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WIND-TUNNEL INVESTIGATION OF PLAIN AILERONS FOR A WING WITH A FULL-SPAN FLAP CONSISTING OF AN INBOARD FOWLER AND AN OUTBOARD RETRACTABLE SPLIT FLAP

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SUMMARY

An investigation was made in the NACA 7- by 10-foot wind tunnel of three plain ailerons on an NACA 23012 wing with full-span combinations of Fowler and split-type flaps. The static rolling, yawing, and hinge moments were determined and are presented for several angles of attack and flap deflections. In addition, the lateral-control characteristics were computed for a typical pursuit airplane with two of the arrangements.

The results indicated that a plain sealed aileron with internal balance will provide lateral control for airplanes equipped with full-span combinations of slotted and split-type flaps. Flight tests of at least one of the combinations are recommended.

INTRODUCTION

The NACA has undertaken an extensive investigation for the purpose of developing lateral-control devices suitable for use on wings equipped with full-span trailing-edge high-lift devices. In this investigation, a plug-type, spoiler-slot aileron has been developed that gave satisfactory lateral control on a wing with a full-span slotted flap but was unsatisfactory for use with a split flap. A more complicated lateral-control system, which consists of a plain aileron on the trailing edge of a slotted flap in conjunction with a slot-lip aileron, has also been developed. (See references 1 and 2.) From the wind-tunnel results, both of these devices appear satisfactory for use on a wing with a full-span slotted flap;

flight tests are planned. A type of lateral-control device that has proved satisfactory for use with full-span retractable split flaps is the plain aileron. Wind-tunnel and flight tests of this device are reported in references 3 and 4.

The present tests were made to determine the characteristics of a plain aileron on a wing with an outboard retractable split-type flap and an inboard flap of a type giving a higher lift and lower drag than the split flap. The Fowler flap was selected for the inboard location because it is believed to be a representative slotted-type flap and it gave the largest increment in maximum lift coefficient of any of the single slotted flaps investigated. (See reference 5.)

From the test results the lateral-control characteristics were computed for a typical pursuit airplane with plain sealed ailerons with and without balance and two combinations of Fowler and split-type flaps.

APPARATUS AND METHODS

All tests were made in the NACA 7- by 10-foot closed-throat wind tunnel (reference 5) at an air speed of about 40 miles per hour, corresponding to a test Reynolds number of approximately 1,440,000. The test set-up is shown schematically in figure 1. The 0.30c Fowler flap was installed on the inboard 0.63 b/2 of the 4- by 8-foot NACA 23012 wing and the ailerons and the split-flap arrangements (references 3, 4, and 6) were installed on the outboard 0.37 b/2 of the wing.

The wing was suspended horizontally in the wind tunnel with the inboard end attached to the tunnel wall to simulate the semispan of a 16-foot wing. The attachment at the wall restrained the wing in pitch but not in roll or yaw. The forces necessary to restrain the outboard end of the wing were measured by the regular balance system. The rolling moments were computed from the difference in the vertical reactions at the outboard end with the aileron neutral and deflected; the yawing moments were similarly computed from the horizontal reactions. The lift coefficients of the wing with aileron and flaps neutral were computed from the vertical outboard reaction and the assumption that the lateral center of pressure of

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the semispan was 0.45 b/2 from the plane of symmetry. This method of computation was not used with flaps down because the type and the deflection of the flaps changed along the span. The lift coefficients for the wing with the flaps deflected were estimated from data in references 5, 6, 7, 8, and 9.

The aileron was manually operated by a crank outside the tunnel near the inboard end of the wing, and the hinge moments were computed from the twist of a calibrated torque rod connecting the crank and the aileron.

The aileron-flap combinations tested are shown in figure 2.

RESULTS AND DISCUSSION

Coefficients

The results of the tests are presented in figures 3 to 19 as curves of rolling-, yawing-, and hinge-moment coefficients plotted against aileron deflection at several angles of attack for each aileron-flap combination.

The symbols used in presenting the results are:

C_L lift coefficient (L/qS)

C_l' rolling-moment coefficient (L'/qbS)

C_n' yawing-moment coefficient (N'/qbS)

C_h aileron hinge-moment coefficient (H_a/qS_ac_a)

c wing chord

c_a aileron chord measured along the airfoil chord line from the hinge axis of the aileron to the trailing edge of the airfoil

b twice span of semispan model

S twice area of semispan model

S_a aileron area behind hinge line

L	twice lift on semispan model
L'	rolling moment about wind axis
N'	yawing moment about wind axis
H_a	aileron hinge moment
q	dynamic pressure of air stream
δ_{f_1}	deflection of inboard Fowler flap
δ_{f_2}	deflection of outboard split flap
α	angle of attack of wing in tunnel

A positive value of L' or C_l' corresponds to a decrease in lift on the model, and a positive value of N' or C_n' corresponds to an increase in drag on the model. Twice the actual lift, area, and span of the model were used in the reduction of the results because the model represents half of a complete wing, as has been previously stated. No corrections have been made to the data for the effect of the tunnel walls. Such corrections may be relatively large for this set-up.

Wind-Tunnel Data

Plain sealed aileron and plain split flap.- The aerodynamic characteristics of the plain aileron with a grease seal and the outboard plain split flap are shown in figures 3 to 7. The rolling-moment coefficients produced by the aileron are largest with only the inboard flap deflected and decreased as the outboard flap was deflected, especially for positive aileron deflections when the flap blanketed the aileron. As reported in references 3 and 4, the adverse yawing-moment coefficients encountered with the outboard flap neutral were decreased when the flap was deflected. The aileron had large hinge-moment coefficients and an up-floating tendency with the split flap neutral but had smaller hinge-moment coefficients and a down-floating tendency with the flap deflected. One test made with the gap at the nose of the aileron unsealed (fig. 3) showed that the presence of even a small gap (0.0007c) decreased the aileron effectiveness. This result is in agreement with previous data.

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Balanced ($0.30c_a$) sealed aileron and plain split flap.- The aerodynamic characteristics of the aileron with a sheet rubber seal and with a $0.30c_a$ unfaired balance and the outboard plain split flap are presented in figures 8 to 12. These data indicate that, in general, this combination provided slightly smaller rolling- and yawing-moment coefficients than the plain sealed aileron and that the balance was not as effective as expected.

Balanced ($0.30c_a$) sealed aileron and balanced split flap.- The aerodynamic characteristics of the aileron with a sheet rubber seal and with a $0.30c_a$ unfaired balance and the balanced split flap are given in figures 13, 14, and 15. The results show that when the outboard flap was deflected, this combination was more effective for lateral control than the same aileron with a plain split flap and that it had smaller hinge-moment coefficients but about the same down-floating tendency. The dip in the hinge-moment coefficient curve at δ_a of about -20° with the outboard flap deflected was probably caused by the fact that the nose of the aileron, when deflected, extended below the lower surface of the main wing. (See fig. 2(d).)

Balanced ($0.35c_a$) sealed and faired aileron and balanced split flap.- The aerodynamic characteristics of the aileron with a sheet rubber seal and with $0.35c_a$ faired balance and the balanced split flap are shown in figures 16 through 19. The aileron with the $0.35c_a$ balance was slightly more effective than the aileron with the $0.30c_a$ balance, probably because the one with the $0.35c_a$ balance had a better shape (arc at top and bottom instead of sharp corners) and a different hinge location (midway between the surfaces instead of near the lower surface). With the flaps deflected 40° the rolling-moment coefficient curve was steep at small negative aileron deflections (fig. 18). This abrupt change was smoothed out by locating the nose of the balanced split flap 0.01c below the lower surface of the wing (figs. 2(e) and 19). The change in flap-nose location also practically eliminated the dip in the hinge-moment coefficient curve.

Application of Data

The lateral-control characteristics have been computed for a typical pursuit airplane (fig. 20) equipped with a 0.30c inboard Fowler flap and with two combinations of 0.15c by 0.37 b/2 sealed ailerons and 0.20c by 0.37 b/2 outboard retractable split-type flaps. The combinations investigated were: (1) the plain aileron and plain split flap (fig. 2(b)) and (2) the balanced aileron with $0.35c_a$ balance and the balanced split flap located 0.01c below the wing lower surface (fig. 2(e)). An equal up-and-down deflection of the ailerons was assumed for all computations because of the change in floating tendency of the ailerons from the flap-neutral to the flap-deflected condition and also, in general, the rolling-moment coefficient produced for a given deflection was greatest for the equal up-and-down deflection arrangement.

The lateral-control characteristics presented in figure 21 were computed from the data in figures 3, 6, 16, and 19, using the aerodynamic characteristics of the ailerons without any corrections and without taking account of the difference in wing plan form. The lift coefficient of the airplane at any particular angle of attack and flap deflection was assumed to be that of the wing in the tunnel, computed as described under Apparatus and Methods. These lift coefficients may not, however, be realized on the airplane.

The results (fig. 21(a)) show that both the plain and the balanced ailerons give about equal rolling-moment coefficients with the flap completely retracted. The adverse (negative) yawing-moment coefficients for a given rolling-moment coefficient are, however, less for the plain aileron than for the balanced aileron; whereas the stick forces, as would be expected, are less for the balanced aileron. The maximum stick force with full aileron deflection for the high-speed flight condition is about 25 percent less for the balanced aileron than for the plain aileron.

