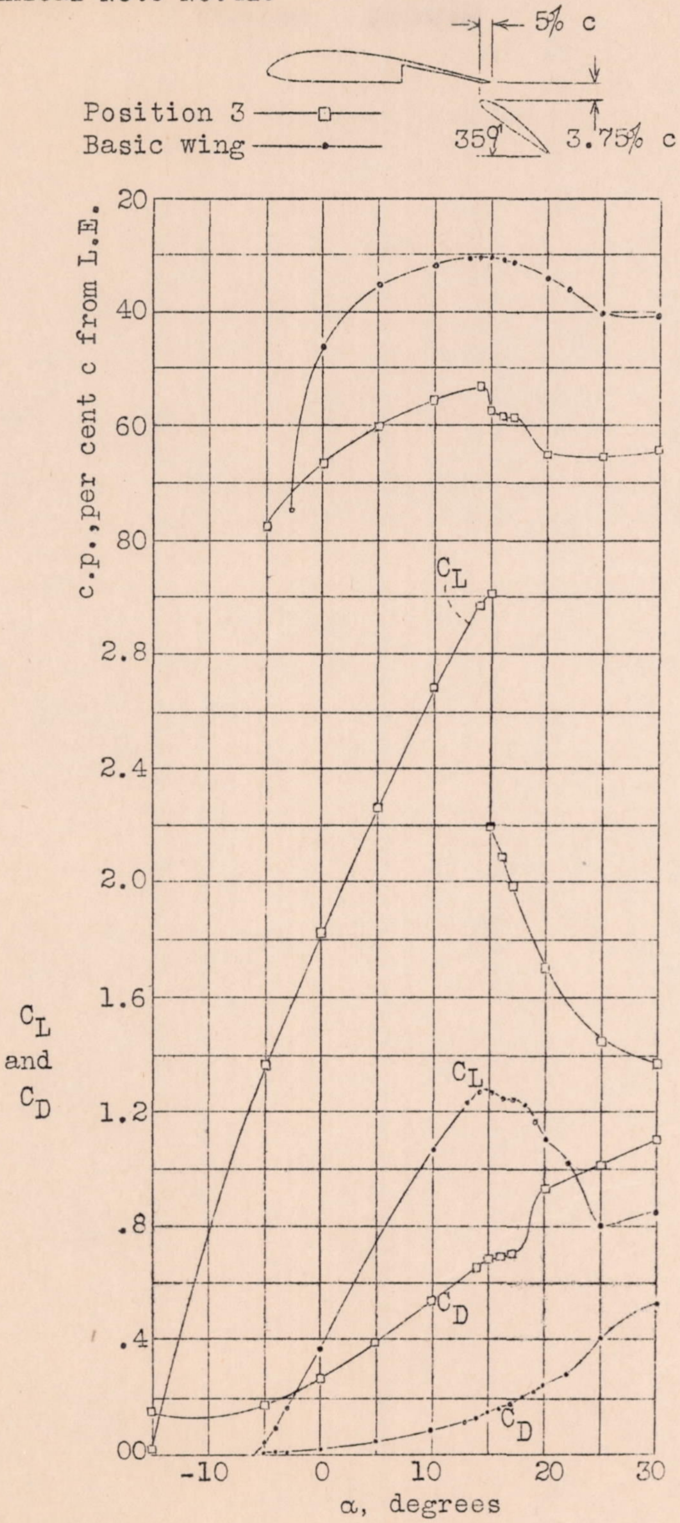


Fig.9 C_L,C_D and c.p. curves for position 3.

