NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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LOW-SPEED WIND-TUNNEL INVESTIGATION OF VARIOUS PLAIN-SPOILER CONFIGURATIONS FOR LATERAL CONTROL ON A 42° SWEPTBACK WING

By Leslie E. Schneiter and James M. Watson

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

A low-speed wind-tunnel investigation of an exploratory nature has been performed to determine a satisfactory location for a spoiler lateral-control device for a sweptback wing. The semispan wing used for the tests had 42° sweepback referred to the wing leading edge and an aspect ratio of 4.01. Spoilers having a projection of 10 percent of the local wing chord were tested at various spanwise and chordwise locations and skew angles. The variation of rolling effectiveness with spoiler projection was determined for one of the most effective locations.

The results showed that a spoiler consisting of a group of segments located near the trailing edge of the wing, slightly inboard from the wing tip, and skewed with reference to the wing so as to be perpendicular to the free-stream air flow had the most nearly constant and highest values of rolling-moment coefficient throughout the usable lift range and would exhibit fairly high values of maximum rolling moment. These spoilers were found to have some of the objectionable characteristics previously found for plain spoilers on unswept wings, namely a reduction of maximum control effectiveness at high angles of attack and a region of ineffectiveness or reversed effectiveness at small spoiler projections.

INTRODUCTION

One of the many problems arising from the use of sweptback wings on high-speed aircraft has been that of securing adequate lateral control. In order to obtain solutions to this problem, the National Advisory Committee for Aeronautics is currently investigating the applicability of various types of lateral-control devices to sweptback wings. One type of lateral-control device that appears to offer some advantages is a spoiler. Some possible advantages of the spoiler-type control device (see references 1 to 5) are the favorable yawing moments associated with spoilers and the fact that, because of the location of the spoilers, the trailing edge of the wing is available for full-span, high-lift flaps. In addition, the wing twisting moments produced by the deflected spoiler will probably be small in comparison with the twisting moments produced by an aileron of the same rolling power and the spoiler will probably have smaller operating forces. The lag in rolling response of the deflected spoiler may, however, be objectionable.

Reported herein are the results of exploratory low-speed tests of various locations of plain spoilers on a 42° sweptback, semispan wing. The wing used had no twist or dihedral and was not equipped with any auxiliary lift device (flaps, slats, and so forth). The tests were performed in the Langley 300 MPH 7- by 10-foot tunnel. Most of the tests were performed with spoilers having a projection of 10 percent of the local wing chord. The variation of rolling effectiveness with spoiler projection was determined for one of the most effective of the spoiler configurations tested.

SYMBOLS AND CORRECTIONS

The forces and moments 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 37.22 inches 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.

C_L lift coefficient $\left(\frac{\text{Twice lift of semispan model}}{qS}\right)$

C_D drag coefficient (D/qS)

C_m pitching-moment coefficient about Y-axis $(M/qS\bar{c})$

C_l rolling-moment coefficient about X-axis (L/qSb)

C_n yawing-moment coefficient about Z-axis (N/qSb)

D twice drag of semispan model, pounds

M twice pitching moment of semispan model about Y-axis, foot-pounds

L rolling moment due to spoiler deflection about X-axis, foot-pounds

N yawing moment due to spoiler deflection about Z-axis, foot-pounds

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

S twice area of semispan model, 32.24 square feet

$\bar{c}$ wing mean aerodynamic chord, 2.89 feet $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$

b twice span of semispan model measured along Y-axis, 11.36 feet

$\frac{b_s}{b/2}$ ratio of spoiler span to wing semispan

c local wing chord measured along lines parallel to X-axis, feet

y lateral distance from plane of symmetry along Y-axis, feet

V free-stream velocity, feet per second

p rolling velocity, radians per second

ρ mass density of air, slugs per cubic foot

α angle of attack with respect to chord plane of model, degrees

β sideslip angle, degrees

δ_s spoiler projection, percent local wing chord

R Reynolds number

The rolling-moment and yawing-moment coefficients represent the aerodynamic effects that occur on a complete wing as a result of the deflection of the spoiler on one semispan wing; the lift, drag, and pitching-moment coefficients represent the aerodynamic effects that occur on the complete wing as a result of the deflection of the spoilers on both semispan wings.

The test data have been corrected for blockage and jet-boundary effects, including the reflection-plane corrections to the rolling-moment and yawing-moment coefficients. The variation of the corrections to the rolling-moment and yawing-moment coefficients with the ratio of the span of the spoiler to the wing semispan $\frac{b_s}{b/2}$ is presented in figure 2. The value of the ratio $\frac{b_s}{b/2}$ used in determining the correction for each particular spoiler was chosen as the spanwise distance from the inboard end of the spoiler to the wing tip divided by the wing semispan. This procedure was used since the turbulent flow over the wing caused by an inboard spoiler was thought to be carried out to the wing tip by the normal spanwise flow associated with swept wings and would therefore effectively destroy any smooth flow at the tip in a manner similar to a spoiler at the tip. No corrections were made to the data to account for wing twist caused by spoiler projection.

APPARATUS AND MODEL

The semispan-sweptback-wing model was mounted in the Langley 300 MPH 7- by 10-foot tunnel as shown in figure 3. The root chord of the model was adjacent to the ceiling of the tunnel, the ceiling thereby serving as a reflection plane. The model was mounted on the balance system in such a manner that all forces and moments acting on the model could be measured. A small clearance was maintained between the model and the tunnel ceiling so that no part of the model came in contact with the tunnel structure. A root fairing strip was attached to the model to deflect the air that flows through the clearance hole between the model and the tunnel ceiling into the tunnel test section so as to minimize the effects of any such inflow on the flow over the model.

The model had 42° sweepback referred to the wing leading edge, an aspect ratio of 4.01, and was constructed of laminated mahogany to the plan form shown in figure 1. The airfoil section normal to the 0.272-chord line was constant throughout the span and was of NACA 64_1-112 airfoil profile. The tip of the wing was rounded off beginning at $0.975\frac{b}{2}$ in both plan form and cross section. The model had no geometric twist, dihedral, or auxiliary lift devices (flap, slats, and so forth).

Sketches showing the various spoiler configurations tested are presented in figure 4. The various spoiler configurations will be referred to, hereinafter, by the number shown in figure 4. All the spoilers had projections of 0.10c except spoiler 18 which had projections throughout the range of 0.005c to 0.10c. The spoilers were constructed of thin sheet aluminum and were attached to the wing with wood screws. Any gap between the wing and lower edge of the spoiler was sealed with cellulose tape.

TESTS

The tests were performed at an average dynamic pressure of approximately 51 pounds per square foot, which corresponds to a Mach number of about 0.18 and a Reynolds number of about 3,800,000 based on the wing mean aerodynamic chord of 2.89 feet.

The tests, in general, were run throughout a range of angle of attack of -10° to 24°.

Nearly all the spoiler-location tests were performed with spoilers or spoiler segments having a projection of 10 percent of the local wing chord. The variation of spoiler rolling effectiveness with projection was determined through a range of spoiler projection for spoiler 18. Transition was not fixed for any of the tests.

RESULTS AND DISCUSSION

The aerodynamic characteristics in pitch of the plain wing are presented in figure 5 and the results of the spoiler-location tests are presented in figures 6 to 10. The results of the spoiler-projection tests are presented in figure 11.

The lift, drag, and pitching-moment coefficients for all the configurations are presented along with the rolling-moment and yawing-moment coefficients since these data may be usable in developing a dive brake or a similar device from the spoiler configurations. The results indicate that only spoiler 7 (fig. 7) and spoilers 14 and 15 (fig. 9) would be directly applicable to the design of a dive brake since these spoilers caused about the smallest changes in pitching-moment coefficient and location of the aerodynamic center from those of the plain wing. The other spoiler configurations tested gave too large changes in pitching-moment coefficient and aerodynamic center to be of much use as dive brakes.

Several general effects of the spoilers on rolling-moment coefficient may be noted from figures 6 to 10. In general, the rolling effectiveness of a spoiler of a given span was greatest when the spoiler was perpendicular to the free stream. This fact may be seen from a comparison of the results of tests with spoiler 3 (fig. 6) and spoilers 16 and 17 (fig. 10), all of which are 60-percent-span spoilers or spoiler segments. The spoiler rolling effectiveness at low and negative lift coefficients usually increases as the spoiler or spoiler segments are shifted chordwise toward the trailing edge of the wing. This effect is particularly noticable for spoilers 1, 2, and 3 in figure 6 and to a lesser extent for spoilers 12, 13, 14, and 15 in figure 9 and has been noted in previous investigations of plain spoilers on unswept wings. (See references 1 and 2.) Also noteworthy is the effect of spanwise location of a constant-percent-span spoiler as illustrated by spoilers 16 and 18 in figure 10. In this instance, a 60-percent-span spoiler was moved 20 percent of the wing span inboard from the tip of the wing. The rolling-moment coefficients produced by the spoiler located at the tip were appreciably lower throughout the lift range than those produced by the spoiler at the more inboard location. A previous investigation (reference 3) of an unswept wing indicates that as a 60-percent-span spoiler is moved toward the wing tip its rolling effectiveness increases. The fact that these sweptback-wing tests show the effect of spanwise location on the spoiler rolling effectiveness to be opposite to that presented in reference 3 may be reasonably explained in terms of the tip stalling characteristics.

These general trends indicated that a spoiler or group of spoiler segments located slightly inboard from the wing tip along a chord line toward the wing trailing edge and so located as to be perpendicular to the free-stream air flow would have the most nearly constant and highest values of rolling-moment coefficient throughout the usable lift range and would exhibit fairly high values of maximum rolling moment. Spoiler 18 is such a spoiler and is considered to be one of the best spoilers tested in this investigation, both in regard to rolling effectiveness and to practicality of installation on an airplane.

Figures 6 to 10 show that the spoiler rolling-moment coefficient reached a maximum at or near an angle of attack of about 16° which corresponds to about 80 percent of the maximum lift of the plain wing. It may be seen from figure 5 that at this angle of attack for the plain wing the slope of the pitching-moment curve becomes unstable and the drag starts to increase rapidly. A visual study of the behavior of tufts on the upper surface of the wing showed that a sudden stalling of the tip occurred at this angle of attack. This very rapid stall may be a condition encountered only at the Reynolds number at which the tests were performed ($R = 3,800,000$). The results of previous tests in the Langley 19-foot pressure tunnel of a complete wing (with individual panels having the same geometric characteristics as the wing reported herein) through a large range of Reynolds number indicated that at higher Reynolds numbers, the break in the pitching-moment and the rolling-moment curves would be delayed to a higher angle of attack.

The rolling effectiveness of spoiler 18 through a range of projection at several angles of attack is presented in figure 11. These results indicate that a reversal in spoiler effectiveness occurs at low projections. The loss of rolling effectiveness of the spoilers at high positive and negative angles of attack and the reversal of effectiveness at small spoiler projections are similar to the effects noted for plain spoilers on unswept wings, references 3 and 2, respectively. Data on unswept wings (reference 4) show, however, that these difficulties may be overcome by the use of plug ailerons.

The yawing-moment coefficients produced by the spoilers generally were of the same sign as the rolling-moment coefficients (a condition usually referred to as favorable yaw) and were quite large. In several instances the yawing-moment coefficient was of the order of 30 to 40 percent of the rolling-moment coefficient at the maximum value of rolling-moment coefficient. (See spoiler 5, fig. 7, and spoiler 18, fig. 10.) The yawing moments usually became negative at an angle of attack between 16° and 18° which corresponds to the angle of attack at which the wing tip stalled and the pitching moments became unstable.

