NACA

RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF CONTROL CHARACTERISTICS AT TRANSONIC SPEEDS OF A TAPERED 45° SWEPTBACK WING OF ASPECT RATIO 3 HAVING A HORN-BALANCED FULL-SPAN CONTROL

By John G. Lowry and Joseph E. Fikes

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
April 10, 1952

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SUMMARY

An investigation was made at transonic speeds in the Langley high-speed 7- by 10-foot tunnel to determine hinge-moment and effectiveness characteristics of a horn-balanced control on an aspect-ratio-3, 45° sweptback wing. The investigation was extended through the transonic speed range by testing in the high velocity field over a reflection plane on the sidewall of the tunnel.

The results of the investigation indicated that the horn balance was effective at subsonic speeds in reducing the hinge moments of the control but was relatively ineffective at transonic speeds.

INTRODUCTION

The problem of balancing control surfaces has always been one of the more difficult problems associated with providing adequate control for an aircraft. There are several summary reports (references 1 to 4) that cover the problem in the subsonic speed range but only a few data are available at transonic and supersonic speeds. The National Advisory Committee for Aeronautics is at the present time investigating the various types of aerodynamic balances in the transonic speed range. In this investigation no attempt is being made to obtain design data, that is, to determine the amount of balance required to completely balance the surface. The emphasis is being placed, however, on finding which of the conventional balances appears promising at transonic speeds.

The present paper presents one such investigation - a limited study of an unshielded horn balance on an aspect-ratio-3, 45° swept wing. One horn shape was investigated through a limited angle of attack and control deflection range at speeds from Mach number 0.7 to 1.1.

COEFFICIENTS AND SYMBOLS

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

C_l gross rolling-moment coefficient at plane of symmetry $\left(\frac{\text{Rolling moment of semispan model}}{qSb}\right)$

C_h flap hinge-moment coefficient $\left(\frac{\text{Flap hinge moment about hinge line of semispan flap}}{q2M'}\right)$

S twice wing area of basic semispan model, 0.202 square foot

b twice semispan of basic model, 0.778 foot

$\bar{c}$ mean aerodynamic chord of basic wing, 0.269 foot $\left(\frac{2}{S}\int_0^{b/2} c^2\,dy\right)$

M' area moment of semispan flap (without horn) rearward of hinge line about hinge line, 0.000692 foot cubed

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

c local wing chord, feet

y spanwise distance from plane of symmetry

ρ mass density of air, slugs per cubic foot

V free-stream velocity, feet per second

M effective Mach number over span of model

$$\left(\frac{2}{s} \int_0^{b/2} cM_a \, dy\right)$$

M_a average chordwise local Mach number

M_l local Mach number

R Reynolds number of wing based on $\bar{c}$

α angle of attack, degrees

δ flap deflection relative to wing-chord plane, measured in a plane perpendicular to flap hinge axis (positive when trailing edge is down), degrees

Parameters:

$$C_{h_\alpha} = \left(\frac{\partial C_h}{\partial \alpha}\right)_\delta$$

$$C_{h_\delta} = \left(\frac{\partial C_h}{\partial \delta}\right)_\alpha$$

$$C_{L_\delta} = \left(\frac{\partial C_L}{\partial \delta}\right)_\alpha$$

$$C_{l_\delta} = \left(\frac{\partial C_l}{\partial \delta}\right)_\alpha$$

The subscripts outside the parentheses indicate the factors held constant during the measurement of the parameters in the vicinity of $\delta = 0^\circ$ and $\alpha = 0^\circ$, respectively. All the force and moment coefficients are based on the area and span of the basic wing without the horn balance. This allows for easier evaluation with other types of balances (references 5 to 7) that were investigated on the same wing.

MODEL AND APPARATUS

The semispan model used during this investigation was tested on the sidewall reflection plane setup of the Langley high-speed 7- by 10-foot tunnel and had a quarter-chord sweep angle of 45.58°, aspect ratio 3, taper ratio 0.5, and an NACA 64A010 airfoil section measured in a plane at 45° to the plane of symmetry. Pertinent dimensions of the model and the reflection-plane plate are given in figure 1 and a photograph of a typical wing mounted on the reflection plane is shown in figure 2. The wing was equipped with a full-span, plain flap-type control of 25.4 percent of the chord measured parallel to the plane of symmetry. The flap was equipped with a triangular-shaped horn balance having an area equal to 13 percent of the flap area (fig. 3).