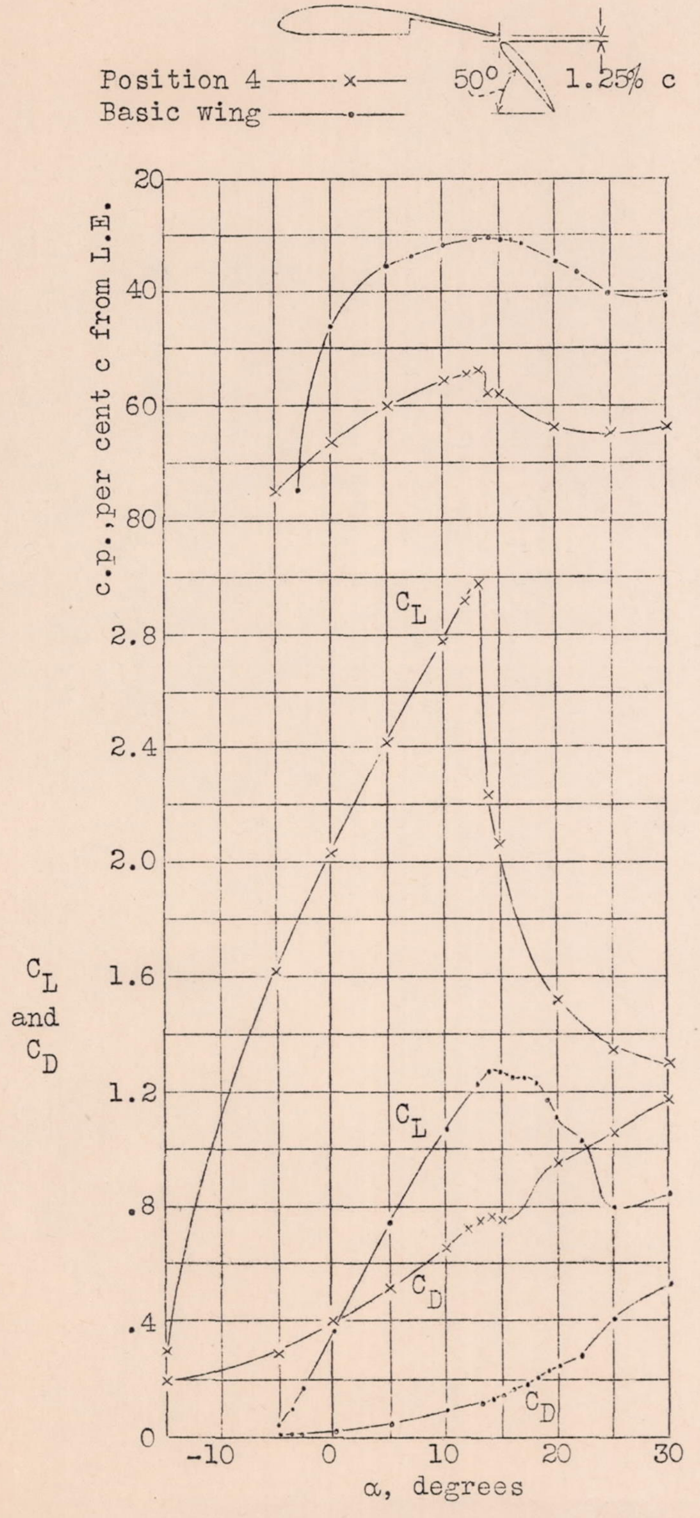


Fig.10 C_L, C_D and c.p. curves for position 4

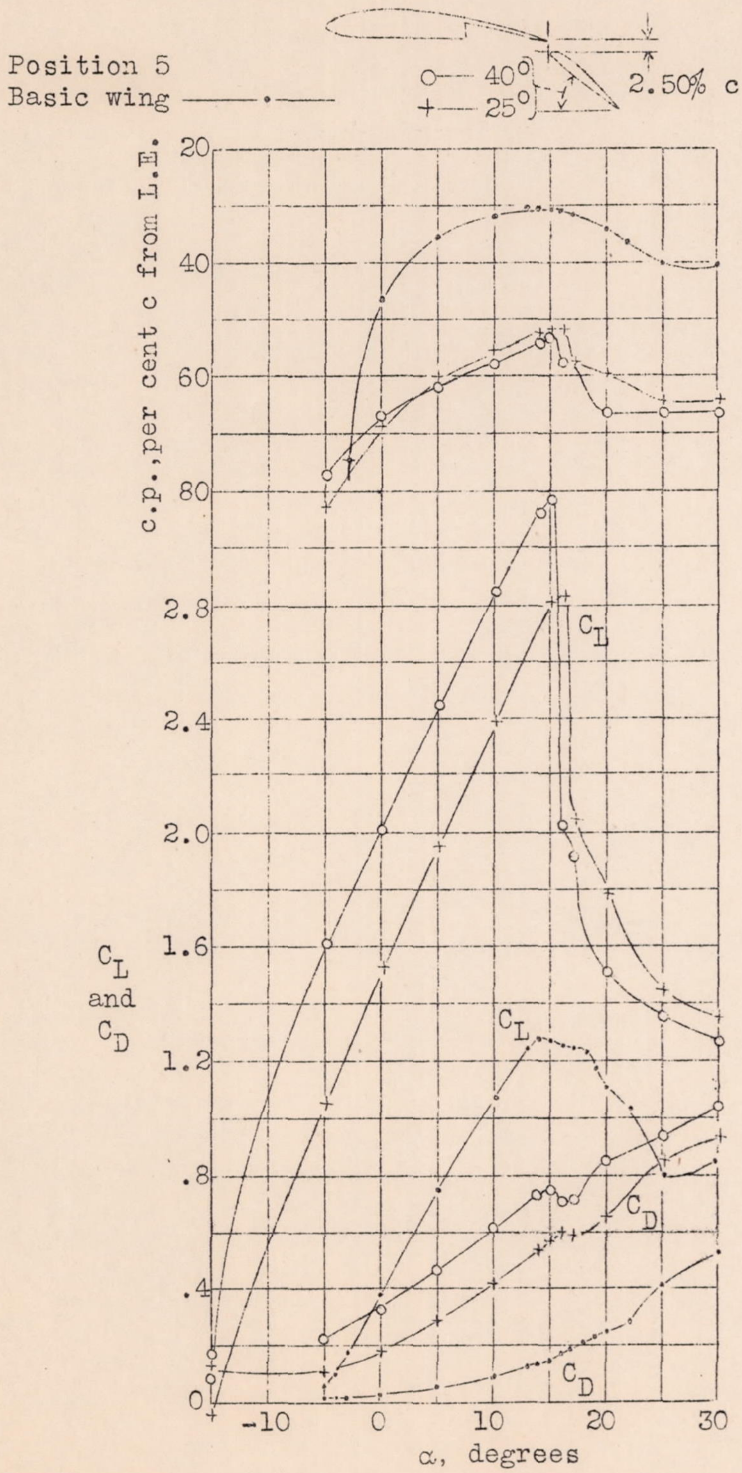


