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RESEARCH MEMORANDUM

INVESTIGATION OF EFFECT OF SPAN AND SPANWISE LOCATION OF PLAIN AND STEPPED SPOILER AILERONS ON LATERAL CONTROL CHARACTERISTICS OF A WING WITH LEADING EDGE SWEPT BACK 51.3°

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

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INVESTIGATION OF EFFECT OF SPAN AND SPANWISE LOCATION OF PLAIN AND STEPPED SPOILER AILERONS ON LATERAL CONTROL CHARACTERISTICS OF A WING WITH LEADING EDGE SWEPT BACK 51.3°

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SUMMARY

A wind-tunnel investigation was made at low speed to determine the lateral control characteristics of a 51.3° sweptback-wing model equipped with either plain or stepped spoiler ailerons having a fixed projection of 5-percent-wing chord and various spans and spanwise locations. The spoiler-aileron configurations were tested on the wing alone, on the wing with a simulated fuselage, on the wing with a simulated fuselage and either a 0.487-span outboard drooped nose, a 0.487-span inboard split flap, or a combination of the two devices.

The results of the investigation indicated that spanwise rolling-effectiveness charts of flap-type ailerons can not be used to predict the effectiveness of spoiler-type ailerons on swept wings. The effectiveness of the spoiler ailerons generally increased with increase in aileron span and when the spanwise location of a constant-span aileron was moved inboard; however, the optimum aileron spanwise location was found to depend on both the spoiler-aileron configuration and the wing configuration. Plain spoiler ailerons were found to produce the greatest rolling effectiveness at low angles of attack and stepped spoiler ailerons produced the greatest rolling effectiveness at high angles of attack.

In general, the yawing-moment coefficients produced by various spoiler ailerons were found to be favorable over most of the angle-of-attack range and were increased when the spanwise location of a constant-span plain or stepped spoiler aileron was moved from inboard to outboard or when the aileron span was increased.

A comparison of the lateral control characteristics of 0.6-semispan inboard spoiler ailerons having 0.05-chord projections and two 0.167-chord conventional flap-type ailerons having total deflections of 15° indicated that the spoiler-aileron characteristics were equal to or more favorable than those of the flap-type ailerons – particularly at high values of lift coefficient.

INTRODUCTION

The necessity of providing adequate lateral control on high-speed aircraft having sweptback wings has presented a problem to airplane designers, since conventional-type ailerons tend to lose effectiveness at high subsonic and transonic speeds. In order to provide solutions to this problem, the National Advisory Committee for Aeronautics is currently investigating the applicability of various other types of lateral-control devices to wings having suitable plan forms for transonic and supersonic speeds. Among the more promising types of lateral-control devices currently being investigated are spoiler-type ailerons. Previous spoiler-type-aileron investigations made on unswept and swept wings (references 1 to 8) indicate some of the beneficial effects that are obtained with spoiler-type ailerons, such as: increase in rolling moment with increase in Mach number; increase in rolling effectiveness with increase in lift-flap deflection; generally favorable yawing moments; practicable use of full-span flaps with spoiler-type ailerons; and smaller wing-twisting moments than flap-type ailerons and hence higher reversal speeds with spoiler ailerons (reference 9). In addition, spoiler ailerons provide low stick forces; and, in the investigation of reference 5, it was noted that no appreciable effects on the hinge-moment characteristics were observed with changes in Mach number for the spoiler-type aileron as contrasted to the increases in hinge-moment coefficient shown or anticipated for the conventional sealed plain aileron.

The effects of span and spanwise location of spoiler ailerons on the characteristics of an unswept wing have been reported previously in reference 1; however, these effects have not been thoroughly investigated on a swept wing. Accordingly, the present investigation was undertaken to determine the effect on the lateral control characteristics of varying the span and spanwise location of plain and stepped spoiler ailerons on a highly swept wing. The present investigation was made at low speed in the Langley 300 MPH 7- by 10-foot tunnel. The characteristics in pitch of a 51.3° sweptback-wing model were investigated for several model configurations in conjunction with various spans and spanwise locations of both plain and stepped spoiler ailerons having a projection of 5 percent of the local wing chord. The aforementioned model configurations are: the plain wing; the wing with a simulated fuselage; and the wing with a simulated fuselage and either an outboard 0.487-span drooped nose deflected 30°, an inboard 0.487-span, 0.26-chord split flap deflected 40°, or a combination of the two devices. In addition, the effect of simulated actuating arms located at two different positions with respect to the spoiler aileron on the rolling-moment and yawing-moment characteristics of a 0.60-semispan stepped spoiler aileron was determined.

SYMBOLS AND CORRECTIONS

The forces and moments measured on the wing are presented about the wind axes. The X-axis is in the plane of symmetry of the model and is parallel to the tunnel air flow. The Z-axis is in the plane of symmetry of the model and is perpendicular to the X-axis. The Y-axis is perpendicular to both the X-axis and Z-axis. All three axes intersect at a point 1.586 feet rearward of the leading edge of the wing root on the line of intersection of the plane of symmetry and the chord plane of the model, as shown in figure 1. This position corresponds to 30 percent of the mean aerodynamic chord.

C_L	lift coefficient (Lift/qS)
$C_{L_{max}}$	maximum lift coefficient
C_D	drag coefficient (D/qS)
C_m	pitching-moment coefficient $(M/qS\bar{c})$
C_l	rolling-moment coefficient (L/qSb)
C_n	yawing-moment coefficient (N/qSb)
D	drag of model, pounds
M	pitching moment of model about Y-axis, foot-pounds
L	rolling moment due to spoiler-aileron projection about X-axis, foot-pounds
N	yawing moment due to spoiler-aileron projection about Z-axis, foot-pounds

q	dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$
S	wing area (5.73 sq ft)
b	span of model (4.22 ft)
b_s	span of spoiler aileron, feet
A	aspect ratio of the wing, 3.11 (b^2/S)
$\bar{c}$	wing mean aerodynamic chord (M.A.C.), 1.424 feet $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$
c	local wing chord measured along lines parallel to X-axis at $\alpha = 0^\circ$, feet
y	lateral distance from plane of symmetry along Y-axis, feet
y_i	lateral distance from plane of symmetry along Y-axis to inboard end of aileron, feet
y_o	lateral distance from plane of symmetry along Y-axis to outboard end of aileron, feet
V	free-stream velocity, feet per second
ρ	mass density of air, slugs per cubic foot
α	angle of attack of wing with respect to chord plane of model, degrees
δ_{a_t}	total aileron deflection, resulting from equal up- and down-aileron deflections on both wing semispans, measured in a plane perpendicular to aileron hinge axis, degrees

The rolling-moment and yawing-moment coefficients represent the aerodynamic effects that occur on the complete wing as a result of the projection of a spoiler aileron on the right semispan wing.

Jet-boundary corrections have been applied to the angle of attack and drag data according to the methods of reference 10. Blockage corrections have been applied to the data by the methods of reference 11.

No corrections have been applied to the data to account for model support strut tares or for the small amount of wing twist produced by the projection of the spoiler ailerons.

APPARATUS AND MODEL

The sweptback-wing model was mounted horizontally in the Langley 300 MPH 7- by 10-foot tunnel on two struts which, in turn, were mounted on a six-component balance system in such a manner that all the forces and moments acting on the model could be measured (fig. 2).

The laminated mahogany model was constructed according to the plan-form dimensions shown in figure 1. The model was swept back 51.3° at the leading edge, had an aspect ratio of 3.11 and a taper ratio of 0.50, and had neither twist nor dihedral. The wing sections parallel to the plane of symmetry were NACA 65_1-012.

The wing model was equipped with a drooped nose which had a span of 0.487b extending from $0.438\frac{b}{2}$ to $0.925\frac{b}{2}$ on each wing panel. Details of the 0.26c split flap are shown in figure 1. The split flap extended from the fuselage outward on each wing panel and had a semispan of $0.487\frac{b}{2}$.

A simulated fuselage, used during most of the investigation to prevent any disturbed flow over the right wing from affecting the flow over the left wing when the spoiler ailerons were projected, was made of $\frac{3}{4}$-inch plywood according to the dimensions shown in figure 1 and had rounded edges.

One of the two configurations of spoiler ailerons investigated consisted of spoiler segments, each having a span of $0.10\frac{b}{2}$ and a projection of 5 percent of the local wing chord, attached to the upper surface of the right wing in a stepped fashion with the span of each segment normal to the plane of symmetry (figs. 2(a) and 3). The midpoint of each spoiler segment was on the 0.70c line of the wing, and the span and spanwise location of the spoiler ailerons were varied during the investigation. This spoiler configuration will be referred to herein as the stepped spoiler aileron. The other configuration consisted of a series of continuous-span spoiler ailerons, each having various spans and spanwise locations, attached to the upper surface of the right wing along the 0.70c line (figs. 2(b) and 4). This spoiler aileron, herein called the plain spoiler aileron, had a projection of 0.05c. Both the stepped and plain spoiler ailerons were prefabricated of aluminum angle and were mounted in such a manner that the front face of the ailerons was normal to the wing surface.

The simulated actuating arms tested in conjunction with a $0.60\frac{b}{2}$ stepped spoiler aileron are shown in figure 5. The arms were constructed of thin solid triangular-shaped pieces of aluminum, each of which had a chord of 0.10c and a maximum height of 0.05c. Each actuating arm was mounted normal to the wing surface on the outboard end of each spoiler-aileron segment as shown in figure 5.

TESTS

All the tests of this investigation were performed in the Langley 300 MPH 7- by 10-foot tunnel at a dynamic pressure of 25.2 pounds per square foot, with a corresponding Mach number of 0.13 and a Reynolds number of 1.3×10^6, based on a wing mean aerodynamic chord of 1.424 feet.

Tests were conducted through an angle-of-attack range from -6° to the wing stall for the following model configurations: the plain wing; wing with the simulated fuselage; and the wing with the simulated fuselage and either the outboard drooped nose deflected 30°, the inboard split flap deflected 40°, or a combination of the two devices. Various spans and spanwise locations of both plain and stepped spoiler ailerons were then investigated with each of these model configurations through the same angle-of-attack range. In addition, tests were made on the wing with the simulated fuselage using the simulated actuating arms at the two positions shown in figure 5 in conjunction with a $0.60\frac{b}{2}$ stepped spoiler aileron located from $0.20\frac{b}{2}$ to $0.80\frac{b}{2}$.

RESULTS AND DISCUSSION

Wing Aerodynamic Characteristics - Spoiler Ailerons Retracted

The lift, drag, and pitching-moment characteristics of the wing-model configurations without the spoiler ailerons are shown in figure 6.

The data presented in figure 6 show that the configurations consisting of the plain wing and the wing with a simulated fuselage had approximately the same lift characteristics. Although deflection of the split flap increased the lift coefficient over most of the α range, it had little effect on $C_{L_{max}}$. Deflection of the drooped nose tended to delay the wing stall to higher values of α, and thus, when the drooped nose was deflected in conjunction with the split flap on the wing with a simulated fuselage, almost a constant increment of C_L was obtained over the entire angle-of-attack range.

The drag data show that at low values of lift coefficient the drag coefficient was larger for the wing with the high-lift and stall-control devices than for the plain wing, whereas at high values of C_L the drag coefficient for the plain wing was larger. In addition, the drooped nose was particularly effective in reducing the drag coefficient at high values of lift coefficient.

The pitching-moment data presented in figure 6 show that at low values of C_L the aerodynamic center is generally slightly ahead of the $0.30\bar{c}$ for all configurations, and that deflection of either the split flap or the drooped nose produced more negative pitching moments than those of the plain wing but did not eliminate the unstable stalling characteristics of the wing.

Wing Aerodynamic Characteristics – Spoiler Ailerons Projected

The characteristics of the wing equipped with the plain and stepped spoiler-aileron configurations used in this investigation (figs. 3 to 5) are presented in figures 7 to 27.

In order to provide some information on the characteristics of spoiler-type ailerons when used as speed brakes or glide-path controls on swept wings (as, for example, was provided for unswept wings (reference 12)) the effects of the various spoiler-aileron configurations on the the wing lift, drag, and pitching-moment characteristics are shown in figures 7 to 26. The incremental effects of the various spoiler-aileron configurations on the lift, drag, and pitching-moment data of figures 7 to 26 are those produced by spoiler ailerons projected on one semispan of a complete wing; however, when used as speed brakes or glide-path controls, spoiler ailerons would be projected simultaneously on both semispans of a complete wing, thereby producing twice the incremental effects shown on the figures herein. In general, projection of either the plain or stepped spoiler ailerons on any of the wing configurations tested decreased the lift coefficient at given angles of attack and increased the coefficient of drag. Increasing the span or moving the spanwise location of either a plain or stepped spoiler aileron having a constant span from outboard to inboard produced successively larger decreases in lift coefficient and increases in C_D. No appreciable change in pitching moment was produced by the projection of any of the plain or stepped spoiler ailerons on any of the wing configurations tested.

Spoiler ailerons on the plain wing and on the wing with a simulated fuselage.- The effects of span and spanwise location of both plain and stepped spoiler ailerons on the lateral control characteristics of the 51.3° sweptback wing alone and with a simulated fuselage are shown in figures 7 to 9 and figures 10 to 17, respectively. A comparison of these data shows that the simulated fuselage had little or no effect on the rolling-moment and yawing-moment characteristics of the wing model, therefore the discussion of these characteristics for the two model configurations has been combined in the present section.

Up to an angle of attack of approximately 18°, the values of rolling-moment coefficient produced by projection of the stepped spoiler ailerons generally increased with increase in angle of attack, whereas the values of C_l for the plain spoiler ailerons generally decreased with increase in α over most of the α range. In general, at angles of attack below 12°, projection of inboard plain spoiler ailerons produced larger values of rolling-moment coefficients than inboard stepped spoiler ailerons, and outboard plain spoiler ailerons of $0.60\frac{b}{2}$ and larger produced larger values of C_l than corresponding stepped spoiler ailerons; however, at angles of attack of and above approximately 12° the stepped spoiler ailerons usually had the largest values of rolling moment. These effects are somewhat different than those reported in reference 2, which showed that the rolling effectiveness of an outboard stepped spoiler aileron was better than that of an outboard plain spoiler aileron over the entire α range. In general, the rolling-moment coefficient was increased as the spanwise location of a constant $0.60\frac{b}{2}$ plain or stepped spoiler aileron was moved from outboard to inboard or as the aileron span was increased. This effect of aileron span and spanwise location on the rolling moments agrees with similar results previously reported in references 2 and 7. Over most of the angle-of-attack range, the plain spoiler aileron located from $0.0\frac{b}{2}$ to $0.6\frac{b}{2}$ and the stepped spoiler aileron located from $0.1\frac{b}{2}$ to $0.7\frac{b}{2}$ produced the highest rolling moments of any $0.6\frac{b}{2}$ plain and stepped spoiler ailerons, respectively, investigated.

In order to determine whether spanwise rolling-effectiveness charts of flap-type ailerons on swept wings could also be used for spoiler-type controls - as was found for unswept wings in reference 1 - the data in figures 15, 16, and 17 were compared with the data of references 3 and 13. This comparison shows that the span and spanwise location of spoiler-type ailerons had more effect on the wing rolling moments than the span and spanwise location of flap-type ailerons, and that the geometry of spoiler-type ailerons also affects the wing rolling moments. In addition, in references 3 and 13 it was shown that the rolling effectiveness of a partial-span flap-type aileron located over any portion of the wing span could be accurately predicted from spanwise rolling-effectiveness charts since the effectiveness of partial-span flap-type ailerons was additive. The data presented herein, however, show that the rolling effectiveness of partial-span spoiler-type ailerons are not additive, inasmuch as inboard and outboard spoiler ailerons have spanwise effectiveness characteristics that cannot be combined into one curve and all the results shown in figure 17 cannot be predicted from the charts shown in figures 15 and 16. Therefore, design charts for flap-type ailerons, such as given in reference 13, in general, should not be used for spoiler-type ailerons on swept wings.

The spoiler-aileron configurations tested on the wing alone and the wing with a simulated fuselage usually had favorable yawing-moment coefficients (having the same sign as the values of C_l) at angles of attack below approximately 16° – the plain spoiler ailerons usually producing slightly more favorable yawing moments than the stepped spoiler ailerons. In general, C_n became less favorable with increase in α, and in most instances, the yawing moments became more favorable when the aileron span was increased or the spanwise location of a constant-span spoiler aileron was moved from inboard to outboard for both the plain and stepped aileron configurations.

Effect of stall-control and high-lift devices on spoiler-aileron-control characteristics.- Because of the difficulties exhibited by swept-wing airplanes in obtaining sufficient high lift for specific maneuvers, high-lift flaps and stall-control devices will probably be utilized during landing and take-off, and the lateral control characteristics of swept-wing airplanes in this condition are important, particularly at large angles of attack. The lateral control characteristics produced by various plain and stepped spoiler ailerons on the swept-wing model with a simulated fuselage and either a deflected drooped nose, a deflected split flap, or a combination of drooped nose and split flap are shown in figures 18 to 20, 21 to 23, and 24 to 26, respectively.

A comparison of the data of figures 18 to 26 with the data of figures 10 to 17 shows that for the wing configurations in which the stall-control and/or high-lift devices were used in conjunction with the spoiler aileron, the trends in the rolling-moment data, especially at high angles of attack, were generally similar to those noted for the other configurations tested. In general, up to angles of attack of 14° plain spoiler ailerons were more effective than corresponding stepped spoiler ailerons at all spanwise locations; and for ailerons of $0.6\frac{b}{2}$, the plain spoiler aileron located from $0.2\frac{b}{2}$ to $0.8\frac{b}{2}$ usually gave the highest values of C_l. However, at angles of attack above 14°, stepped spoiler ailerons were generally more effective than plain spoiler ailerons; and for ailerons of $0.6\frac{b}{2}$, the inboard stepped spoiler ailerons produced the highest values of C_l. In the moderate angle-of-attack range and at high angles of attack, the rolling moments produced by aileron projection generally increased as a constant-span plain or stepped spoiler aileron was moved inboard; however, at low and moderate values of α for the drooped-nose split-flap wing configuration, an opposite effect was noted (figs. 18 to 26). In general, deflection of the drooped nose caused a slight decrease in C_l of both plain and stepped spoiler ailerons as compared with the values of C_l obtained on the wing without high-lift and stall-control devices; deflection of the split flap decreased C_l of the stepped spoiler aileron, but had no consistent effect on C_l of the plain spoiler aileron; and deflection of both the drooped nose and split flap increased C_l of all outboard spoiler ailerons at low angles of attack and increased C_l of all ailerons at high angles of attack. (Compare figs. 18 to 26 with figs. 10 to 17.)

The yawing moments produced on the wing with the high-lift and stall-control devices were also similar in trend to the yawing moments of the other configurations tested. (Compare figs. 18 to 26 with figs. 10 to 17.) The wing configurations on which the drooped nose was deflected usually had slightly more favorable yawing moments over a greater angle-of-attack range than any other configurations tested, and these yawing moments were particularly more favorable at high angles of attack. Deflection of the split flap alone had an inconsistent effect on the values of C_n.

Effect of actuating arms on characteristics of a stepped spoiler aileron.- The effects of simulated actuating arms located normal to the 0.70 chord line or normal to the face of a $0.60\frac{b}{2}$ stepped spoiler aileron located from $0.20\frac{b}{2}$ to $0.80\frac{b}{2}$ (fig. 5) on the lateral control characteristics of the wing with simulated fuselage are shown in figure 27. The data show that simulated actuating arms had no appreciable effect on the aileron effectiveness at high angles of attack, but that the actuating arms normal to the ailerons increased the aileron effectiveness at low angles of attack. All of the configurations for which data are shown in figure 27 had almost the same yawing-moment characteristics.

Comparison of Spoiler-Type and Flap-Type Ailerons

A comparison of the lateral-control characteristics of the spoiler-type ailerons reported herein and of the 0.167c flap-type ailerons of reference 3 on a 51.3° sweptback wing is shown in figure 28. Although the simulated fuselage and the wing aspect ratio of the present investigation and that reported in reference 3 differed slightly ($A = 3.11$ in present investigation and 3.43 in investigation of reference 3), the geometric differences are such as to favor the flap-type aileron in this comparison. A plain spoiler aileron located from $0.0\frac{b}{2}$ to $0.6\frac{b}{2}$ and a stepped spoiler aileron located from $0.1\frac{b}{2}$ to $0.7\frac{b}{2}$ were the optimum $0.6\frac{b}{2}$ plain and stepped spoiler ailerons, respectively, for the present investigation. The $0.51\frac{b}{2}$ flap-type aileron extending from $0.30\frac{b}{2}$ to $0.81\frac{b}{2}$ was the optimum partial-span aileron (of about $0.5\frac{b}{2}$ or less) for the investigation of reference 3, and the $0.40\frac{b}{2}$ flap-type aileron extending from $0.59\frac{b}{2}$ to $0.99\frac{b}{2}$ was the more practicable aileron (from considerations of span and spanwise location) of reference 3. The lateral control characteristics of these aileron configurations are compared in figure 28 by utilizing spoiler-aileron projections of 0.05c. and total deflections of the flap-type ailerons of 15°.

The data in figure 28 show that the plain spoiler aileron had approximately the same rolling effectiveness throughout the angle-of-attack range as the $0.51\frac{b}{2}$ flap-type aileron, but had more rolling effectiveness than the $0.40\frac{b}{2}$ flap-type aileron. In addition, at low angles of attack, the stepped spoiler aileron had about the same rolling effectiveness as that of the $0.40\frac{b}{2}$ flap-type aileron and slightly less than the $0.51\frac{b}{2}$ flap-type aileron; however, at high angles of attack, projection of the stepped spoiler aileron gave values of rolling moment considerably higher than either of the flap-type ailerons or the plain spoiler aileron. The yawing-moment coefficients produced by either of the spoiler ailerons were more favorable than those of the flap-type ailerons, except at very high angles of attack, for which the yawing moments of the stepped spoiler aileron were more unfavorable than those of any of the other aileron configurations.

The comparison discussed in the preceding paragraph is based on low-speed data and neglects any discussion of aileron hinge moments or the effects of compressibility on any of the aileron characteristics. However, the data of references 5, 6, and 8 show the increase in effectiveness with increase in Mach number up to high subsonic speeds obtained with spoiler ailerons as contrasted to opposite effects obtained with flap-type ailerons, and the data of reference 5 also show the generally more beneficial effects on spoiler-aileron hinge moments than on flap-type aileron hinge moments of increases in the Mach number.

CONCLUSIONS

A wind-tunnel investigation was made at low speed to determine the lateral control characteristics of a 51.3° sweptback-wing model equipped with either plain or stepped spoiler ailerons having a fixed projection of 5-percent-wing chord and various spans and spanwise locations. The spoiler-aileron configurations were tested on the wing alone, on the wing with a simulated fuselage, on the wing with a simulated fuselage and either an 0.487 span outboard drooped nose, an 0.487 span inboard split flap, or a combination of the two devices. The results of the investigation led to the following conclusions:

1. The rolling effectiveness of both plain and stepped spoiler ailerons generally increased when the aileron span was increased and when the spanwise location of a constant-span spoiler aileron was moved inboard, except at low and moderate angles of attack for the split-flap drooped-nose wing configuration, for which an opposite effect of spanwise location was noted. The optimum aileron spanwise location was found to depend on both the spoiler-aileron configuration and the wing configuration.

2. Spanwise rolling-effectiveness charts of flap-type ailerons cannot be used to predict the effectiveness of spoiler-type ailerons on swept wings.

