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No. 598

WIND-TUNNEL TESTS OF A CLARK Y WING WITH "MAXWELL"

LEADING-EDGE SLOTS

By William E. Gauvain
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SUMMARY

Aerodynamic force tests of a Clark Y wing equipped with "Maxwell" type leading-edge slots were conducted in the N.A.C.A. 7- by 10-foot tunnel to ascertain the aerodynamic characteristics, which involved the determination of the best slot-gap opening, the effects of slot width, and the effect of a trailing-edge flap.

The Maxwell wing with a wide-chord slat ($0.30 c_w$) and with a $0.211 c_w$ split flap deflected 60° had a C_{Lmax} of 2.53 or about twice that of the plain wing. The wing with the wide slat also had, in general, improved aerodynamic characteristics over those of the Maxwell wing with a narrow ($0.175 c_w$) slat. The Maxwell wing with a narrow slat had about the same aerodynamic characteristics as a Handley Page slotted wing with approximately the same size of slat.

INTRODUCTION

Numerous devices for increasing the lift of airplane wings have been tested in the N.A.C.A. 7- by 10-foot wind tunnel as part of a general investigation of factors affecting the speed range of airplanes. The devices tested have included flaps of various types, fixed slots, movable slots, and combinations of slots and flaps.

At the request of the Bureau of Aeronautics, Navy Department, an investigation was made of the aerodynamic characteristics of a wing with the Maxwell type of leading-edge slot, which differs essentially from the Handley Page slot in that the moving parts operate solely by rotation. (See fig. 1.) The Maxwell slat also provides a means for producing an unbroken leading-edge contour when it is in the closed condition.

MODEL

The model, as a plain wing, had the Clark Y profile, a span of 60 inches, and a chord of 10 inches. The main wing portion was made of laminated mahogany to an accuracy of ± 0.010 inch; the slat, because of its small size, was made of aluminum alloy to an accuracy of ± 0.005 inch. The slat was supported from the main wing by three steel intermediate fittings and by two end plates. The slat was locked in the open position by three adjustable links, one in the center and one at each end. For the slat-closed, or plain-wing, condition the upper end of the slat was pressed tightly against the wing and the bottom opening of the slot was filled with plasticine and faired to a smooth contour.

In order to cover a wide range of slat width, slats of two different chord sizes were made. The narrow slat (fig. 2) had a chord of 1.75 inches ($0.175 c_w$) and the wide slat (fig. 3) had a chord of 3.0 inches ($0.30 c_w$). The narrow Maxwell slat is comparable with the average Handley Page slat, which has a $0.15 c_w$ chord. The wide Maxwell slat was considered to have the extreme practical width.

A full-span split flap 2.11 inches wide ($0.211 c_w$) was also used with the model, the flap consisting of a steel plate fastened to the wing with screws and wooden blocks. It was set at 60° to the wing chord, 2.11 inches forward of the trailing edge of the main wing.

TESTS

The model was mounted on the standard force-test tripod of the N.A.C.A. 7- by 10-foot open-throat wind tunnel. (See reference 1 for details of tunnel and balances.) The tests were made at a dynamic pressure of 16.37 pounds per square foot, corresponding to an air speed of 80 miles per hour at standard sea-level conditions. The average test Reynolds Number, based on the wing chord of 10 inches, was 609,000.

Preliminary tests were made to find the best average gap opening that would give the highest $C_{L_{max}}$ for the wings with each size of slat, both with and without a

flap. This best gap opening proved to be about 10 percent of the slat chord for both the narrow and wide slats (figs. 4(a) and 4(b)).

Six combinations were tested, as follows:

Plain wing.

Slot open, narrow slat.

Slot open, wide slat.

Plain wing, flap deflected.

Slot open, narrow slat, flap deflected.

Slot open, wide slat, flap deflected.

RESULTS AND DISCUSSION

The detailed test results, corrected for jet-boundary effects and for static-pressure gradient along the jet, are plotted in figures 5 and 6. The data are given as absolute coefficients of lift, drag, and pitching moment about the quarter-chord point of the wing:

$$C_L = \frac{L}{qS}$$

$$C_D = \frac{D}{qS}$$

$$C_{m_{c/4}} = \frac{M}{qcS}$$

where q is the dynamic pressure

S , the basic wing area

c , the basic wing chord

Slight variations may be found in the slot-sealed runs due to small inaccuracies in forming the plasticine over the slot lower opening.

Table I gives a comparison of some results of the various wing combinations tested and of the Handley Page type slotted wing. Data for the Handley Page slot were taken from reference 2 and corrected for wind-tunnel effects so as to be directly comparable with the results of the present tests. It should be noted that the speed-range criterion ($C_{L_{max}}/C_{D_{min}}$) for all wings considered in the investigation varies directly as the $C_{L_{max}}$, as all wings assume the plain-wing profile for $C_{D_{min}}$.

The effect of increasing the slat size is shown by comparing the Maxwell wings with the narrow and with the wide slat (fig. 5). The $C_{L_{max}}$ with the narrow slat is 1.81 and with the wide one 2.07, a difference of 14 percent, although the actual increase in wing area (main wing area + slat area) is only 4.7 percent. The angle of attack for $C_{L_{max}}$ is also increased, as is the steepest angle of glide, indicated by L/D at $C_{L_{max}}$. Although the $C_{L_{max}}$ increased with slat chord, the 0.30 c_w slat was considered the largest practical size that could be used, owing to the structural and mechanical difficulties encountered with large moving surfaces in full-size aircraft.

By the addition of a trailing-edge flap to the plain wing, the $C_{L_{max}}$ is increased from 1.26 to 2.09 or 66 percent. The flap shifted the lift curve to the left and also somewhat reduced the angle of attack for $C_{L_{max}}$. In addition, as may be seen from figure 6, large pitching-moment variations are introduced.

Although the addition of a flap to the Maxwell slotted wing appreciably increases the $C_{L_{max}}$, the increase is only about 60 percent as large as that due to adding the flap to the plain wing. The $\Delta C_{L_{max}}$ due to the flap on the wing with the wide slat is 0.46, or 22 percent, and for the small slat $\Delta C_{L_{max}} = 0.50$, or 28 percent. The angle of attack at $C_{L_{max}}$ is reduced from 25.8° to 21.6° for the wing with flap and wide slat and from 23° to 16.7° for the wing with flap and narrow slat.

