To: Mr. Chas. J. McCarthy

60

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

SPECIAL REPORT #23

PRELIMINARY WIND-TUNNEL AND FLIGHT TESTS OF A BALANCED SPLIT FLAP

By Fred E. Weick and Floyd L. Thompson
Langley Memorial Aeronautical Laboratory

August 1934

Special Rpt. #23

PRELIMINARY WIND-TUNNEL AND FLIGHT TESTS OF A BALANCED SPLIT FLAP

By Fred E. Weick and Floyd L. Thompson

INTRODUCTION

One disadvantage that has been apparent in the operation of split flaps as used to date is the time and effort required to operate them. In this connection an investigation is being made of possible means for balancing them aerodynamically to make their operation easier. Several arrangements have been tested in the 7 by 10 foot wind tunnel, and the results of the wind-tunnel tests as well as preliminary flight tests on one of the more promising forms are given in this paper.

WIND-TUNNEL TESTS

Apparatus and methods.- The 7 by 10 foot wind tunnel is described in reference 1 together with the balance and standard test procedure. For these tests a special model arrangement was used with which changes in the flaps could be made conveniently. The main airfoil had a chord of 20 inches and a span of 20 inches, and was located between two longitudinal vertical planes, or end plates, extending 14 inches ahead of and 14 inches behind the model and entirely through the jet vertically. Thus the flow over the airfoil was approximately two-dimensional in character. The main airfoil had the Clark Y section, and the dimensions of the flaps are shown in figure 1.

The entire series of tests, which are still under way, include both split flaps and upper-surface ailerons with many hinge-axis locations. Only one of the more promising forms, which has also been tested in flight, is considered here and the results are compared with those for a plain unbalanced split flap of the same size.

The tests were made at a dynamic pressure corresponding to a tunnel speed of 80 miles per hour in standard air, giving a Reynolds Number of approximately 1,218,000. The results are uncorrected for wind-tunnel wall effect.

Results.- Curves of lift, drag, and center of pressure are given for the balanced split flap in figure 2 and for the unbalanced one in figure 3. With the flap neutral the maximum lift coefficient with the present test arrangement was approximately the same as that with the usual model of aspect ratio 6 but with the unbalanced split flap, for which a direct comparison is available, it was about 5 percent lower (references 2 and 3). In the present tests, the maximum lift coefficient was 12 percent higher with the balanced split flap than with the unbalanced one.

The shift in the center of pressure due to flap deflection was about the same with both types of flap. The pitching-moment coefficients are given for both types in figure 4, and the hinge-moment coefficients in figure 5. The hinge moments were about 50 percent greater for the unbalanced flap than for the balanced one.

FLIGHT TESTS

Apparatus.- The balanced split flap was tested in flight on a special wing of an F-22 airplane. This wing is rectangular in form with a span of 30 feet and a chord of 66 inches. For lateral control this wing is fitted with the retractable ailerons described in reference 4. The flap (figs. 6 to 8) extended across the full span of the wing with the exception of a 3-foot cut-out at the center. The arrangement of the flap was geometrically similar to that of the model. On the full-sized airplane the flap chord was 10.7 inches and the hinge axis was located 1.6 inches below the lower surface of the flap and 2.1 inches behind the leading edge of the flap. The maximum deflection was 56°. Control of the flap was obtained by means of a 22-inch lever in the cockpit moving through an arc of 48°. This lever was connected with the flap by push-pull rods, equipped with ball-bearing joints in order to eliminate friction. The flap was constructed of laminated spruce with a fabric cover.

Tests and results.- The first flight tests showed that the force required to operate the flap was satisfactory. It was found that the flap could be operated readily at air speeds of the order of 65 m.p.h., which is the desirable air speed for operating the flap on this airplane. At this speed the pilots estimated that a force of about 25 pounds was required to deflect the flap. At the outset the flap was operated several times as the airplane approached the ground for landings. Further testing disclosed, however, that the airplane did not balance longitudinally with the control stick free when the flap was down and that it would be advisable to correct this condition for more extensive tests.

