TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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THE AERODYNAMIC CHARACTERISTICS OF A MODEL WING HAVING A SPLIT FLAP DEFLECTED DOWNWARD AND MOVED TO THE REAR

By Fred E. Weick and Thomas A. Harris
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Washington
May, 1932

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SUMMARY

Tests were made on a model wing with three different sized split trailing-edged flaps, in the N.A.C.A. 7 by 10 foot wind tunnel. The flaps were formed of the lower rear portion of the wing and were rotated downward about axes at their front edges. The lift, drag, and center of pressure were measured with the axis in its original position and also with it moved back in even steps to the trailing edge of the main wing, giving in effect an increase in area. The split flaps when deflected about their original axis locations gave slightly higher maximum lift coefficients than conventional trailing-edge flaps, and the lift coefficients were increased still further by moving the axes toward the rear. The highest value of $C_{L\ max}$, which was obtained with the largest flap hinged at 90 per cent of the chord from the leading edge, was 2.52 as compared with 1.27 for the basic wing.

INTRODUCTION

Among the devices for increasing the maximum lift coefficient over that obtained with a conventional wing, the one most commonly used has probably been the trailing-edge flap, which is deflected downward to increase the camber of the wing. A few tests have been made on airfoils with flaps in which the rear portion of the airfoil is split into upper and lower sections and the lower section deflected downward. (References 1 and 2.) In at least two cases the flap has been moved to the rear as well as deflected downward in angle, giving in effect an increase in area as well as in camber. A flap of this nature was incorporated in the Alfaro airplane entered in the Guggenheim Safe Aircraft Competition. (Reference 3.) The most recent developments along this line are the results of the work of Mr. E. F. Zap, who has carried on many wind-tunnel tests on model wings and also flight tests on an airplane equipped with the Zap flap. In flight the flap was effective not only in giving a lower minimum speed but also, by virtue of its increase in drag, in making possible steeper glides and shorter landings over obstacles.

The present tests were made as part of a series on high-lift devices (references 4 and 5) in the N.A.C.A. 7 by 10 foot wind tunnel. Lift, drag, and pitching moment were measured for a basic Clark Y airfoil equipped with split flaps of three different sizes. Each flap could be rotated downward about an axis at its front edge. The tests were made with a range of angular deflections at each of several fore-and-aft locations of the axis along the basic wing chord.

APPARATUS AND METHODS

The model wing (fig. 1), which had a chord of 10 inches and a span of 60 inches, was constructed of laminated mahogany and steel plate. The ordinates for the basic Clark Y airfoil are given in Table I. The hinged flap was made of 1/8-inch steel plate beveled at the trailing edge; when closed it was flush with the lower surface of the airfoil. When the axis of any flap was in the trailing edge position there was a slight gap between the flap and the main portion of the airfoil. This gap was closed with Plasticine after preliminary tests had shown that it caused a loss of lift.

The three sizes of flaps tested had chord lengths of 0.20 c, 0.30 c, and 0.40 c, c being the chord of the basic wing. The 0.20 c flap was tested with its axis at 0.80 c, 0.90 c, and 1.0 c from the leading edge, the 0.30 c flap with its axis at 0.70 c to 1.0 c, and the 0.40 c flap with its axis at 0.60 c to 1.0 c, all with even 0.10 c intervals. The flaps, which were hinged in split bearings, could be locked in any angular position. The tests were made with the flaps deflected at 15° intervals, or less where necessary, over a sufficient range to determine the highest value of $C_{L_{max}}$ for each hinge location.

The 7 by 10 foot wind tunnel is described in detail together with the balance and standard test procedure in reference 6. Because of the high lift obtained with some of the flap settings, the model was supported by a fine wire at each end in addition to the regular center support. The tests were made at 80 miles per hour, which corresponds to a Reynolds Number of 609,000, based on the 10-inch chord of the basic wing. No corrections were made for tunnel-wall interference.

RESULTS AND DISCUSSION

Values of C_L, C_D, and c.p., all based on the dimensions of the basic wing, are plotted against angle of attack (figs. 2 and 13) for all of the flap positions tested.

Maximum lift with flap axis in original location.- The highest lift coefficient obtained by depressing the split flaps without moving the axis to the rear was very nearly the same for all three flap sizes, as shown in the following table:

Flap size	Highest $C_{L\,max}$	Flap angle
0.20 c	2.12	60°
.30 c	2.16	50°
.40 c	2.14	40°

These values are about 10 per cent higher than the maximum lift coefficients obtained with a conventional flap having a chord length of 0.30 c. (Reference 7.)

Maximum lift with flap axis moved back to increase the area.- With each size of flap the maximum lift coefficient increased as the flap axis was moved back to the 0.90 c position. With the 0.20 c flap it continued to increase slightly as the axis was moved to the trailing edge, but with the larger sized flaps the values were slightly lower for the trailing-edge axis location than for the one at 0.90 c.

Contour lines showing constant values of $C_{L\,max}$ obtained with the trailing edge of the flap within the range of the positions tested are shown in Figures 14, 15, and 16 for the three different flap sizes. These charts show the highest values of $C_{L\ max}$ for the three flaps to be as follows:

Flap size	Highest $C_{L\ max}$	Axis location	Flap angle
0.20 c	2.27	1.00 c	68°
.30 c	2.45	.93 c	62°
.40 c	2.52	.90 c	54°

The highest value, which represents an increase of 98 per cent over the value of 1.27 for the plain wing, was obtained with the 0.40 c flap. It was closely approached, however, by the 0.30 c flap which was only 3 per cent lower.

Center of pressure.- At the angles of attack within the ordinary flight range, rotating the flap downward moves the center of pressure to the rear, and shifting the axis back moves the center of pressure still farther to the rear. For the 0.40 c flap in the position giving the highest value of $C_{L\ max}$, the center of pressure is about 17 per cent of the chord behind the position for the basic wing at the same angle of attack. Although this difference may seem excessive, it is not likely to cause great difficulty in connection with the balance of an airplane because the greater lift coefficient with the flap extended results in a substantially greater downwash angle, which increases the download on the tail.

Comparison with the Fowler variable-area wing.- The Fowler wing, shown in Figure 17, has an extension airfoil which can be moved to the rear and downward in a manner somewhat similar to the split flaps of the present tests. It represents a refinement of the simple flaps, however, for the gap between the trailing edge of the main wing and the nose of the extension airfoil forms a slot to help maintain unburbled air flow over the extension airfoil at the high angles of attack. A model of the Fowler wing with a 0.40 c extension airfoil has been tested under the same conditions as those of the present tests. (Reference 5.) The Fowler model can be compared directly with the 0.40 c split flap with the hinge axis at the trailing edge of the main wing. The maximum lift coefficient of the Fowler wing was 3.17 as compared with 2.40 for the plain split flap in the same position, which shows the effectiveness of the slot in improving the air flow over the extension airfoil.

Effect on airplane performance.- If an average parasol monoplane were fitted with the 0.40 c split flap having the extended position which gave the highest value of $C_{L\ max}$, the landing speed, according to the results of the present tests, should be reduced to about 70 per cent of the original value if the gross weight remained unchanged. The high speed would be the same as the original if the installation of the flap did not increase the parasite drag of the airplane.

The original landing speed could be obtained with the wing area reduced to about 50 per cent of the original value, the gross weight remaining the same. In this case the high speed would be increased slightly but the take-off and climb would be impaired.

The lower values of L/D with the flap extended would make possible much steeper glides than with the original wing, a great advantage in making short landings over obstacles.

CONCLUSIONS

1. The maximum lift coefficients obtained with the split flaps with the original axis locations were very nearly the same for the three flap sizes tested and were somewhat higher than those given by conventional trailing-edge flaps.

2. The maximum lift coefficient was increased by moving the hinge axis of the flap back to 0.90 c for the 0.40 c flap, 0.93 c for the 0.30 c flap, and to the trailing edge for the 0.20 c flap.

3. The highest value of $C_{L\ max}$, which was obtained with the 0.40 c flap, was only 3 per cent higher than the highest obtained with the 0.30 c flap and 11 per cent higher than that with the 0.20 c flap.

