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No. 763

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WIND-TUNNEL INVESTIGATION OF TWO AIRFOILS WITH  
25-PERCENT-CHORD GWINN AND PLAIN FLAPS

By Milton B. Ames, Jr.  
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WIND-TUNNEL INVESTIGATION OF TWO AIRFOILS WITH  
25-PERCENT-CHORD GWINN AND PLAIN FLAPS

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SUMMARY

Aerodynamic force tests of an N.A.C.A. 23018 airfoil with a Gwinn flap having a chord 25 percent of the overall chord and of an N.A.C.A. 23015 airfoil with a plain flap having a 25-percent chord were conducted in the N.A.C.A. 7- by 10-foot wind tunnel to determine the relative merits of the Gwinn and the plain flaps.

The tests indicated that, based on speed-range ratios, the plain flap was more effective than the Gwinn flap. At small flap deflections, the plain flap had the lower drag coefficients at lift-coefficient values less than 0.70. For lift coefficients greater than 0.70, however, the Gwinn flap at all downward flap deflections had the lower drag coefficients.

INTRODUCTION

Improvement in airplane performance has depended somewhat on the development and the use of high-lift devices. As an aid to designers, the N.A.C.A. has conducted many experimental investigations of various types of flap and has reported the effects of these different flaps on high or low drag at high lift (glide-path control), low drag in the cruising-speed condition, and high lift and low drag at the take-off.

The present investigation, conducted in the N.A.C.A. 7- by 10-foot wind tunnel, was of a high-lift device identified as the Gwinn flap and included for comparison the tests of a plain flap. The Gwinn flap is essentially a flat plate mounted at a point very near the trailing edge of the wing. In its neutral position, the flap extends past the trailing edge of the wing, thereby resulting

in an increased over-all chord and wing area. In some respects the Gwinn flap is similar to the plain flap. Both flaps deflect upward or downward so that either of them may be used as a high-lift device and also as an aileron.

The principal purpose of this investigation was to determine the relative merits of the Gwinn and the ordinary plain flaps as high-lift devices. Previous tests (reference 1) have been conducted on airfoils with plain flaps; the models used, however, were not comparable with the Gwinn flap model used in this investigation. The models of the airfoils with the Gwinn and the plain flaps used in these tests had the same over-all chord, span, aspect ratio, and approximate maximum thickness.

## APPARATUS AND TESTS

### Models

Two airfoil models were tested: An 8-inch-chord N.A.C.A. 23018 airfoil section with a Gwinn flap having a chord 25 percent of the over-all chord (fig. 1) and a 10-inch-chord N.A.C.A. 23015 airfoil section with a plain flap having a 25-percent chord (fig. 2). Each model has a span of 60 inches and an over-all chord of 10 inches. The maximum thickness of the model with the Gwinn flap, based on over-all chord, is 14.4 percent of the chord and, of the model with the plain flap, 15 percent. Both airfoils and the plain flap are made of laminated beech; the Gwinn flap is made of aluminum. In order to mount the Gwinn flap, 5 percent of the over-all chord was removed from the trailing edge of the N.A.C.A. 23018 airfoil section. The flaps are arranged to move up or down about their respective hinge axes or to lock rigidly in a given position. Flap deflections were measured with respect to the airfoil chord line, and all gaps between the airfoils and the flaps were sealed with plasticine to prevent air leakage.

### Wind Tunnel and Balance

The tests were made in the N.A.C.A. 7- by 10-foot tunnel, which has a closed throat and return passage. The tunnel and the regular 6-component balance are described in references 2 and 3.

## Tests

Test conditions.- The dynamic pressure was maintained constant throughout the tests at 16.37 pounds per square foot, corresponding to an air speed of about 80 miles per hour at standard sea-level conditions. The average test Reynolds Number was 609,000, based on the air speed and the 10-inch airfoil chord.

Test procedure.- Tare tests were conducted to determine the effects of the model-supporting strut on the lift, the drag, and the pitching moments of the two airfoils and flaps.

The main portion of the investigation consisted in determinations of lift, drag, and pitching moments for flap deflections of  $-10^\circ$ ,  $-5^\circ$ ,  $-2^\circ$ ,  $0^\circ$ ,  $2^\circ$ ,  $5^\circ$ ,  $10^\circ$ ,  $15^\circ$ ,  $30^\circ$ ,  $45^\circ$ ,  $60^\circ$ , and  $79^\circ$  throughout an angle-of-attack range from  $-12^\circ$  to beyond the stall for each of the airfoils.

