TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 498

# WIND-TUNNEL MEASUREMENTS OF AIR LOADS ON SPLIT FLAPS

By Carl J. Wenzinger
Langley Memorial Aeronautical Laboratory



Washington
May 1934

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 498

# WIND-TUNNEL MEASUREMENTS OF AIR LOADS ON SPLIT FLAPS

By Carl J. Wenzinger

## SUMMARY

Tests were made in the N.A.C.A. 7 by 10 foot wind tunnel to determine the control forces and air loads acting on split flaps. Clark Y wing models were used with two different sizes of full-span split flaps; one having a medium chord (0.25c) and the other a narrow chord (0.15c). Hinge moments of the flaps were measured and also the division of load between the flaps and the wing.

The investigation showed that, at the angles of attack and flap deflections for maximum lift, the lift loads on the split flaps were only 5 percent and 9 percent of the total lift for the narrow and medium-chord flaps respectively. The ratio of drag on the flaps to total drag increased greatly with decreasing angle of attack, reaching a value of approximately unity at small negative angles of attack with the flaps fully deflected.

The normal force on the split flaps increases both with angle of attack and with flap deflection for angles of attack below the stall. The value of the normal-force coefficient is about 1.40 at the angle of attack and flap deflection for maximum lift with either of the flaps tested. The center of pressure of the load on the split flaps in general moves forward with decreasing flap deflection and with increasing angle of attack from small negative angles up to the stall.

The hinge moments of the narrow-chord split flap were about 42 percent those of the medium-chord flap when deflected to give approximately the same maximum lift, but they are considered to be still too large for rapid and easy flap operation.

## INTRODUCTION

Split trailing-edge flaps are now being utilized to a considerable extent on airplanes for reducing the landing speed and for increasing the range of gliding angles. The use of these flaps has given rise to several new problems, particularly those involving control forces and methods of construction and operation. Some of the aerodynamic characteristics of wings equipped with split flaps have already been investigated and considerable data are available on the lift, drag, and center of pressure of these combinations. (See references 1, 2, and 3.) Very little data, however, have been available to designers concerning the characteristics of split flaps alone.

The present investigation was made in order to obtain data regarding control forces and the air loads on split flaps. Hinge moments of the flaps and the division of load between flap and wing were measured, and from these data the center of pressure of the load on the flap was calculated. Clark Y wing models were used with two different sizes of full-span split flaps, one having a medium chord and the other a narrow chord.

## APPARATUS AND TESTS

Models.- The two models used were rectangular Clark Y airfoils, each having a 10-inch chord and 60-inch span. The main portion of each airfoil was constructed of laminated mahogany to the specified ordinates given in table I. The trailing-edge portions were formed by the split flaps and by upper-surface ailerons as shown in figure 1. The two sets of flaps and ailerons were made of duralumin because of their small size (0.15 and 0.25 of the wing chord). Both were hinged to the wing in such a manner that they could be locked rigidly in place or allowed to swing freely about their hinge axes. In addition, the flaps could be supported in position but entirely separate from the main part of the wing.

Wind tunnel.- The 7 by 10 foot wind tunnel, which has an open test section, is described in reference 4, together with the balances and standard test procedure. The tests were made at an air speed of 80 miles per hour, corresponding to a Reynolds Number of 609,000.

Tests.- Aerodynamic force tests were made in which lift, drag, and pitching moment were measured for the wing with flaps attached and deflected various amounts at several angles of attack. Most of the tests were made with ailerons neutral, and a few arrangements were tested with the aileron deflected upward. The tests were then repeated, measuring the same components for the main part of the wing only, the flap being separately supported in position.

A series of tests was also made in which the hinge moments of the flaps were measured for different deflections at several angles of attack. The flaps were arranged to hinge freely on the wing for these tests, and were connected to a device that measured the hinge moments by means of the calibrated twist of a long slender torque rod extending along the hinge axis from the flap to the balance frame outside the air jet.

Accuracy.- The maximum variations in test results up to the stall as determined by check tests made after complete changes of experimental set-up are as follows: $C_L \pm 0.008$; $C_D \pm 0.004$; $C_H \pm 0.00009$. Beyond the stall the results are somewhat irregular, probably because of unsymmetrical flow over the wing and flap. The data were not corrected for tunnel-wall effect.

## RESULTS AND DISCUSSION

The results are given in the form of curves of lift, drag, normal-force, and hinge-moment coefficients, and center-of-pressure location, in figures 2 to 11. The coefficients are the usual absolute ones, defined as follows:

$$C_L = \frac{\text{lift}}{q\ S}$$

$$C_D = \frac{\text{drag}}{q\ S}$$

$$C_H = \frac{\text{hinge moment}}{q\ c\ S}$$

$$C_{N_1} = \frac{\text{normal force on flap}}{q\ S_f}$$

where S, total wing area, flap neutral

$S_f$, flap area

c, total wing chord, flap neutral

q, dynamic pressure

Characteristics of wing complete with split flap.- Lift, drag, and center of pressure for several flap deflections up to that for maximum lift are given for the wing with the 0.15c split flap in figure 2, and for the 0.25c split flap in figure 3. The results exhibit no unusual characteristics for the arrangements tested, and agree well with what would be expected from previous tests reported in reference 1.