Precise measurements to determine the effect of the flap on maximum lift in flight have not been made up to the present time. The readings of the air-speed meter at minimum speed were noted, but there is some doubt as to the precision of the readings at very low speeds. The wind-tunnel results indicate that the minimum speed should be reduced about 20 percent by the use of the flap. The minimum speed of the F-22 as flown in these tests with the flap up is approximately 53 m.p.h. Thus, the flap should reduce the minimum speed to about 43 m.p.h.

The chief interest in tests with these flaps lay in determining the effect and the desirability of quick operation. In order to make further tests to determine the behavior of the airplane with the flap operated quickly under various flight conditions, it was desirable to obtain longitudinal balance and static stability at low speeds with the stick free. The center of gravity of the airplane was shifted without satisfactory results and a larger stabilizer was tried (25 percent oversize). The latter modification had to be discarded because of severe tail vibration with flaps down. A condition of stability with stick free and power off both with flaps up and flaps down was finally attained by attaching tabs to the elevators. These tabs had a chord of 2 inches, a span of 25 inches, and were deflected 10° with respect to the elevator. The airplane with power off then balanced at a speed of 62 m.p.h. with the flaps down and at a speed of 57 m.p.h. with the flaps up. A more satisfactory condition would be one in which the order of the speeds was reversed, but with the balance obtained it was possible to proceed with the additional tests desired.

Several tests were made to determine the behavior of the airplane when the flap was operated quickly. With the airplane gliding steadily at 57 m.p.h. with the flap up and stick free, it was found that quick operation of the flap caused a smooth transition to a steady glide at 62 m.p.h. with corresponding changes in attitude and flight path. With the airplane gliding steadily at 62 m.p.h. with the flap down and stick free, quick operation of the flap caused a momentary increase in speed with one or two oscillations during the transition to a steady glide at 57 m.p.h.

Another type of test was made with the stick held back to obtain a steady glide at close to minimum speed with the flaps down. The flaps were then closed quickly and the stick released so that it was free to assume the position corresponding to a gliding speed of 57 m.p.h. with the flap up. This procedure would seem to be about the worst possible that a pilot could attempt with flaps for it leaves the airplane flying at a speed considerably less than the stalling speed with the flaps closed. The effect as observed by the pilot was that the airplane seemed to drop appreciably, then nose over, pick up speed rapidly, and oscillate several times before the new steady gliding condition with flaps up was attained. This type of operation was repeated several times at an altitude of about 500 feet so that the ensuing motion could be observed from the ground. The decided change in attitude and rapid increase in speed were obvious features that could be detected without difficulty. The most interesting feature of the ground observations concerns the change in flight path. By sighting along a straight edge held parallel to the original flight path with flap down an observer could tell that there was very little, if any, increase in steepness of the glide angle over that corresponding to the flap-down condition. The original flight path was apparently maintained for a considerable distance while the airplane picked up speed, so that the rate of descent actually was considerably increased. As the increase in air speed was observed to be of the order of 50 percent, the increase in rate of descent would appear to be of the same order. Following the phase of the motion wherein the speed increased, there appeared to be a fairly smooth transition to the flatter gliding path corresponding to the condition of flaps up. Further experiments then showed that by the use of the elevators the change in attitude and air speed could be greatly reduced and the oscillations eliminated, the entire transition to the new gliding condition being made fairly smoothly.

<u>Discussion</u>.- It should be appreciated that the attainment of hinge moments permitting the flap to be operated quickly by means of a simple lever was achieved to some extent by the use of a narrow-chord flap as well as by offsetting the hinge axis from the leading edge of the flap. The wind-tunnel tests indicate, however, that the flap is

as effective as a plain split flap of appreciably greater chord so that the small hinge moments attained from both sources are attributable to the balanced type of flap.

