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# WARTIME REPORT

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## WIND-TUNNEL INVESTIGATION OF A PLAIN AND A SLOT-LIP AILERON ON A WING WITH A FULL-SPAN FLAP CONSISTING OF AN INBOARD FOWLER AND AN OUTBOARD SLOTTED FLAP

By F. M. Rogallo and Marvin Schuldenfrei

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# WIND-TUNNEL INVESTIGATION OF A PLAIN AND A SLOT-LIP AILERON ON A WING WITH A FULL-SPAN FLAP CONSISTING OF AN INBOARD FOWLER AND AN OUTBOARD SLOTTED FLAP

By F. M. Rogallo and Marvin Schuldenfrei

## SUMMARY

An investigation was made in the NACA 7- by 10-foot tunnel of a slot-lip aileron and a plain aileron, singly and in combination, on an NACA 23012 wing with a full-span flap. The flap consisted of a 0.30c Fowler flap over the inboard 63 percent of the wing span and a modified slotted flap over the remainder of the wing. The static rolling, yawing, and hinge moments were determined and presented for several angles of attack and for various combinations of deflections of the inboard and outboard flaps.

The characteristics of these lateral-control devices were essentially the same as those of similar devices on the wing with full-span NACA slotted flaps as tested in a previous investigation. With the same modifications as recommended in the previous investigation, these devices should provide acceptable lateral-control characteristics throughout the useful flight range.

The Fowler and modified slotted-flap combination gave an estimated 14-percent increase in maximum lift coefficient over that of the full-span NACA slotted flap of the investigation previously mentioned.

## INTRODUCTION

This report continues the investigation of slot-lip and plain aileron characteristics with full-span flaps as reported in reference 1. For the present investigation, the full-span slotted flap was replaced by a Fowler flap inboard of the aileron system and a modified slotted flap over the outboard portion of the wing. The section aerodynamic characteristics of both of these flaps are given in reference 2; the modified slotted flap, having the slot lip located at 0.90c, was selected for use with the slot-lip and plain ailerons because it showed a higher $C_{L_{max}}$ than the slotted flap of reference 1.

## APPARATUS AND METHODS

The tests were made in the NACA 7- by 10-foot wind tunnel at about 40 miles per hour with the 4- by 8-foot semispan model investigated in reference 1. The model was modified for a combination of Fowler and slotted full-span flaps, sections of which are shown in figure 1. Ordinates for these flaps are given in reference 2. Calculations of the rolling, yawing, and hinge moments were similar to those of reference 1. The values of tunnel lift coefficient for the plain wing were computed from the outboard vertical reaction measured in the tunnel, assuming a lateral center of pressure of 0.45 semispan. References 2 and 3 were used to estimate the corresponding wing lift coefficients with flaps deflected.

The optimum deflection for maximum lift of the Fowler flap was selected as 40° (reference 2). The outboard modified slotted flap was tested at deflections of 15°, 25°, and 35° in combination with the Fowler flap. It was thought that the plain aileron alone might furnish adequate control for low outboard flap deflections. Consequently, the 15° and the 25° outboard flap deflections were tested with the slot-lip aileron locked in the neutral position.

## RESULTS AND DISCUSSION

The following symbols are used in the presentation of results:

$C_L$ lift coefficient $\left(\frac{L}{qS}\right)$

$C_l'$ rolling-moment coefficient $\left(\frac{L'}{qbS}\right)$

$C_n'$ yawing-moment coefficient $\left(\frac{N'}{qbS}\right)$

$C_{h_p}$ plain aileron hinge-moment coefficients $(H_p/qb_pc_p^2)$

$C_{h_{sl}}$ slot-lip aileron hinge-moment coefficient $(H_{sl}/qb_{sl}\ c_{sl}^2)$

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$c$ wing chord

$c_p$ plain aileron chord behind hinge axis

$c_{sl}$ slot-lip aileron chord behind hinge axis

$b$ twice the span of semispan model

$b_p$ plain aileron span

$b_{sl}$ slot-lip aileron span

$S$ twice the area of semispan model

$L$ twice the lift of semispan model

$L'$ rolling moment about wind axis

$N'$ yawing moment about wind axis

$H_p$ plain aileron hinge moment

$H_{sl}$ slot-lip aileron hinge moment

$q$ dynamic pressure of air stream

$\alpha$ uncorrected angle of attack

$\delta$ aileron or flap deflection, positive when trailing edge moves down

Positive $L'$ or $C_l'$ corresponds to a decrease in lift on the model, and positive $N'$ or $C_n'$ corresponds to an increase in drag on the model. Twice the lift, area, and span were used in reducing test data since the model represents half of a complete wing. No corrections were applied for effects of tunnel walls. Such corrections may be relatively large for this test installation.

The aerodynamic characteristics of a plain aileron with flaps retracted, and also with the inboard flap deflected 40°, are presented in figures 2 and 3. These test conditions correspond to the present-day practice of using flaps inboard of the ailerons, and offer a basis for determining the effect of the additional outboard flap and the slot-lip aileron.

The aerodynamic characteristics of the plain aileron alone in conjunction with the outboard slotted flaps deflected 15° and 25°, respectively, are given in figures 4 and 5. There is a slight increase in rolling moment but a proportionately larger increase in adverse yawing moment when the outboard flap is deflected 15°. A 25° flap deflection decreases the rolling moment relative to that at 15° but scarcely changes the adverse yawing moment at a given aileron deflection. Also significant is the decrease in the slope of the rolling-moment curve at small aileron deflections when the outboard flap is deflected.

Calculations show an estimated increase in maximum lift coefficient of 11, 14, and 17 percent for 15°, 25°, and 35° outboard flap deflections, respectively.

It is further estimated from reference 2 that the combination of 40° Fowler and 35° modified slotted flap would have approximately 14 percent greater maximum lift coefficient than the slotted flap of reference 1.

