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RESEARCH MEMORANDUM

AN INVESTIGATION OF A SUPERSONIC AIRCRAFT CONFIGURATION HAVING A TAPERED WING WITH CIRCULAR-ARC SECTIONS AND 40° SWEEPBACK

STABILITY AND CONTROL CHARACTERISTICS AT A MACH NUMBER OF 1.61 OF THE COMPLETE CONFIGURATION EQUIPPED WITH SPOILERS

By Clyde V. Hamilton and Cornelius Driver

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

September 10, 1954

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AN INVESTIGATION OF A SUPERSONIC AIRCRAFT CONFIGURATION HAVING A TAPERED WING WITH CIRCULAR-ARC SECTIONS AND 40° SWEEPBACK

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SUMMARY

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 1.61 to determine the stability and control characteristics of a supersonic aircraft configuration with a 40° sweptback wing and equipped with spoiler lateral control devices. Some effects of various types of spoilers, spoiler span, projection, and chordwise location were investigated, as well as the hinge-moment characteristics for a plain spoiler.

The addition of the spoilers had little effect on the stability characteristics of the basic configuration except to provide a favorable yawing moment due to spoiler projection in contrast to the adverse yaw resulting from conventional aileron deflection.

An 80-percent-semispan plain spoiler projected 5 percent of the local wing chord was about as effective in producing roll as two flap-type, 50-percent outboard, semispan ailerons (20-percent chord) deflected differentially ±10°. At zero angle of attack, the hinge moment for equal rolling effectiveness of the plain spoiler was about one-third that of the ailerons, but the drag increment resulting from spoiler projection was about 19 percent greater than that resulting from the ailerons. Removal of the outboard half of the plain spoiler resulted in about 50-percent reduction in rolling effectiveness.

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INTRODUCTION

A research program has been in progress at the Langley Aeronautical Laboratory to investigate some of the lateral control problems that may be encountered in high-speed flight. Experimental investigations at transonic and supersonic speeds have indicated that spoilers may offer some advantages as a lateral control device. For example, a comparison of spoilers with flap-type controls shows, in reference 1, that for the same rolling effectiveness the spoiler-type control may cause less wing twisting moment. In reference 2, the data indicate that spoilers produce smaller hinge moments.

The purpose of the present investigation was to determine from force measurements the longitudinal and lateral stability and control characteristics of a supersonic aircraft configuration having a 40° sweptback wing equipped with various types of spoilers. In addition, some effects of spoiler span, projection, and chordwise position were investigated.

The tests were performed in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 1.61 and a Reynolds number of 2.5×10^6 based on the wing mean aerodynamic chord.

COEFFICIENTS AND SYMBOLS

The results are referred to the stability axis system (fig. 1) with the reference center-of-gravity location at 25 percent of the wing mean aerodynamic chord.

C_m pitching-moment coefficient, $\frac{M'}{qS\bar{c}}$

C_L lift coefficient, $\frac{-Z}{qS}$

C_X longitudinal-force coefficient, $\frac{-X}{qS}$

C_n yawing-moment coefficient, $\frac{N}{qSb}$

C_l rolling-moment coefficient, $\frac{L}{qSb}$

C_Y lateral-force coefficient, $\frac{Y}{qS}$

C_{H_S} spoiler hinge-moment coefficient, $\frac{H_S}{2qM_S}$

C_{H_a} aileron hinge-moment coefficient, $\frac{H_a}{2qM_a}$

M Mach number

H_S spoiler hinge moment about line of intersection of spoiler and wing surface

H_a aileron hinge moment about aileron hinge line

M_S moment area of spoiler above spoiler hinge line (0.000284 ft^3)

M_a moment area of aileron rearward of aileron hinge line (0.00180 ft^3)

S wing area (1.158 sq ft)

b wing span (2.155 ft)

c wing chord

$\bar{c}$ wing mean aerodynamic chord (0.577 ft)

q free-stream dynamic pressure

α angle of attack of body center line, deg

α_W angle of attack of wing, deg

β angle of sideslip of body center line, deg

δ_a aileron deflection, trailing edge up is negative

δ_S spoiler deflection, projection above wing is negative

M' pitching moment about Y-axis

N yawing moment about Z-axis

L rolling moment about X-axis

Z force along Z-axis

X force along X-axis

Y force along Y-axis

MODEL AND TESTS

The model (fig. 2) had a tapered wing of aspect ratio 4 with 10-percent-thick circular-arc sections normal to the quarter-chord line and swept back 40° at the quarter-chord line. The trailing-edge flap-type ailerons (described in ref. 3) were flat-sided controls having a trailing-edge thickness of 0.5 of the hinge line thickness and were installed on the outboard halves of the wing semispan. The aileron chord was 20 percent of the local wing chord.

The spoilers and their location are also shown in figure 2 and are described in the following table:

Spoiler	Type	Location of inboard end	Location of outboard end	Chordwise position	Projection, δ_S
[a]1	Plain	$0.15 \frac{b}{2}$	$0.95 \frac{b}{2}$	0.55c	-0.05c
2	Hinged	$.15 \frac{b}{2}$	$.95 \frac{b}{2}$	.55c	-.05c
3	Step	$.15 \frac{b}{2}$	$.95 \frac{b}{2}$	.55c	-.05c
4	Plain	$.15 \frac{b}{2}$	$.95 \frac{b}{2}$	.65c	-.05c
4(a)	Plain	$.15 \frac{b}{2}$	$.95 \frac{b}{2}$	.65c	-.02c
5	Plain	$.15 \frac{b}{2}$	$.55 \frac{b}{2}$	.65c	-.05c
5(a)	Plain	$.15 \frac{b}{2}$	$.55 \frac{b}{2}$	.65c	-.02c

[a]Gaged for measuring hinge moment.

The spoilers were mounted on the right wing panel only along a constant chord line and their height was proportional to the local chord.

The model was equipped with a six-component internal strain-gage balance to facilitate the measurement of forces and moments. In addition, the right aileron and one spoiler (number 1) were equipped with strain gages for measuring hinge moments.

The model had a 1/8-inch-wide transition strip, No. 60 carborundum grains, 1/8 inch rearward of the leading edge of the right wing in order to insure turbulent flow over the wing. The tests were made at angles of attack from -8° to 16° and at angles of sideslip from -8° to 8°. The basic results are presented for a Reynolds number of 2.5×10^{6} based on the wing mean aerodynamic chord of 0.577 foot since tests made at various Reynolds numbers indicated little change in the spoiler hinge-moment coefficient.

The Mach number variation in the test section was approximately ± 0.01 and the flow angle variation in the horizontal and vertical planes was approximately $\pm 0.1^{\circ}$. No corrections were applied to the data to account for these variations. The angles of attack and sideslip were corrected for deflection of the model under load. The base pressure was measured and the longitudinal-force data were adjusted to a base pressure equal to free-stream static pressure.

The estimated errors in the individual measured quantities, based on balance and instrument restrictions and repeatability of the data, are as follows:

C_m	± 0.003
C_L	± 0.004
C_X	± 0.001
C_l	± 0.0004
C_n	± 0.0005
C_Y	± 0.001
C_{H_S}	± 0.005
C_{H_a}	± 0.005
α, deg	± 0.1
β, deg	± 0.1

RESULTS AND DISCUSSION

Rolling-moment characteristics.- Of the three types of spoilers tested (fig. 3), it was found that the plain spoiler (number 1) was slightly more effective in producing roll than the hinged type (number 2), while the step type (number 3) was the least effective of the three.

These results are similar to the results reported in reference 4. The change in chordwise position of the plain spoiler from 0.55c to 0.65c (fig. 3) had little effect on roll. These results are similar to the effects reported in references 5 and 6.

The nonlinear variation of C_l with spoiler projection δ_S (figs. 4 and 5) indicates that small projections of the spoiler are relatively ineffective in producing roll since the initial projection of the spoiler occurs within the boundary layer over the wing. The removal of the outboard half of the plain spoiler (fig. 5) resulted in about a 50-percent decrease in rolling effectiveness. This decrease in effectiveness is larger than would be expected from consideration of the results reported in reference 7.

Yawing-moment characteristics.- All spoilers provided favorable yawing moments (fig. 3) throughout the angle-of-attack range. Either removal of the outboard half of the spoiler (fig. 5) or a reduction in δ_S from 5 to 2 percent of the local chord (figs. 4 and 5) resulted in large decreases in C_n throughout the angle-of-attack range.

Longitudinal characteristics.- The lift and drag differences between the three spoiler arrangements tested were small (fig. 6).

An increase in δ_S resulted in a large increase in the drag increment (fig. 7) in the angle-of-attack range from -8° to 4° as well as an increase in the positive values of C_m and a decrease in C_L for a constant angle of attack.

The removal of the outboard half of the plain spoiler at the 0.65c location resulted in a large decrease in the drag increment (fig. 8) in the angle-of-attack range from -8° to 4°. There was little change in C_{L_α} or C_{m_α} as a result of the removal of the outboard half of the plain spoiler.

Characteristics in sideslip at $\alpha = 0^{\circ}$.- The effect of spoiler projection (plain number 1, $\delta_S = 0.05c$) on the sideslip derivatives C_{Y_β}, C_{n_β}, and C_{l_β} at $\alpha = 0^{\circ}$ (fig. 9) is small. The increments in C_Y and C_n due to spoiler projection increased slightly with positive angles of β as the spoiler becomes more normal to the airstream. Spoiler projection decreased the lift and increased the drag throughout the sideslip range. There was little or no effect on the pitching moment in sideslip.

Comparison of Spoiler With Aileron

The plain spoiler (number 4, 0.80 b/2 span, $\delta_S = 0.05c$ at the 0.65c station, mounted on upper surface of right wing only) is about as effective in producing roll as the flap-type aileron (fig. 2) deflected differentially $\pm 10^\circ$ (fig. 10). The total drag of the model equipped with spoiler number 4 is considerably higher than that for the model with the ailerons deflected $\pm 10^\circ$ in the range of angle of attack from -8° to 4°. At angles of attack near 8° and above, the drag of the spoiler and the ailerons is equal since boundary-layer separation has probably occurred ahead of the 0.65c location on both models. (See ref. 8.)

The spoiler and aileron hinge-moment coefficients are presented in figures 11 and 12, respectively. The spoiler hinge-moment coefficients are less linear than those for the aileron. The spoiler hinge moments (fig. 11) are the moments about a line at the surface of the wing and are based on the moment area above the spoiler hinge line.

Estimates for a full-scale hypothetical airplane at a Mach number of 1.61, a wing loading of 50 pounds per square foot, and an altitude of 35,000 feet ($C_L \approx 0.055$, $\alpha \approx 0^\circ$) indicate that for equal rolling effectiveness the spoiler hinge moment would be 704 foot-pounds, whereas the aileron hinge moment would be about 2,510 foot-pounds. The total drag of the airplane equipped with the spoiler was 19 percent greater than that for the airplane with the ailerons deflected $\pm 10^\circ$.

