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EFFECTS OF PLAIN AND STEP SPOILER LOCATION AND PROJECTION ON THE LATERAL CONTROL CHARACTERISTICS OF A PLAIN AND FLAPPED 42° SWEPTBACK WING AT A REYNOLDS NUMBER OF 6.8×10^6

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RESEARCH MEMORANDUM

EFFECTS OF PLAIN AND STEP SPOILER LOCATION AND PROJECTION ON THE LATERAL CONTROL CHARACTERISTICS OF A PLAIN AND FLAPPED 42° SWEPTBACK WING AT A REYNOLDS NUMBER OF 6.8×10^6

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SUMMARY

An investigation has been conducted in the Langley 19-foot pressure tunnel to determine the effects of spoiler geometry and location on the low-speed lateral control characteristics of a wing swept back 42° at the leading edge with and without high-lift and stall-control devices. The wing incorporated NACA 64_1-112 airfoil sections perpendicular to the 0.273-chord line and had an aspect ratio of 4.01 and a taper ratio of 0.625. Plain and step spoiler arrangements of various spans and spoiler projections were investigated at several spanwise and chordwise locations at a Reynolds number of 6.8×10^6 and a Mach number of 0.16 through an angle-of-attack range from -4° to the stall. In addition, a few arrangements were investigated at a Reynolds number of 3.8×10^6.

The results indicate that the increments of rolling moment obtained from spoilers extending inboard from the tip and outboard from the root cannot be combined in a single spanwise effectiveness curve as in the case of straight wings.

Based on equal-span spoilers having a projection of 10 percent of the local chord, the step spoiler was most effective if located slightly inboard of the wing tip for the plain-wing configuration; whereas the plain spoiler was most effective if located in the vicinity of the plane of symmetry. With flaps deflected, both spoilers were most effective when located slightly inboard of the wing tip.

With flaps neutral, the plain spoiler was more effective than the step spoiler for low spoiler projections in the low and moderate angle-of-attack range. With flaps deflected, the plain spoiler was generally more effective throughout the entire angle-of-attack range and spoiler projections investigated.

For all configurations investigated, a forward spoiler chordwise location generally reduced the spoiler effectiveness in the low and moderate angle-of-attack range and increased the effectiveness in the higher angle-of-attack range.

INTRODUCTION

The data of references 1, 2, and 3 have shown that the effectiveness of a spoiler on sweptback wings is dependent upon both spoiler geometry and location. Although reference 3 does permit an evaluation of spoiler type, the data do not permit a complete evaluation of spoiler effectiveness as affected by such factors as spoiler span, projection, and location. In order to study the effects of spoiler geometry and location on the lateral control characteristics of a sweptback wing in more detail, tests have been made in the Langley 19-foot pressure tunnel to determine the low-speed spoiler lateral control characteristics of a plain and flapped 42° sweptback wing. The wing incorporated NACA 64_1-112 airfoil sections perpendicular to the 0.273-chord line and had an aspect ratio of 4.01 and a taper ratio of 0.625.

Plain and step spoiler arrangements of various spans and spoiler projections were investigated at several spanwise and chordwise locations on the basic wing and on the wing equipped with a fuselage and high-lift and stall-control devices. These devices included extensible round-nose leading-edge flaps, trailing-edge half-span and full-span split flaps, and upper-surface fences.

All the tests of the investigation were conducted at a Reynolds number of 6.8×10^6 and a Mach number of 0.16. Additional tests of a few configurations were made at a Reynolds number of 3.8×10^6 and a Mach number of 0.09.

SYMBOLS

All moments are taken about a system of axis (wind axis) originating in the plane of symmetry at the quarter-chord point of the mean aerodynamic chord.

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

ΔC_L increment in lift coefficient due to spoiler projection

C_D drag coefficient $\left(\frac{\text{Drag}}{qS}\right)$

ΔC_D increment in drag coefficient due to spoiler projection

C_m pitching-moment coefficient $\left(\frac{\text{Pitching moment}}{qS\bar{c}}\right)$

ΔC_m increment in pitching-moment coefficient due to spoiler projection

C_n yawing-moment coefficient $\left(\frac{\text{Yawing moment}}{qSb}\right)$

C_l rolling-moment coefficient $\left(\frac{\text{Rolling moment}}{qSb}\right)$

q dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

b wing span measured normal to the plane of symmetry, feet

b_s spoiler span measured normal to the plane of symmetry, feet

b_a aileron span measured normal to the plane of symmetry, feet

δ_a aileron deflection measured normal to aileron hinge line, positive when trailing edge is deflected downward, degrees

δ_s spoiler projection, fraction of chord

S wing area, square feet

$\bar{c}$ mean aerodynamic chord measured parallel to the plane of symmetry, 2.892 feet $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$

c local wing chord measured parallel to the plane of symmetry, feet

y spanwise ordinate measured normal to the plane of symmetry, feet

α angle of attack, degrees

ρ mass density, slugs per cubic foot

V free-stream velocity, feet per second

Subscripts:

exp experimental

est estimated

T total

MODEL AND TESTS

Model

The wing was constructed of laminated mahogany to the plan form shown in figure 1. The angle of sweep of the wing leading edge was 42.05° and the airfoil profiles perpendicular to the 0.273-chord line were NACA 64_1-112 sections. The 0.273-chord line corresponds to the 0.25-chord line of the wing with unswept panels. The wing had an aspect ratio of 4.01 and a taper ratio of 0.625 and had no geometric twist or dihedral. The wing tips were parabolic in plan form and elliptical in cross section.

The high-lift and stall-control devices are shown in figure 2. The leading-edge flap was of the round-nose extensible type which extended from 0.40b/2 to 0.975b/2 and had a constant chord of 3.19 inches and was deflected approximately 50° with the section chord line. The trailing-edge high-lift device was a split flap having a chord of 18.4 percent of the local wing chord measured parallel to the plane of symmetry. Half-span and full-span split flaps extended 50 and 97.5 percent of the wing span, respectively, and were deflected 60°. The split-flap deflection is measured in a plane perpendicular to the 0.273-chord line and is the angle formed by the flap chord line and the lower surface of the wing. The upper-surface fences (fig. 2(c)) were located at 50 percent of the wing semispan and were constructed of $\frac{1}{16}$-inch sheet steel cut to fit the upper surface of the wing. The fences extended from 5 percent of the local chord to the wing trailing edge. The height of the fences was arbitrarily set at 60 percent of the maximum thickness of the local airfoil section parallel to the plane of symmetry.

Details of the spoiler arrangements investigated are shown in figures 3 and 4. Two types of spoiler arrangements were investigated through a range of spoiler projections of 2.5, 5, 7.5, and 10 percent of the local chord. The plain spoiler (figs. 3(a) and 4(a)), consisted of 0.10b/2 segments (measured perpendicular to the plane of symmetry) which were placed end to end along a constant percentage chord line. The step spoiler (figs. 3(b) and 4(b)) consisted of a series of spoiler segments, each 10 percent of the wing semispan in length, which were skewed on the wing surface so that they were perpendicular to the plane of symmetry. The span and spanwise location of any spoiler configuration were varied by changing the number and location of spoiler segments.

The fuselage, which had a fineness ratio of 10.2:1, was circular in cross section and tapered to a point at each end. The maximum diameter of the fuselage, which was constant at the wing center section, was 12.3 percent of the wing span. The fuselage was used in the investigation in a midwing configuration and no fillets were used at the wing-fuselage juncture. Details of the fuselage are given in reference 4.

Tests

The tests were conducted in the Langley 19-foot pressure tunnel with the model mounted in the tunnel as shown in figure 5. The air in the tunnel was compressed to a density of 0.0055 slug per cubic foot. All tests of the investigation were conducted at a Reynolds number of 6.8×10^6 and a Mach number of 0.16 with the exception of the plain wing and wing-fuselage combination, for which additional tests were made at a Reynolds number of 3.8×10^6 and a Mach number of 0.09.

The rolling-moment and yawing-moment characteristics, along with the lift, drag, and pitching-moment characteristics, were determined for all test configurations through an angle-of-attack range from -4° to the stall.

The stall progressions were determined by observation of tufts of wool yarn placed at approximately 10, 20, 40, 60, 80, and 90 percent of the chord and spaced 6 inches on the upper surface of the wing.

REDUCTION OF DATA

All data have been reduced to nondimensional coefficient form. Corrections for support tare and interference effects have been applied to all force and moment data. Jet-boundary corrections determined by means of reference 5 and air-flow-misalinement corrections have been applied to the angle of attack and drag coefficient. In addition, a jet-boundary correction has been applied to the pitching moment. Corrections for jet-boundary effects on rolling and yawing moment were found to be small and therefore have not been applied.

RESULTS AND DISCUSSION

Effect of Spoiler Span

The effects of spoiler span on the aerodynamic characteristics of the various model configurations are presented in figures 6(a) to 6(g), which indicate that the rolling-moment effectiveness of both plain and step spoilers increased with spoiler span up to angles of attack at which the wing stalls. The only significant exception was when the step spoiler extended inboard of 20 percent of the wing semispan, where a decrease in rolling-moment effectiveness was obtained. Further study of the data in figures 6(a) to 6(g) indicates that the rolling-moment effectiveness obtained from spoilers extending inboard from the tip and outboard from the root cannot be combined in a single spanwise effectiveness curve as is the case of straight wings (reference 6). This result makes it impossible to calculate the rolling-moment effectiveness of partial-span spoilers on swept wings by the same method as used in reference 6.

The inability to combine the spanwise rolling-moment effectiveness of spoilers obtained in this investigation into a single spanwise effectiveness curve is due to the fact that the incremental effectiveness of the spoiler segments, when added inboard from the tip, was not equivalent to the incremental effectiveness of the same spoiler segments when added outboard from the root. This fact suggests that, in order to estimate the spoiler rolling-moment effectiveness of a partial-span spoiler, both inboard and outboard spoiler data must be utilized. A method which was found to closely estimate the effectiveness of partial-span spoilers, especially in cases in which large differences occurred in the incremental effectiveness of spoiler segments, is illustrated in figure 7 for an angle of attack of $\alpha = 0$. The correlation obtained with experimental values of the rolling-moment effectiveness of partial-span spoilers when using this method, which utilizes the data of figures 6(a) to 6(g), is shown in figure 8. While satisfactory correlation was obtained with the experimental results of this paper, it should be pointed out that it is probable that this method may not yield the same degree of correlation for wings of different plan forms since the wing flow characteristics are greatly affected by sweep.

While this method is used herein only to estimate the rolling-moment effectiveness of partial-span spoilers, it has been found that the same procedure can be used to determine the effect of spoiler span and spanwise location on the wing lift, drag, and moment characteristics. The basic aerodynamic characteristics of the various model configurations are presented, therefore, in figure 9 to enable the formulation of the wing lift, drag, and moment curves for the wing configurations with various spoiler arrangements which would be useful in evaluating the aerodynamic characteristics of the wing if spoilers were used as speed brakes.

Effect of Spoiler Spanwise Location

Flaps neutral.- The effects of spoiler spanwise location of constant-span, plain and step spoilers having a projection of 0.10c are presented in figures 10(a) and 11. The values of rolling-moment effectiveness for both spoilers located at the wing tip were approximately equal (fig. 10(a)). When the spoilers were moved inboard, the rolling-moment effectiveness of the plain spoiler increased progressively; whereas the effectiveness of the step spoiler increased slightly for the midspan location and then decreased considerably when the inboard end of the span of the step spoiler was located at the wing plane of symmetry. Thus, as indicated in figure 11, the optimum spanwise location for the plain spoiler was in the vicinity of the wing plane of symmetry; whereas that of the step spoiler was slightly inboard of the wing tip. Although no direct comparison is made in this paper, the results of the investigation did indicate that spoiler projection appeared to have no appreciable effect on the optimum spoiler spanwise location. A comparison of data obtained in the present investigation with data from tests of a geometrically similar semispan model (reference 3) at comparable Reynolds numbers indicates that the same trends were obtained for the optimum spanwise location of the step spoilers; however, the magnitude of the rolling-moment effectiveness obtained in the present investigation for inboard-located step spoilers was less than that obtained in reference 3. The discrepancy obtained in the magnitude of the step spoiler rolling-moment effectiveness is believed to result from errors in reflection-plane corrections applied to the semispan data. In order to obtain these reflection-plane corrections, the lift distributions over the wing with full-span and partial-span spoilers must be estimated from potential flow theory. Since potential flow theory does not consider areas of flow separation such as introduced by spoiler-type lateral control, it is reasonable to expect errors in the estimated lift distributions and associated errors of considerable magnitude in the reflection-plane corrections.

The effectiveness of the plain spoiler was superior to that of the step spoiler for all inboard locations throughout the angle-of-attack range up to the stall (fig. 10(a)). At the stall, however, the step spoiler maintained somewhat better effectiveness than the plain spoiler, regardless of spanwise location. Although the effectiveness of both spoilers can be considered negligible for the midspan and outboard spanwise locations, both spoilers located at the plane of symmetry retained somewhat better effectiveness at the stall than was obtained when the spoilers were located farther outboard. Since the inboard spoiler locations on the plain wing are not blanketed in a region of flow separation at the stall, as is the case for outboard spoiler location, it would be expected that inboard-located spoilers would maintain somewhat better effectiveness at the stall than outboard-located spoilers. In addition to producing the greater rolling-moment effectiveness in the low and moderate angle-of-attack range for inboard positions, the plain spoiler also produced the lower decrement in lift coefficient regardless of spoiler span location (figs. 10(a) and 10(b)). These results indicate that the lateral center of pressure for the wing equipped with plain spoilers was located farther outboard than when the wing was equipped with step spoilers. In an effort to indicate how the two types of spoilers affect the flow field over the wing, tuft studies were made of the basic wing with and without a fuselage in the midwing position for various plain and step spoiler arrangements. (See fig. 12.) As indicated in figure 12, the areas of disturbed flow produced by the plain spoiler were located farther outboard than those of the step spoiler. The presence of the fuselage appeared to have little effect on the flow characteristics over the wing equipped with spoilers.

Both types of spoilers produce approximately the same degree of favorable yawing moments which became less favorable with either an increase in angle of attack or inboard movement of the spoiler span location (fig. 10(a)).

Flaps deflected.- For the angle-of-attack range from 0° to 16°, the optimum spoiler spanwise location of the step spoiler on the basic wing with 0.575b/2 leading-edge and half-span flaps deflected (fig. 13) was similar to that obtained for the flap-neutral condition; whereas that of the plain spoiler was shifted outboard to approximately the same optimum spanwise location of the step spoiler. When the trailing-edge flaps were extended to full-span split flaps (fig. 14(a)) the optimum spoiler spanwise location of the plain spoiler was slightly inboard of that obtained with 0.575b/2 leading-edge and half-span split flaps deflected; and when the 0.575b/2 leading-edge flaps were deflected alone (fig. 14(b)), the optimum spoiler spanwise location of the plain spoiler was approximately the same as that obtained with flaps neutral. Since the effect of trailing-edge flaps on the span load distribution is considerably greater than that obtained with leading-edge flaps, it would be expected that the optimum spoiler spanwise location would be affected more by wing trailing-edge configurations than by wing leading-edge devices.

A comparison of the rolling-moment effectiveness of the two spoilers located at their optimum spoiler spanwise locations (fig. 13) indicates that the plain spoiler was more effective than the step spoiler up to an angle of attack of 8°. At 16° the effectiveness of both spoilers was approximately equal. Incomplete data obtained in this investigation and not presented herein indicate that at the stall both spoilers maintained their effectiveness, although it was somewhat less than that obtained at low angles of attack, and the optimum spanwise locations of the two spoilers were found, as in the case of the basic wing, to vary in accordance with the stall progressions of flapped configurations.

Effect of Spoiler Height

The spoiler rolling-moment effectiveness of a range of spoiler projections on the basic wing and the wing equipped with high-lift and stall-control devices are presented in figures 15(a) and 15(b). Both spoilers had spans of 0.475b/2 which extended from 0.5b/2 to 0.975b/2.

Except for step-spoiler projections less than approximately 0.02c, where little or no spoiler effectiveness was indicated in the low and moderate angle-of-attack range, the variation of rolling-moment coefficient with spoiler projection for the flap-neutral configuration at angles of attack of 0° and 8° (fig. 15(a)) was approximately linear throughout the spoiler projection range for both plain and step spoilers. At 16° angle of attack, the variation of rolling-moment coefficient with spoiler projection for both spoilers was approximately linear up to a spoiler projection of 0.05c. At a spoiler deflection of 0.05c, a point of inflection occurred in the variation of rolling-moment coefficient with spoiler projection beyond which the variation of spoiler rolling-moment effectiveness with projection was nonlinear.

With 0.575b/2 leading-edge and full-span split flaps deflected (fig. 15(b)), the variation of rolling-moment effectiveness with spoiler projection was approximately linear for both spoilers throughout the angle-of-attack range for all spoiler projections greater than 0.03c. For spoiler projections less than approximately 0.04c, reversal in the step spoiler effectiveness was encountered at low and moderate angles of attack. Although no reversal in spoiler effectiveness was obtained for the plain spoiler in this range of projections and angles of attack, the data do indicate that the effectiveness of the plain spoiler was such as to produce little or no rolling moment. This ineffectiveness of low spoiler projections for the full-span split-flap configurations has previously been noted in reference 7 for straight wings.