3. A comparison of the effectiveness of plain and stepped spoiler ailerons showed that the plain spoiler ailerons were generally found to produce higher values of rolling-moment coefficient below angles of attack of approximately 12°, and stepped spoiler ailerons were found to produce higher values of rolling-moment coefficient at angles of attack above approximately 12°.

4. Addition of the fuselage to the plain-wing configuration had little effect on the rolling moments produced by the various aileron configurations.

5. Deflection of either the drooped nose or the split flap separately usually had a slight deleterious effect on the spoiler-aileron rolling effectiveness. Deflection of both the drooped nose and the split flap increased the rolling effectiveness of both plain and stepped spoiler ailerons at high angles of attack.

6. In general, the yawing-moment coefficients produced by the various spoiler ailerons were found to be favorable over most of the angle-of-attack range, and were increased when the spanwise location of a constant-span plain or stepped spoiler aileron was moved from inboard to outboard or when the aileron span was increased.

7. The lateral control characteristics of 0.6-semispan inboard spoiler-type ailerons having 0.05-chord projections were equal to or more favorable than those of two 0.167-chord conventional flap-type ailerons having total deflections of 15° previously investigated - particularly at high values of lift coefficient.

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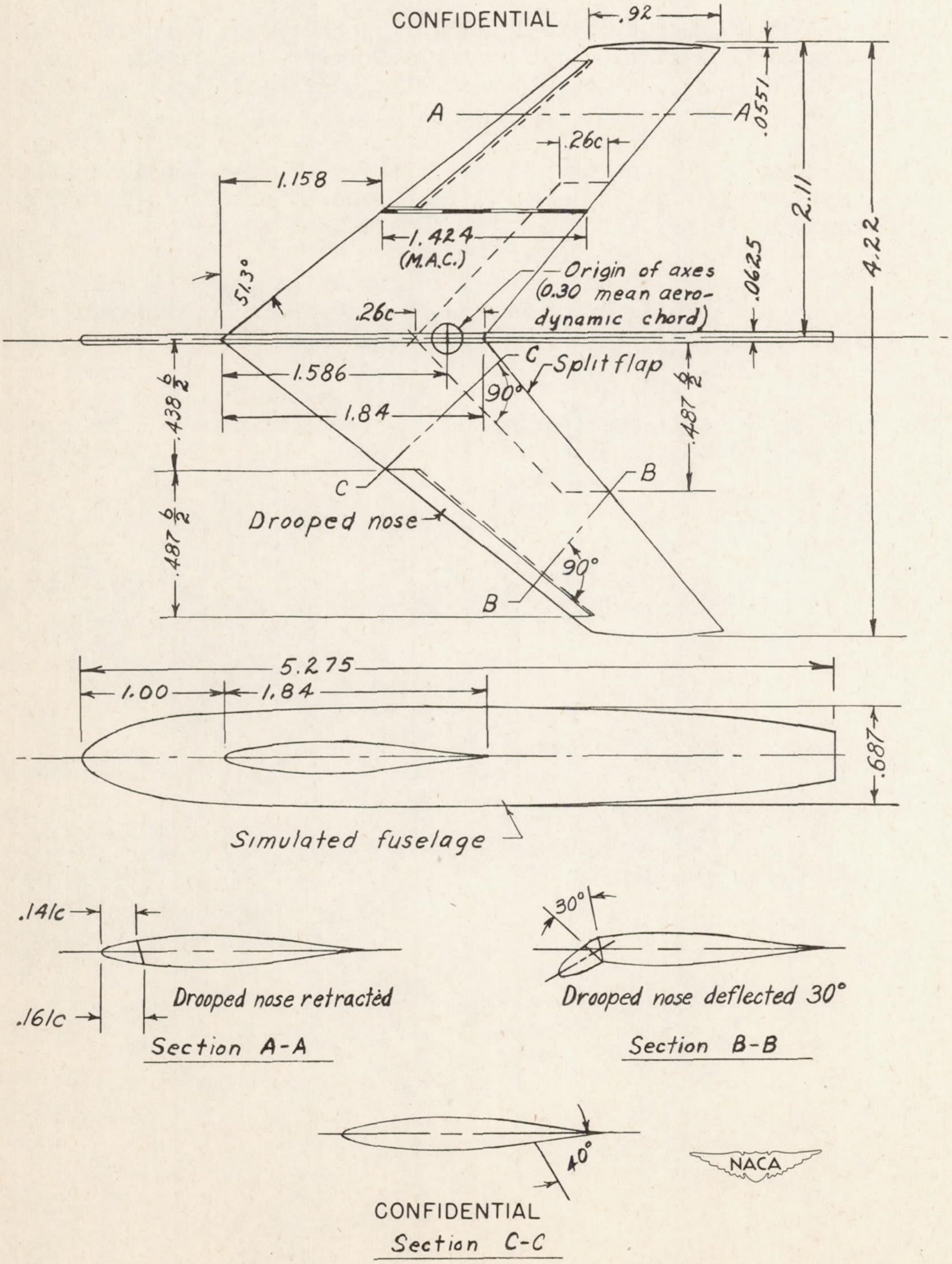
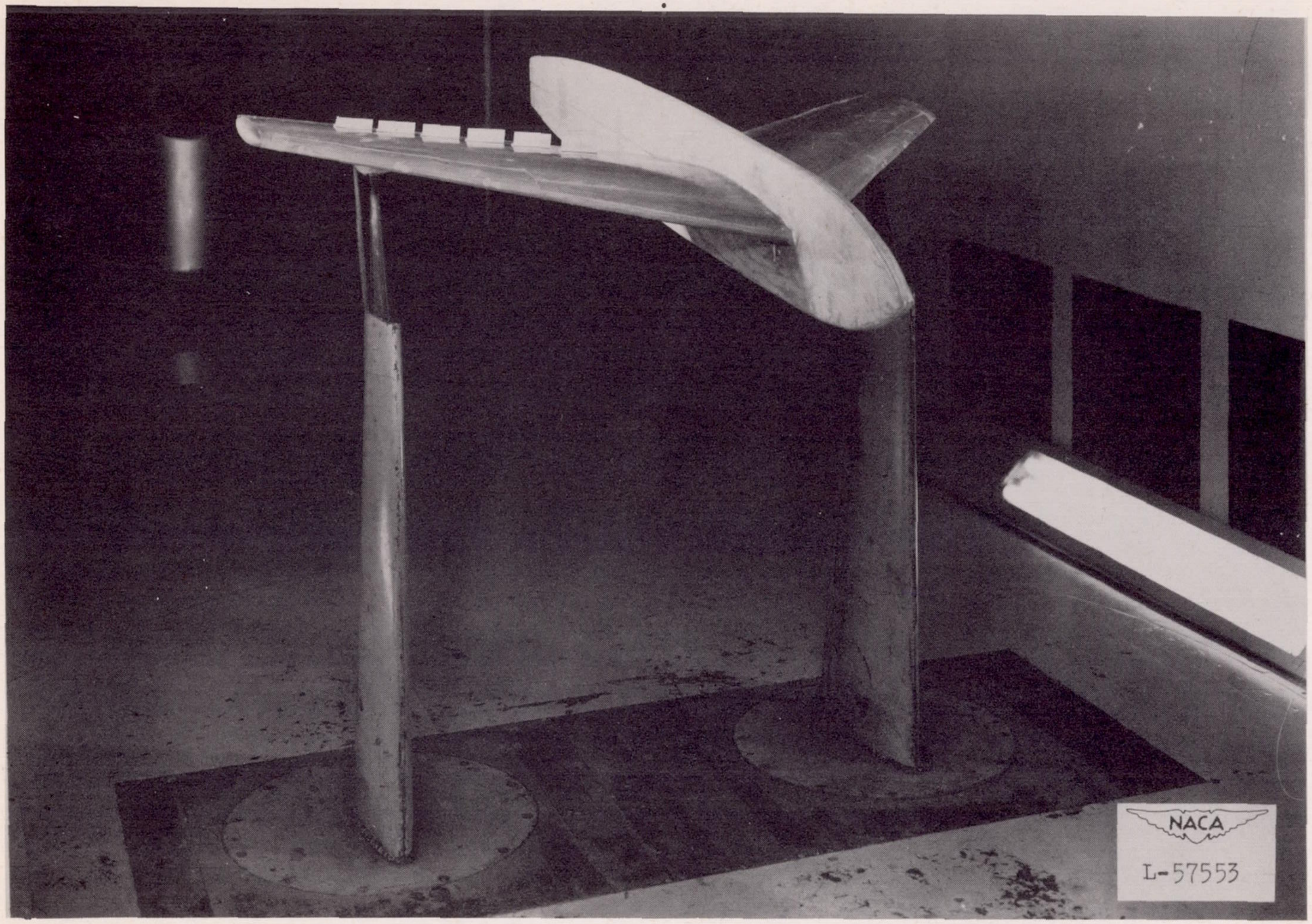
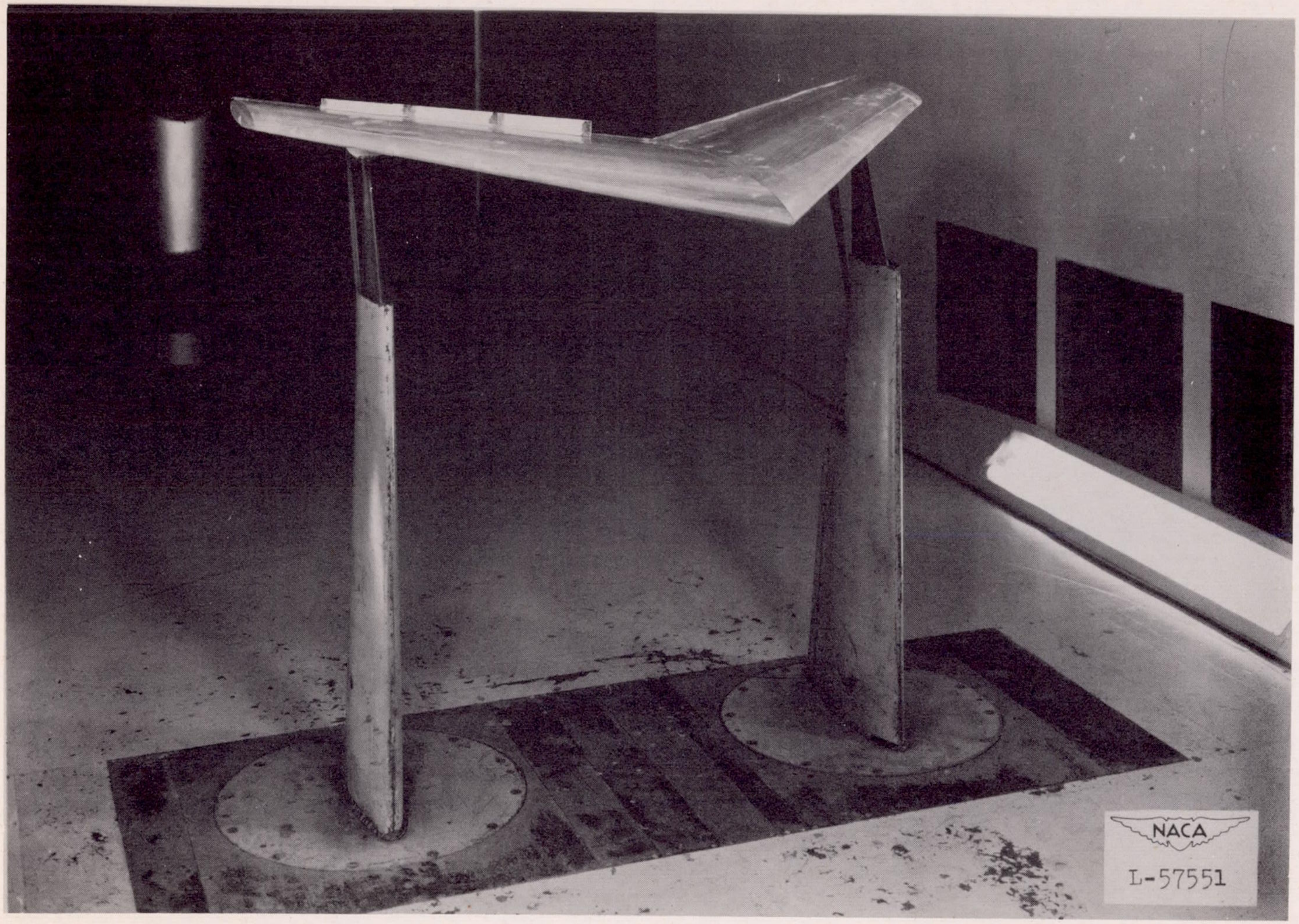


Figure 1.- Sketch of the 51.3° sweptback wing model showing the details of the simulated fuselage, drooped nose, and split flap. $S = 5.73$ square feet; $A = 3.11$; taper ratio = 0.50. (All dimensions are in feet, except as noted.)



(a) Wing model with simulated fuselage and one of the stepped-spoiler-aileron configurations tested.

Figure 2.- The 51.3° sweptback wing mounted in the Langley 300 MPH 7- by 10-foot tunnel.



(b) Wing model with one of the plain-spoiler-aileron configurations tested.

Figure 2.- Concluded.

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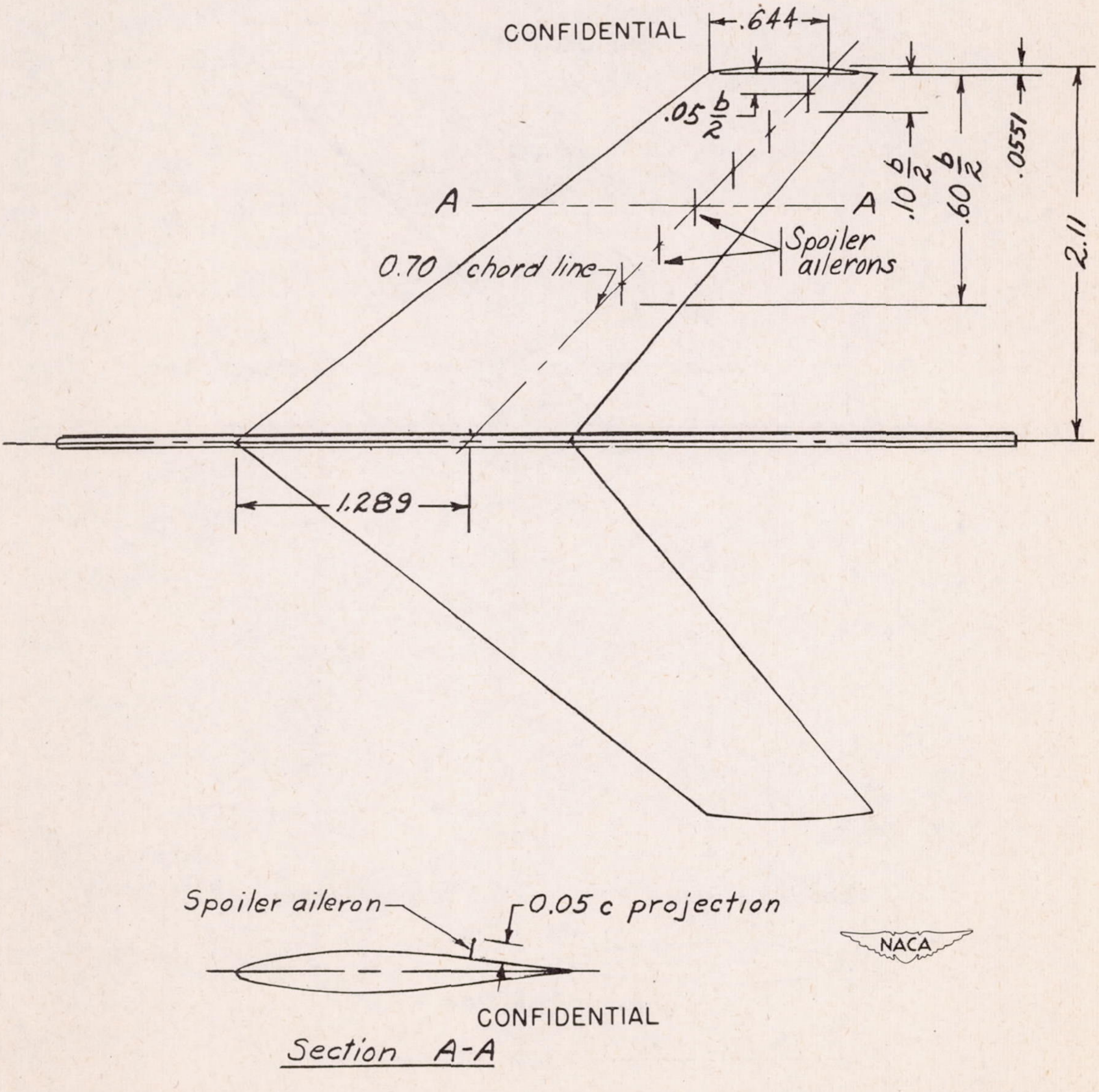

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Figure 3.- Sketch of the 51.3° sweptback wing showing a typical stepped-spoiler-aileron configuration tested. (All dimensions are in feet, except as noted.)

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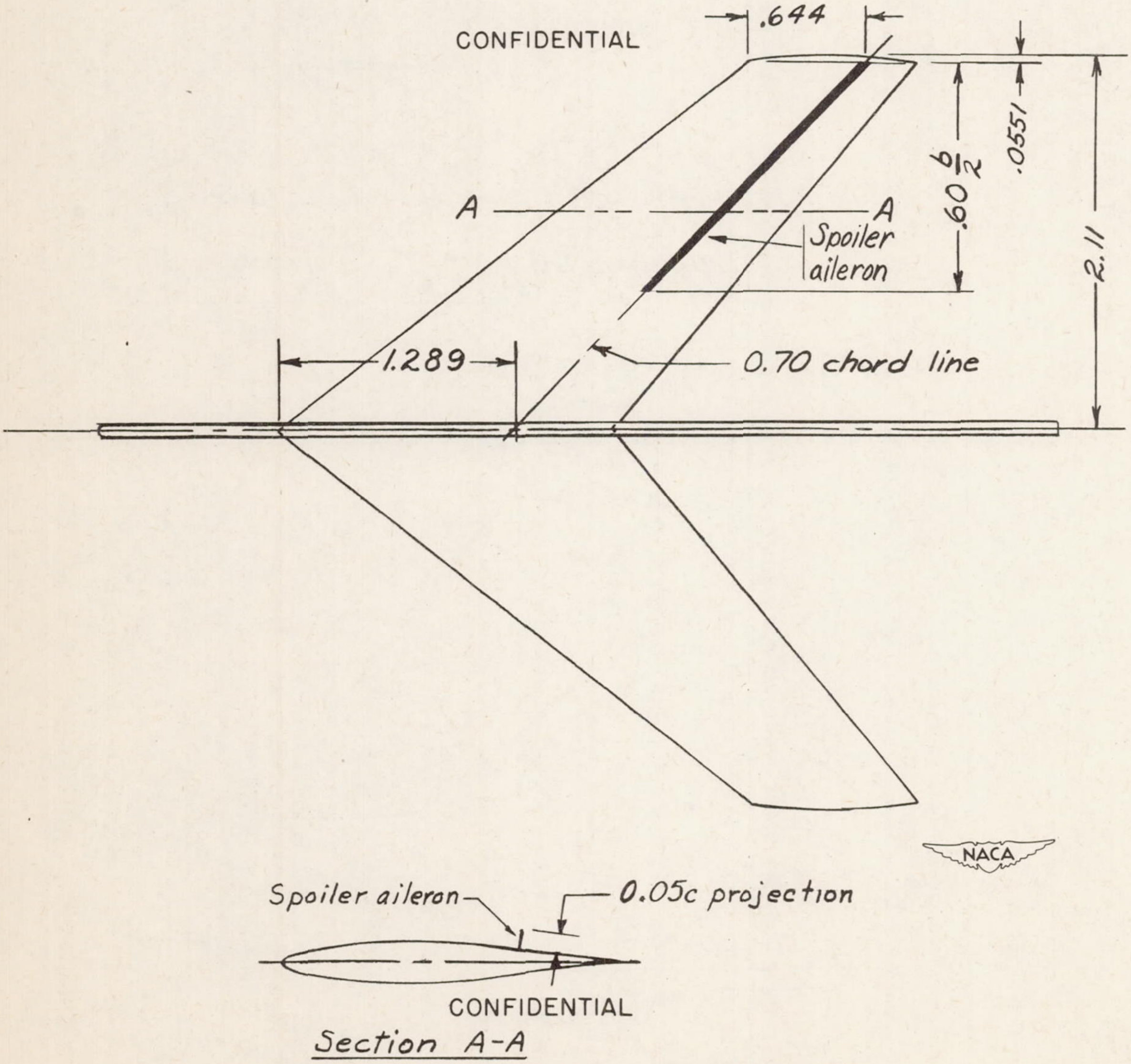

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Figure 4.- Sketch of the 51.3° sweptback wing showing a typical plain-spoiler-aileron configuration tested. (All dimensions are in feet, except as noted.)

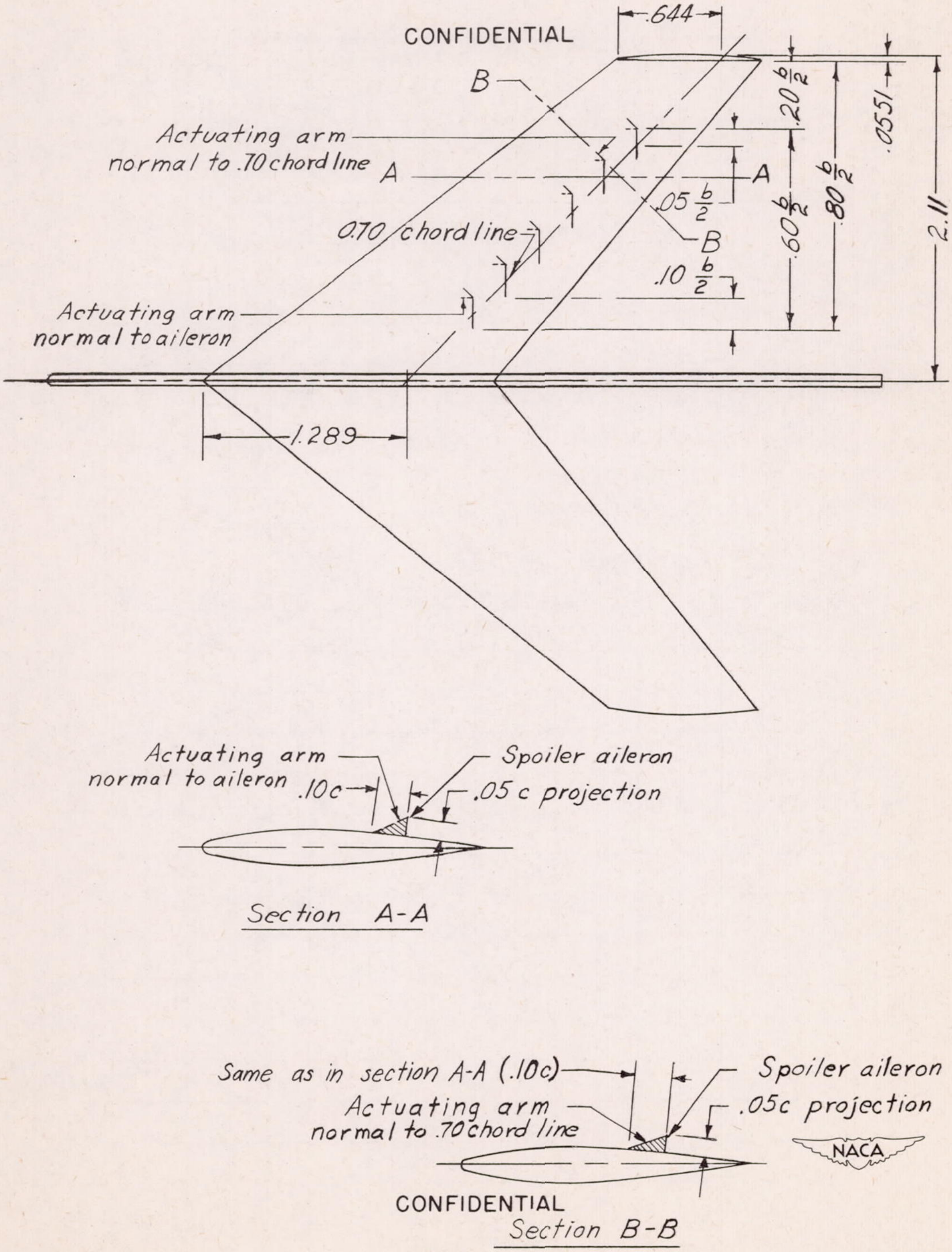


Figure 5.- Sketch of the 51.3° sweptback wing showing the stepped-spoiler-aileron configuration investigated with actuating arms. Aileron span, $\frac{b_s}{b/2} = 0.60$. (All dimensions are in feet, except as noted.)