## RESULTS

## Coefficients

The test results are given in the form of standard absolute coefficients of lift, drag, and pitching moment.

$$C_L = \frac{\text{lift}}{qS}$$

$$C_D = \frac{\text{drag}}{qS}$$

$$C_{m(a.c.)_0} = \frac{\text{pitching moment about aerodynamic center of airfoil with flap neutral}}{qcS}$$

$$\frac{L}{D} = \frac{\text{lift}}{\text{drag}}$$

where

S wing area.

c over-all chord of wing and flap.

q dynamic pressure.

and  $\alpha$  angle of attack.

$\delta_f$  flap deflection (downward deflection is positive).

All coefficients were obtained directly from the balance and refer to the wind (or tunnel) axes.

Corrected test results.- The data were corrected for tunnel effects to aspect ratio 6 in free air. The standard jet-boundary corrections were applied. (See reference 4.) In addition, corrections were applied for the effects of the supporting strut on the aerodynamic coefficients of the models as indicated by the tare tests.

The corrected test results are presented in figures 3 to 6 as plots of lift, drag, and pitching-moment coefficients and lift-drag ratio against angle of attack.

## DISCUSSION

### Gwinn Flap

The lift and the drag coefficients for the airfoil with the Gwinn flap are plotted against angle of attack for the different flap deflections in figure 3. The pitching-moment coefficients and the lift-drag ratios for the same conditions are plotted in figure 4. Figure 3 indicates that  $C_L$  varied regularly with flap deflection except when the flap was deflected  $30^\circ$ . The irregular curve for the  $30^\circ$  flap deflection may be a characteristic of the airfoil-and-flap combination, or it may be attributed to scale effect. The maximum value of  $C_L$  occurred at  $\delta_f = 60^\circ$  (fig. 3(b)), and the maximum value of  $L/D$  was 18.6 at  $\delta_f = 0^\circ$  (fig. 4(a)). The variation of  $C_{m(a.c.)_0}$  with flap deflection was uniform; the upward deflections of the flap tended to give stalling moments, and the downward deflections gave diving moments.

## Plain Flap

The lift and the drag coefficients for the airfoil with the plain flap are plotted against angle of attack for the different flap deflections in figure 5. The pitching-moment coefficients and the lift-drag ratios are plotted in figure 6. As in the case of the Gwinn flap, the  $C_L$  curve for the plain flap deflected  $30^\circ$  is irregular, which may be attributed to the flow characteristics and the scale of the tests. The maximum value of  $C_L$  occurred at  $\delta_f = 60^\circ$  (fig. 5(b)), and the maximum value of  $L/D$  was 19.4 at  $\delta_f = 0^\circ$  (fig. 6(a)).

## Comparison of Gwinn and Plain Flaps

Envelope polar curves of  $C_D$  plotted against  $C_L$  for the airfoils with the Gwinn and the plain flaps at the different values of  $\delta_f$  are given in figure 7. These curves indicate that, for values of  $C_L$  from -0.15 to 0.66 (which covers the high-speed and the cruising-speed ranges) the plain flap had the lower drag. The minimum value of  $C_D$  for the airfoil with the plain flap, 0.0095, occurred at  $\delta_f = 0^\circ$  and, for the airfoil with the Gwinn flap, the minimum value was 0.0107 at  $\delta_f = -2^\circ$ . (See also figs. 3(a) and 5(a).) Only a slight difference existed between the drag characteristics of the Gwinn flap at  $\delta_f = -2^\circ$  and  $\delta_f = 0^\circ$ . The maximum lift coefficient  $C_{L_{max}}$  of the Gwinn flap at  $\delta_f = 60^\circ$  was 2.03 and, of the plain flap at the same flap deflection, was 2.00. (See fig. 8.)

The effect of flap deflection on  $C_D$  at different values of  $C_L$  is shown in figure 9. The plain flap has lower drag coefficients for values of  $C_L$  through 0.70 in the flap-deflection range of  $-10^\circ$  to  $5^\circ$ . At  $C_L = 1.00$ , the Gwinn flap had the lower drag coefficient.

Further comparisons are given in the following table for the conditions of flaps neutral and deflected  $60^\circ$ . The comparison includes the increment of maximum lift coefficient due to flap deflection  $\Delta C_{L_{max}}$ , the speed-range ratio  $C_{L_{max}}/C_{D_{min}}$ , and the glide path, indicated by  $L/D$  at  $C_{L_{max}}$ .

$\delta_f \rightarrow$	$0^\circ$			$60^\circ$				
	$C_{L_{max}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	L/D at $C_{L_{max}}$	$C_{L_{max}}$	$\Delta C_{L_{max}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$ (a)	L/D at $C_{L_{max}}$
Gwinn	1.19	112	7.0	2.03	0.84	190	145	5.1
Plain	1.09	115	11.9	2.00	.91	210	166	4.8

(a)  $C_{D_{min}}$  at  $C_L = 0.20$ .