Division of lift and drag between split flap and wing.- The characteristics for the 0.15c split flap are given in figure 4, and for the 0.25c split flap in figure 5. It will be seen that the lift load on the 0.15c split flap is only about 5 percent of the total lift of the wing and flap combined, at the angle of attack and flap deflection for maximum lift. For the 0.25c split flap the value is about 9 percent of the total lift for the above conditions. Deflecting the aileron up 70° had practically no effect on the division of lift between flap and wing for either of the flaps tested.

The drag load acting on the flap is greatly affected by flap deflection, the greatest proportion of the total drag being carried by the split flaps at the low angles of attack and largest flap deflections. A surprisingly high value was obtained in the case of the 0.25c flap at -7° angle of attack when deflected down 45°. The drag load on the flap was 112 percent of the total drag of the combination (fig. 5) which effect may be attributed to the interference between the flap and the main portion of the wing. With the aileron up 70°, the tendency was to reduce the drag load on the flaps somewhat.

Normal force on split flap.- The normal force acting on the split flap increases both with angle of attack and with flap deflection (figs. 6 and 7), for angles of attack below the stall. The value of the normal-force coefficient for either size of flap tested was about 1.40 at the angle of attack and deflection for maximum lift of the wing-and-flap combination. Above the stall the results are somewhat irregular, probably because of unsymmetrical stalling of the wing.

Center of pressure of load on split flap.- The center of pressure of the load on the split flap in general moves forward with decreasing flap deflection and with increasing angle of attack from small negative angles up to the stall (figs. 6 and 7). At the stall for the 0.15c split flap the variation of center of pressure is from about 26 to 45 percent of the flap chord for deflections of 15° to 30°. The most rearward position was reached at -5° angle of attack, where the variation is from 36 to 52 percent of the flap chord. At the stall for the 0.25c split flap, the center of pressure varies from about 31 to 40 percent of the flap chord (fig. 7). The most rearward position on this flap was reached at -10° angle of attack, where the variation is from 45 to 53 percent for a range of flap deflections from 15° to 45°. At greater negative angles than those for the most rearward positions of the center of pressure, the c.p. moves forward very rapidly.

Hinge moments of split flap.- Coefficients of hinge moment are plotted against angle of attack for the 0.15c flap in figure 8, and for the 0.25c flap in figure 9. Plots of $C_H$ against flap deflections $\delta_f$ are given for the respective flaps in figures 10 and 11.

The hinge moments are not much affected by changes in angle of attack except at large negative angles, where they become very small. Large increases in the hinge moments occur, however, with increasing flap deflection. With the aileron up 70°, the tendency is to increase by a small amount the hinge moments of the flaps at low flap deflections, and to decrease them at the large flap deflections. It will be noted that the hinge-moment coefficient of the 0.15c flap is about 42 percent that of the 0.25c flap when deflected to give approximately the same maximum lift coefficient.

Conventional ailerons having proportions of 0.25c by 0.40 b/2 each, when deflected equally up and down 25°, have a hinge-moment coefficient of about 0.0062 (reference 5). It is evident that the hinge moment of 0.0142 for the 0.15c full-span flap may be considerably too large for rapid and easy deflection. A reduction of the hinge moments of split flaps is very desirable, and an investigation of methods for reducing the hinge moments of conventional split flaps is now being undertaken by the Committee. In addition, pressure-distribution tests would be desirable to give the distribution of chord and span loads on the wing and the split flaps.

## CONCLUSIONS

1. The lift loads on the split flaps at the angles of attack and deflections for maximum lift were found to be 5 percent of the total for the 0.15c flap and 9 percent of the total for the 0.25c flap.

2. The ratio of drag on the flaps to total drag increased greatly with decreasing angle of attack, reaching a value of approximately unity at small negative angles of attack with the flap fully deflected.

3. The normal force on the split flap increases both with angle of attack and with flap deflection for angles of attack below the stall. The coefficient was about 1.40 at the angle of attack for maximum lift with either of the flaps tested.

4. The center of pressure of the load on the split flaps in general moves forward with decreasing flap deflection and with increasing angle of attack from small negative angles up to the stall.

5. When deflected to give approximately the same maximum lift, the hinge moments of the narrow-chord flap are about 42 percent those of the medium-chord flap, but they are considered to be still too large for rapid and easy operation.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 11, 1933.

## REFERENCES

1. Weick, Fred E., and Harris, Thomas A.: The Aerodynamic Characteristics of a Model Wing Having a Split Flap Deflected Downward and Moved to the Rear. T.N. No. 422, N.A.C.A., 1932.

2. Gruschwitz, Eugen, and Schrenk, Oskar: A Simple Method for Increasing the Lift of Airplane Wings by Means of Flaps. T.M. No. 714, N.A.C.A., 1933.

3. Wenzinger, Carl J.: The Effect of Partial-Span Split Flaps on the Aerodynamic Characteristics of a Clark Y Wing. T.N. No. 472, N.A.C.A., 1933.

4. 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.

5. Weick, Fred E., and Wenzinger, Carl J.: Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. I - Ordinary Ailerons on Rectangular Wings. T.R. No. 419, N.A.C.A., 1932.