With 0.575b/2 leading-edge and half-span split flaps deflected with and without upper-surface fences (figs. 15(c) and 15(d)), the variation of rolling-moment effectiveness with spoiler projection was approximately linear through the range of spoiler deflections investigated.

In the low and moderate angle-of-attack range with flaps neutral, the plain spoiler was more effective than the step spoiler for spoiler projections less than approximately 0.07c. With flaps deflected, the plain spoiler was generally more effective throughout the entire angle-of-attack range and spoiler projections investigated.

Effect of Chordwise Location

The effects of chordwise location on the rolling-moment effectiveness of 0.6b/2 span plain and step spoilers are presented in figure 16.

With the outboard end of the spoiler span fixed at 0.975b/2 on the plain wing, the rolling-moment effectiveness of the step spoiler located at 0.50c was less than that obtained at 0.70c location for an angle-of-attack range from -4° to approximately 4°. Beyond 4° angle of attack up to the stall the greatest rolling-moment effectiveness was obtained with the step spoiler located at 0.50c. In the case of the plain spoiler, the degree of rolling-moment effectiveness obtained at the 0.50c location was lower than that obtained at the 0.70c location throughout the angle-of-attack range up to the stall. At the stall the effectiveness of both spoilers was, for all practical purposes, independent of chord location. The inability of chord location to affect the rolling-moment effectiveness of the spoilers at the stall is attributed to wing-tip flow separation, which is characteristic of the wing not equipped with stall-control devices. When the plain spoiler was located inboard of the wing tip (0.20b/2 to 0.80b/2), a forward chord location (0.50c) decreased the rolling-moment effectiveness of the plain spoiler from that obtained at the 0.70c location in the angle-of-attack range from -4° to 11°. Beyond 11° to the stall, the rolling-moment effectiveness of the plain spoiler was slightly greater for the 0.50c location than for the 0.70c location. At the stall the effectiveness appeared to be independent of chord location as was the case for outboard locations.

With the outboard end of the plain spoiler located at 0.975b/2 and 0.575b/2 leading-edge and half-span split flaps deflected, an increase in rolling-moment effectiveness of the plain spoiler was obtained only for the angle-of-attack range from 10° through the stall when the plain spoiler was moved forward from the 0.70c line to the 0.50c location.

The decrease in rolling-moment effectiveness that was obtained when spoilers were moved forward to the 0.50c location is not in agreement with previously published data of an unswept wing incorporating 44-series airfoil sections (reference 6). This discrepancy is believed to be due to airfoil section inasmuch as two-dimensional data from the Ames 1- by $3\frac{1}{2}$-foot tunnel for an airfoil section similar to that used in the present investigation is in qualitative agreement with the results presented herein.

Effect of Reynolds Number

Figure 17 presents the effects of Reynolds number on the spoiler effectiveness of 0.10c plain and step spoilers located at two spanwise positions on the basic wing with and without a fuselage. As indicated from the data of figure 17, increasing the Reynolds number from 3.8×10^6 to 6.8×10^6 increased the spoiler rolling-moment effectiveness on both wing configurations over most of the angle-of-attack range and generally extended the spoiler effectiveness to higher angles of attack.

Comparison of Spoiler and Aileron Effectiveness

A partial comparison of spoiler and aileron effectiveness is presented in figures 18(a) and 18(b) for three angles of attack. The following discussion is based on a 0.5b/2 span spoiler of 0.10c projection and a half-span flat-sided outboard aileron having a total deflection of 25° (reference 8).

For the flap-neutral condition (fig. 18(a)) the results indicate that when the spoiler spans were fixed at the wing tip, the effectiveness of the aileron was approximately equal to, and in some cases better than, that produced by either spoiler arrangement. When the spoilers were located inboard toward the plane of symmetry, the plain spoiler was more effective than the aileron and the step spoiler was less effective than the aileron. Although rolling-moment data are not presented for angles of attack at the stall, comparison of the data of reference 8 with results obtained in this investigation indicates the effectiveness of the aileron through the stall was considerably greater than that obtained with either type of spoiler investigated.

With 0.575b/2 leading-edge and half-span split flaps deflected, both spoilers regardless of spanwise location were more effective than the aileron. The only exception was in the case of the step spoilers located at the plane of symmetry at low and moderate angles of attack where the aileron was more effective.

CONCLUSIONS

From an investigation of the low-speed lateral control characteristics carried out at a Reynolds number of 6.8×10^6 on a 42° sweptback wing with and without high-lift and stall-control devices, the following conclusions were made:

1. The rolling-moment effectiveness obtained from spoilers extending inboard from the tip and outboard from the root cannot be combined in a single spanwise effectiveness curve as in the case of straight wings.

2. Based on equal-span spoilers having a spoiler projection of 0.10c, the step spoiler was more effective if located slightly inboard of the

wing tip for the plain wing configuration; whereas the plain spoiler was more effective if located in the vicinity of the plane of symmetry. With flaps deflected, both spoilers were more effective when located slightly inboard of the wing tip.

3. With flaps neutral, the plain spoiler was more effective than the step spoiler for low spoiler projections in the low and moderate angle-of-attack range. With flaps deflected, the plain spoiler was generally more effective throughout the range of angles of attack and spoiler projections investigated.

4. For all model configurations investigated, a forward spoiler chordwise location generally reduced the spoiler effectiveness in the low and moderate angle-of-attack range and generally increased the effectiveness in the higher angle-of-attack range.

5. The rolling-moment effectiveness of both spoilers was increased over most of the angle-of-attack range by an increase in Reynolds number from 3.8×10^6 to 6.8×10^6.

6. Based on a spoiler span of 50 percent of the semispan and a spoiler projection of 10 percent of the local chord, the effectiveness of a half-span aileron having a total deflection of 25° was approximately equal to and in some cases better than that produced by either spoiler arrangement for the flap-neutral condition with the spoilers fixed at wing tip. When the spoilers were located at the plane of symmetry, the plain spoiler was more effective than the aileron, whereas the lowest effectiveness was obtained for the step spoiler. With flaps deflected, both spoilers, regardless of spanwise location, were in most cases more effective than the aileron.

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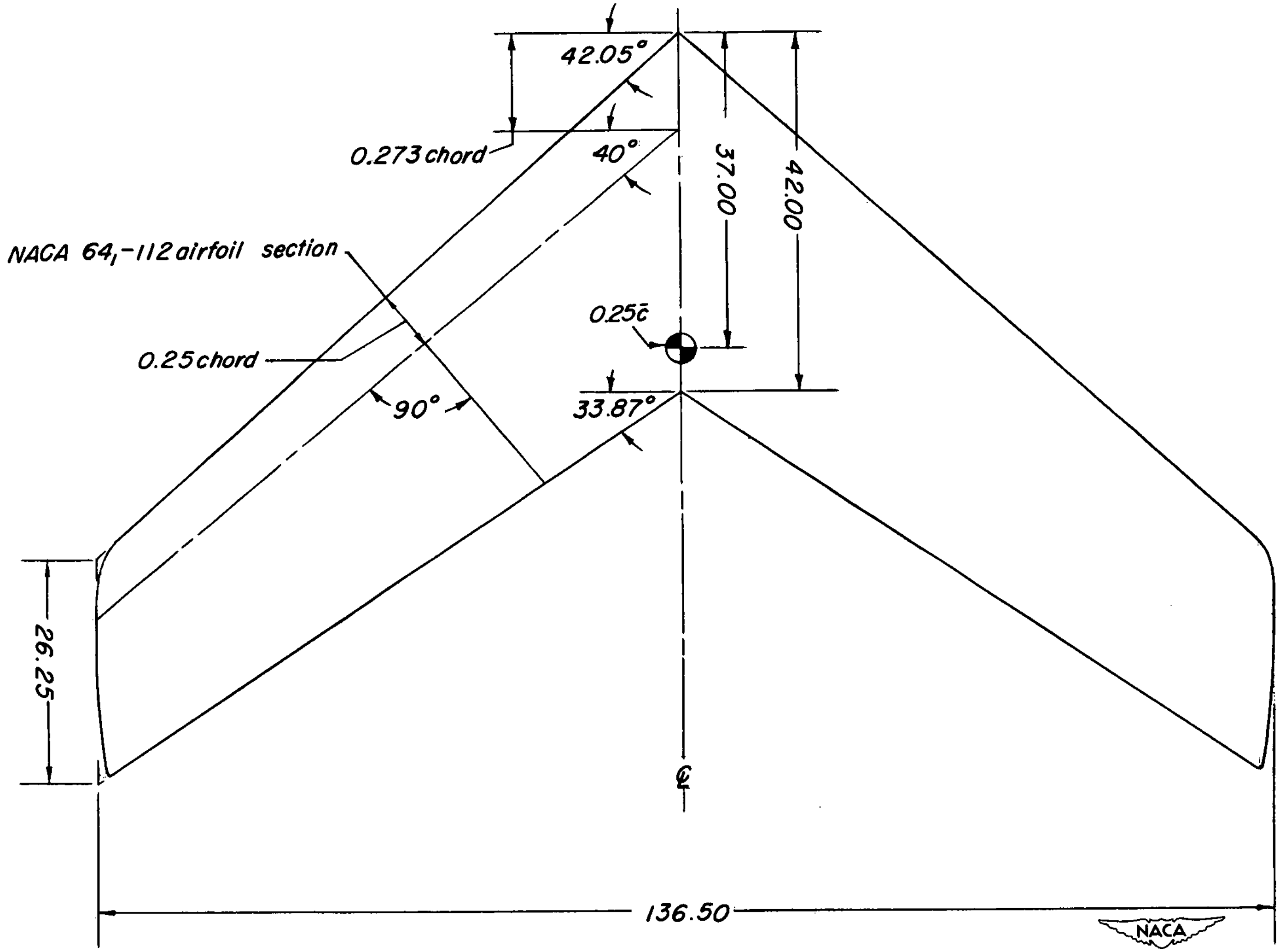


Figure 1.- Plan form of 42° sweptback wing. Area, 4643 square inches; mean aerodynamic chord, 34.71 inches; aspect ratio, 4.01; taper ratio, 0.625. All dimensions are in inches.

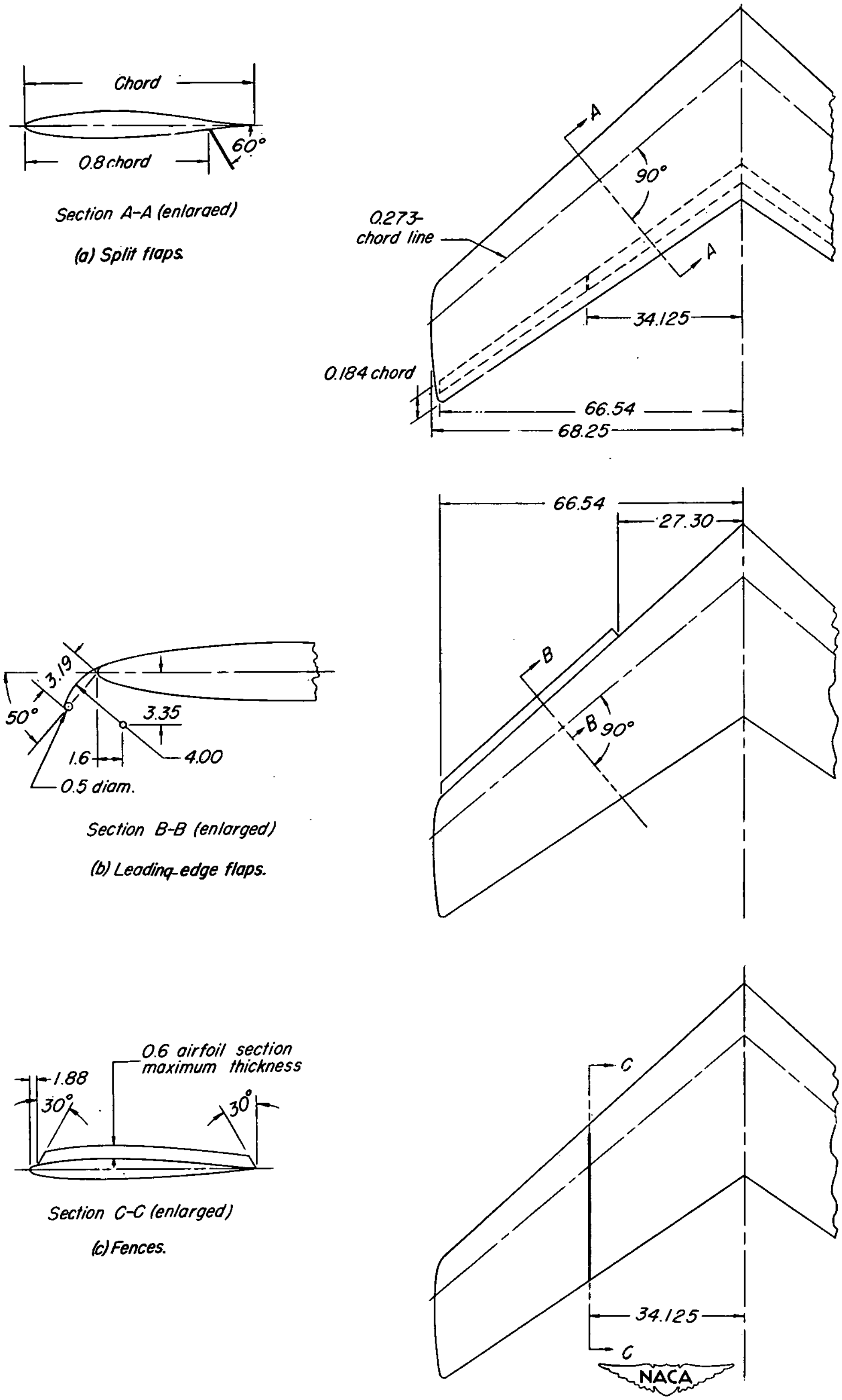


Figure 2.- Details of high-lift and stall-control devices. All dimensions are in inches.