4. With the 0.40 c flap in the best position a maximum lift coefficient of 2.52 was obtained, as compared with 1.27 for the basic wing.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 7, 1932.

REFERENCES

1. Bamber, Millard J.: Wind-Tunnel Tests on an Airfoil Equipped with a Split Flap and a Slot. T.N. No. 324, N.A.C.A., 1929.

2. Noda, Tetsuwo: The Hiraki-Bane Variable Section Airfoil. Paper before Society of Mechanical Engineers of Japan published in Home Edition, Vol. 33, No. 155, pp. 131-137. Abstract in Mech. Eng., Vol. 53, No. 6, p. 448.

3. The Daniel Guggenheim Fund for the Promotion of Aeronautics, Inc.: The Daniel Guggenheim International Safe Aircraft Competition, Final Report, 1930.

4. Weick, Fred E., and Sanders, Robert: Wind-Tunnel Tests of a Hall High-Lift Wing. T.N. No. 417, N.A.C.A., 1932.

5. Weick, Fred E., and Platt, Robert C.: Wind-Tunnel Tests of the Fowler Variable-Area Wing. T.N. No. 419, N.A.C.A., 1932.

6. 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.

7. Weick, Fred E., and Shortal, Joseph A.: The Effect of Multiple Fixed Slots and a Trailing-Edge Flap on the Lift and Drag of a Clark Y Airfoil. T.R. No. 427, N.A.C.A., 1932.