CONCLUDING REMARKS

An investigation has been performed in the Langley 4- by 4-foot supersonic pressure tunnel to determine the effect of spoilers on the aerodynamic characteristics of a supersonic aircraft configuration having a 40° sweptback wing. Some effects of spoiler-type controls, spoiler span, projection, and chordwise position were determined at a Mach number of 1.61. Hinge moments were also determined on one configuration. The investigation has shown that an 80-percent-semispan plain spoiler (projected 5 percent of the local wing chord at the 55-percent-chord position) mounted on the upper surface of the right wing was the most effective in producing roll of the three types tested. The plain spoiler was about as effective in roll as two conventional ailerons deflected differentially $\pm 10^\circ$. Removal of the outboard half of the plain spoiler resulted in a 50-percent decrease in effectiveness. The investigation has shown that for this configuration small projections of the spoiler are relatively ineffective in producing roll. For equal rolling effectiveness, the hinge moment for the plain spoiler was approximately one-third that for the conventional ailerons deflected differentially $\pm 10^\circ$, whereas the resulting drag force was about 19 percent greater.

The spoilers had little effect upon the stability characteristics of the basic configuration except to provide a favorable yawing moment due to spoiler projection as opposed to the adverse yaw resulting from deflections of the conventional ailerons.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 3, 1954.

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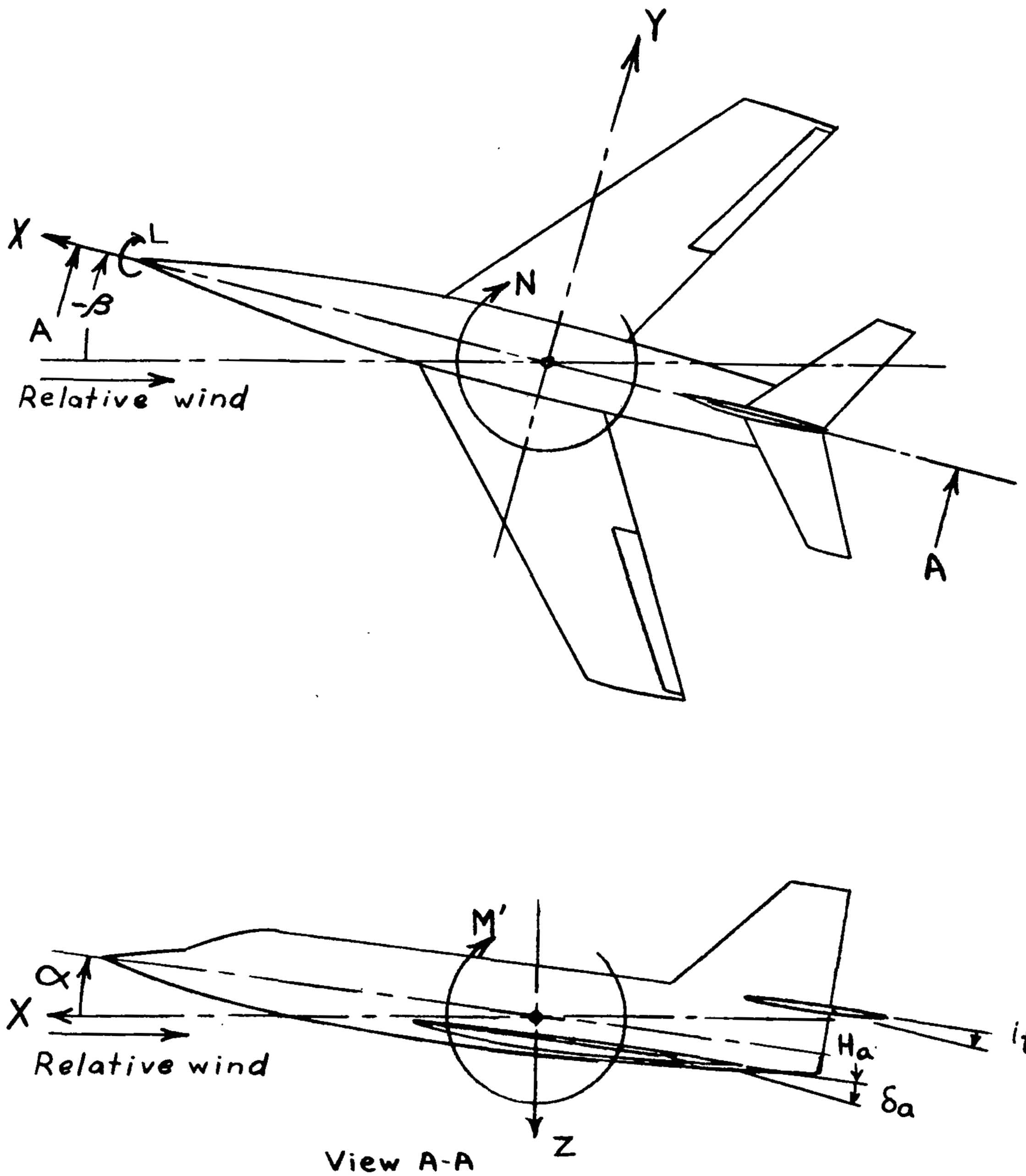


Figure 1.- System of stability axes. Arrows indicate positive values.

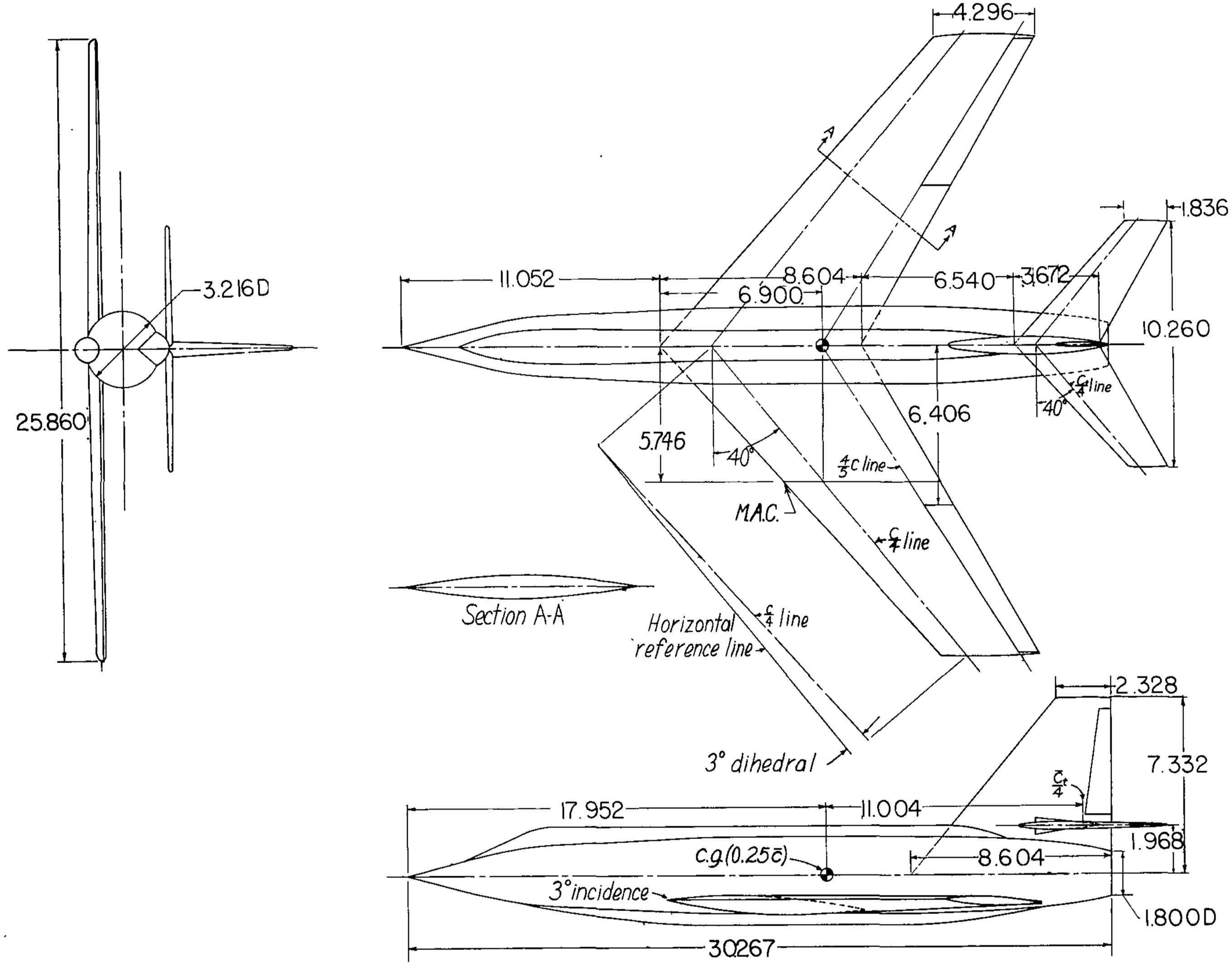
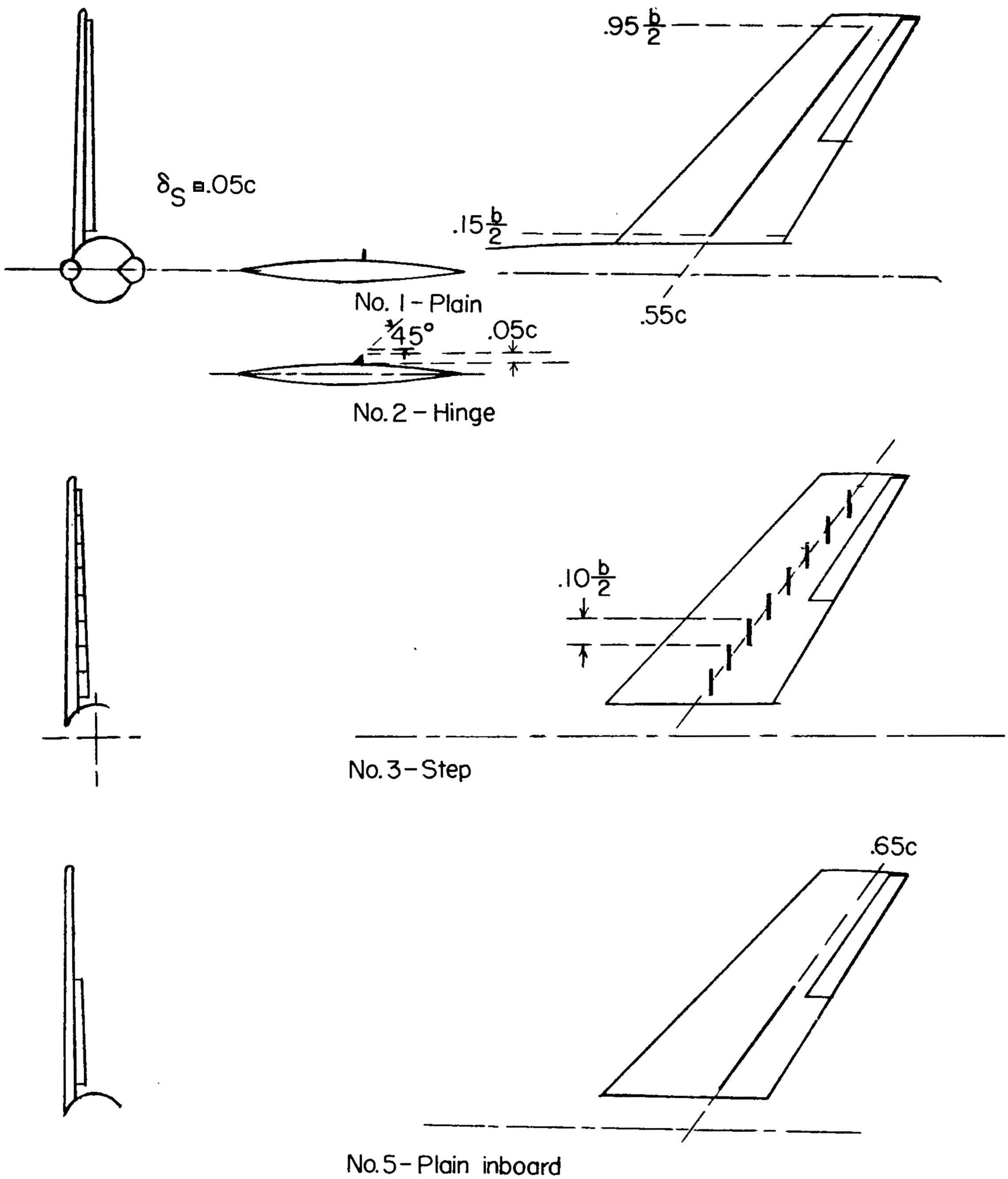