From this table it is observed that, although the Gwinn flap both neutral or deflected  $60^\circ$  has slightly higher values of  $C_{L_{max}}$ , the increment of  $C_{L_{max}}$  caused by deflecting the flap is greater for the plain flap. The comparison also indicates that the plain flap has the higher speed-range ratio whether the flap is neutral or deflected  $60^\circ$  and whether  $C_{D_{min}}$  is taken at  $\delta_f = 0^\circ$  or at  $C_L = 0.20$ . A comparison of the values of L/D at  $C_{L_{max}}$  shows that a steeper gliding angle could be obtained with the plain flap deflected  $60^\circ$  than with the Gwinn flap at the same deflection.

#### CONCLUDING REMARKS

The results of this investigation of an N.A.C.A. 23018 airfoil with a Gwinn flap having a chord 25 percent of the over-all chord and of an N.A.C.A. 23015 airfoil with a plain flap having a 25-percent chord indicated that, from a consideration of speed-range ratio, the plain flap was more effective than the Gwinn flap.

A comparison of the two types of flap at small flap deflections showed that, for values of the lift coefficient of 0.70 or less, the plain flap had the lower drag coeffi-



cient. At all downward flap deflections, however, the Gwinn flap had the lower drag coefficient at lift coefficients greater than 0.70.

Langley Memorial Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., April 4, 1940.

#### REFERENCES

1. Wenzinger, Carl J.: Wind-Tunnel Investigation of Ordinary and Split Flaps on Airfoils of Different Profile. T.R. No. 554, N.A.C.A., 1936.
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.
3. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with Various Arrangements of Slotted Flaps. T.R. No. 664, N.A.C.A., 1939.
4. Wenzinger, Carl J., and Ames, Milton B., Jr.: Wind-Tunnel Investigation of Rectangular and Tapered N.A.C.A. 23012 Wings with Plain Ailerons and Full-Span Split Flaps. T.N. No. 661, N.A.C.A., 1938.

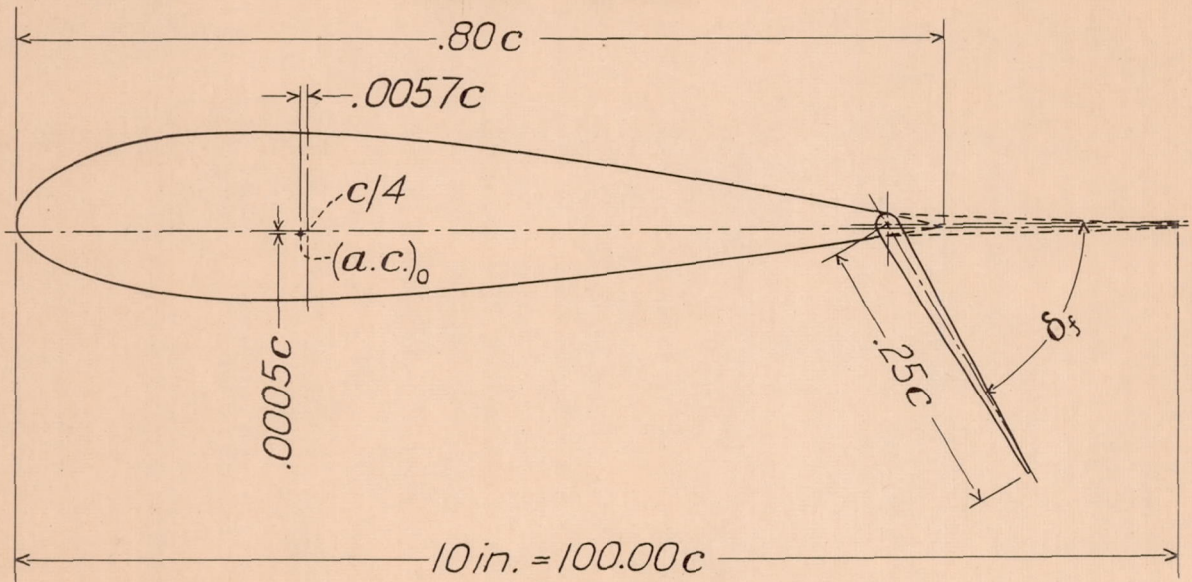


Figure 1.- Gwinn flap on the rectangular N.A.C.A. 23018 airfoil.