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

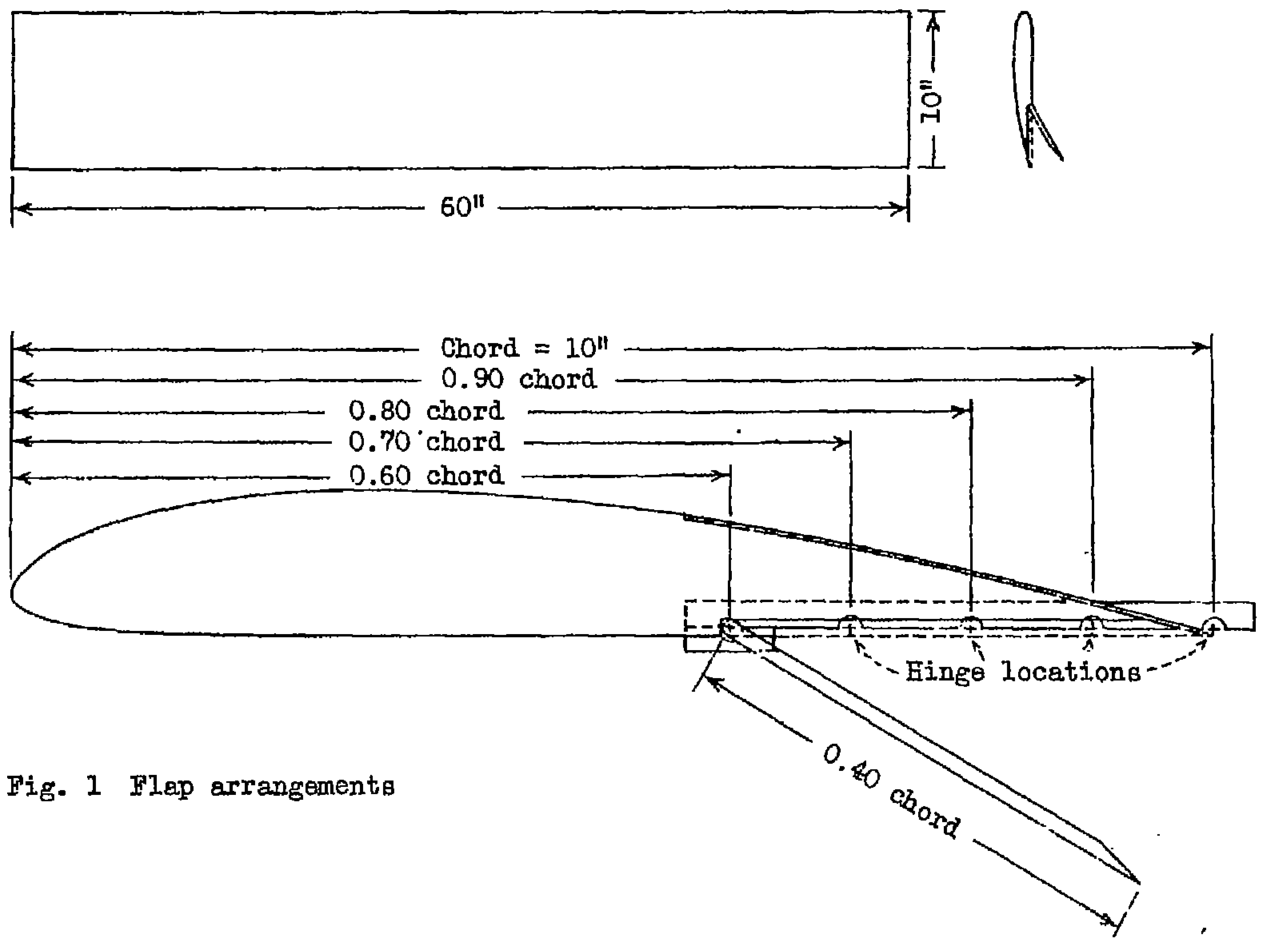

Fig. 1 Flap arrangements

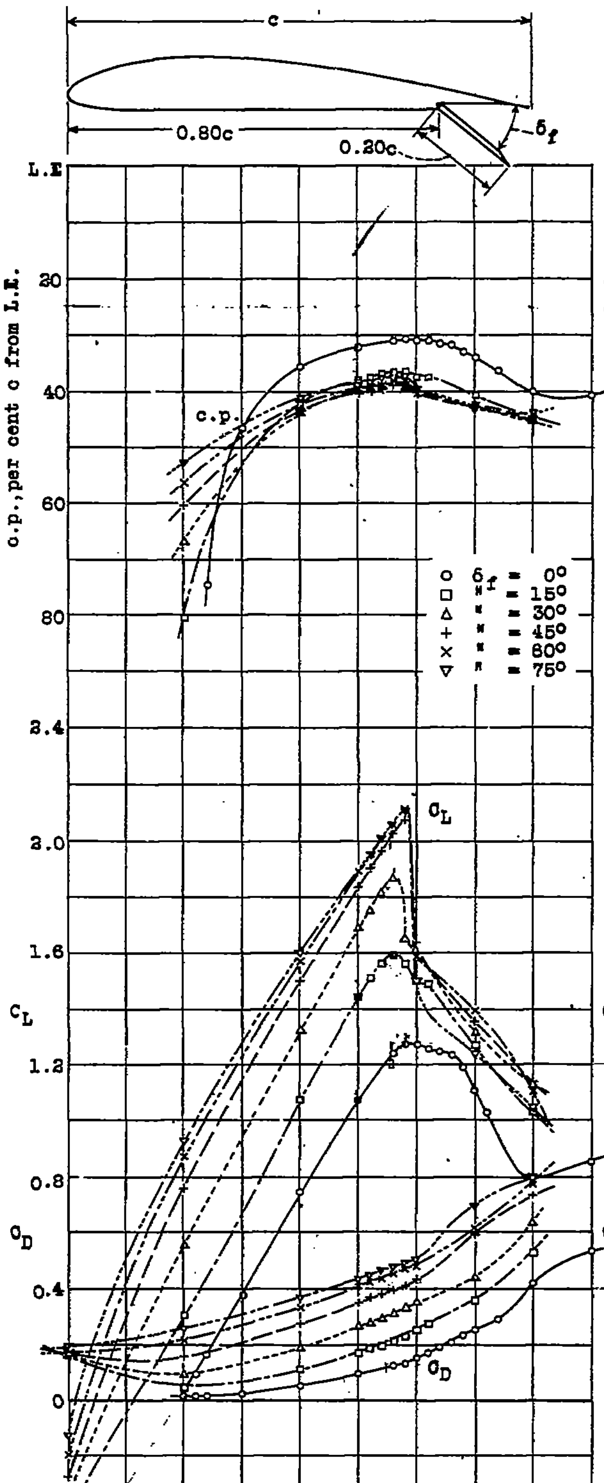

Fig.2 The 20 per cent c flap hinged at 80 per cent c

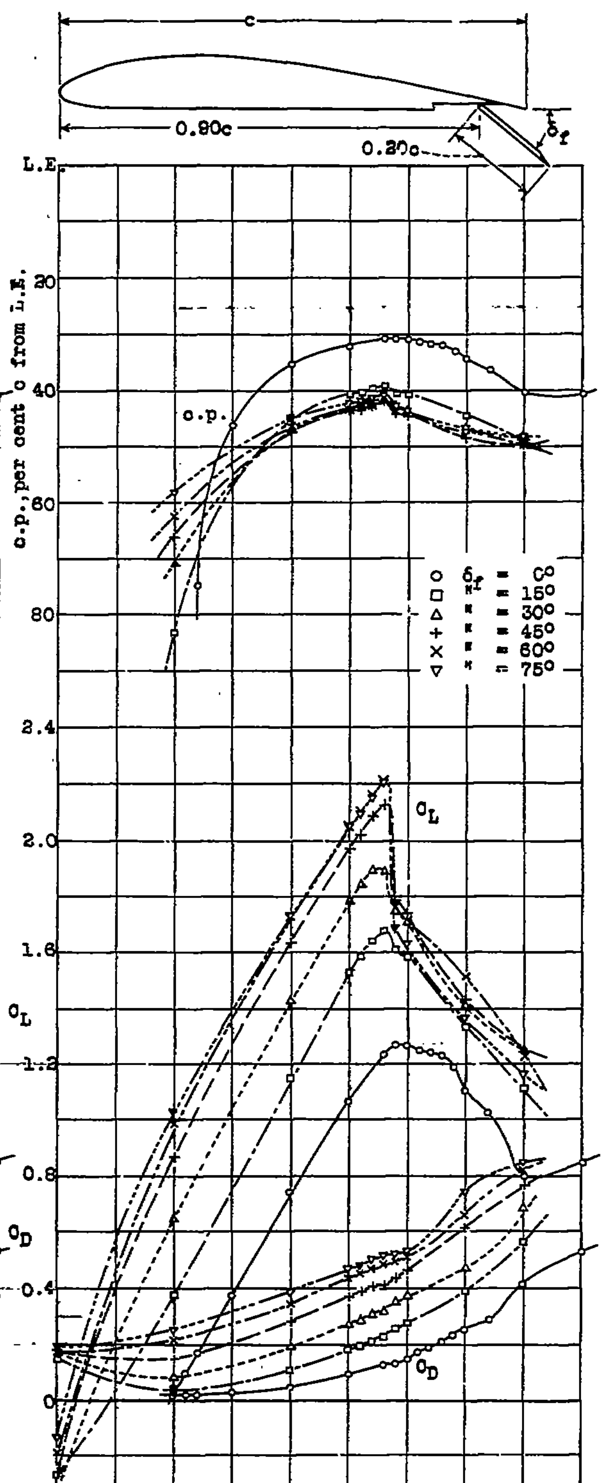

Fig.3 The 20 per cent c flap hinged at 90 per cent c