The Handley Page wing with the 0.147 c_w slat, the size

most generally used, was considered to be a fair basis for comparison with the narrow or 0.175 c_w slatted Maxwell wing. From table I it can be seen that both these wings have approximately the same aerodynamic characteristics except for the glide-angle criterion (L/D at $C_{L_{max}}$). In this case the value for the Handley Page wing indicates a steeper glide angle for landing.

A common disadvantage of the slotted type of wing appears to be the high angle of attack at which $C_{L_{max}}$ occurs and, for the present arrangements, the angle is approximately 9° to 12° higher than that for the plain wing. In order to keep the angle of attack at $C_{L_{max}}$ within reasonable limits for landing conditions the use of flaps with leading-edge slots appears to be desirable.

CONCLUSIONS

1. The Maxwell wing with the wide slat and flap had the highest $C_{L_{max}}$ of the combinations tested, namely, 2.53.

2. For a given slat size the Maxwell wing with the narrow slat has approximately the same aerodynamic characteristics as the Handley Page type of slotted wing.

3. The addition of a trailing-edge flap to the slotted wings tested appreciably increased the $C_{L_{max}}$, but the increase was less than that obtained with a flap on the plain wing.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 24, 1937.

REFERENCES

1. 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.
2. Weick, Fred E., and Wenzinger, Carl J.: Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. VII - Handley Page Tip and Full-Span Slots with Ailerons and Spoilers. T.N. No. 443, N.A.C.A., 1933.

TABLE I

Comparison of Slots and Flaps

Wing	$C_{L_{max}}$	$\Delta C_{L_{max}}$	α at $C_{L_{max}}$ deg.	$\frac{C_{L_{max}}}{C_{D_{min}}}$	L/D at $C_{L_{max}}$
Plain Clark Y	1.26	-	14	84.0	10.7
Maxwell, 0.175 c_w slat	1.81	0.55	23	120.7	6.94
Maxwell, 0.30 c_w slat	2.07	.81	25.8	138.1	6.44
Plain, 0.211 c_w split- flap deflected 60°	2.09	.83	11.8	139.4	4.92
Maxwell, 0.175 c_w slat, 0.211 c_w split flap deflected 60°	2.31	1.05	16.7	154.1	4.71
Maxwell, 0.30 c_w slat, 0.211 c_w split flap deflected 60°	2.53	1.27	21.6	168.7	4.53
Handley Page, 0.147 c_w slat	1.83	.57	25	122.1	5.11