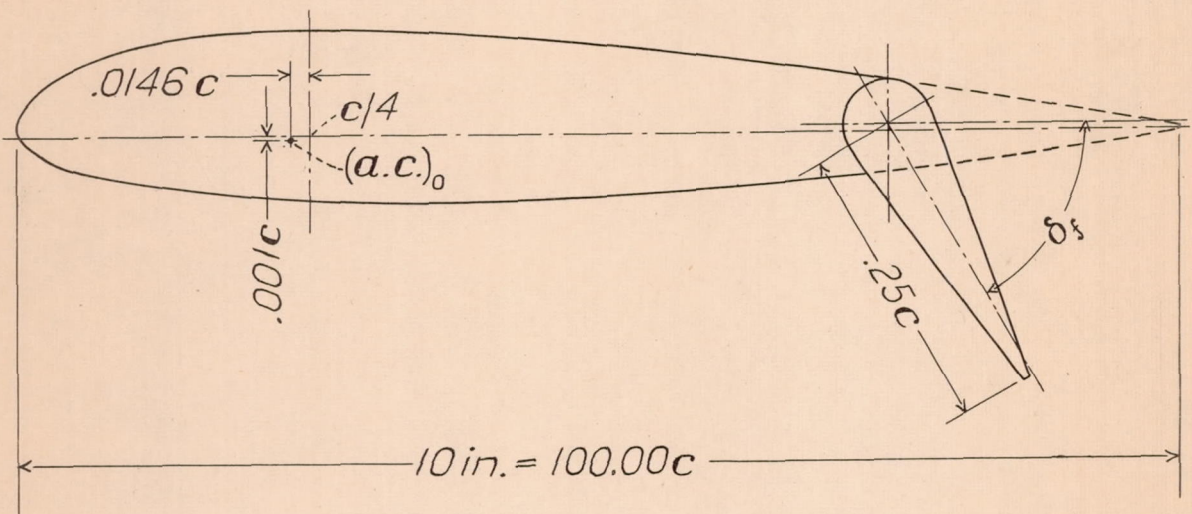


Figure 2.- Plain flap on the rectangular N.A.C.A. 23015 airfoil.