The pitching moments presented herein apply directly to dive brakes and are therefore approximately twice as large as those produced by spoiler lateral control. Nevertheless some indication of the relative pitching moments of the various spoiler configurations can be obtained from the data presented. The effect of the various spoilers on the wing pitching-moment characteristics were generally such as to produce a trim change and, in many instances, a large change in the location of the wing aerodynamic center although no definite consistent trends could be noted for the variation of aerodynamic-center location or trim change with spoiler location.

In evaluating the rolling power of these spoilers in a roll, the rolling-moment coefficients alone are not a complete index of effectiveness. It appears necessary to consider not only the rolling moment produced by the spoiler C_l/δ_s but also the yawing moment produced by the spoiler C_n/δ_s, the yawing moment produced by the rolling wing C_n/p, the rolling moment of the wing in sideslip C_l/β, the wing damping in roll C_l/p, and the moments of inertia of the airplane. The combined effects of these factors have not been investigated herein but it is believed that consideration of these various factors is not necessary in comparing the relative merits of the various spoilers, but may be necessary in comparing the merits of one of the spoilers with an aileron giving a comparable maximum rolling moment.

CONCLUDING REMARKS

The results of low-speed tests of various spoiler configurations on a 42° sweptback, semispan wing showed that a spoiler consisting of a group of segments located near the trailing edge of the wing, slightly inboard from the wing tip, and skewed with reference to the wing so as to be perpendicular to the free-stream air flow had the most nearly constant and highest values of rolling-moment coefficient throughout the usable lift range and would exhibit fairly high values of maximum rolling moment. These spoilers were found to have some of the objectionable characteristics previously found for plain spoilers on unswept wings, namely a reduction of maximum control effectiveness at high angles of attack and a region of ineffectiveness or reversed effectiveness at small spoiler projections.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., March 12, 1948

REFERENCES

1. Shortal, J. A.: Effect of Retractable-Spoiler Location on Rolling- and Yawing-Moment Coefficients. NACA TN No. 499, 1934.

2. Wenzinger, Carl J., and Rogallo, Francis M.: Wind-Tunnel Investigation of Spoiler, Deflector, and Slot Lateral-Control Devices on Wings with Full-Span Split and Slotted Flaps. NACA Rep. No. 706, 1941.

3. Fischel, Jack, and Tamburello, Vito: Investigation of Effect of Span, Spanwise Location, and Chordwise Location of Spoilers on Lateral Control Characteristics of a Tapered Wing. NACA TN No. 1294, 1947.

4. Rogallo, Francis M., and Swanson, Robert S.: Wind-Tunnel Development of a Plug-Type Spoiler-Slot Aileron for a Wing with a Full-Span Slotted Flap and a Discussion of Its Application. NACA ARR, Nov. 1941.

5. Fitzpatrick, James E., and Furlong, G. Chester: Effect of Spoiler-Type Lateral-Control Devices on the Twisting Moments of a Wing of NACA 230-Series Airfoil Sections. NACA TN No. 1298, 1947.

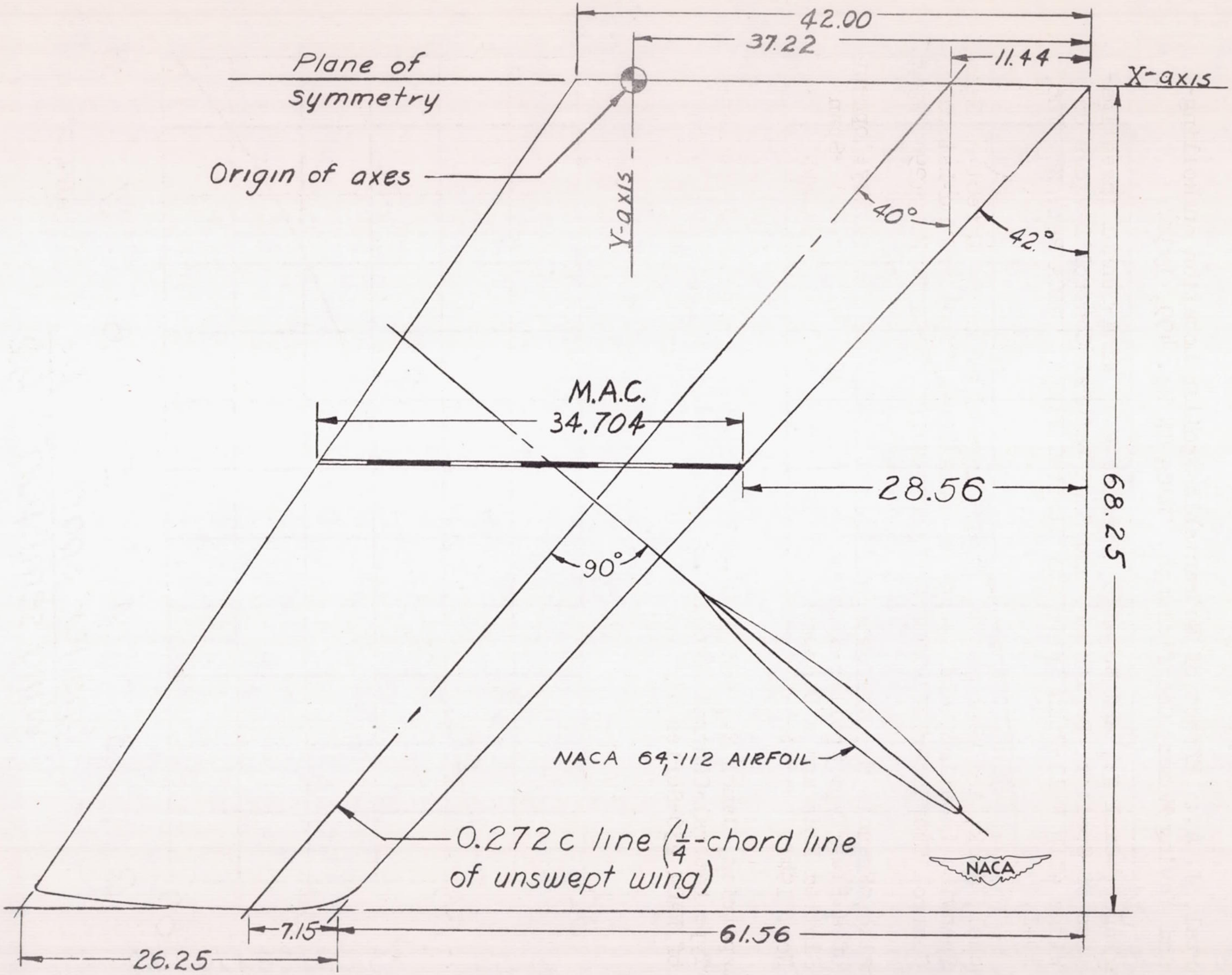


Figure 1.- The 42° sweptback wing. Area, 32.24 square feet; aspect ratio, 4.01; taper ratio, 0.625. All dimensions are in inches unless otherwise noted.

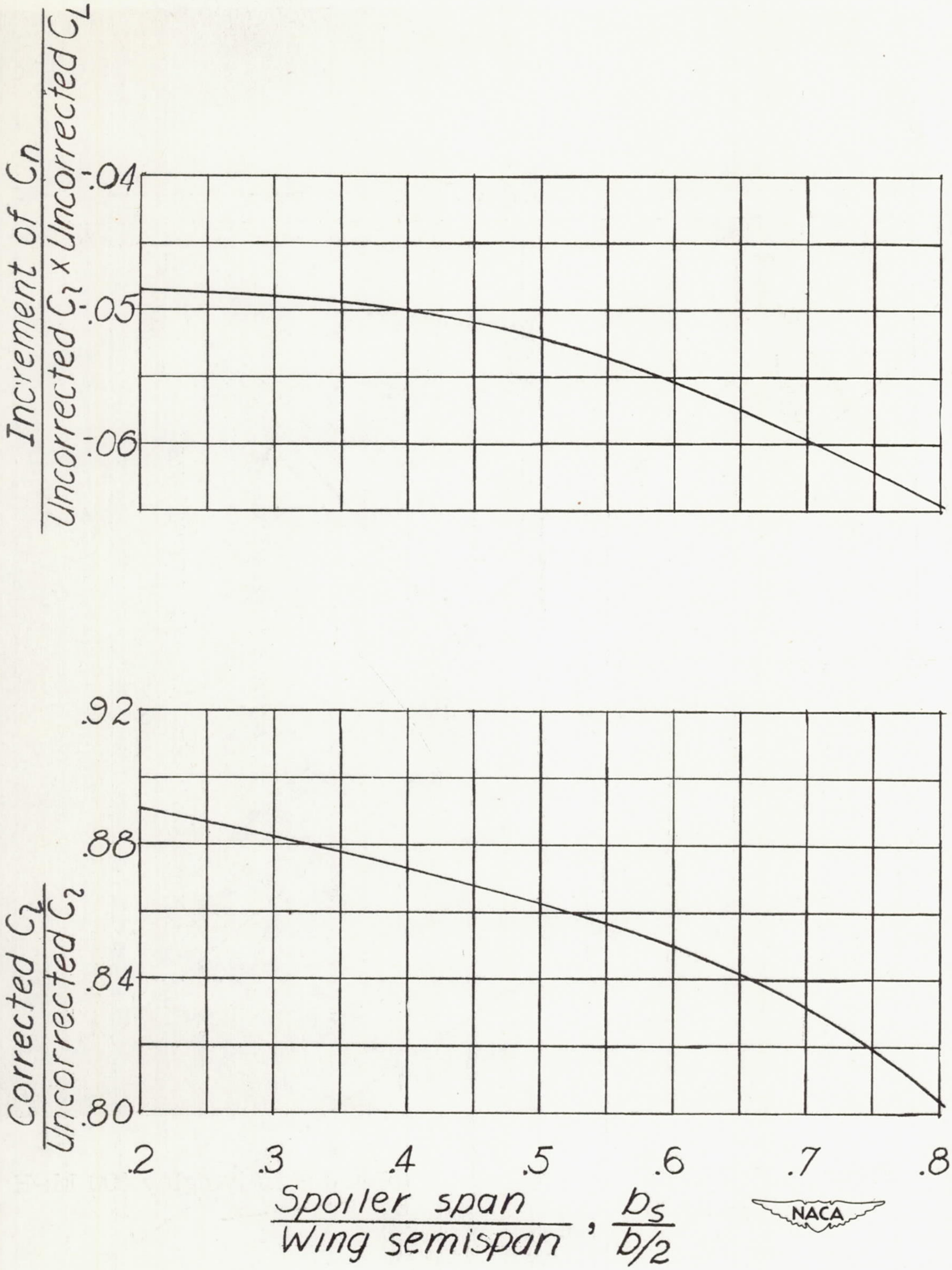


Figure 2.- Variation of corrections to rolling-moment and yawing-moment coefficients with ratio of spoiler span to wing semispan.