With both flaps extended and deflected (fig. 21(b)), the rolling-moment coefficients are greater for the balanced aileron in combination with the balanced split flap than for the plain aileron and plain split flap combination. This result was anticipated because the wind-tunnel data previously presented showed the ailerons to be more effective with the balanced than with the plain split flap. The adverse (negative) yawing-moment coefficients for a given rolling-moment coefficient are less with the flaps extended and deflected than with the flaps retracted.

For the low angle-of-attack condition the yawing-moment coefficients are favorable (positive). The stick forces, as is to be expected, are less for the balanced aileron but in no case are they very large because of the relatively low speeds considered.

Computations made, as outlined in reference 10, of the reduction in stick force due to rolling showed that neither of the aileron arrangements would be over-balanced.

CONCLUDING REMARKS

The results of the tests indicated that lateral control could be obtained with plain sealed ailerons on a wing with an inboard Fowler flap and an outboard split-type flap. The rolling-moment coefficients produced by a given aileron deflection were larger for the aileron in combination with a deflected retractable balanced split flap than with the deflected retractable plain split flap. It is believed, moreover, that the lateral control system will work equally well with any other type of inboard flap.

Flight tests of a wing with an inboard flap of the slotted type, a sealed aileron with a faired $0.35c_a$ balance, and an outboard retractable balanced split flap located 0.01c below the wing lower surface are recommended.

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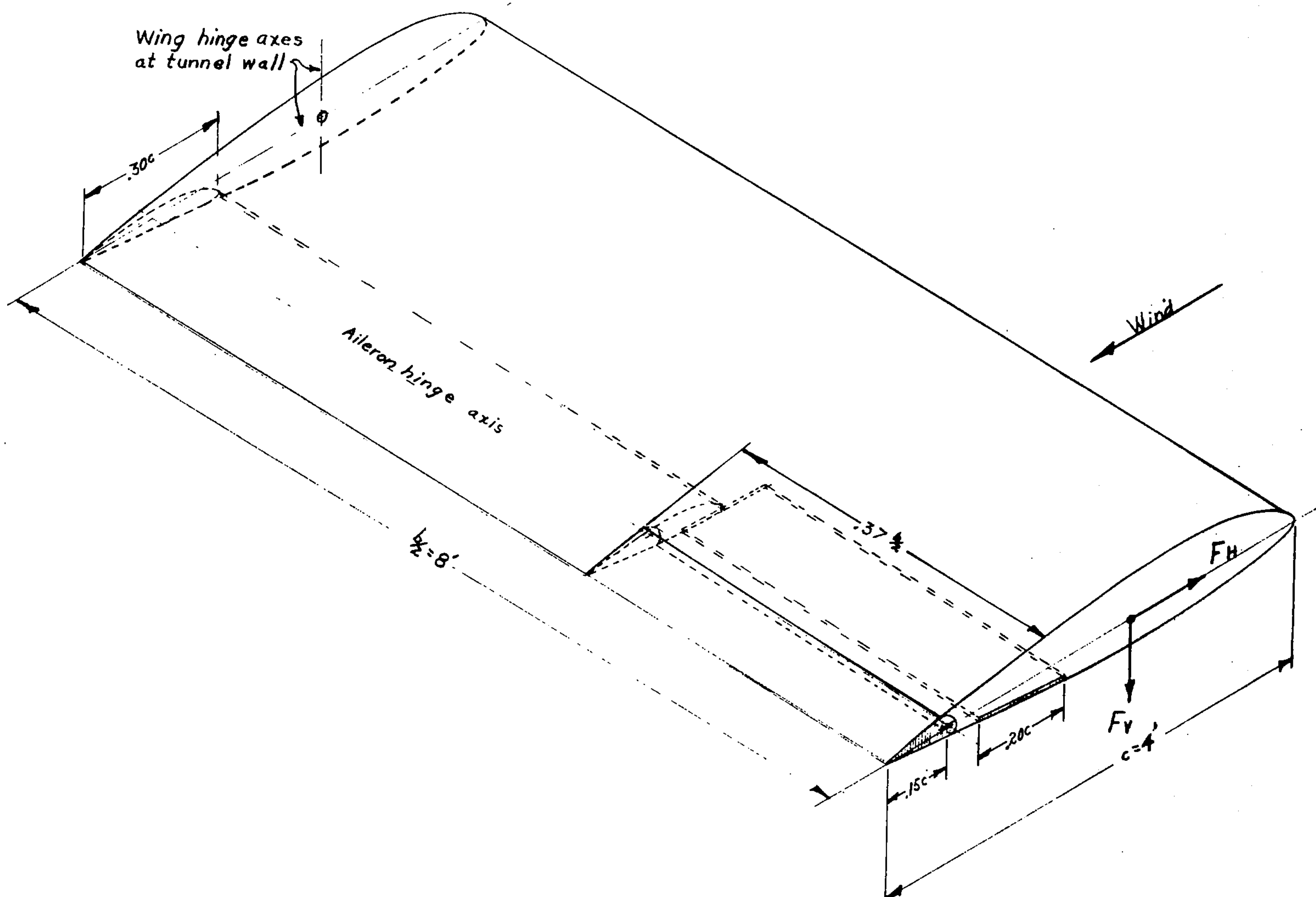


FIGURE 1.- Schematic diagram of test set-up.

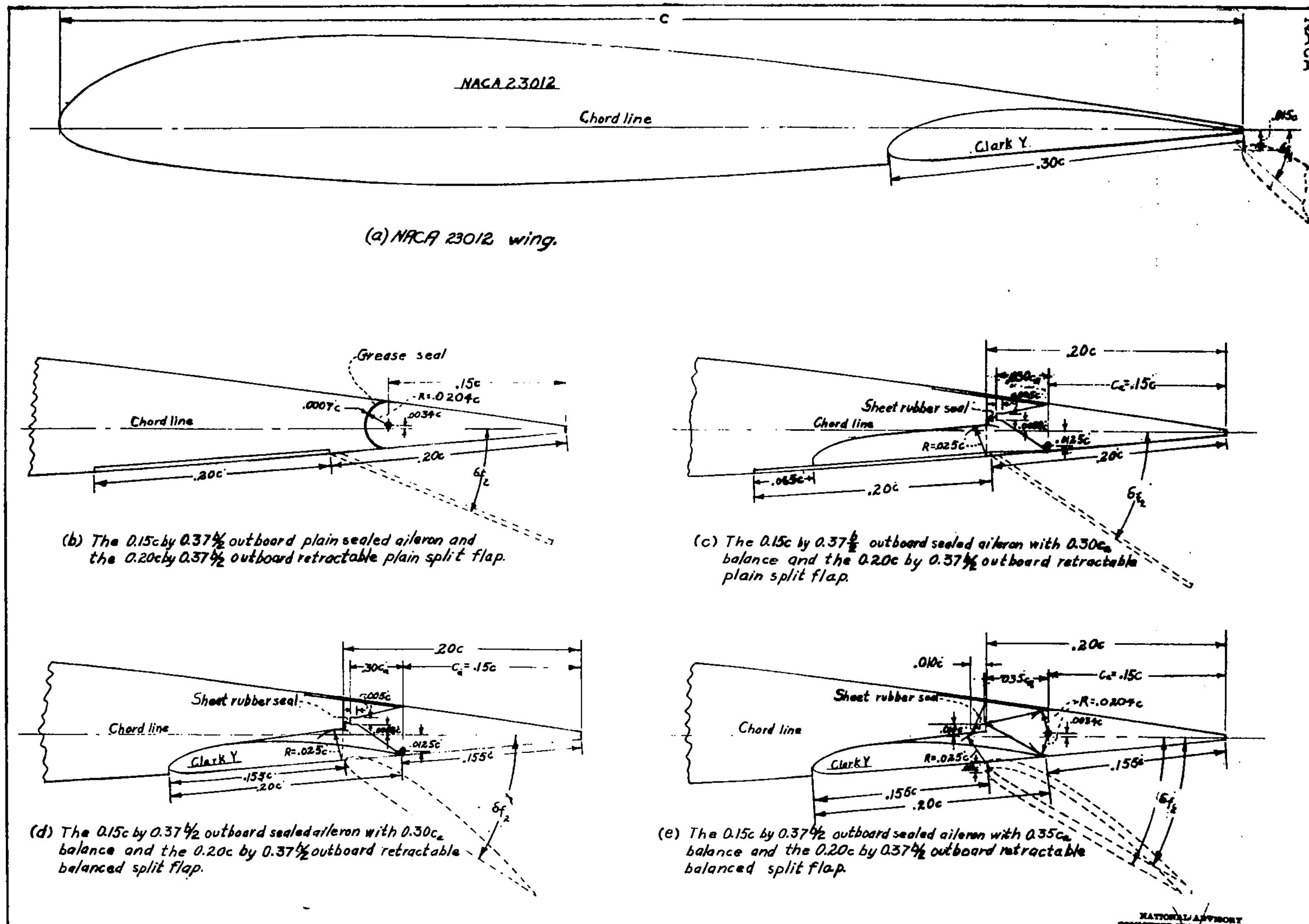


FIGURE 2.- NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap and four combinations of outboard sealed aileron and outboard retractable split flap. Aileron, 0.15c by 0.37 b/2; flap, 0.20c by 0.37 b/2.