TABLE I

Ordinates of Clark Y Section in Percent of Chord

Rad. L.E. 1.50 Rad. T.E. 0.06

| Distance from L.E. | Upper | Lower |
|---|---|---|
| 0 | 3.50 | 3.50 |
| 1.25 | 5.45 | 1.93 |
| 2.5 | 6.50 | 1.47 |
| 5 | 7.90 | .93 |
| 7.5 | 8.85 | .63 |
| 10 | 9.60 | .42 |
| 15 | 10.69 | .15 |
| 20 | 11.36 | .03 |
| 30 | 11.70 | .00 |
| 40 | 11.40 | .00 |
| 50 | 10.52 | .00 |
| 60 | 9.15 | .00 |
| 70 | 7.35 | .00 |
| 80 | 5.22 | .00 |
| 90 | 2.80 | .00 |
| 95 | 1.49 | .00 |
| 100 | .12 | .00 |

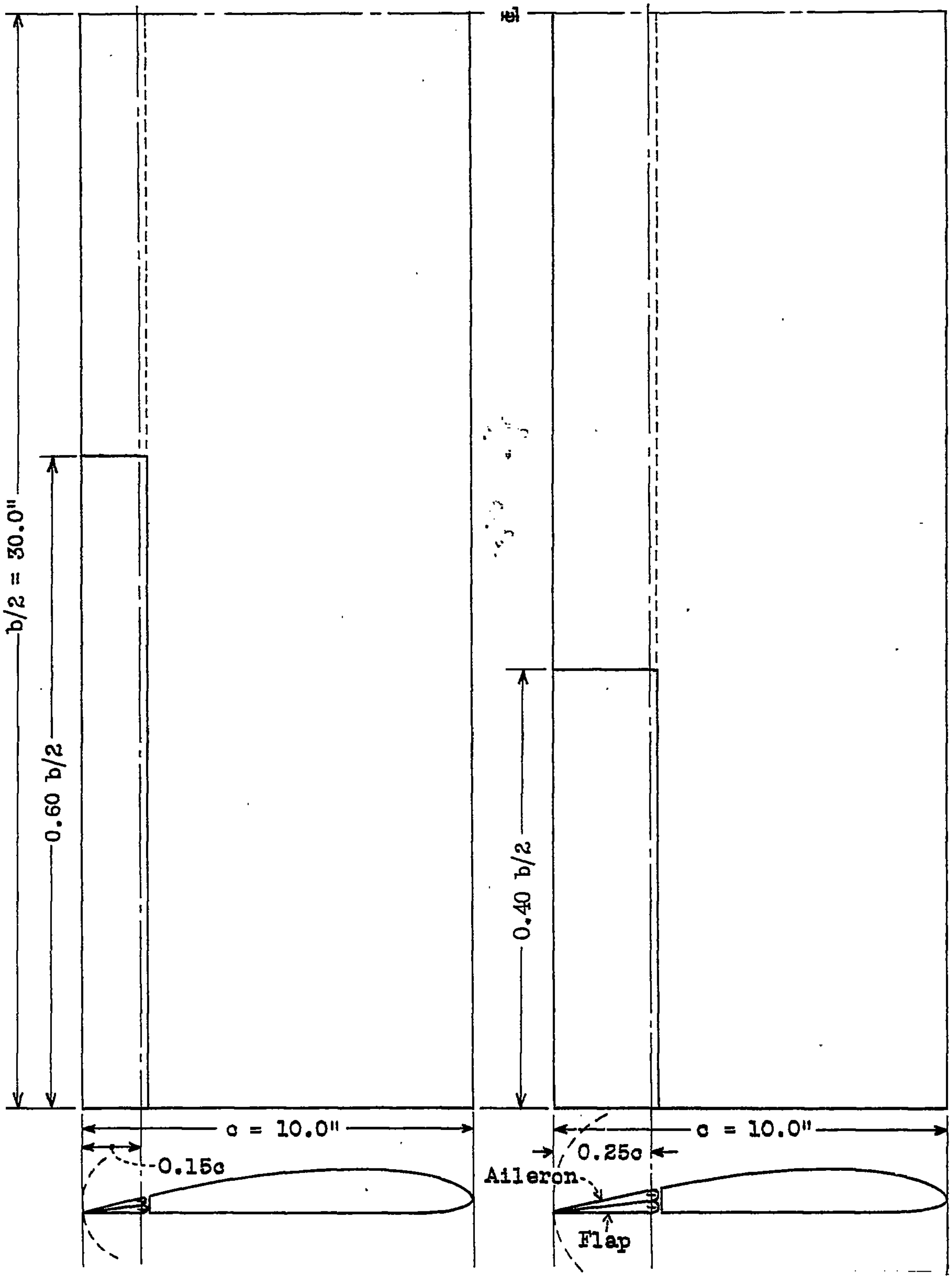


Figure 1.- Clark Y wings with split flaps and upper-surface ailerons.