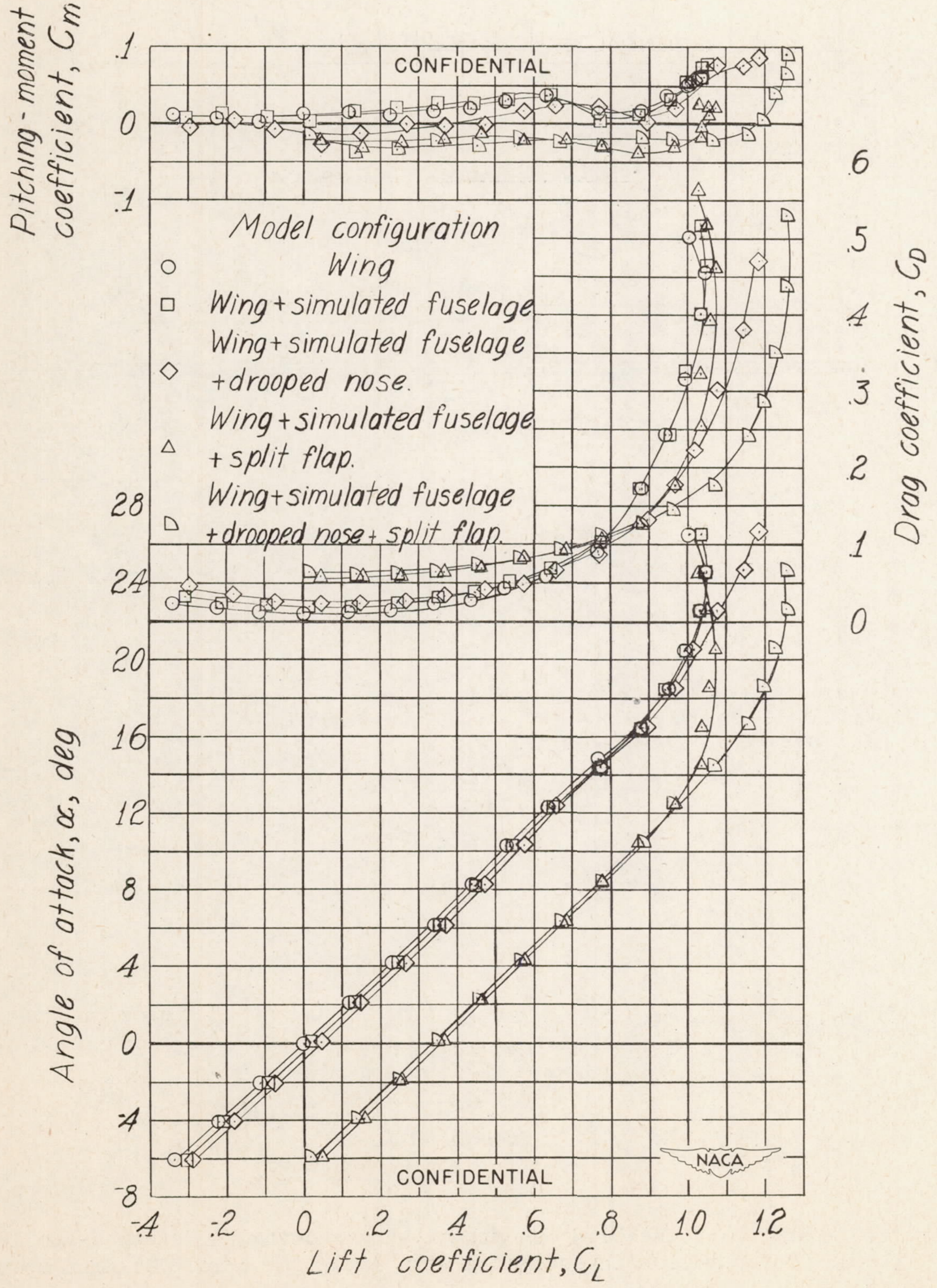


Figure 6.- Aerodynamic characteristics of the basic wing configurations tested.

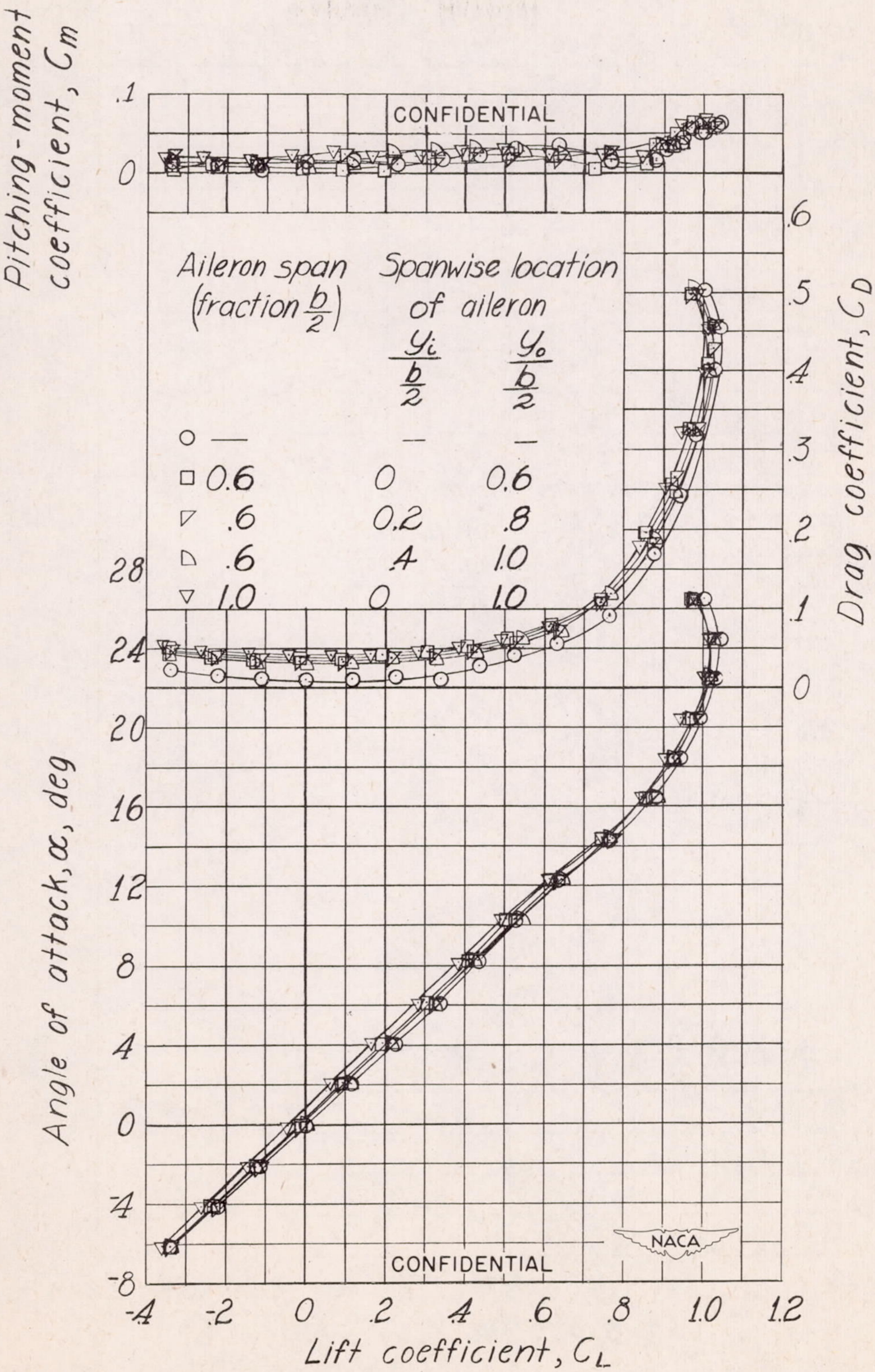
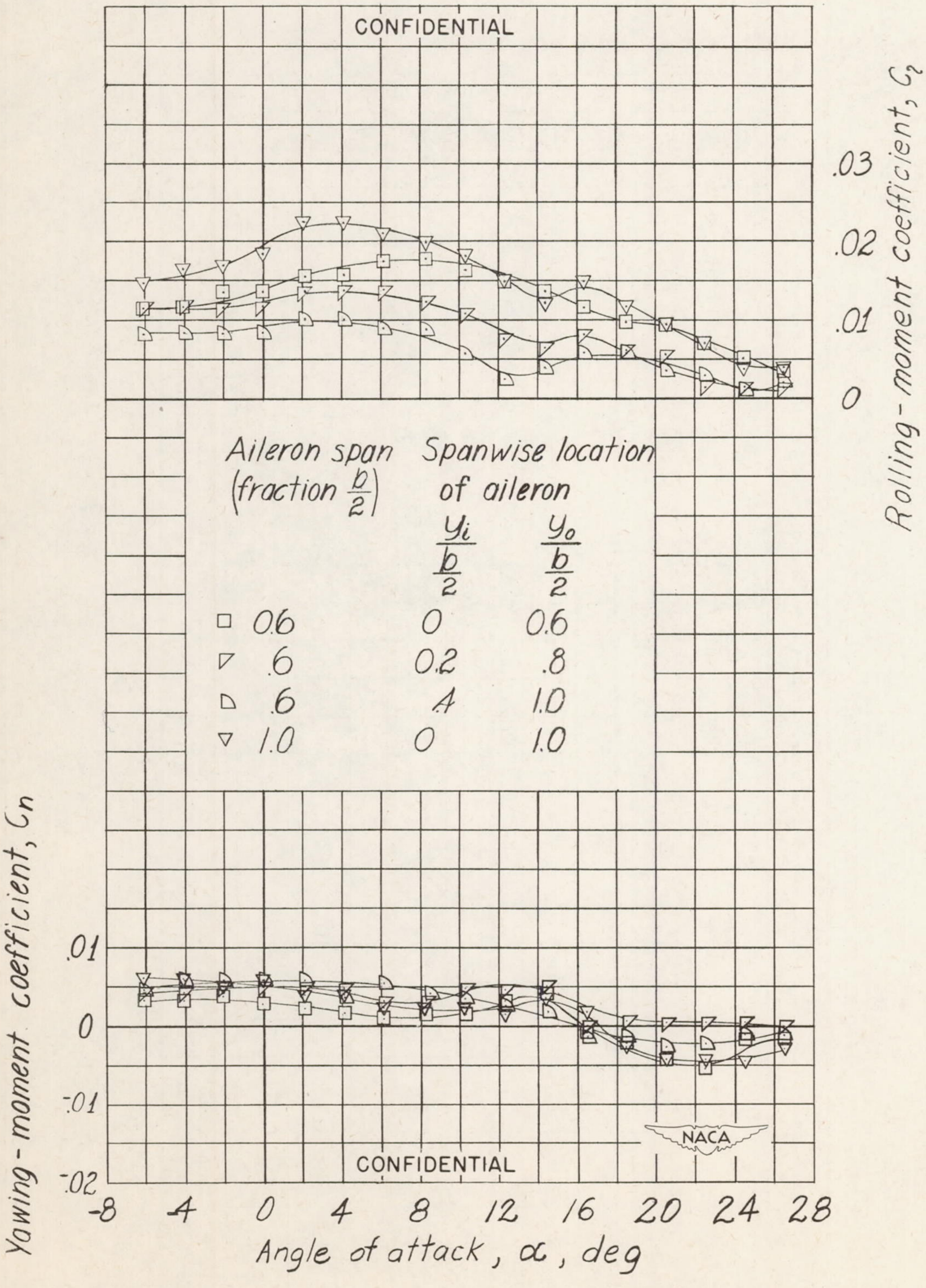


Figure 7.- Effect of span and spanwise location of plain spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing.



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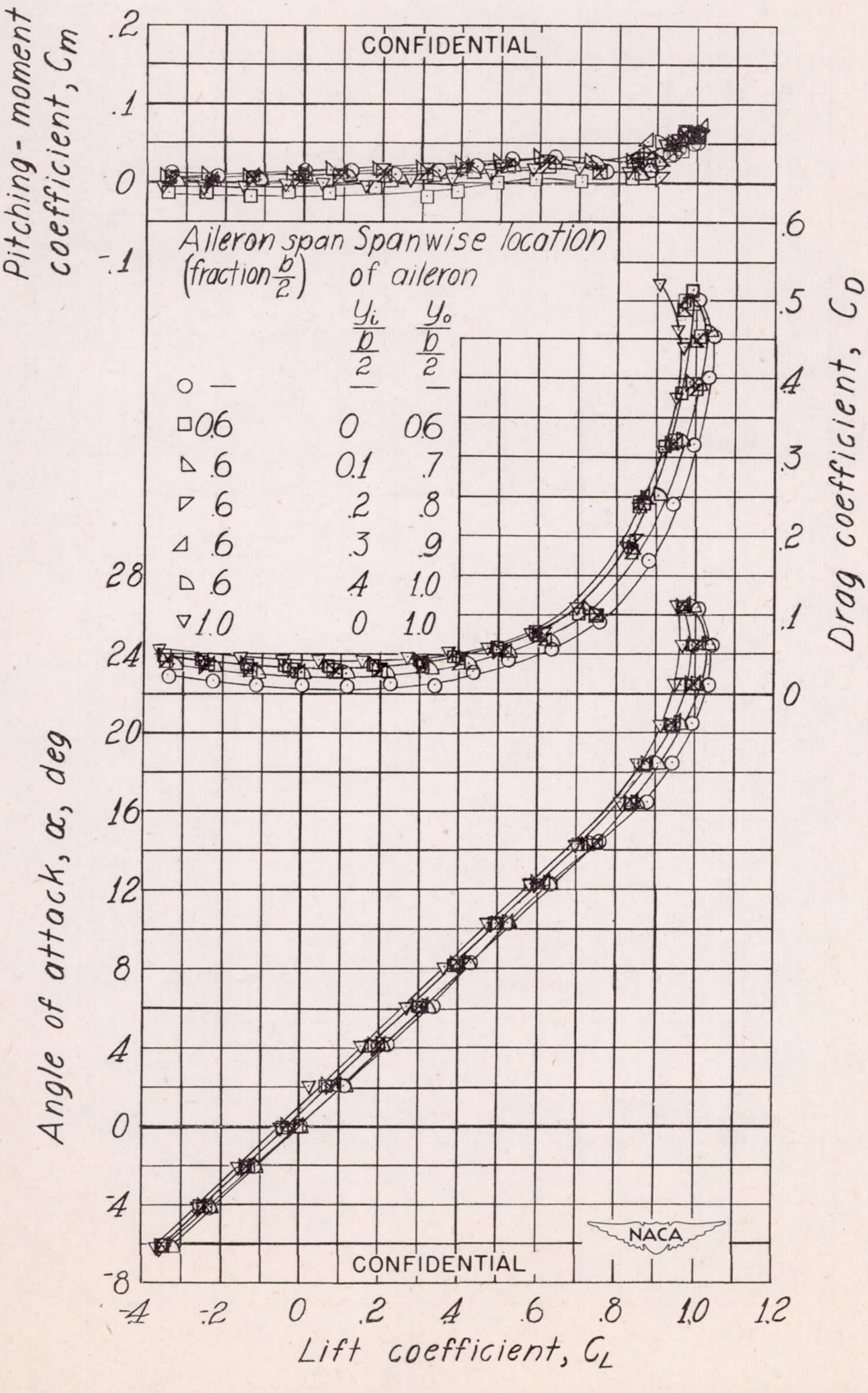

Figure 8.- Effect of span and spanwise location of stepped spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing.

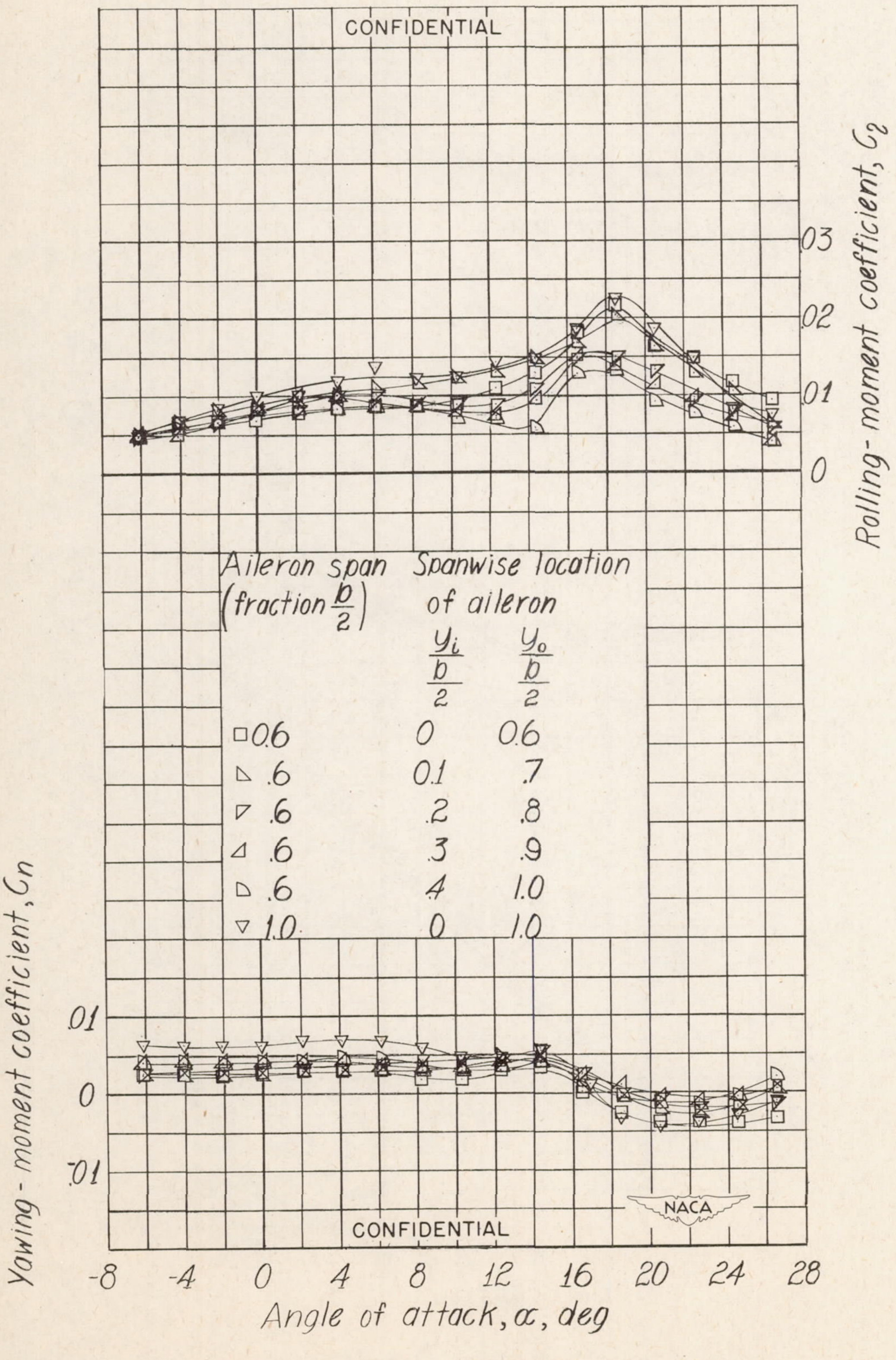

Figure 8.- Concluded.

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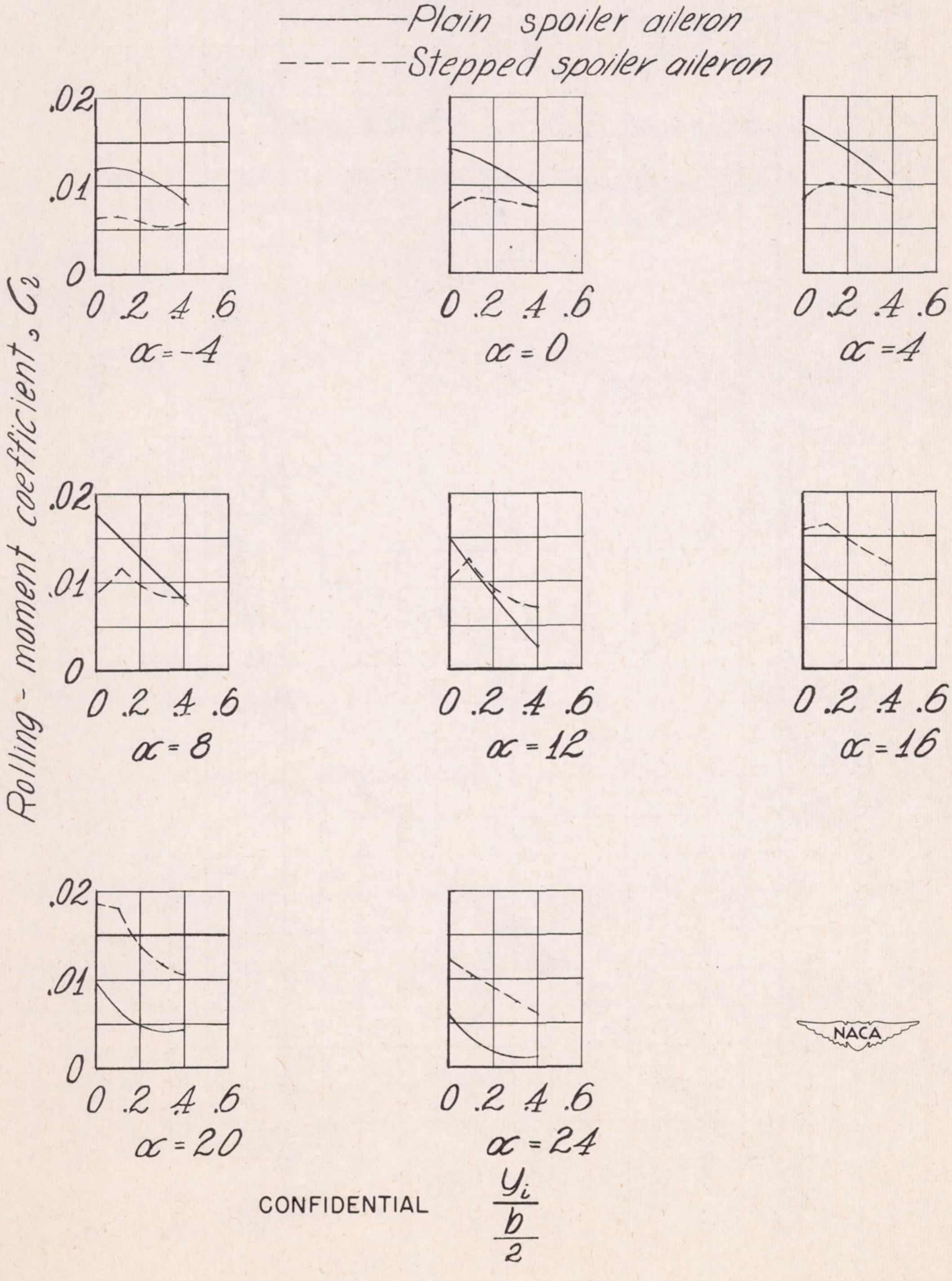

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Figure 9.- Variation of rolling-moment coefficient with spanwise location of a constant-span plain and stepped spoiler aileron on the 51.3° sweptback wing. Aileron span, $\frac{b_s}{b/2} = 0.60$.