From the tests of quick operation of the flap it was concluded that deflecting the flap quickly from its closed position has no dangerous results if the tail is designed to take care of the new conditions of longitudinal balance. The attainment of longitudinal balance and stability with flaps is, however, not a specific problem concerned with the use of a quickly operated flap. A sudden closing of the flap at minimum speed with flaps down is, of course, potentially dangerous when performed at very low altitudes. With the exercise of reasonable judgment, however, it seems unlikely that quick operation of the flap can be regarded as anything but an unqualified advantage over the type of operation that requires considerable time and effort. At the present time it is planned to proceed with further tests in which actual measurements of the motion following quick operation of the flap will be made.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 20, 1934.

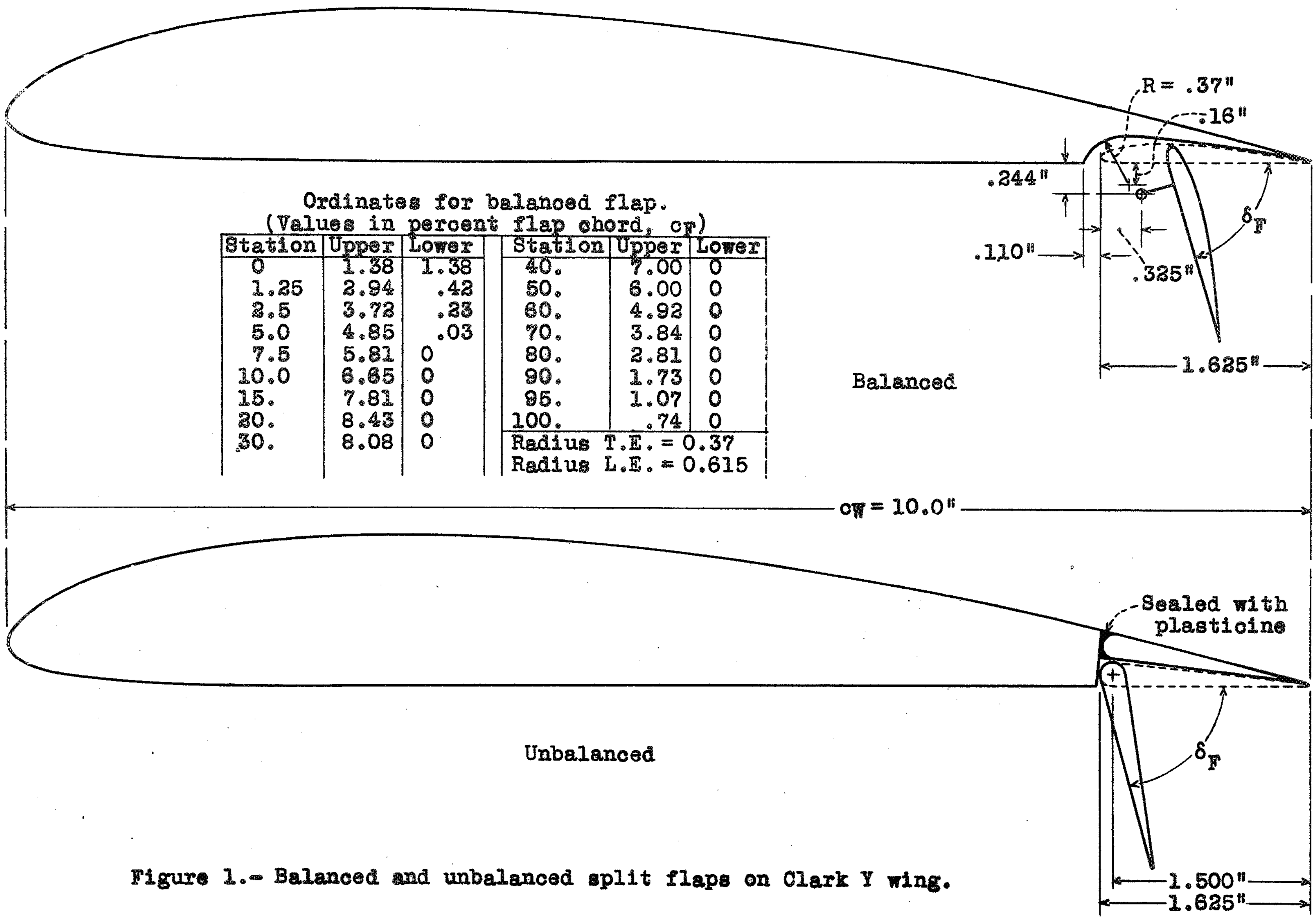
REFERENCES

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. Wenzinger, Carl J.: Wind-Tunnel Measurements of Air Loads on Split Flaps. T.N. No. 498, N.A.C.A., 1934.

3. Weick, Fred E., and Wenzinger, Carl J.: Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. XII - Upper-Surface Ailerons on Wings with Split Flaps. T.R. No. 499, N.A.C.A., 1934.

4. Thompson, Floyd L.: Retractable Ailerons for Use with Flaps. N.A.C.A. (Confidential) Memo. Report, December 1933.



Ordinates for balanced flap.
(Values in percent flap chord, c_F)

Station	Upper	Lower	Station	Upper	Lower
0	1.38	1.38	40.	7.00	0
1.25	2.94	.42	50.	6.00	0
2.5	3.72	.23	60.	4.92	0
5.0	4.85	.03	70.	3.84	0
7.5	5.81	0	80.	2.81	0
10.0	6.65	0	90.	1.73	0
15.	7.81	0	95.	1.07	0
20.	8.43	0	100.	.74	0
30.	8.08	0	Radius T.E. = 0.37		
			Radius L.E. = 0.615		

Figure 1.- Balanced and unbalanced split flaps on Clark Y wing.