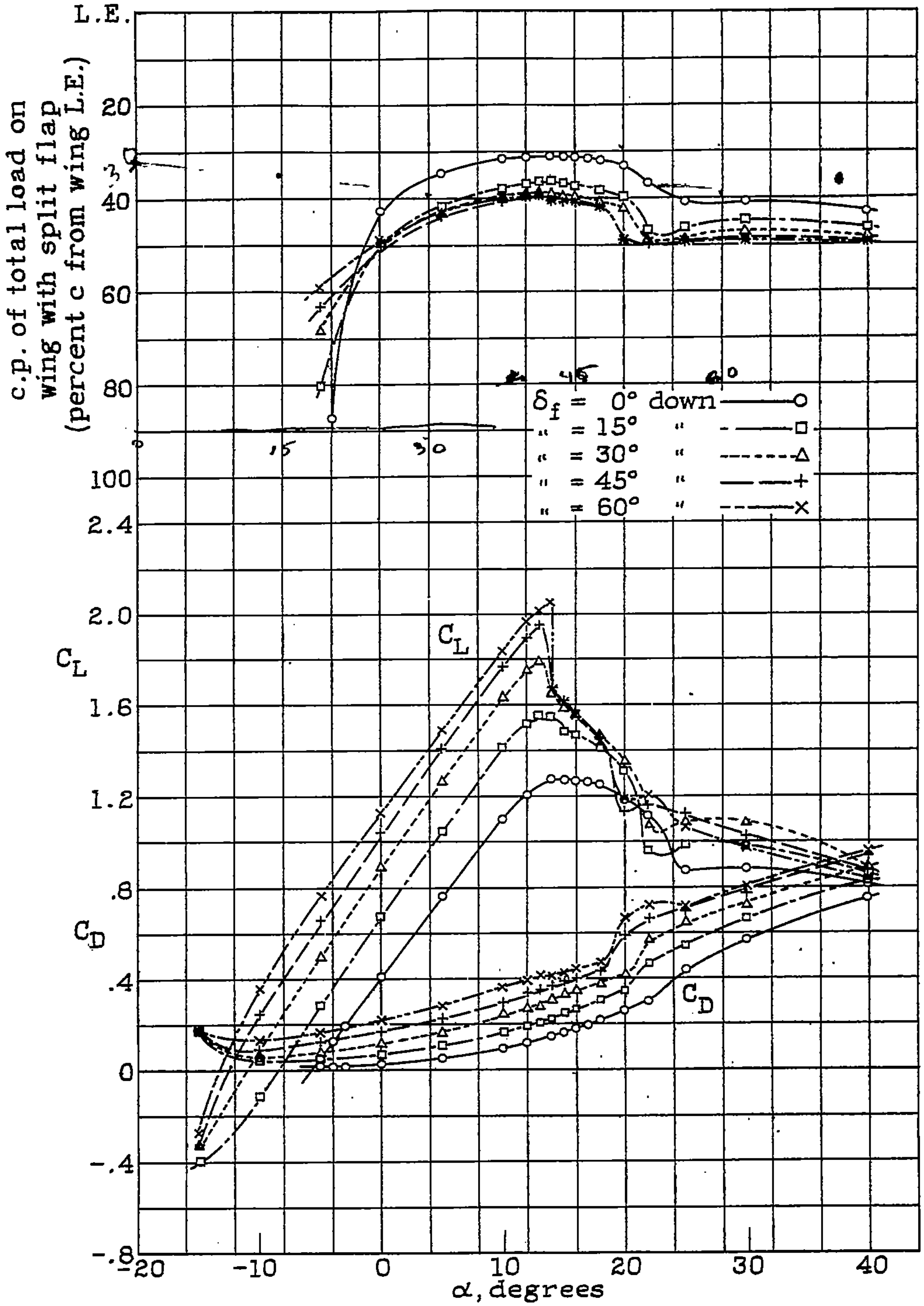


Figure 2.- Lift, drag, and center of pressure for wing with 0.15c full-span split flap.