The aerodynamic characteristics of the slot-lip aileron in conjunction with the plain aileron, and with the slotted flap deflected 25° and 35°, are presented in figures 6 and 7. There is no essential difference between these results and the results of the previous investigation (reference 1). The maximum rolling moments obtainable with the slot-lip aileron are very large compared with the plain aileron alone, and the adverse yawing moments are small. In general, deflection of the plain aileron in the same direction as the adjacent slot-lip aileron, with outboard flap at 25° or 35°, adds little to the rolling moment but increases the adverse yawing moment. As suggested in reference 1, it may be desirable to deflect the plain aileron in the opposite direction to that of the adjacent slot-lip aileron in order to reduce the adverse yawing effect, while decreasing the available rolling moment only slightly.

Various linkage systems are discussed in reference 1 for operating the two ailerons separately and in combination. As in reference 1, it is recommended that either the span or chord of the plain aileron be increased by about 50 percent to obtain greater effectiveness. This increase should be taken into account in making stick-force and linkage calculations.

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## CONCLUDING REMARKS

The characteristics of the plain and slot-lip ailerons on the wing with full-span Fowler and modified slotted flaps, as tested in the present investigation, were essentially the same as the characteristics of similar devices on the wing with full-span NACA slotted flaps, as tested in a previous investigation. An increase in maximum lift coefficient of approximately 14 percent was indicated by use of the flaps of the present report over the slotted flaps of the previous investigation.

The 0.10c by 0.37 b/2 plain aileron tested was considered too small; an increase of about 50 percent in its area is recommended. With this modification, a combination of plain and slot-lip ailerons should provide acceptable lateral-control characteristics throughout the useful flight range.

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

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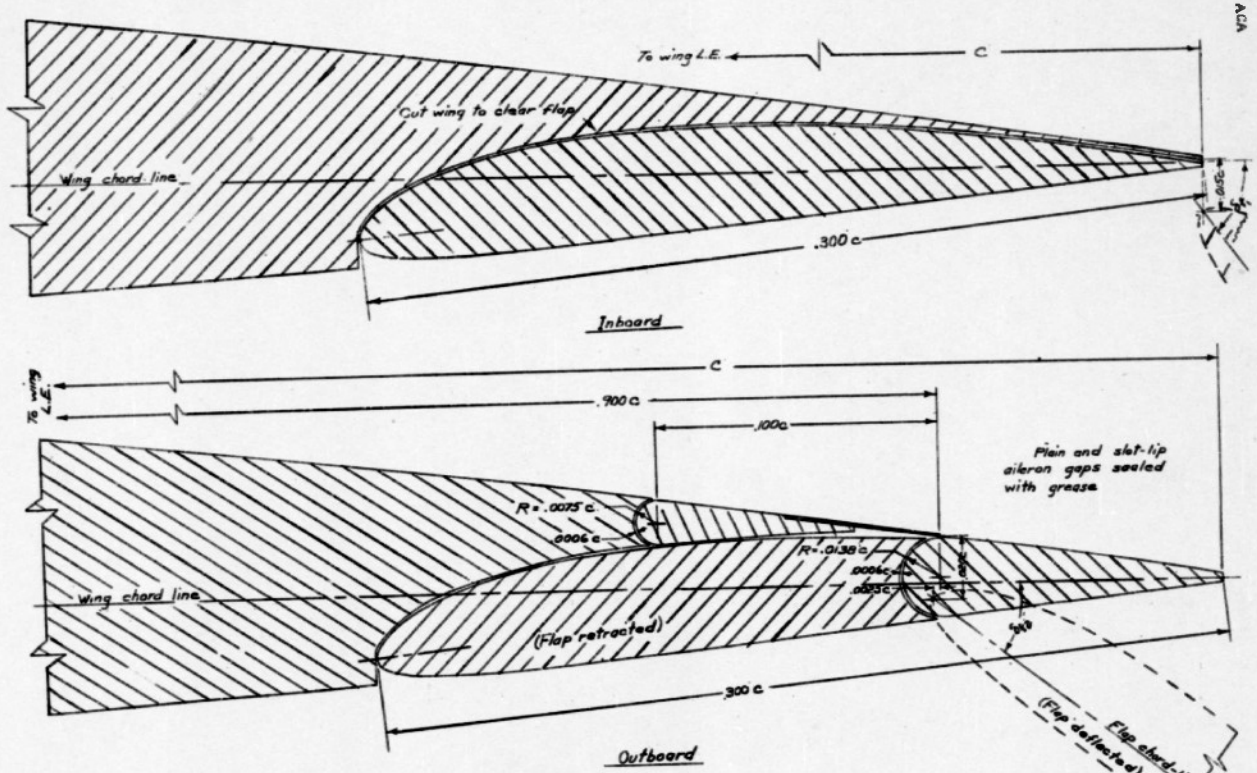


FIGURE 1.- Section of sealed 0.37$\frac{c}{2}$ slot-lip and plain ailerons on an 8-foot semispan NACA 23012 wing with a 0.37$\frac{c}{2}$ modified slotted flap outboard and with a 0.63$\frac{c}{2}$ Fowler flap inboard.

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FIG. 1

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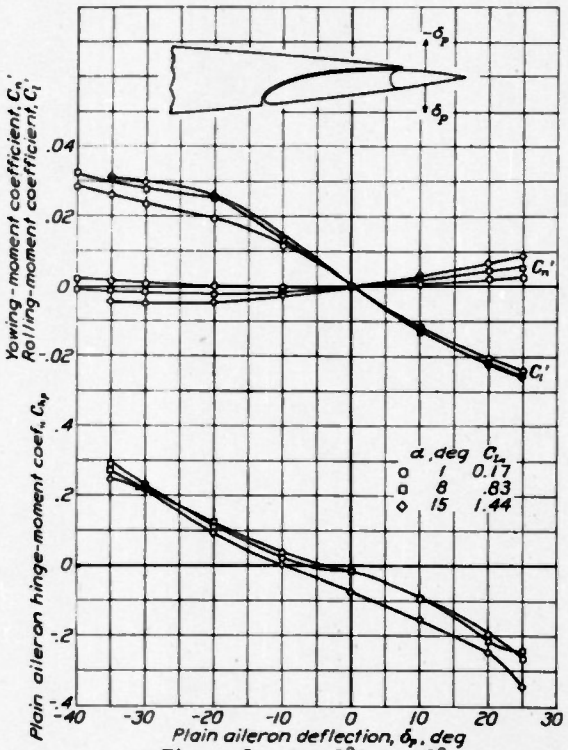


Figure 2.- $\delta_{f_1}, 0^\circ$; $\delta_{f_2}, 0^\circ$.