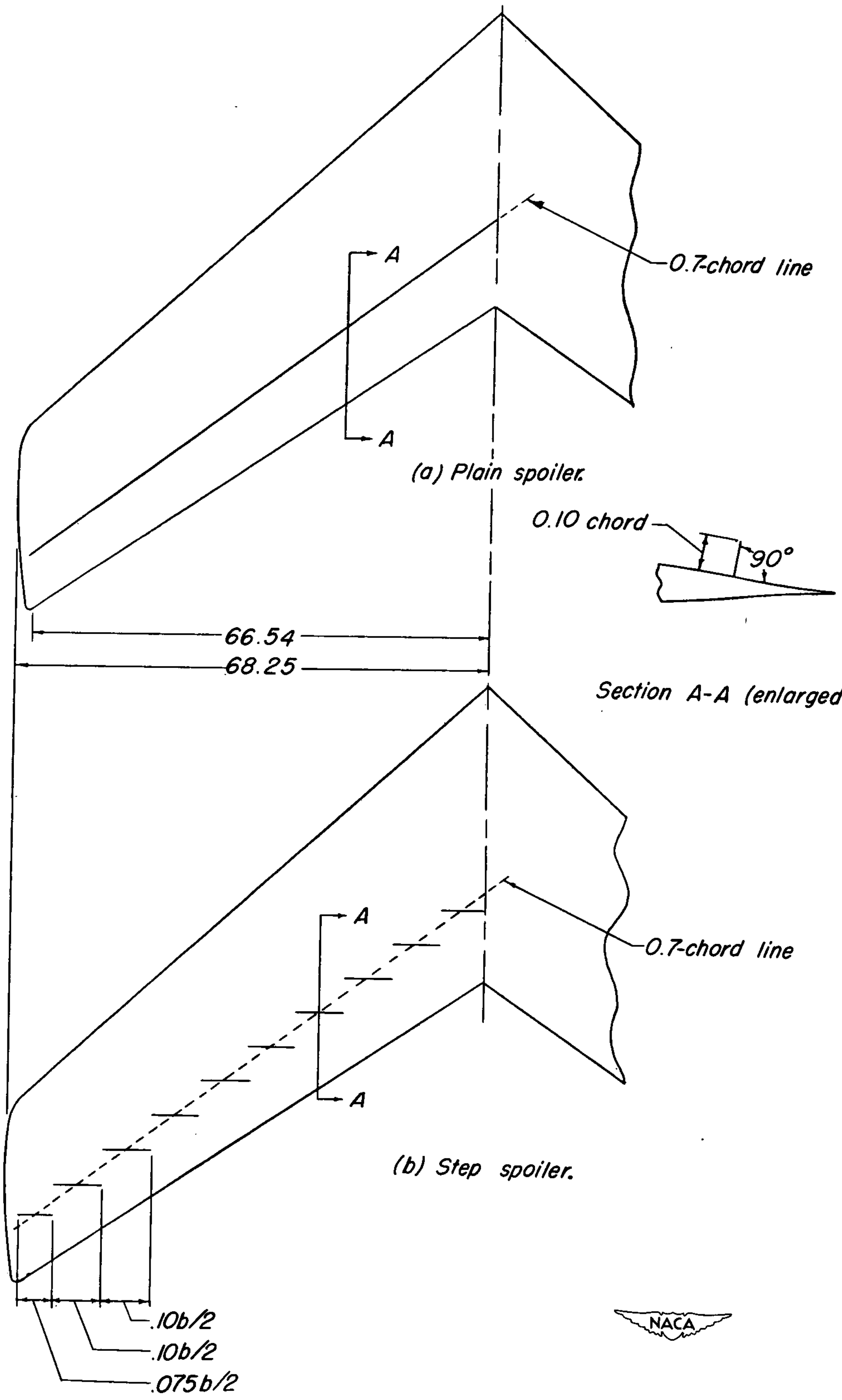
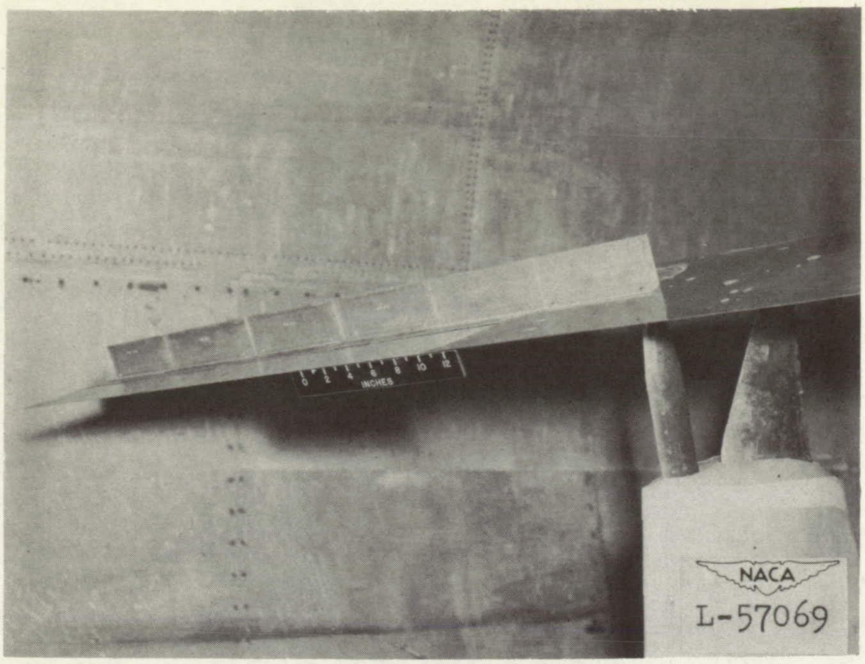
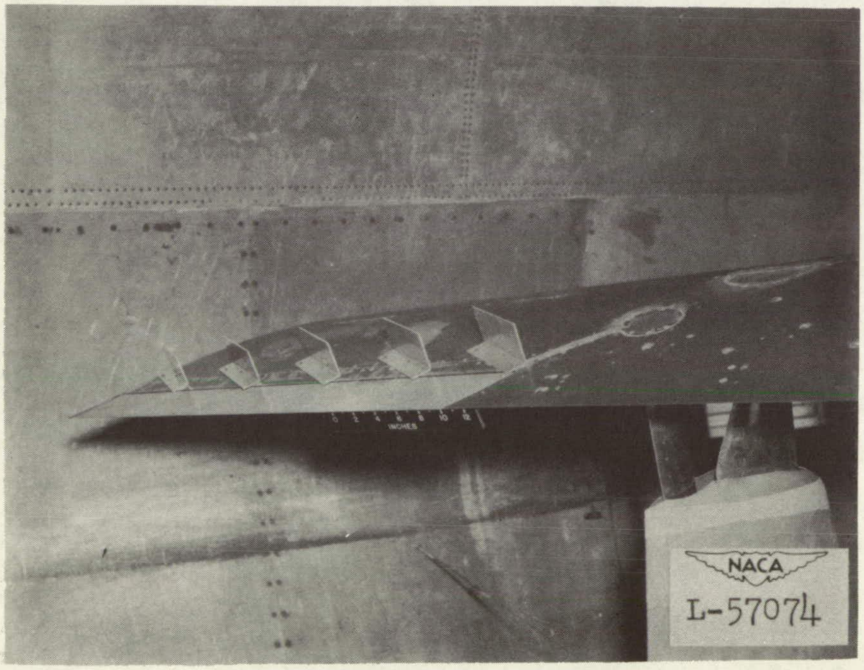


Figure 3.- Geometry of plain and step spoilers. All dimensions are in inches.



(a) Plain spoiler.



(b) Step spoiler.

Figure 4.- Installation of plain and step spoilers on a 42° sweptback wing.

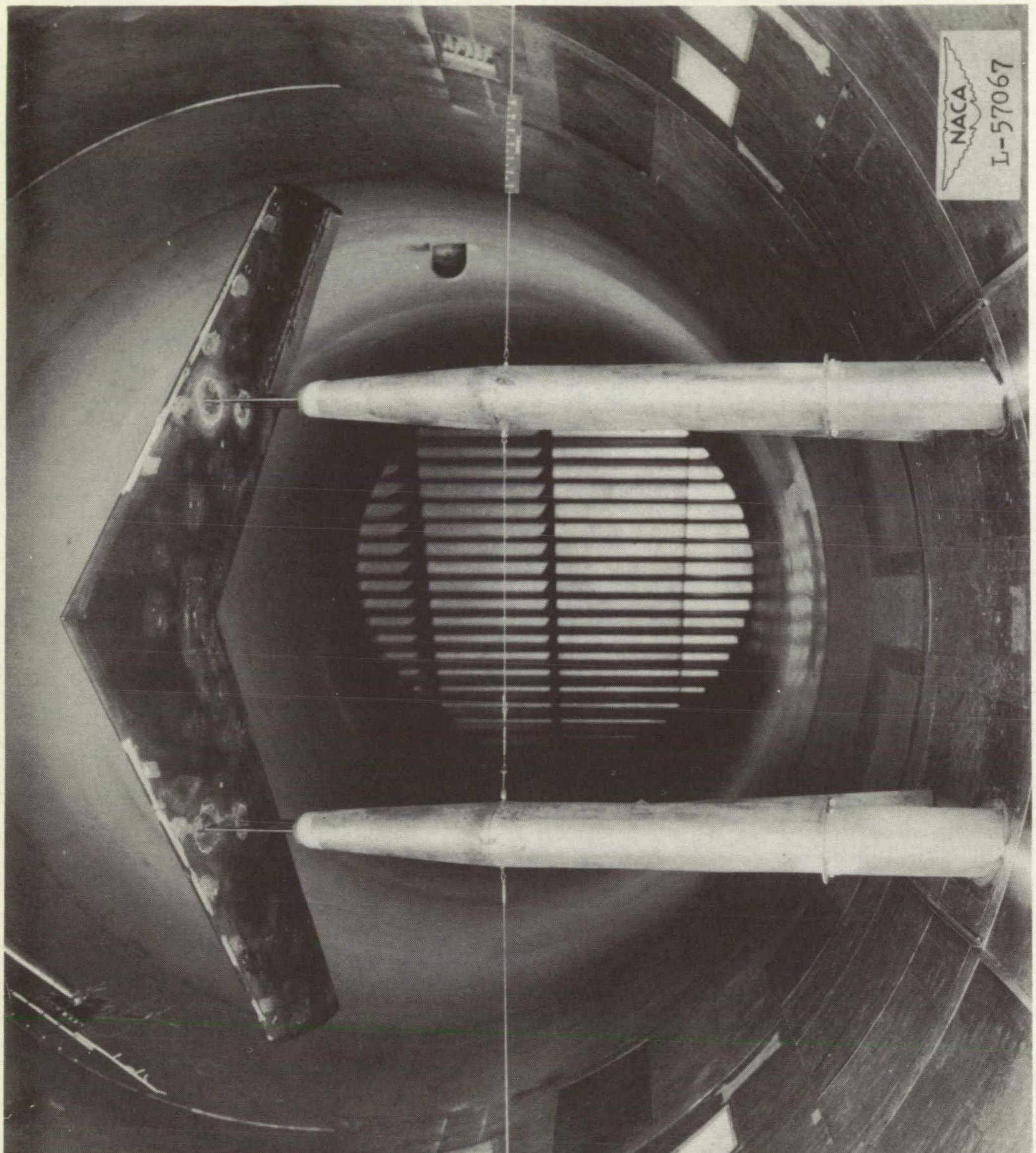
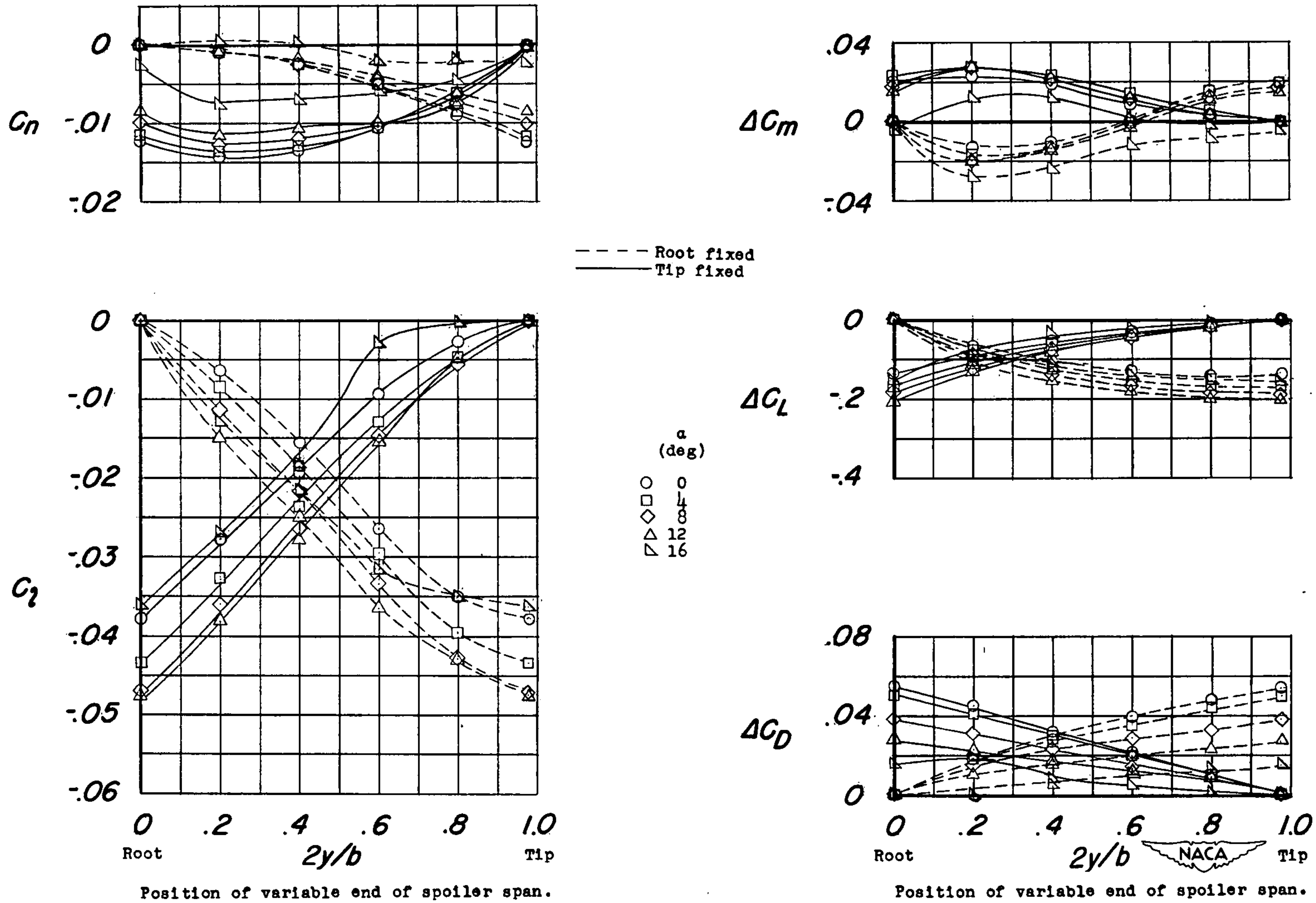
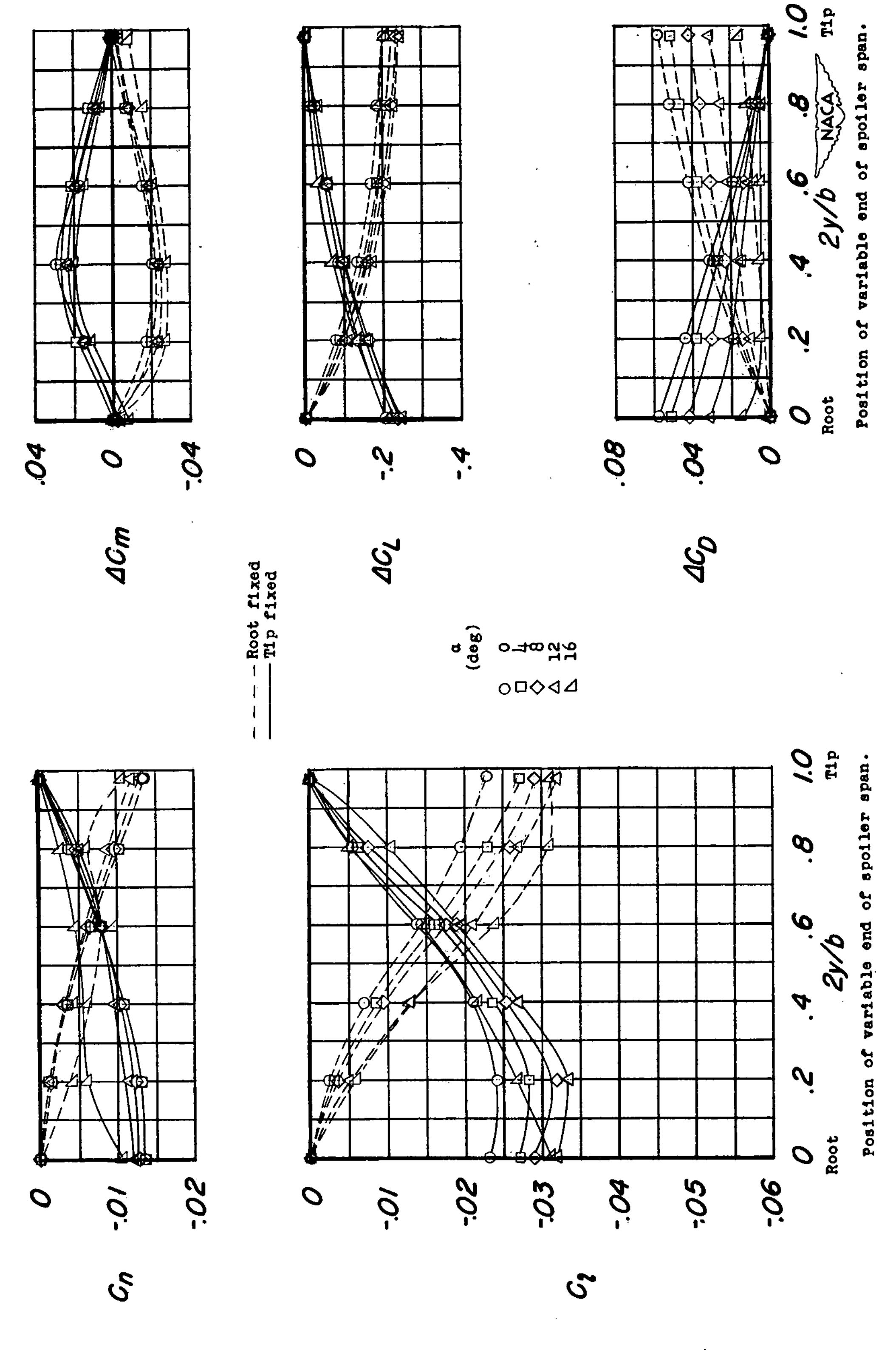


Figure 5.- The 42° sweptback wing mounted in the Langley 19-foot pressure tunnel.