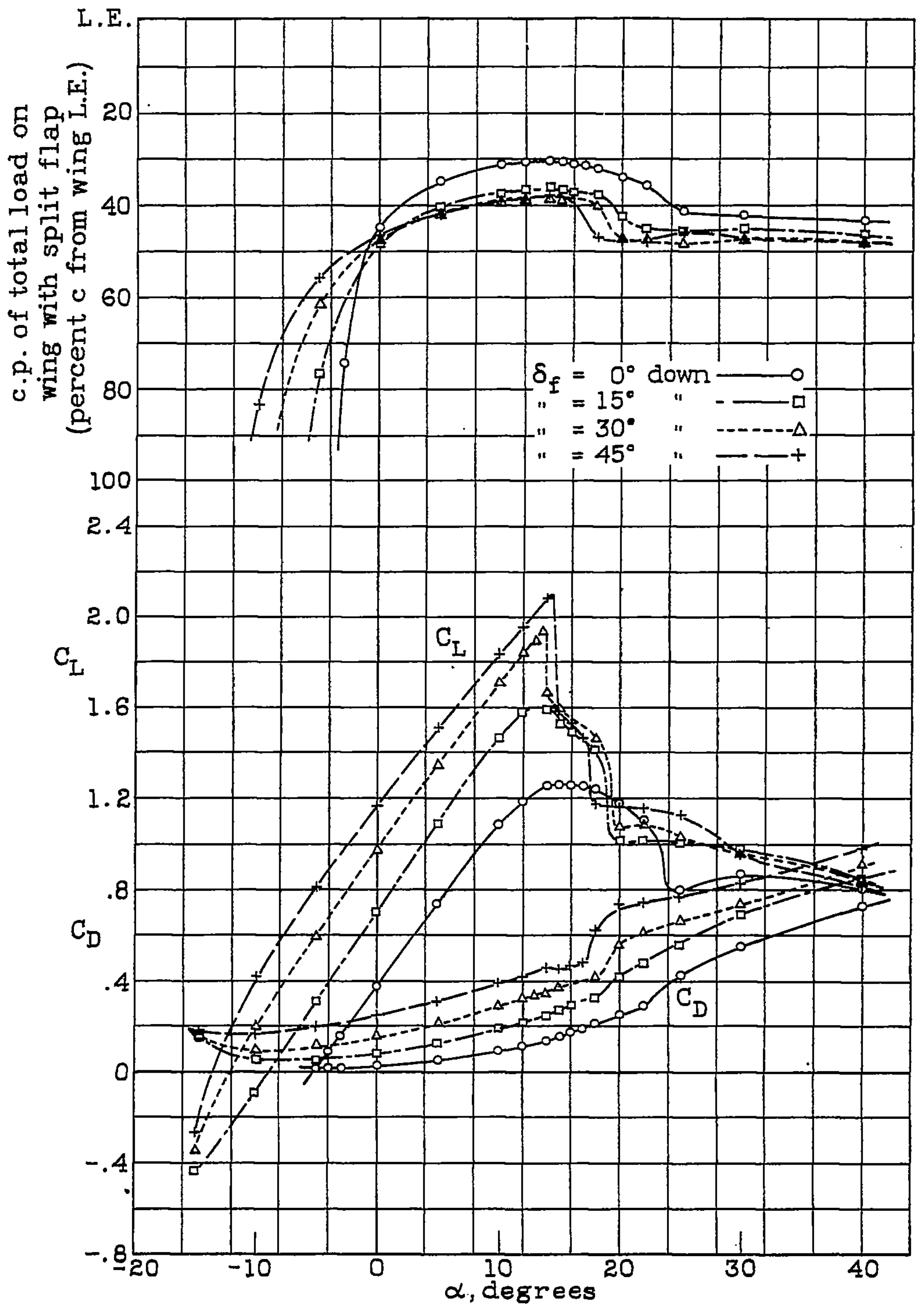


Figure 3.- Lift, drag, and center of pressure for wing with 0.25c full-span split flap.

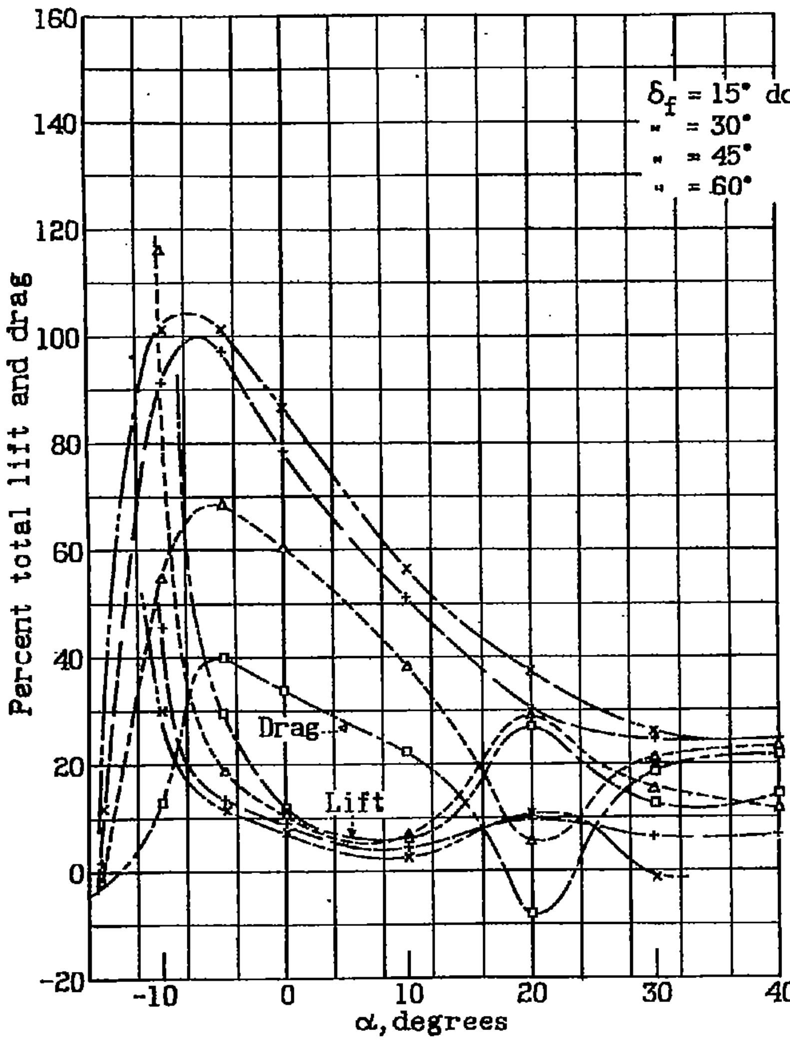


Figure 4.- Lift and drag acting on flap. 0.15c full-span split flap.