Figure 2.- Details of model of supersonic aircraft configuration. Dimensions in inches unless otherwise noted.



Note — No. 4 is identical to No. 1 but is located at .65c.

Details of spoilers

Figure 2.- Concluded.

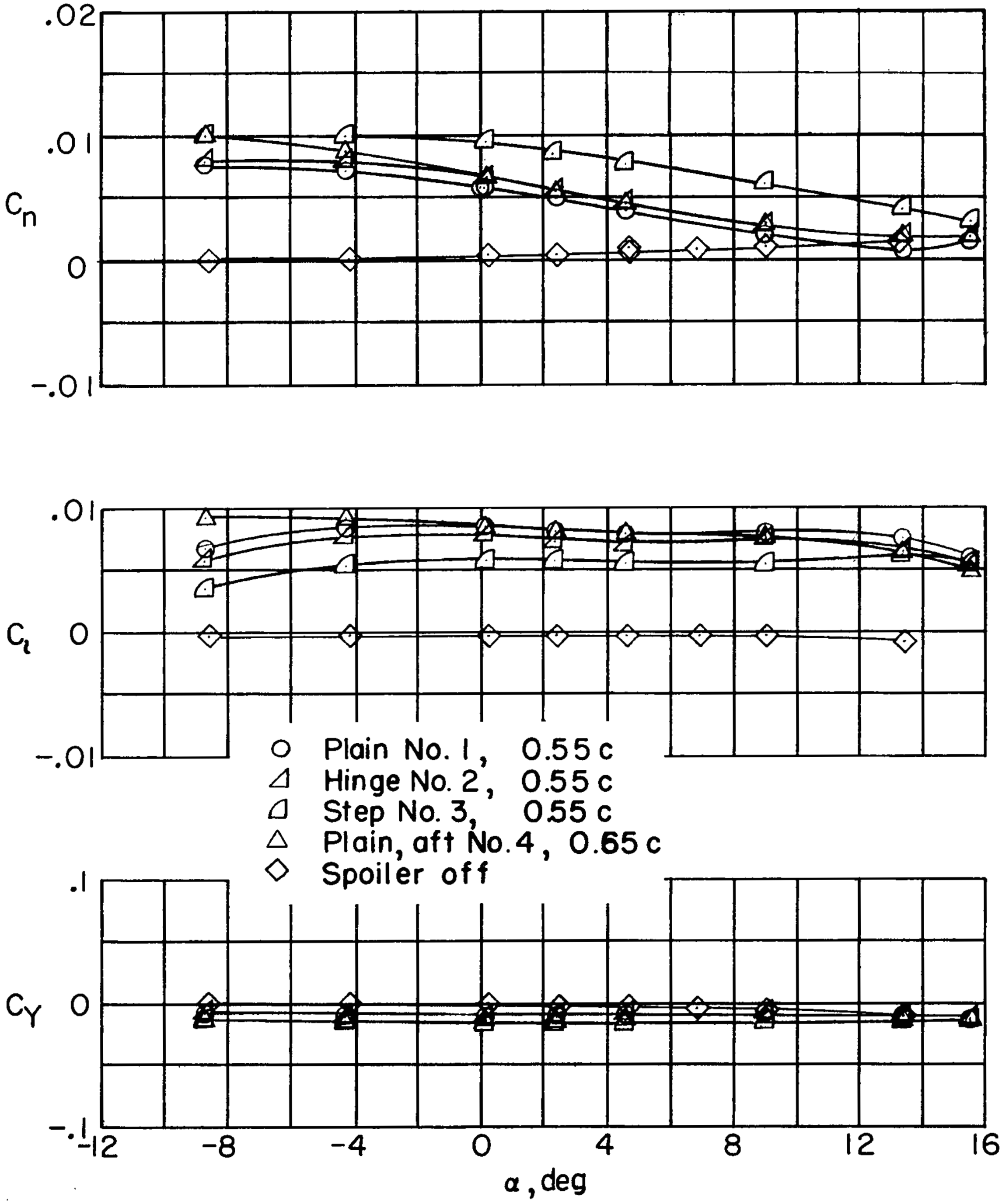


Figure 3.- Effect of spoiler type and chordwise position on spoiler effectiveness. M = 1.61.

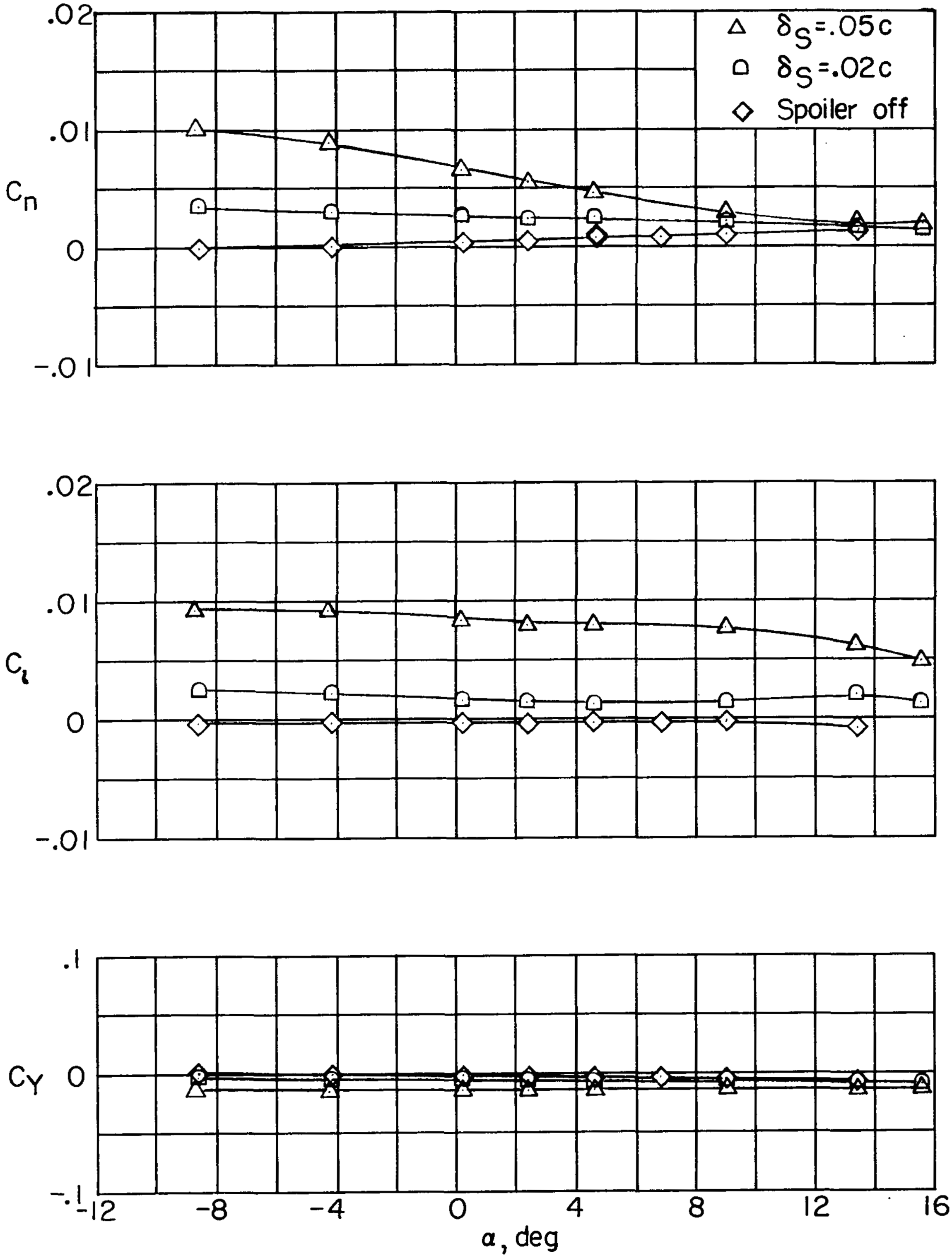


Figure 4.- Effect of spoiler projection on characteristics of plain spoiler number 4 (at 0.65c).