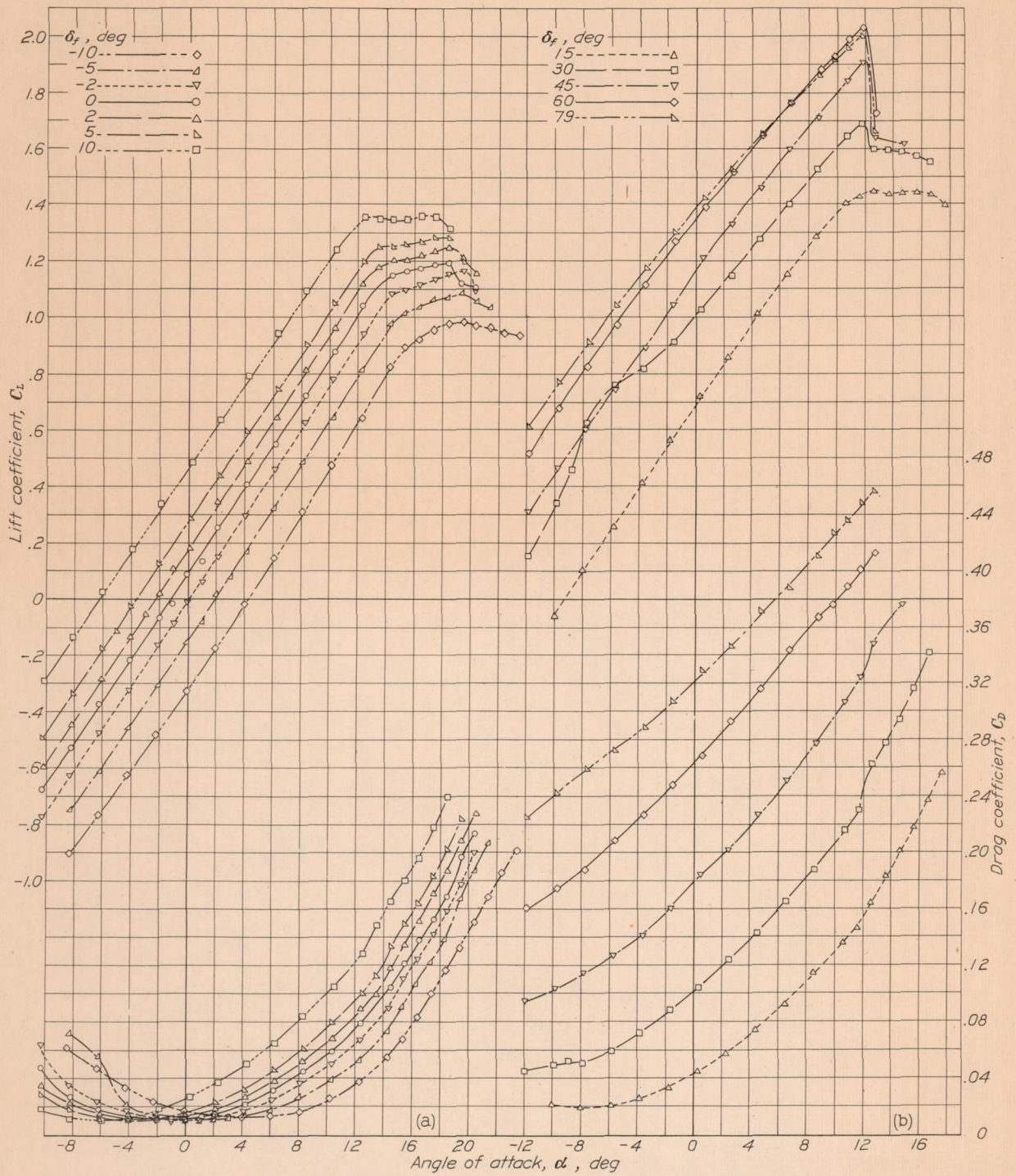


Figure 3.- Lift and drag coefficients of the rectangular N.A.C.A. 23018 