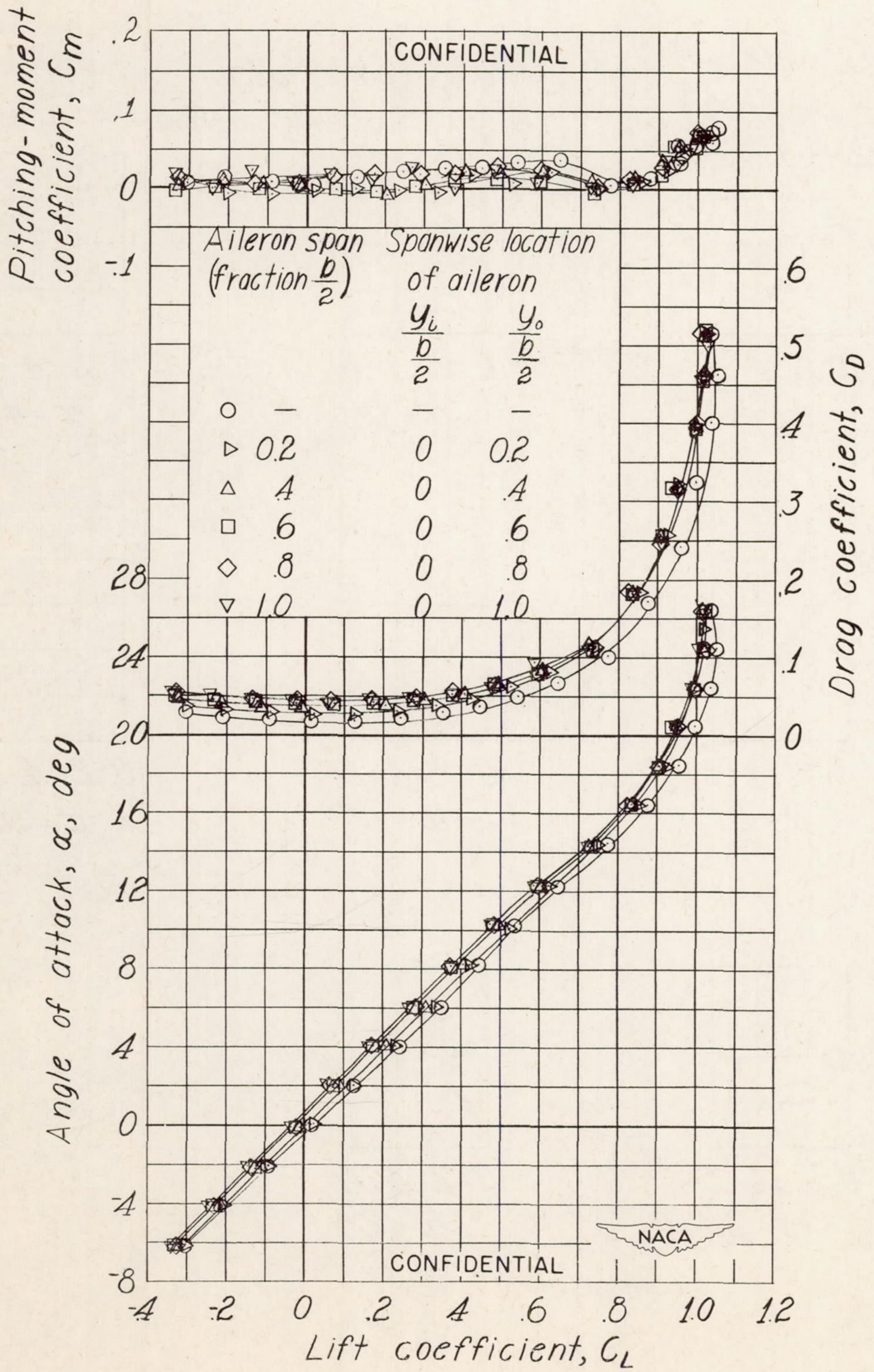
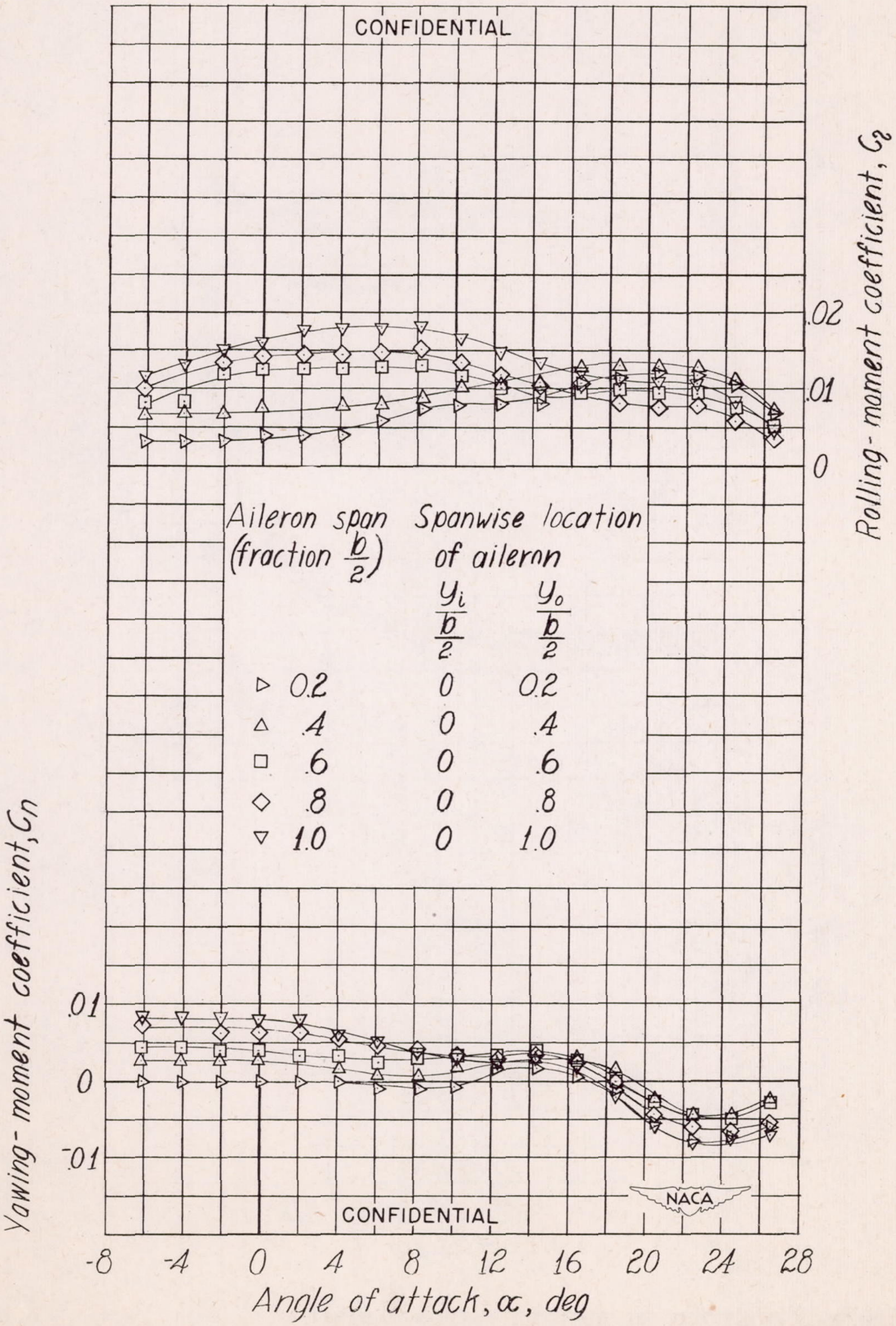


Figure 10.- Effect of span of inboard plain spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage.



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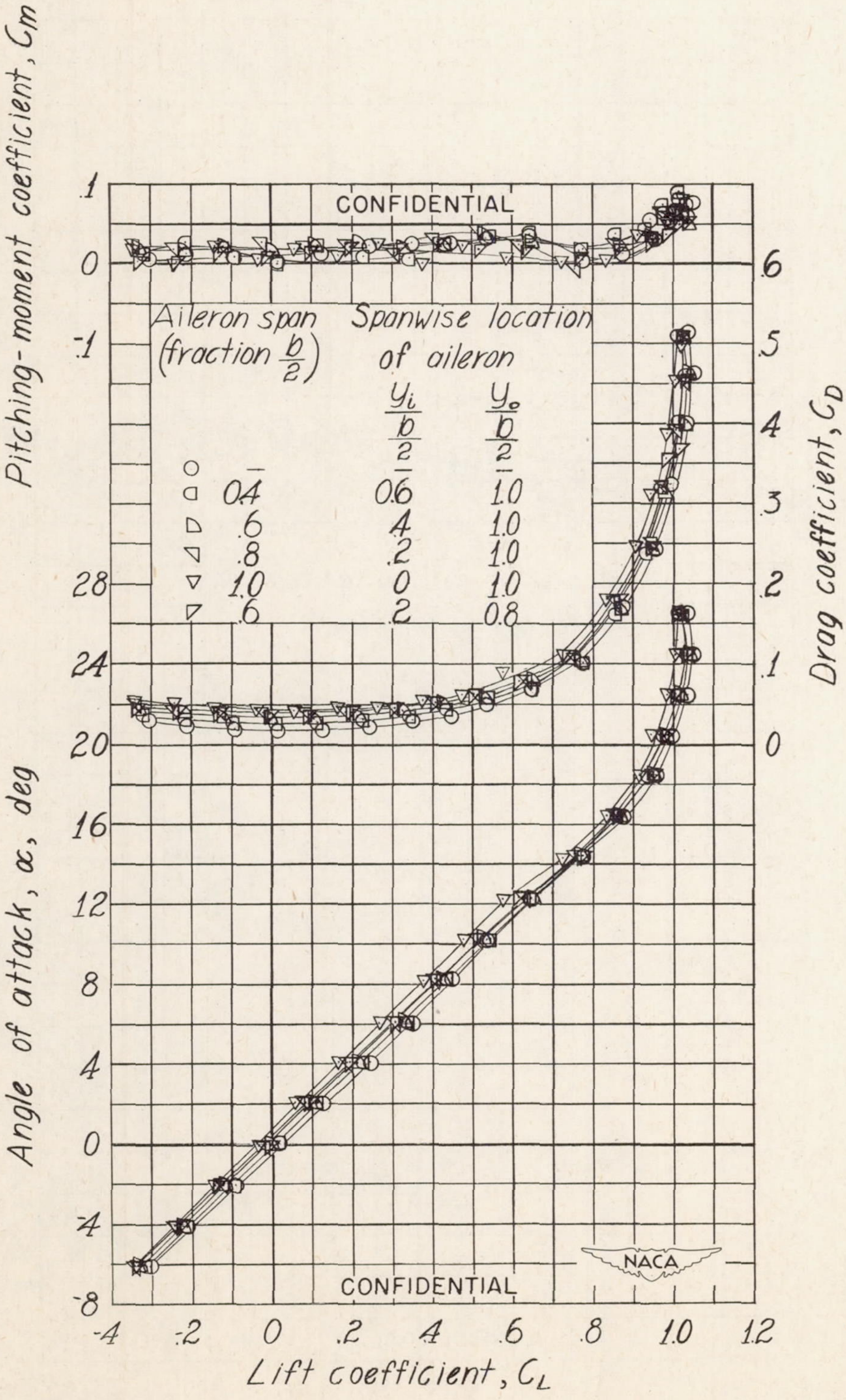
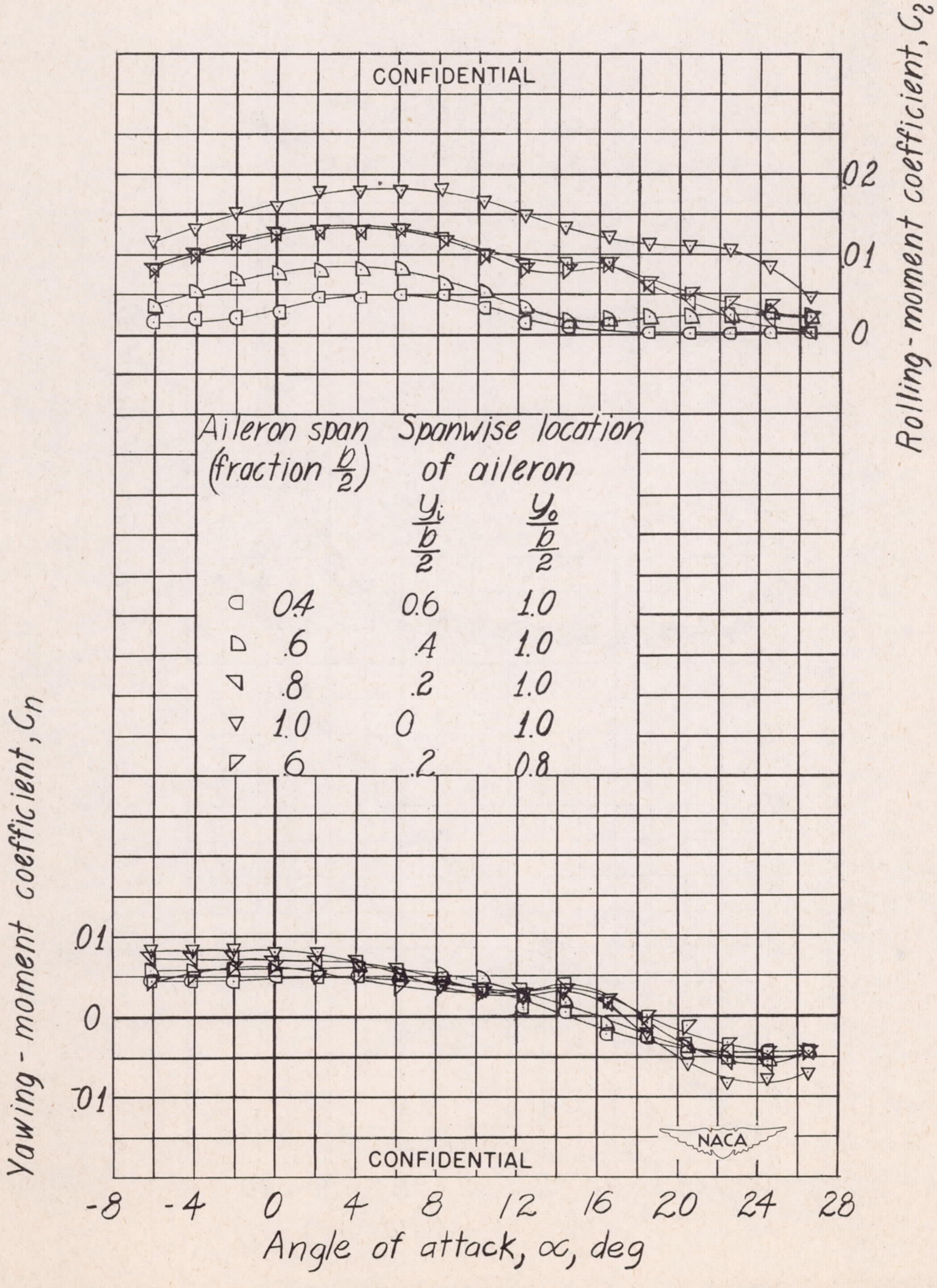


Figure 11.- Effect of span of outboard plain spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage.



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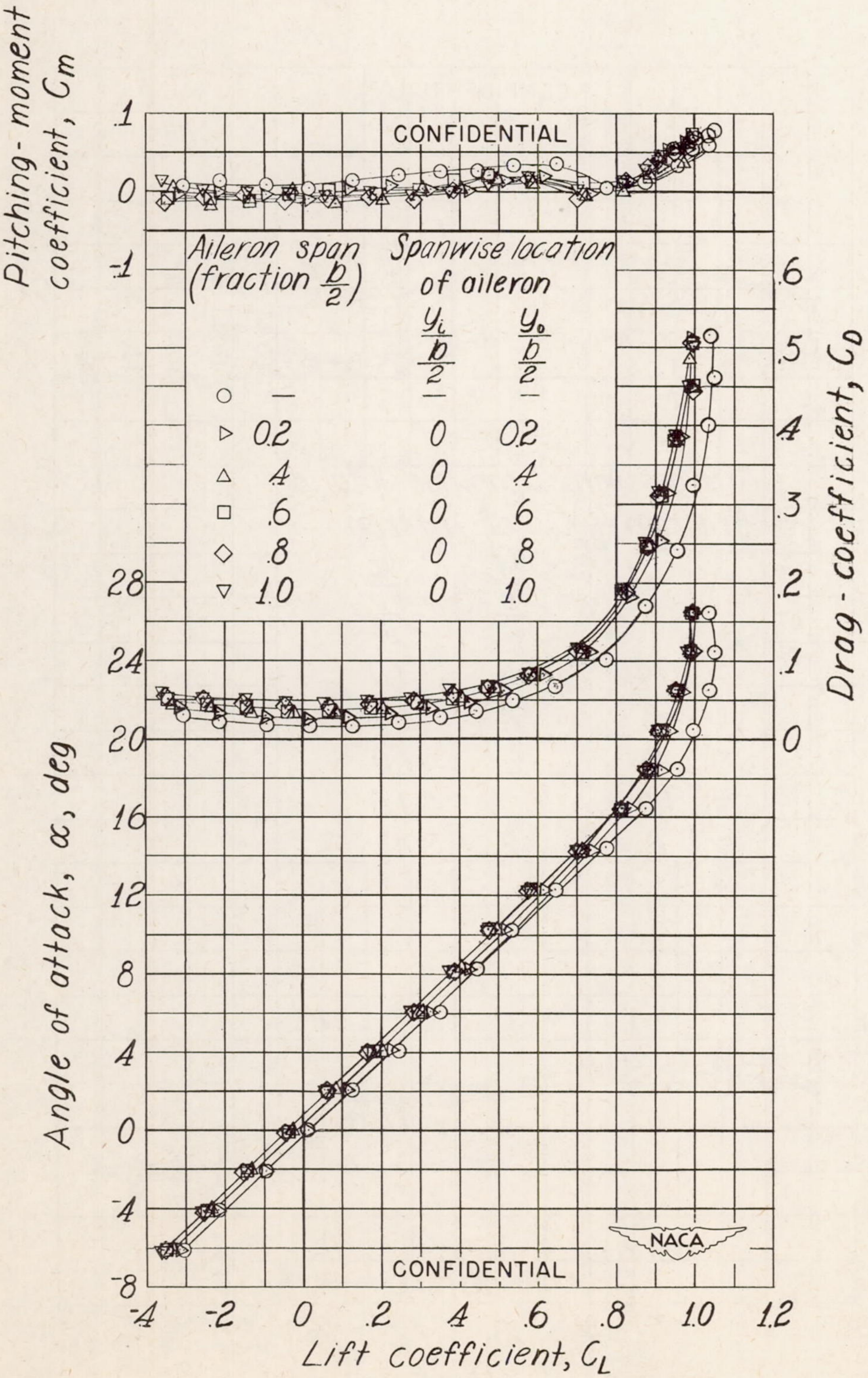
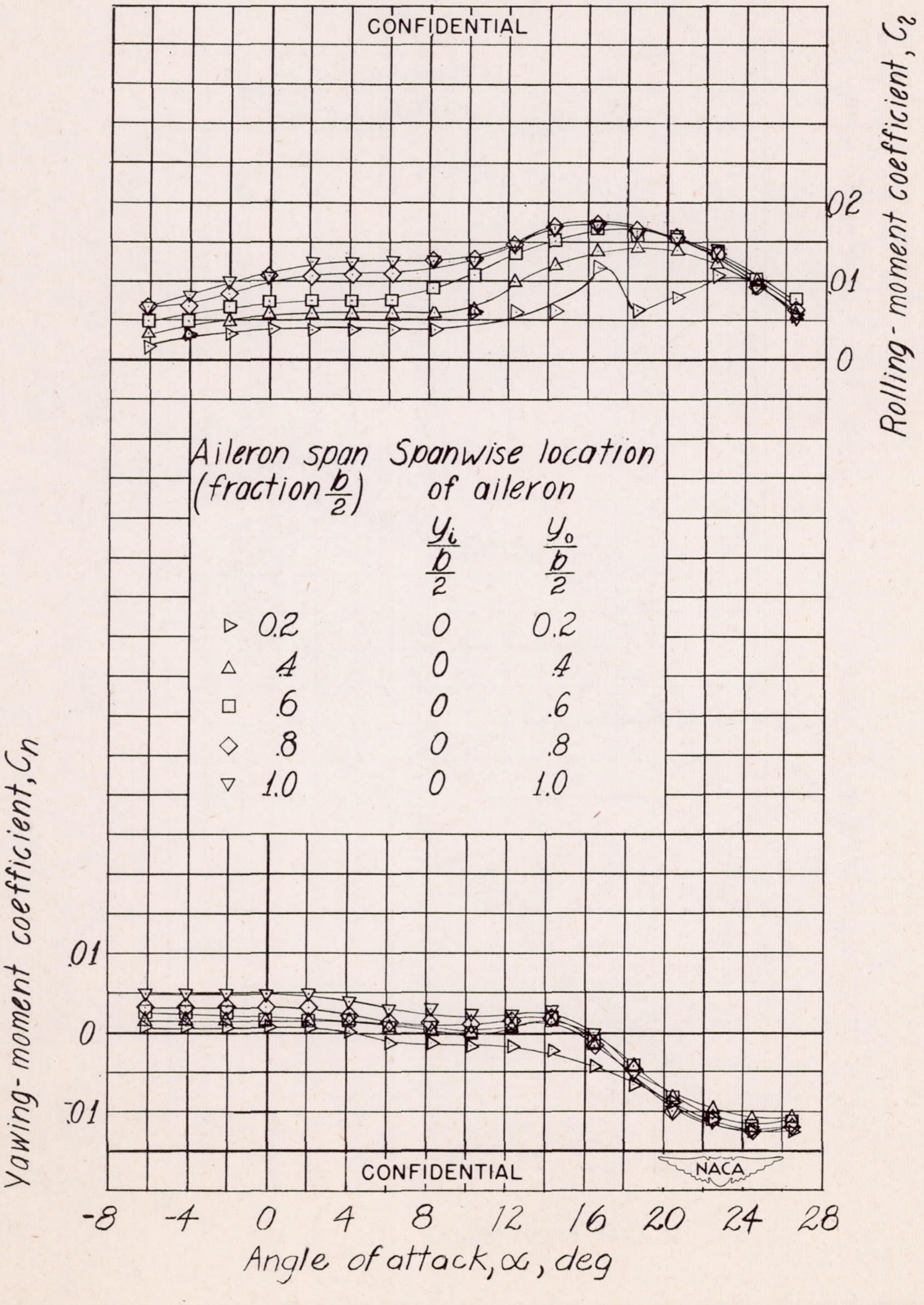


Figure 12.- Effect of span of inboard stepped spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage.