The steel model was mounted on an electrical strain-gage balance which was attached to the tunnel wall and shielded from the air stream. A strain-gage beam was attached to the flap hinge pin that indicated the flap hinge moments. The model butt extended through a turntable in the reflection-plane plate with the clearance gap, about 1/16 inch, sealed by a sponge-rubber wiper seal glued to the lower surface of the turntable (references 7 and 8).

TESTS

The tests were made on the sidewall reflection-plane test setup of the Langley high-speed 7- by 10-foot tunnel. The reflection-plane test setup was devised as a method of testing small semispan models through the transonic speed range and utilized the high-velocity flow field over a plate mounted about 3 inches from the tunnel wall. The technique is further described in reference 8.

Typical contours of local Mach number distribution in the vicinity of the model location are shown in figure 4. The contours indicate a Mach number variation over the model of as much as 0.05 at high Mach numbers. No attempt has been made to evaluate the effects of this Mach number variation on the force measurements of this model configuration. The effective test Mach number was obtained from similar contour charts using the relationship

$$M = \frac{2}{S} \int_0^{b/2} cM_a \, dy$$

Lift, rolling-moment, and control hinge-moment data were obtained through a Mach number range of 0.70 to 1.10 and an angle-of-attack range of 0° to 12°. Flap deflections of 0°, ±5, and -10° were covered in the test. A typical variation of Reynolds number with Mach number is presented in figure 5.

CORRECTIONS

The aileron-effectiveness parameters $C_{l_{\delta}}$ presented herein represent the aerodynamic effects on a complete wing produced by the deflection of the control surface on only one semispan of the complete wing. A reflection-plane correction, which accounts for the carry-over of load to the other wing, has been applied to the parameter $C_{l_{\delta}}$ throughout the Mach number range tested. The corrected value of $C_{l_{\delta}}$ was obtained by multiplying the measured value of $C_{l_{\delta}}$ by the correction factor of 0.672 which was obtained from an unpublished experimental investigation at low speed ($M = 0.25$) and theoretical considerations. Although the corrections are based on incompressible conditions, it is believed that the results obtained by applying the correction factor give a better representation of the true conditions than the uncorrected results.

The design of the wing necessitated the use of a long hinge pin extension to accommodate the hinge-moment strain-gage beam. Measurable deflections in torsion were evident when control hinge moments were applied. These deflections were found to be a direct function of the hinge moment applied and control deflections have been corrected accordingly.

RESULTS AND DISCUSSION

Variation of the aerodynamic characteristics with control deflection are shown in figure 6. The effectiveness and hinge-moment parameters obtained from figure 6 are shown in figures 7 and 8. The data for the plain control were obtained from reference 6.

The hinge-moment parameters $C_{h_{\alpha}}$ and $C_{h_{\delta}}$ (fig. 7) indicate that the horn balance provides a positive increment in $C_{h_{\alpha}}$ throughout the speed range investigated, but balances $C_{h_{\delta}}$ only for $M < 1.0$. The ratio of the increments in the $C_{h_{\alpha}}$ and $C_{h_{\delta}}$ in the subsonic range are very similar to those found on unswept wings with unshielded horn balances at low speed (reference 3). The ineffectiveness of the horn in reducing C_{h_δ} above $M = 1.0$ is in agreement with the results of an investigation of a shielded horn on a 35° sweptback wing (reference 9).

The effectiveness parameters C_{L_δ} and C_{l_δ} (fig. 8) show the same variation with Mach number as the plain control, that is, a decrease in effectiveness near a Mach number of 1.00, but the addition of the horn increases the effectiveness throughout the speed range, probably because of the increase of control area.

CONCLUDING REMARKS

An investigation at transonic speeds of a horn-balanced control on an aspect-ratio-3, 45° sweptback wing indicated that the horn balance reduced the hinge moments of the control due to deflection at subsonic speeds, but not in the transonic speed range. The horn balance provided a positive increment in the variation of the hinge-moment coefficient with angle of attack throughout the speed range, and actually resulted in positive values of this parameter at subsonic speeds.