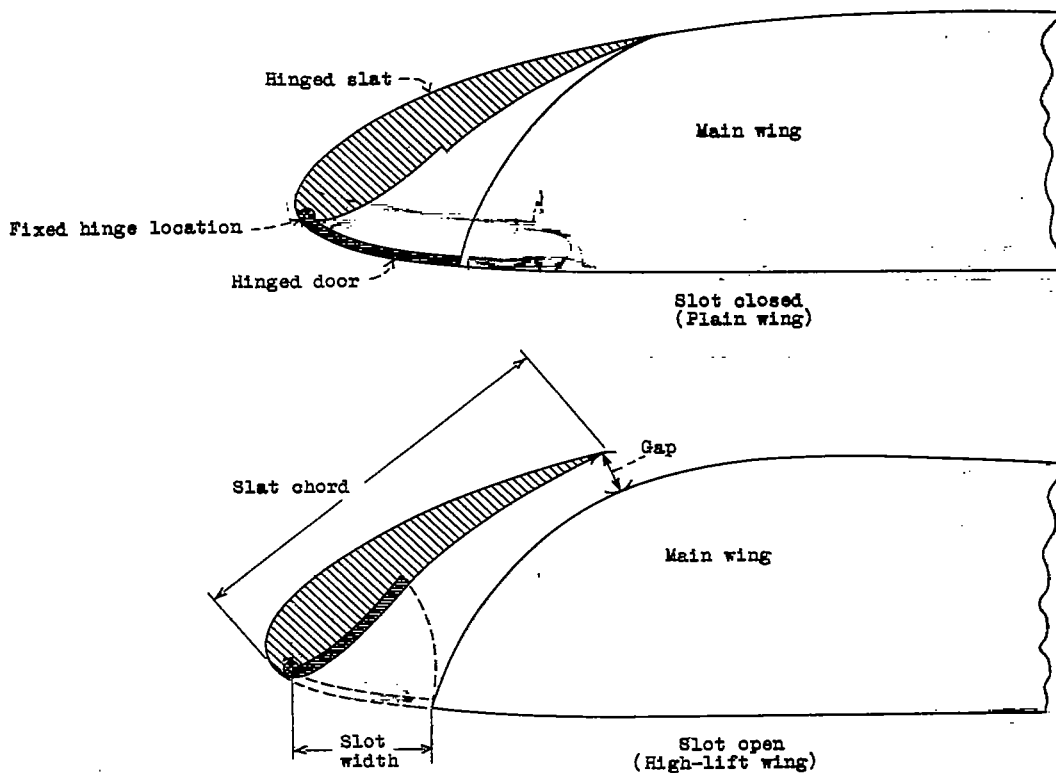


Figure 1 (a). - Arrangement of Maxwell slot

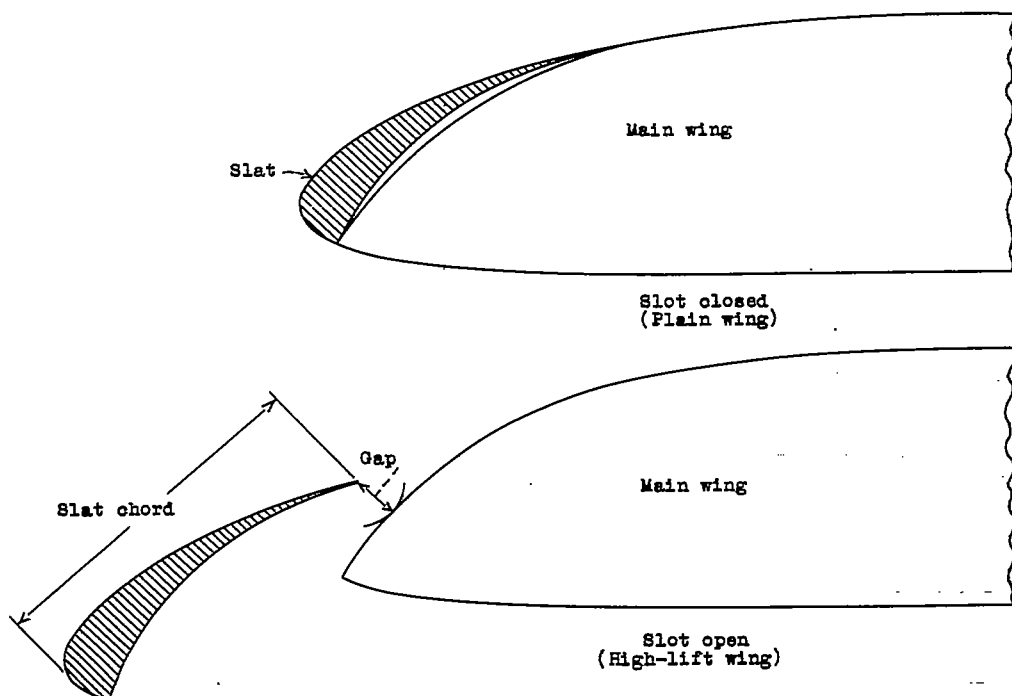
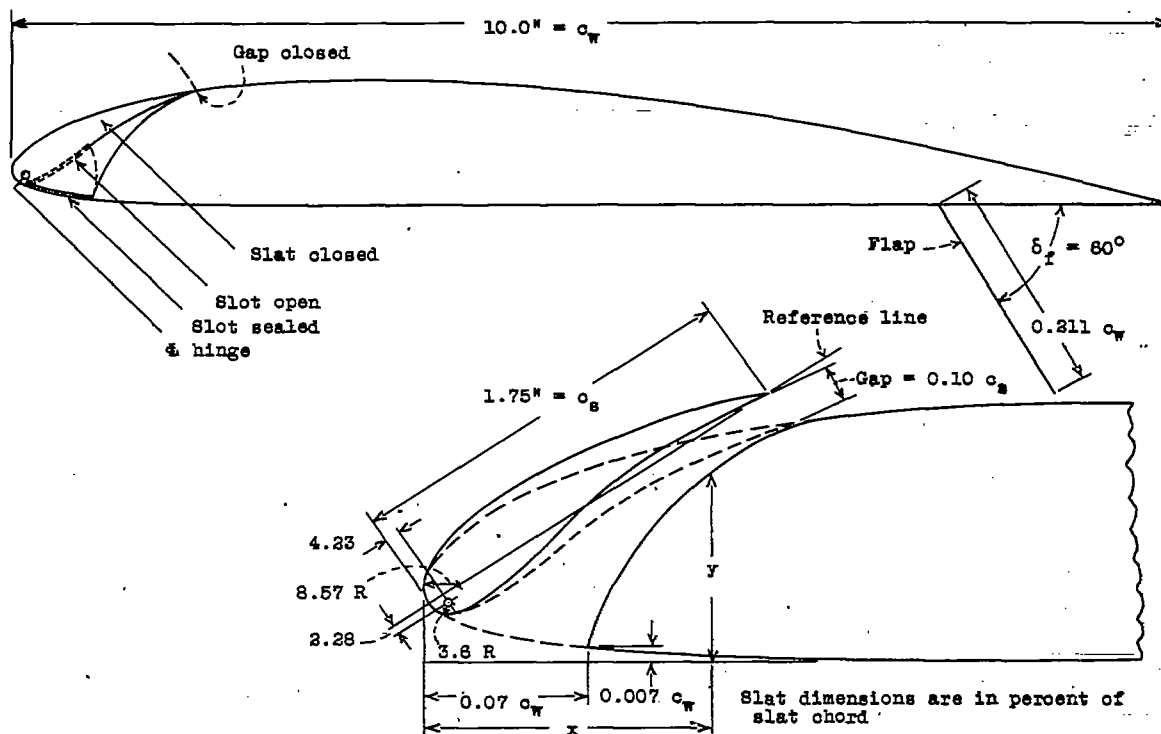


Figure 1 (b). - Arrangement of Handley Page slot



Slat ordinates in percent of slat chord

Station	Upper	Lower
0	0	0
4.29	7.31	-6.05
5.72	8.12	-6.23
7.15	8.75	-6.34
8.58	9.38	-6.45
14.29	11.26	-6.34
20.00	12.51	-5.72
25.72	13.25	-4.80
31.43	13.49	-3.54
37.15	13.43	-2.08
42.86	13.03	-.57
48.57	12.46	.57
54.29	11.80	1.37
60.00	10.57	1.83
65.71	9.43	2.08
71.43	8.23	2.17
77.14	6.80	2.06
82.86	5.32	1.71
88.57	3.72	1.14
94.28	1.94	.29
100.00	.171	-.69