airfoil with 0.25c Gwinn flap.

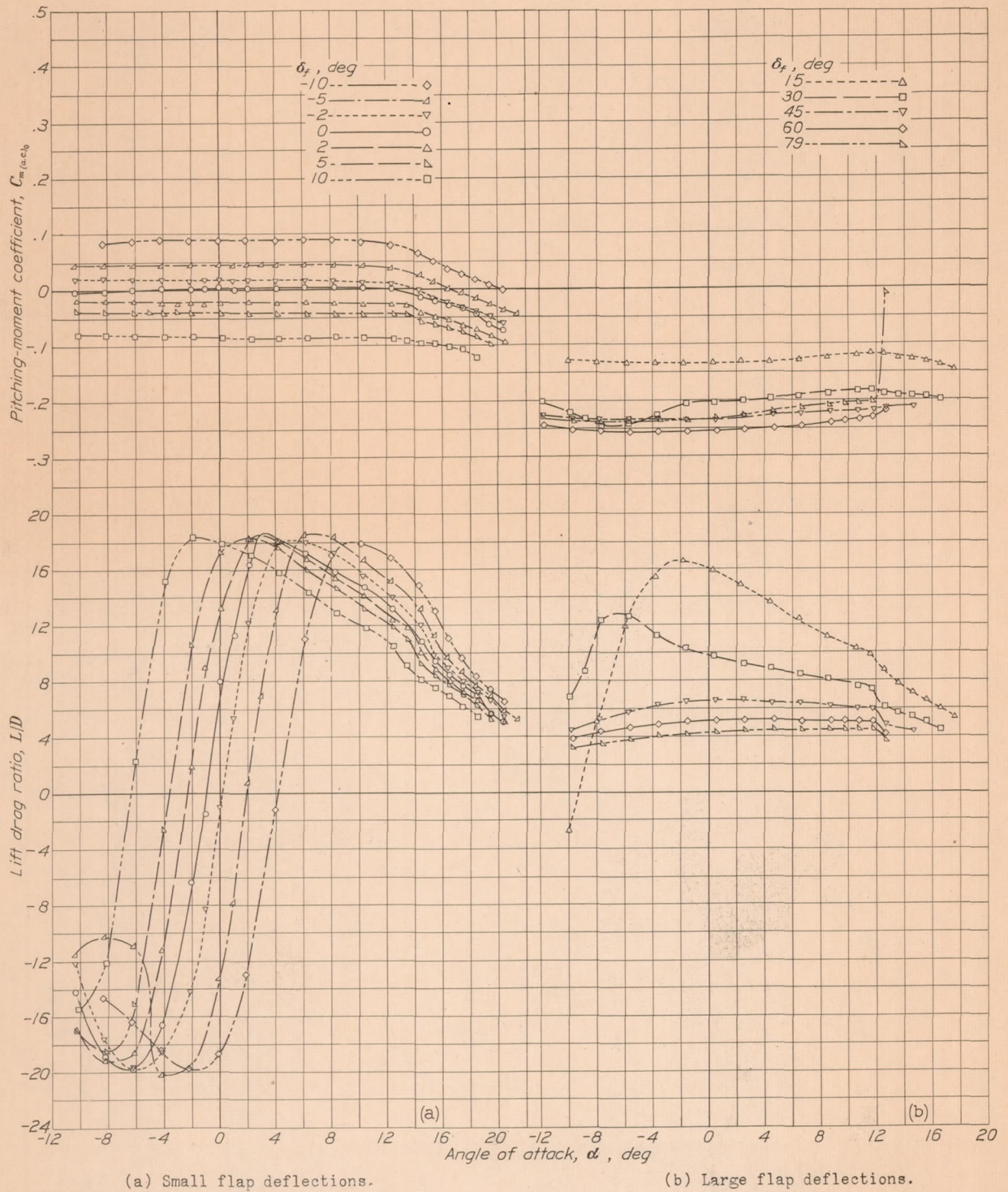
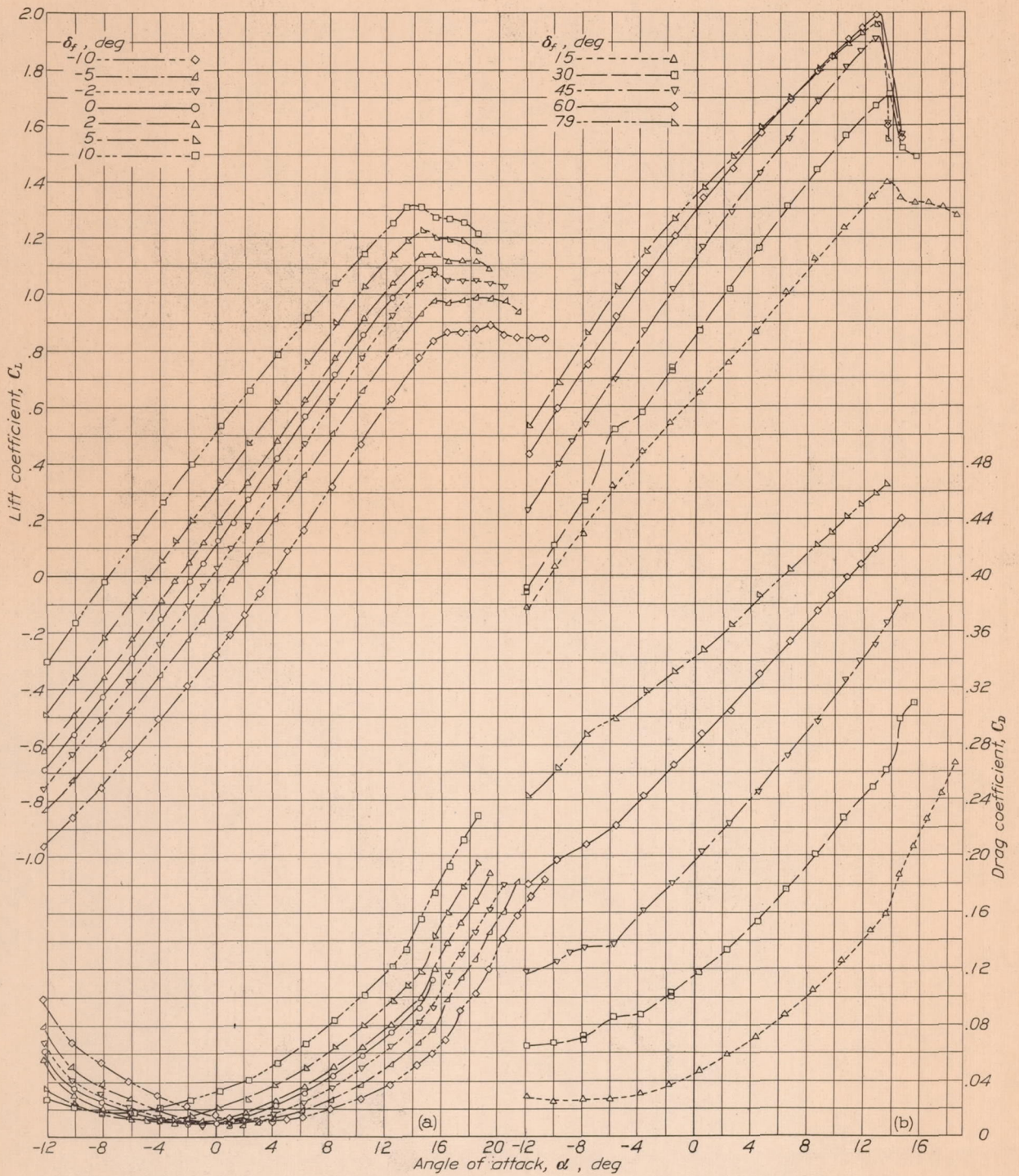