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

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7. Lockwood, Vernard E., and Fikes, Joseph E.: Preliminary Investigation at Transonic Speeds of the Effect of Balancing Tabs on the Hinge-Moment and Other Aerodynamic Characteristics of a Full-Span Flap on a Tapered 45° Sweptback Wing of Aspect Ratio 3. NACA RM L52A23, 1952.

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9. Johnson, Harold I., and Brown, B. Porter: Measurements of Aerodynamic Characteristics of a 35° Sweptback NACA 65-009 Airfoil Model with $\frac{1}{4}$-Chord Horn-Balanced Flap by the NACA Wing-Flow Method. NACA RM L9B23a, 1949.

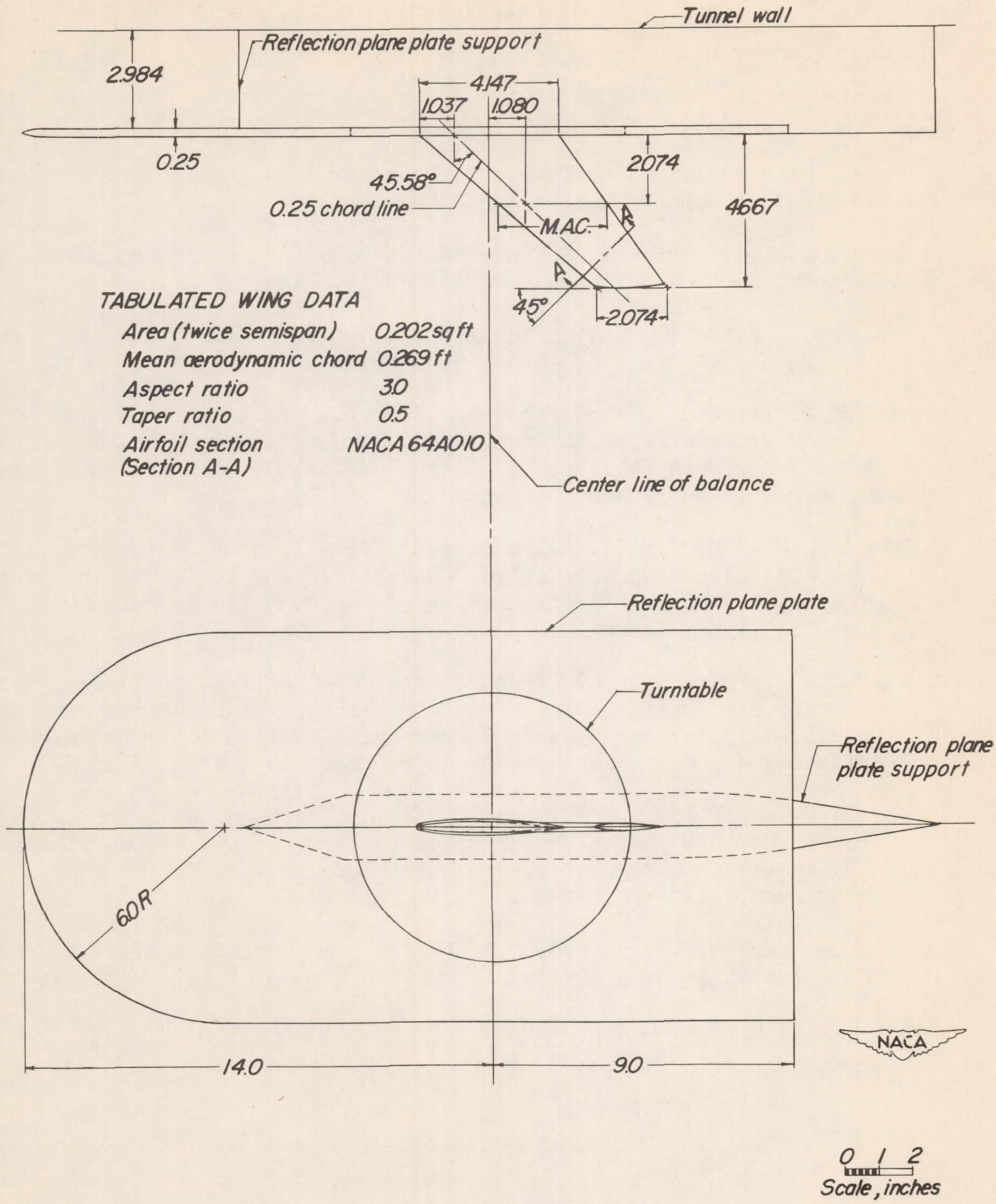


Figure 1.- Basic wing model mounted on the reflection plane in the 7- by 10-foot high-speed tunnel.