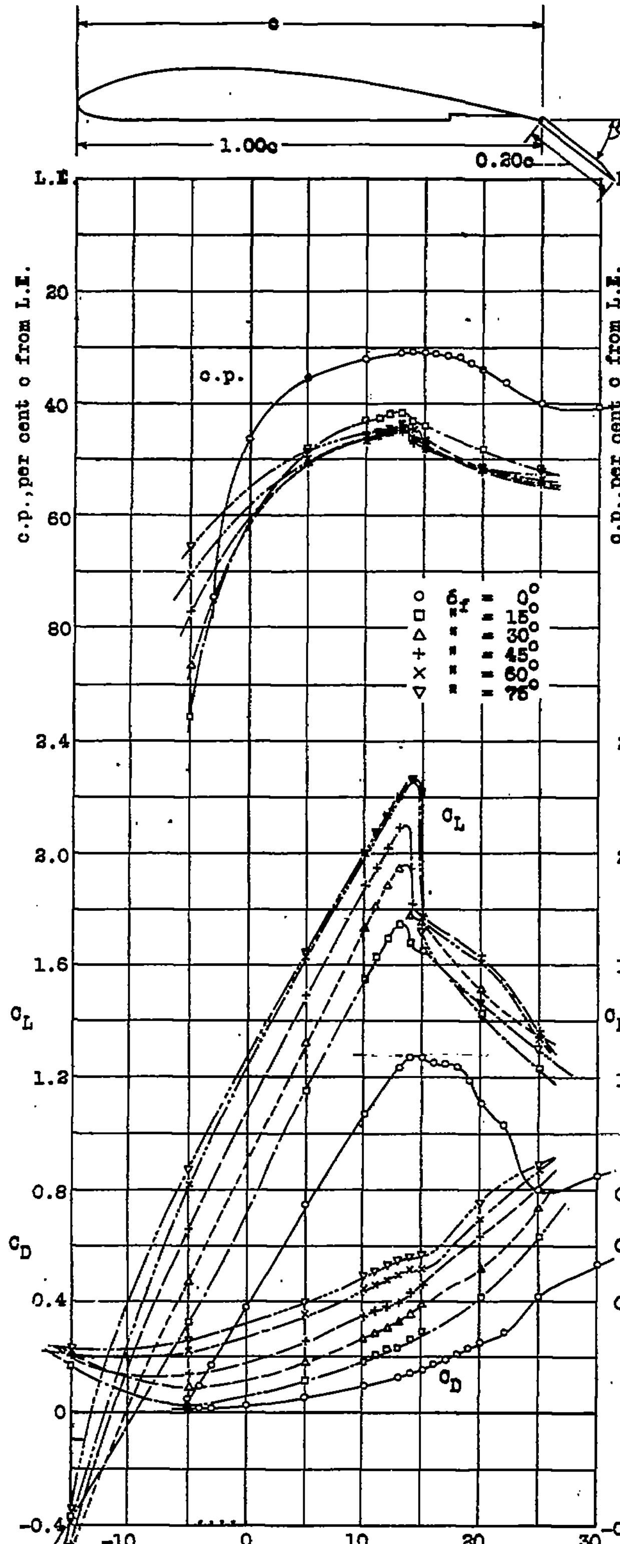

Fig.4 The 20 per cent c flap hinged at 100 per cent c

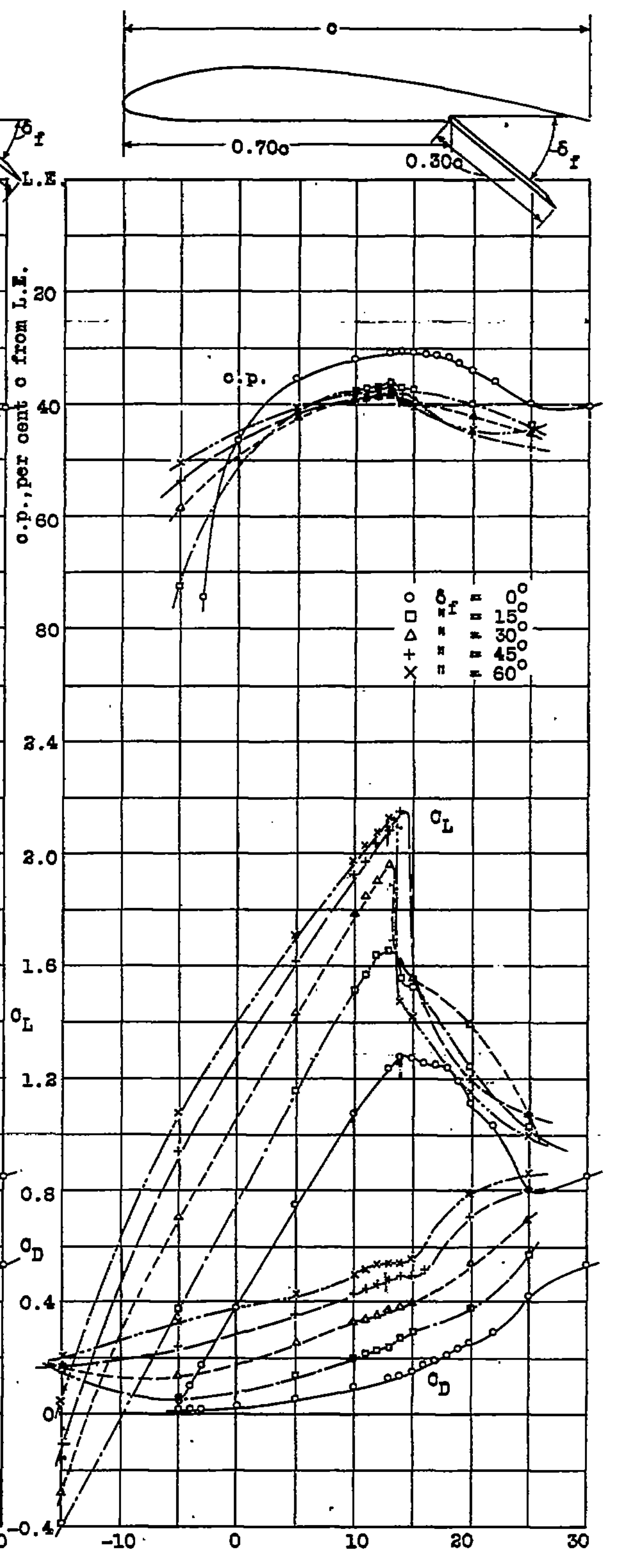

Fig.5 The 30 per cent c flap hinged at 70 per cent c

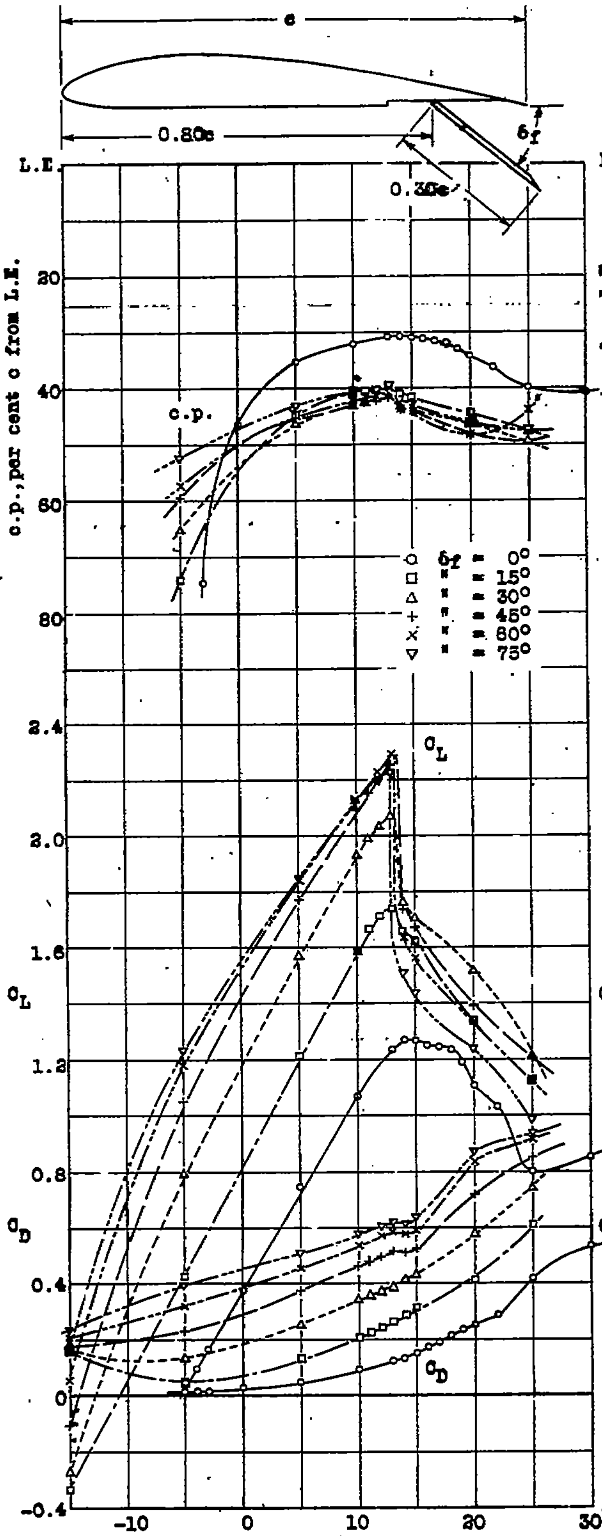

Fig.6 The 30 per cent c flap hinged at 80 per cent c