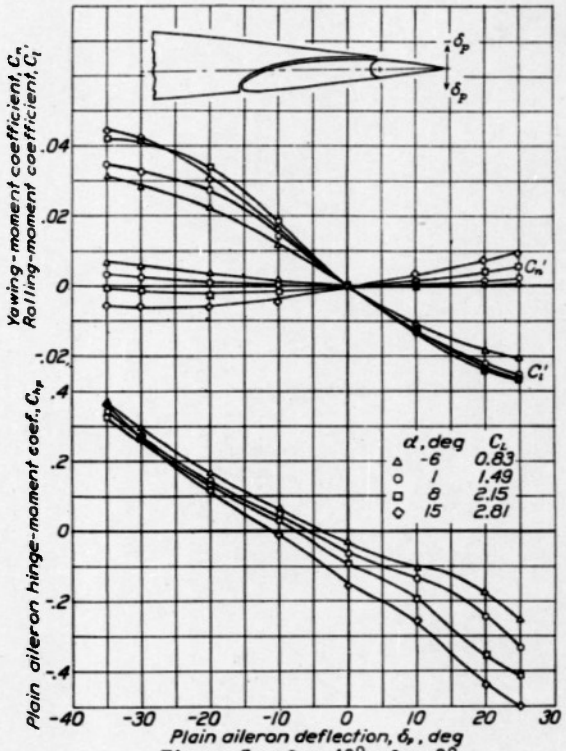


Figure 3.- $\delta_{f_1}, 40^\circ$; $\delta_{f_2}, 0^\circ$

Figures 2 and 3.- Aerodynamic characteristics of a 0.10c by 0.37b/2 plain sealed aileron on an NACA 23012 wing with a 0.30c by 0.63b/2 inboard Fowler flap, $f_1$, and a 0.30c by 0.37b/2 outboard modified slotted flap, $f_2$.

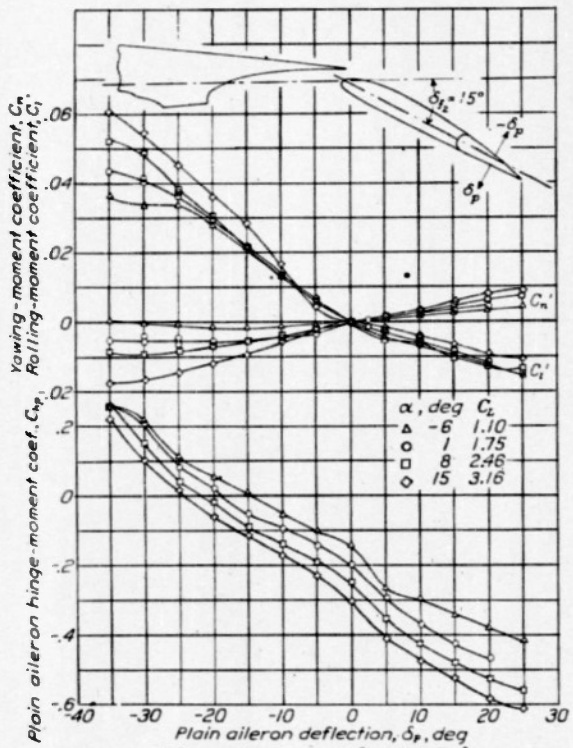


Figure 4.- $\delta_{f_1}$,40°; $\delta_{f_2}$,15°

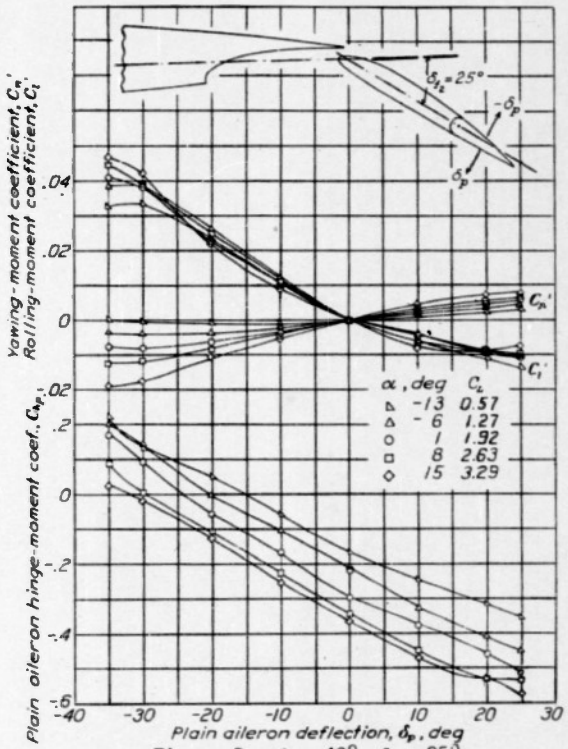


Figure 5.- $\delta_{f_1}$,40°; $\delta_{f_2}$,25°

Figures 4,5.- Aerodynamic characteristics of a 0.10c by 0.37b/2 plain sealed aileron on an NACA 23012 wing with a 0.30c by 0.63b/2 inboard Fowler flap, $f_1$, and a 0.30c by 0.37b/2 outboard modified slotted flap, $f_2$.