Fig.11 C_L,C_D and c.p. curves for position 5.

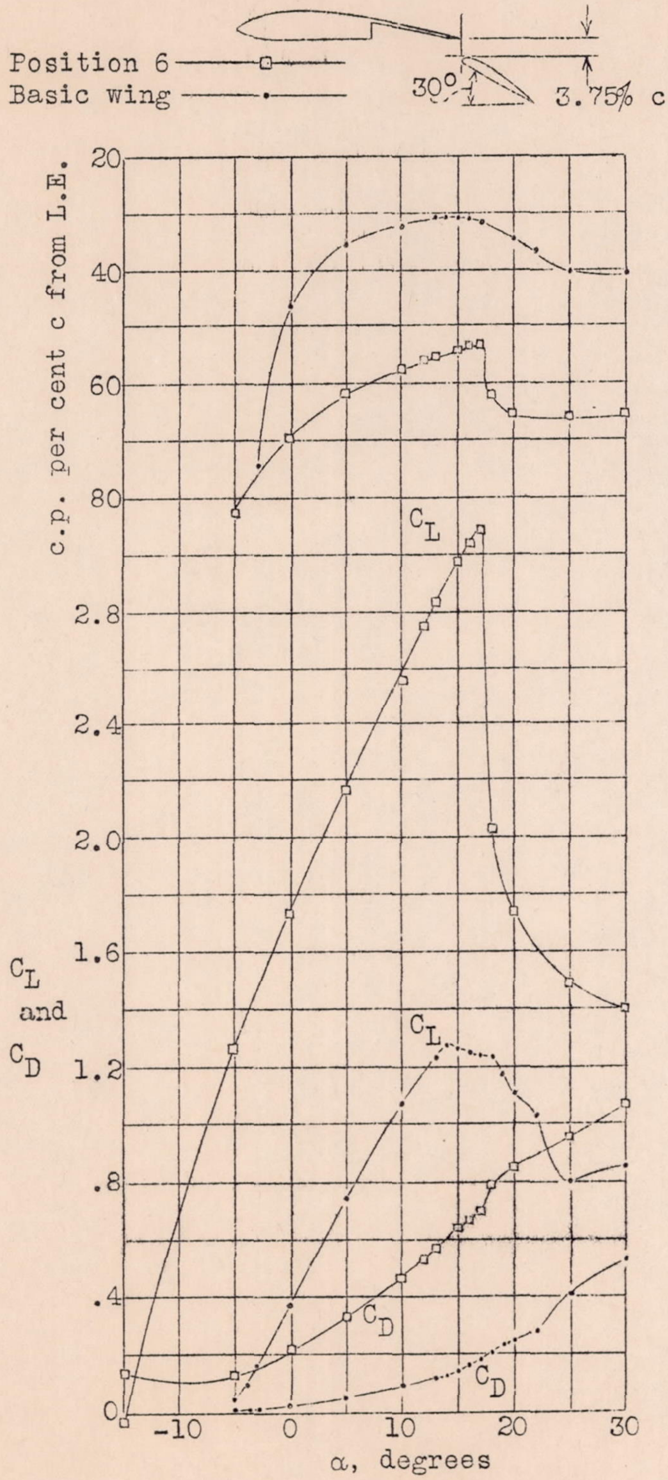


Fig.12 C_L,C_D and c.p. curves for position 6.