Fig. 2

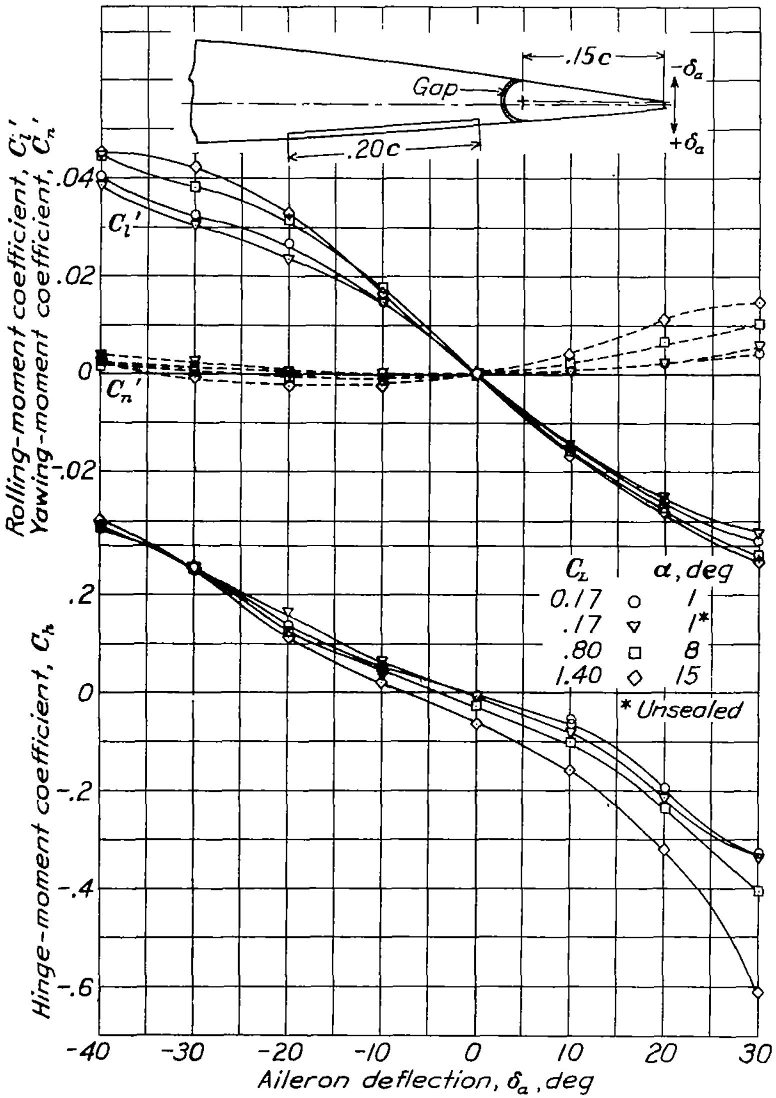


Figure 3.- $\delta_{f_1} = 0^\circ$; $\delta_{f_2} = 0^\circ$.

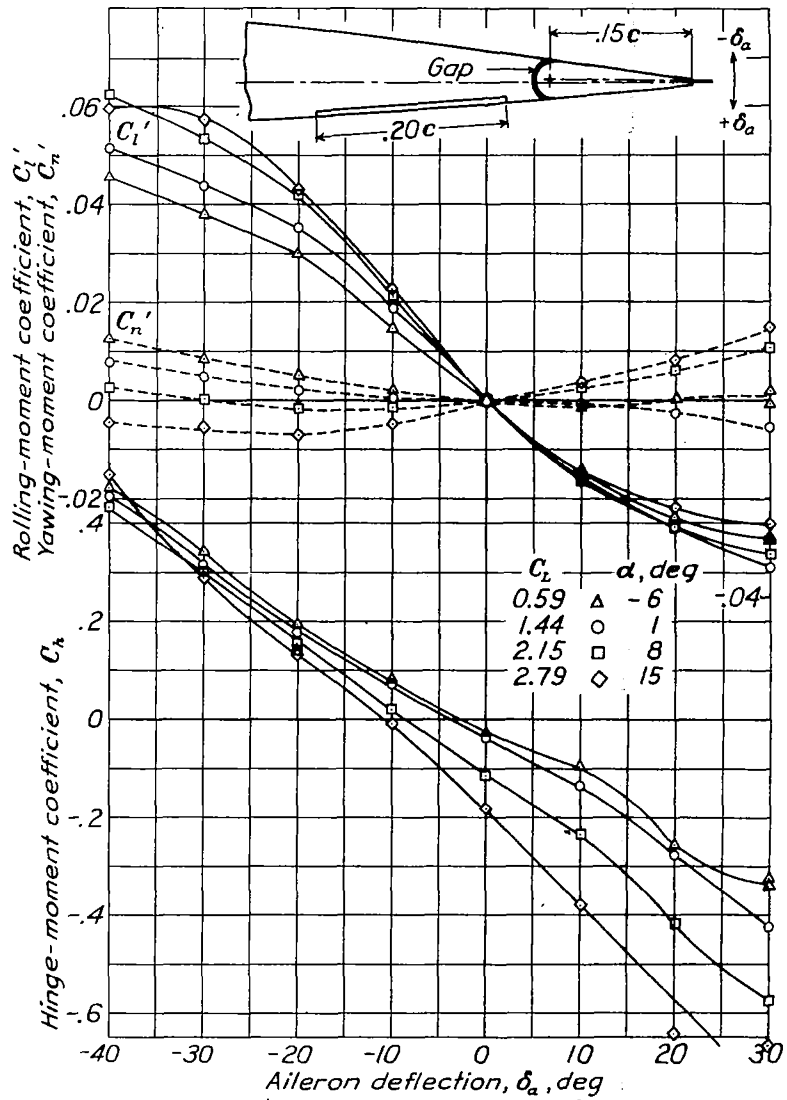


Figure 4.- $\delta_{f_1} = 40^\circ$; $\delta_{f_2} = 0^\circ$.

Aerodynamic characteristics of a 0.15c by 0.37 b/2 plain sealed aileron on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f_2).

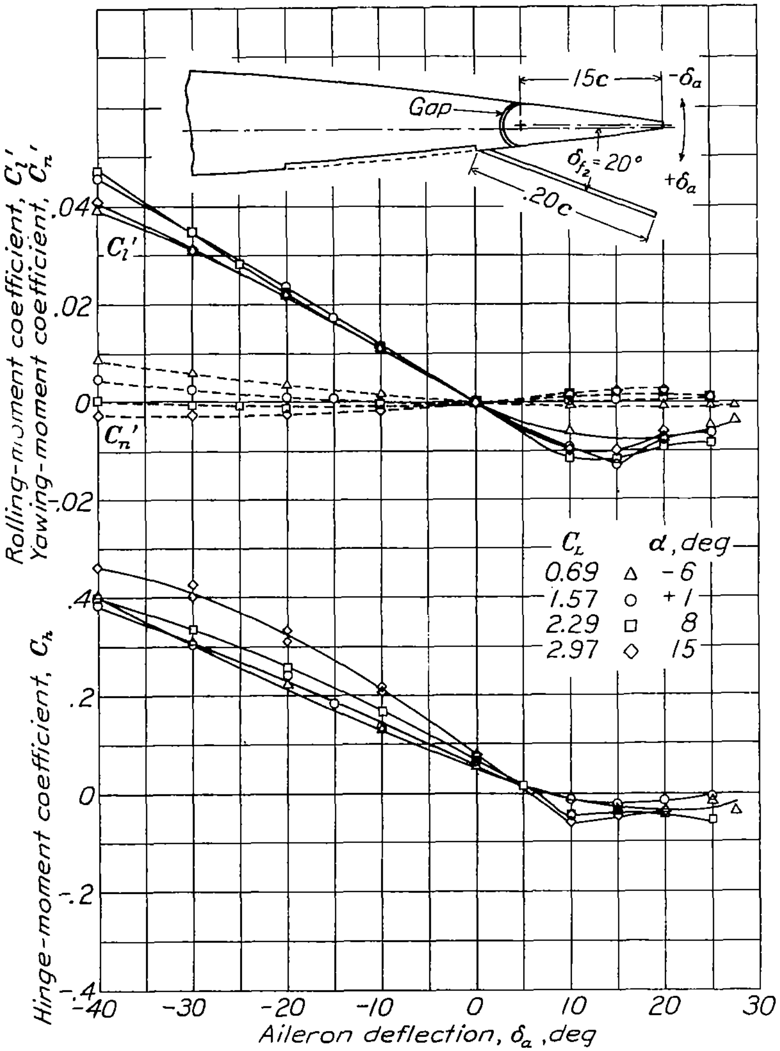


Figure 5.- $\delta_{f_1}=40°$; $\delta_{f_2}=20°$.