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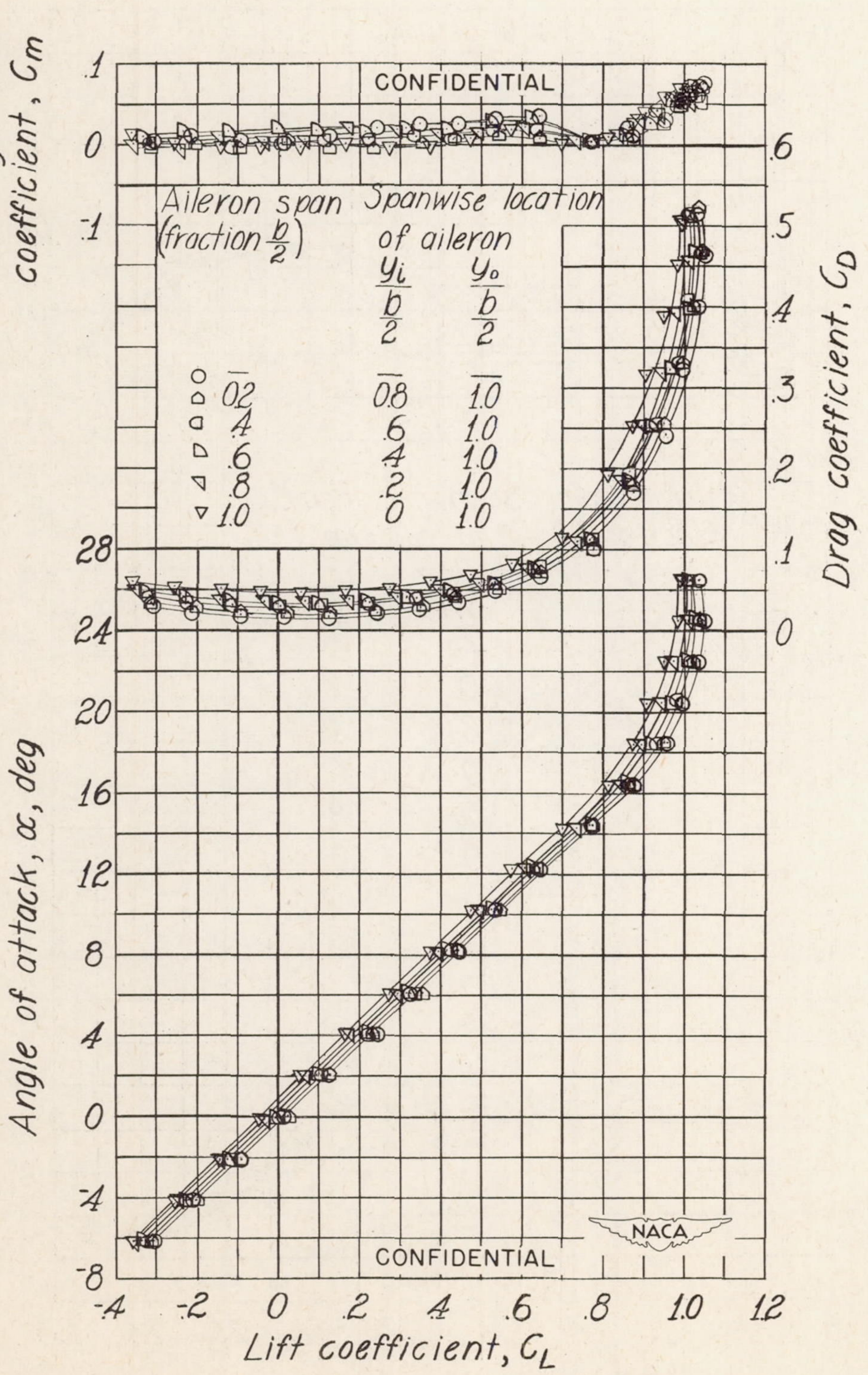


Figure 13.- Effect of span of outboard stepped spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage.

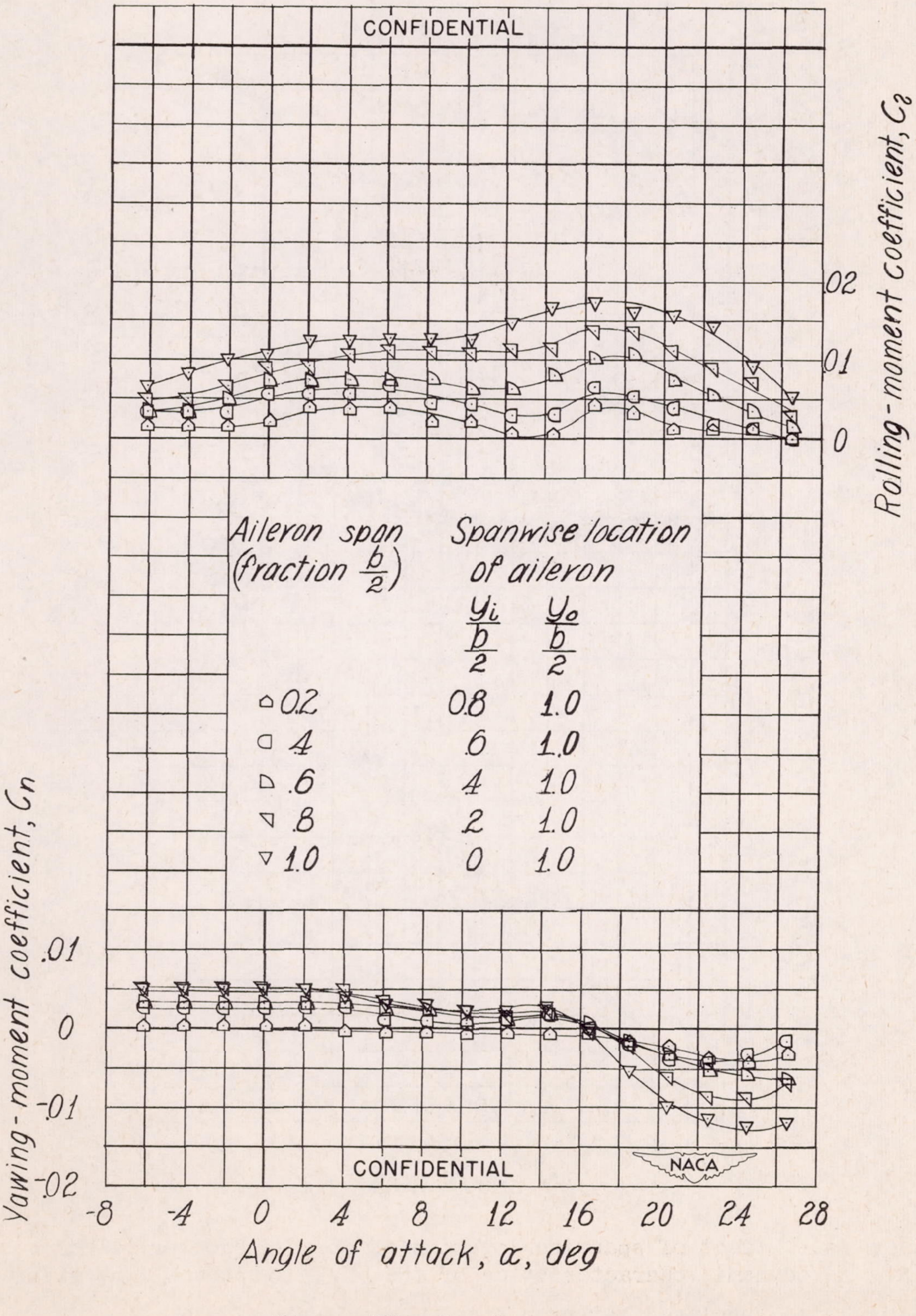


Figure 13.- Concluded.

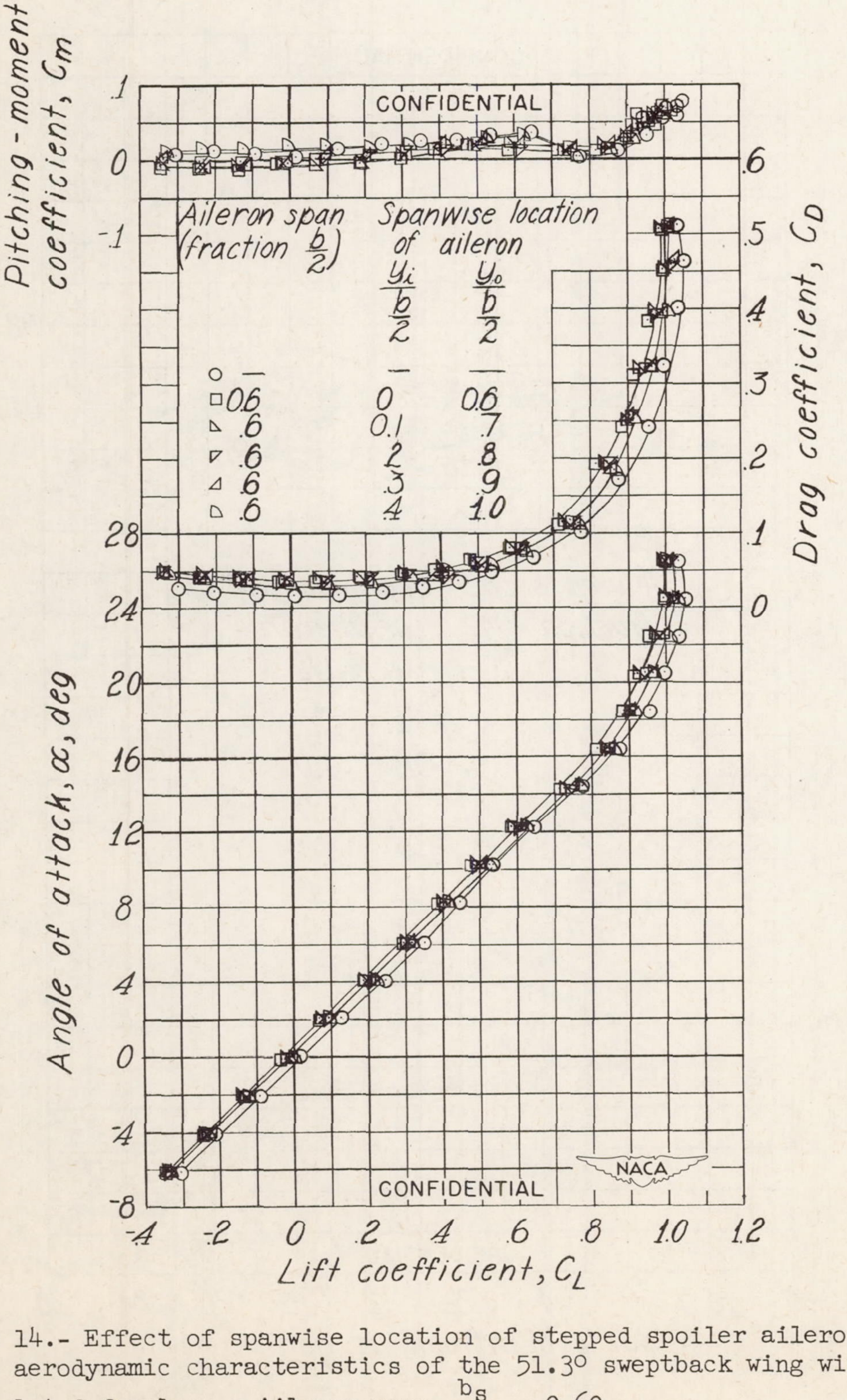
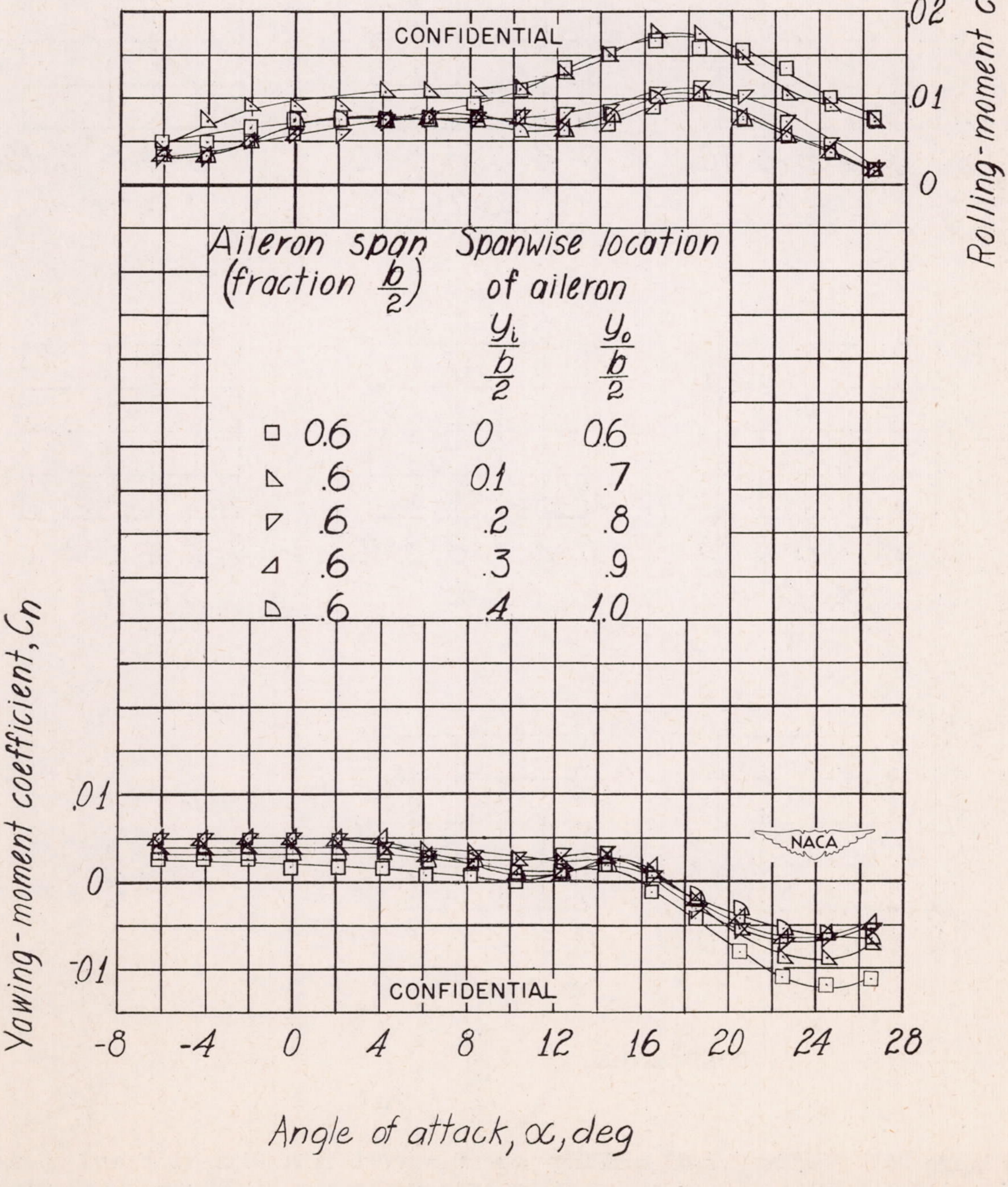


Figure 14.- Effect of spanwise location of stepped spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage. Aileron span, $\frac{b_s}{b/2} = 0.60$.



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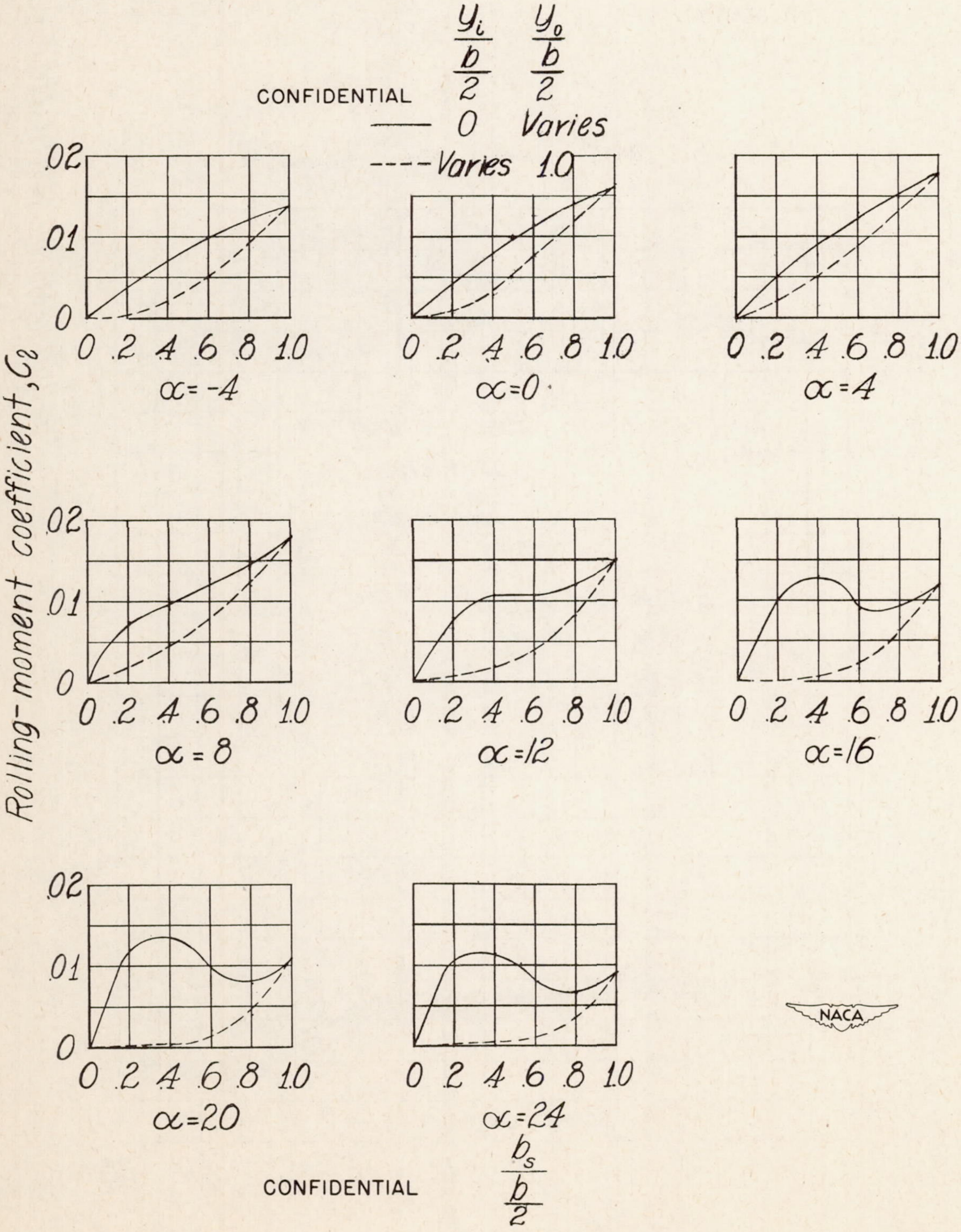

Figure 15.- Variation of rolling-moment coefficient with span and spanwise location of a plain spoiler aileron on the 51.3° sweptback wing with a simulated fuselage.

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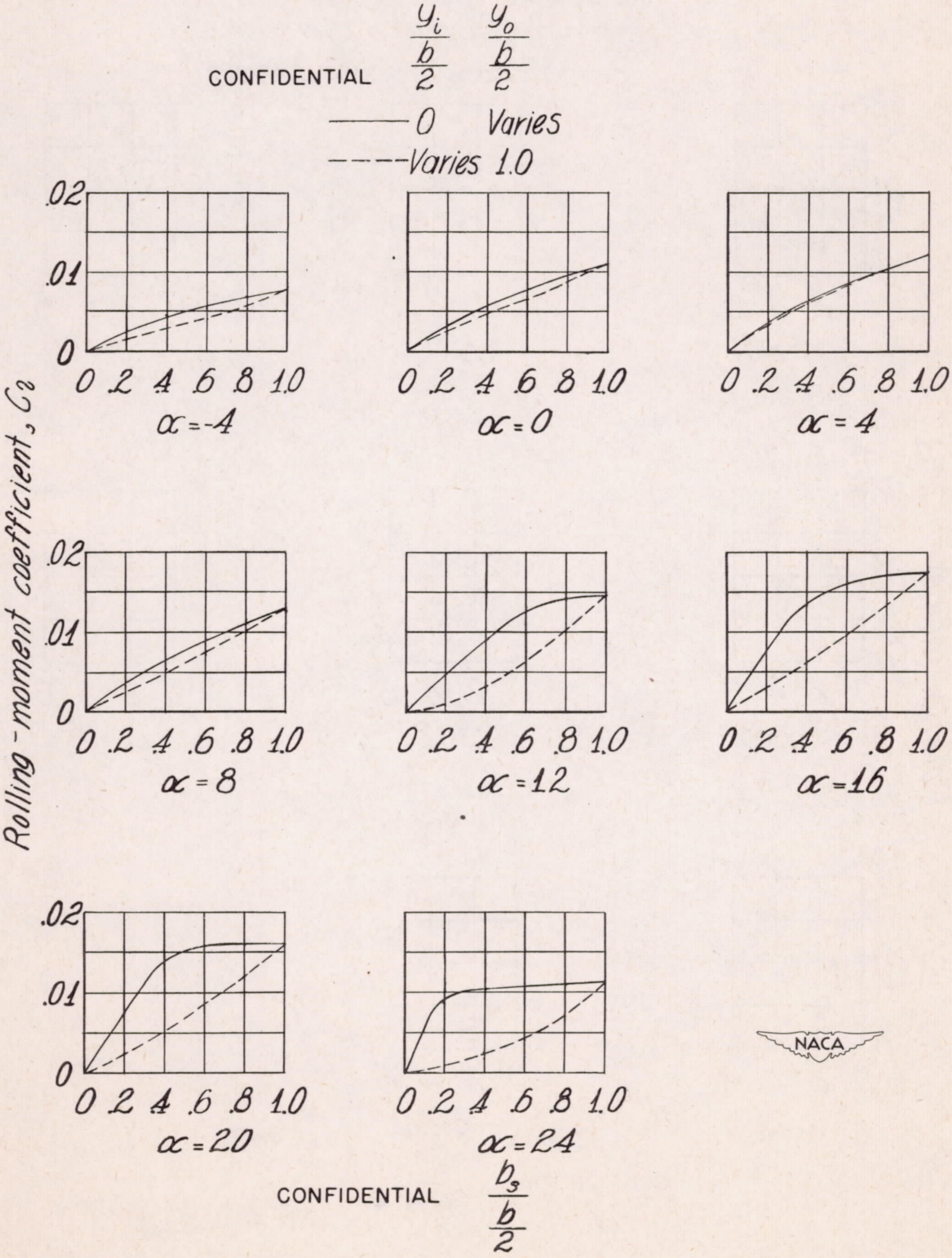

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Figure 16.- Variation of rolling-moment coefficient with span and spanwise location of a stepped spoiler aileron on the 51.3° sweptback wing with a simulated fuselage.