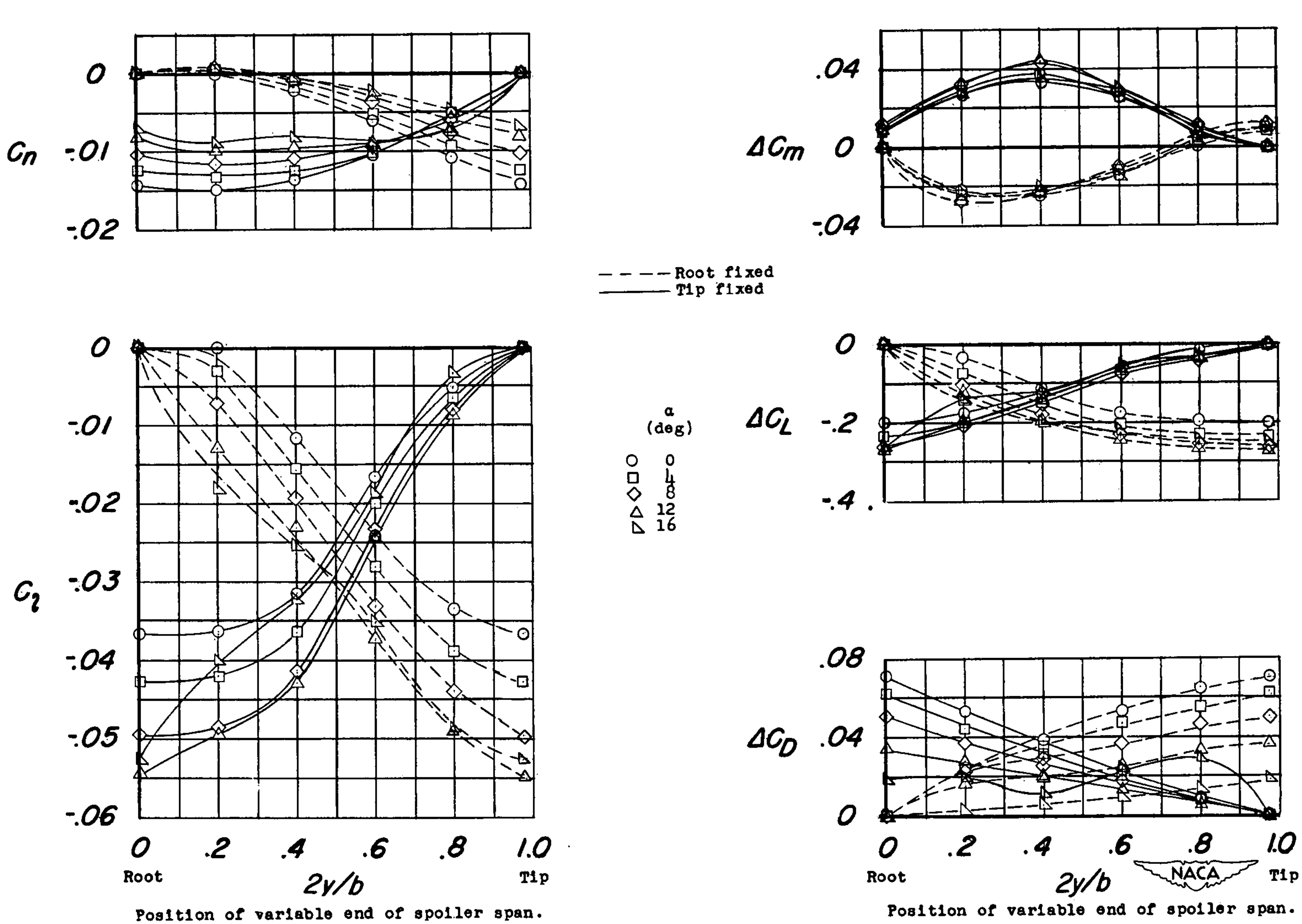
(a) Basic wing; plain spoiler, δ_s = 0.10c.

Figure 6.- Effect of spoiler span on the aerodynamic characteristics of a 42° sweptback wing. R = 6.8×10^6.



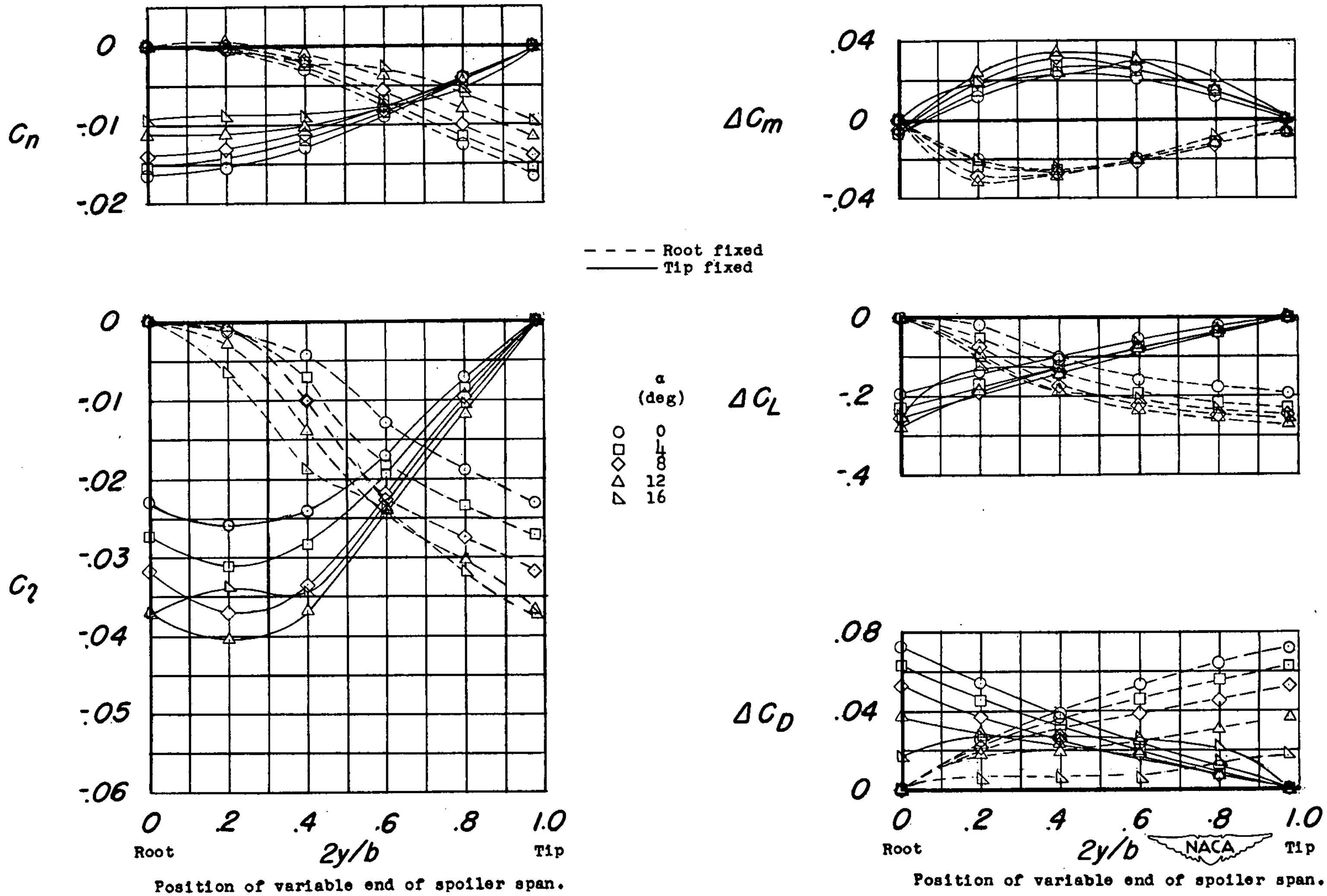
(b) Basic wing; step spoiler, $\delta_s = 0.10c$.

Figure 6.- Continued.



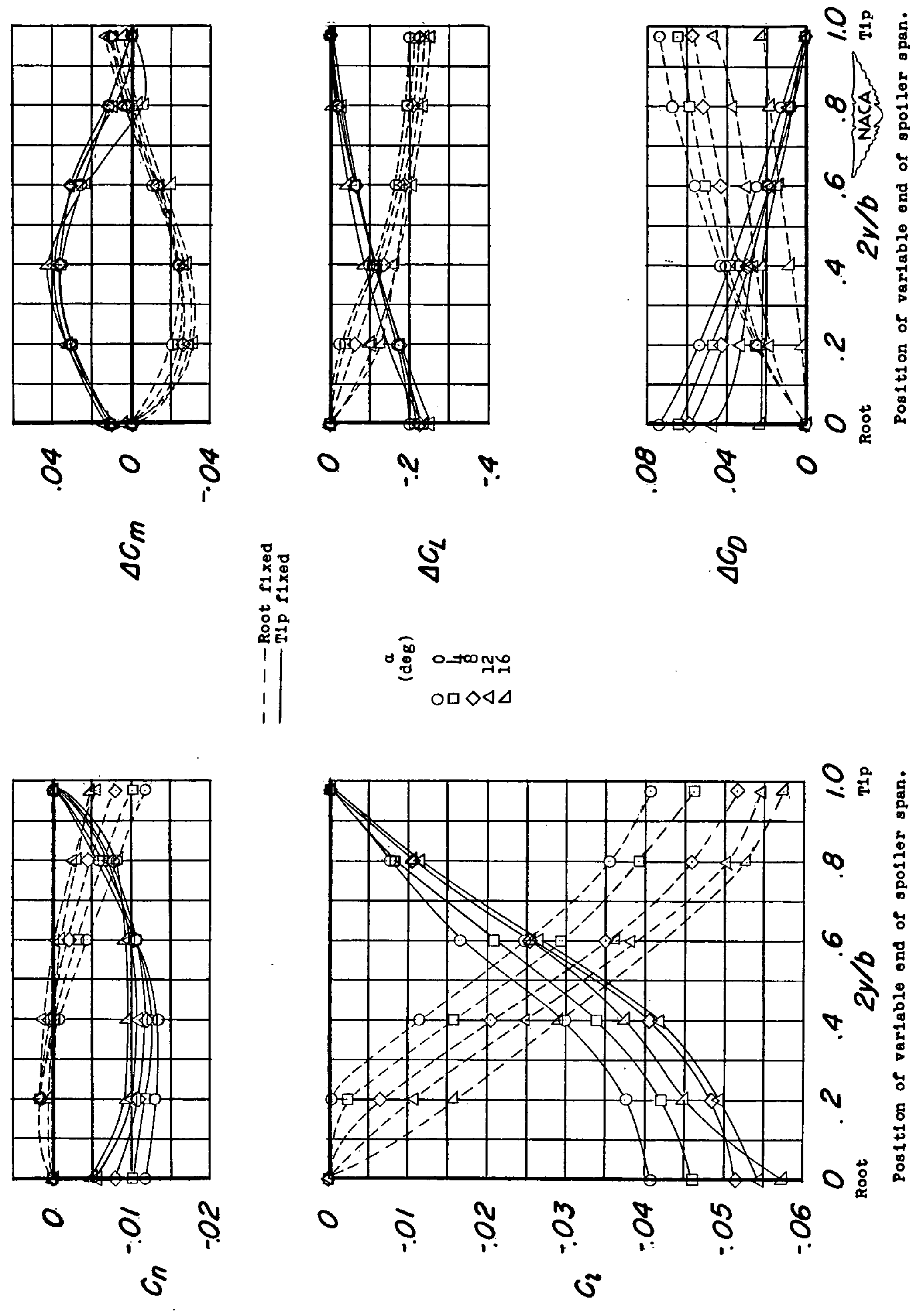
(c) $0.575\frac{b}{2}$ leading-edge and half-span split flaps deflected; plain spoiler, $\delta_s = 0.10c$.

Figure 6.- Continued.



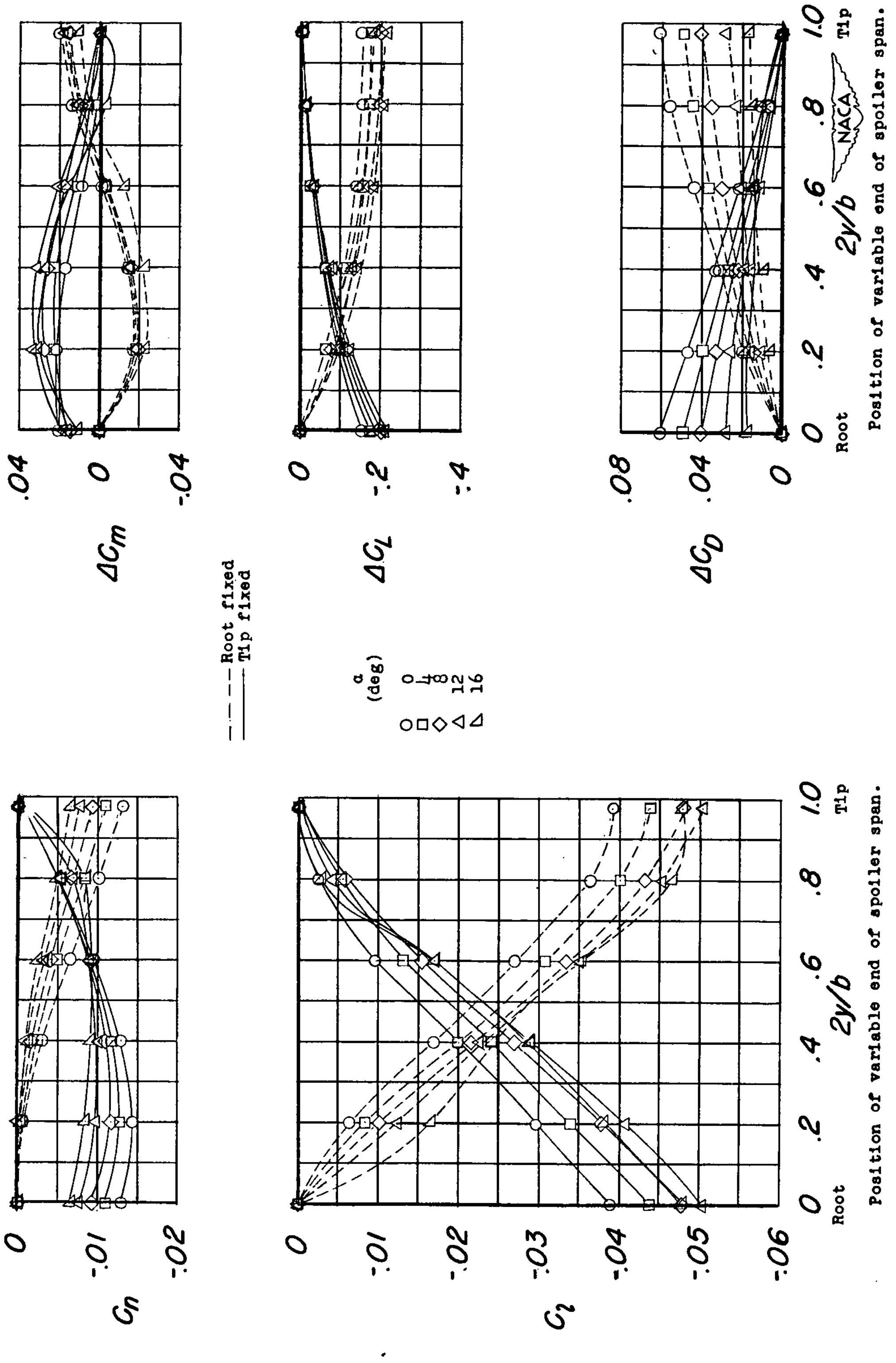
(d) $0.575\frac{b}{2}$ leading-edge and half-span split flaps deflected; step spoiler, $\delta_s = 0.10c$.

Figure 6.- Continued.



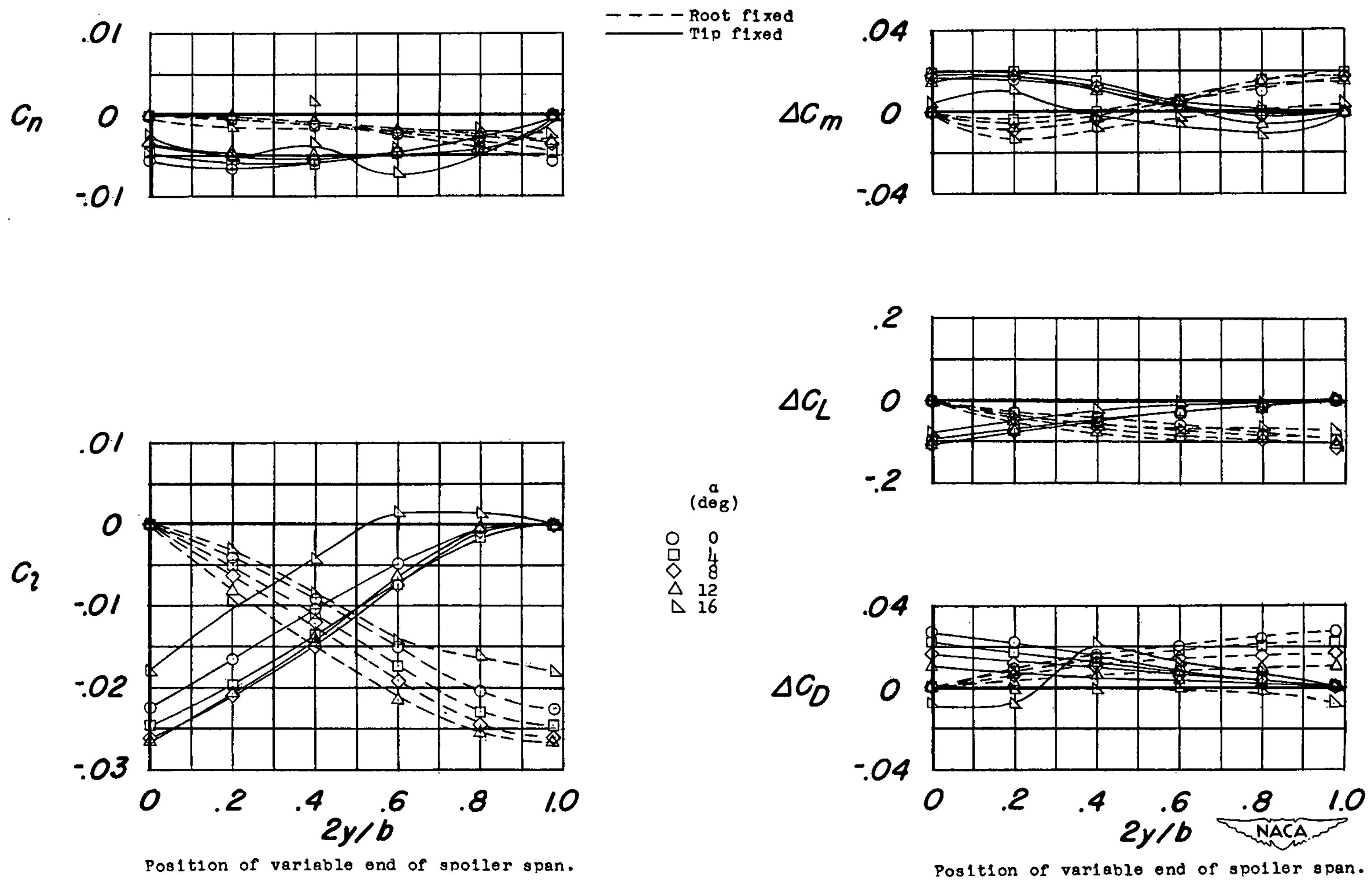
(e) $0.575\frac{b}{2}$ leading-edge and full-span split flaps deflected; plain spoiler, $\delta_s = 0.10c$.