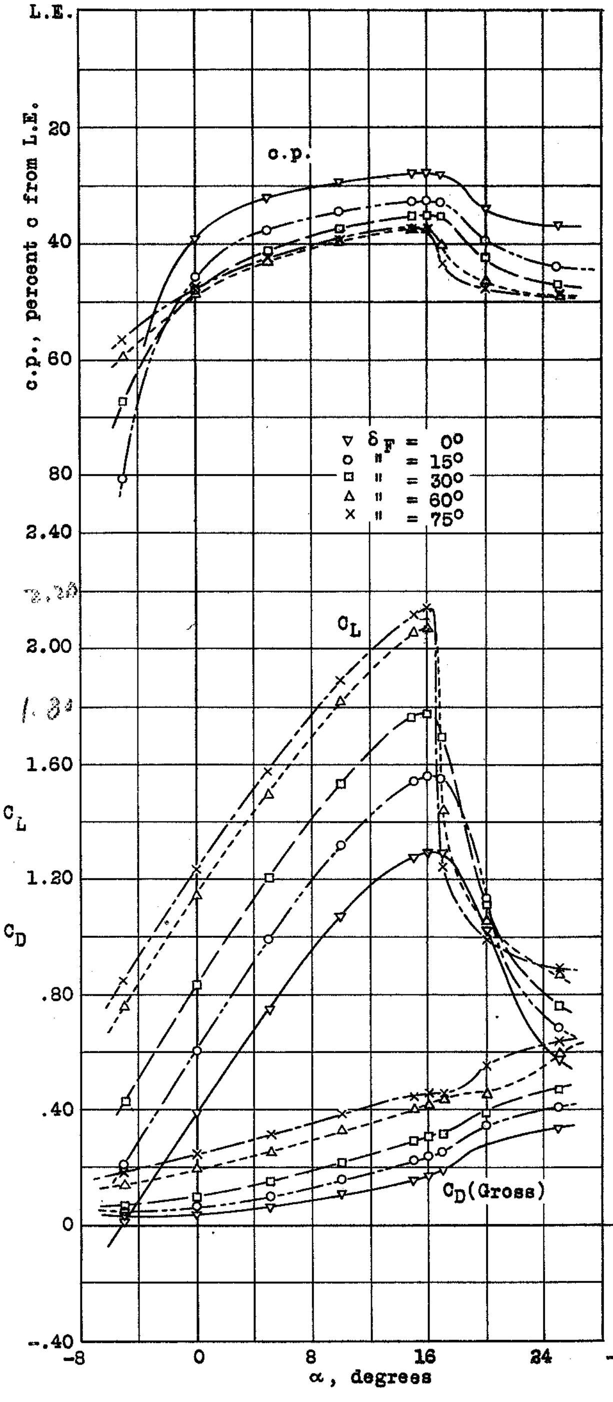


Figure 2.- Lift, drag, and c.p. for wing with balanced split flap.

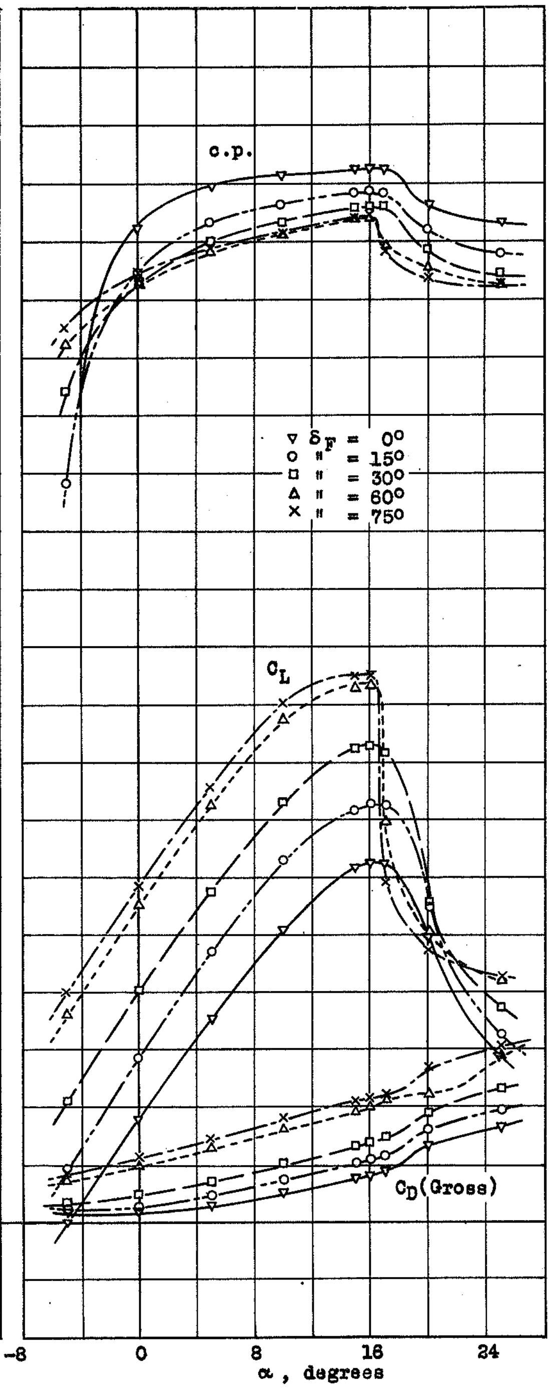


Figure 3.- Lift, drag, and c.p. for wing with unbalanced split flap.