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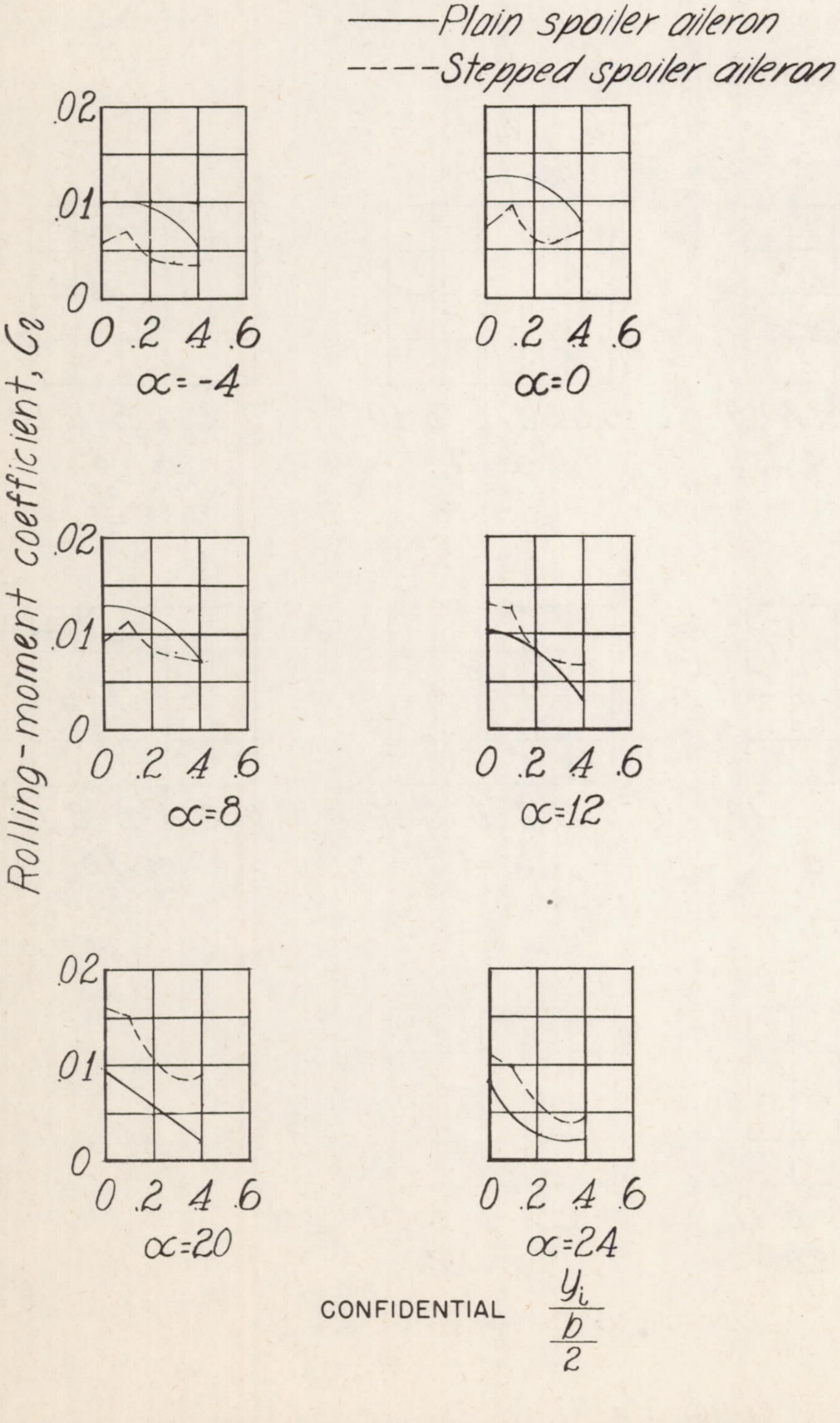

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Figure 17.- Variation of rolling-moment coefficient with spanwise location of a constant-span plain and stepped spoiler aileron on the 51.3° sweptback wing with a simulated fuselage. Aileron span, $\frac{b_s}{b/2} = 0.60$.

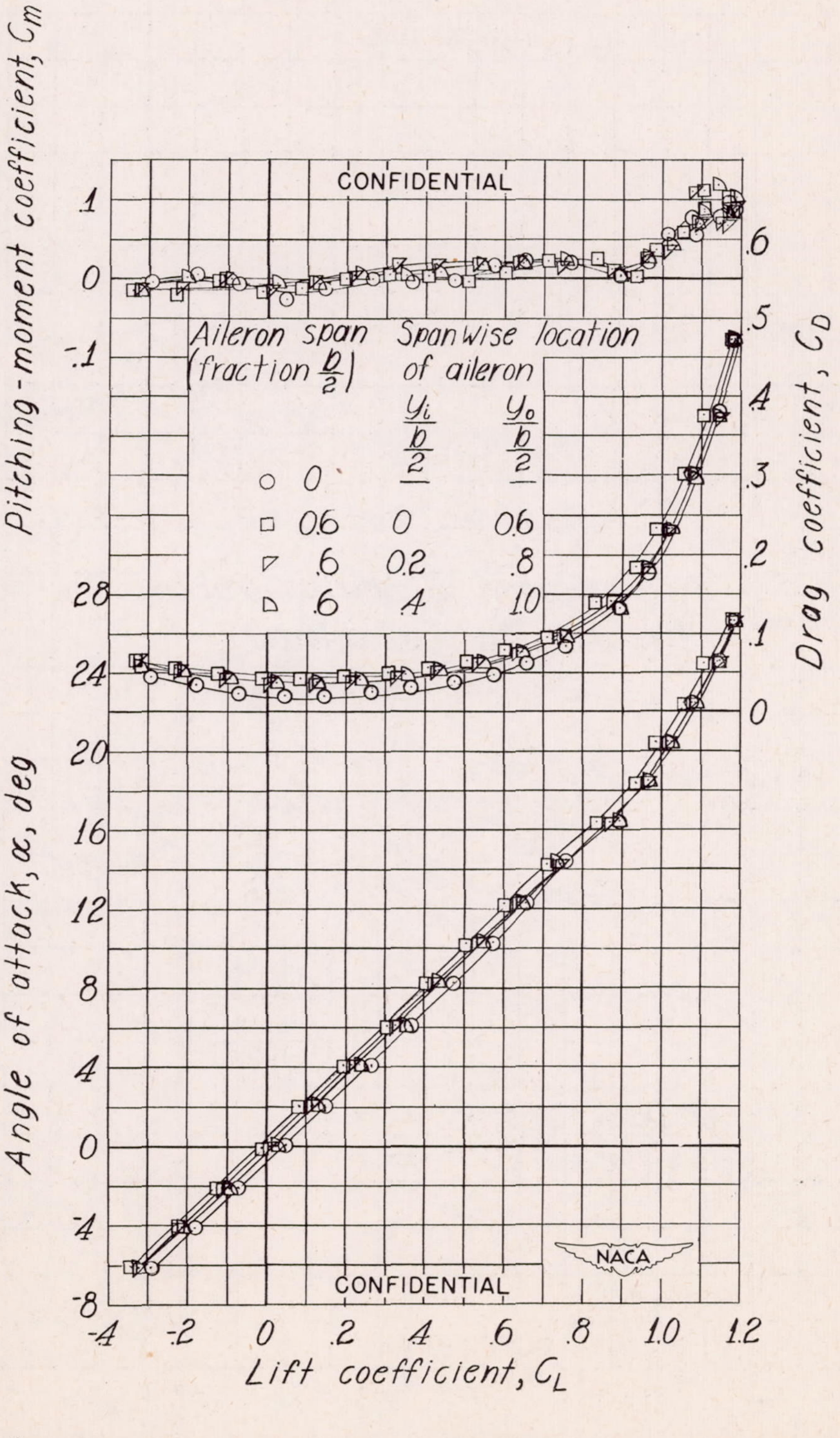
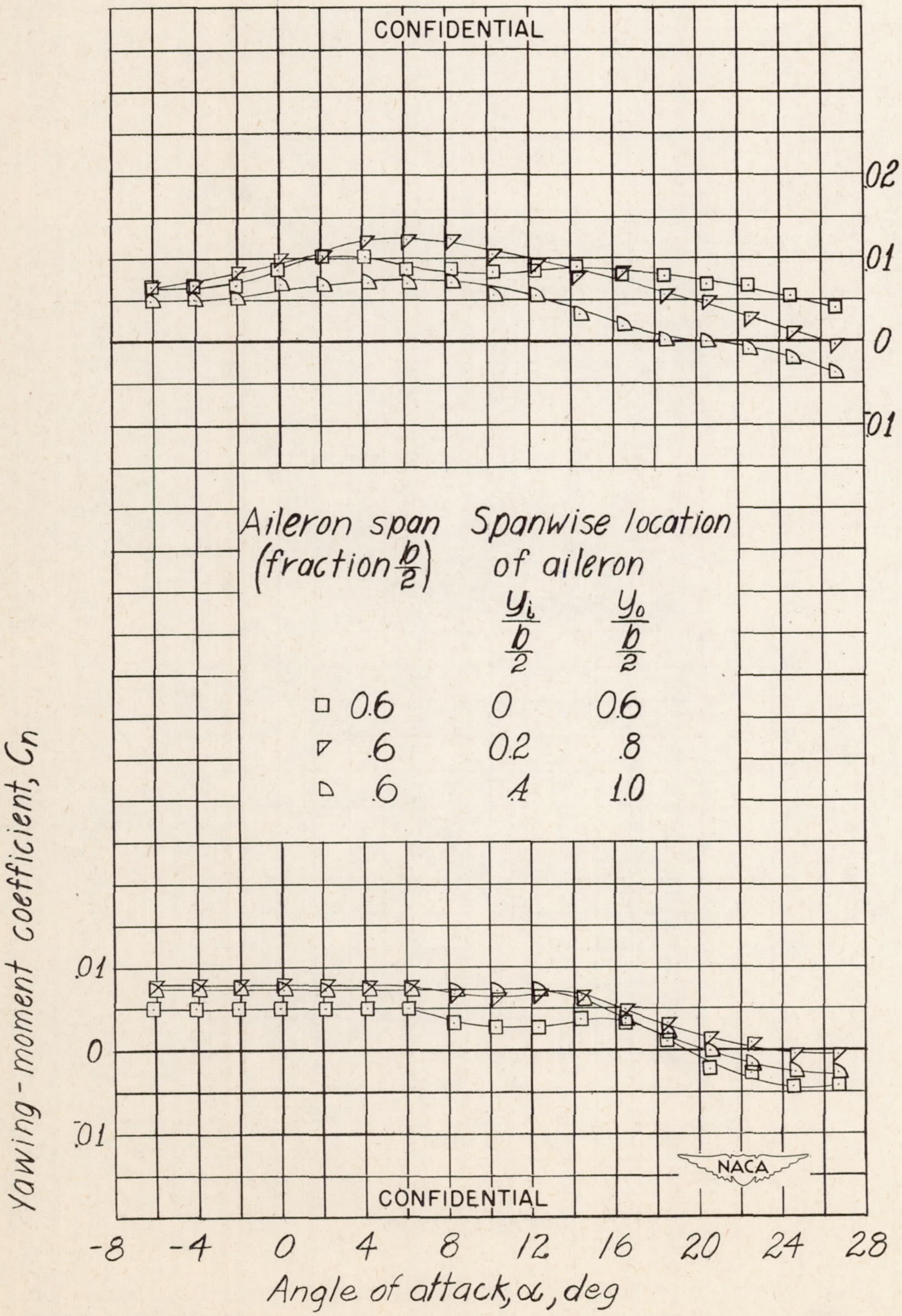


Figure 18.- Effect of spanwise location of plain spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage. Drooped nose deflected 30°.



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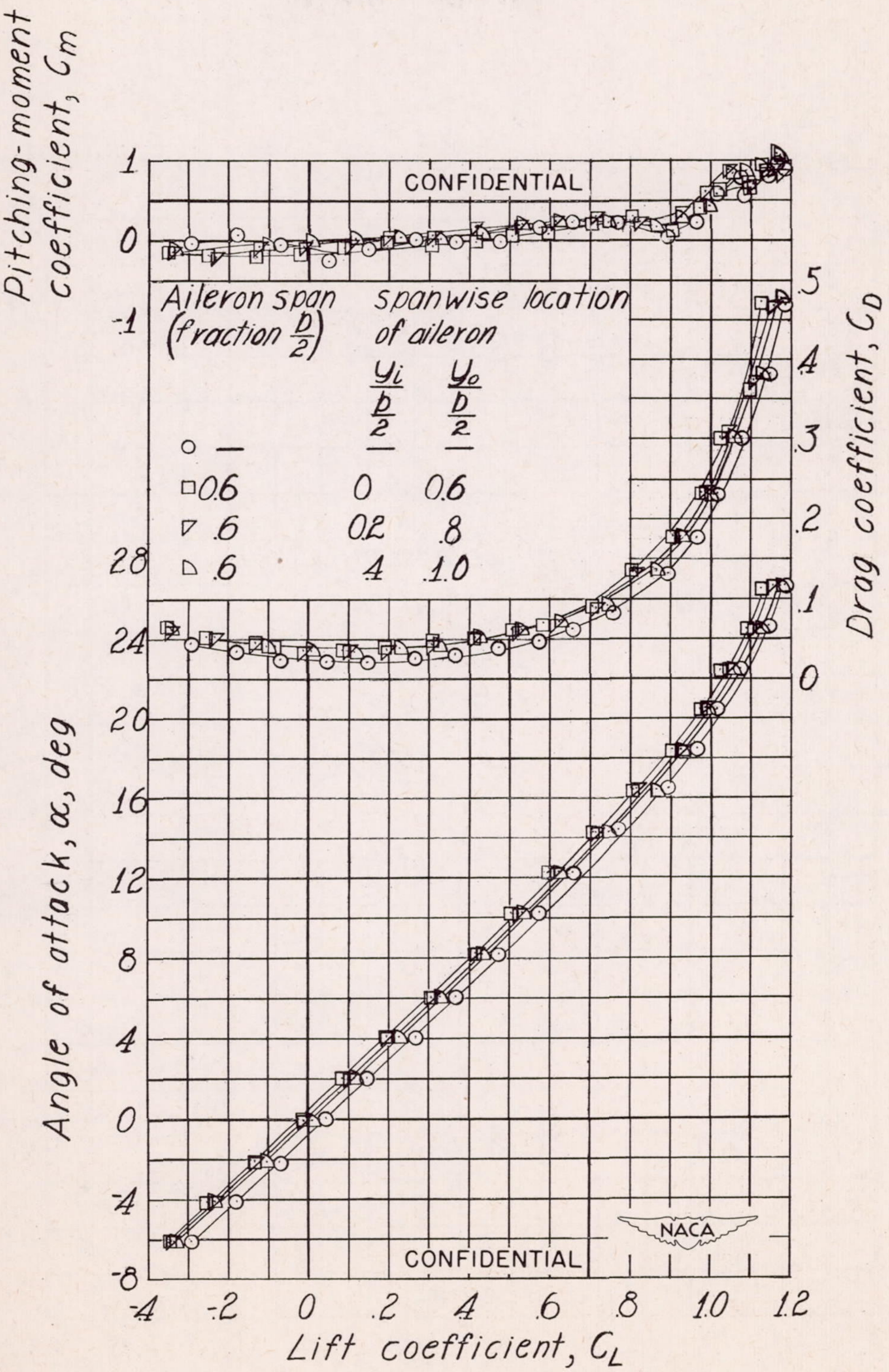
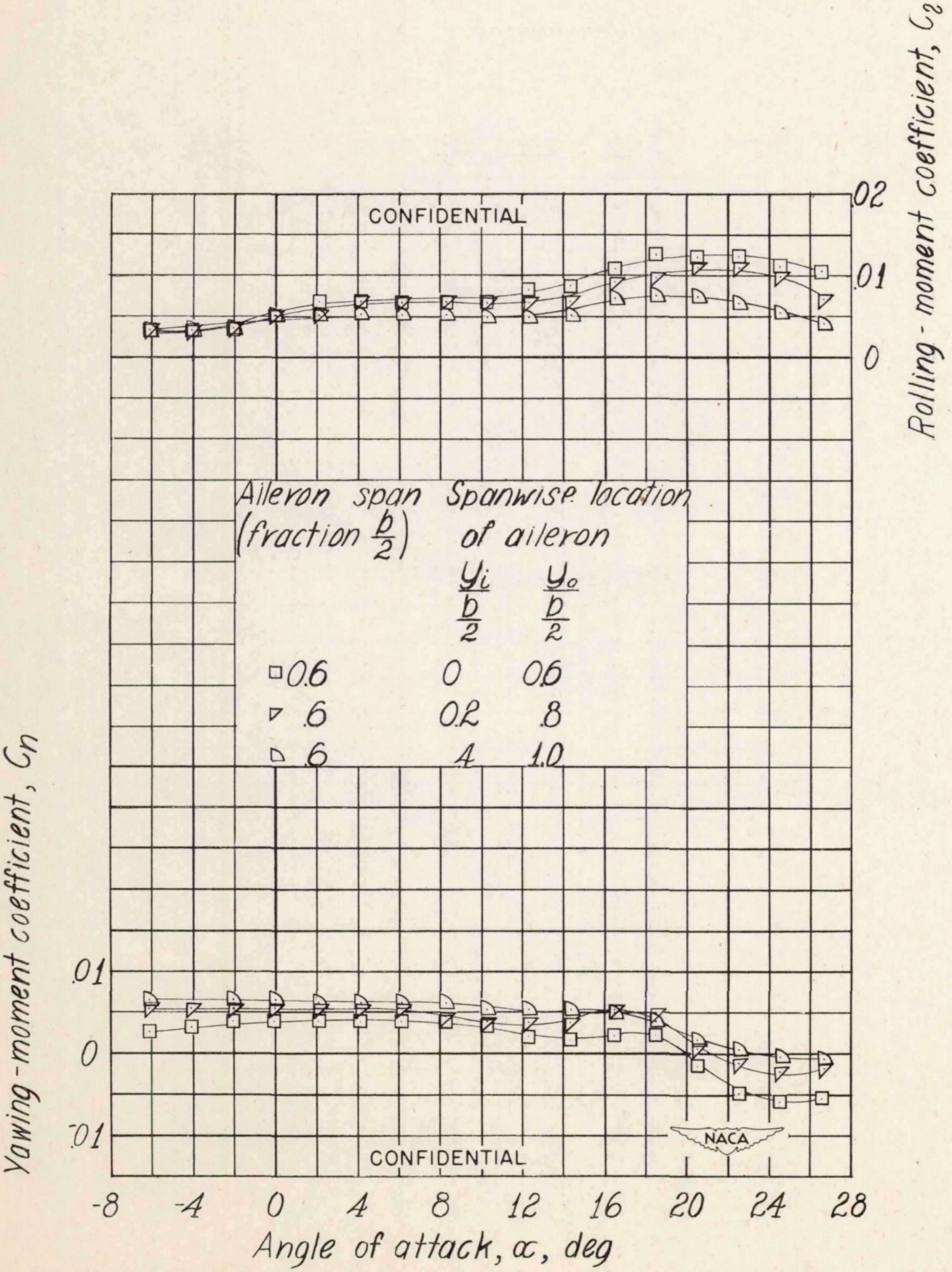


Figure 19.- Effect of spanwise location of stepped spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage. Drooped nose deflected 30°.



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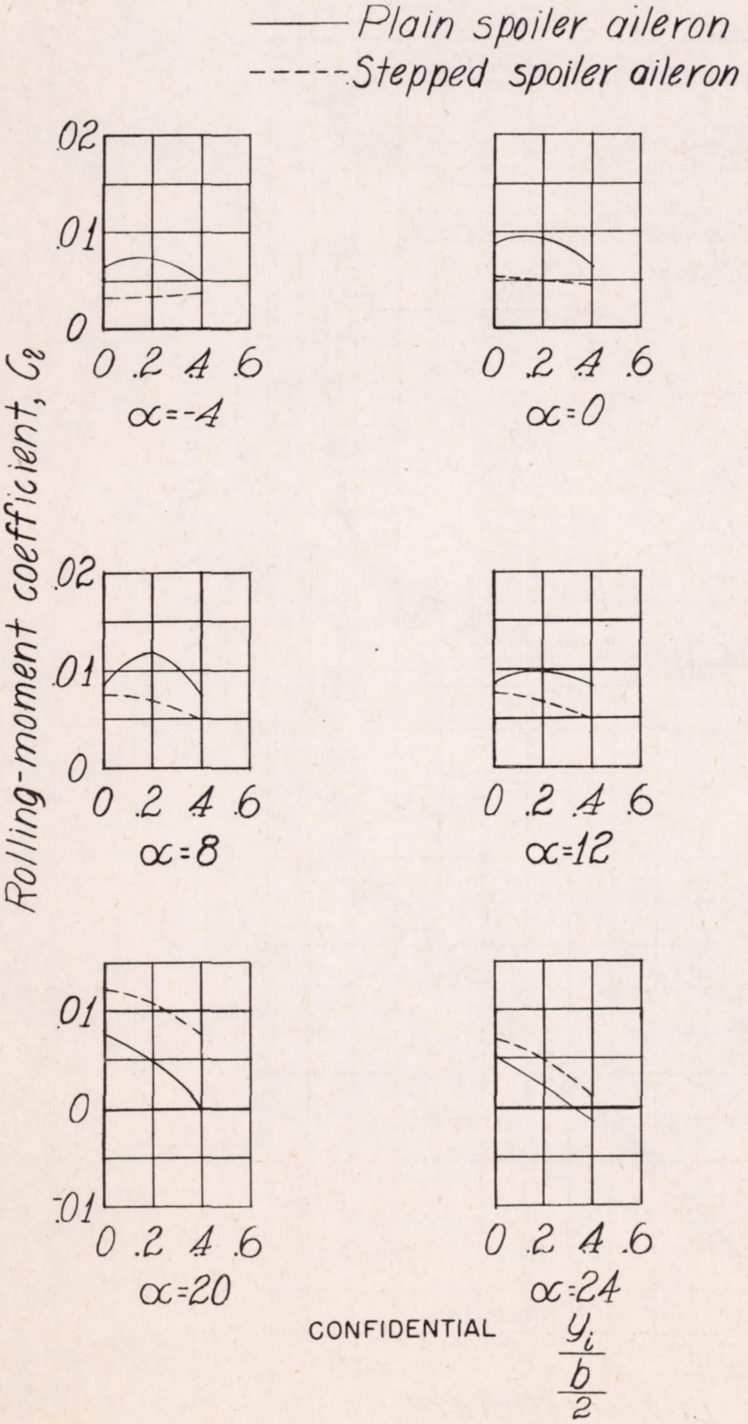

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Figure 20.- Variation of rolling-moment coefficient with spanwise location of a constant-span plain and stepped spoiler aileron on the 51.3° swept-back wing with a simulated fuselage. Drooped nose deflected 30°. Aileron span, $\frac{b_s}{b/2} = 0.60$.