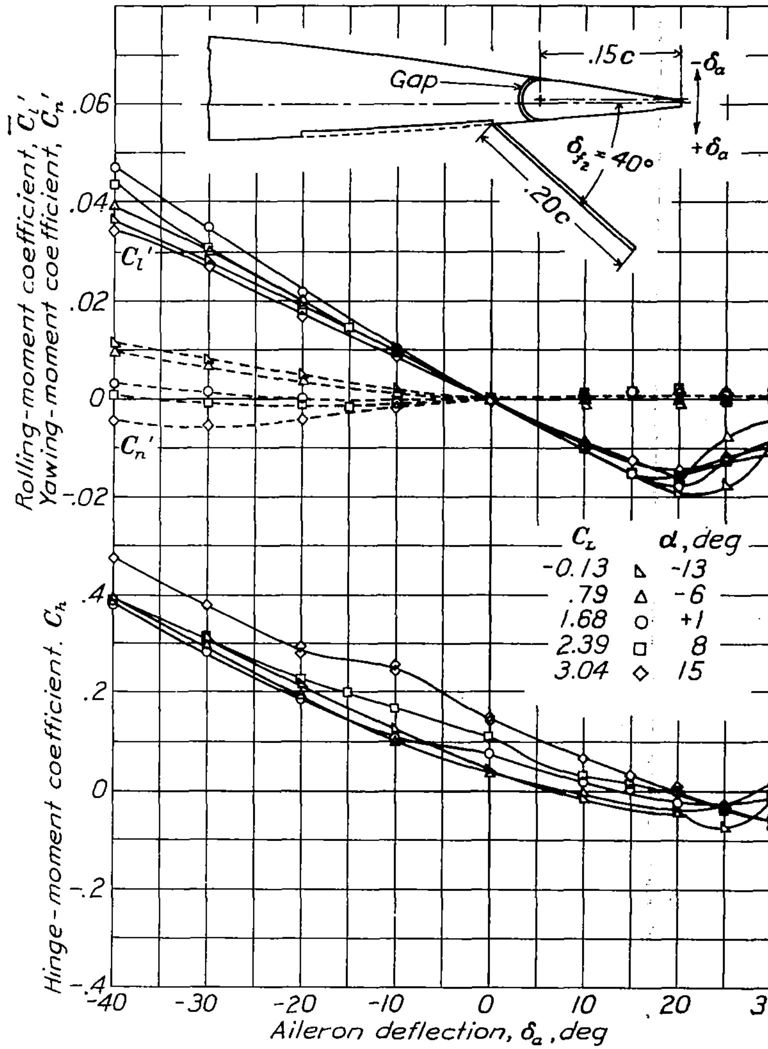


Figure 6.- $\delta_{f_1}=40°$; $\delta_{f_2}= 40°$.

Aerodynamic characteristics of a 0.15c by 0.37 b/2 plain sealed aileron on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap (f_1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f_2).

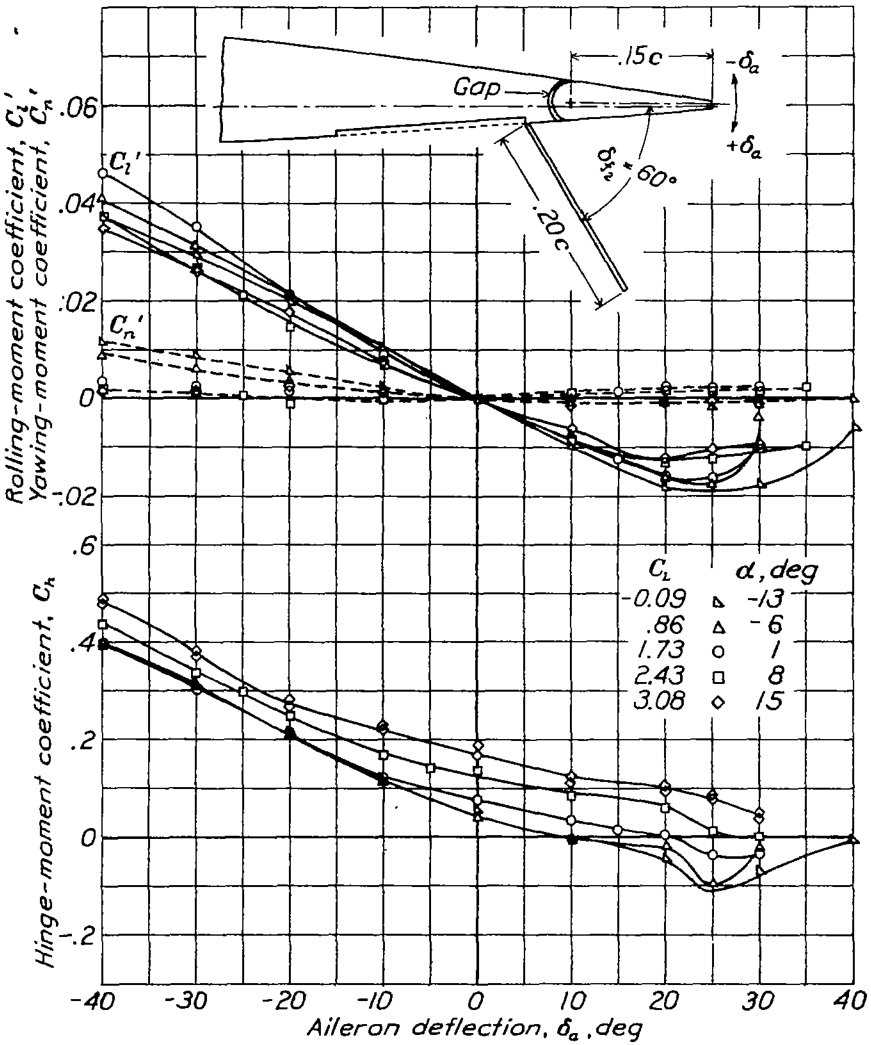


Figure 7.- $\delta_{f_1} = 40°$; $\delta_{f_2} = 60°$. Plain sealed aileron.

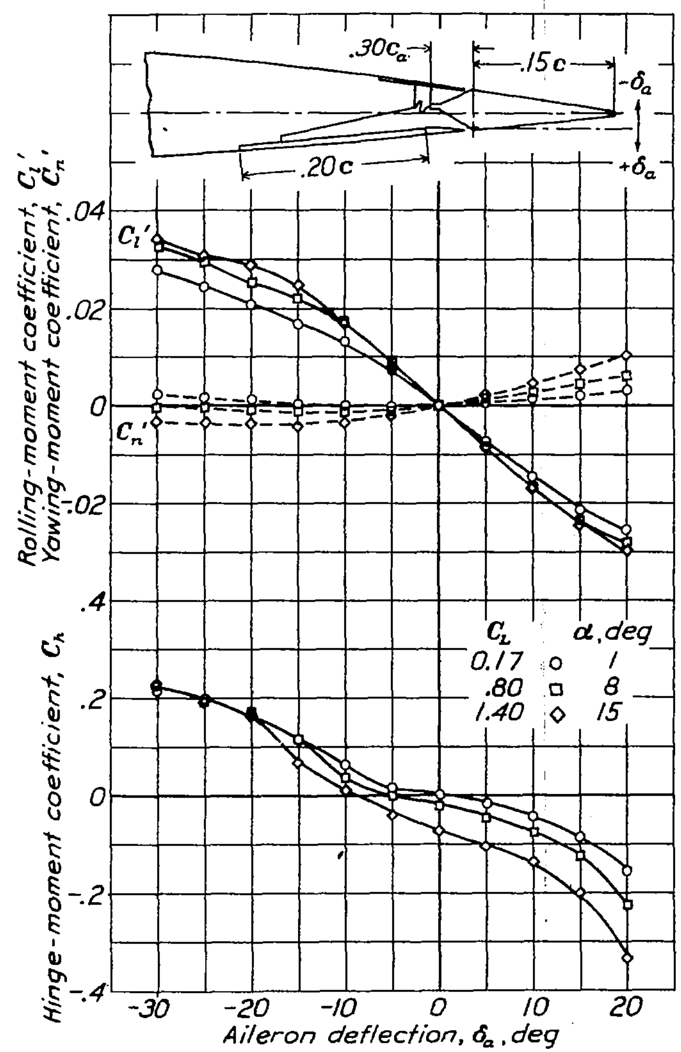


Figure 8.- $\delta_{f_1} = 0°$; $\delta_{f_2} = 0°$. Sealed aileron. with 0.30c_a balance

Aerodynamic characteristics of a 0.15c by 0.37 b/2 aileron — — — — — — — — — — on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap.(f_2).

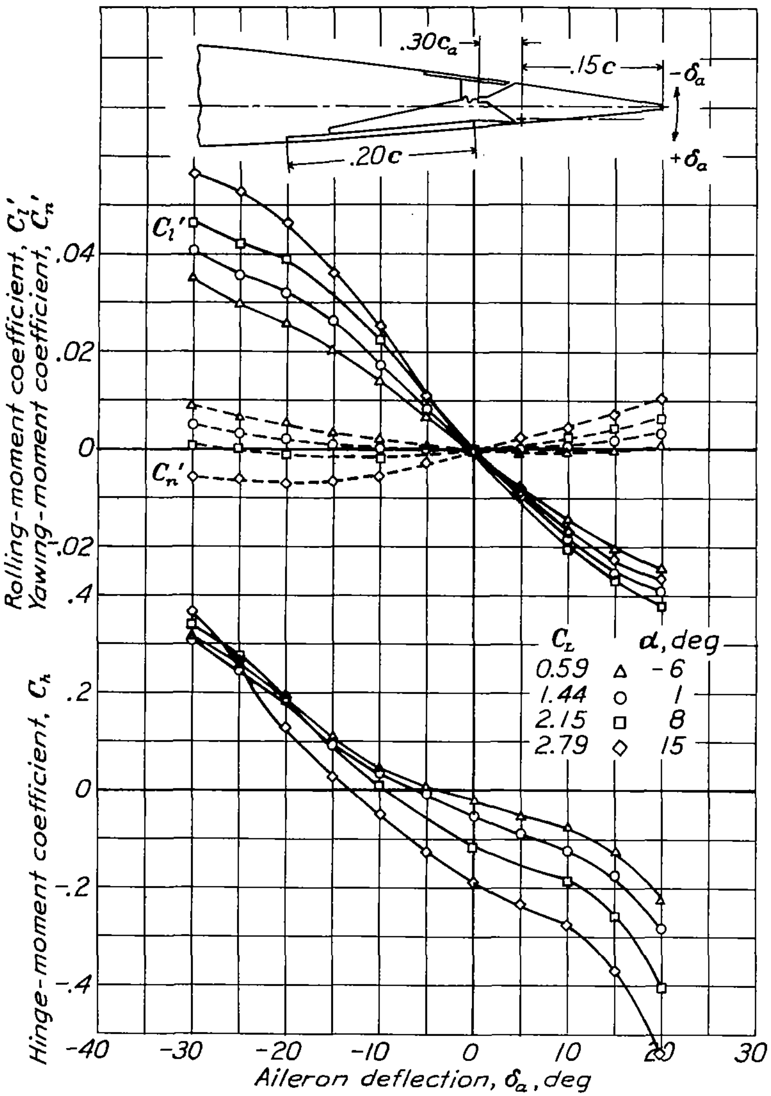


Figure 9.- $\delta_{f_1} = 40^\circ; \delta_{f_2} = 0^\circ$.