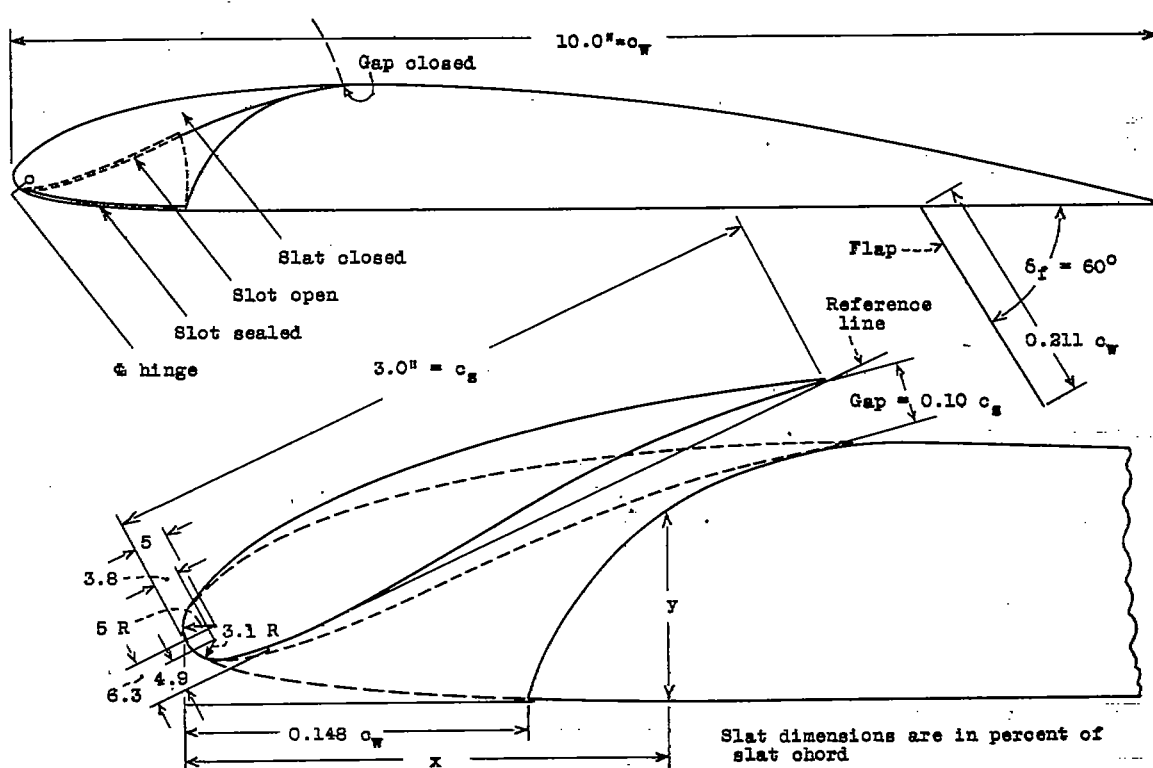
Nose contour in percent of wing chord

x	y
7.34	1.66
7.74	2.86
8.25	3.66
8.83	4.66
9.51	5.66
10.30	6.66
11.28	7.66
12.35	8.66
13.64	9.66
15.68	10.66

Slat 1.75 inches 17.5 percent wing chord
 Flap 2.11 " 21.1 " " " "
 Slot gap 0.175 " 10 " " "

Ordinates from reference line.
 T.E. radius 0.43 percent slat chord,

Figure 3.- The Clark Y wing with 0.175 c_w Maxwell slat, with and without a split flap.



Slat ordinates in percent of slat chord

Station	Upper	Lower
0	6.34	6.34
5	12.04	1.23
10	14.12	.33
15	15.35	.00
20	15.98	.03
25	16.22	.20
30	16.25	.50
35	16.02	.83
40	15.55	1.27
45	14.95	1.74
50	14.18	2.24
55	13.28	2.67
60	12.28	2.94
65	11.18	2.97
70	10.05	2.97
75	8.67	2.77
80	7.24	2.40
85	5.67	1.94
90	4.01	1.37
95	2.24	.67
100	.23	.23

Nose contour in percent of wing chord		
x	y	
14.80	.16	
15.07	1.00	
15.49	2.00	
15.99	3.00	
16.56	4.00	
17.24	5.00	
18.01	6.00	
18.93	7.00	
20.00	8.00	
21.41	9.00	
23.30	10.00	
26.24	11.00	
31.00	Tangent	

Component	Value	Unit	Percent of	Reference
Slat	3.0	inches	30.0	percent wing chord
Flap	2.11	"	21.1	"
Slot gap	0.30	"	10	" slat "

Ordinates from reference line.
 T.E. radius 0.23 percent slat chord

Figure 3.-The Clark Y wing with 0.30 c_w Maxwell slat, with and without a split flap