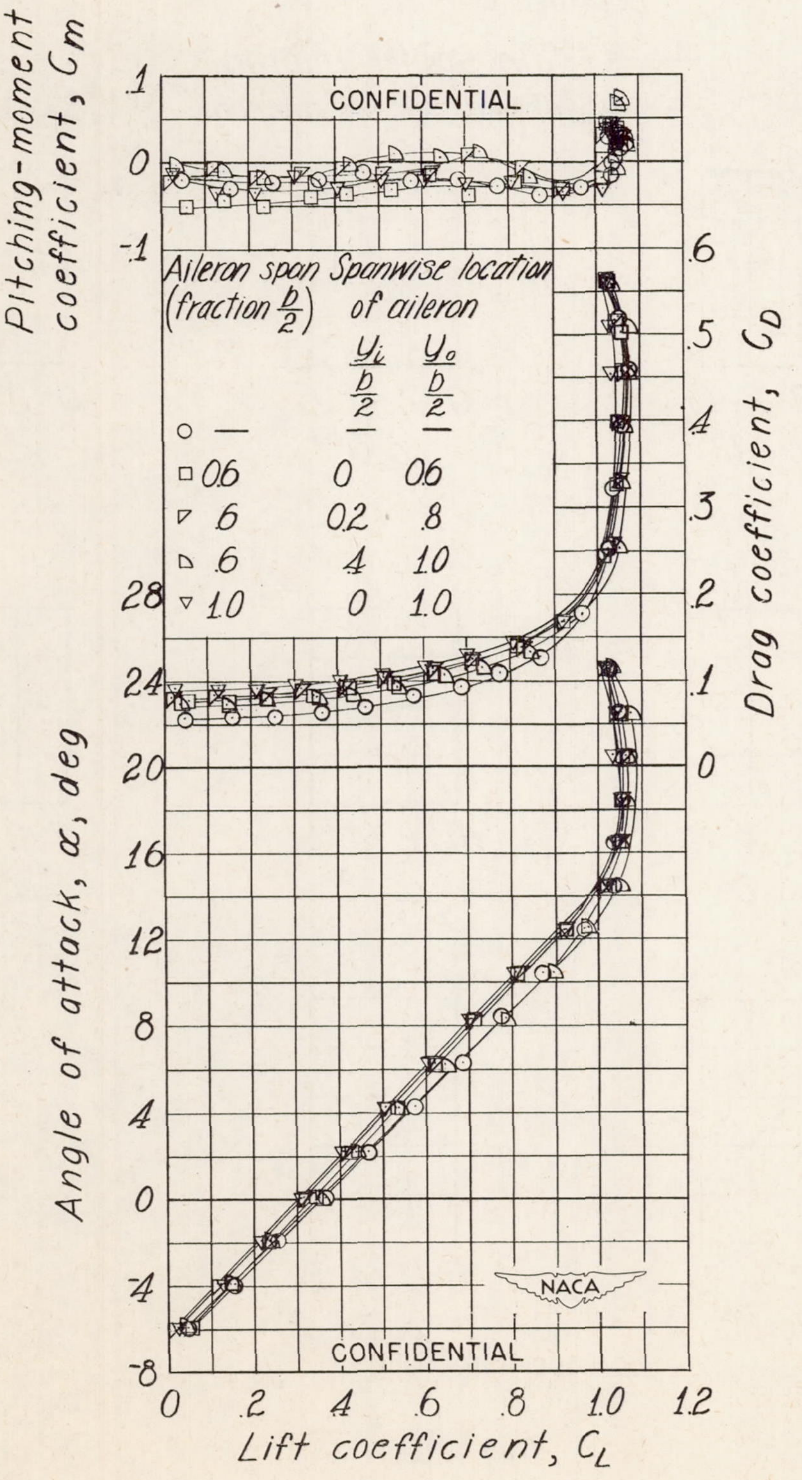
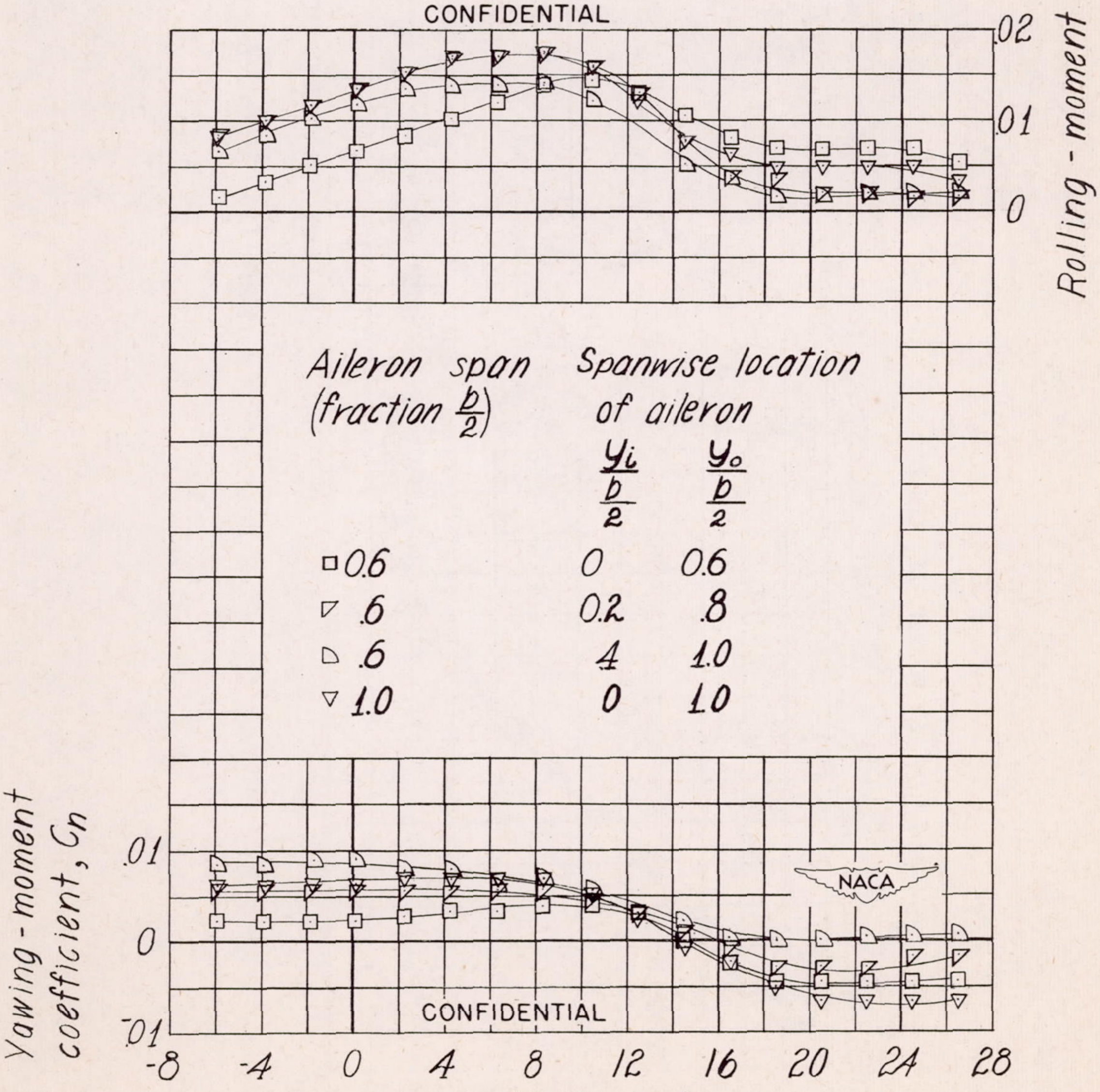


Figure 21.- Effect of span and spanwise location of plain spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage. Split flap deflected 40°.



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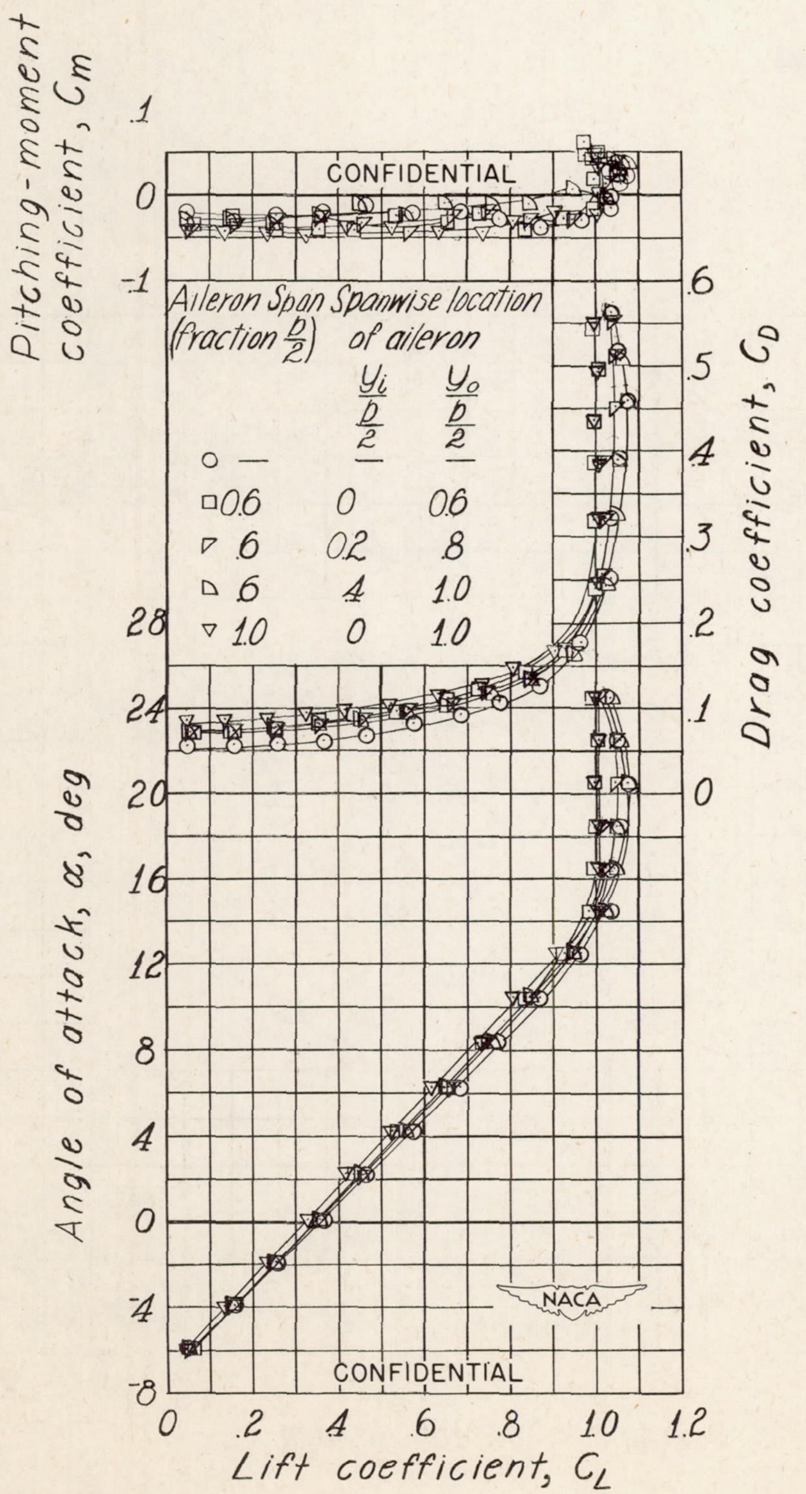
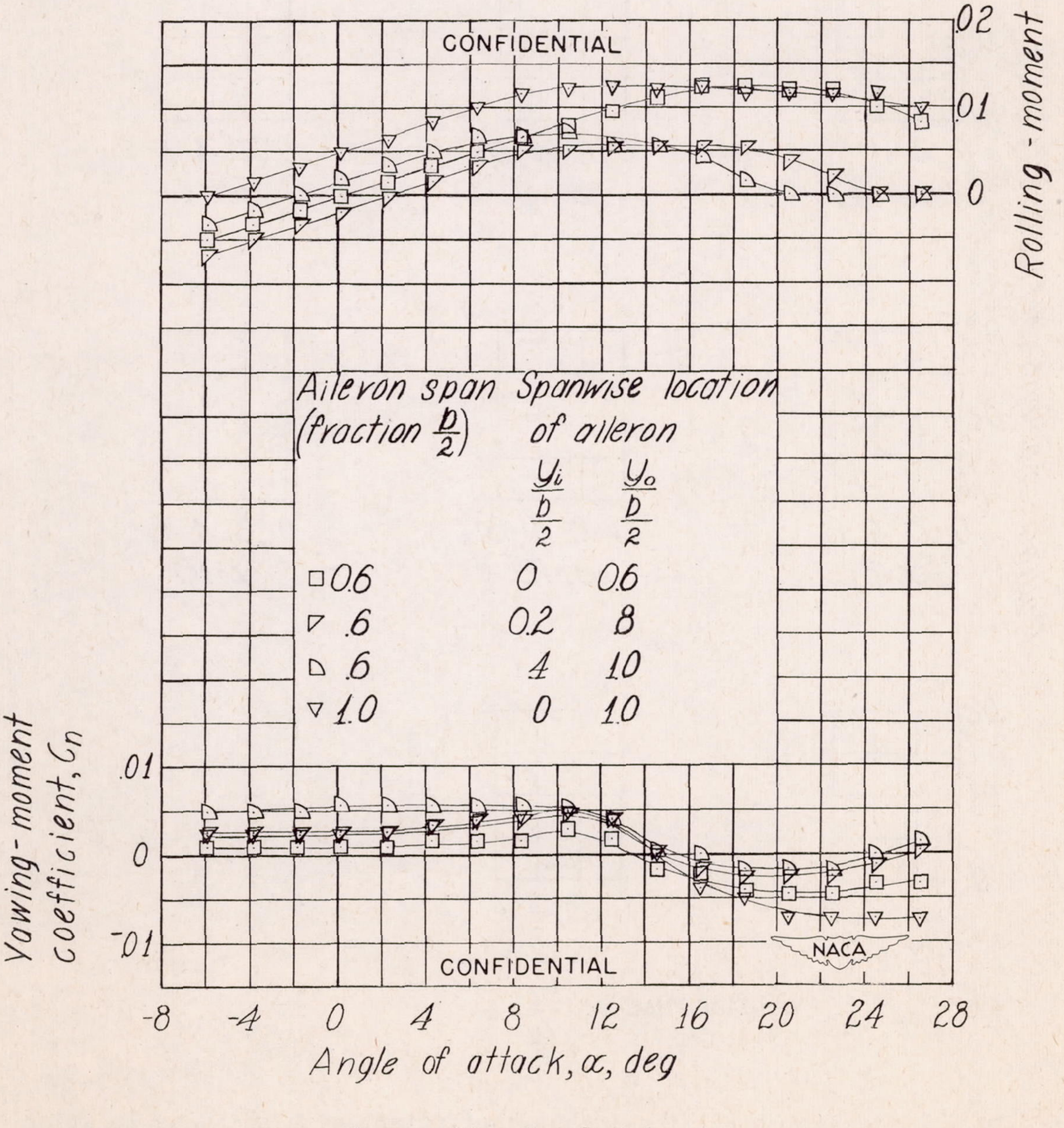


Figure 22.- Effect of span and spanwise location of stepped spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage. Split flap deflected 40°.



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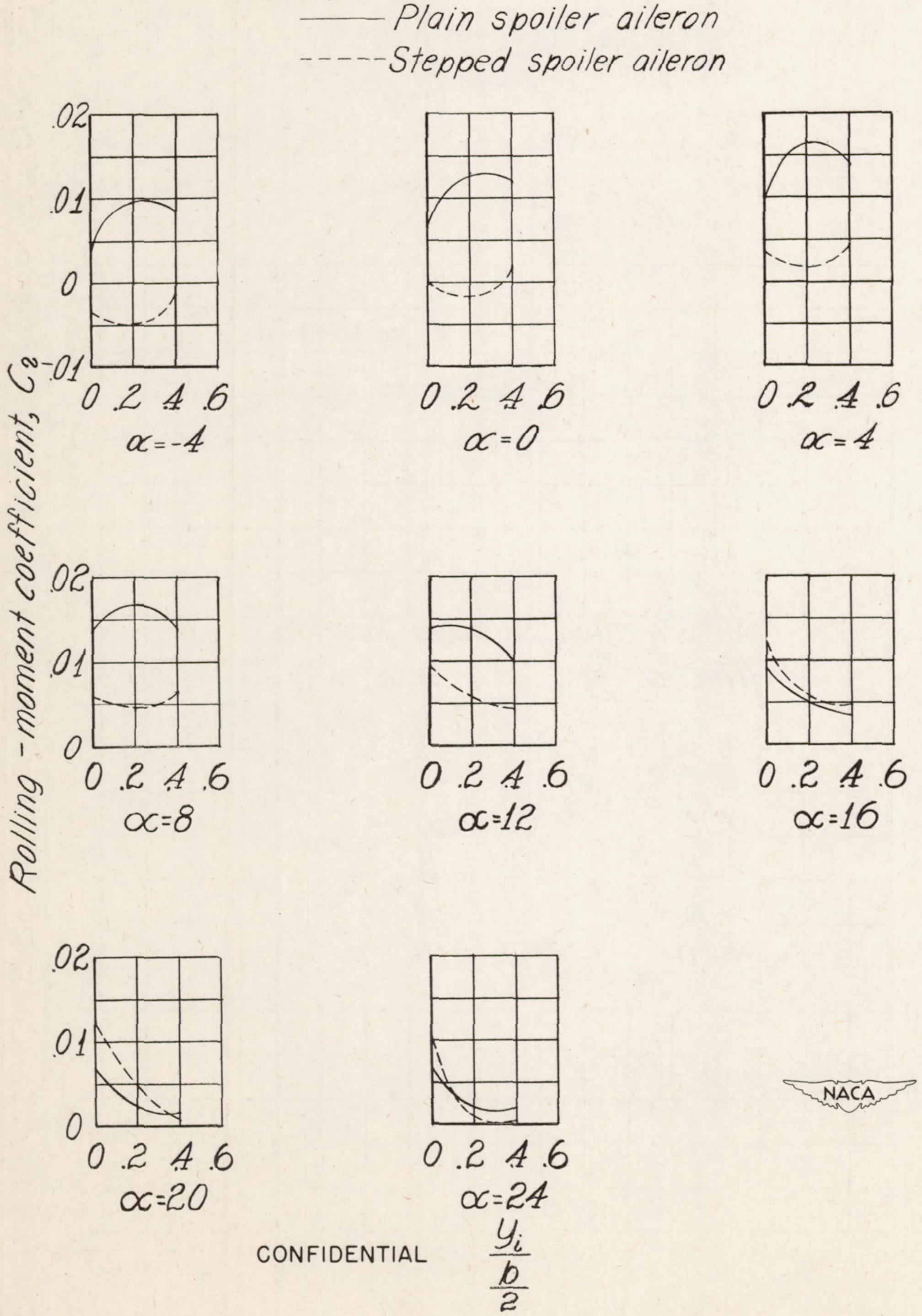

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Figure 23.- Variation of rolling-moment coefficient with spanwise location of a constant-span plain and stepped spoiler aileron on the 51.3° sweptback wing with a simulated fuselage. Split flap deflected 40°. Aileron span, $\frac{b_s}{b/2} = 0.60$.

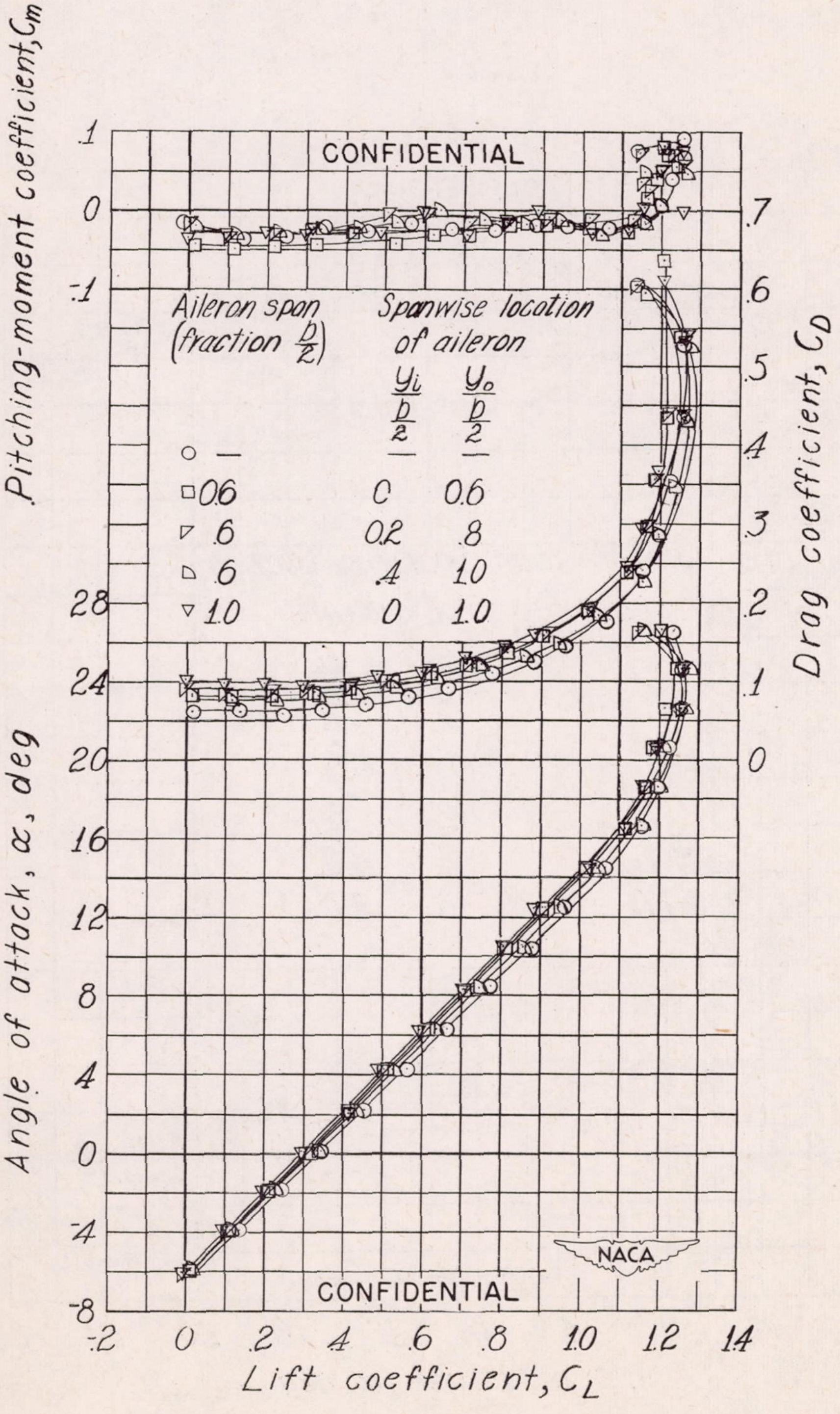
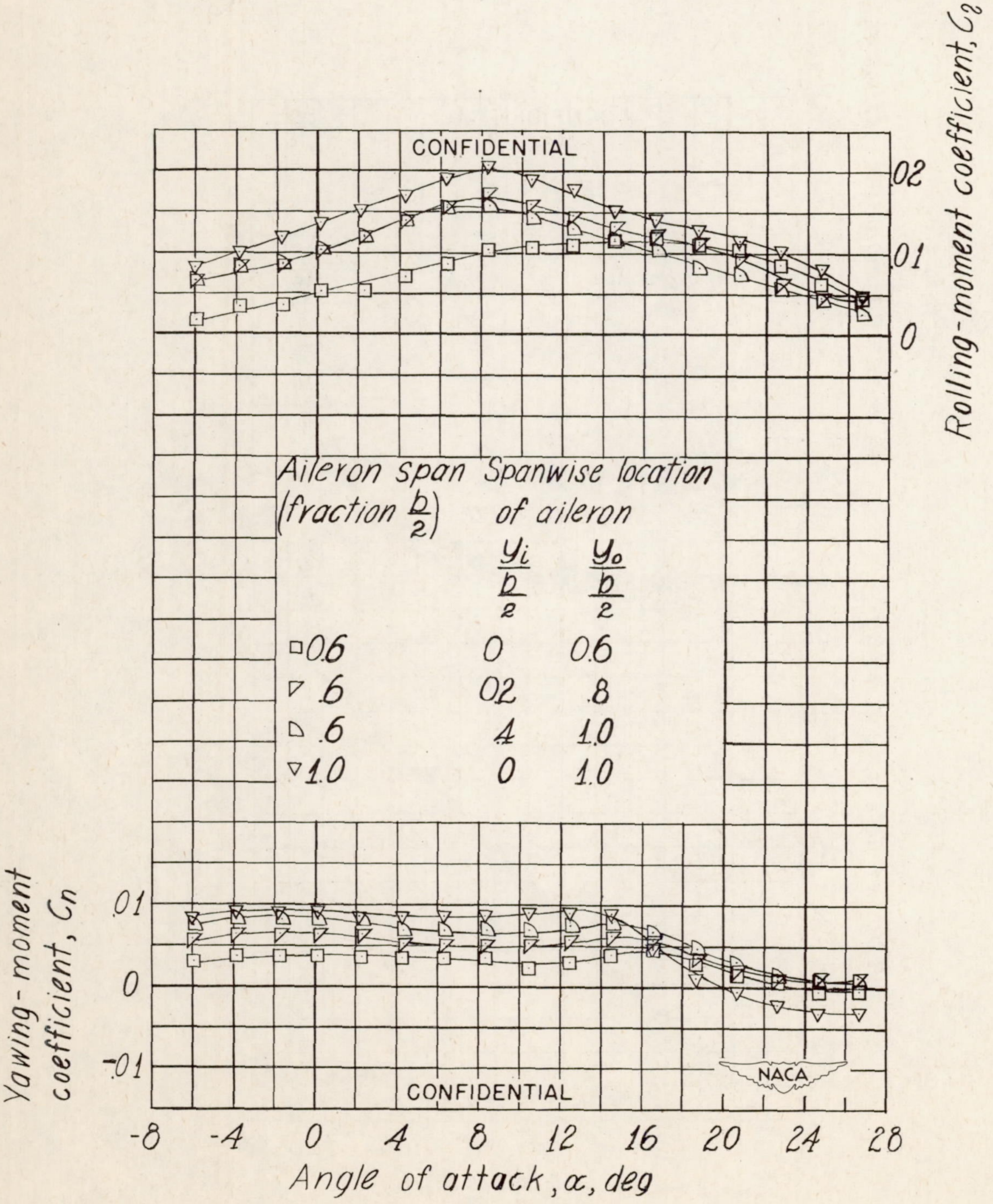