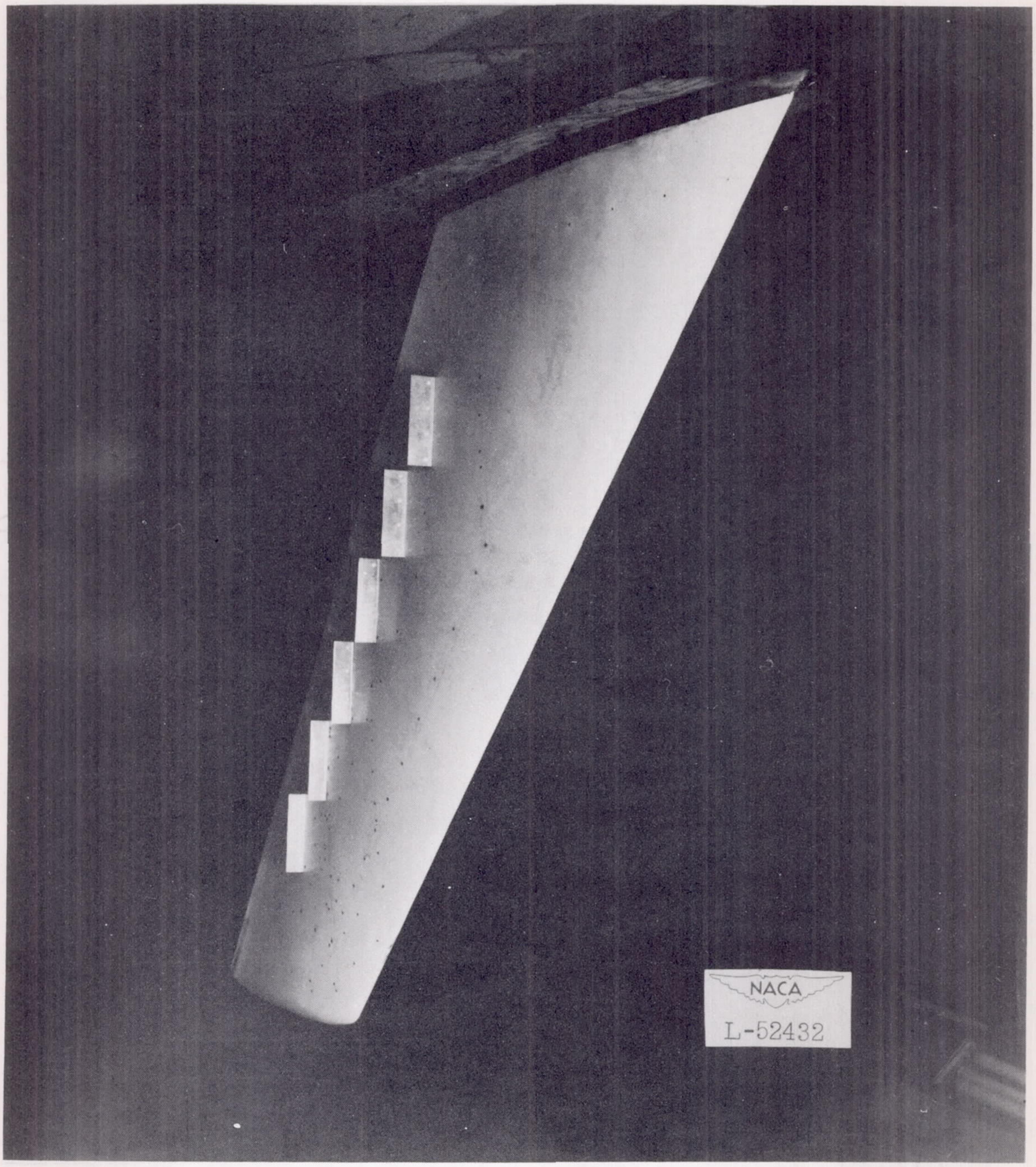
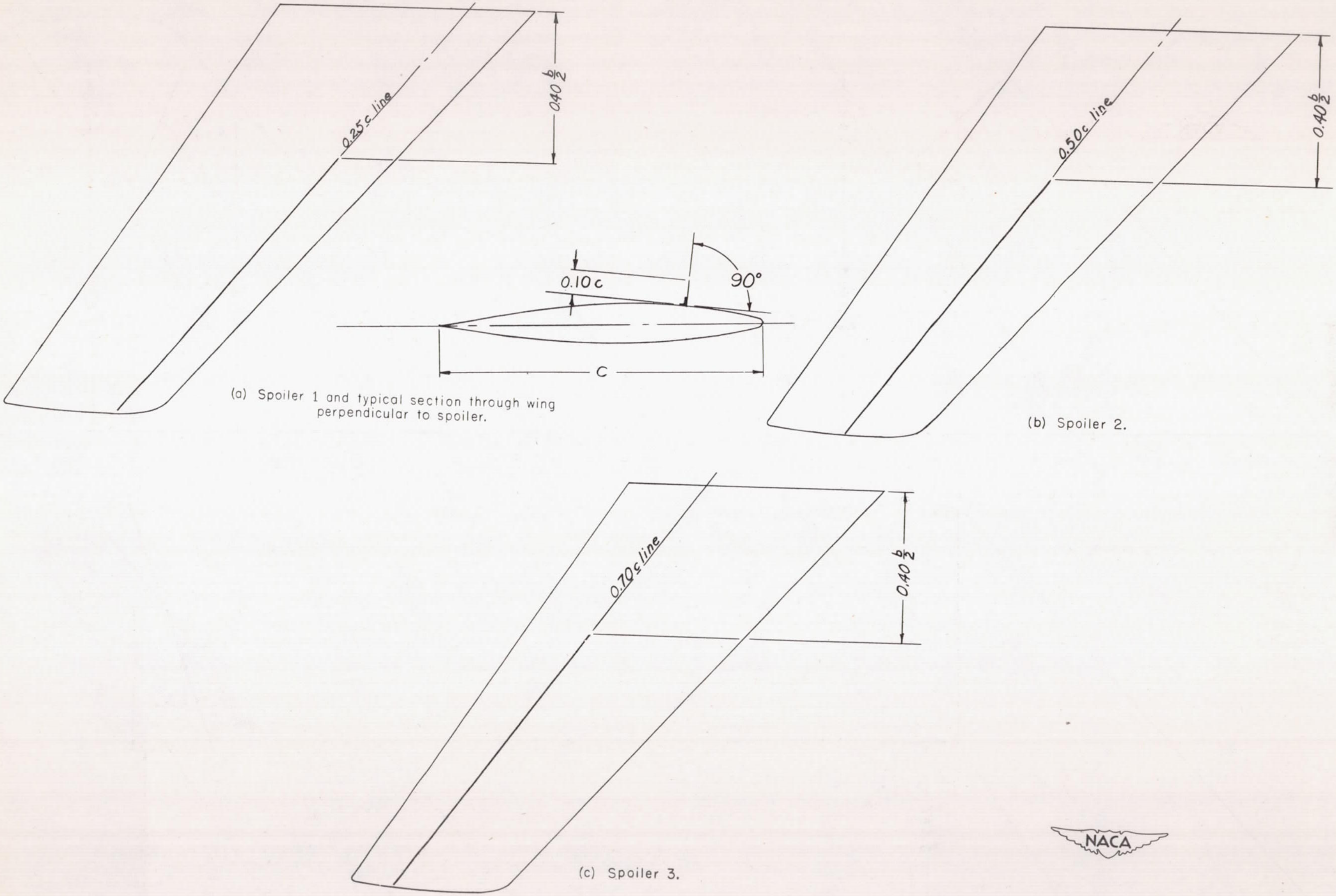


Figure 3.- The 42° sweptback wing mounted in Langley 300 MPH 7- by 10-foot tunnel. Spoiler 18 shown.

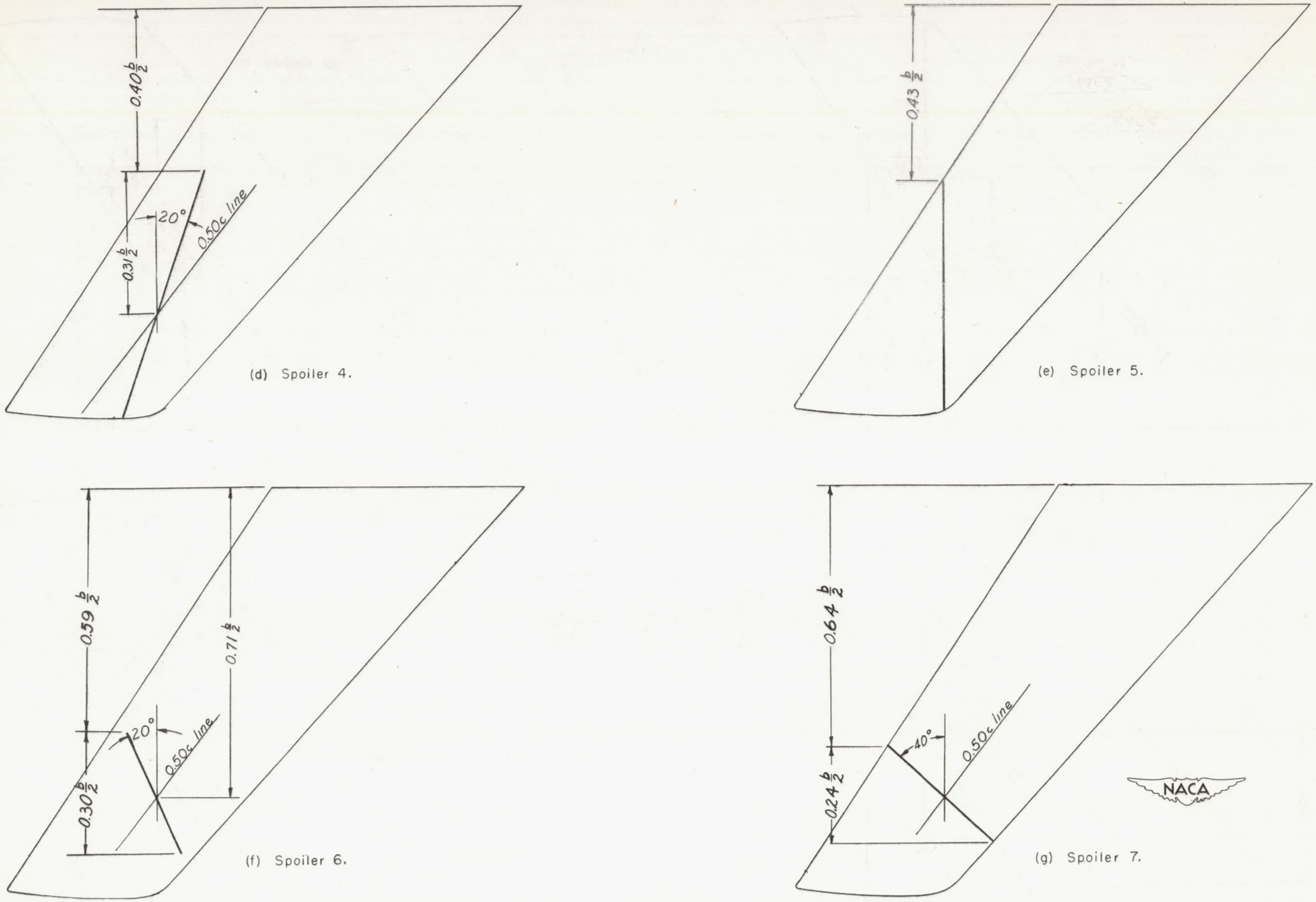


(a) Spoiler 1 and typical section through wing perpendicular to spoiler.

(b) Spoiler 2.

(c) Spoiler 3.

Figure 4.- Various spoiler configurations tested on 42° sweptback wing.



(d) Spoiler 4.

(e) Spoiler 5.

(f) Spoiler 6.

(g) Spoiler 7.

Figure 4.- Continued.