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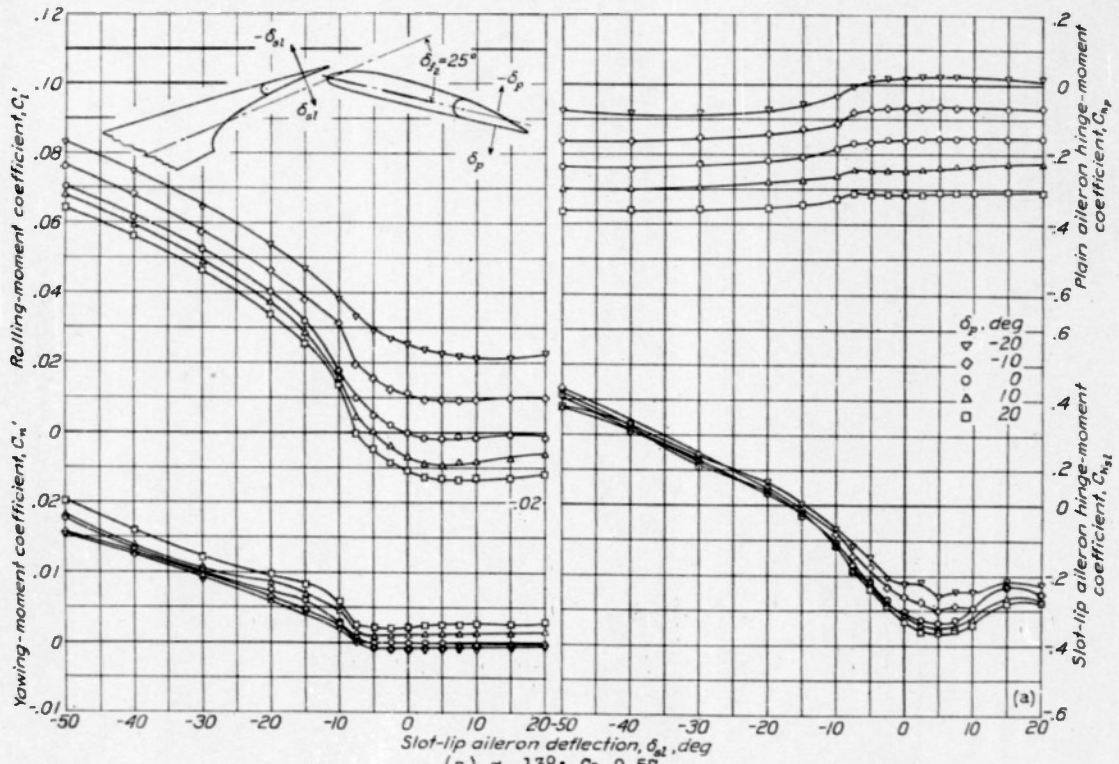
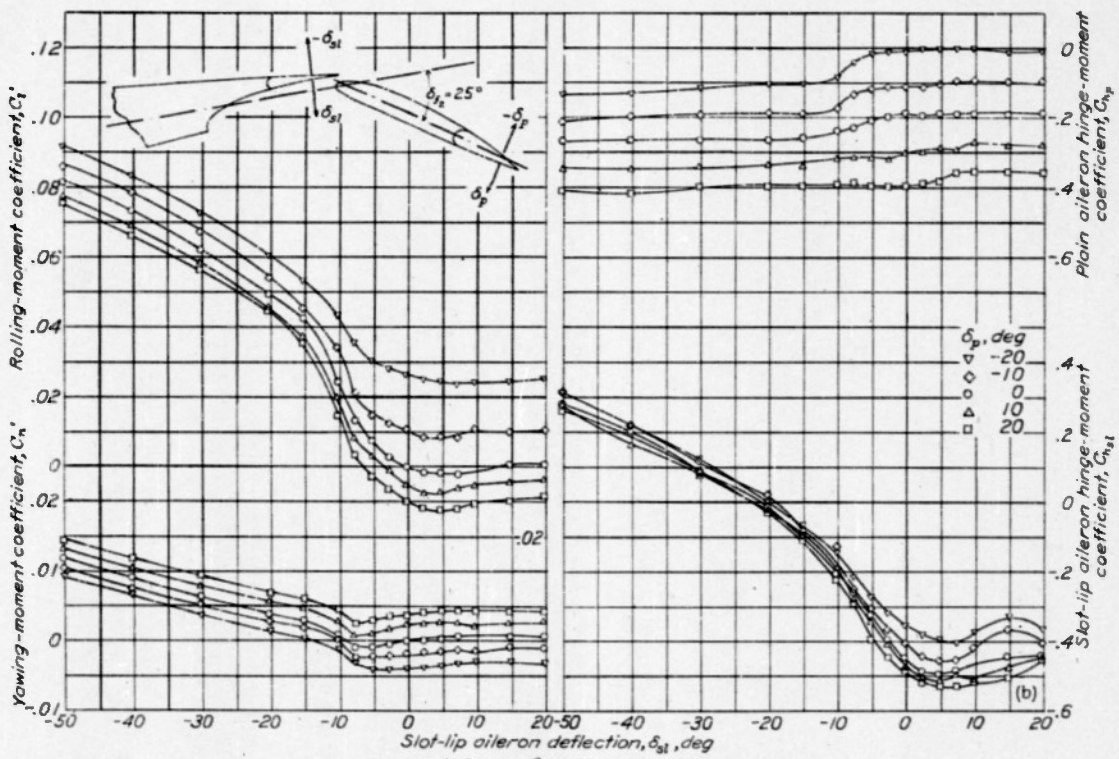