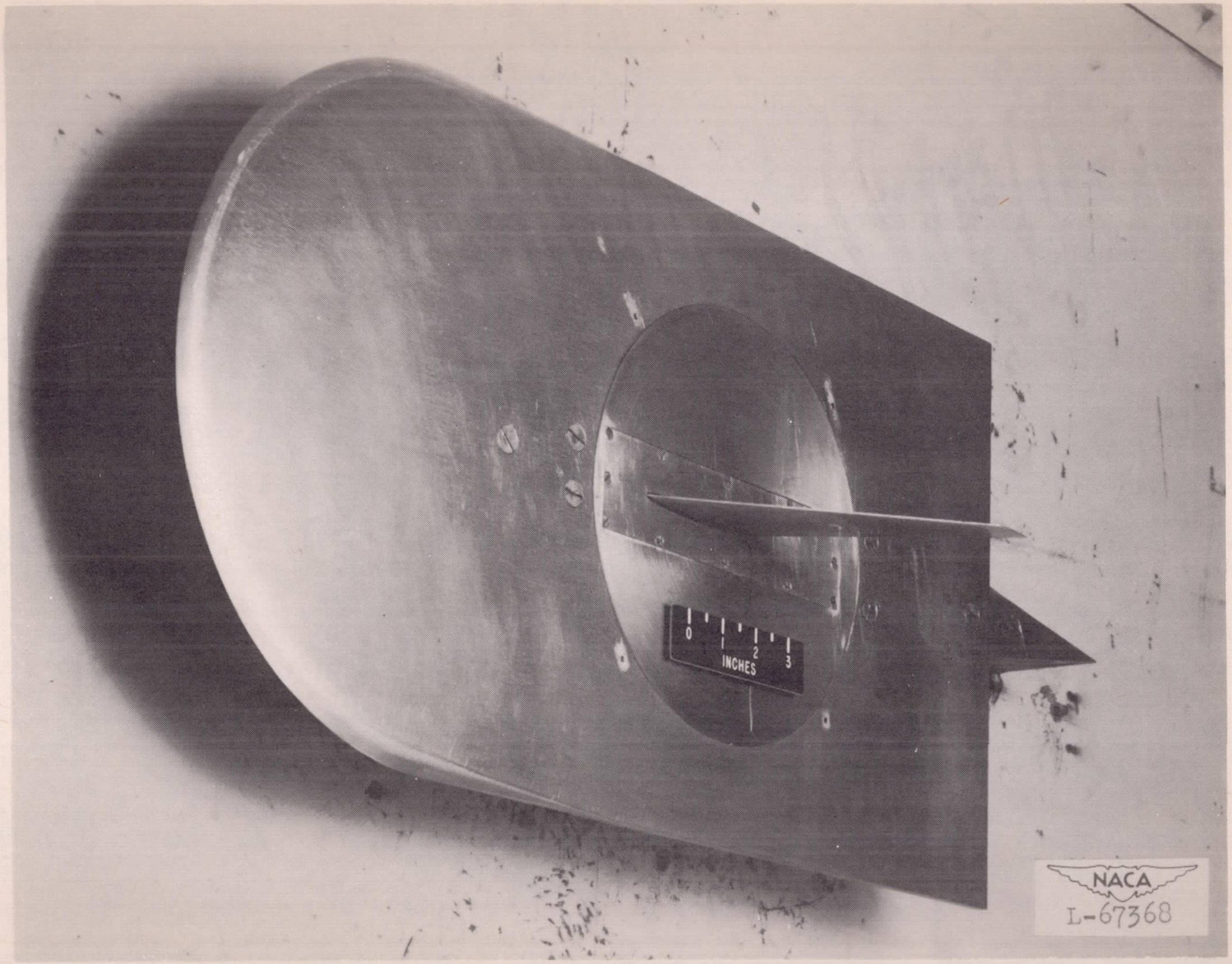


Figure 2.- View of typical model mounted on the reflection plane in the 7- by 10-foot high-speed tunnel.