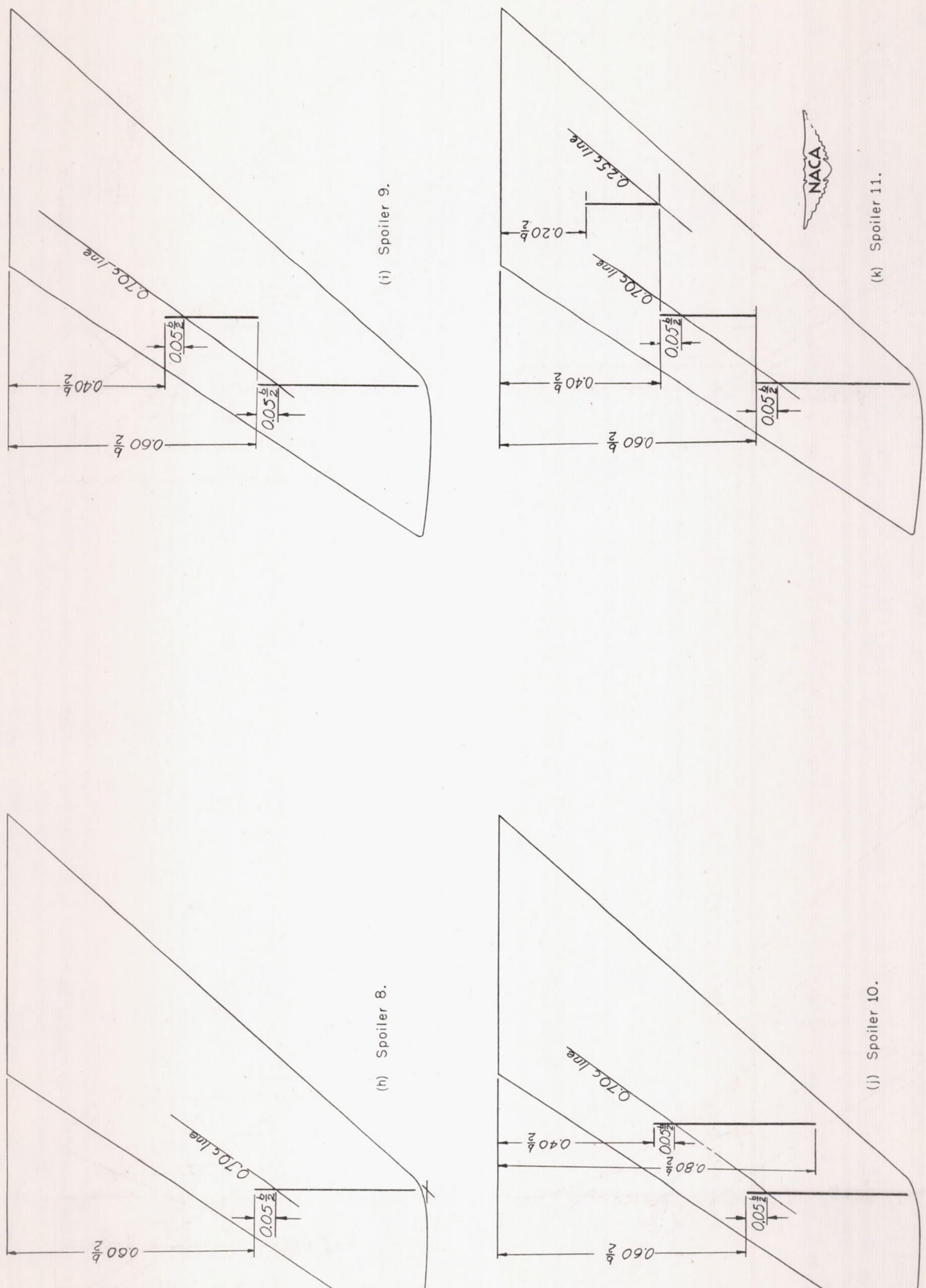


Figure 4.- Continued.

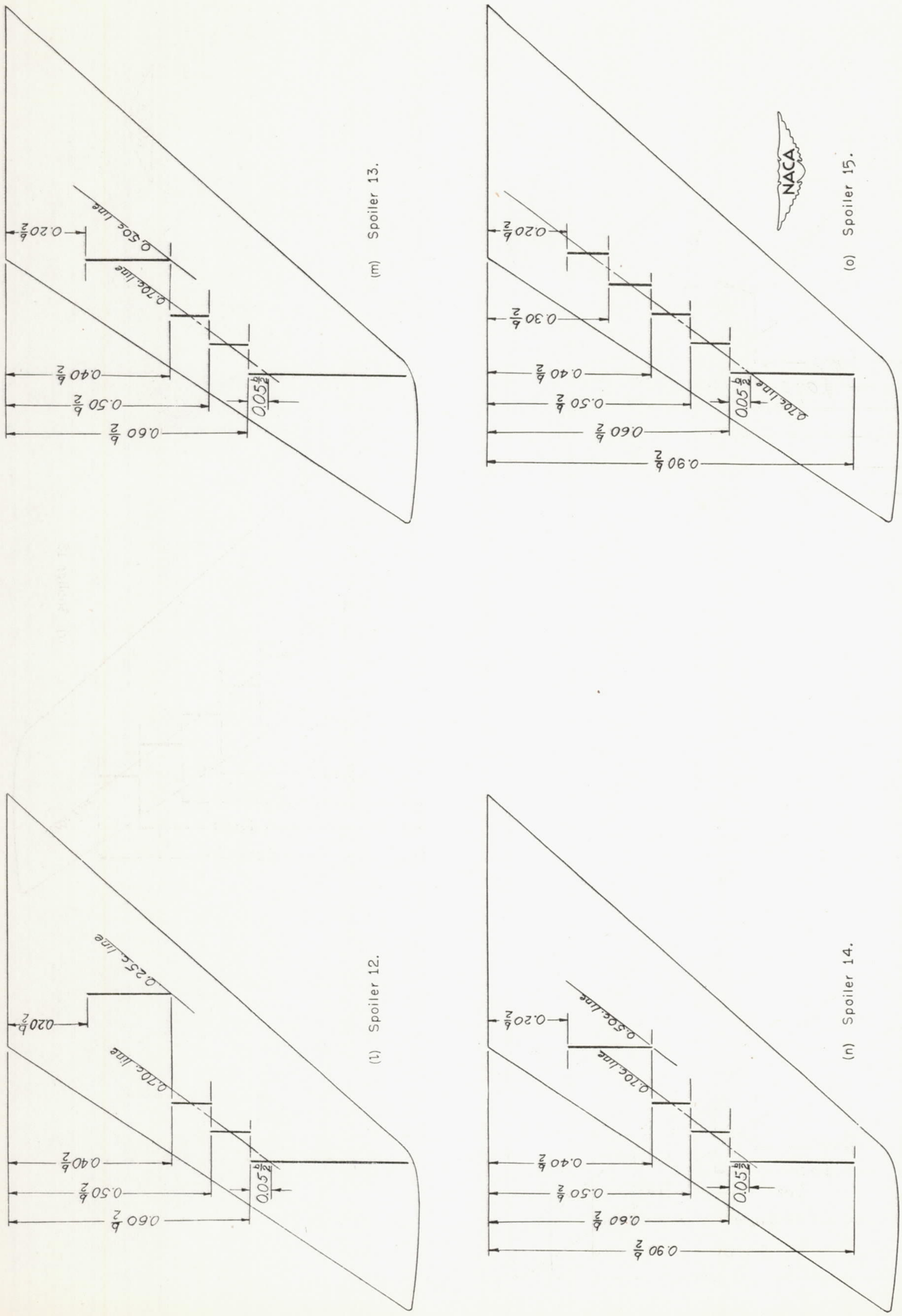
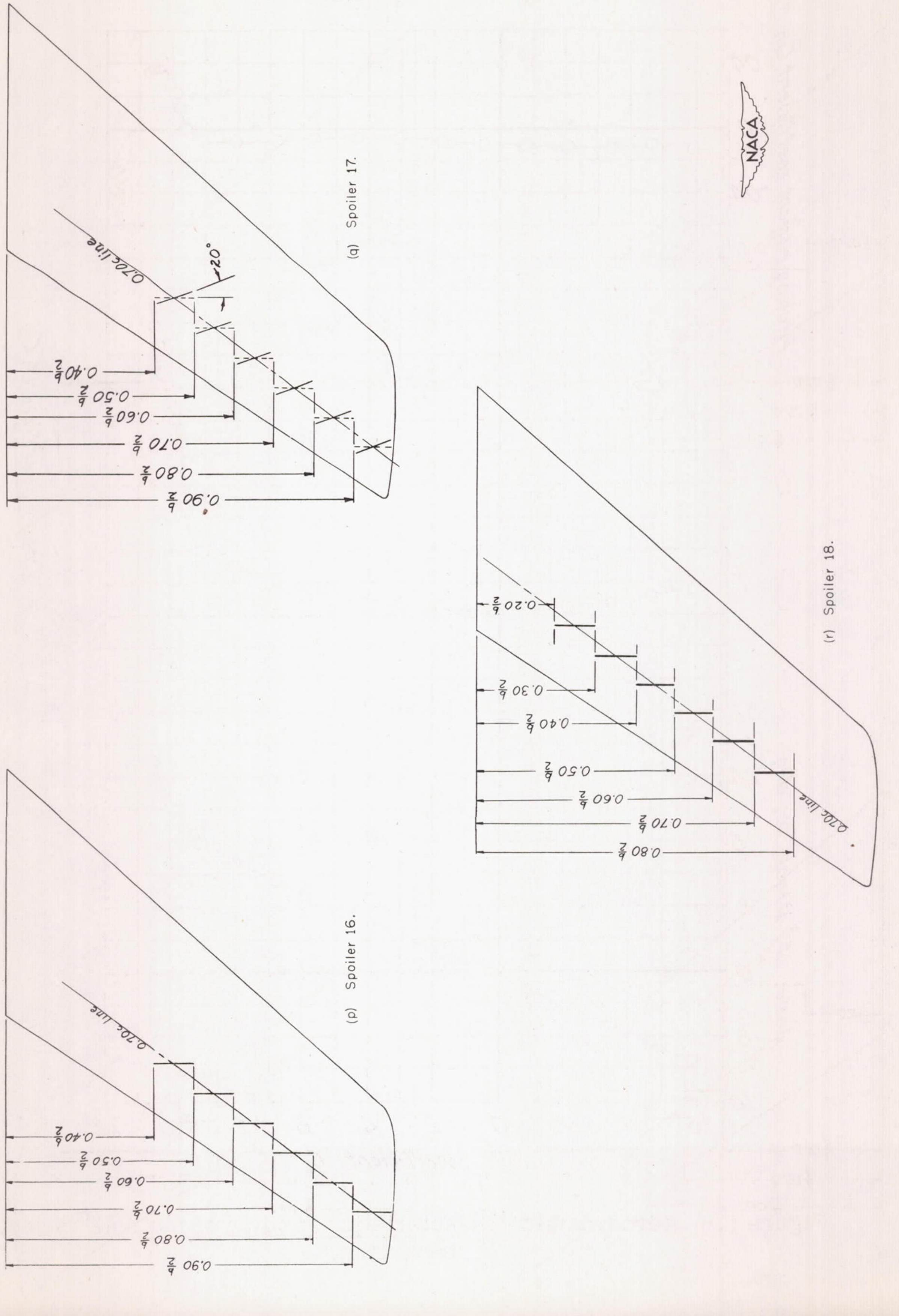


Figure 4.- Continued.



(p) Spoiler 16.

(q) Spoiler 17.

(r) Spoiler 18.

Figure 4.- Concluded.