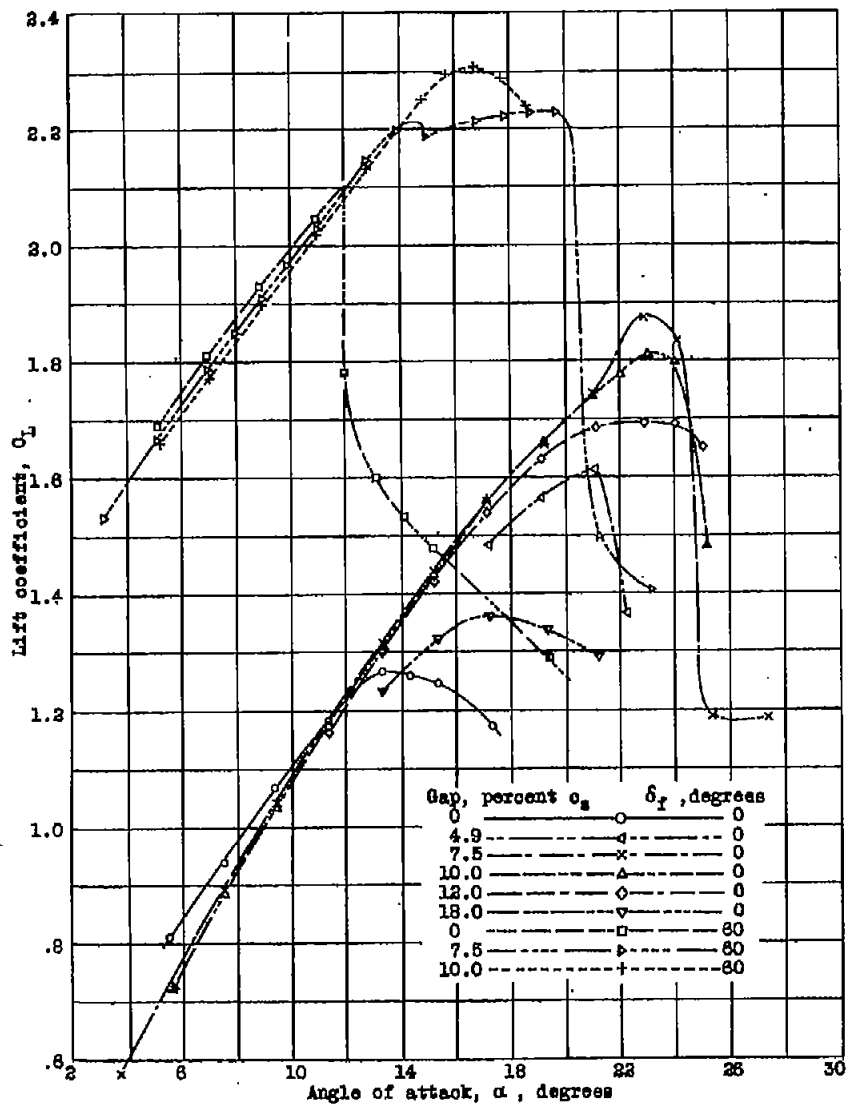
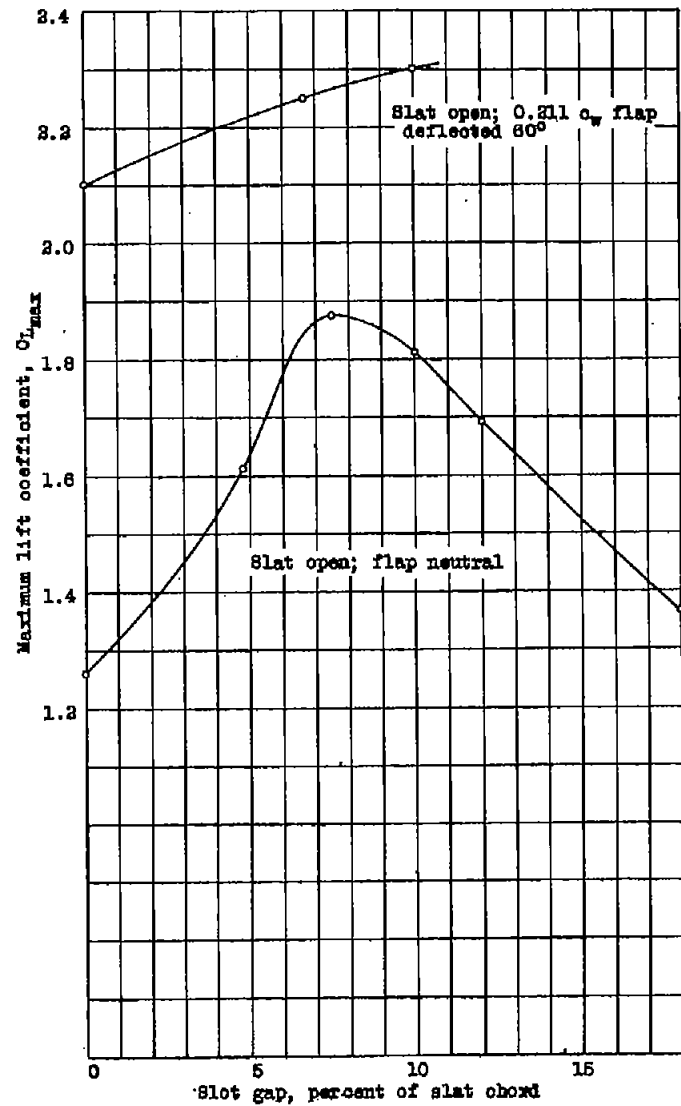


Figure 4 (a).- The Clark Y wing with 0.175 c_w Maxwell slat. Effect of various gaps on maximum lift with flap neutral and deflected.



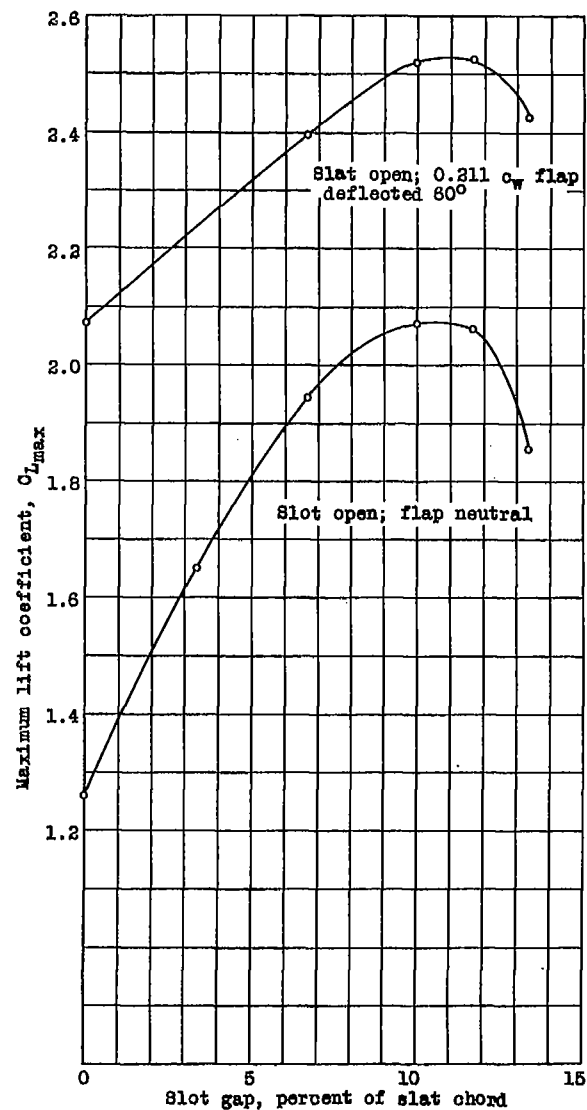
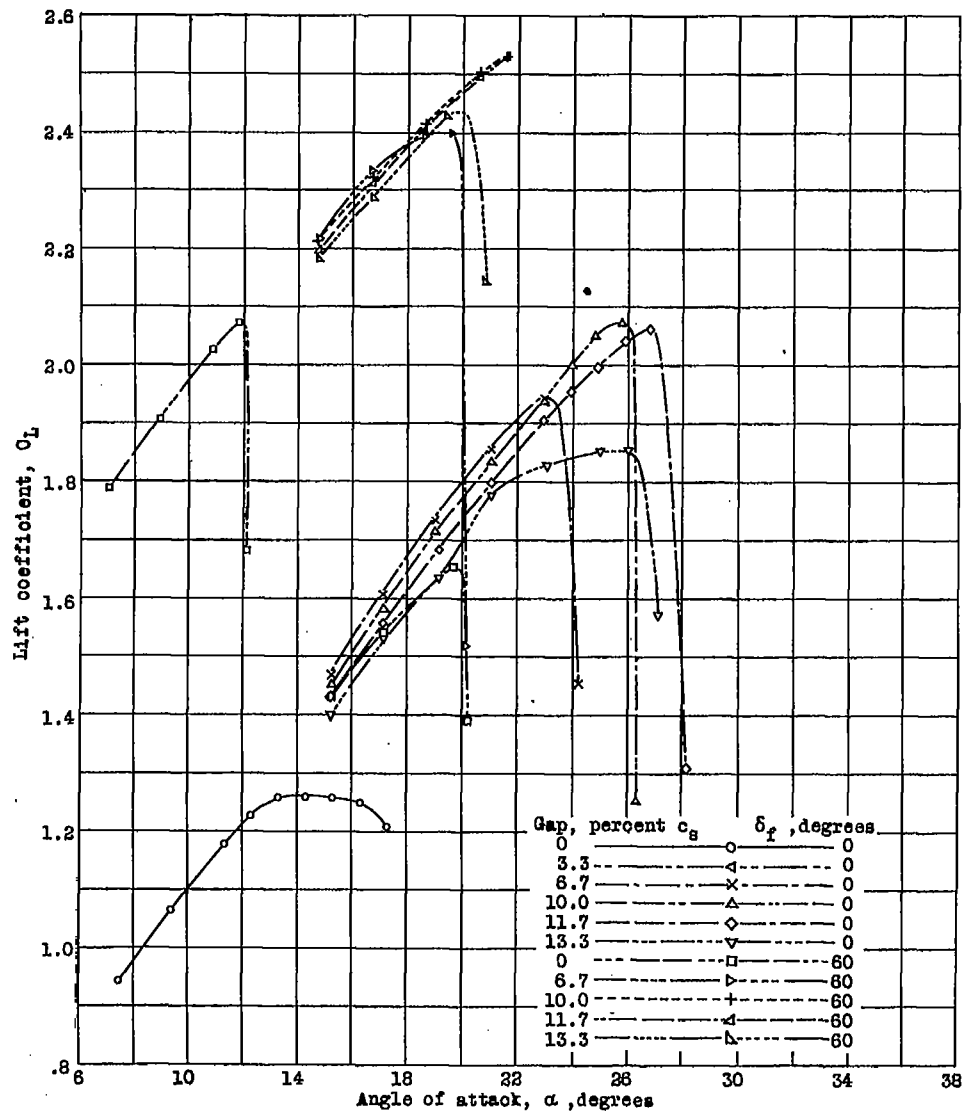