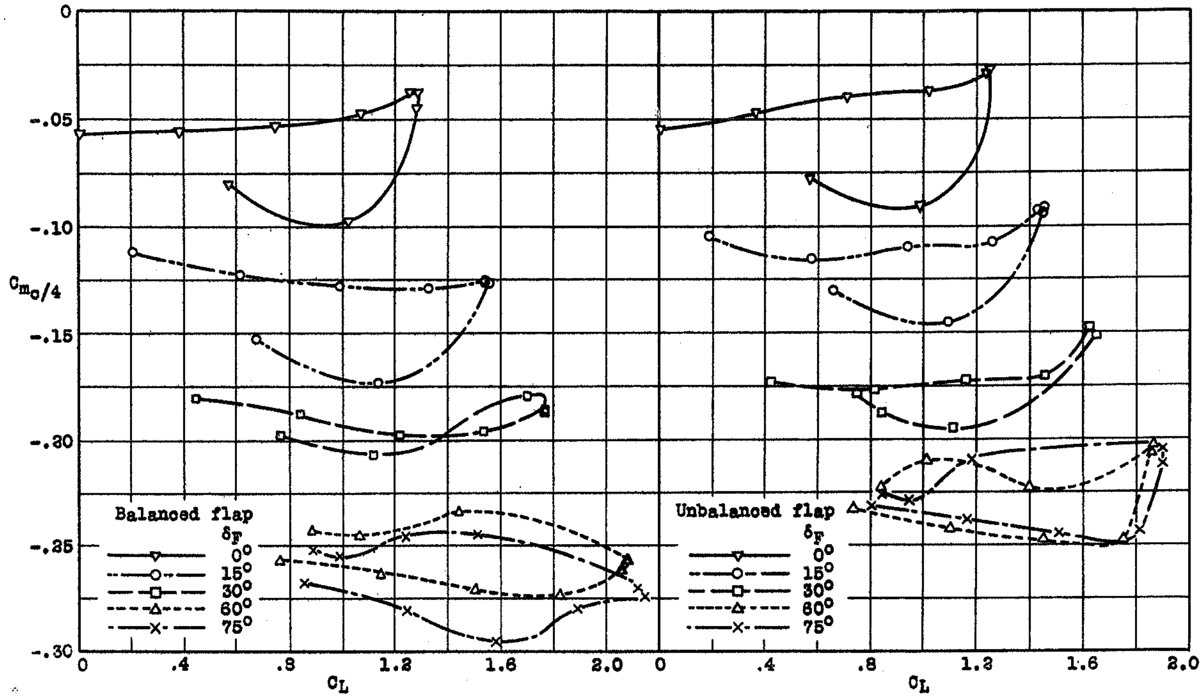


Figure 4.- Pitching-moment coefficient variation with lift coefficient for balanced and unbalanced flaps.