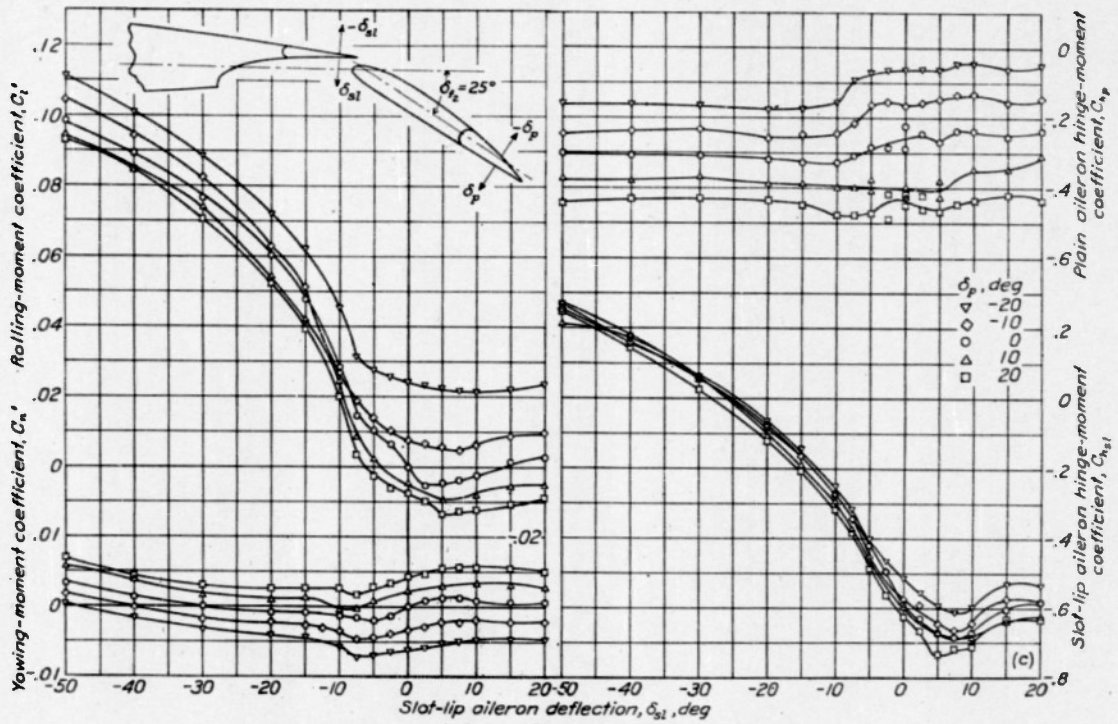

(a) $\alpha$, -13°; $C_L$, 0.57

Figures 6a to e.- Aerodynamic characteristics of sealed 0.10c by 0.37b/2 plain and slot-lip ailerons on an NACA 23012 wing with a 0.30c by 0.63b/2 inboard Fowler flap, $f_1$, and a 0.30c by 0.37b/2 outboard modified slotted flap, $f_2$. $\delta_{f_1}$, 40°; $\delta_{f_2}$, 25°.




(b) α, -6°; $C_L$, 1.27

Figure 6 - Continued.