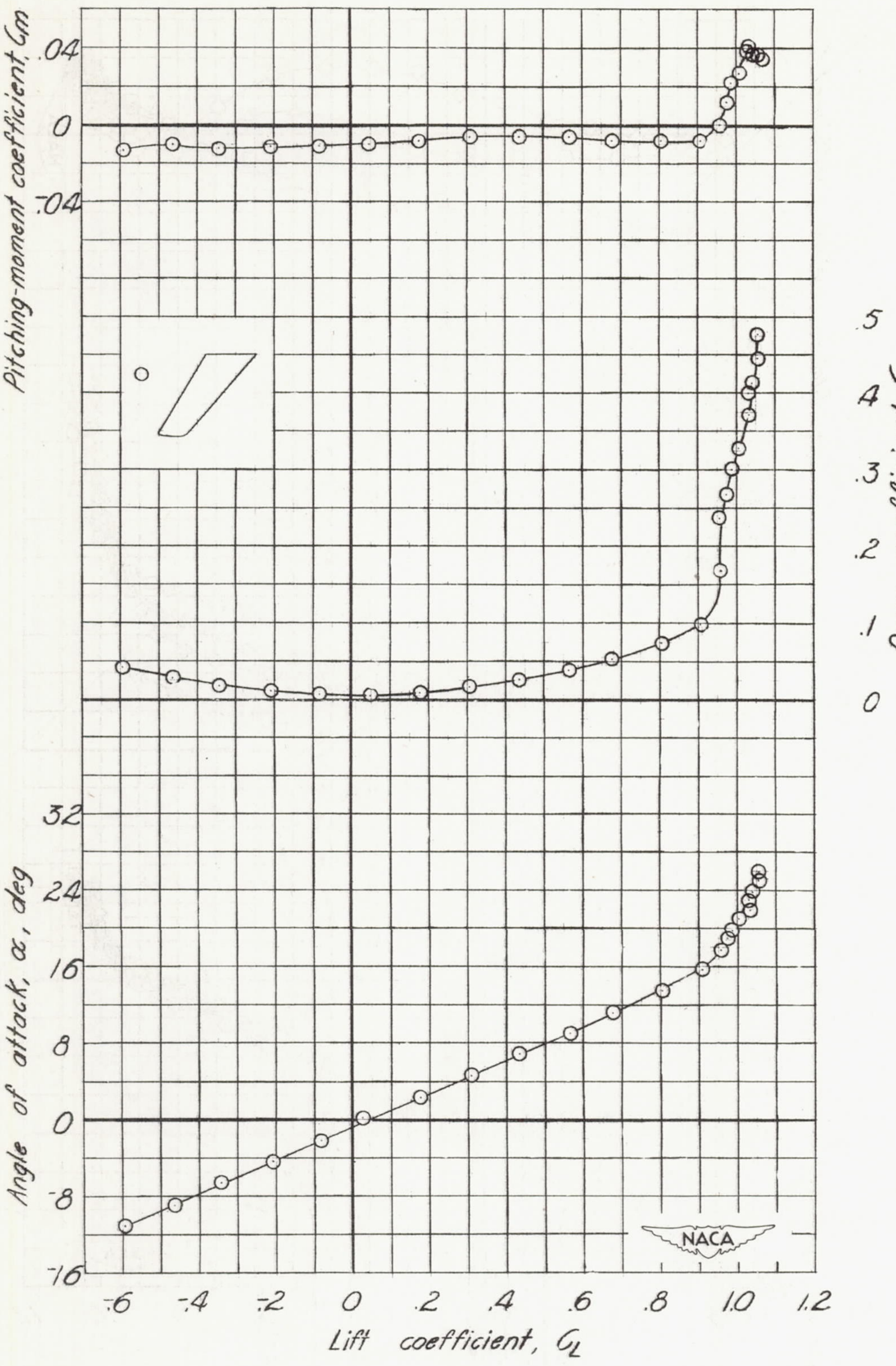


Figure 5.- Aerodynamic characteristics in pitch of plain 42° swept-back wing.

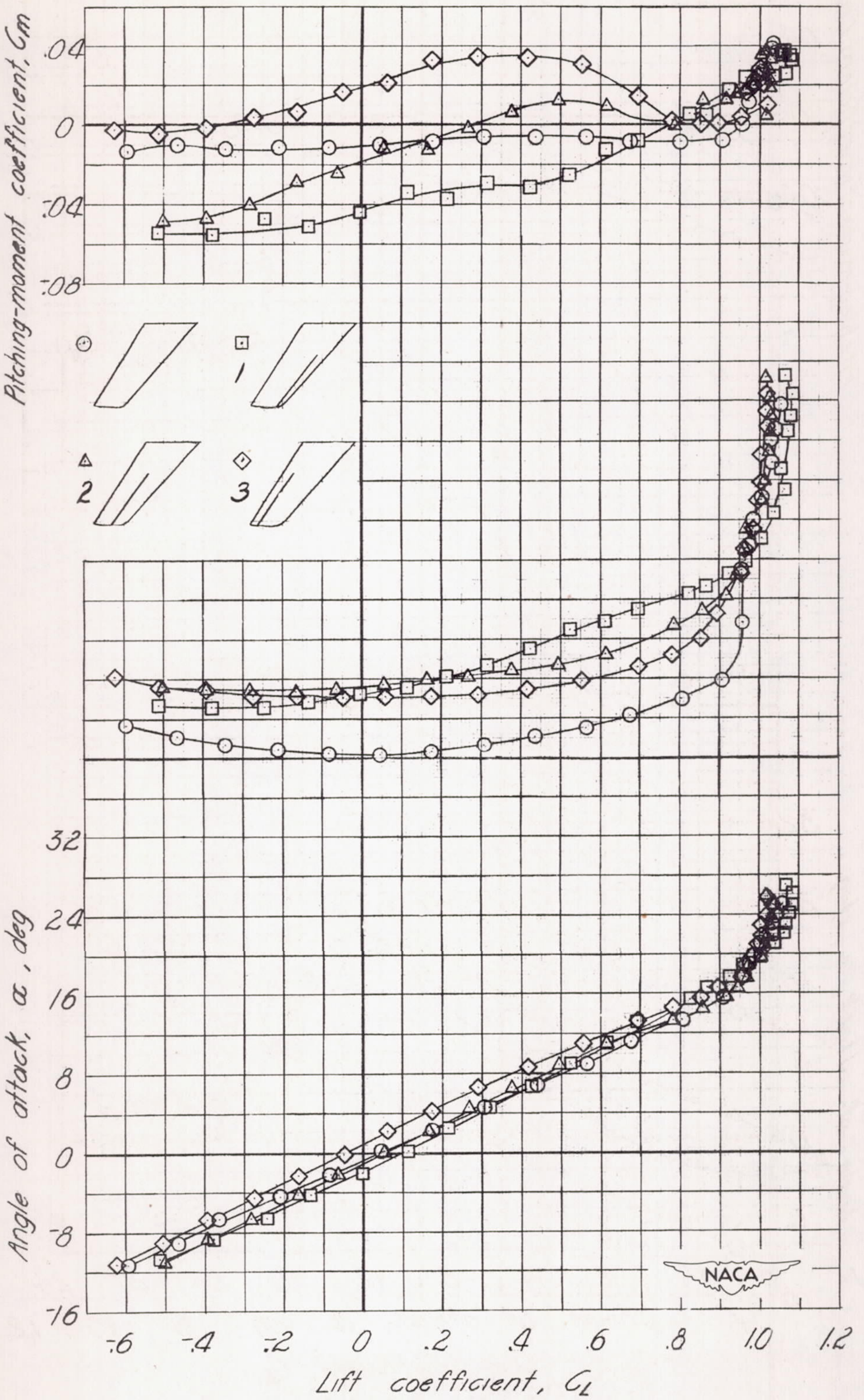


Figure 6.- Aerodynamic characteristics of plain wing and wing with spoilers 1, 2, and 3.

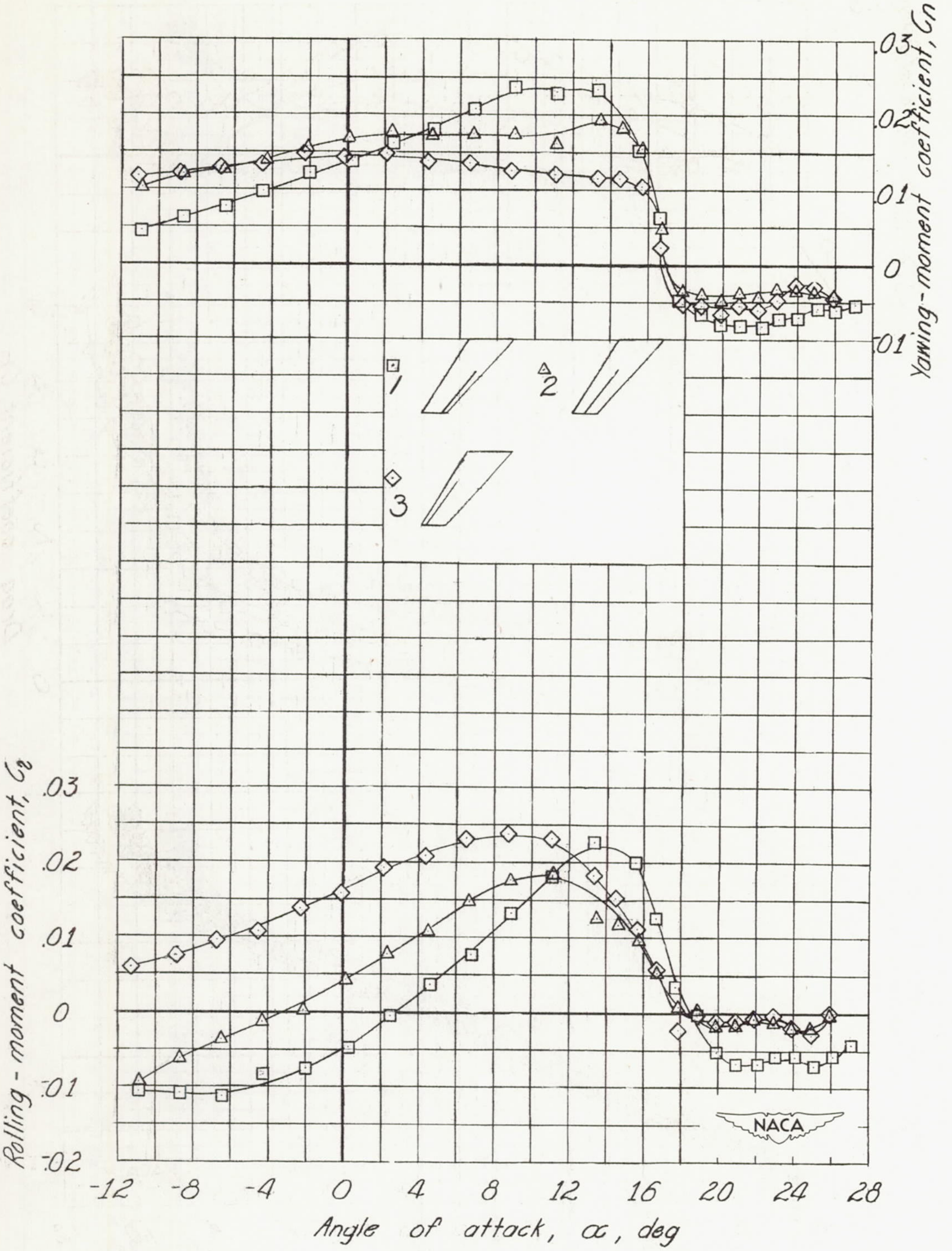


Figure 6.- Concluded.