Figure 6.- Continued.



(f) $0.575\frac{b}{2}$ leading-edge flaps deflected; plain spoiler, $\delta_s = 0.10c$.

Figure 6.- Continued.



(g) Basic wing; plain spoiler, $\delta_s = 0.05c$.

Figure 6.- Concluded.

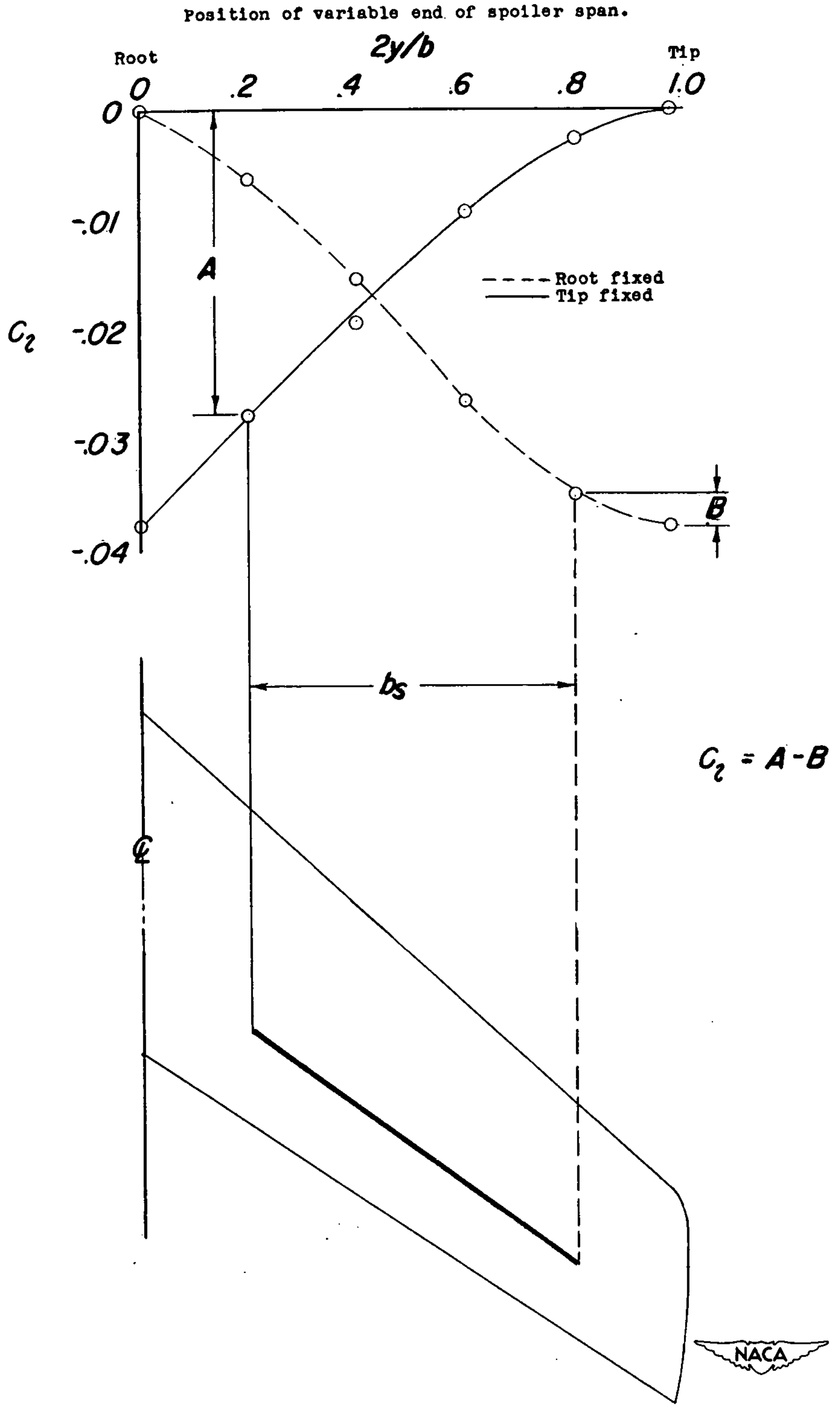
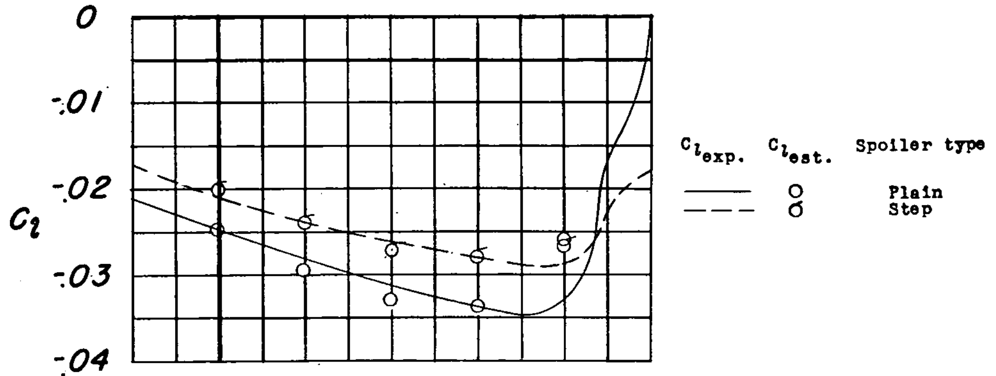
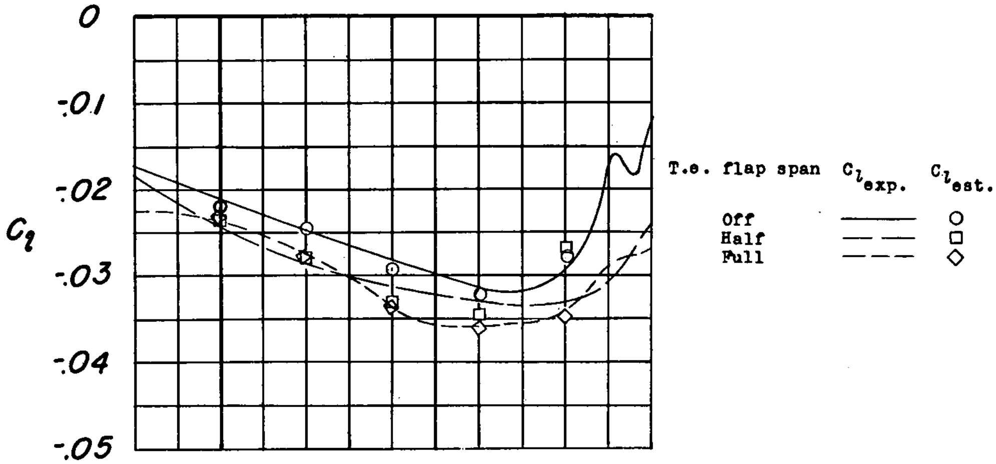


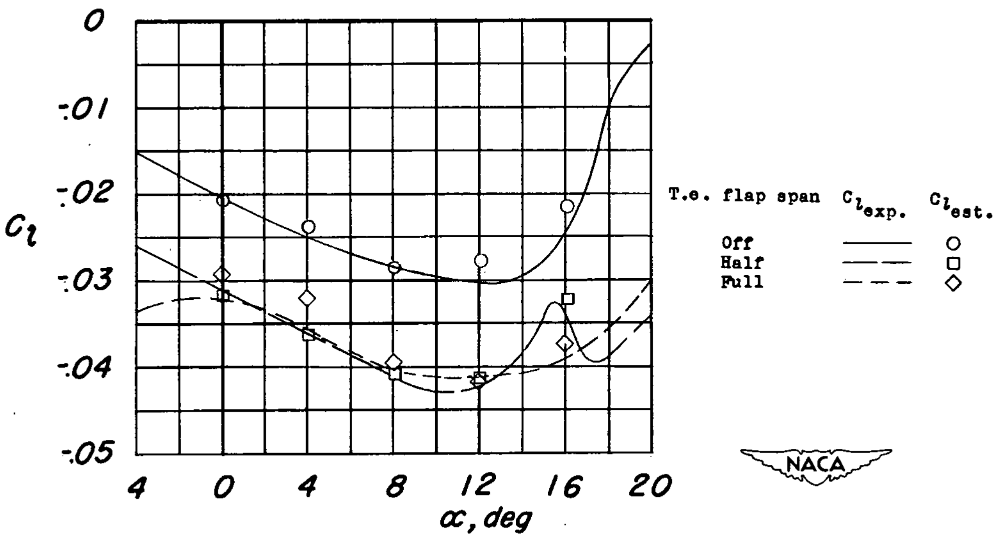
Figure 7.- Procedure for estimating the effects of spoiler span and spanwise location on the aerodynamic characteristics of a 42° sweptback wing. $\alpha = 0$.



Basic wing; spoiler span: 0.2 to 0.8b/2.



0.575b/2 leading-edge and split flaps deflected; plain spoiler span: 0.1 to 0.6b/2.



0.575b/2 leading-edge and split flaps deflected; plain spoiler span: 0.3 to 0.8b/2.

Figure 8.- Comparison of the estimated and experimental rolling-moment coefficients for various model configurations and spoiler spans. $\delta_s = 0.10c$. $R = 6.8 \times 10^6$.

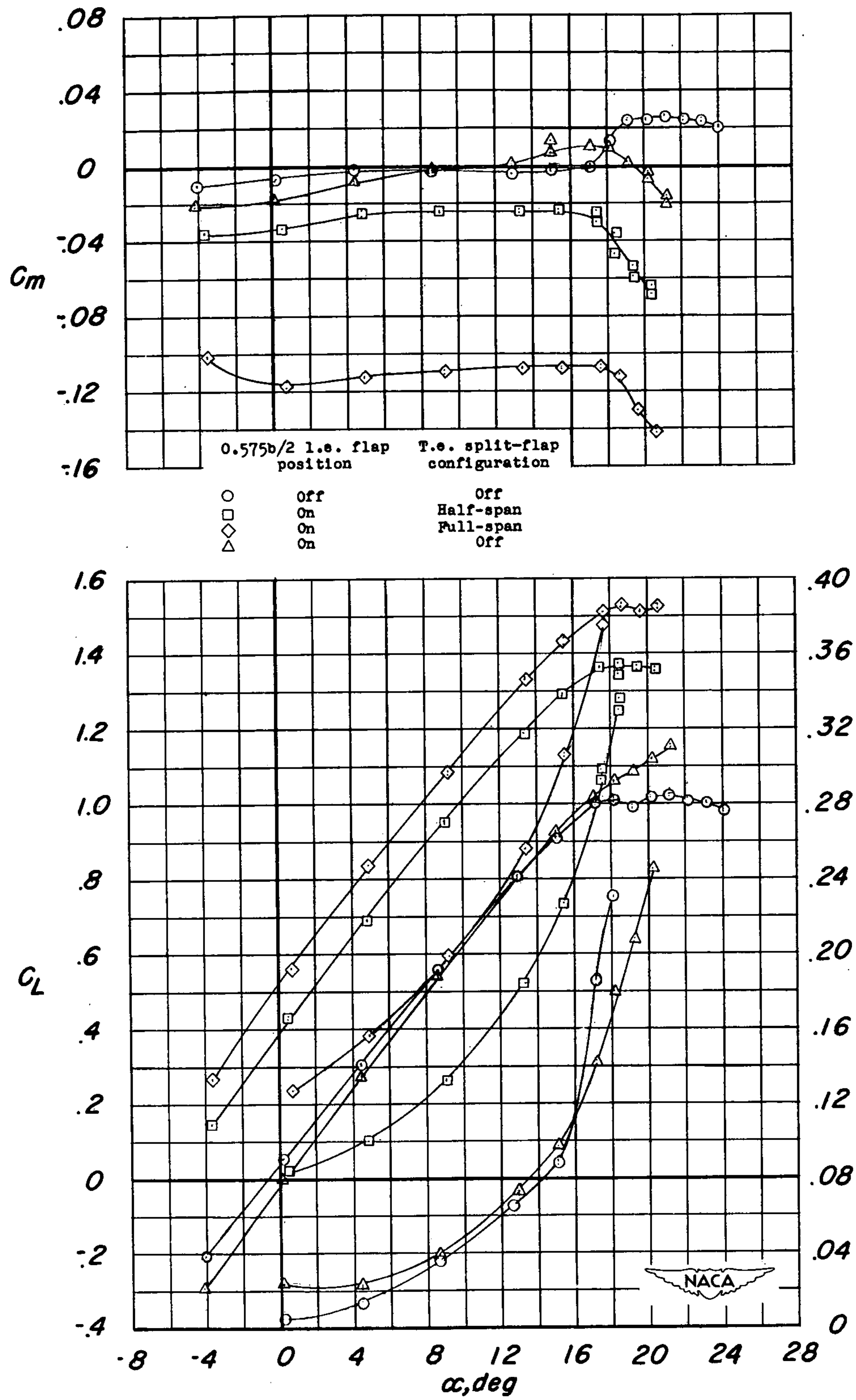
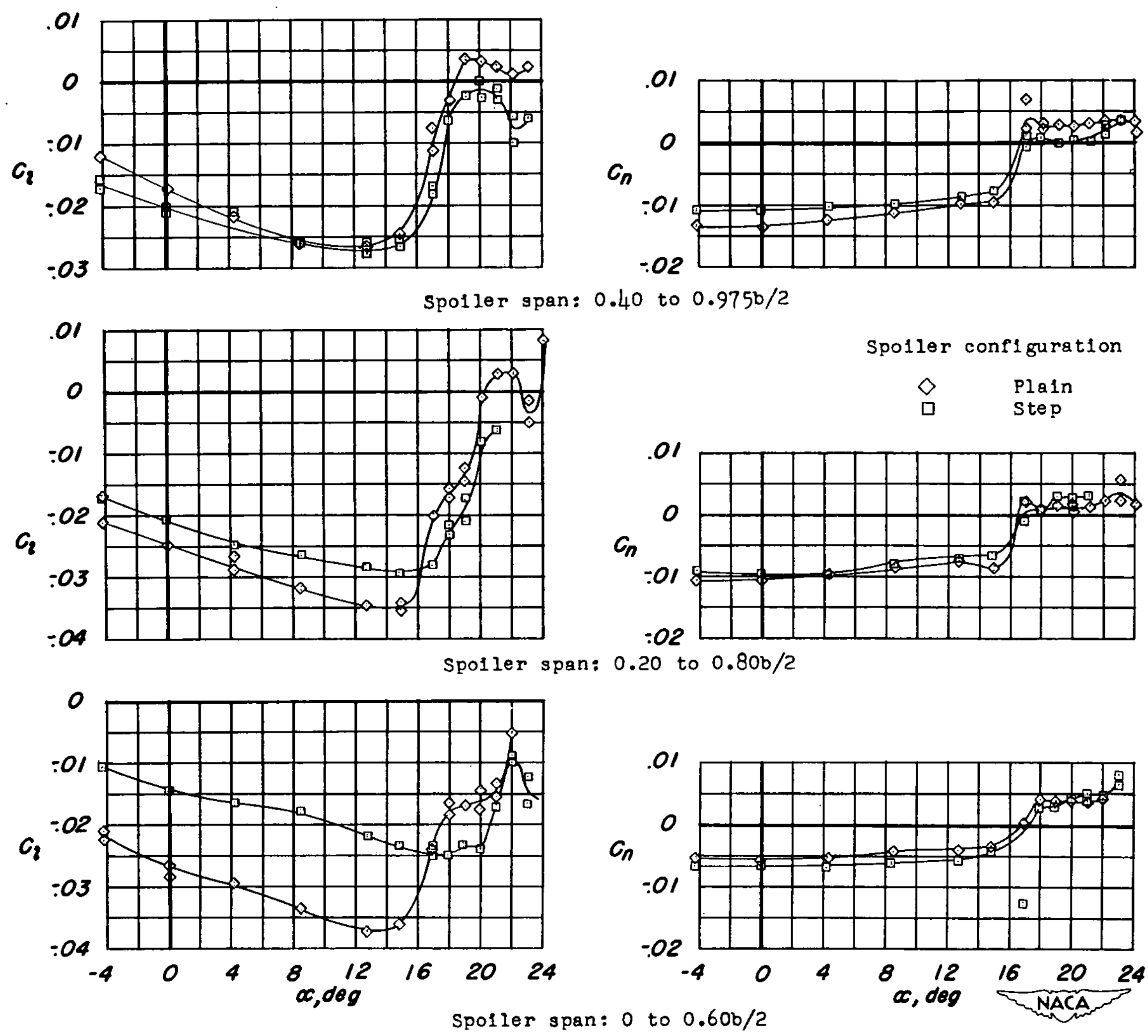
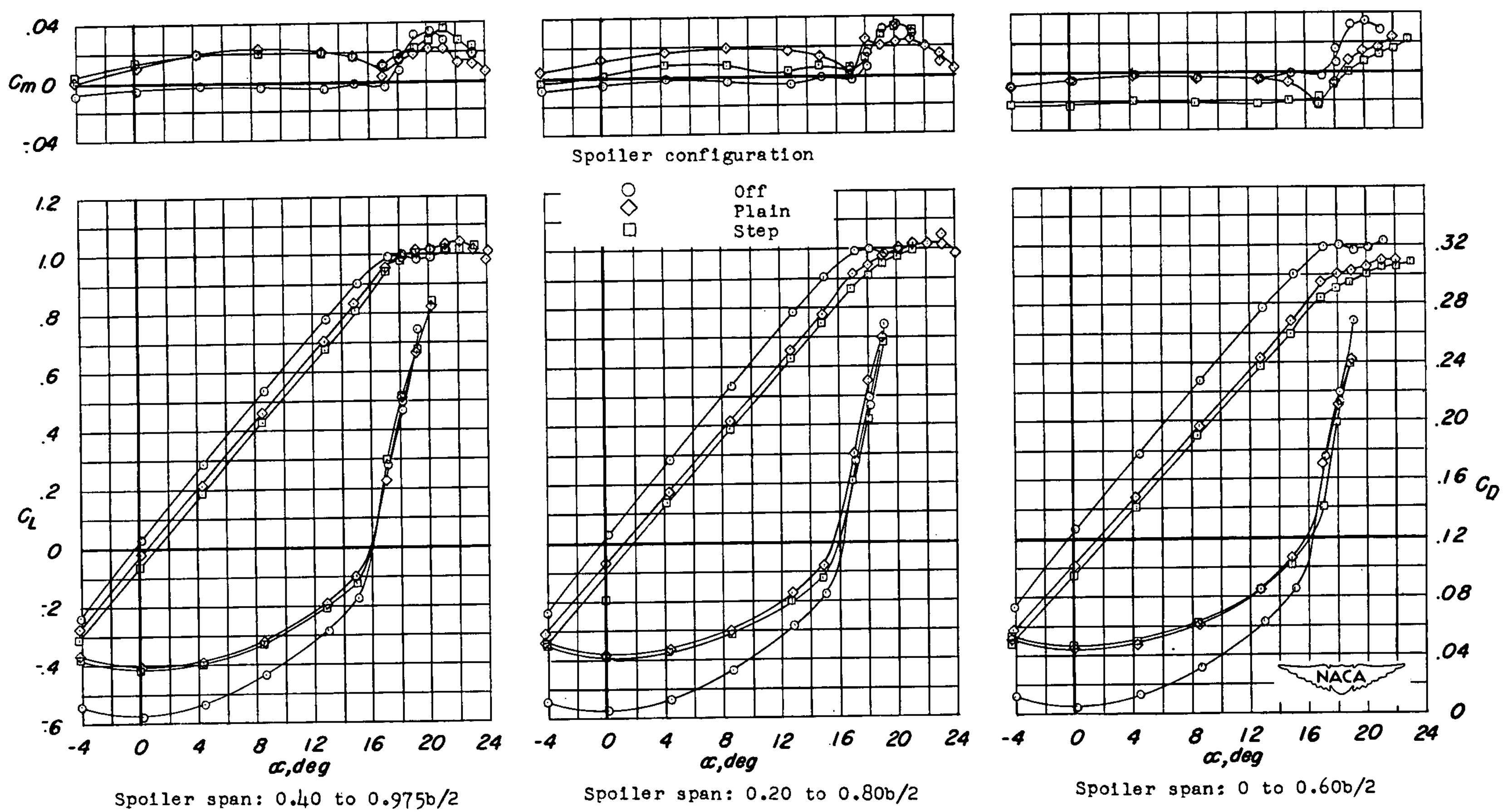