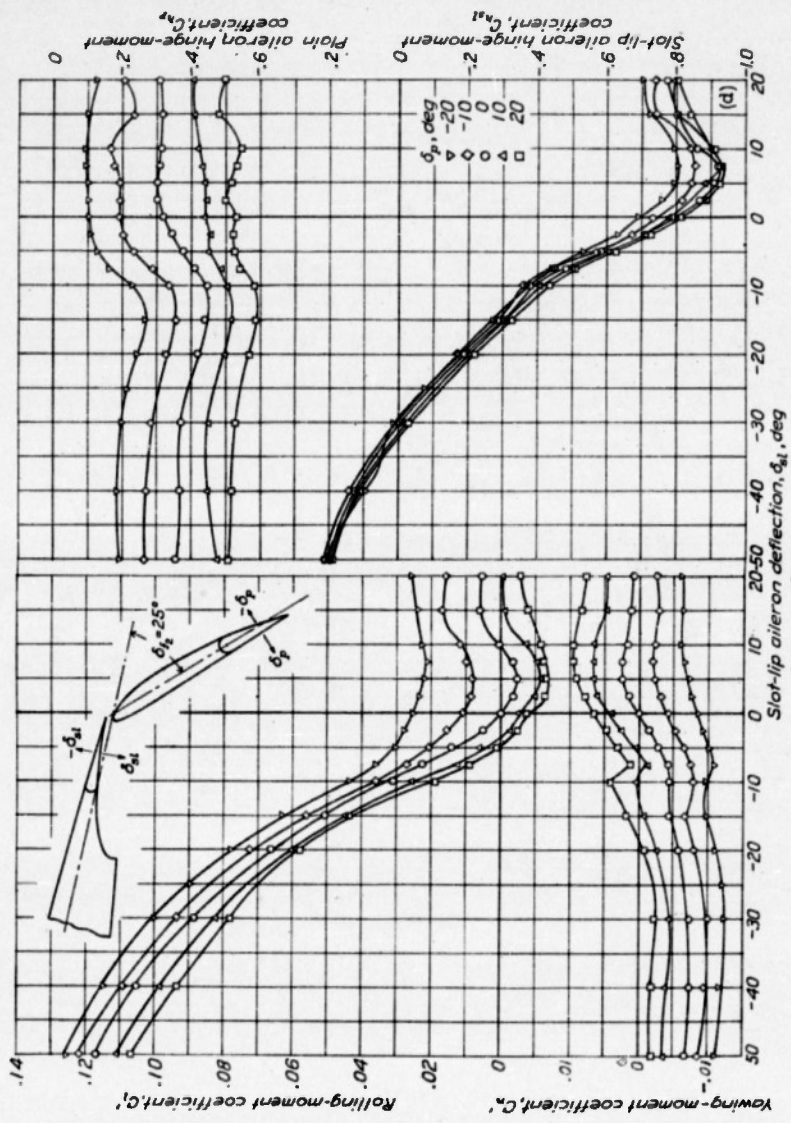



(c) α, 1°; $C_L$,1.92

Figure 6.- Continued

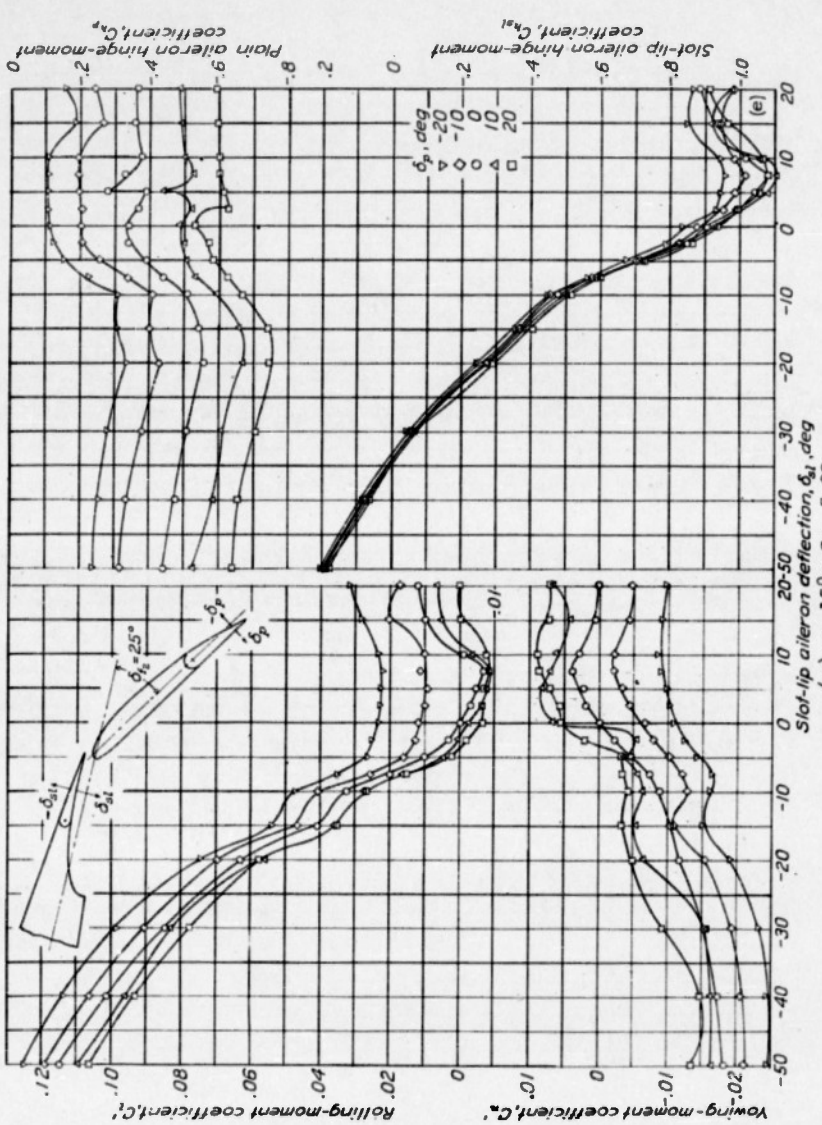


(11)



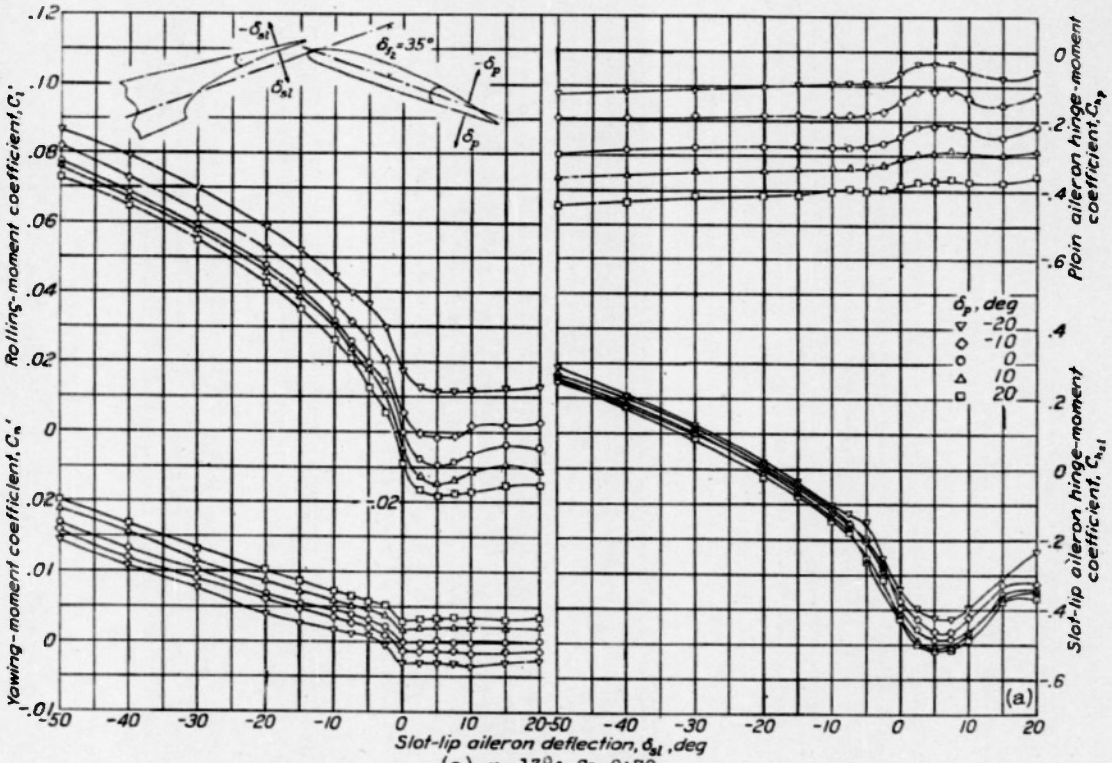

(d) α, 8°; $C_L$, 2.63

**Figure 6.- Continued.**




(e) α, 15°; $C_L$, 3.29

Figure 6.- Concluded.




(a) $\alpha$, -13°; $C_L$, 0.70

Figures 7a to e.- Aerodynamic characteristics of sealed 0.10c by 0.37b/2 plain and slot-lip ailerons on an NACA 23012 wing with a 0.30c by 0.63b/2 inboard Fowler flap, $f_1$, and a 0.30c by 0.37b/2 outboard modified slotted flap, $f_2$. $\delta_{f_1}$, 40°; $\delta_{f_2}$, 35°.