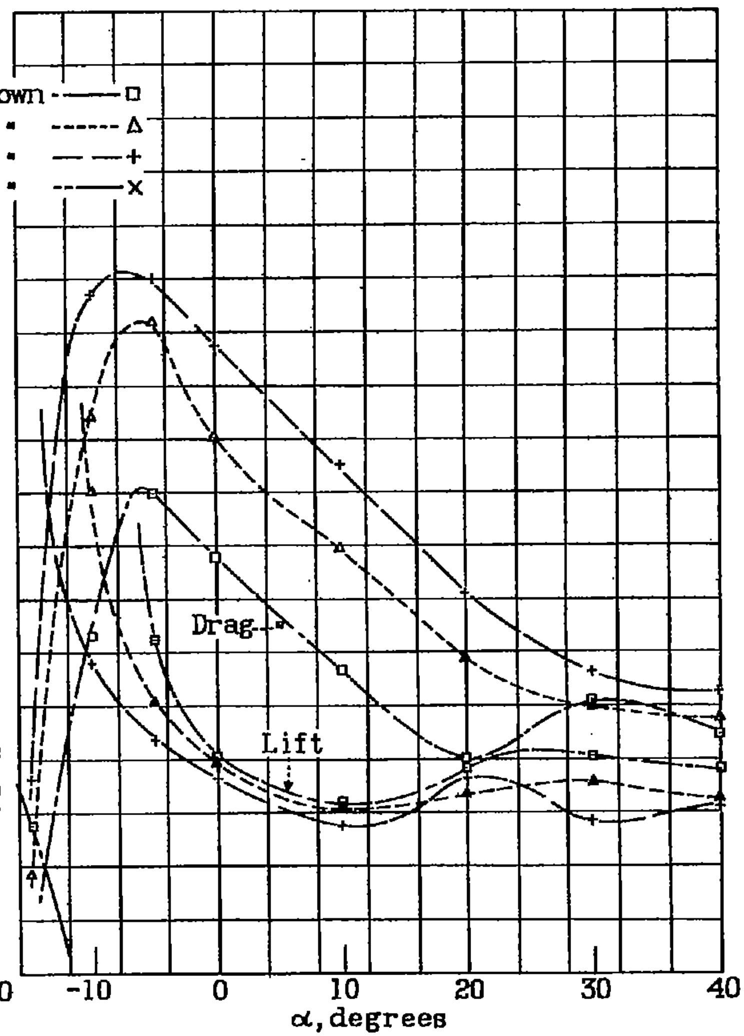


Figure 5.- Lift and drag acting on flap. 0.25c full-span split flap.