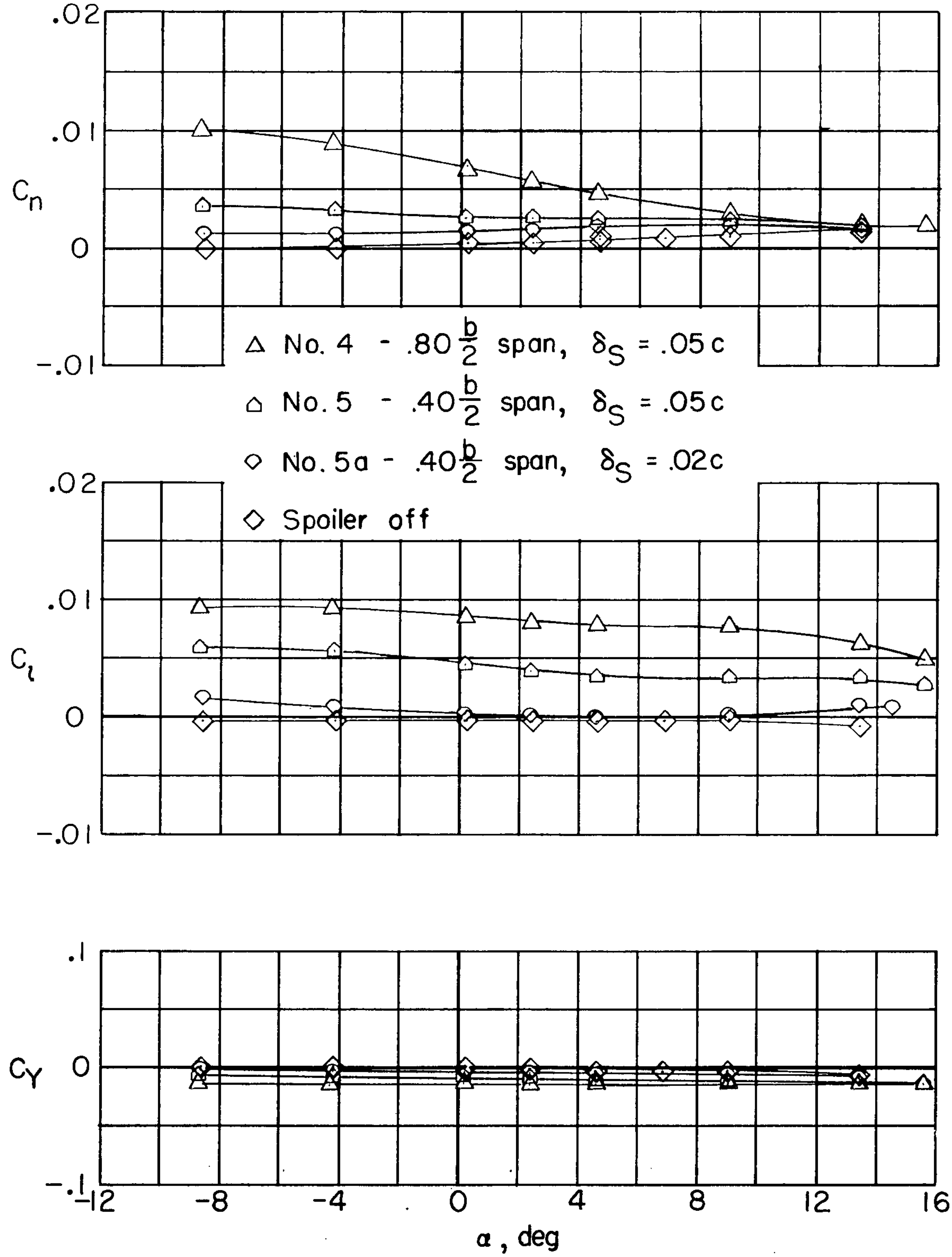


Figure 5.- Effect of span and projection on plain spoiler characteristics. M = 1.61.

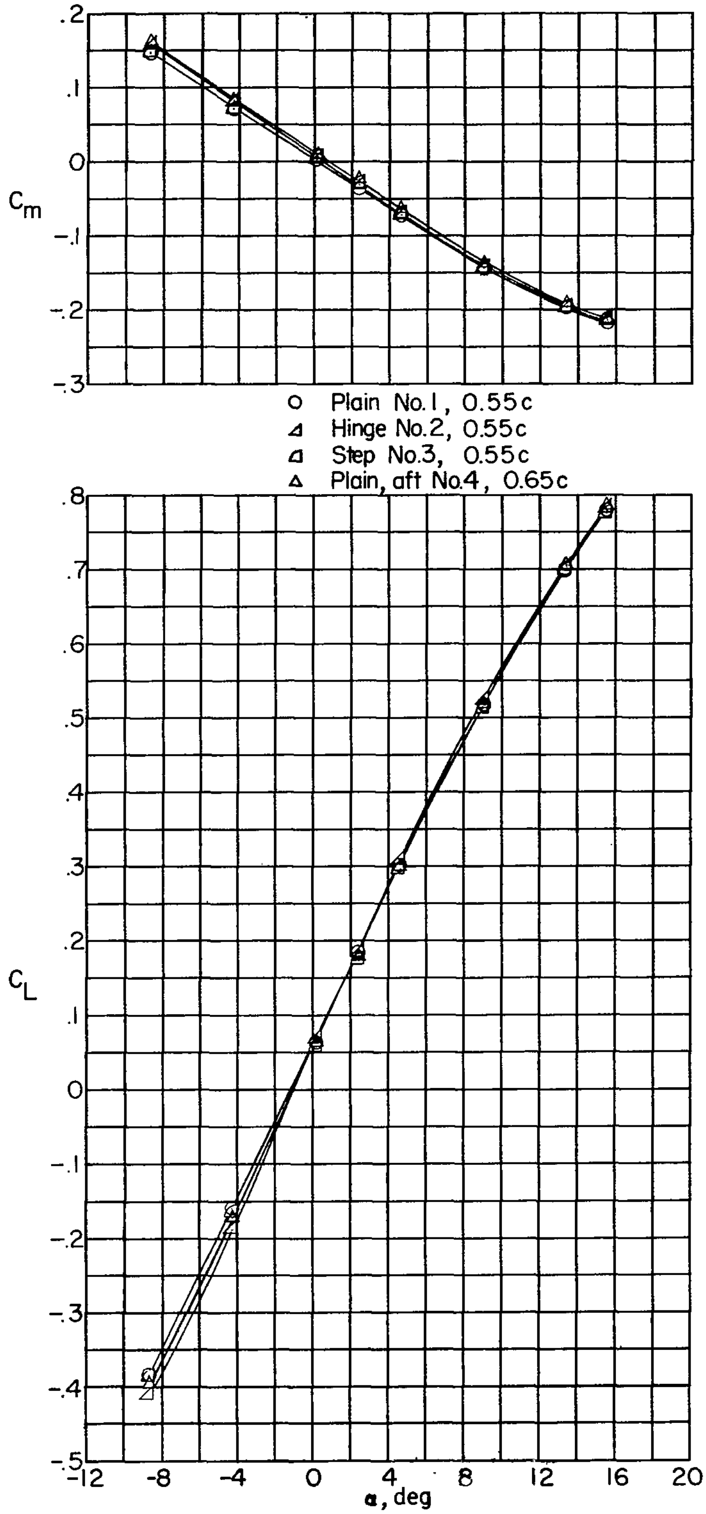


Figure 6.- Effect of spoiler type and chordwise position on the aerodynamic characteristics in pitch.

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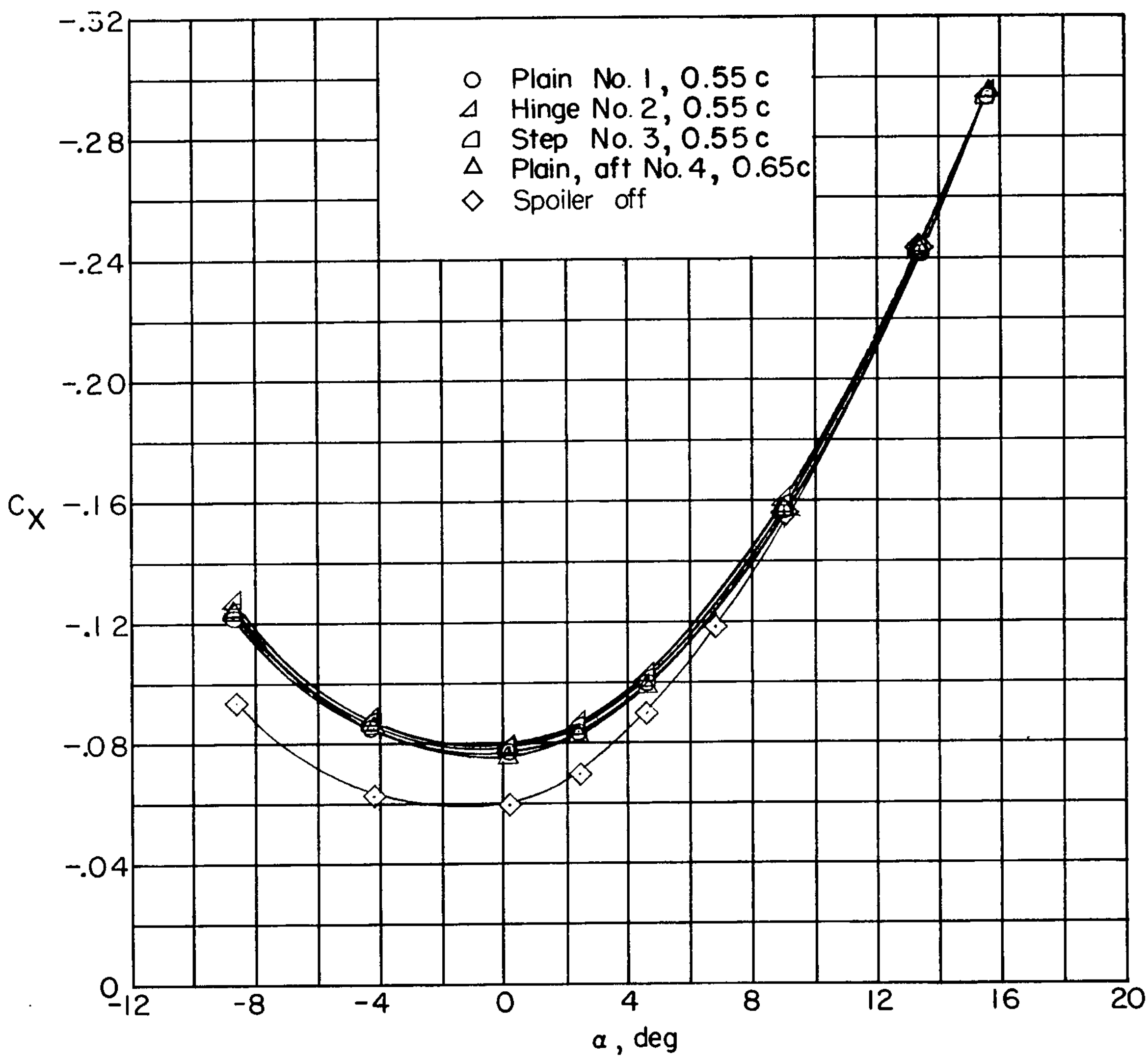

Figure 6.- Concluded.