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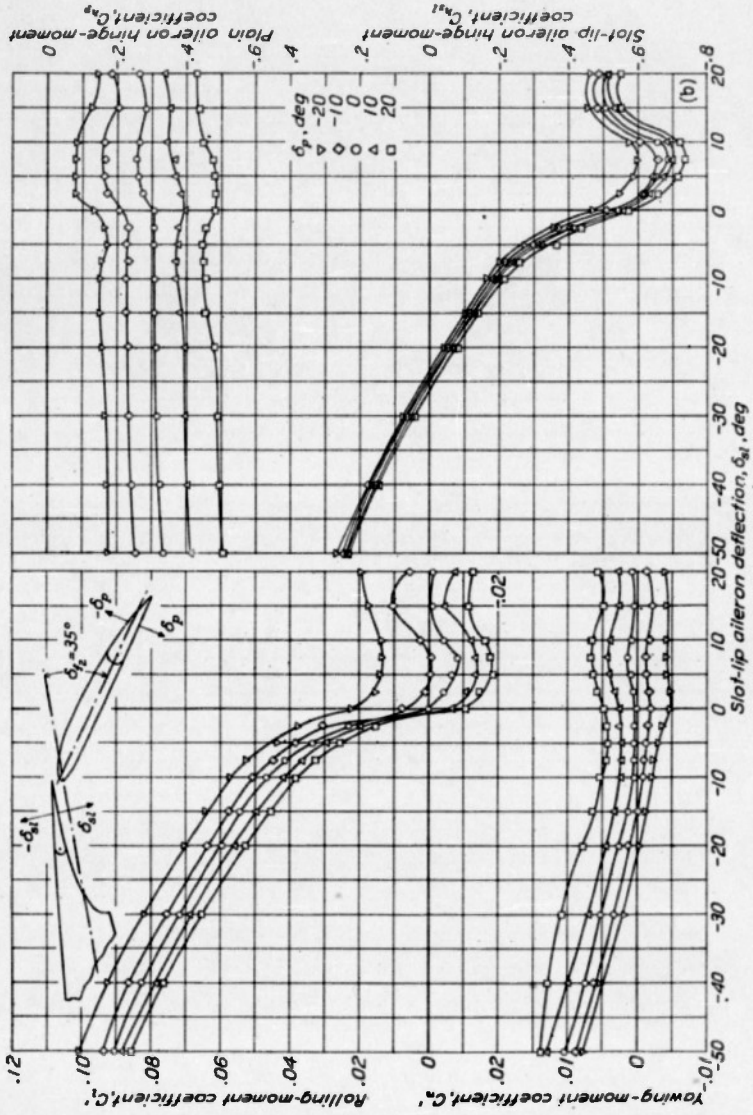
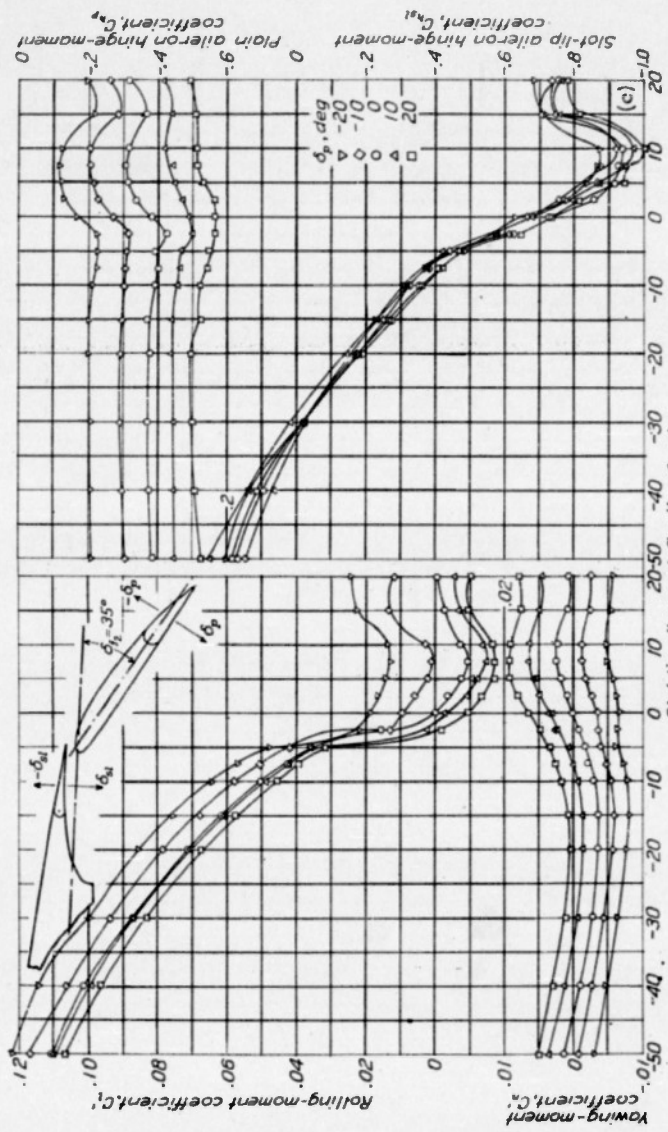