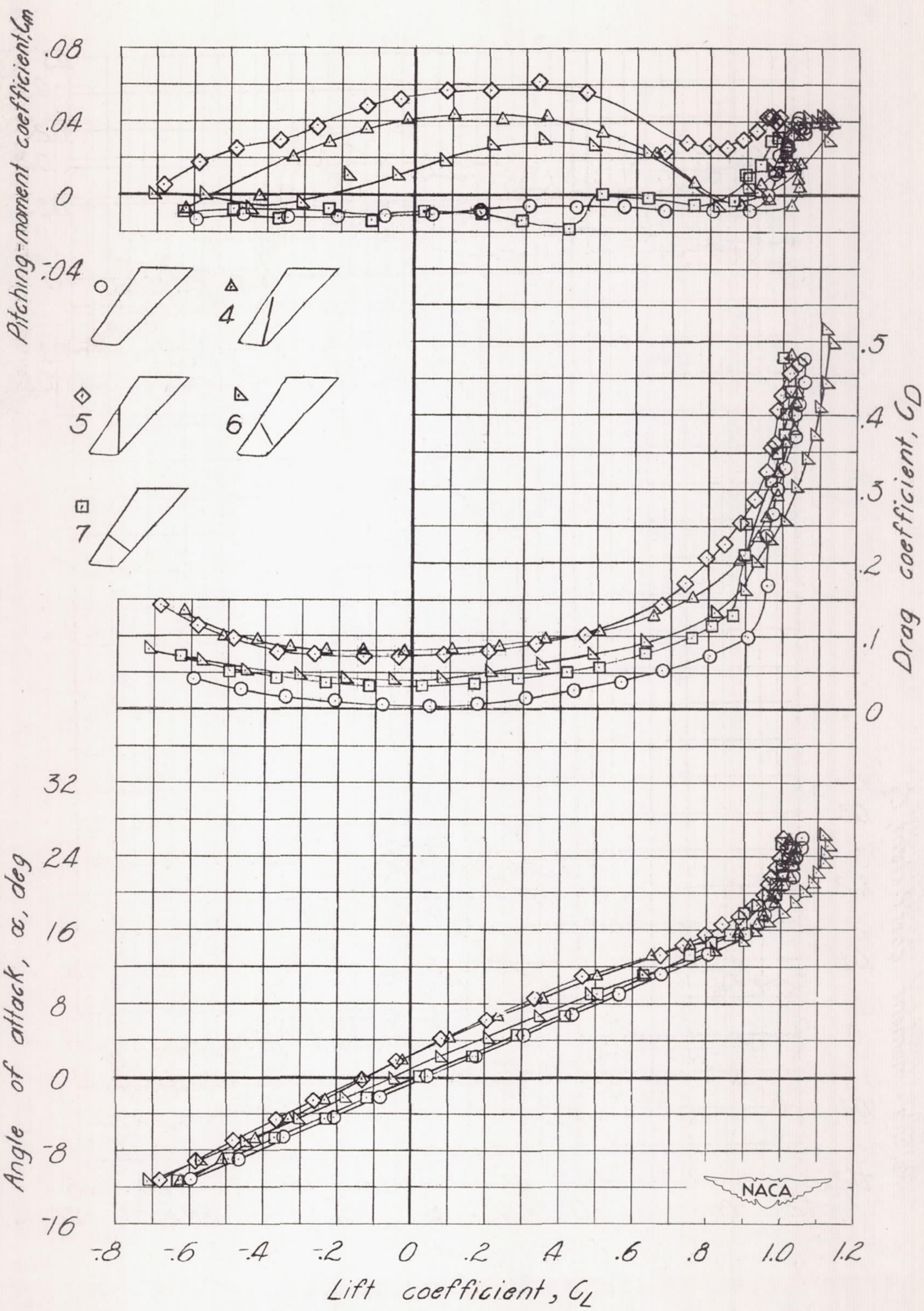


Figure 7.- Aerodynamic characteristics of plain wing and wing with spoilers 4, 5, 6, and 7.

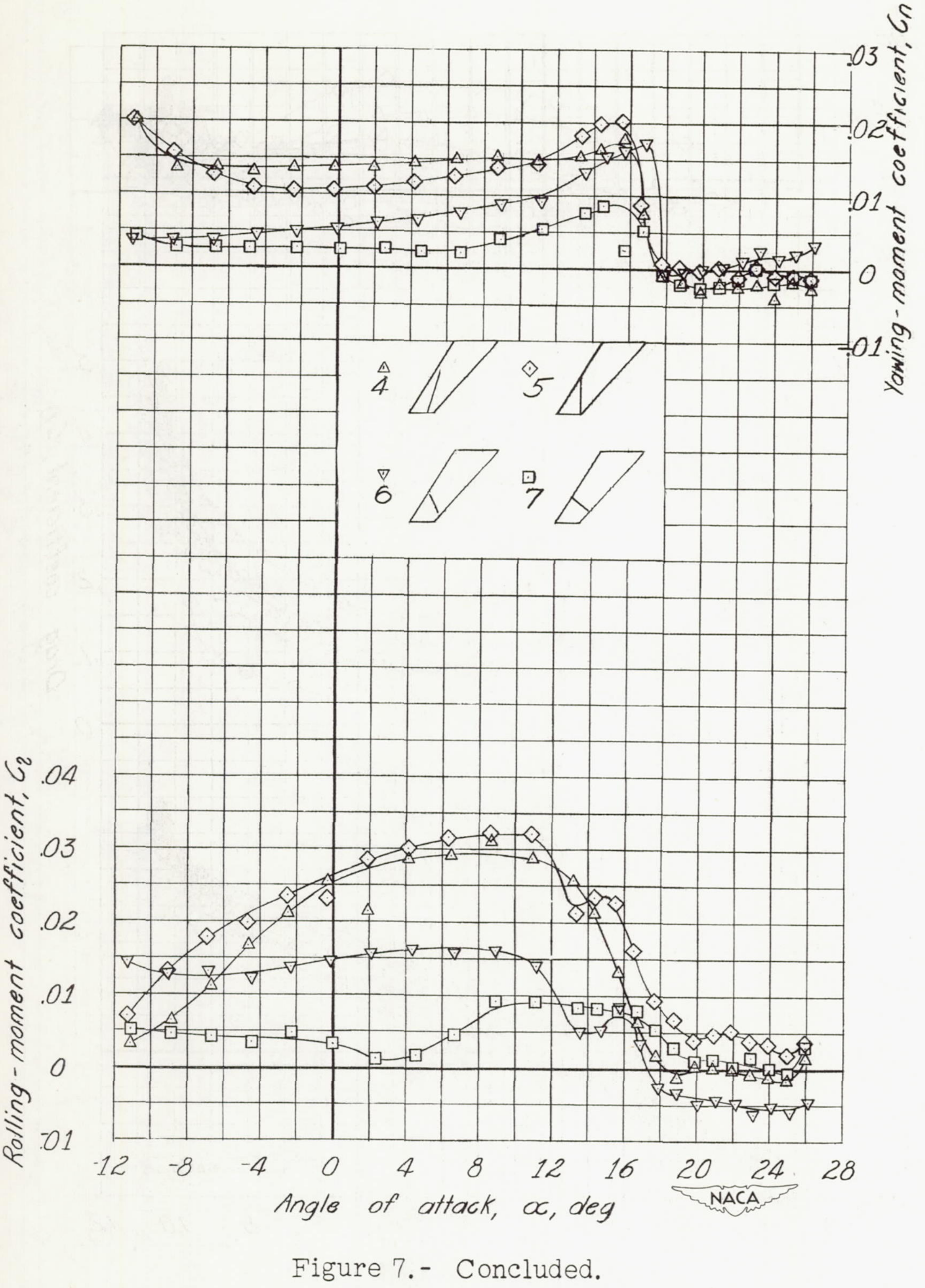


Figure 7.- Concluded.

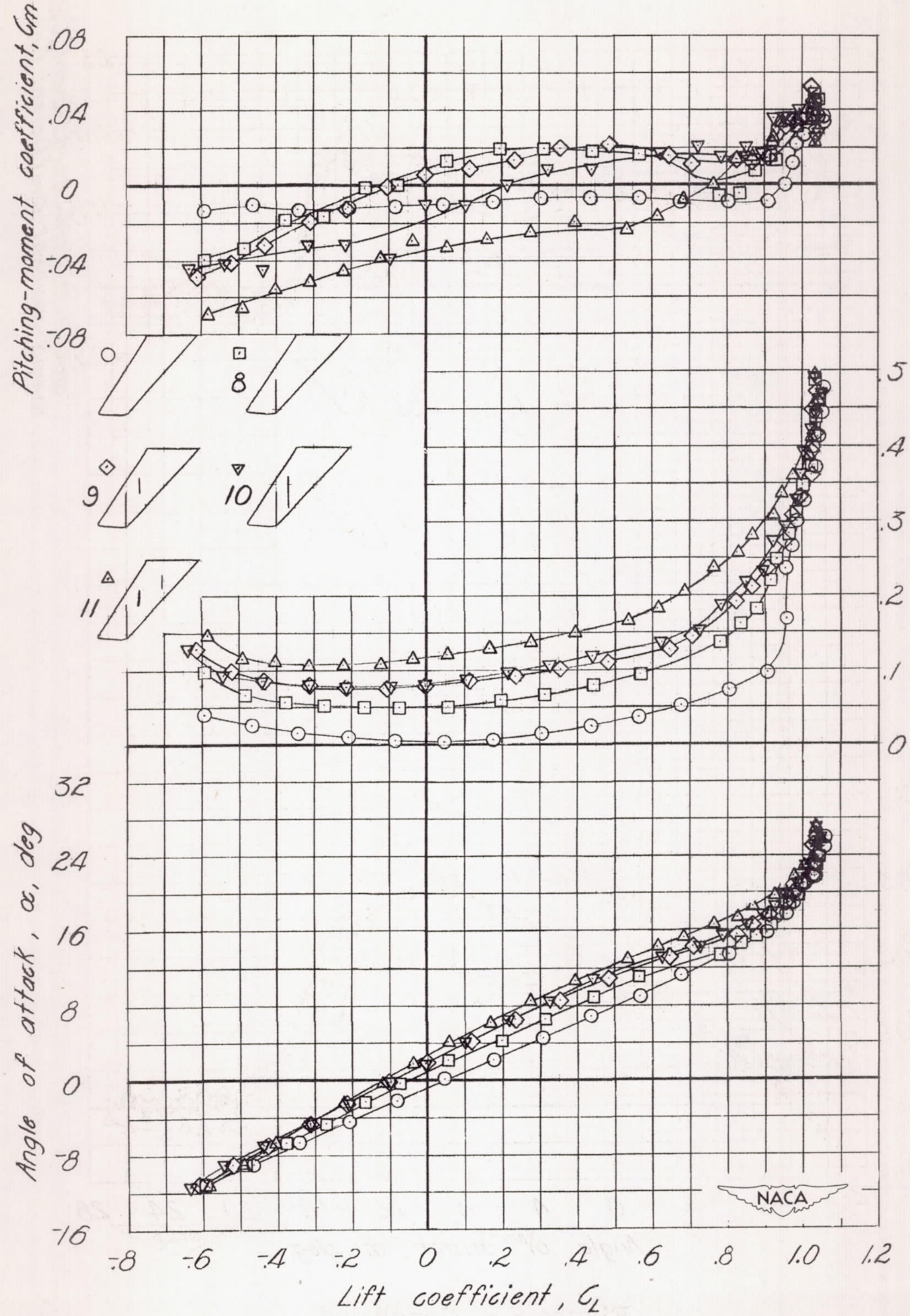
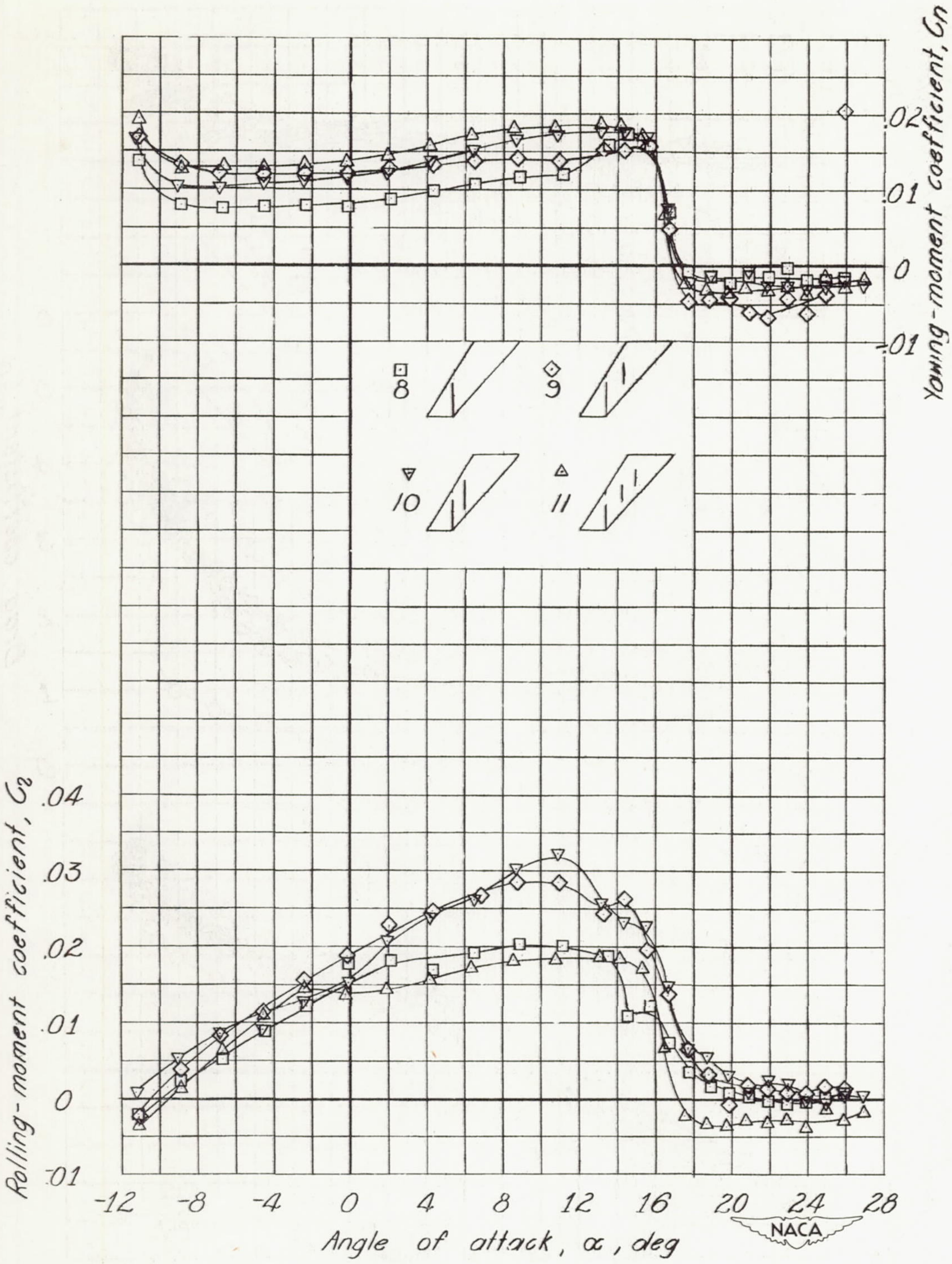