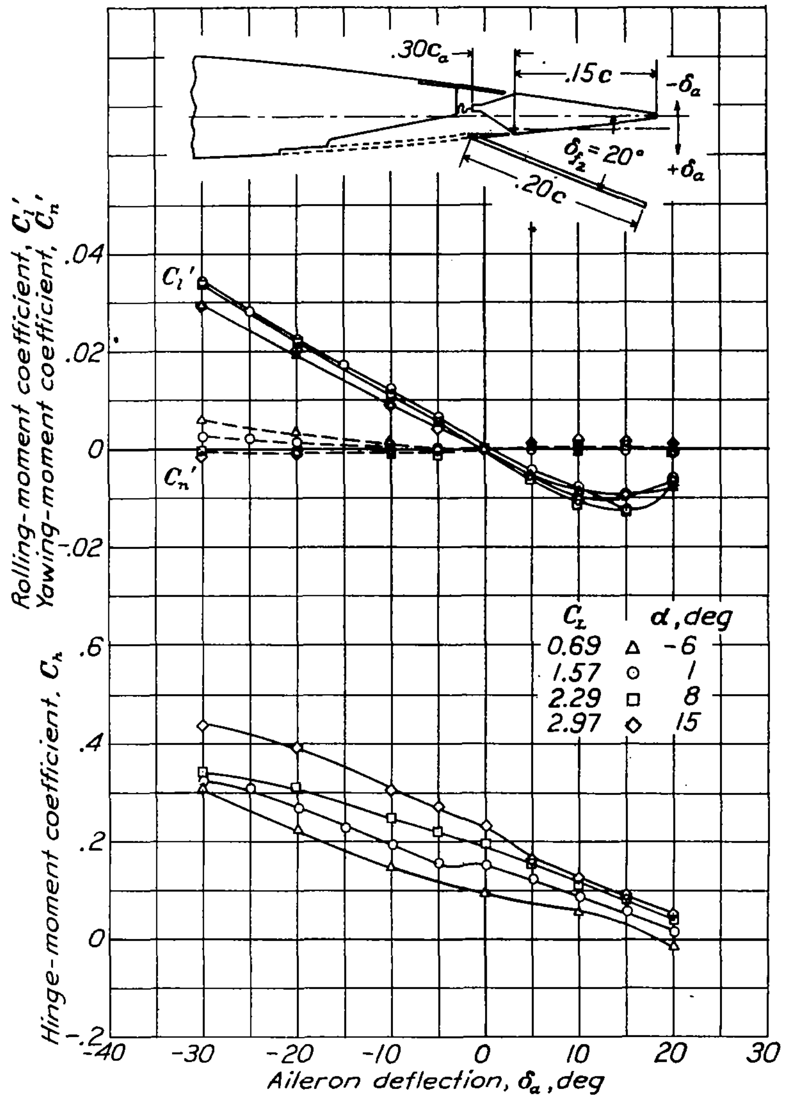


Figure 10.- $\delta_{f_1} = 40^\circ; \delta_{f_2} = 20^\circ$

Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with 0.30c_a balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f_2).

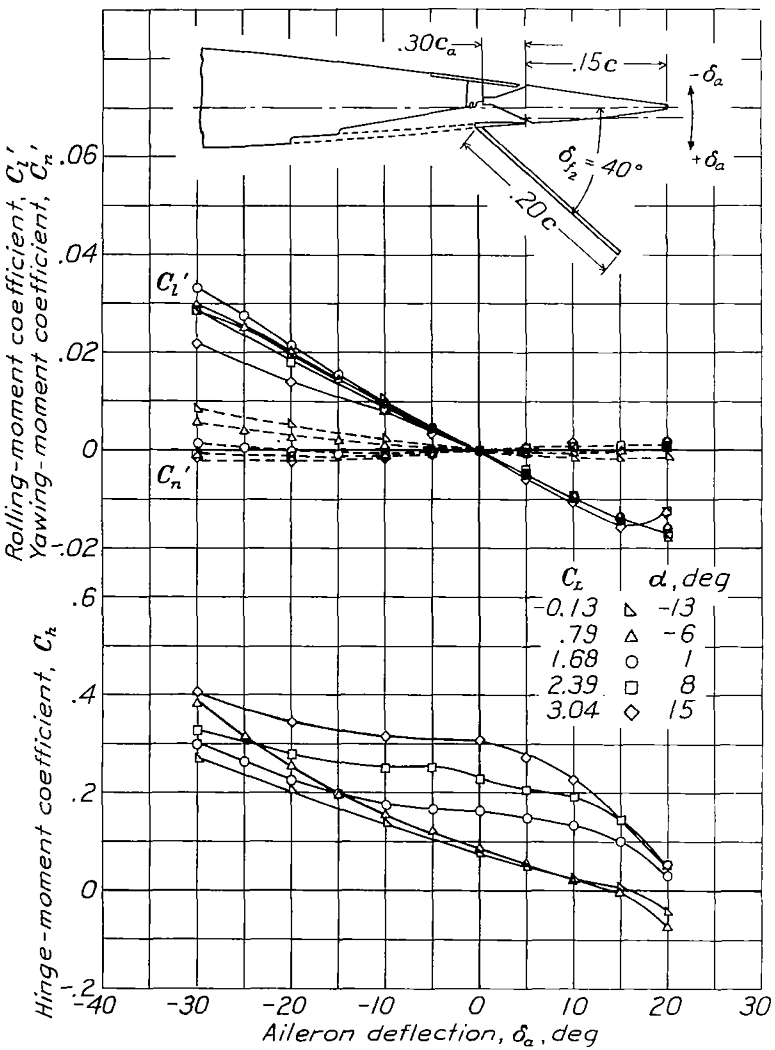


Figure 11.- $\delta_{f_1} = 40^{\circ}$; $\delta_{f_2} = 40^{\circ}$.

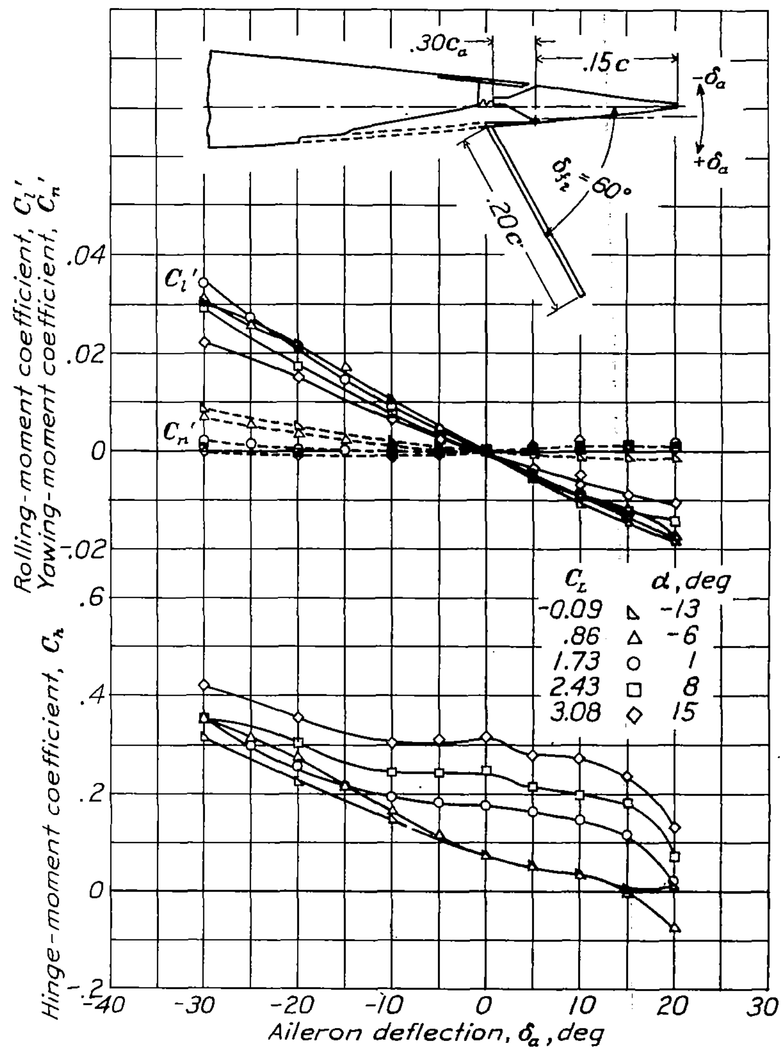


Figure 12.- $\delta_{f_1} = 40^{\circ}$; $\delta_{f_2} = 60^{\circ}$.

Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with $0.30c_a$ balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f_2).

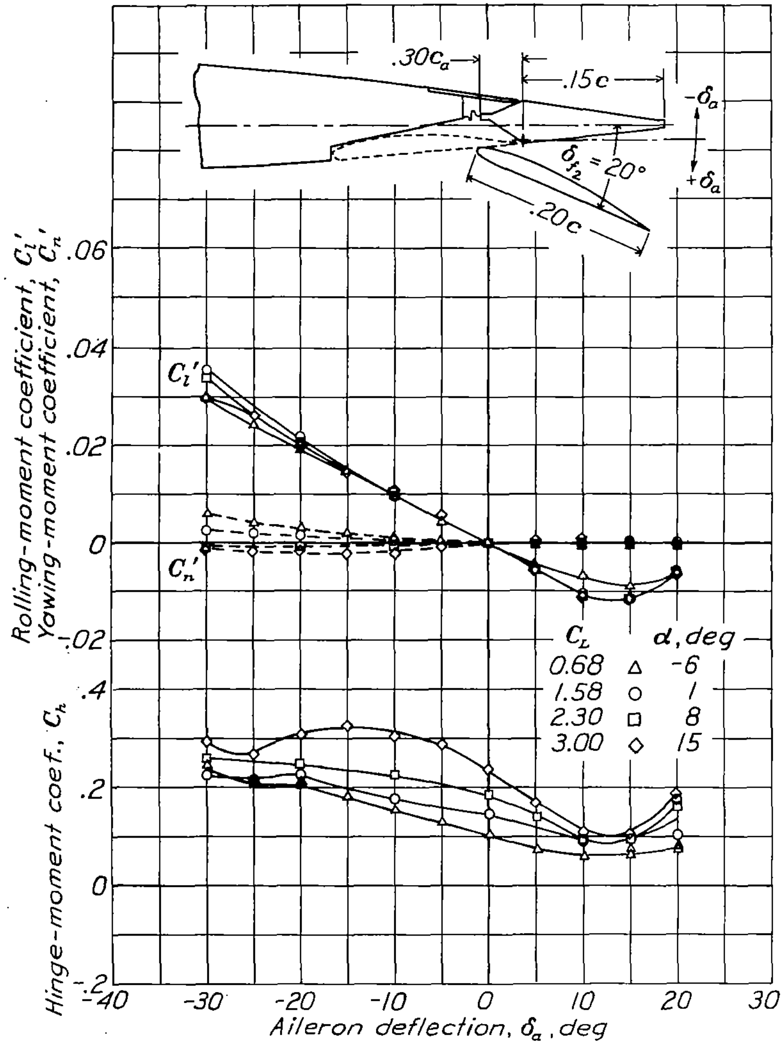


Figure 13.- δ_{f_1} = 40°; δ_{f_2} = 20°.

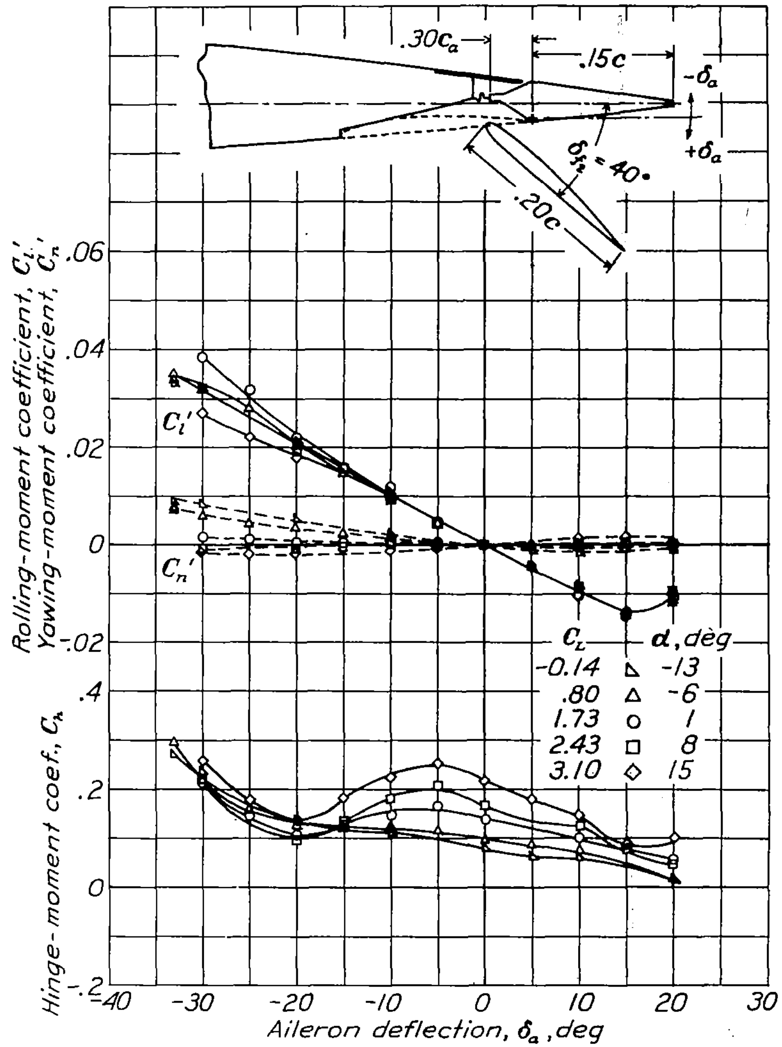


Figure 14.- δ_{f_1} = 40°; δ_{f_2} = 40°.

Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with 0.30c_a balance on an NACA 23012 **wing** with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard **retractable** balanced split flap(f_2).

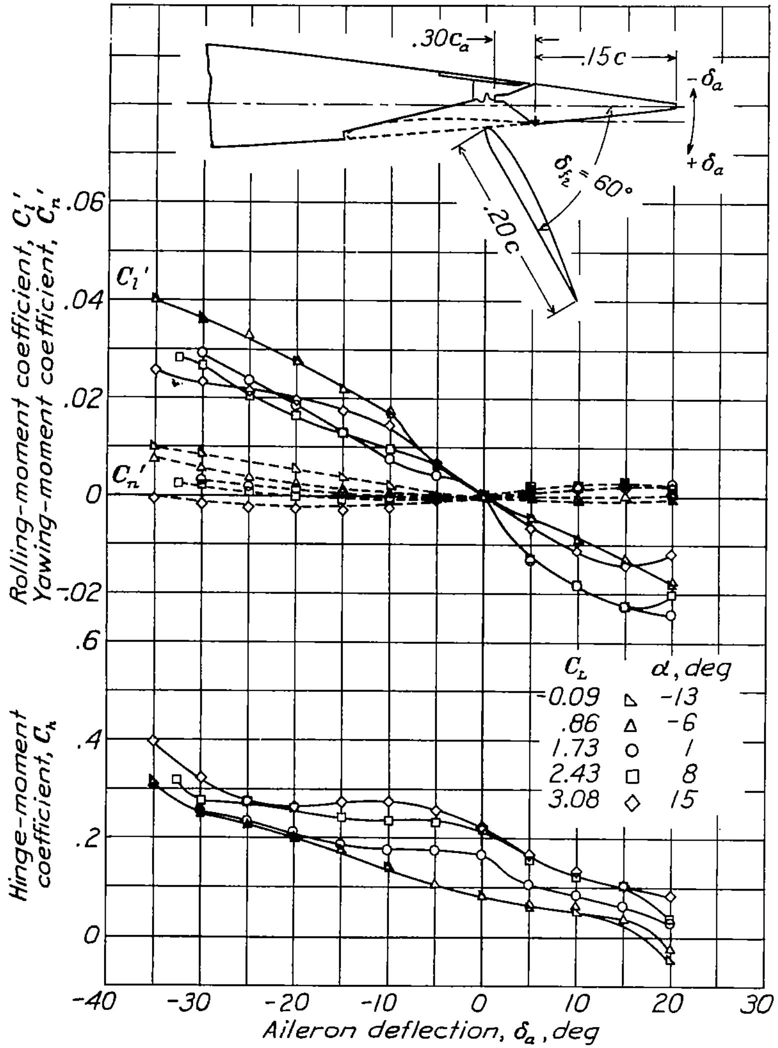


Figure 15.- δ_{f_1}=40°;δ_{f_2}=60°.Balance 0.30c_a.