Figure 4 (b).- The Clark Y wing with 0.30 c_w Maxwell slat. Effect of various gaps on maximum lift with flap neutral and deflected.

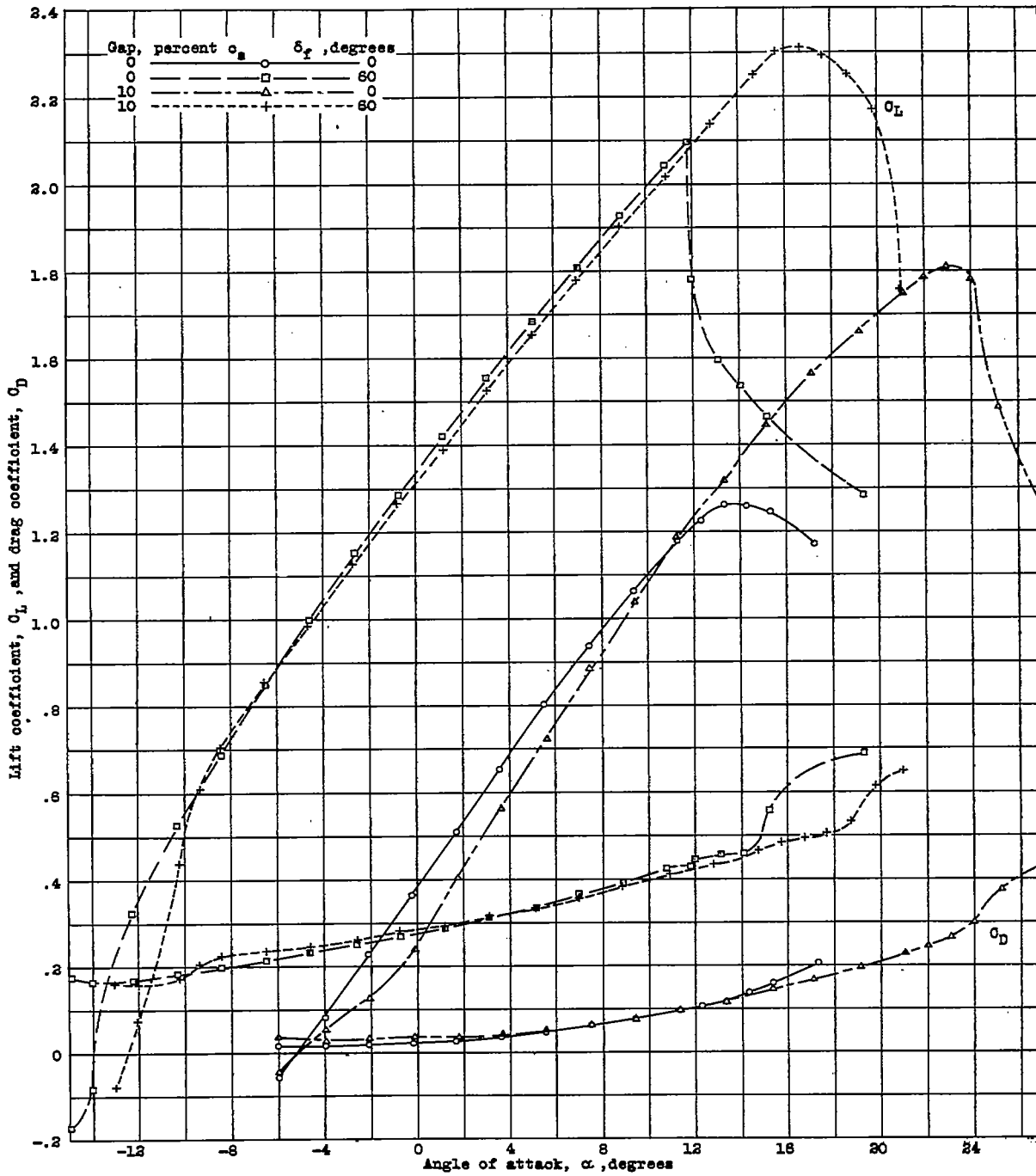


Figure 5 (a).— The Clark Y wing with 0.175 c_w Maxwell slat both open and closed and 0.211 c_w split flap both neutral and deflected.