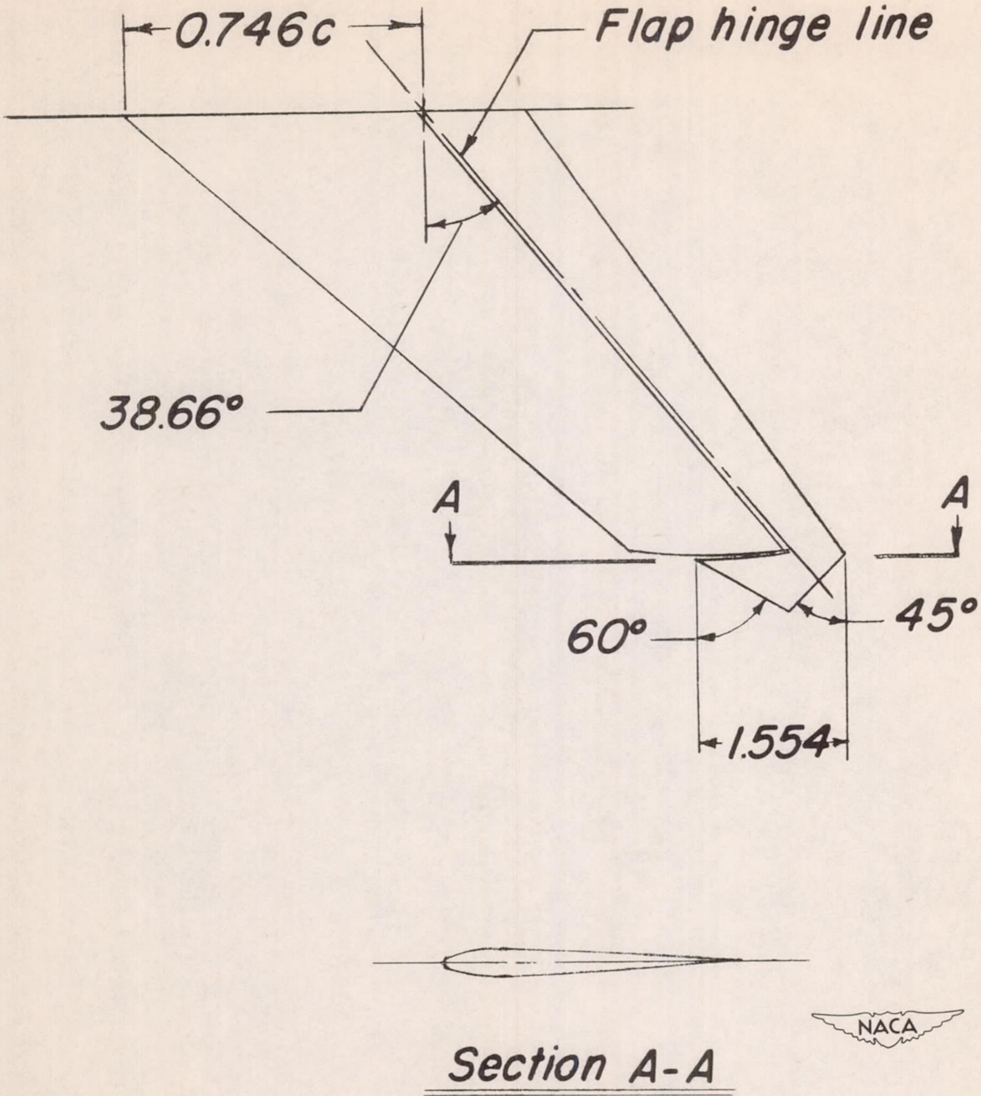


Figure 3.- Details of control tested.