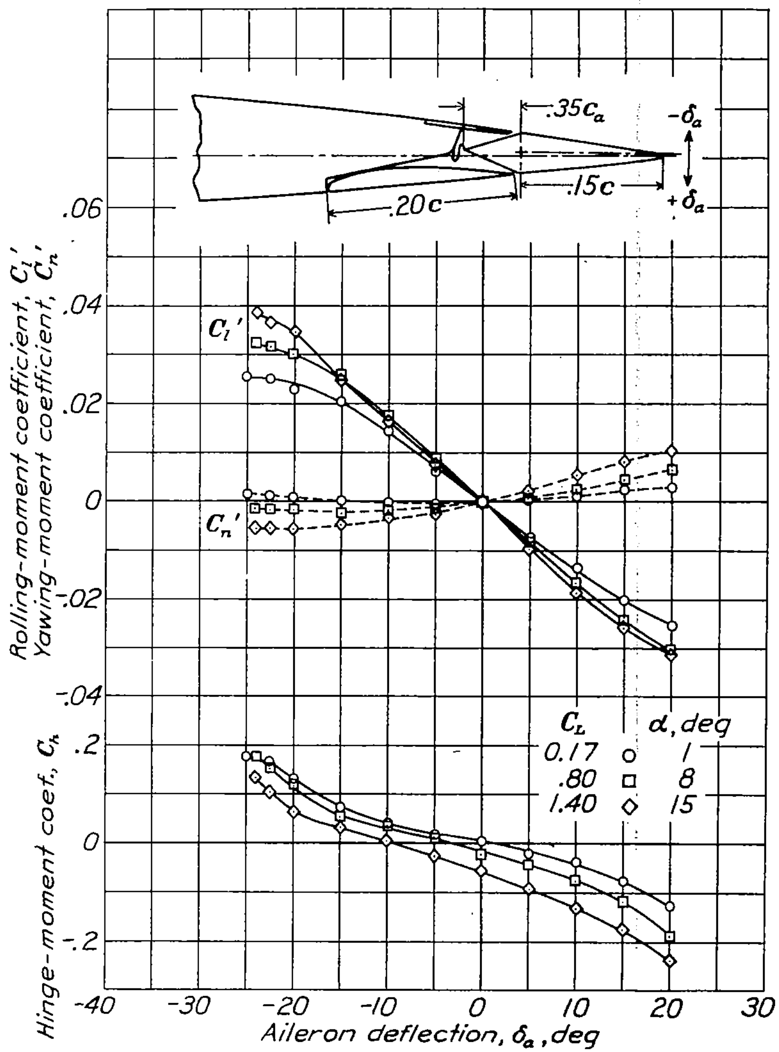


Figure 16.- δ_{f_1}=0°;δ_{f_2}=0°.Balance 0.35c_a

Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable balanced split flap(f_2).

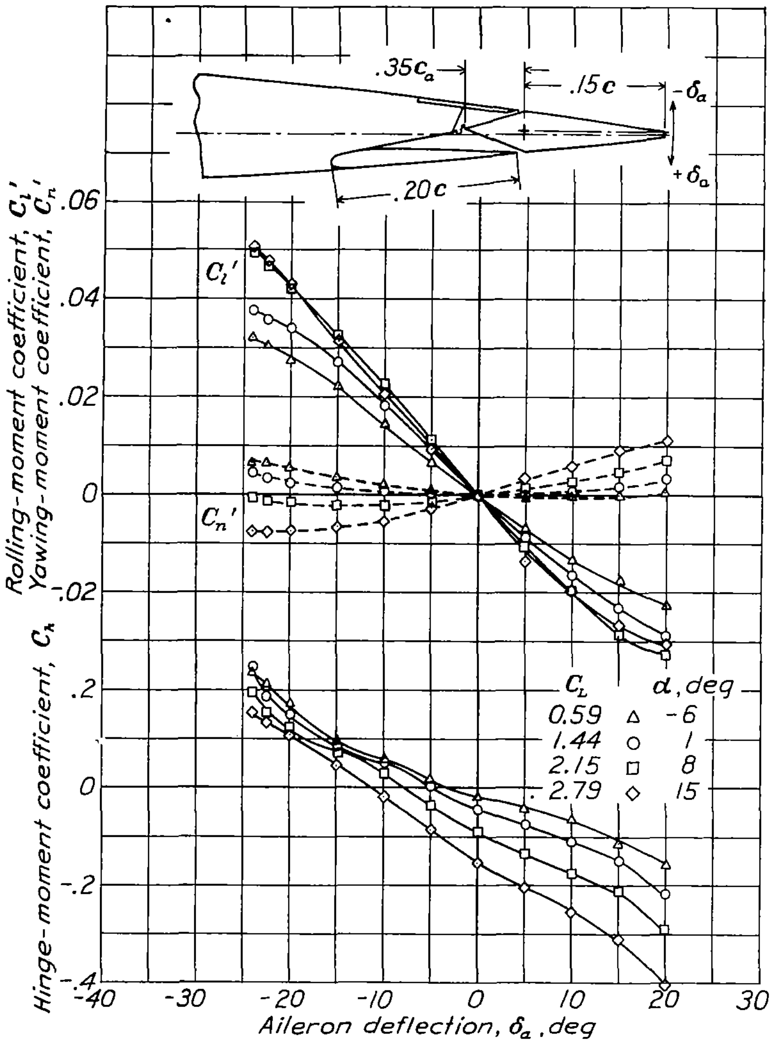


Figure 17.- $\delta_{f_1} = 40^\circ$; $\delta_{f_2} = 0^\circ$.

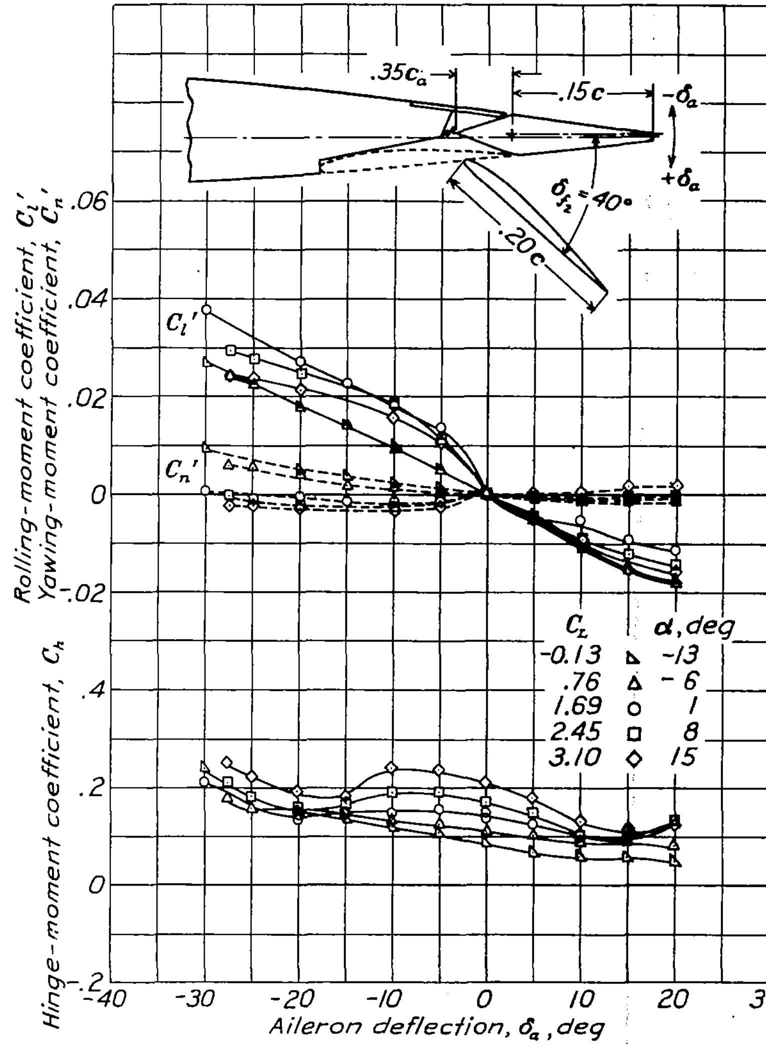


Figure 18.- $\delta_{f_1} = 40^\circ$; $\delta_{f_2} = 40^\circ$.

Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with a 0.35c_a balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable balanced split flap(f_2).