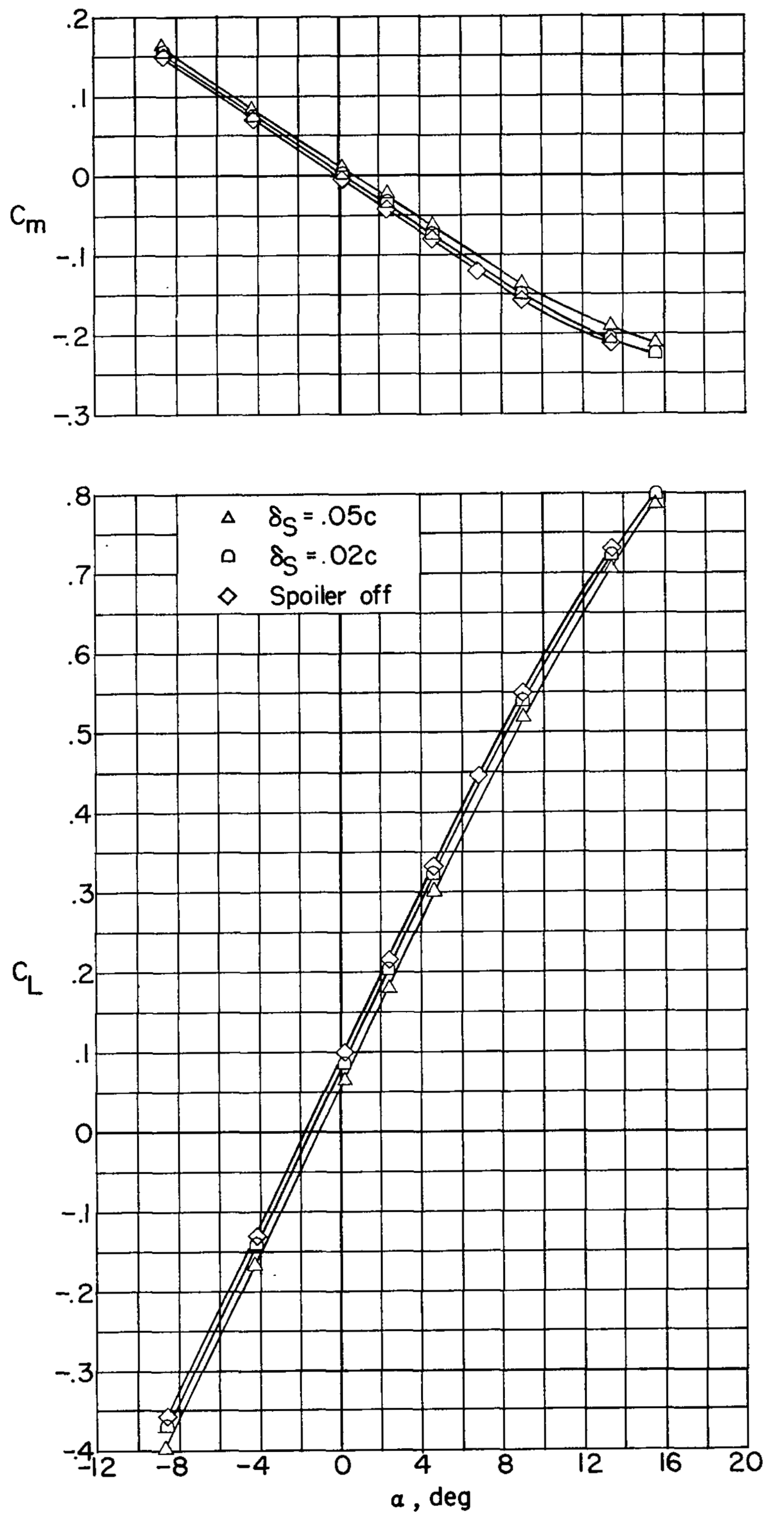

Figure 7.- Effect of spoiler projection on the aerodynamic characteristics in pitch.

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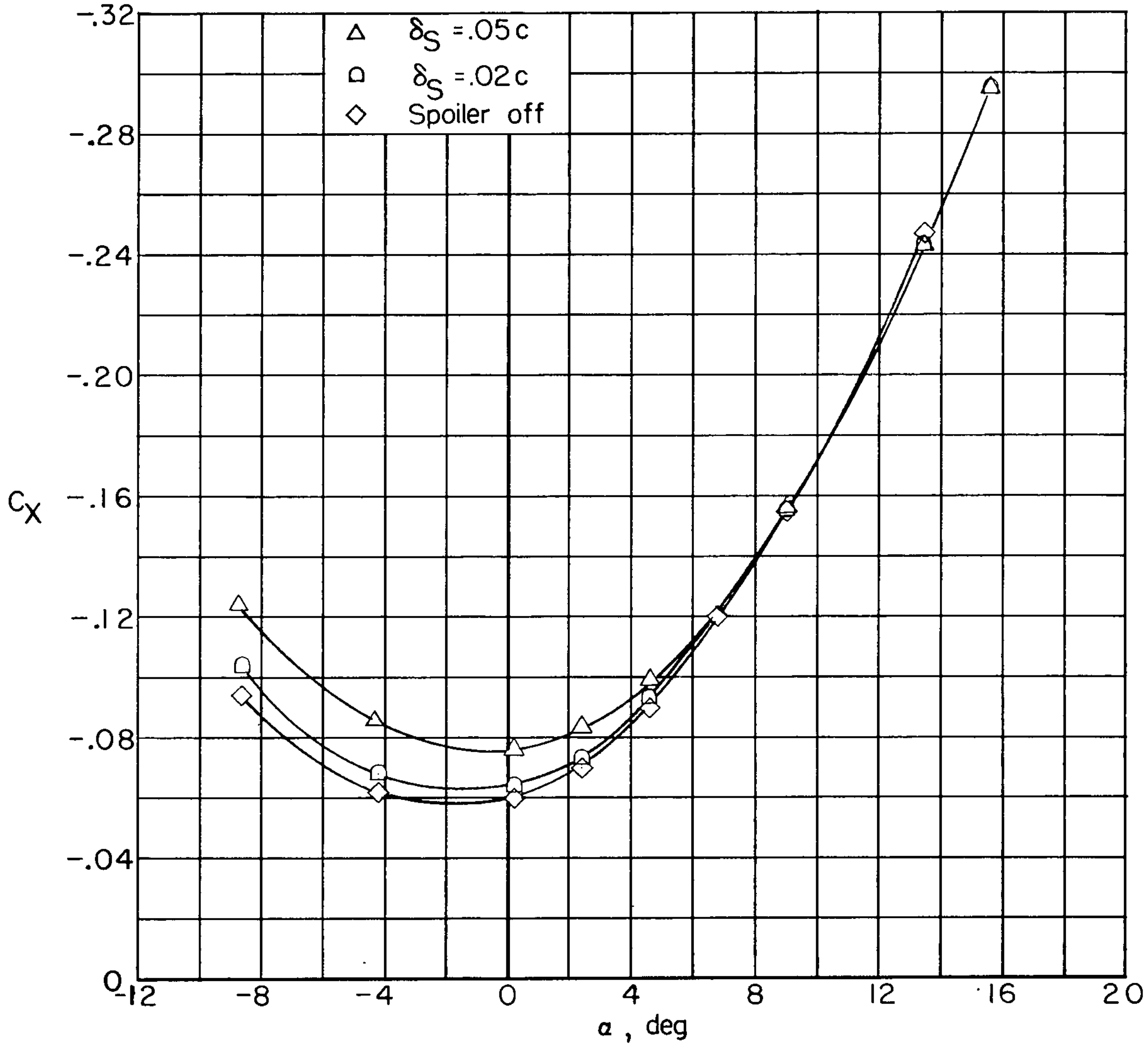

Figure 7.- Concluded.

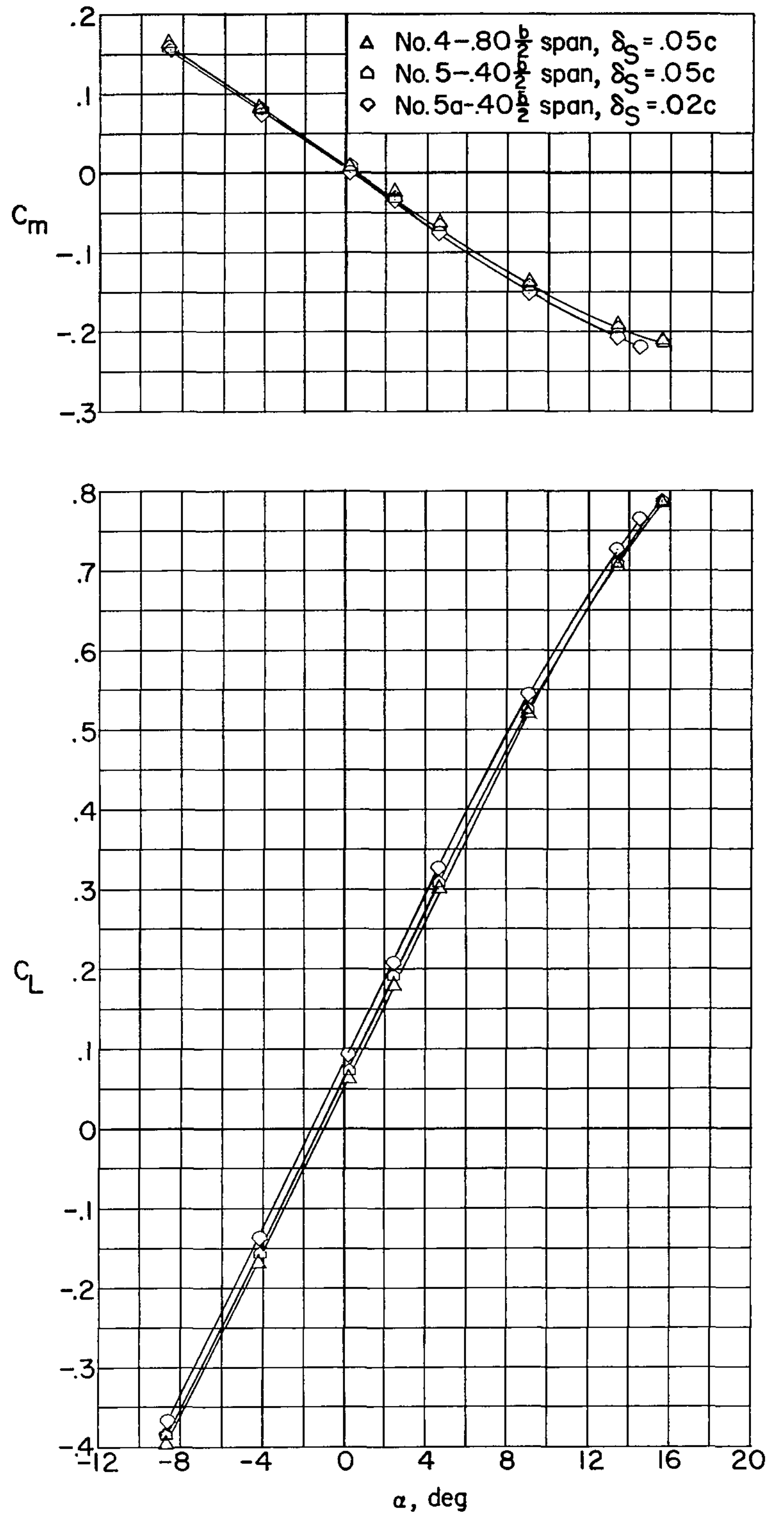

Figure 8.- Effect of spoiler span and projection on the aerodynamic characteristics in pitch.