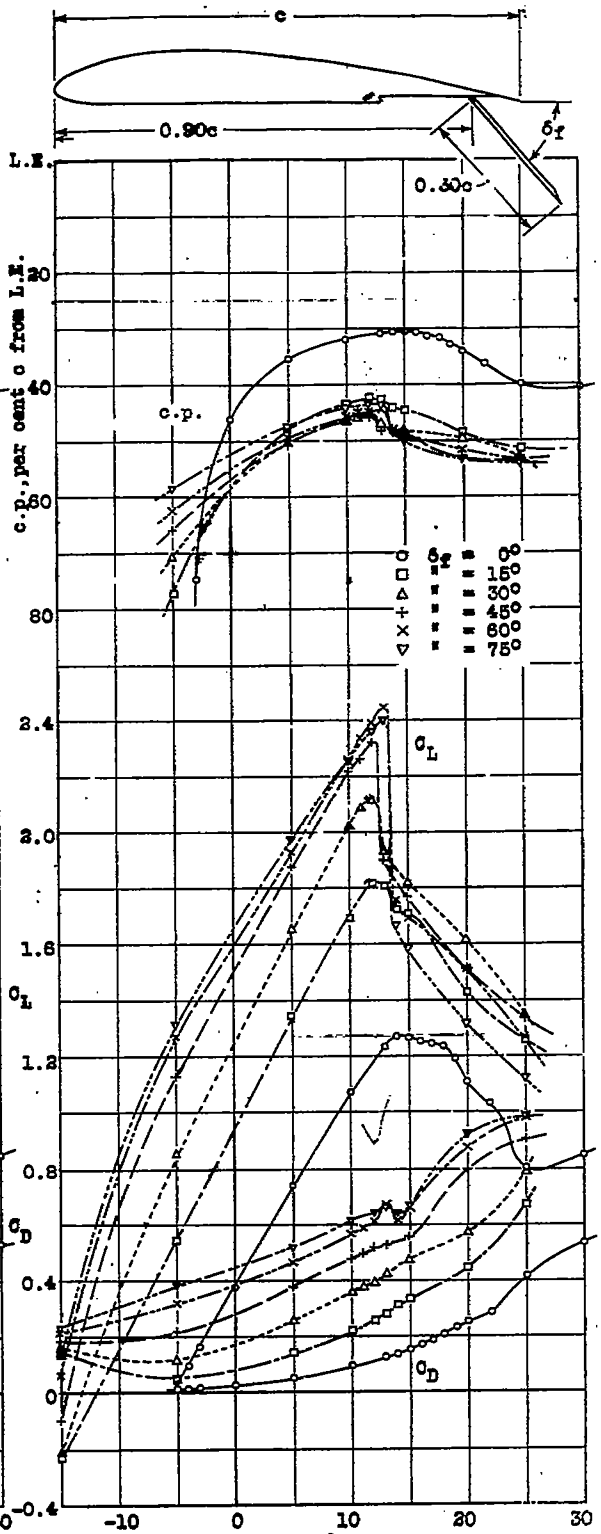

Fig.7 The 30 per cent c flap hinged at 90 per cent c

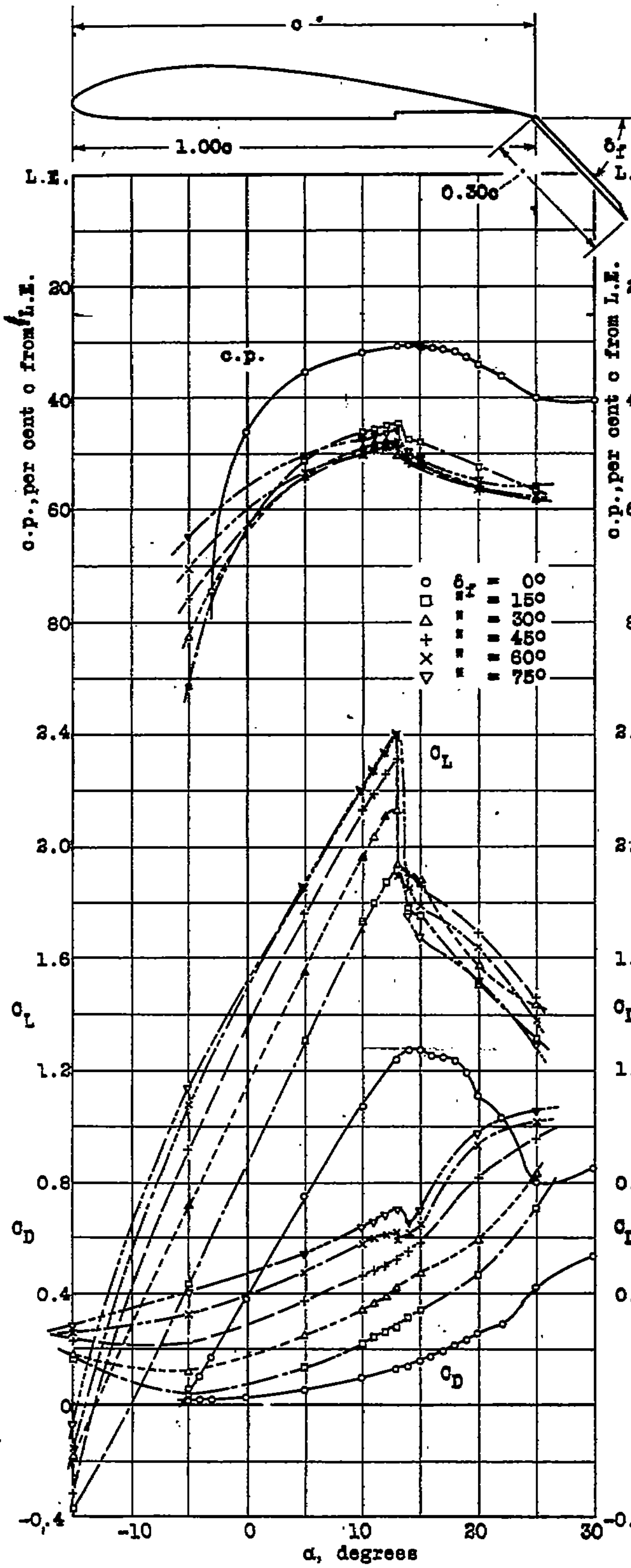

Fig.8 The 30 per cent c flap hinged at 100 per cent c

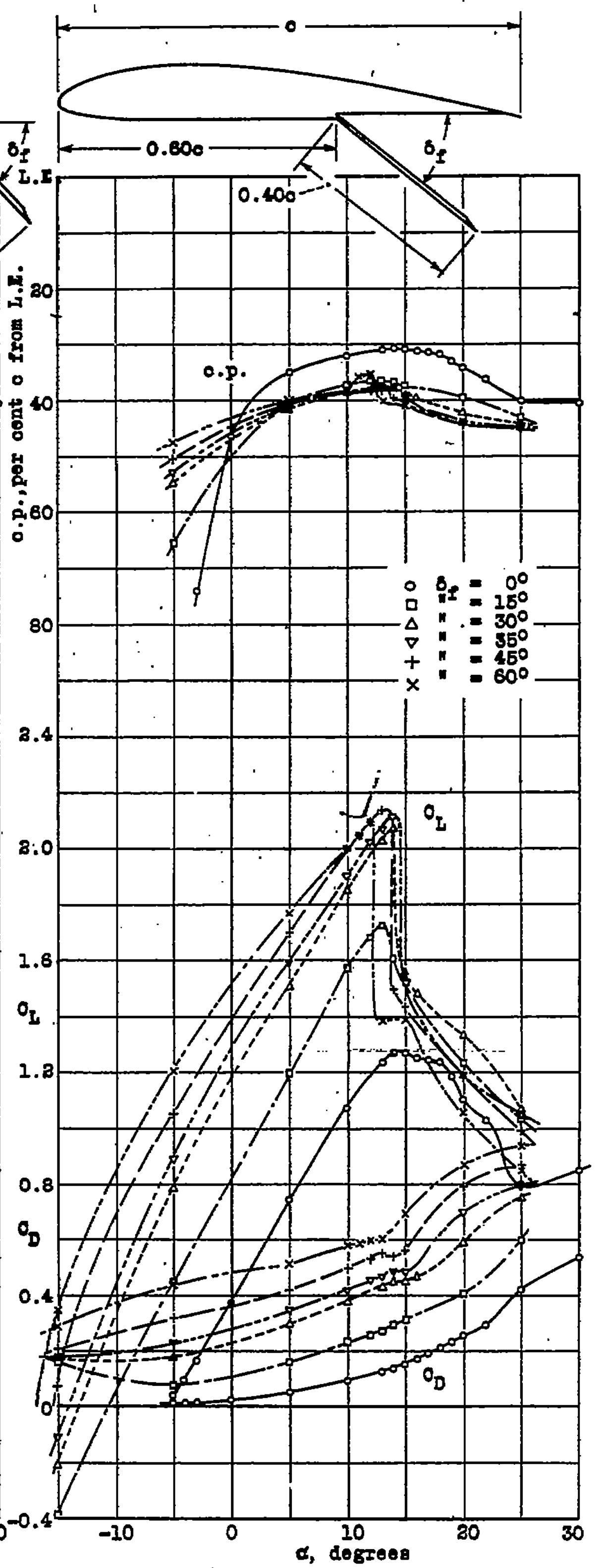

Fig.9 The 40 per cent c flap hinged at 60 per cent c

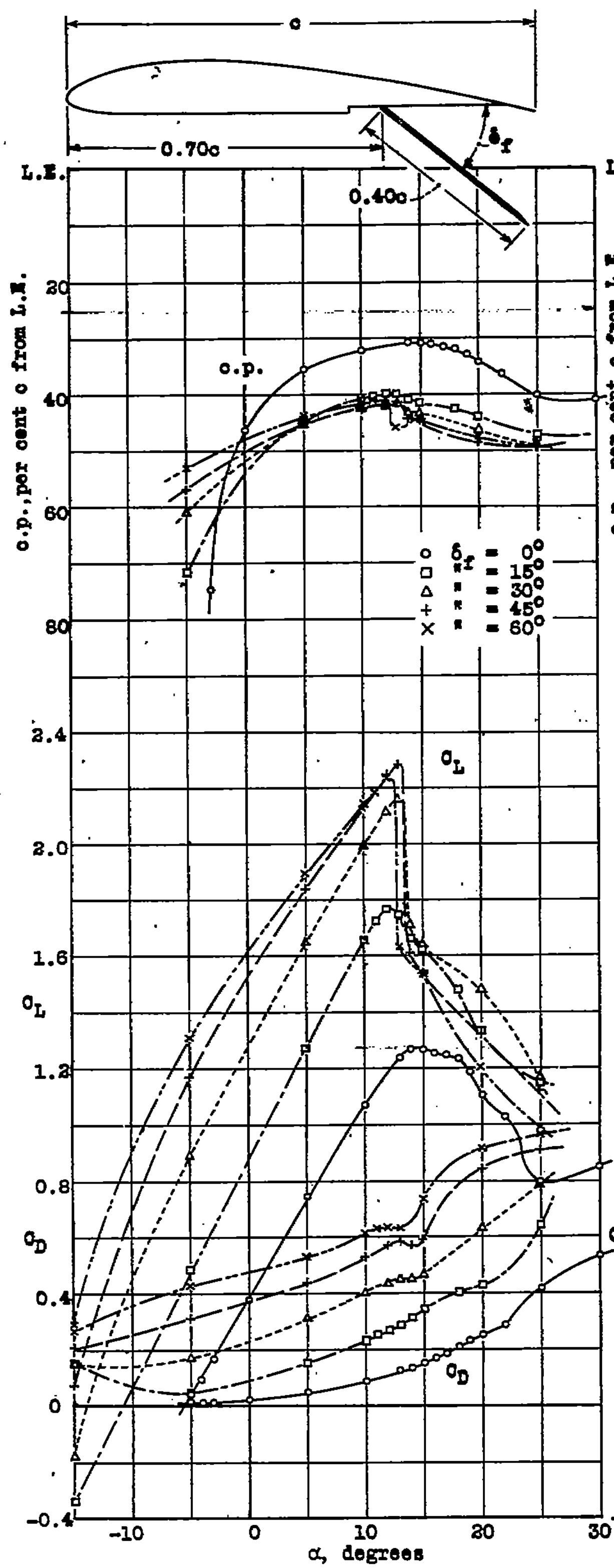