Figure 4.- Pitching-moment coefficients and lift-drag ratios of the rectangular N.A.C.A. 23018 airfoil with 0.25c Gwinn flap.



(a) Small flap deflections.

(b) Large flap deflections.

Figure 5.- Lift and drag coefficients of the rectangular N.A.C.A. 23015 airfoil with 0.25c plain flap.

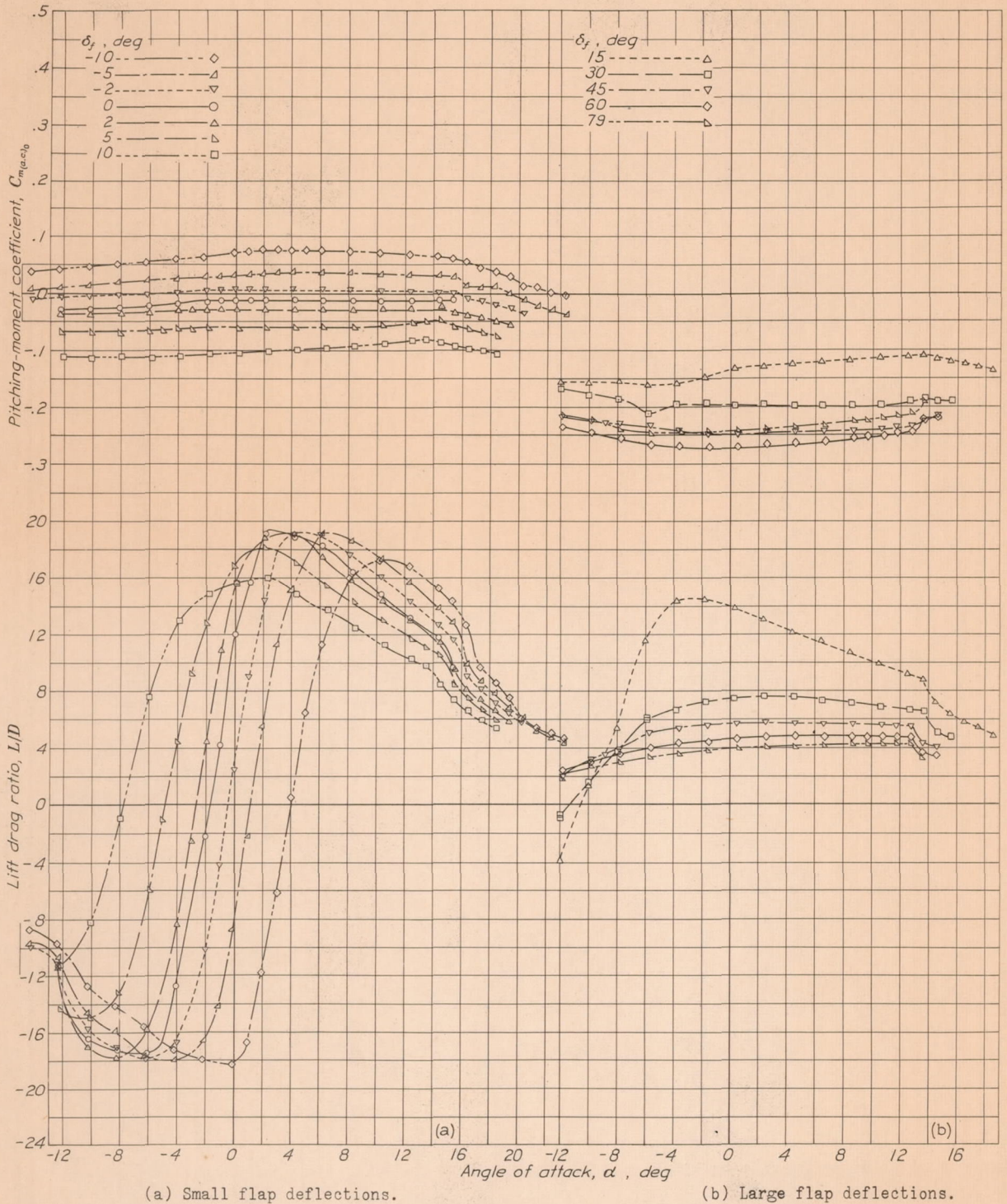


Figure 6.- Pitching-moment coefficients and lift-drag ratios of the rectangular N.A.C.A. 23015 airfoil with 0.25c plain flap.

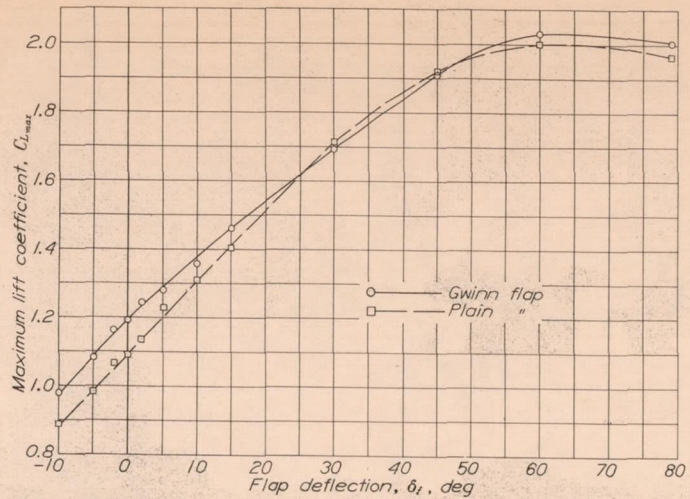


Figure 8.- Effect of flap deflection on maximum lift coefficient. The 0.25c Gwinn flap on the N.A.C.A. 23018 airfoil and the 0.25c plain flap on the N.A.C.A. 23015 airfoil.