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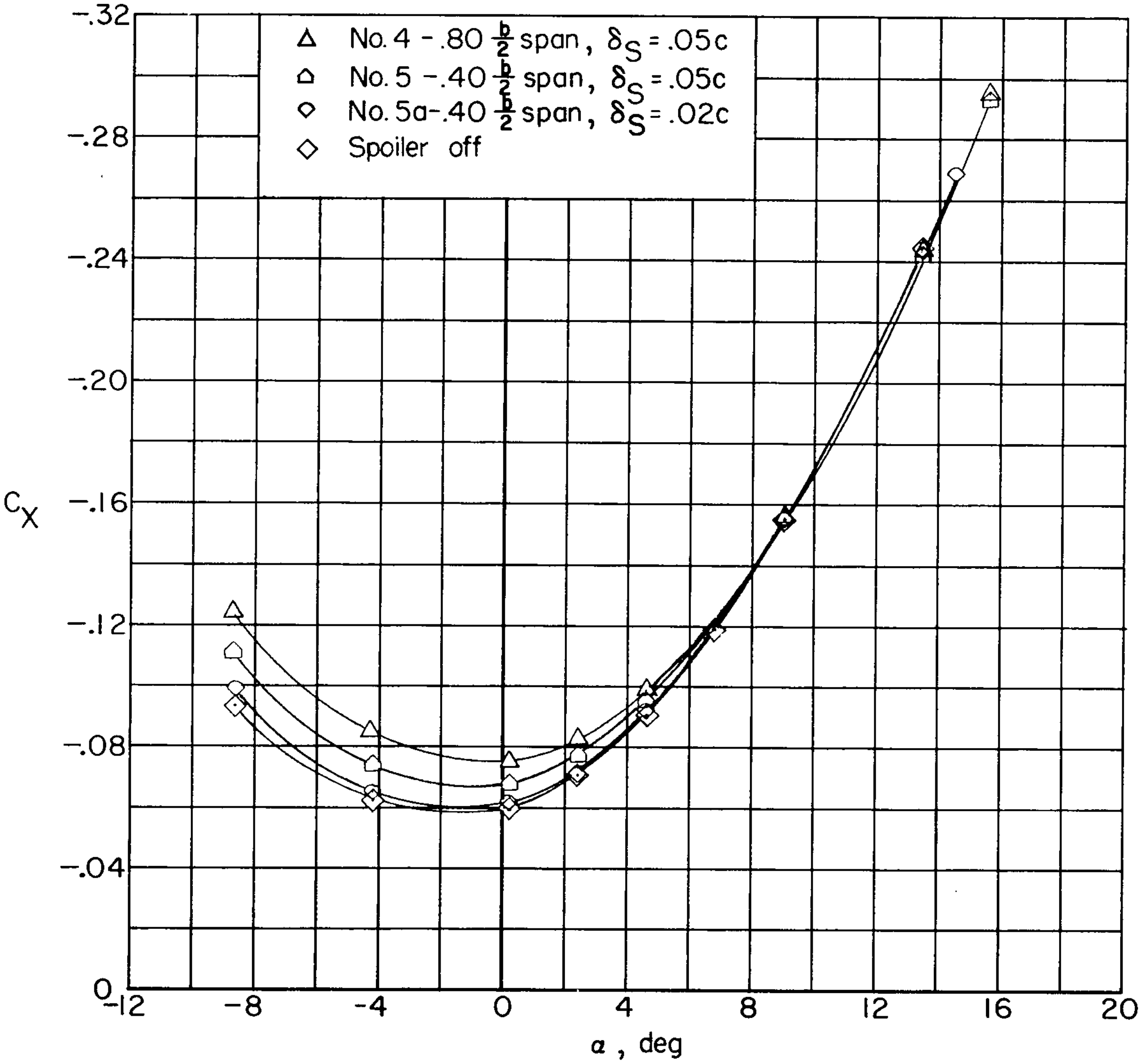

Figure 8.- Concluded.

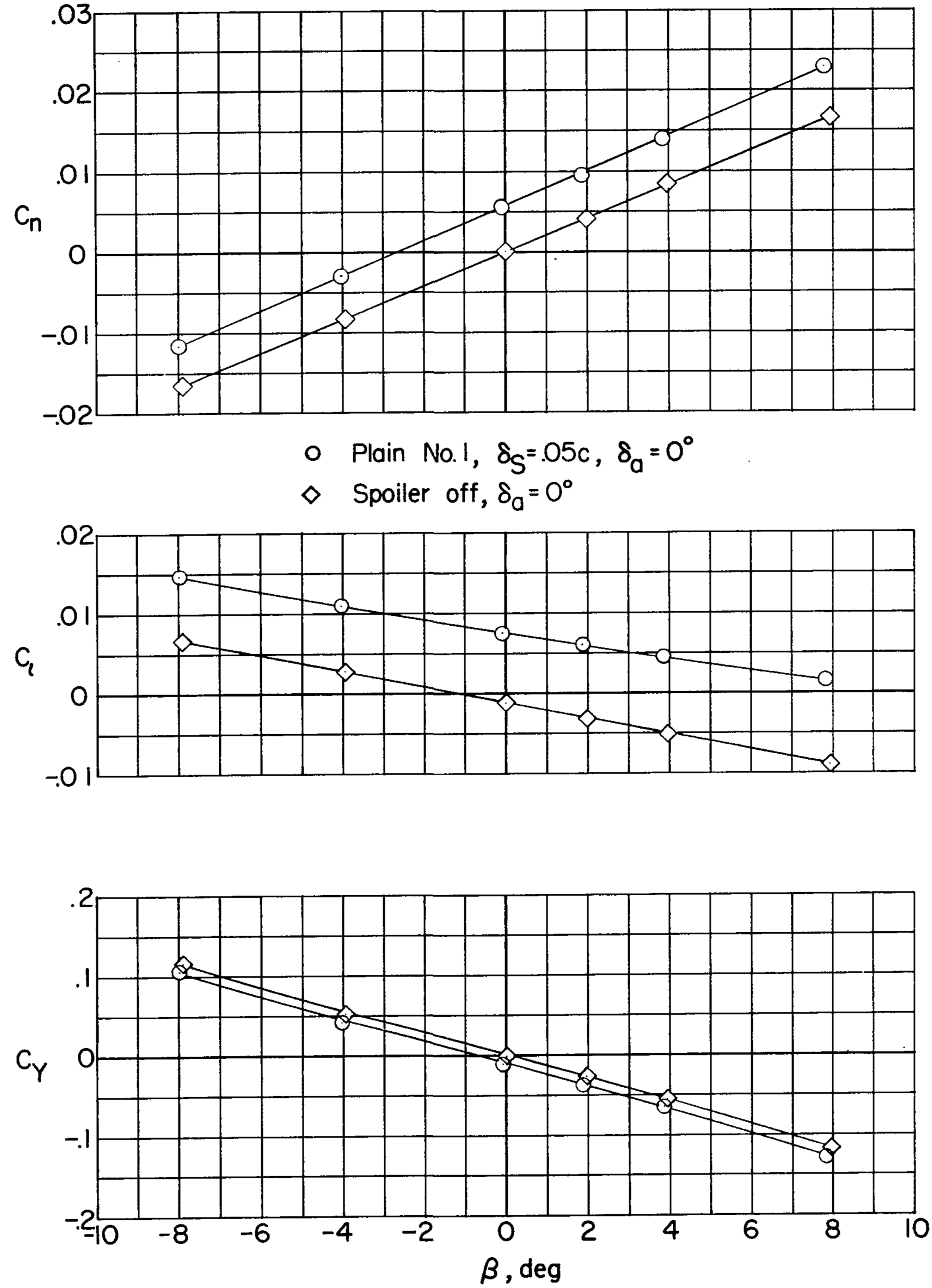

Figure 9.- Effect of spoiler projection on the aerodynamic characteristics in sideslip. $\alpha = 0^{\circ}$.