Figure 8.- Aerodynamic characteristics of plain wing and wing with spoilers 8, 9, 10, and 11.



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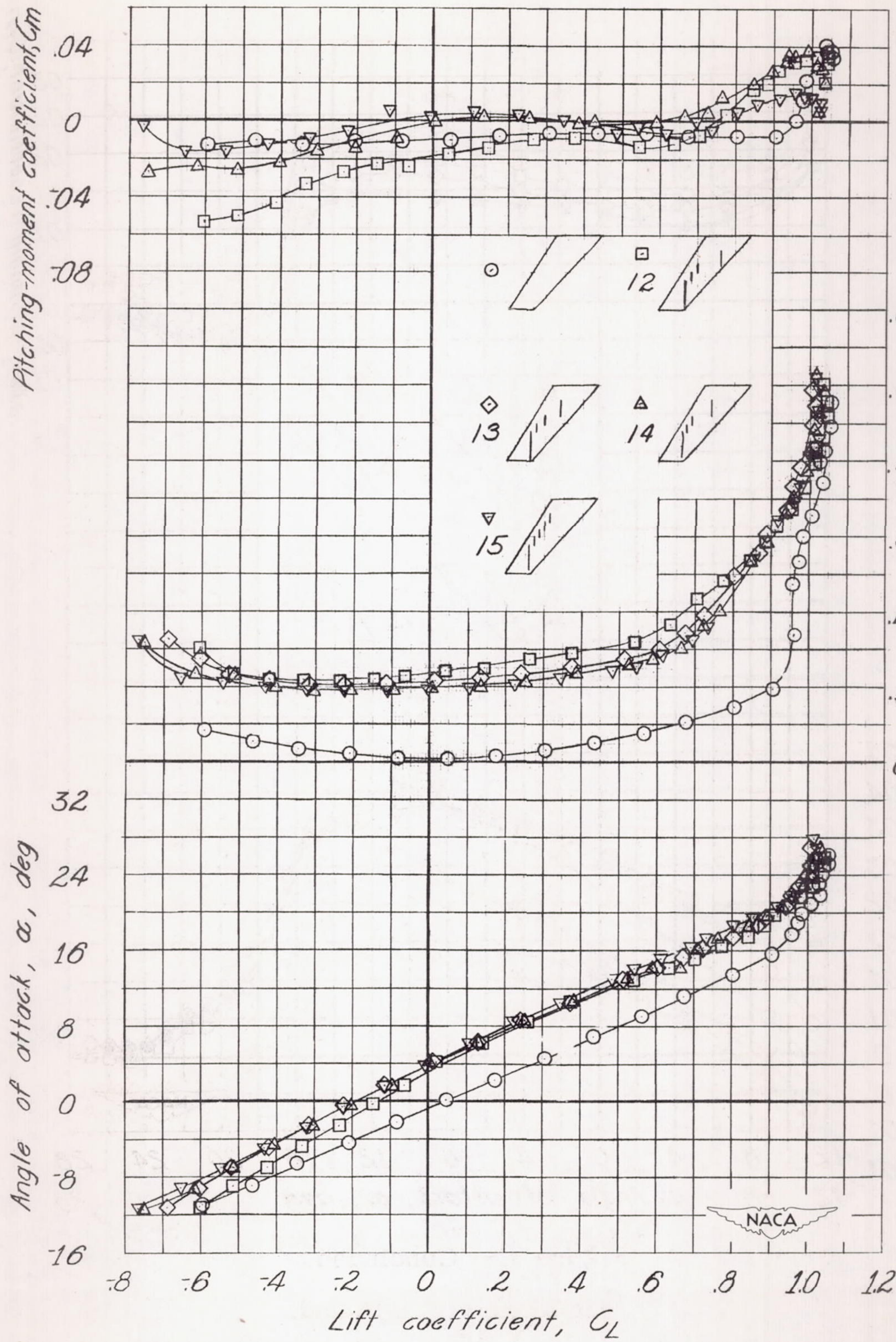

Figure 9.- Aerodynamic characteristics of plain wing and wing with spoilers 12, 13, 14, and 15.

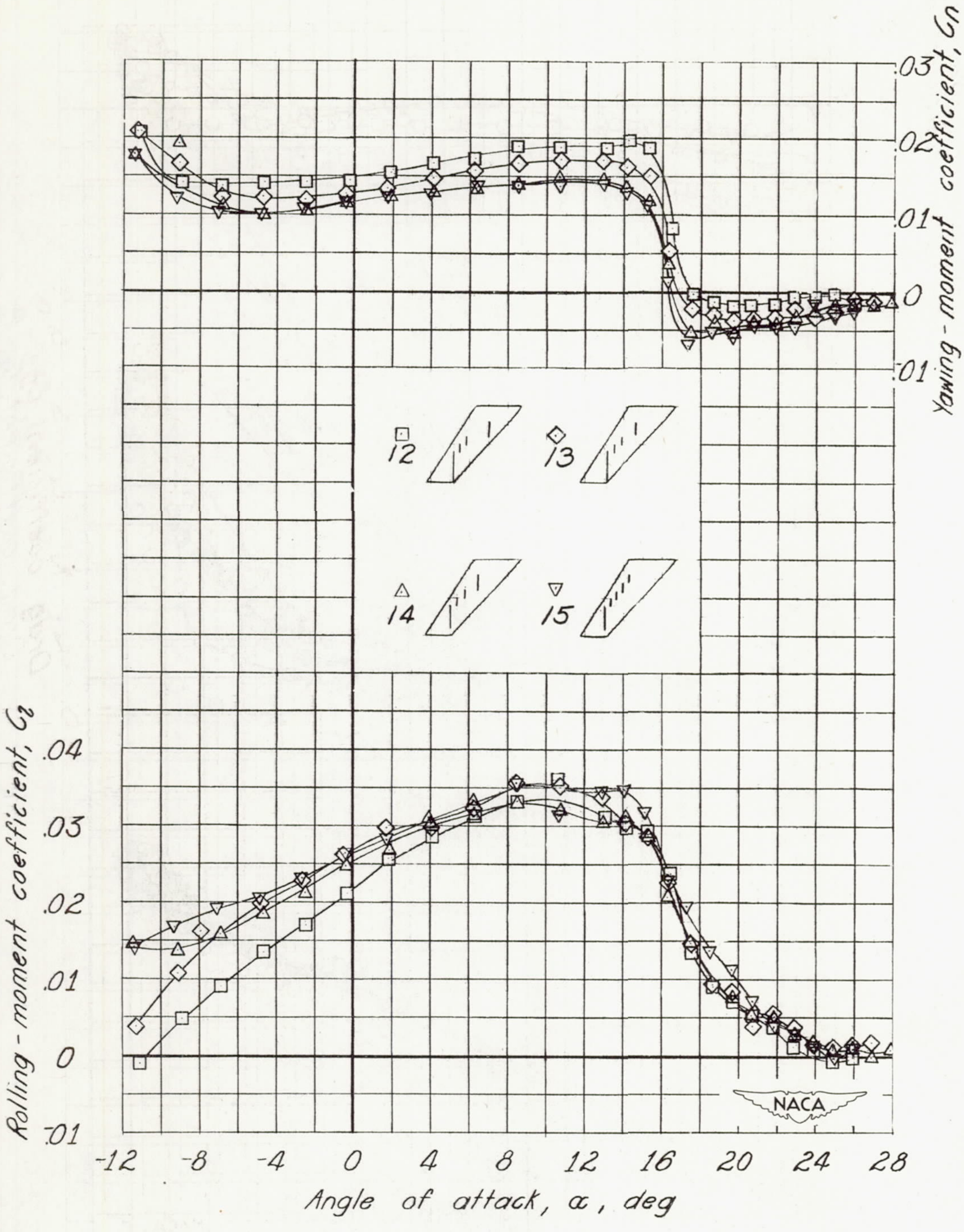

Figure 9.- Concluded.