Figure 9.- Aerodynamic characteristics of basic wing configurations. $R = 6.8 \times 10^6$.



(a) C_l and C_n against α.

Figure 10.- The effect of spanwise location of constant span plain and step spoilers on the aerodynamic characteristics of the basic wing. $\delta_s = 0.10c$. $R = 6.8 \times 10^6$.



(b) C_L, C_D, and C_m against α.

Figure 10.- Concluded.

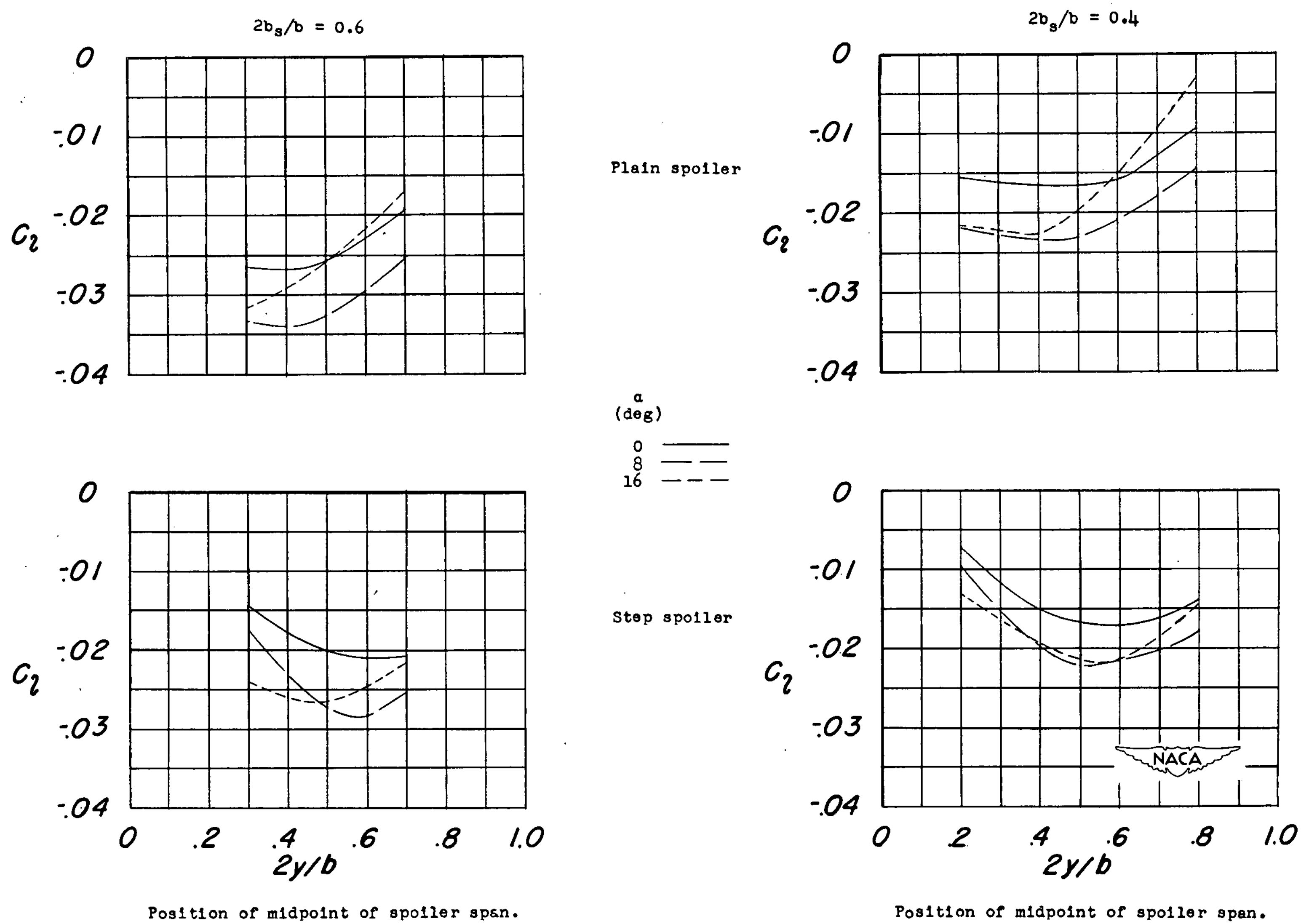
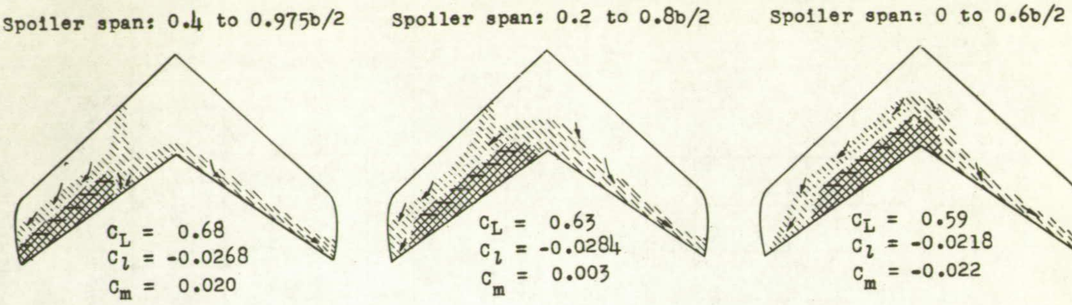
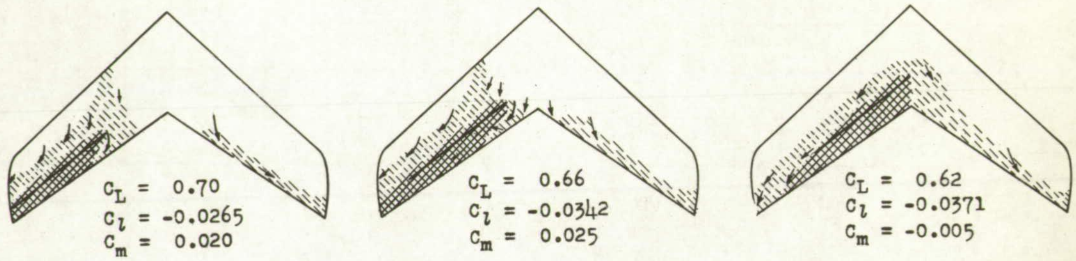


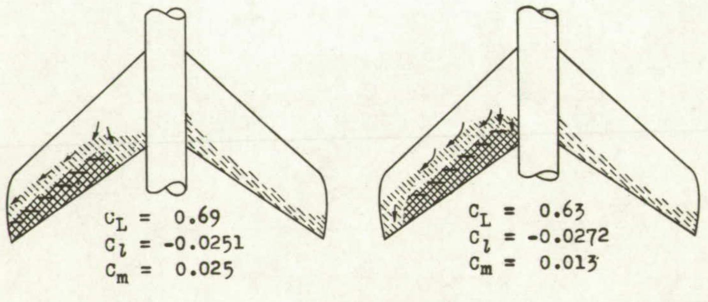
Figure 11.- The effect of span and spanwise location of constant-span plain and step spoilers on the rolling-moment characteristics of the basic wing. $\delta_s = 0.10c$. (Data estimated by procedure in fig. 7.)



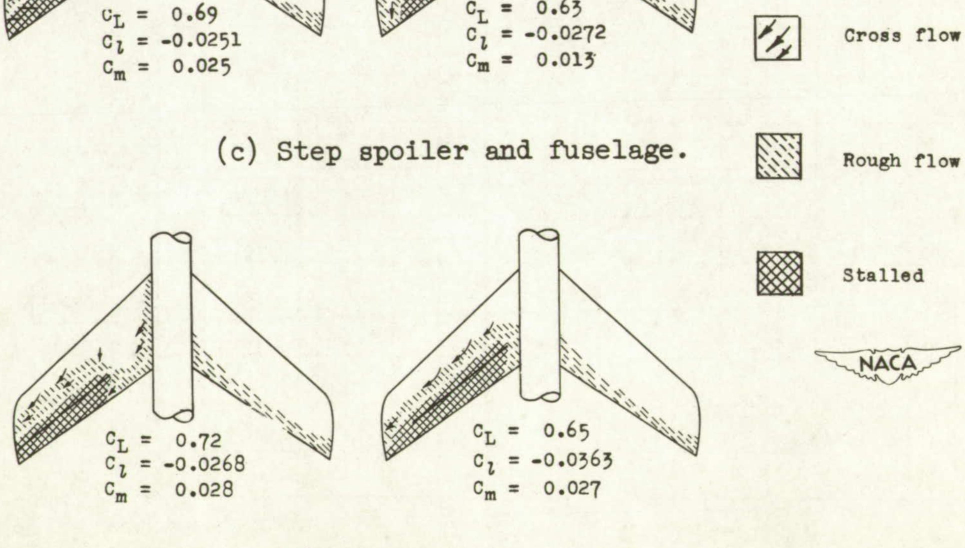
(a) Step spoiler.



(b) Plain spoiler.



(c) Step spoiler and fuselage.



(d) Plain spoiler and fuselage.

Figure 12.- Flow patterns induced by various plain and step spoiler arrangements on the basic wing with and without a fuselage. $\delta_s = 0.10c$; $\alpha = 12.8^{\circ}$.