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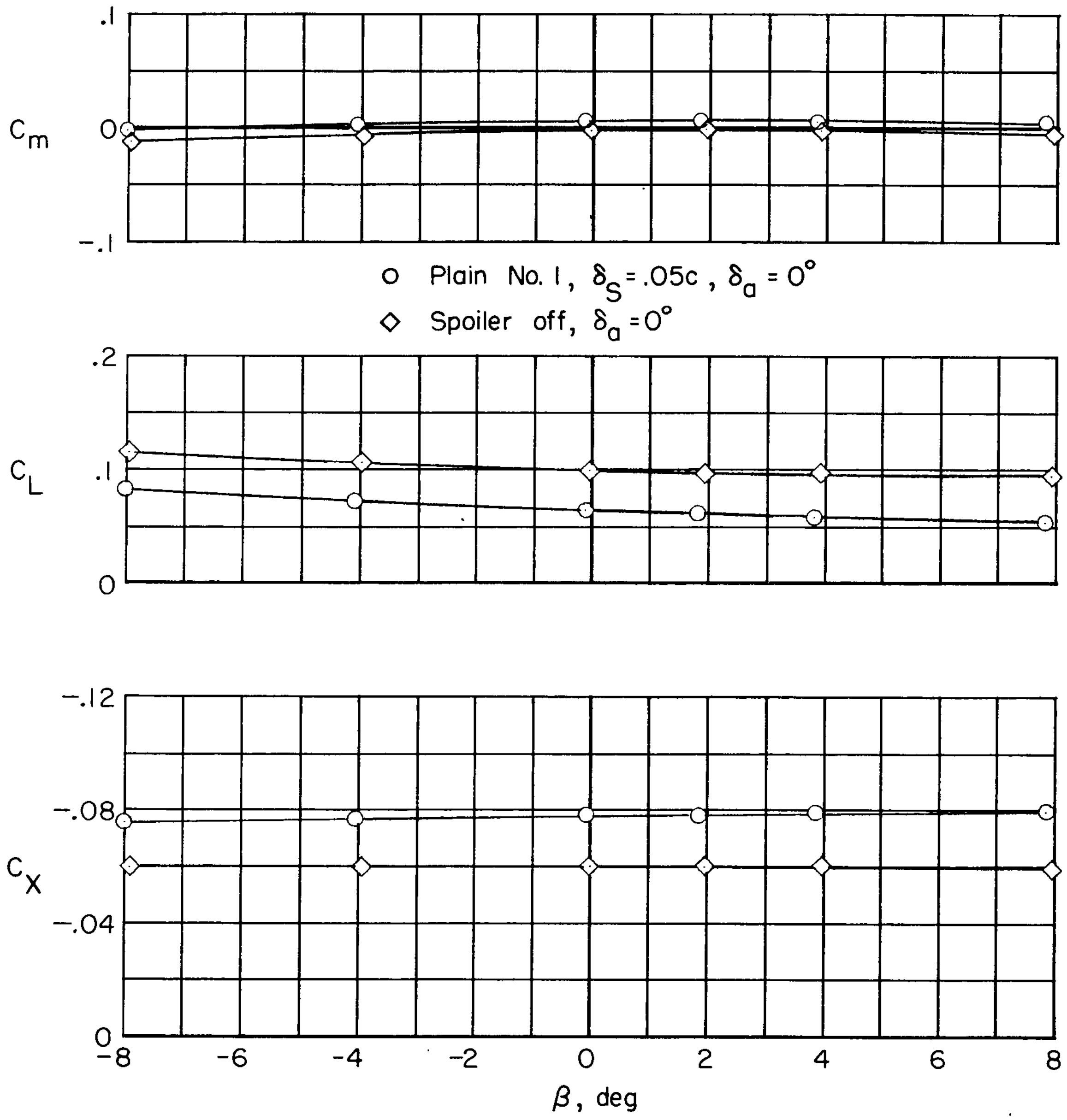

Figure 9.- Concluded.

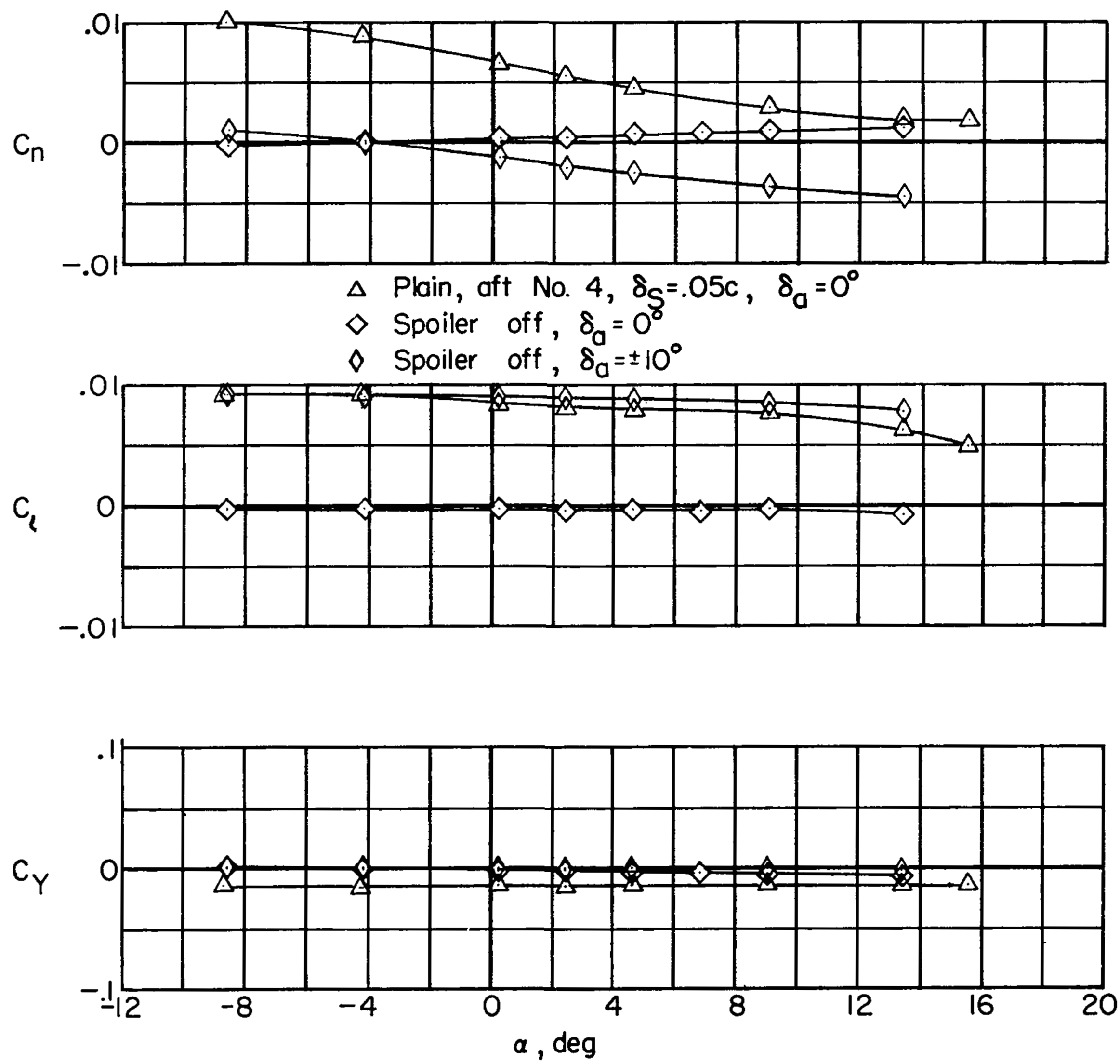

Figure 10.- Comparison between effectiveness of ailerons and plain spoiler number 4 (at 0.65c).

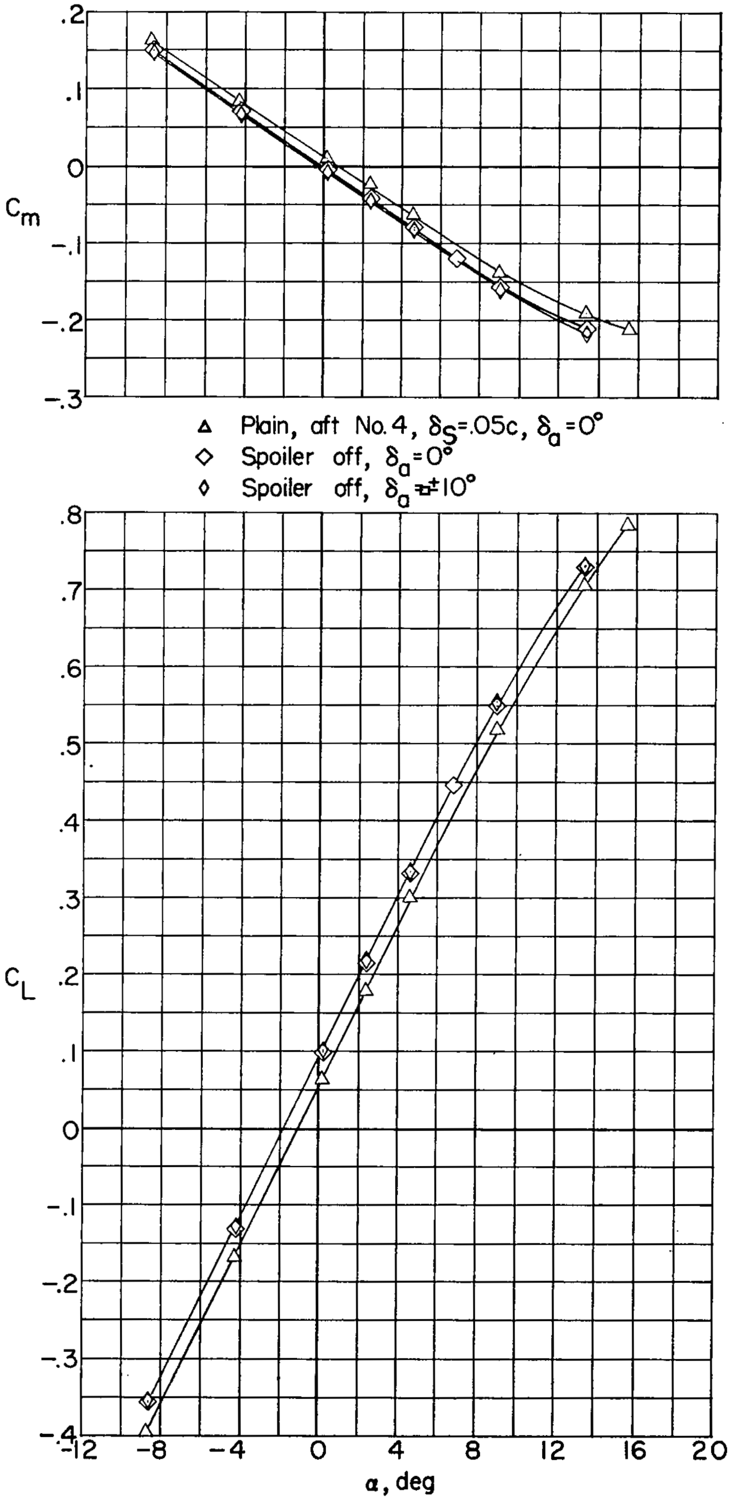

Figure 10.- Continued.