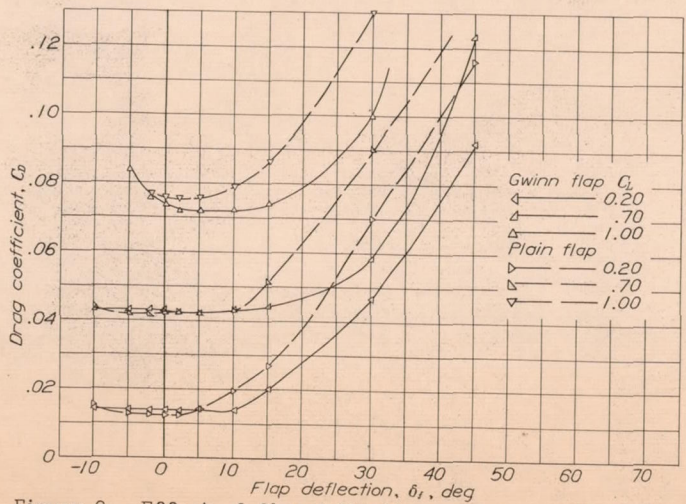


Figure 9.- Effect of flap deflection on drag coefficients at different lift coefficients. The 0.25c Gwinn flap on the N.A.C.A. 23018 airfoil and the 0.25c plain flap on the N.A.C.A. 23015 airfoil.

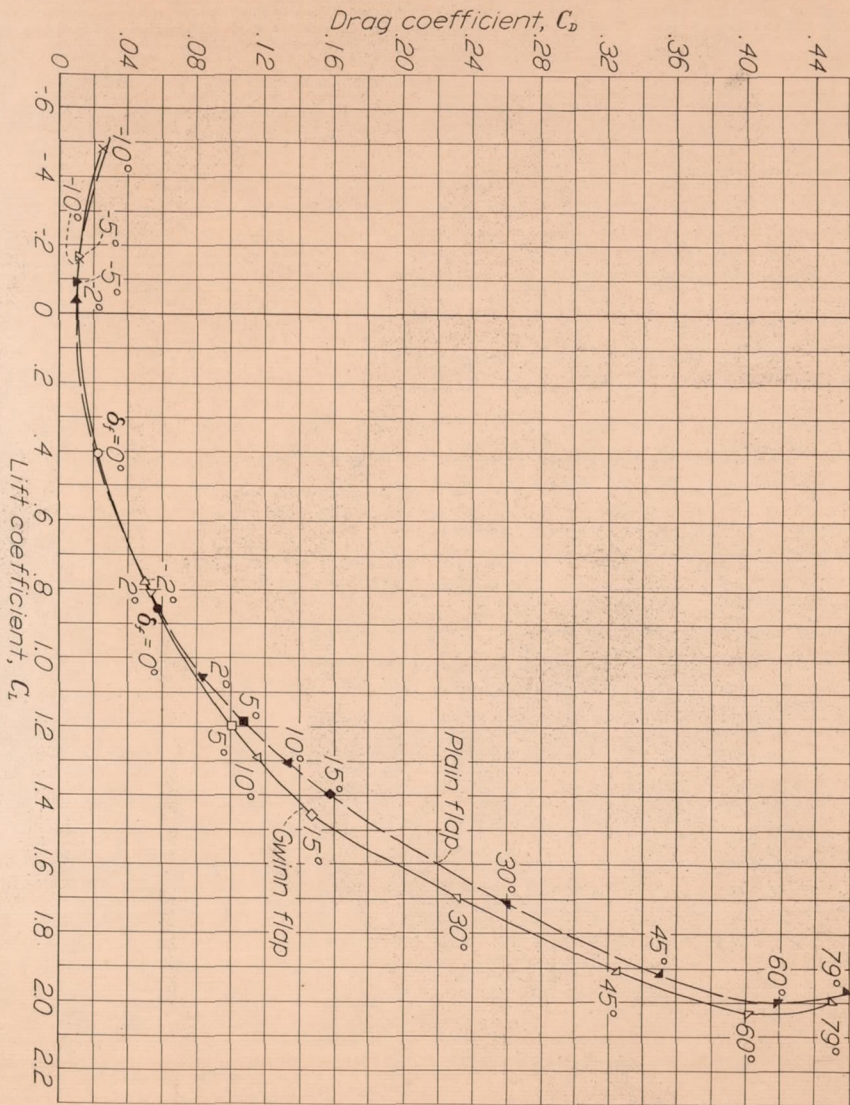


Figure 7.- Comparison of 0.25c Gwinn flap on the N.A.C.A. 23018 airfoil and the 0.25c plain flap on the N.A.C.A. 23015 airfoil. Aspect ratio, 6; Reynolds Number, 609,000.