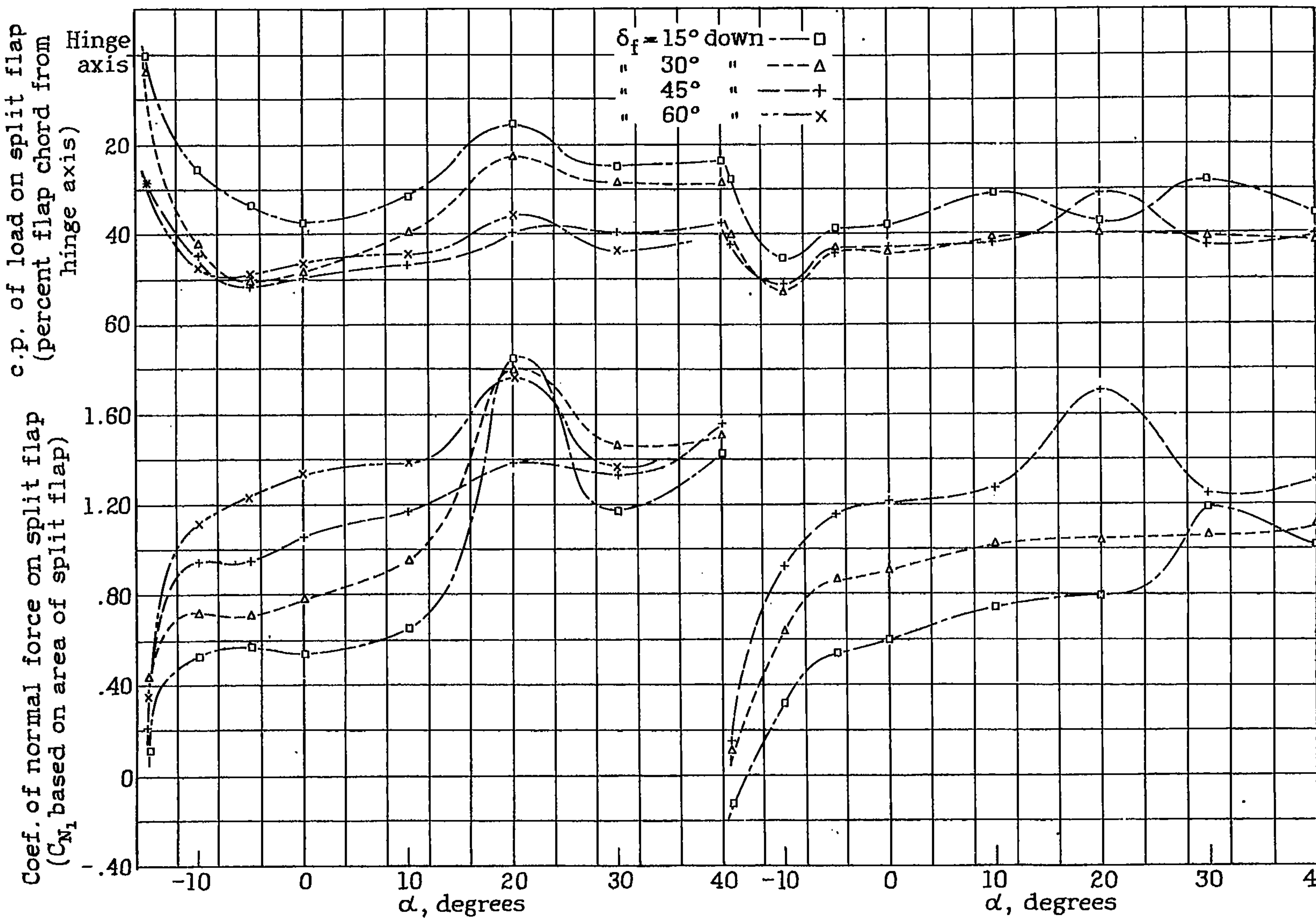


Figure 6.- Normal force and c.p. location on 0.15c full-span split flap

Figure 7.- Normal force and c.p. location on 0.25c full-span split flap

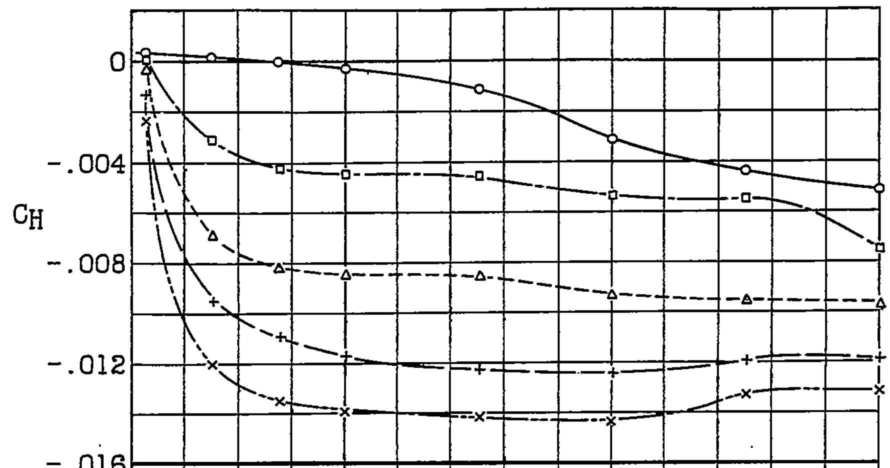


Figure 8.- Hinge moments of 0.15c full-span split flap.