Fig.10 The 40 per cent c flap hinged at 70 per cent c

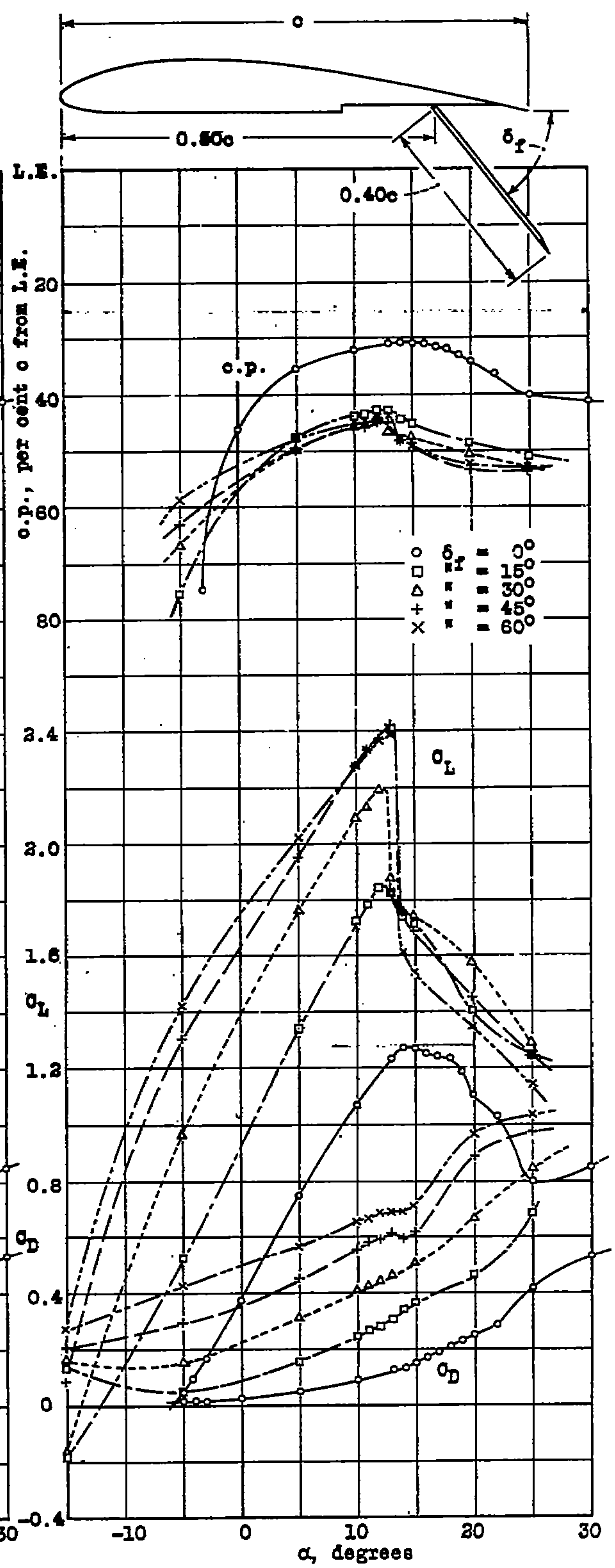

Fig.11 The 40 per cent c flap hinged at 80 per cent c

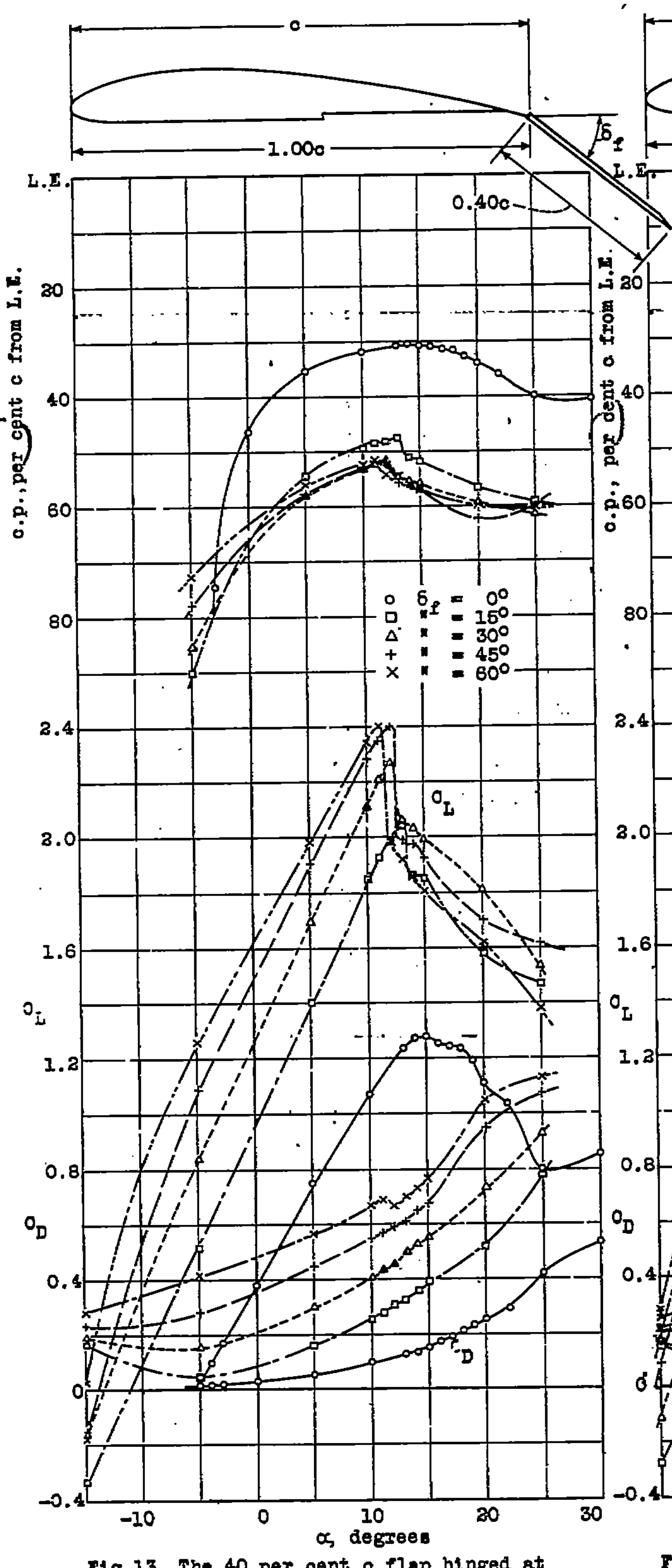

Fig.13 The 40 per cent c flap hinged at 100 per cent c

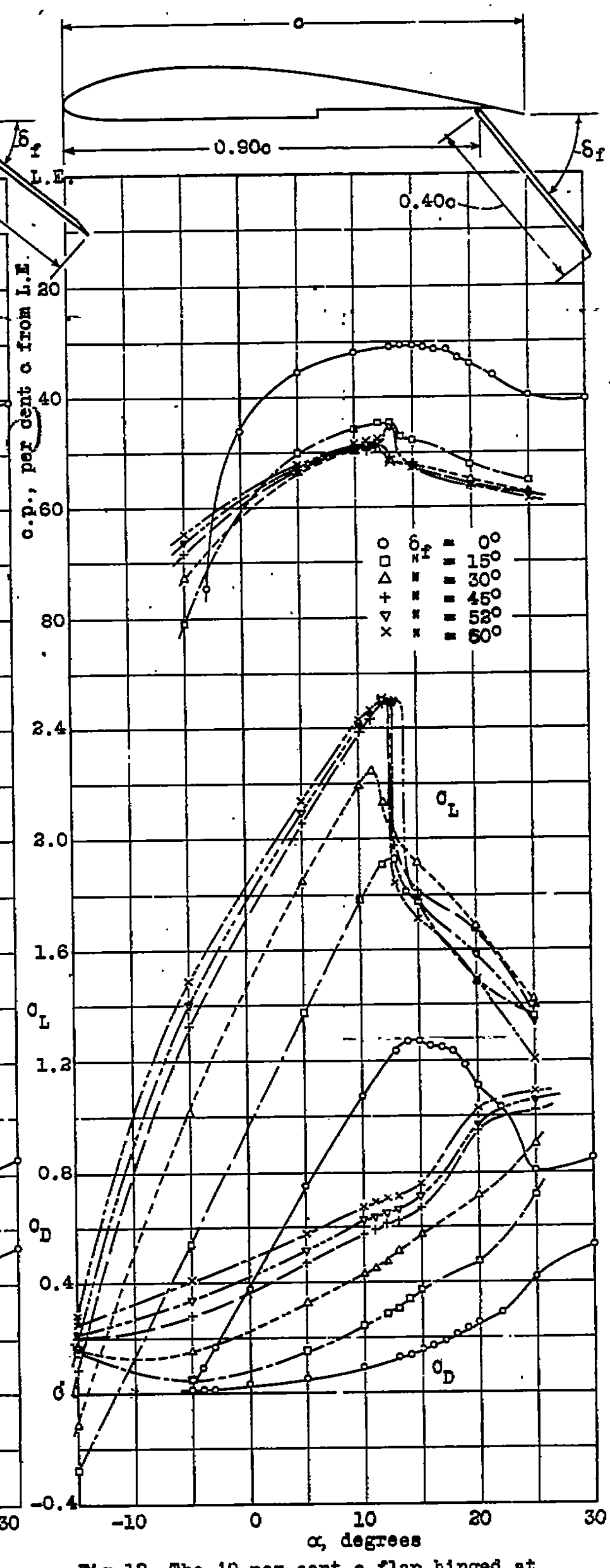