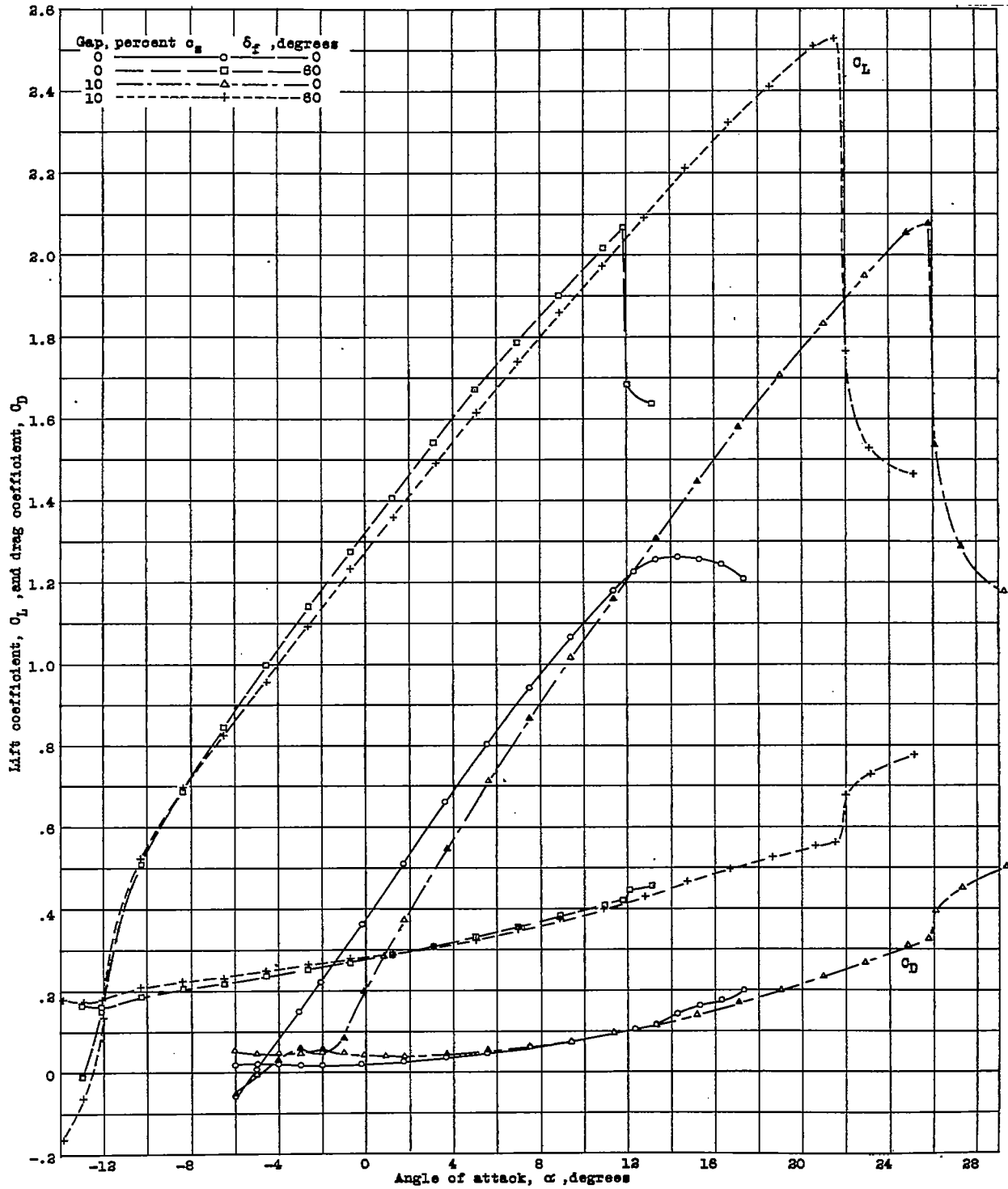


Figure 5 (b).- The Clark Y wing with 0.30 c_w Maxwell slit both open and closed and 0.311 c_w split flap both neutral and deflected.