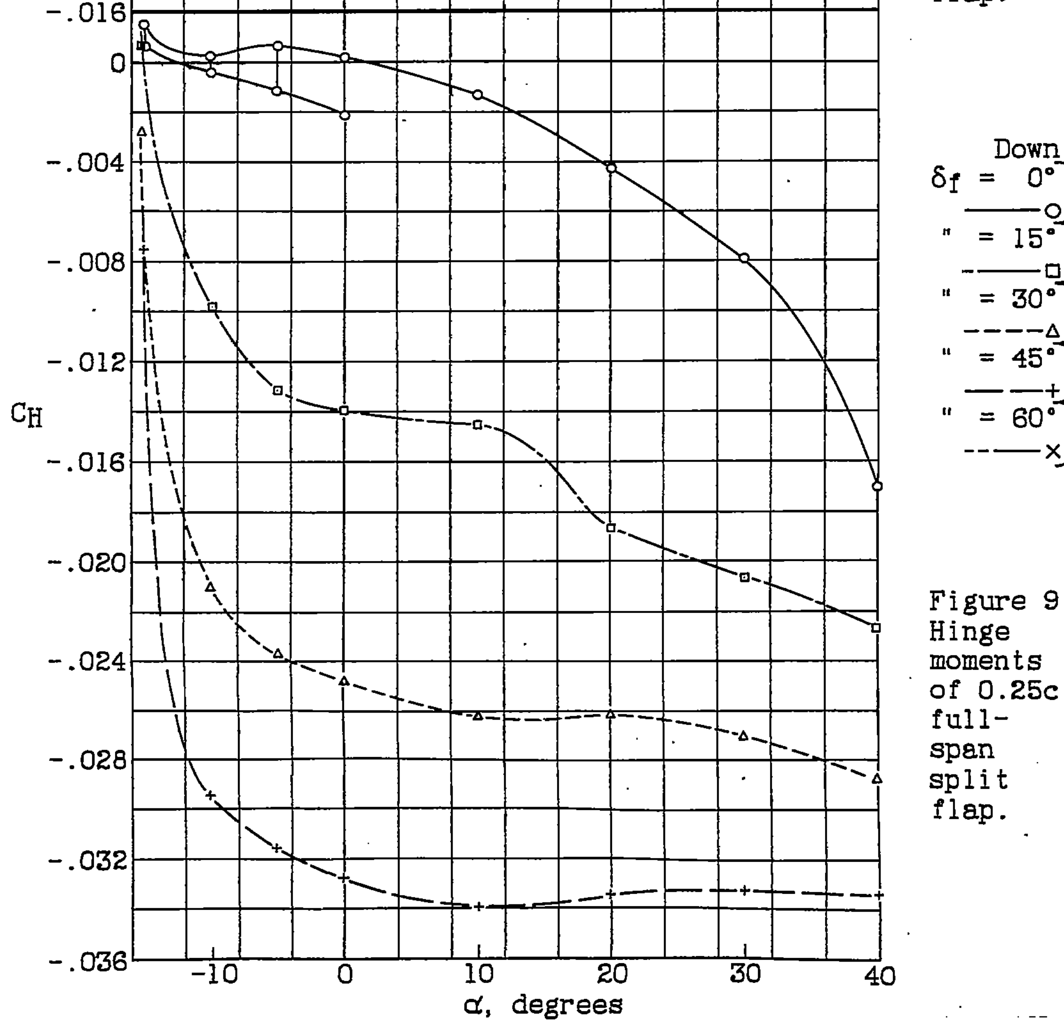


Figure 9.- Hinge moments of 0.25c full-span split flap.

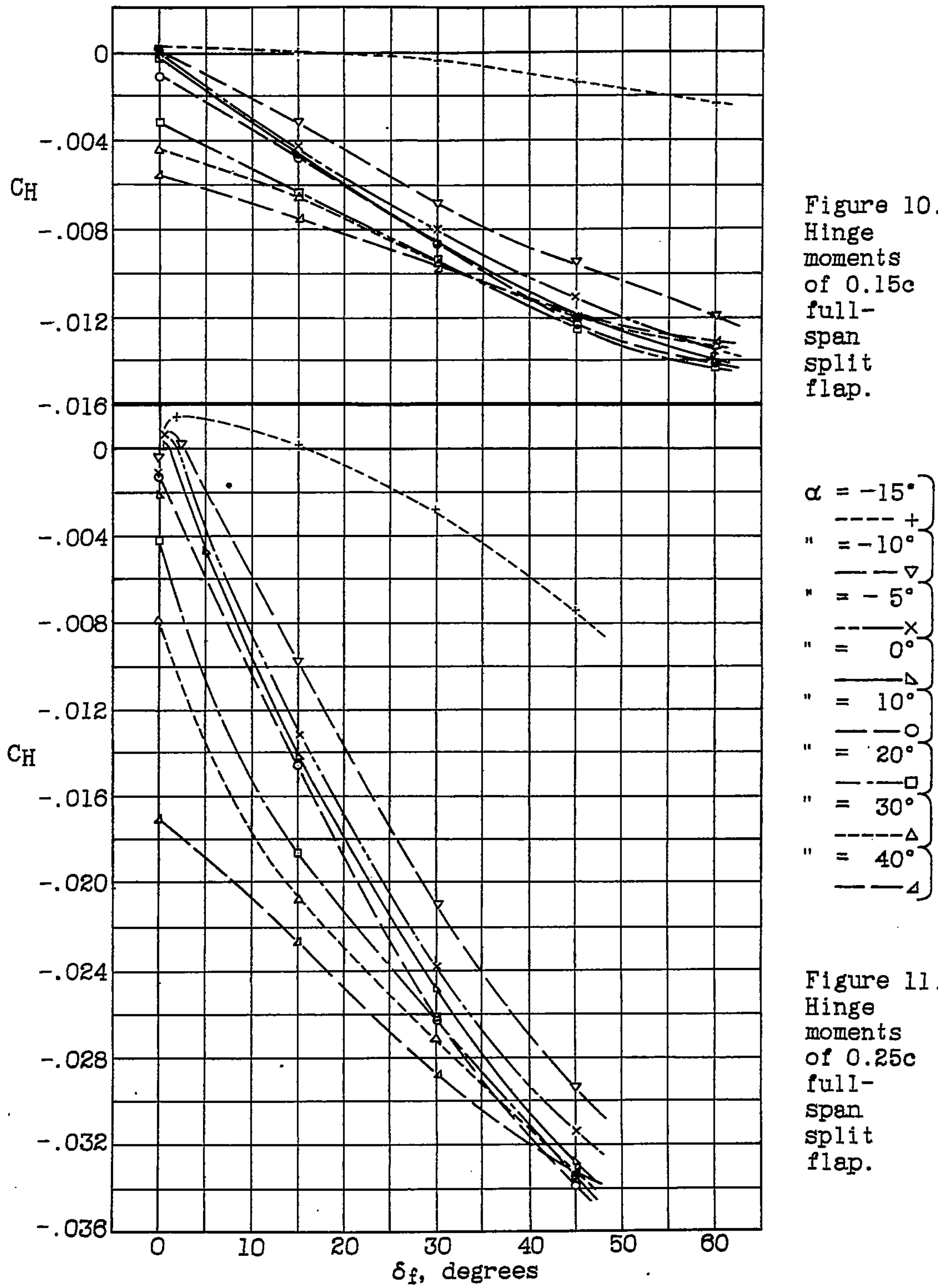


Figure 10.- Hinge moments of 0.15c full-span split flap.

Figure 11.- Hinge moments of 0.25c full-span split flap.