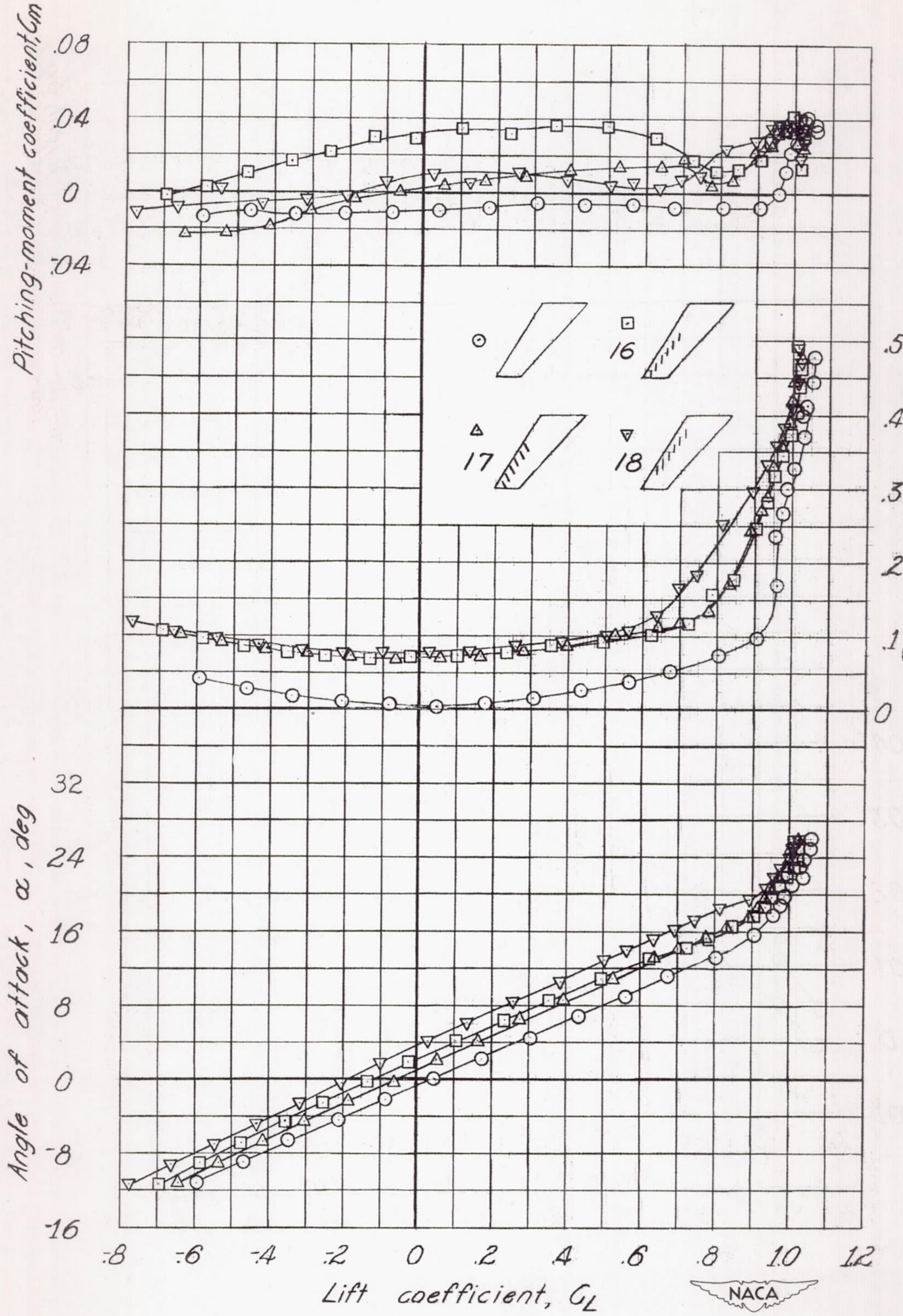

Figure 10.- Aerodynamic characteristics of plain wing and wing with spoilers 16, 17, and 18.

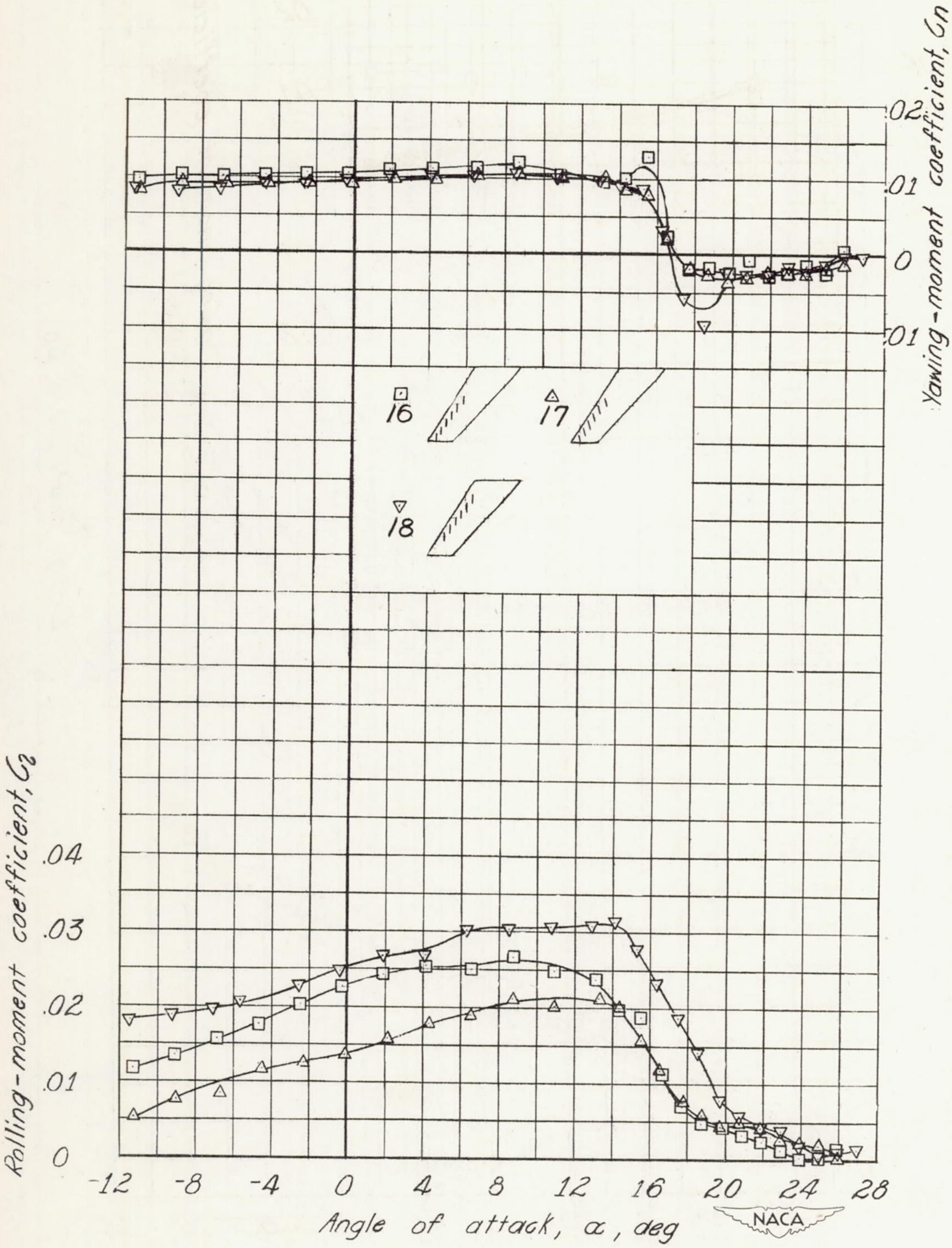

Figure 10.- Concluded.

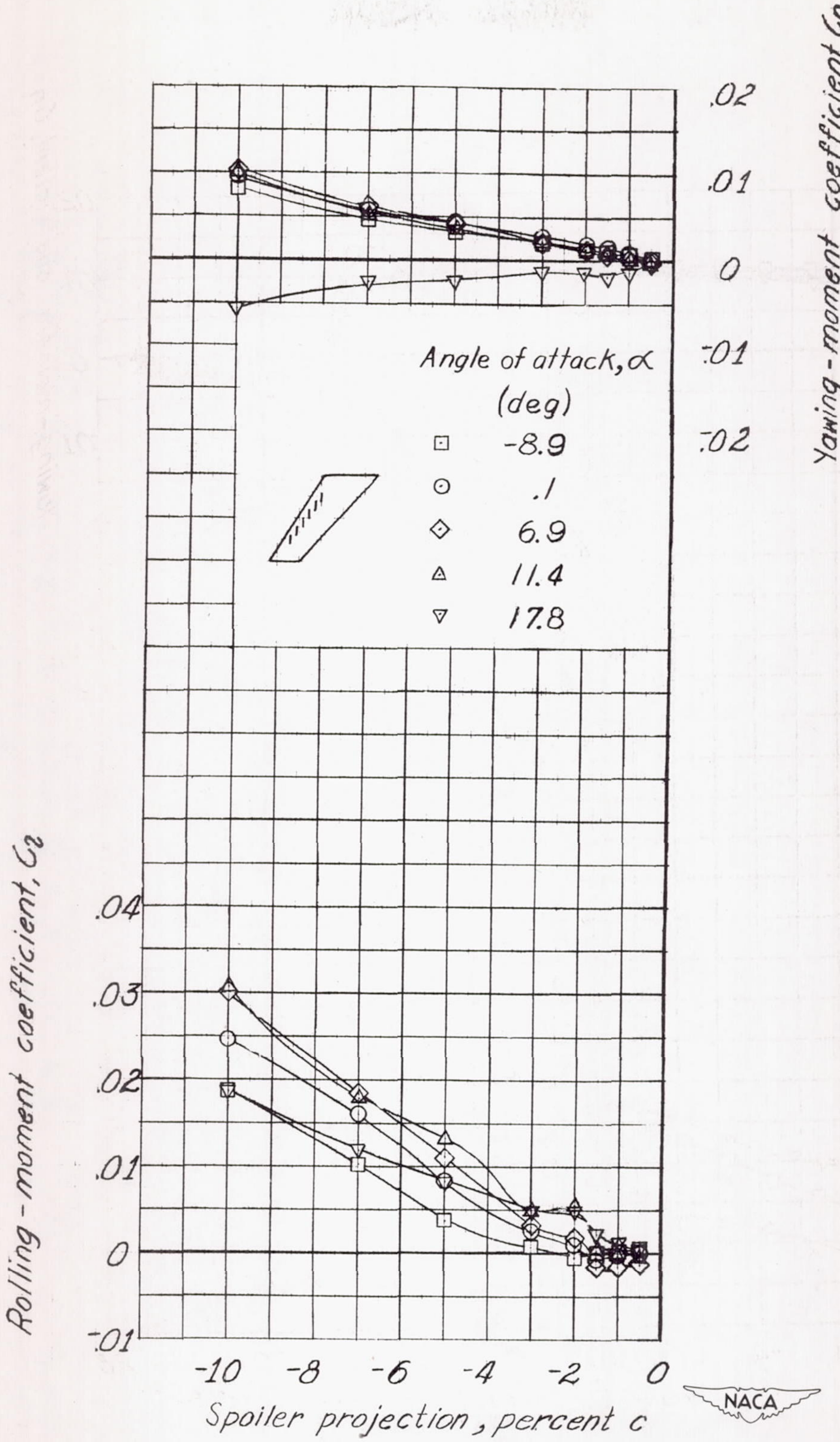

Figure 11.- Variation of rolling-moment and yawing-moment coefficients with spoiler projection. Spoiler 18.