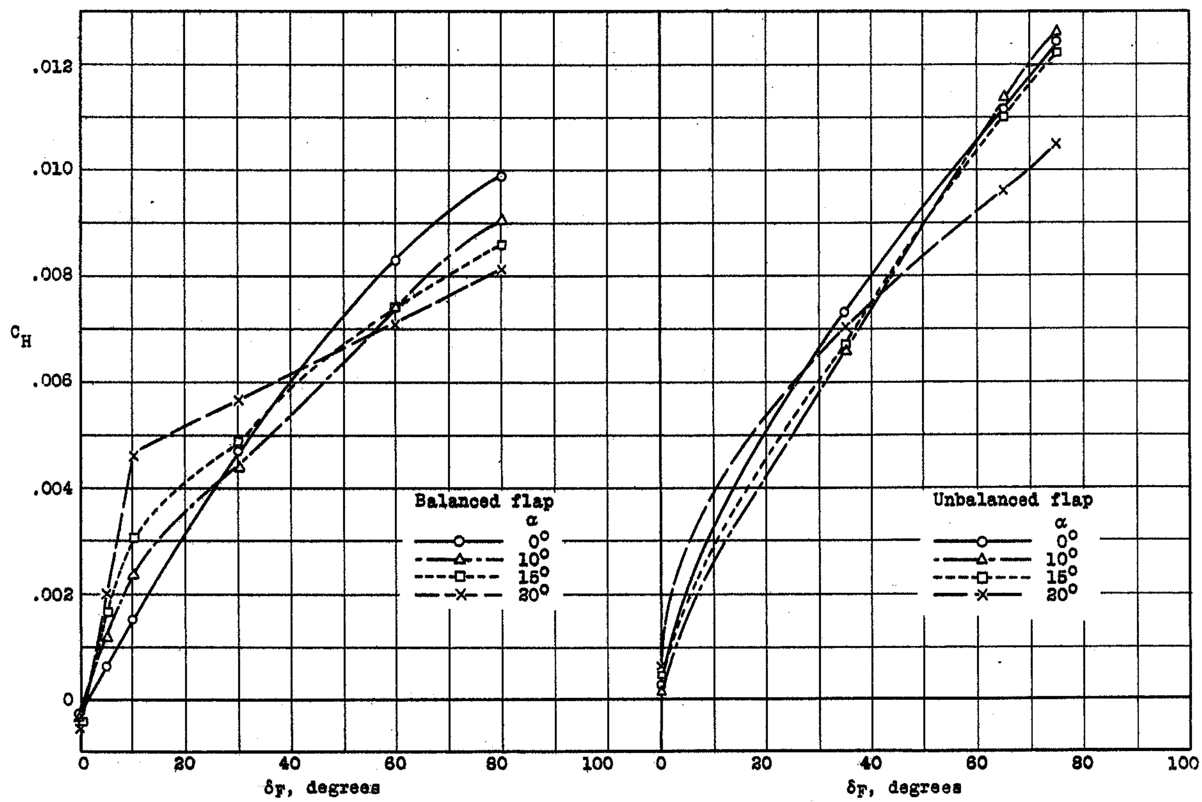


Figure 5.- Hinge-moment coefficient variation with flap deflection for balanced and unbalanced flaps.

Figure 6.- F-22 airplane with balanced split flap and retractable ailerons. Left aileron deflected.