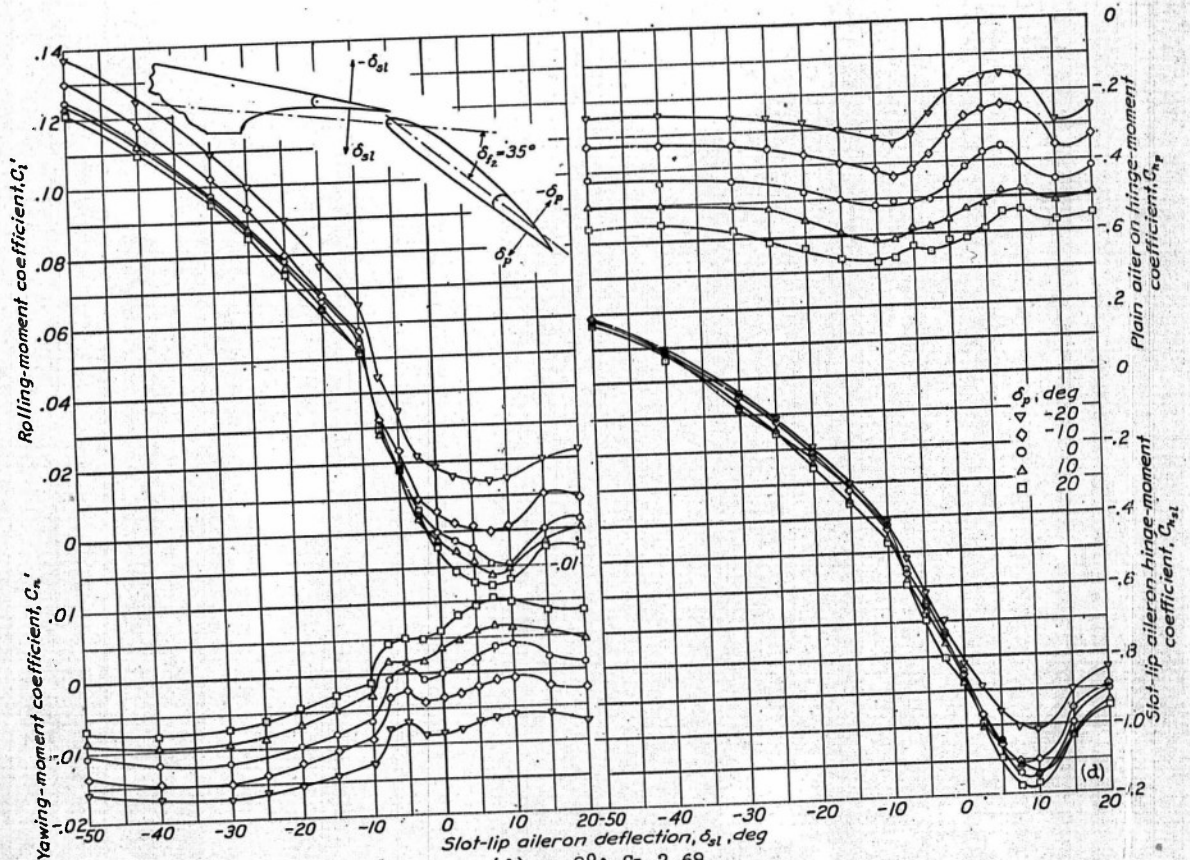

(b) $\alpha$, -6°; $C_L$, 1.32

Figure 7.- Continued.



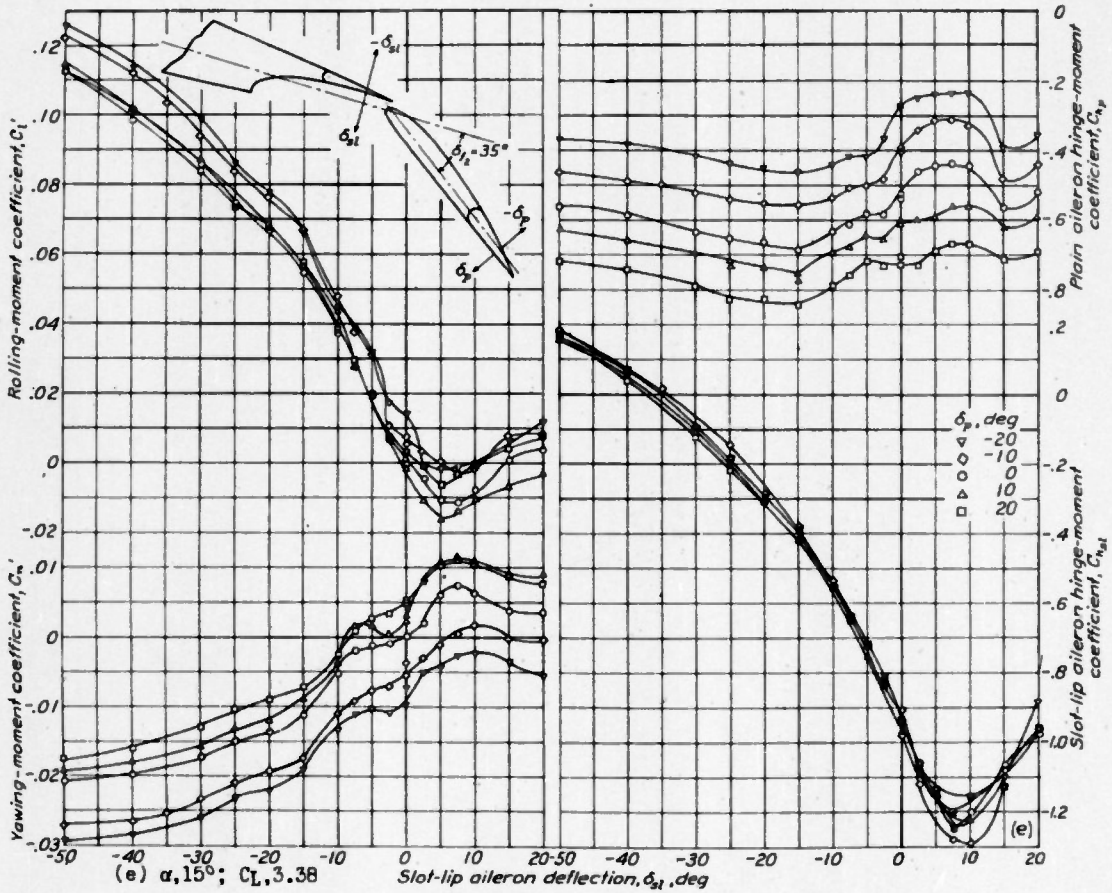

(c) α, 1°; $C_L$, 2.02

Figure 7.- Continued.




(d) $\alpha$, 8°; $C_L$, 2.68

Figure 7.- Continued.




(e) $\alpha$, 15°; $C_L$, 3.38

Figure 7.- Concluded.

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AUTHOR(S): Rogallo, F. M.; Schuldenfrei, M.

ORIGINATING AGENCY: National Advisory Committee for Aeronautics, Washington, D. C.

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Ailerons, Slotted Flaps

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