Fig.12 The 40 per cent c flap hinged at 90 per cent c

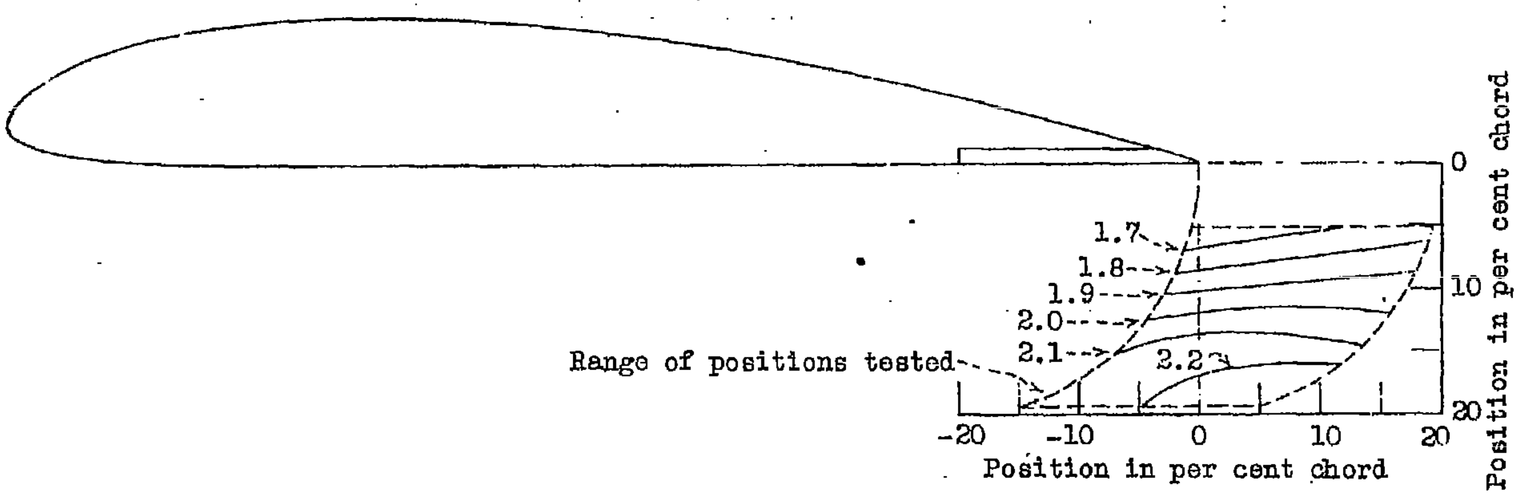

Fig. 14 Contours of $C_{L_{max}}$ for various positions of trailing edge of 20 per cent flap

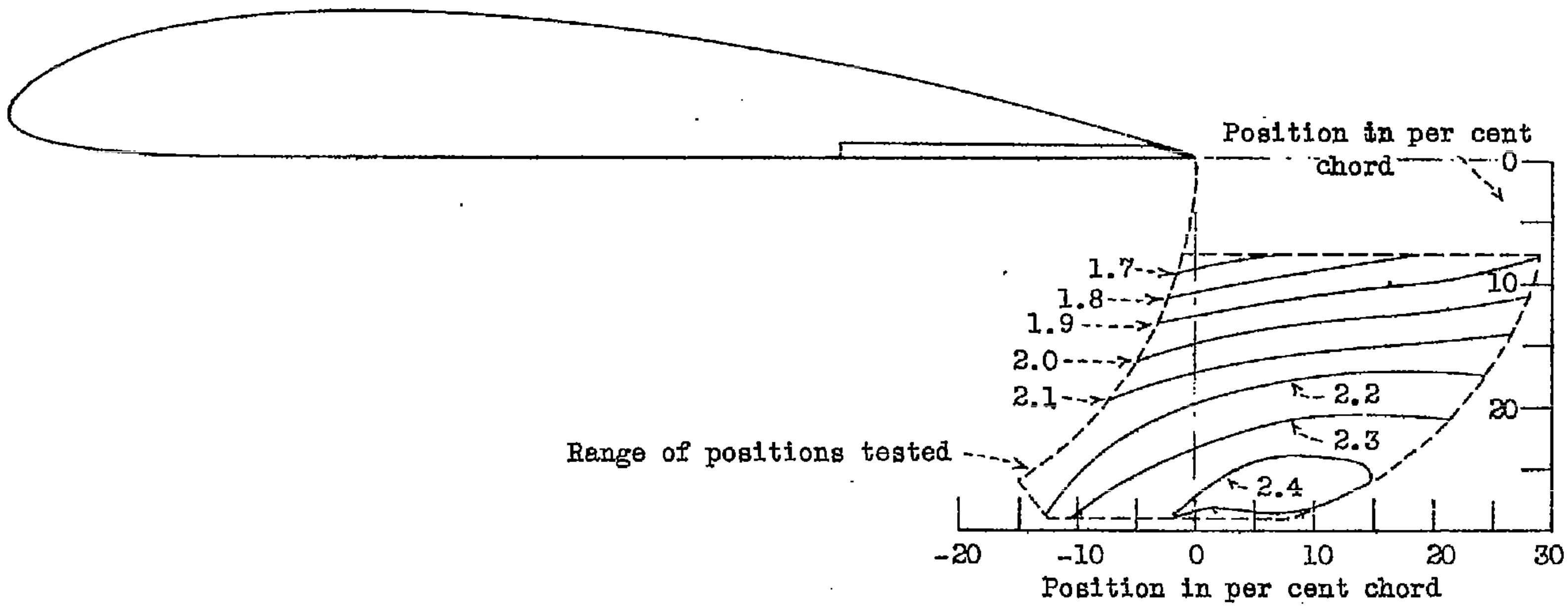

Fig. 15 Contours of $C_{L_{max}}$ for various positions of trailing edge of 30 per cent flap