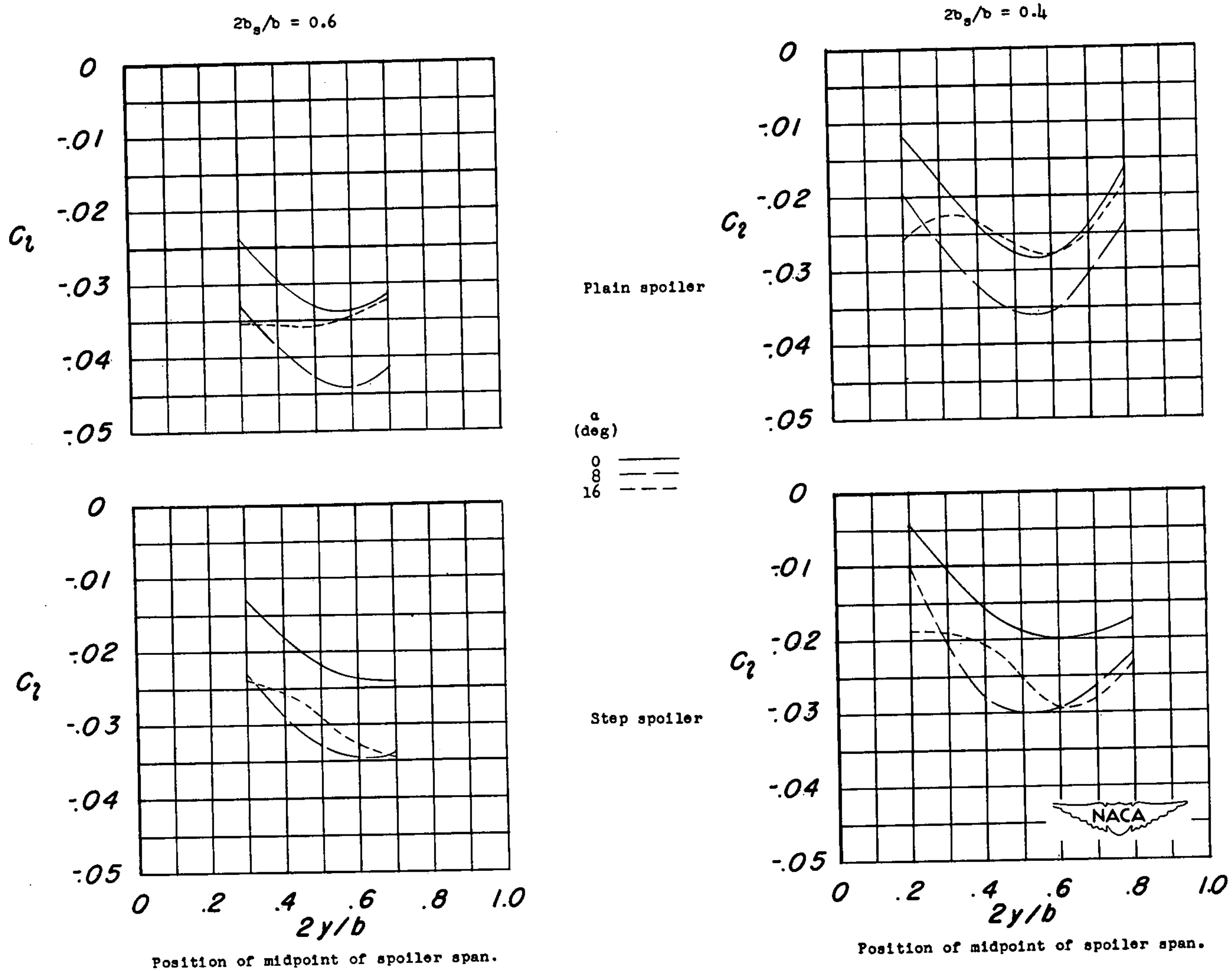
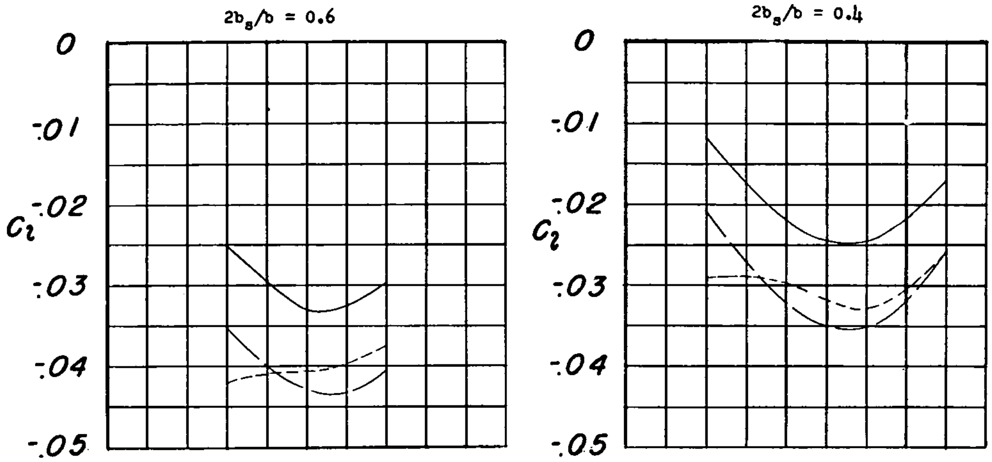
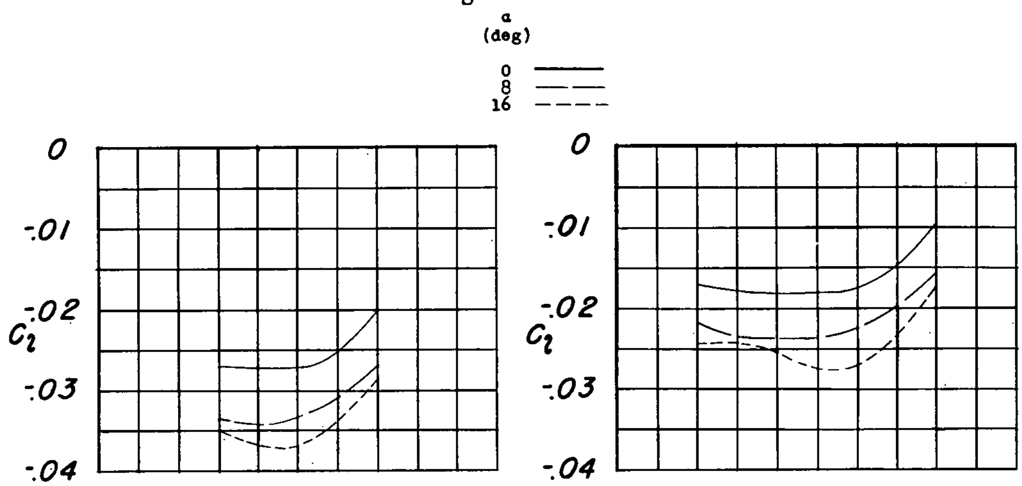


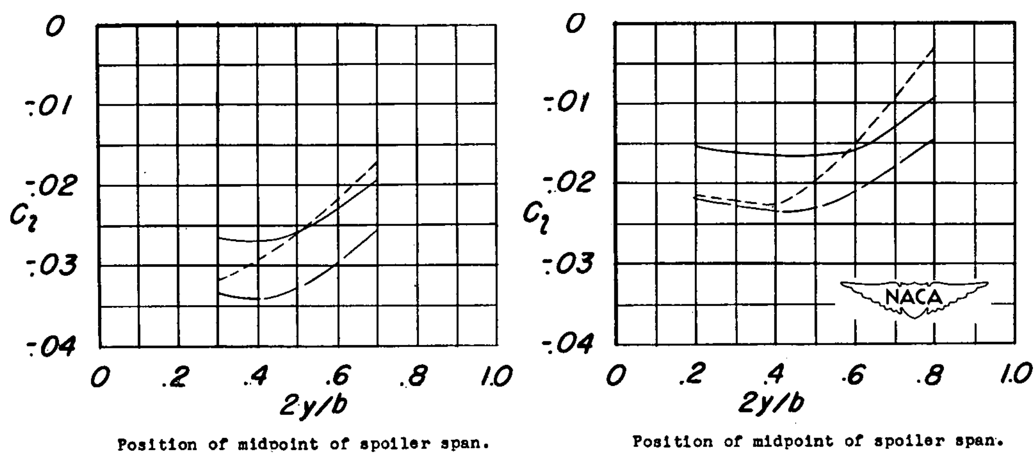
Figure 13.- The effect of span and spanwise location of constant-span plain and step spoilers on the rolling-moment characteristics of the basic wing with $0.575\frac{b}{2}$ leading-edge and half-span split flaps deflected. $\delta_s = 0.10c$. (Data estimated by procedure in fig. 7.)



(a) $0.575\frac{b}{2}$ leading-edge and full-span split flaps deflected; $\delta_s = 0.10c$.

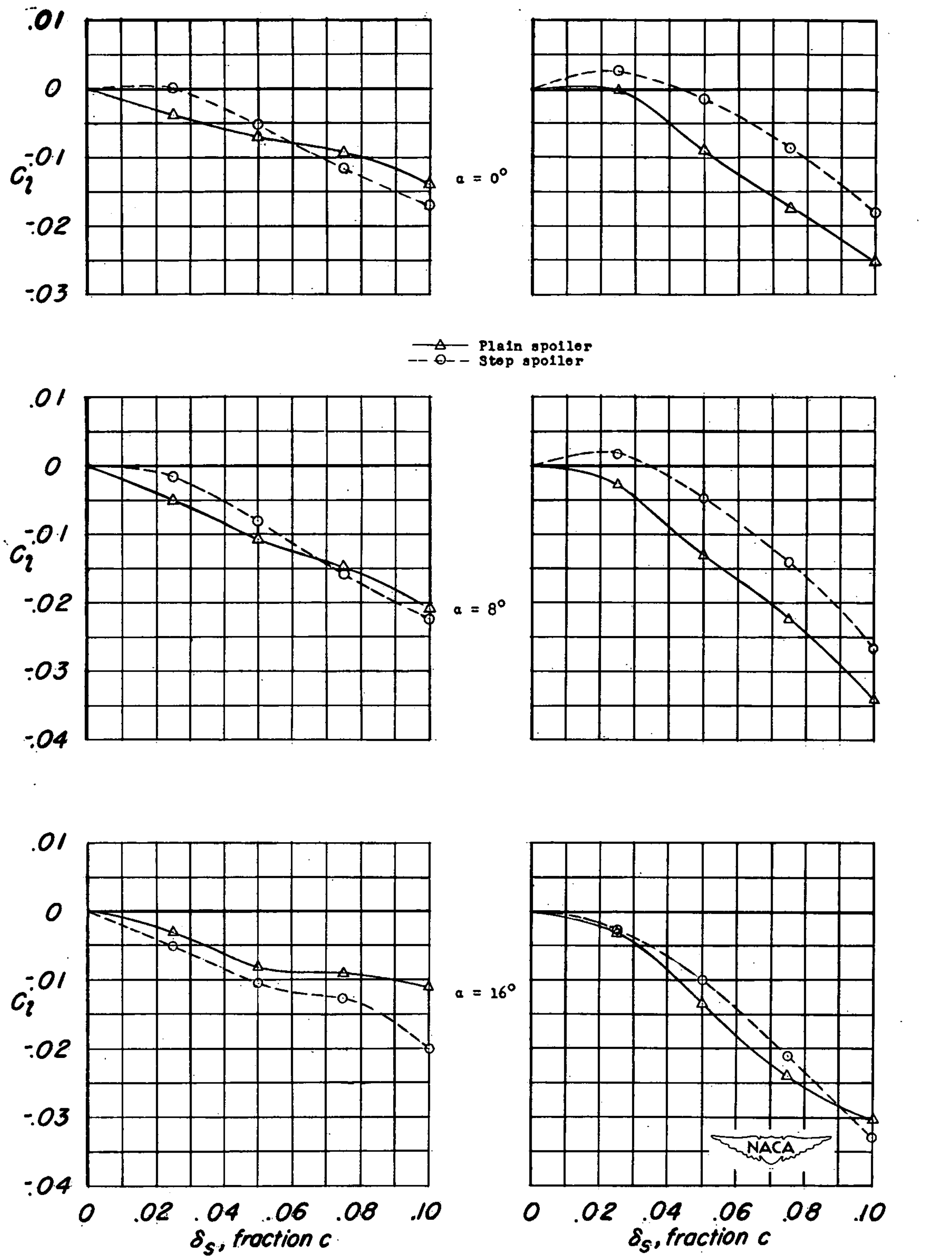


(b) $0.575\frac{b}{2}$ leading-edge flaps deflected; $\delta_s = 0.10c$.



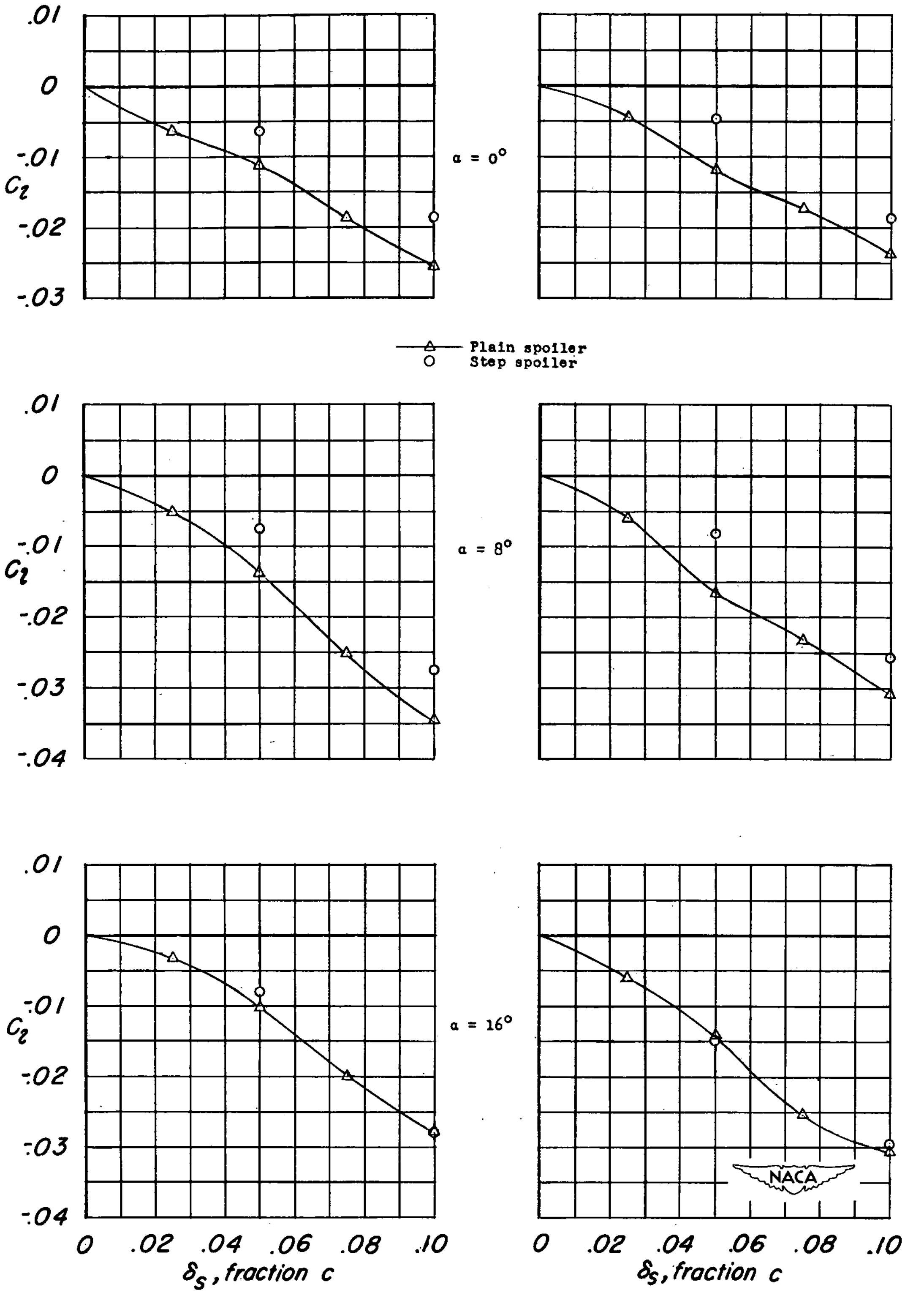
(c) Basic wing; $\delta_s = 0.10c$.

Figure 14.- The effect of span and spanwise location of constant-span plain spoilers on the rolling-moment characteristics of various model configurations. (Data estimated by procedure in fig. 7.) $R = 6.8 \times 10^6$.



(a) Basic wing. (b) $0.575\frac{b}{2}$ leading-edge and full-span split flaps deflected.

Figure 15.- Comparison of plain and step spoilers for various spoiler projections and model configurations. $b_s = 0.475\frac{b}{2}$. $R = 6.8 \times 10^6$.



(c) $0.575\frac{b}{2}$ leading-edge and half-span split flaps deflected.

(d) $0.575\frac{b}{2}$ leading-edge and half-span split flaps deflected and upper-surface fences.

Figure 15.- Concluded.