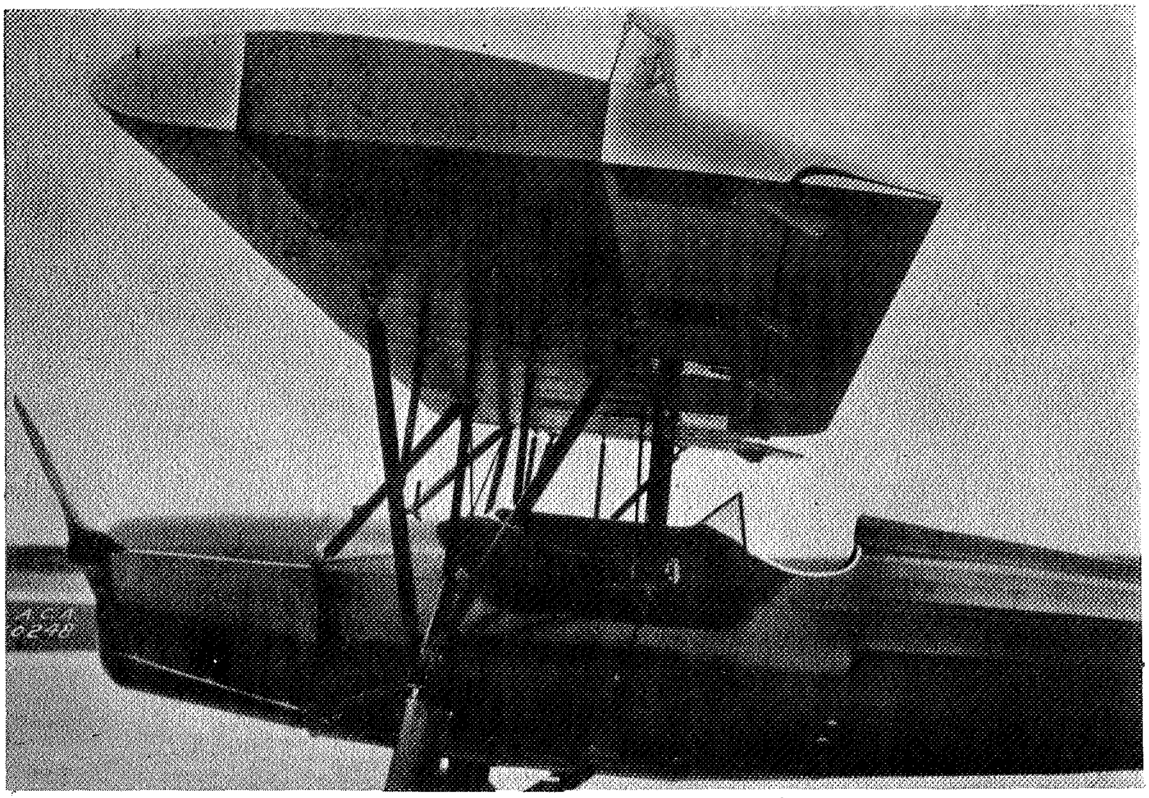


Figure 7.- Flap retracted.