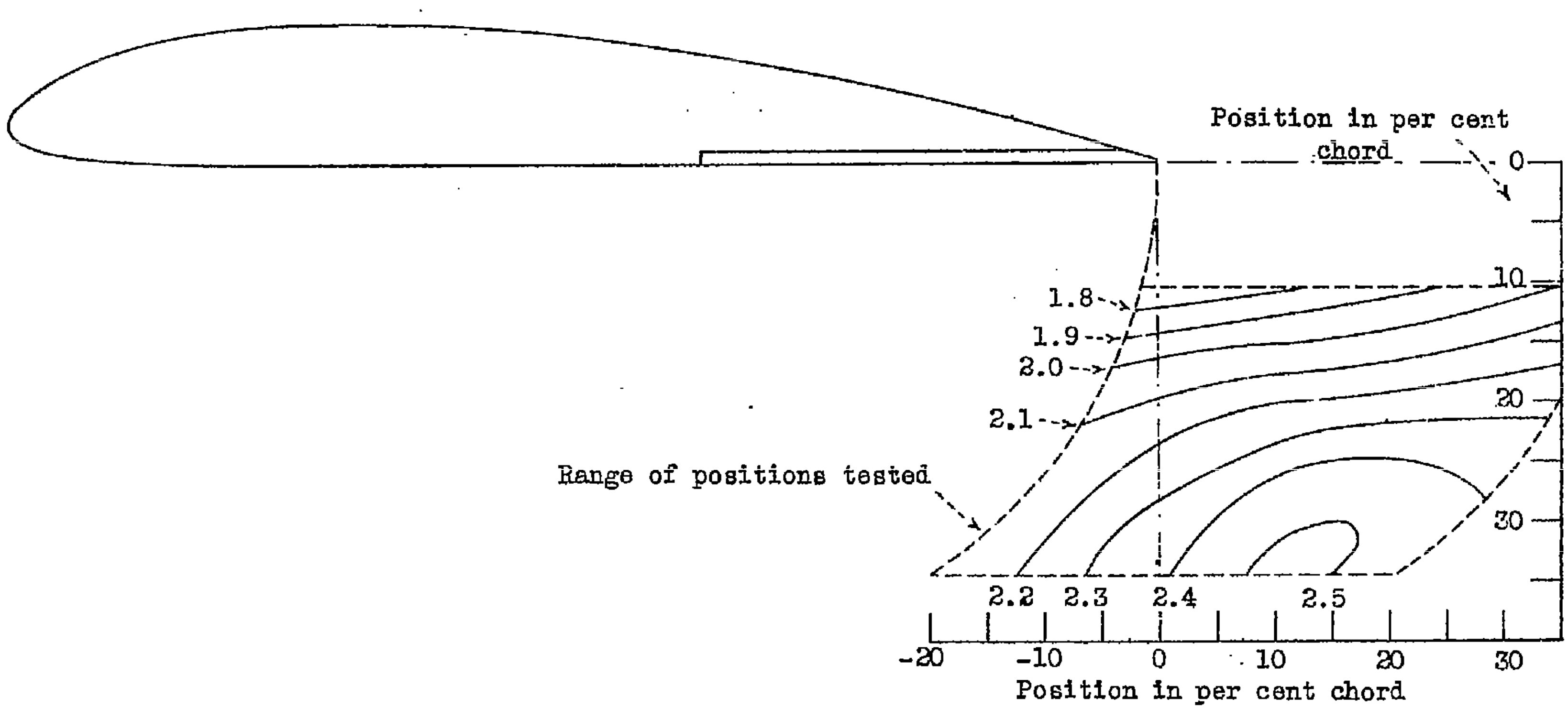

Fig. 16 Contours of $C_{L_{max}}$ for various positions of trailing edge of 20 per cent flap.

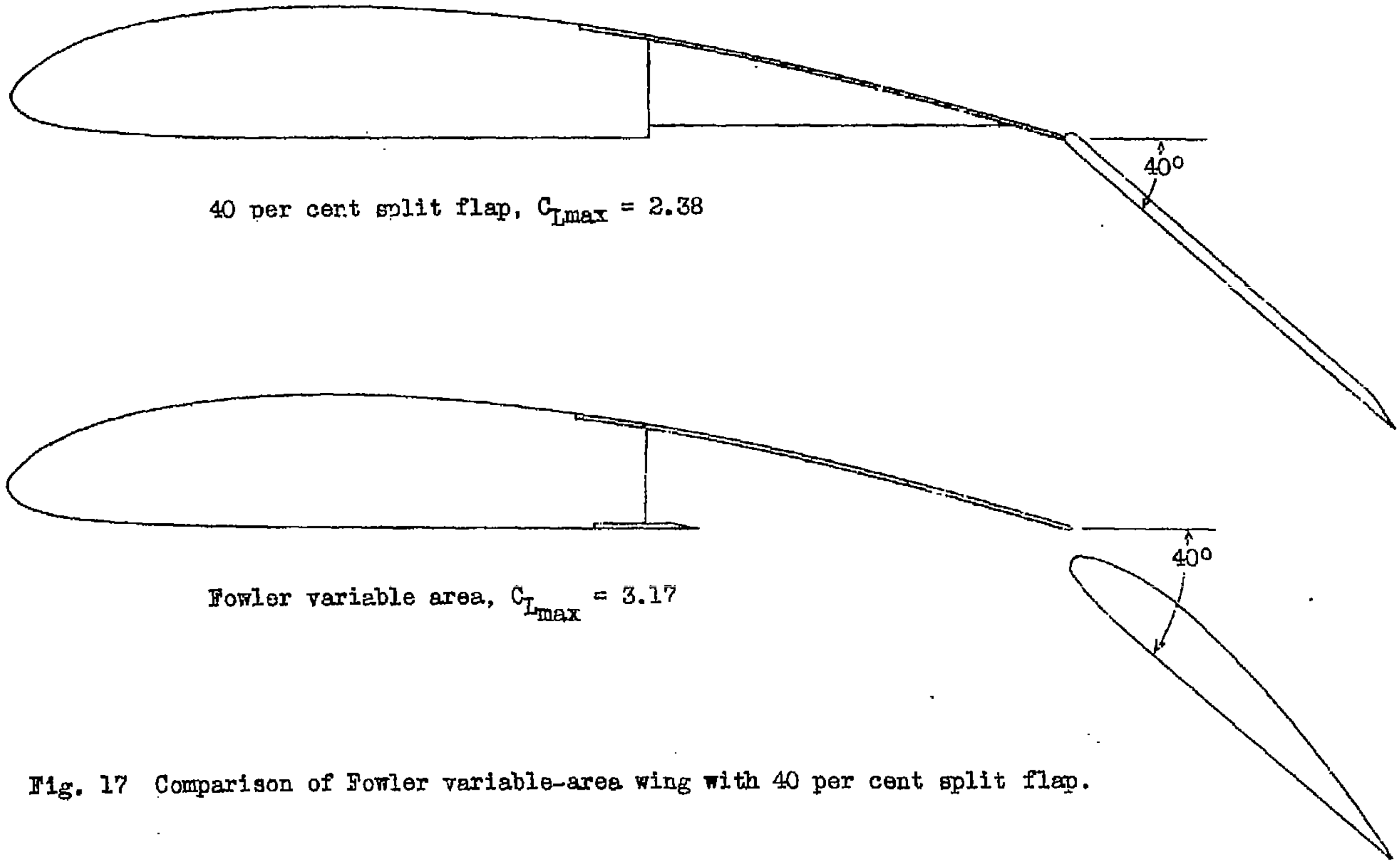

Fig. 17 Comparison of Fowler variable-area wing with 40 per cent split flap.