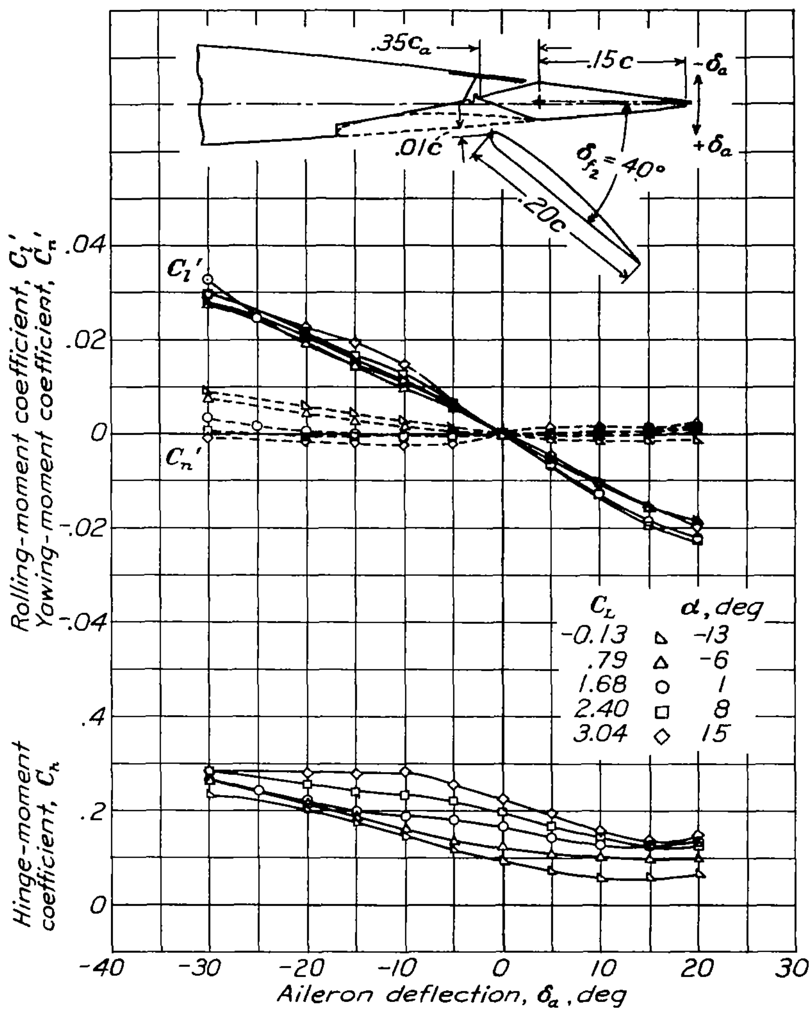
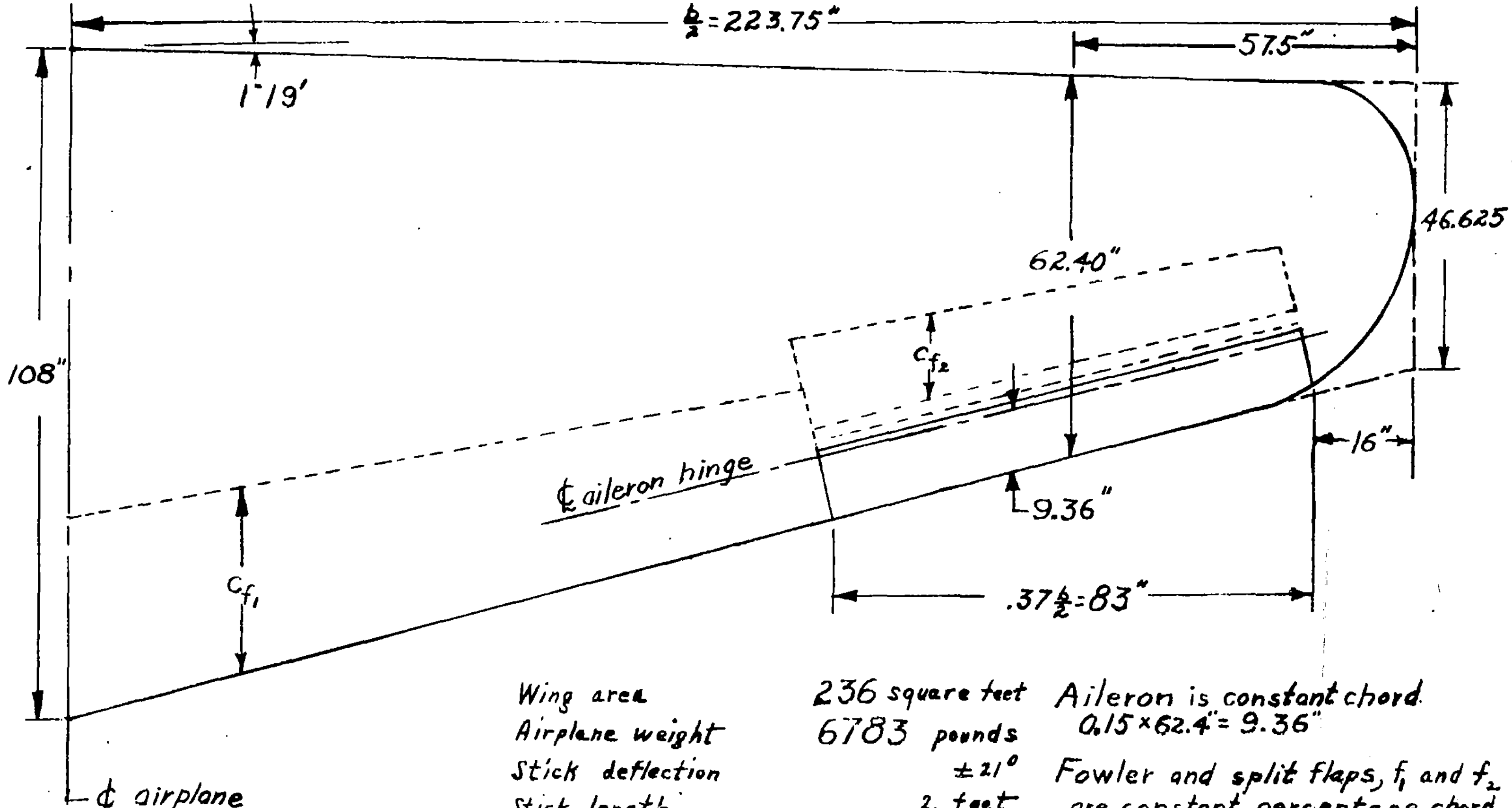


Figure 19.- Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with a 0.35c_a balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable balanced split flap(f_2). δ_{f_1} = 40°; δ_{f_2} = 40°. Nose of "f_2" is located 0.01c below lower surface of wing.



Wing area	236 square feet
Airplane weight	6783 pounds
Stick deflection	±21°
Stick length	2 feet
Aileron deflection, δ_{a_l}	±15°

Aileron is constant chord.
$0.15 \times 62.4" = 9.36"$

Fowler and split flaps, f_1 and f_2 are constant percentage chord.
$c_{f_1} = 0.30c$, $c_{f_2} = 0.20c$.

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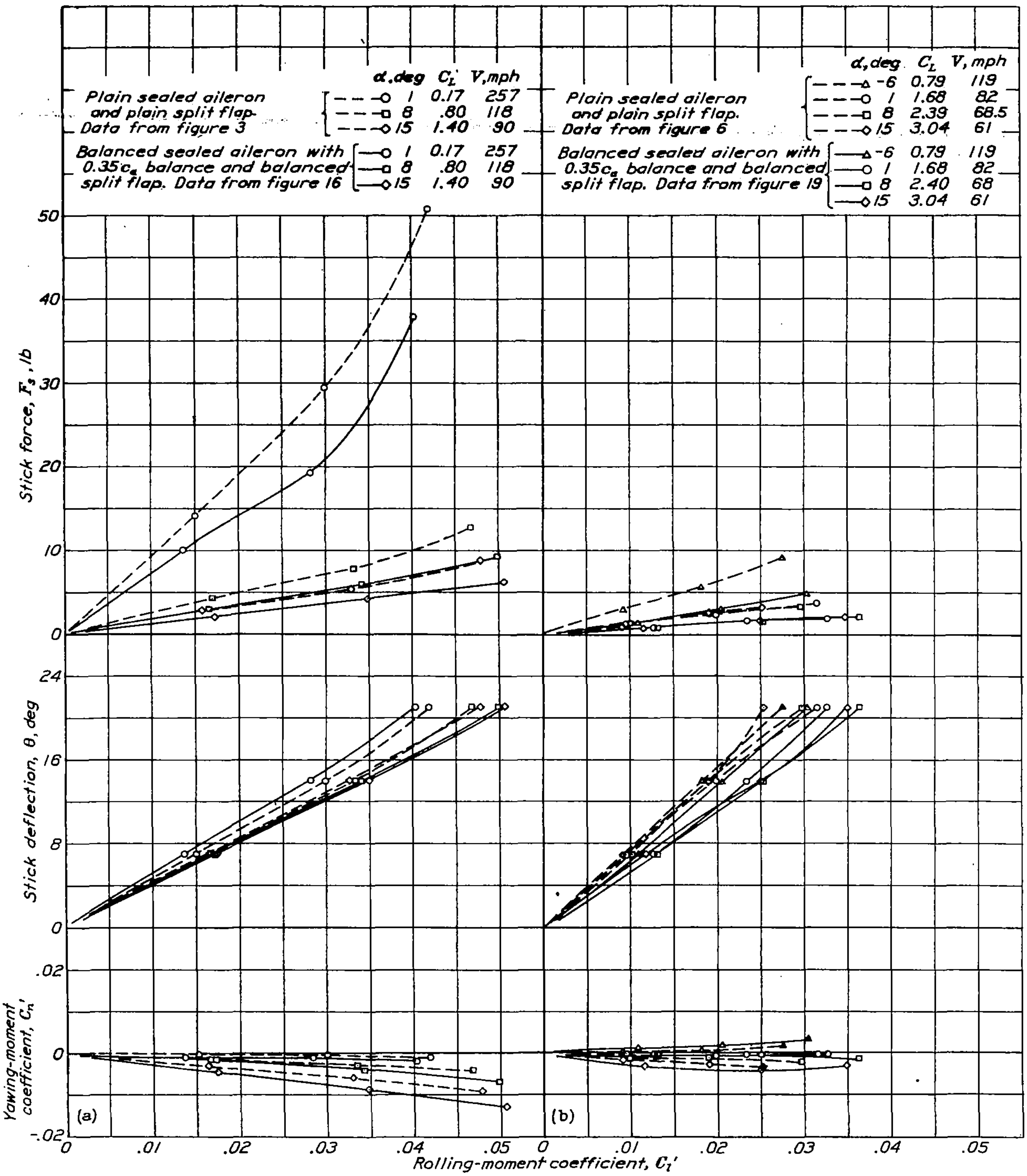
FIGURE 20.- Wing arrangement for typical pursuit airplane.



(a) $\delta_{f_1} = 0°$; $\delta_{f_2} = 0°$.

(b) $\delta_{f_1} = 40°$; $\delta_{f_2} = 40°$.

Figure 21.- Lateral-control characteristics of typical pursuit airplane with a 0.30c inboard Fowler flap (f_1), and with two arrangements of 0.15c by 0.37$\frac{b}{2}$ ailerons and 0.20c by 0.37$\frac{b}{2}$ outboard retractable split-type flaps (f_2).