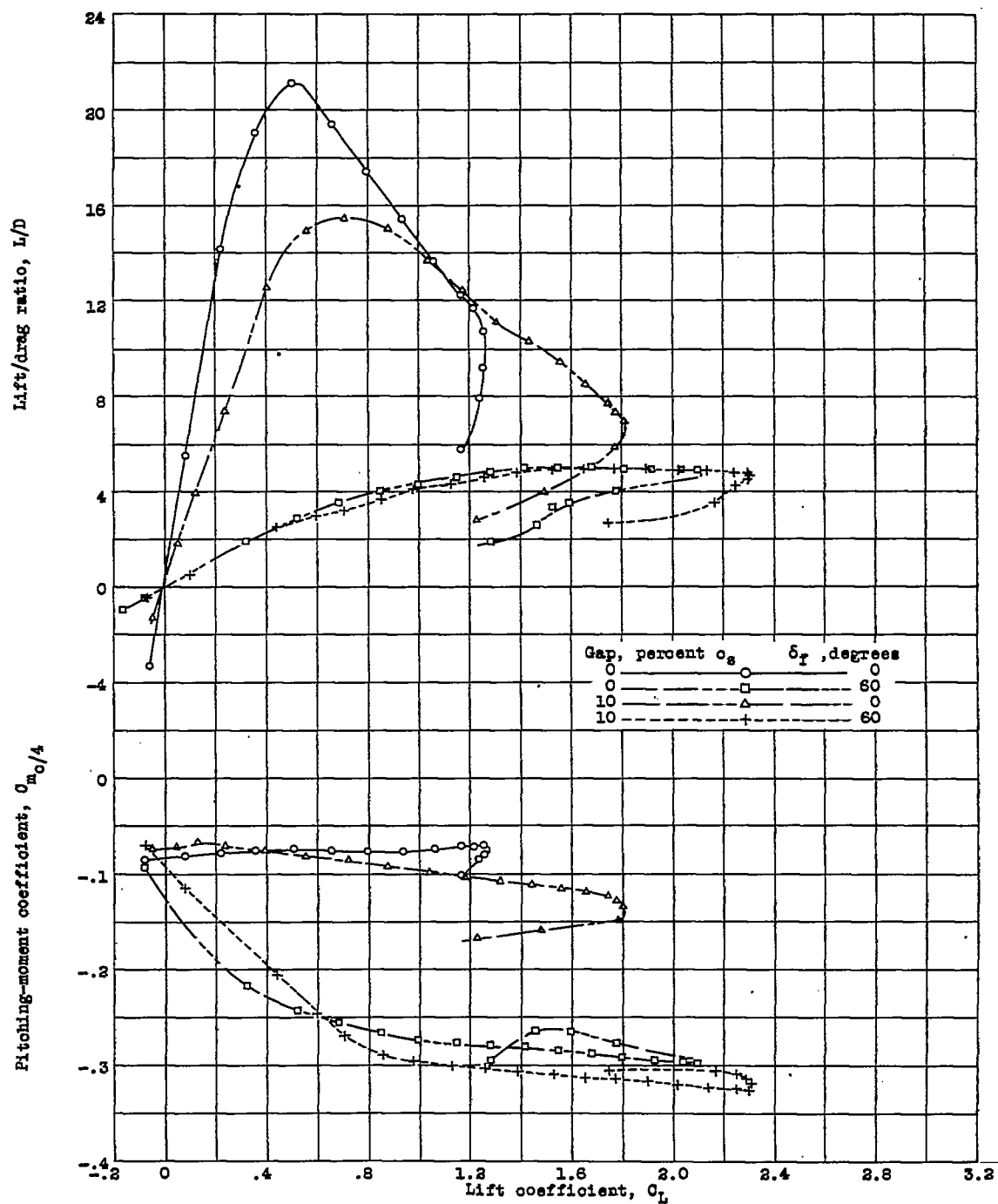


Figure 6 (a).— The Clark Y wing with 0.175 c_w Maxwell slat both open and closed and 0.211 c_w split flap both neutral and deflected.

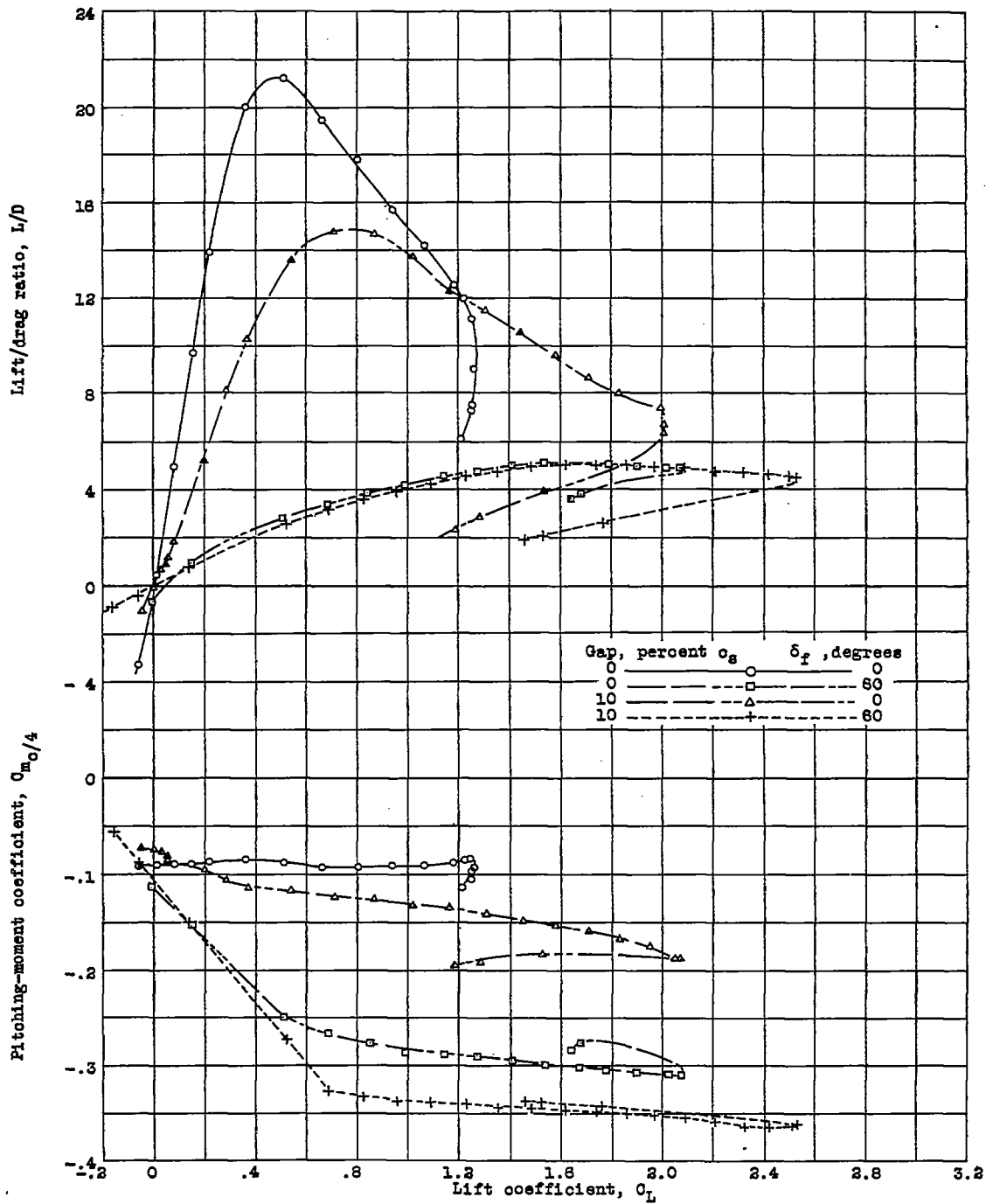


Figure 6 (b).- The Clark Y wing with 0.30 c_s Maxwell slat both open and closed and 0.211 c_w split flap both neutral and deflected.