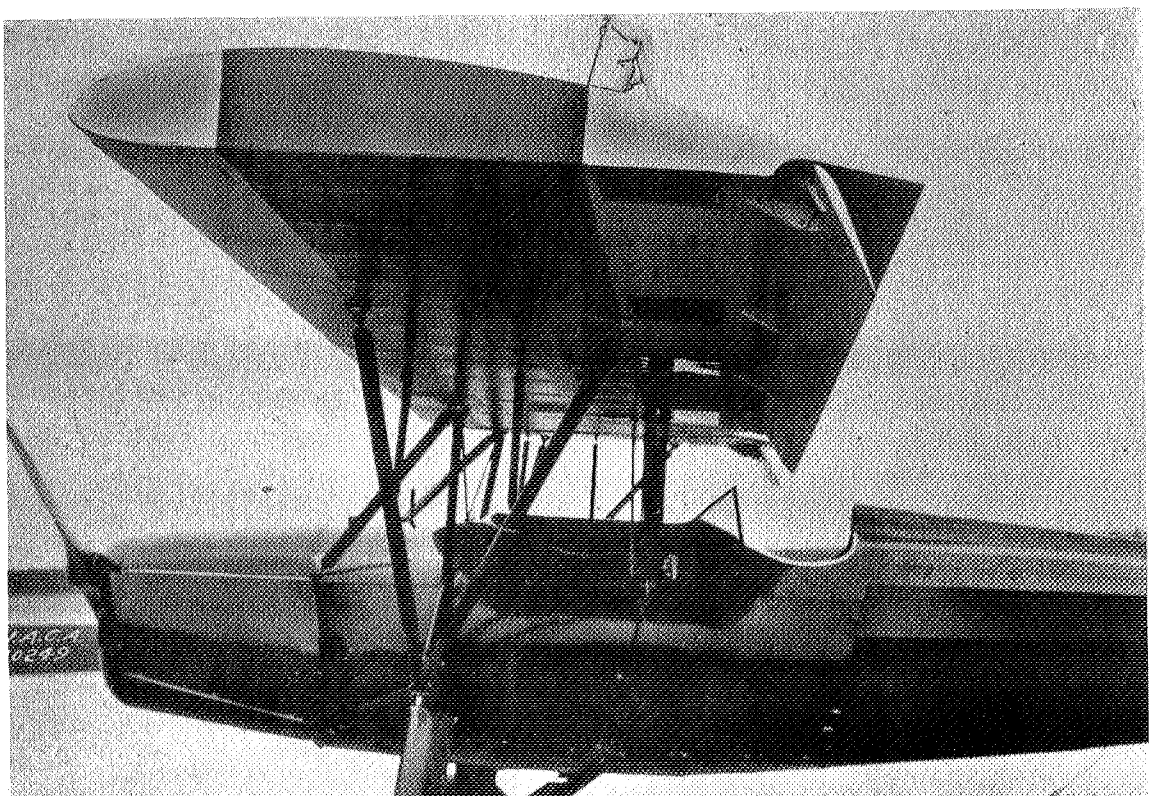


Figure 8.- Flap deflected.