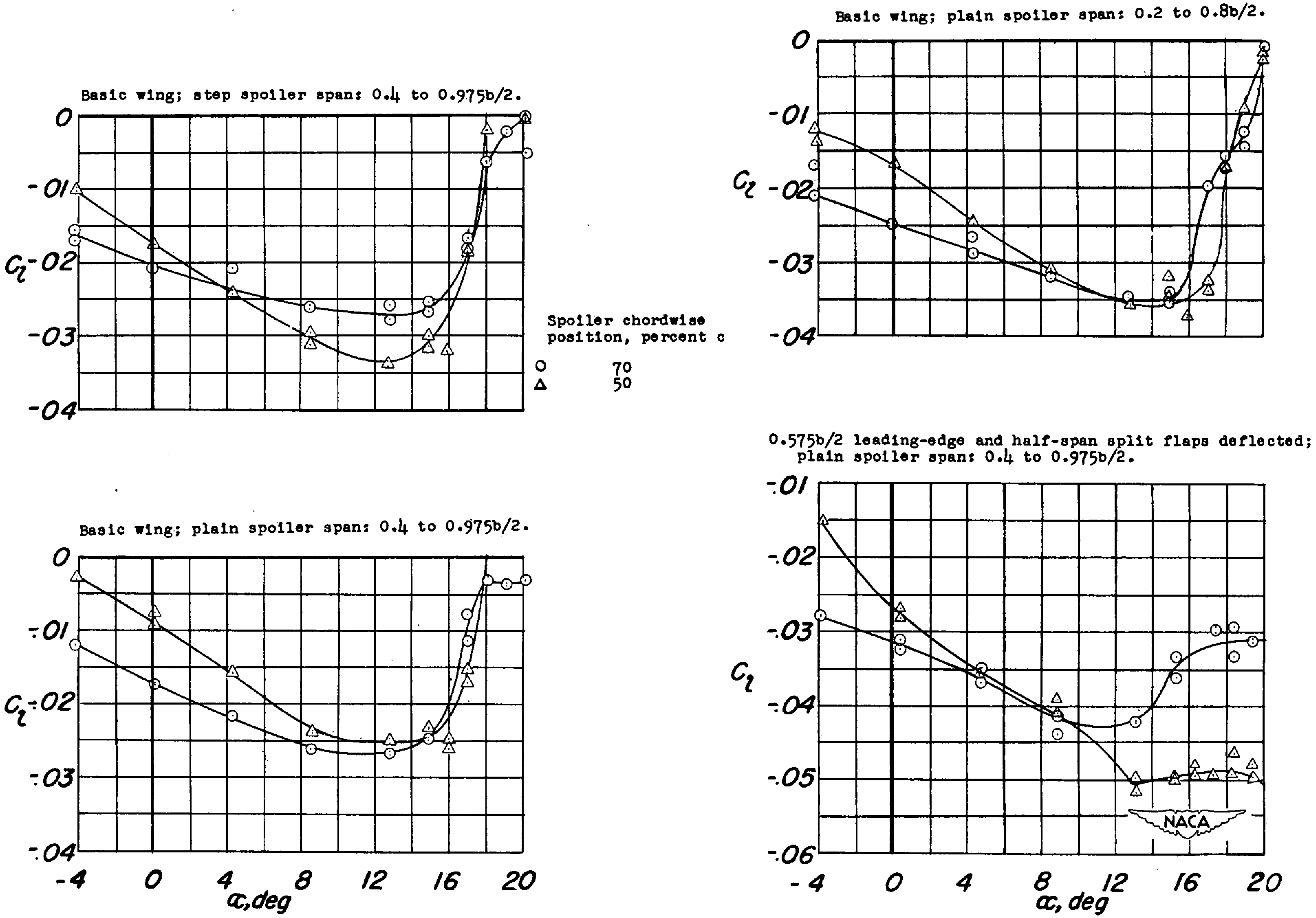
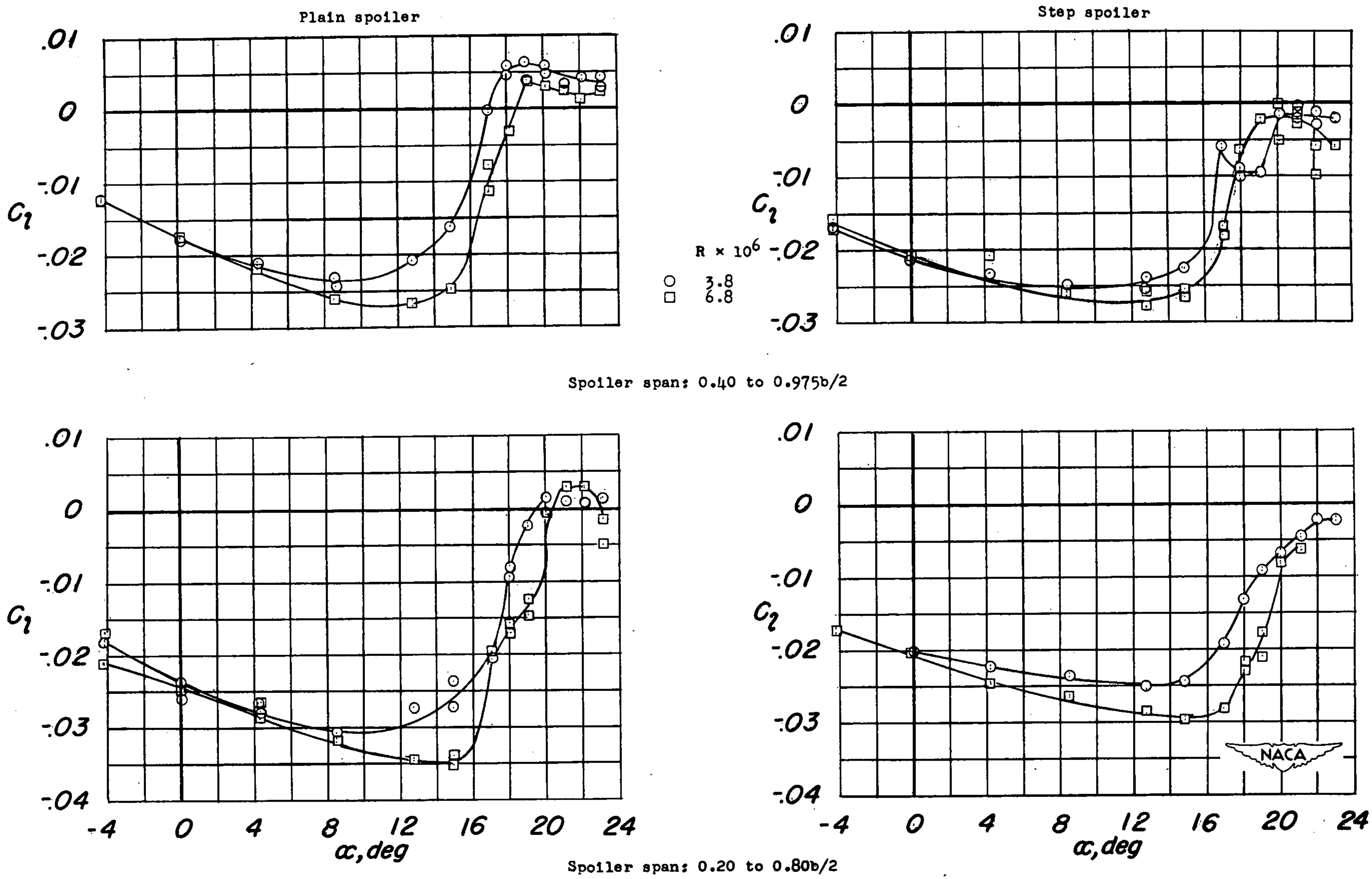
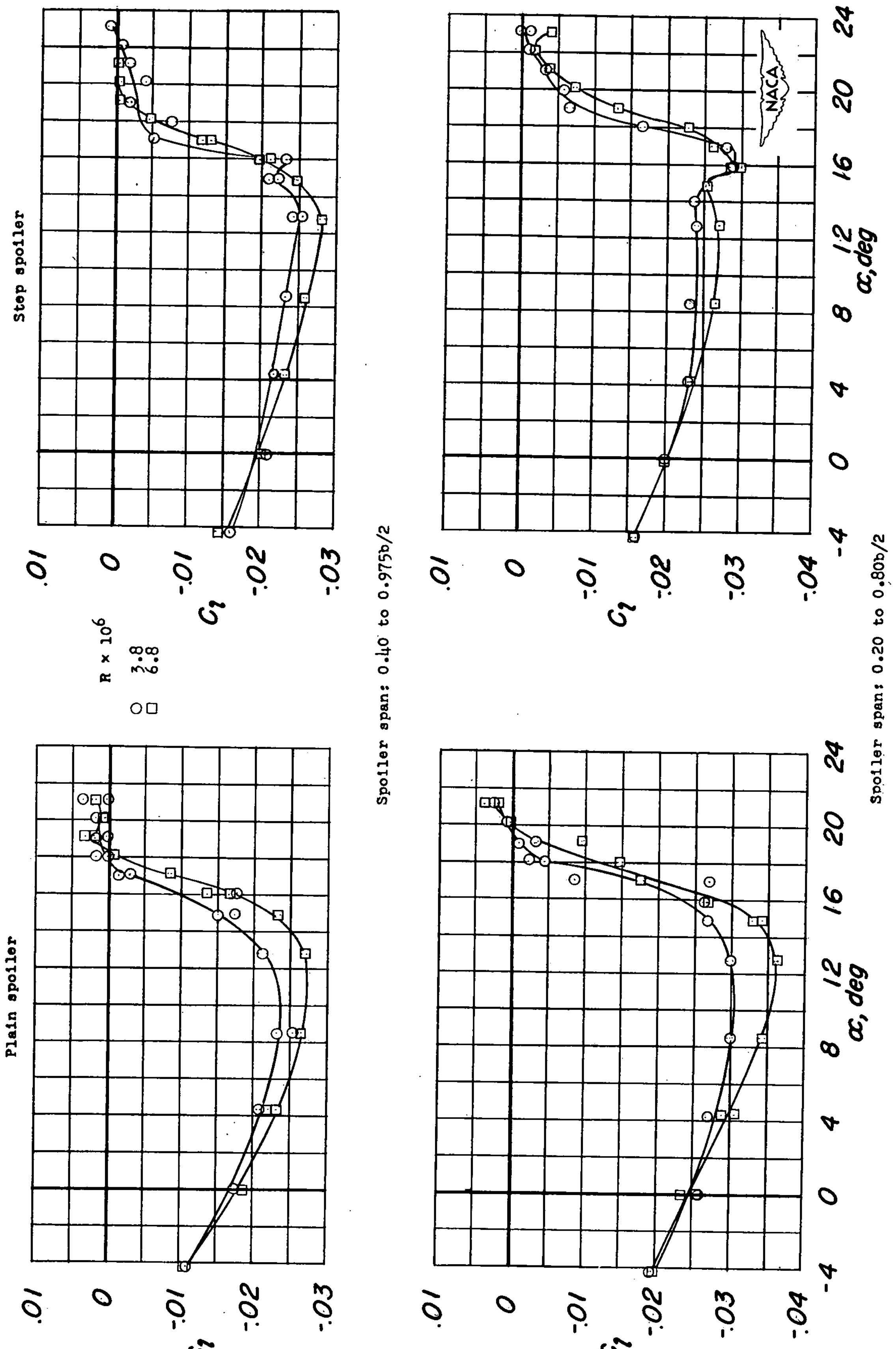


Figure 16.- The effect of chordwise location of constant-span plain and step spoilers on the rolling-moment characteristics of a 42° sweptback wing. $\delta_s = 0.10c$. $R = 6.8 \times 10^6$.



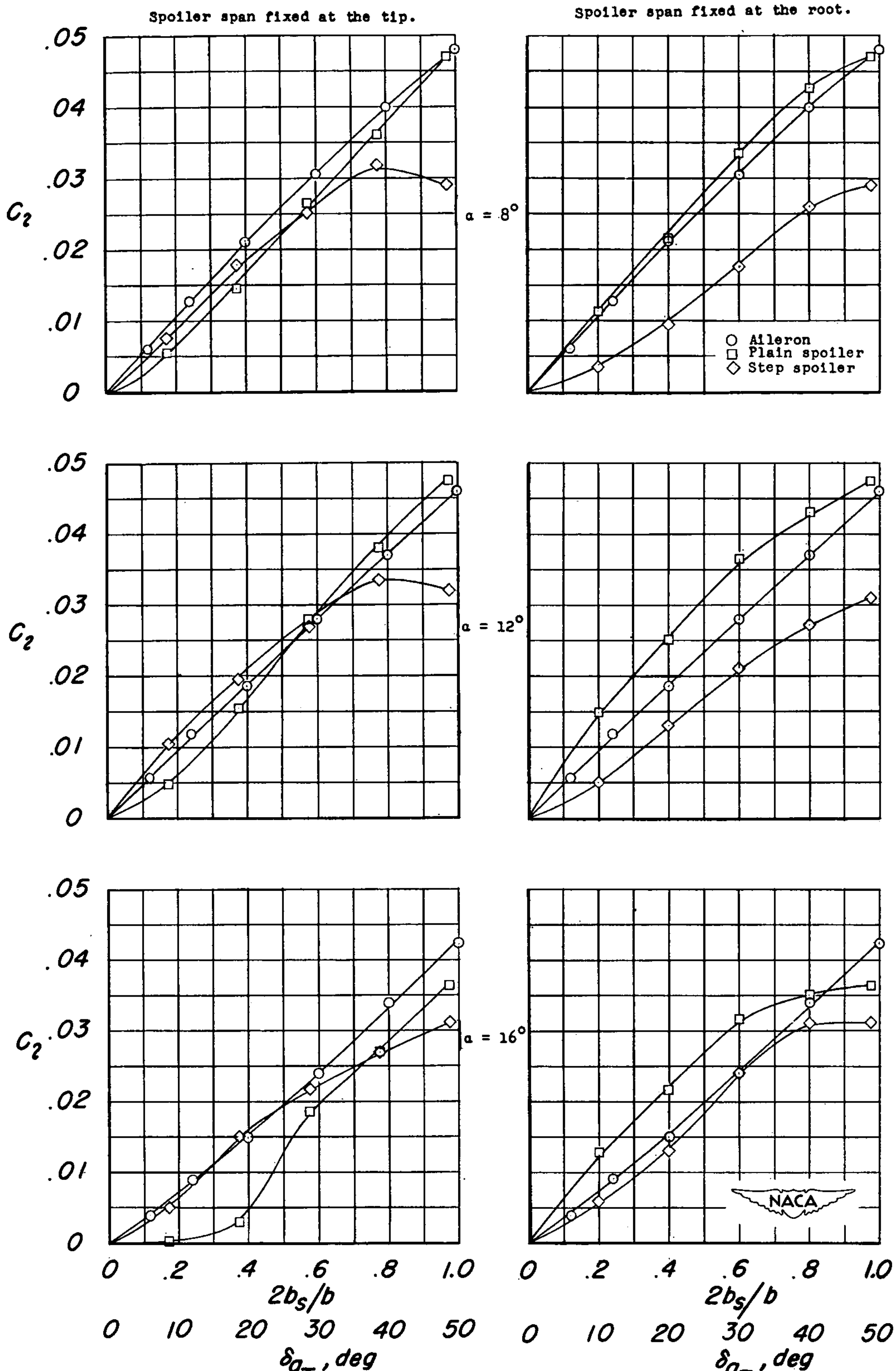
(a) Basic wing.

Figure 17.- The effect of Reynolds number on the rolling-moment characteristics of plain and step spoiler arrangements on basic wing with and without fuselage. $\delta_s = 0.10c$.



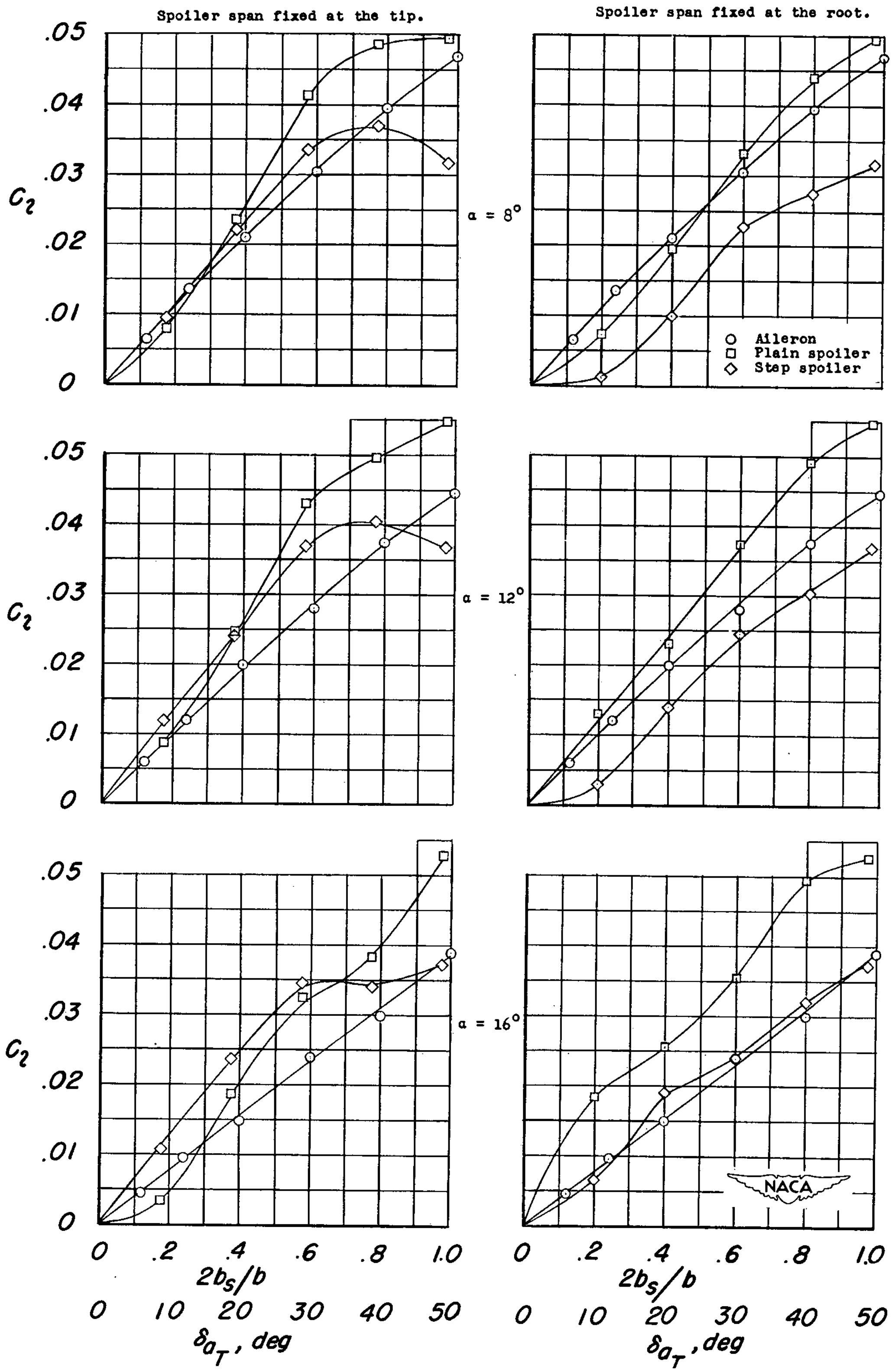
(b) Basic wing with fuselage.

Figure 17.- Concluded.



(a) Basic wing.

Figure 18.- Comparison of rolling-moment coefficients produced by various aileron deflections and spoiler spans. $\delta_s = 0.10c$; $b_a = 0.5\frac{b}{2}$ to $0.975\frac{b}{2}$. $R = 6.8 \times 10^6$.



(b) $0.575\frac{b}{2}$ leading-edge and half-span split flaps deflected.

Figure 18.- Concluded.