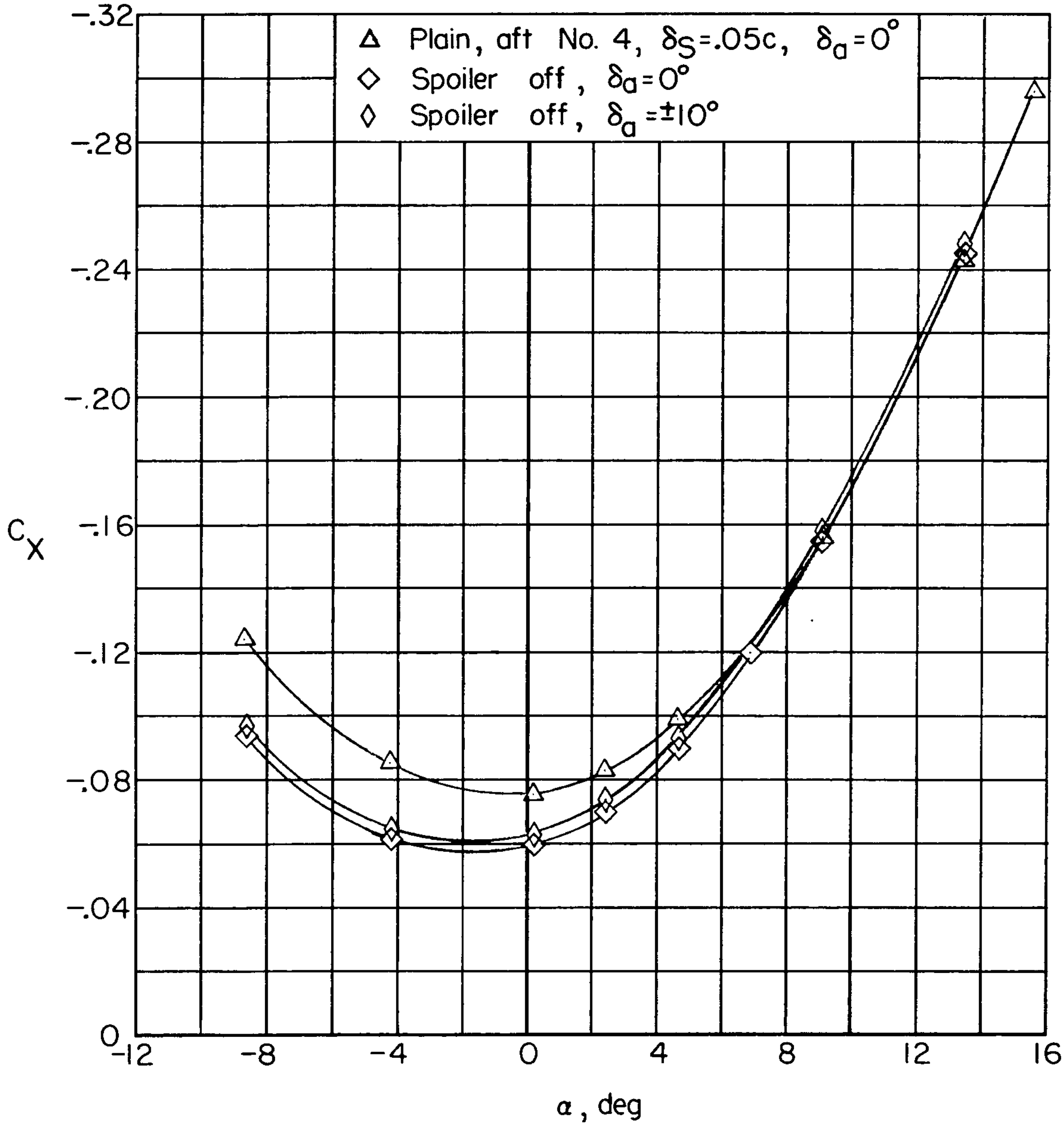

Figure 10.- Concluded.

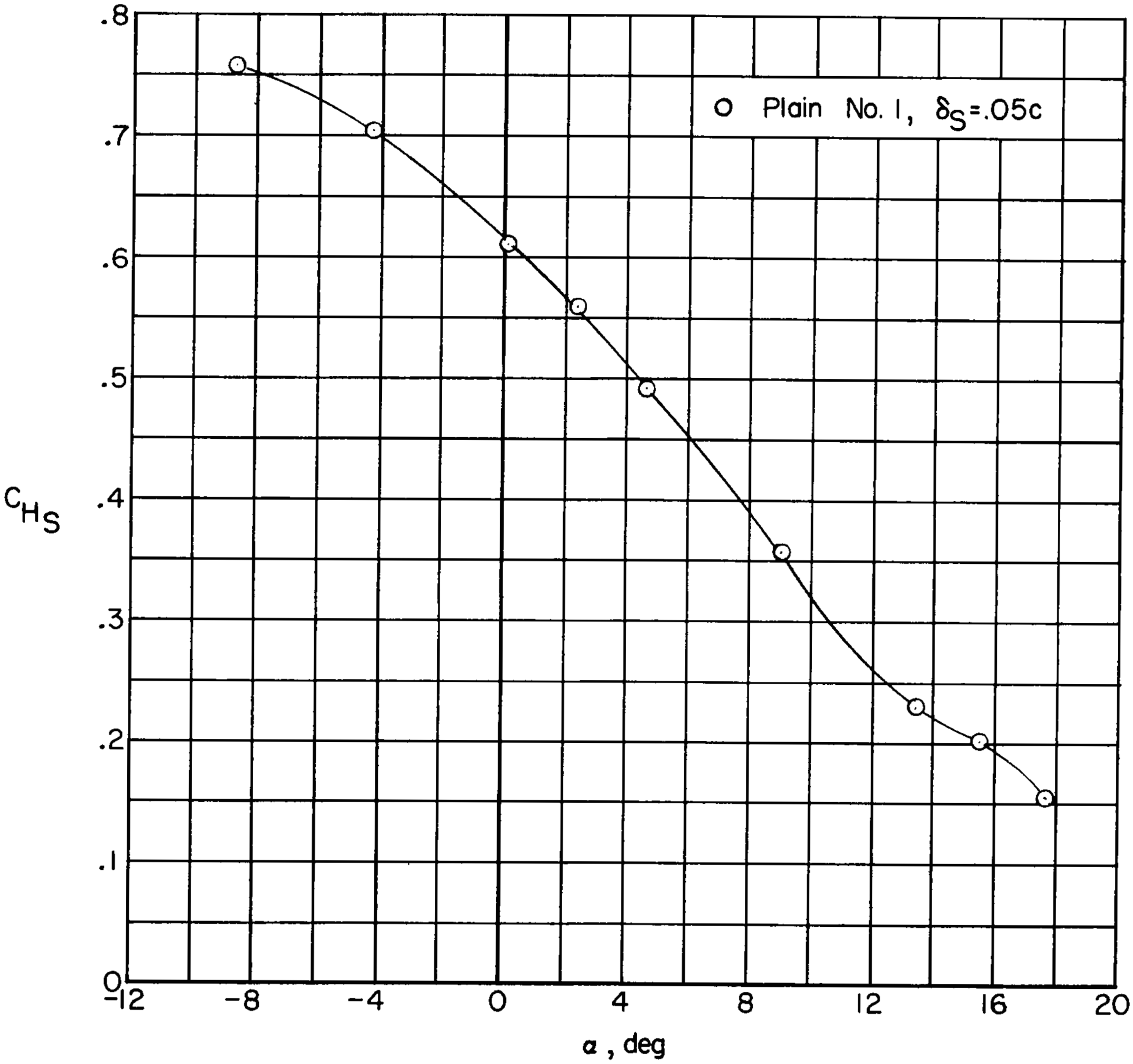

Figure 11.- Spoiler hinge-moment coefficient as a function of angle of attack. M = 1.61.

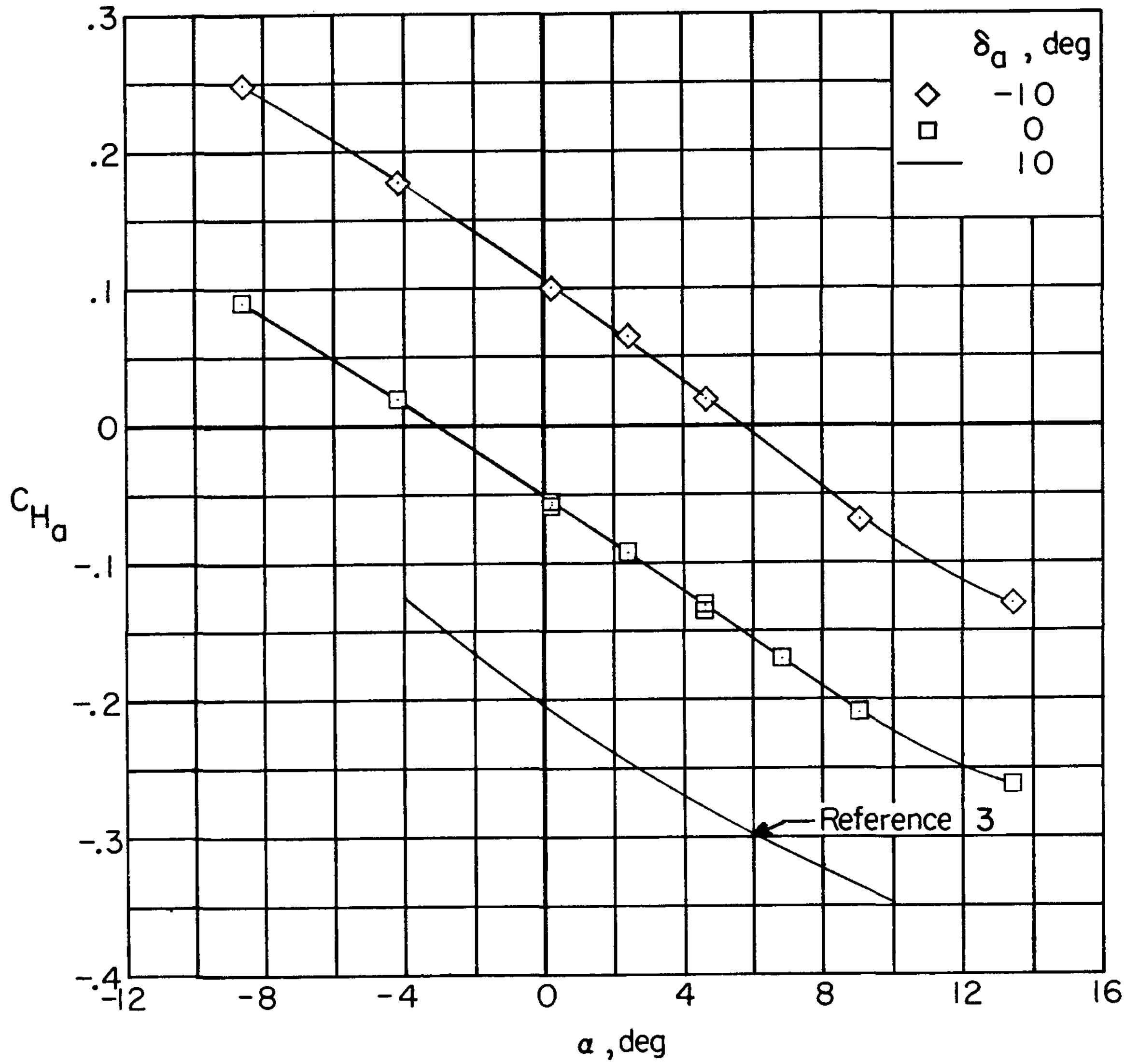

Figure 12.- Aileron hinge-moment coefficient as a function of angle of attack. M = 1.61.

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