Figure 24.- Effect of span and spanwise location of plain spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage. Drooped nose deflected 30°; split flap deflected 40°.



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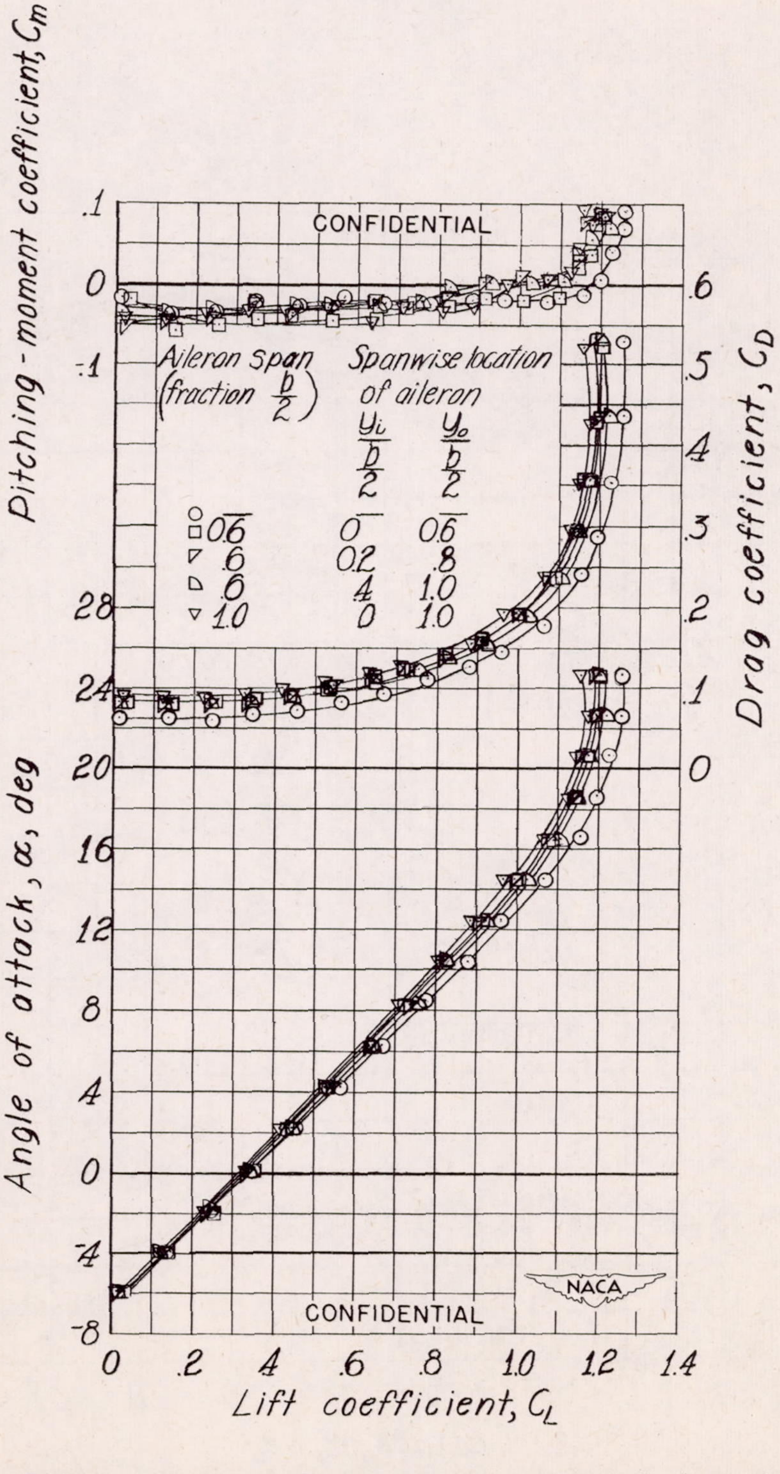

Figure 25.- Effect of span and spanwise location of stepped spoiler ailerons on the aerodynamic characteristics of the 51.3° sweptback wing with a simulated fuselage. Drooped nose deflected 30°; split flap deflected 40°.

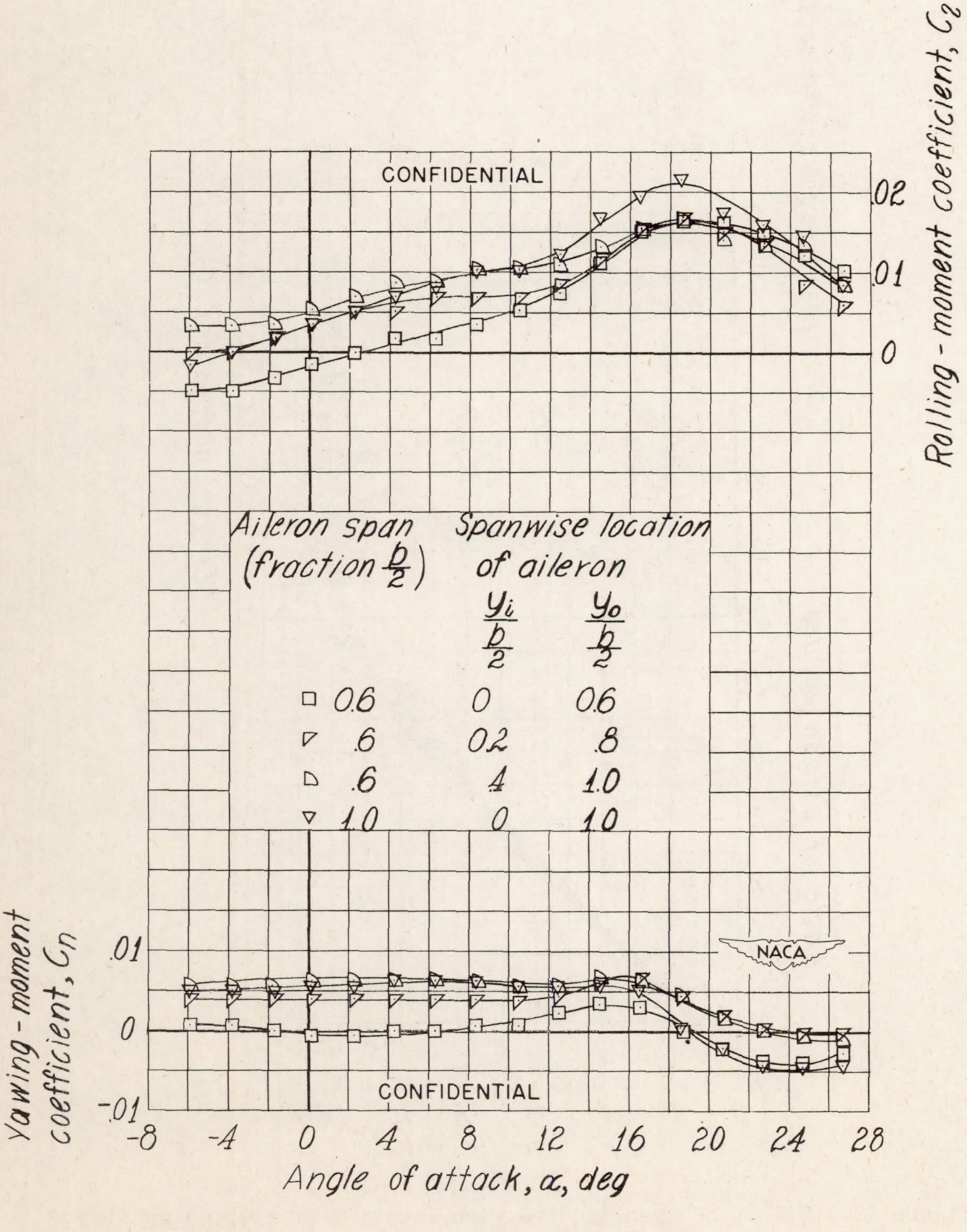

Figure 25.- Concluded.

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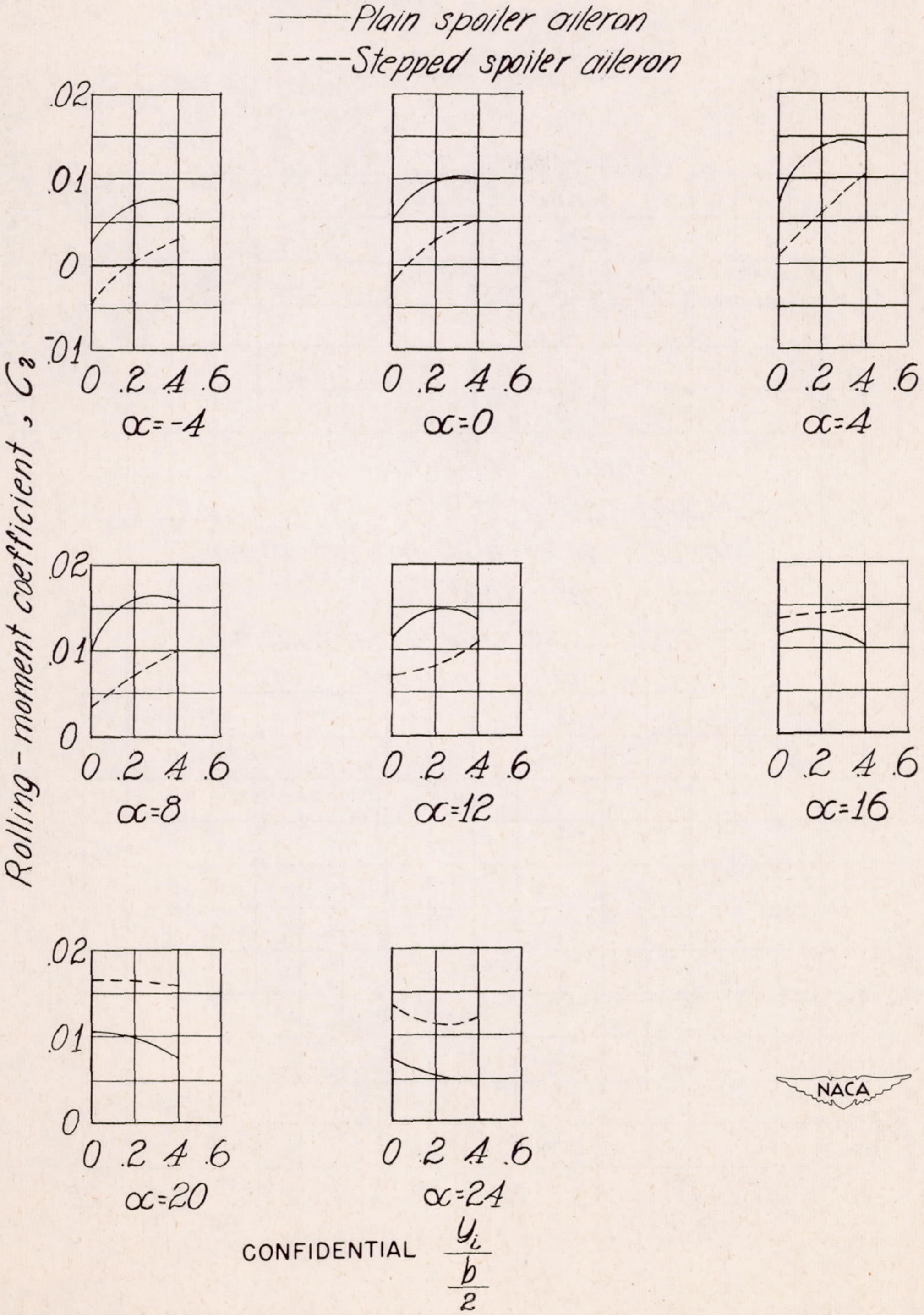

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Figure 26.- Variation of rolling-moment coefficient with spanwise location of a constant-span plain and stepped spoiler aileron on the 51.3° wing with a simulated fuselage. Drooped nose deflected 30°; split flap deflected 40°. Aileron span $\frac{b_s}{b/2} = 0.60$.

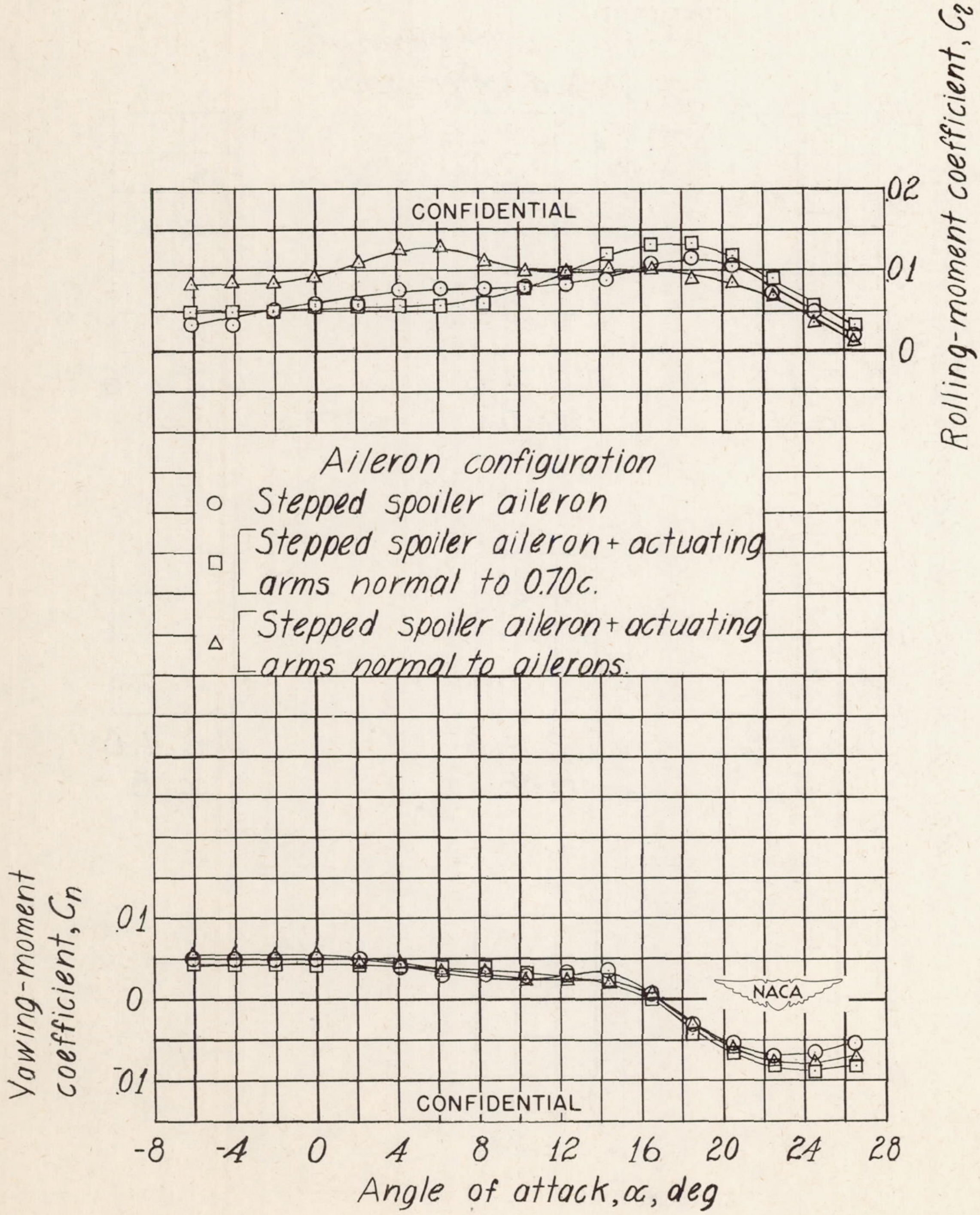

Figure 27.- Effect of two types of simulated actuating arms for stepped spoiler ailerons on the rolling-moment and yawing-moment characteristics of the 51.3° sweptback wing with a simulated fuselage. Aileron span, $\frac{b_s}{b/2} = 0.60$; $\frac{y_i}{b/2} = 0.20$; $\frac{y_o}{b/2} = 0.80$.

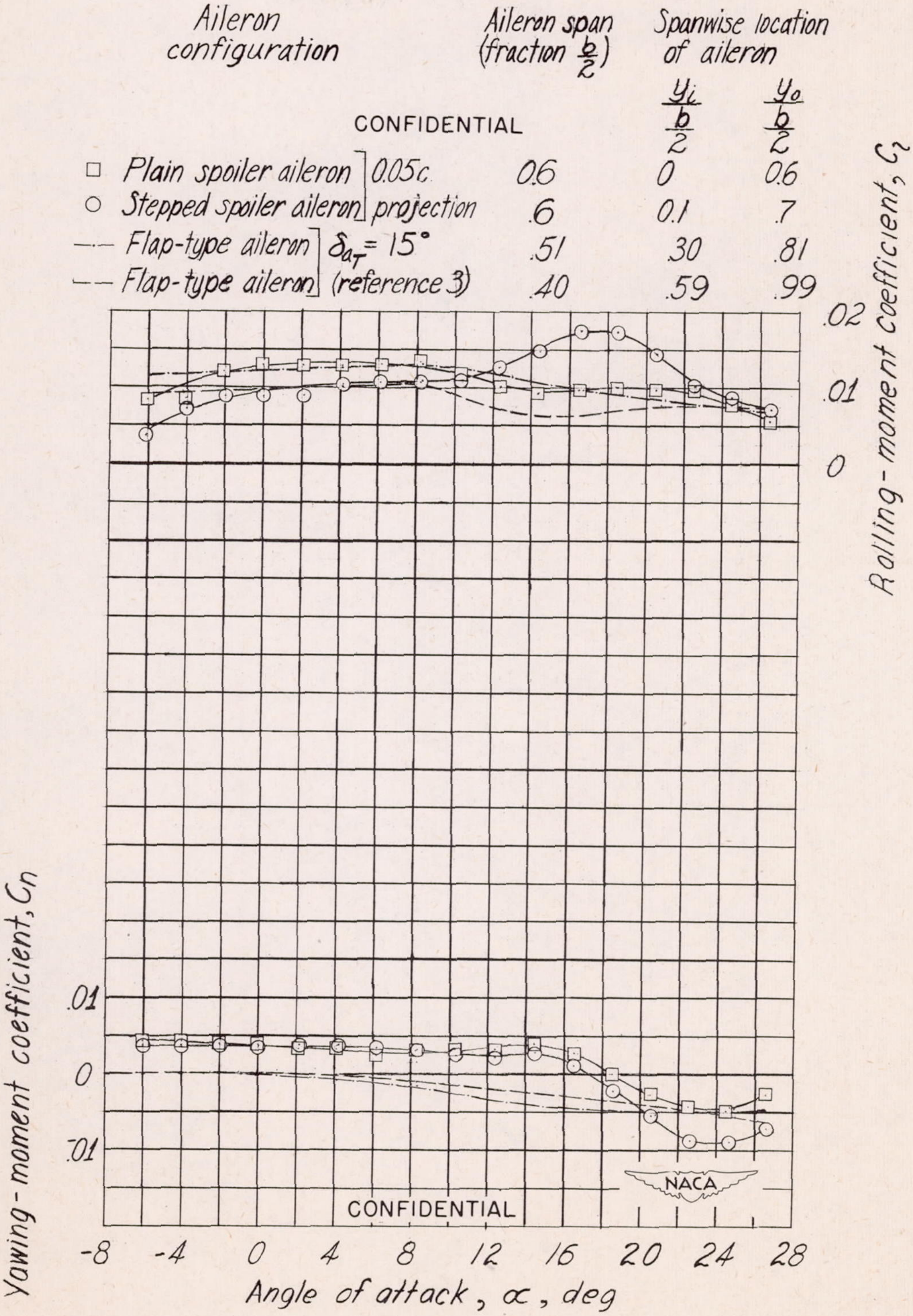

Figure 28.- Comparison of lateral-control characteristics of spoiler-type and conventional flap-type ailerons on a 51.3° sweptback wing with a simulated fuselage.

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