$$\frac{\text{Area of horn}}{\text{Area of flap}} = 0.13$$

$$\frac{\text{Area of horn ahead of hinge line}}{\text{Area of flap and horn behind hinge line}} = 0.10$$

$$\frac{\text{Moment area of horn ahead of hinge line}}{\text{Moment area of flap and horn behind hinge line}} = 0.17$$

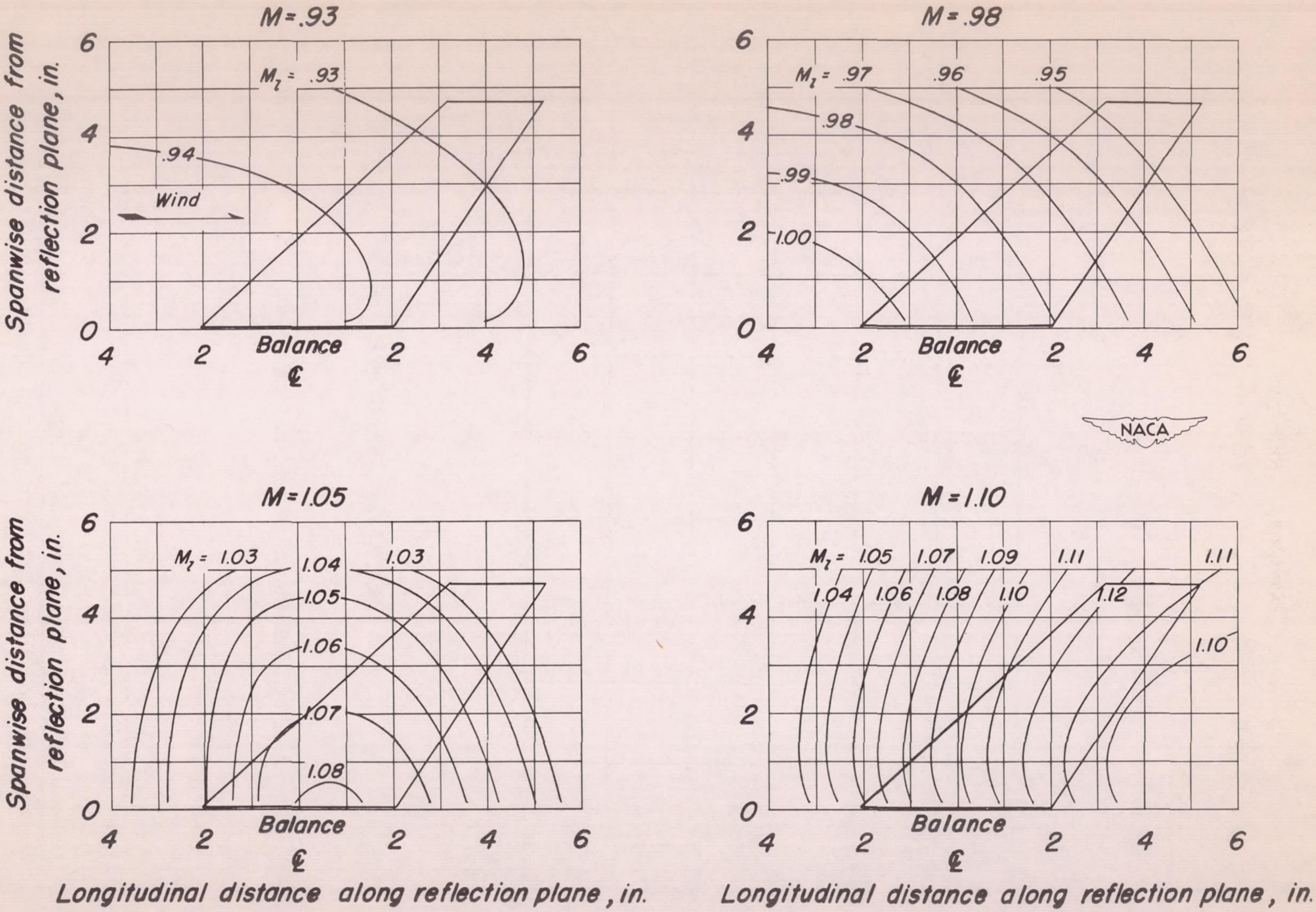


Figure 4.- Typical Mach number contours over the sidewall reflection plane in region of model location.

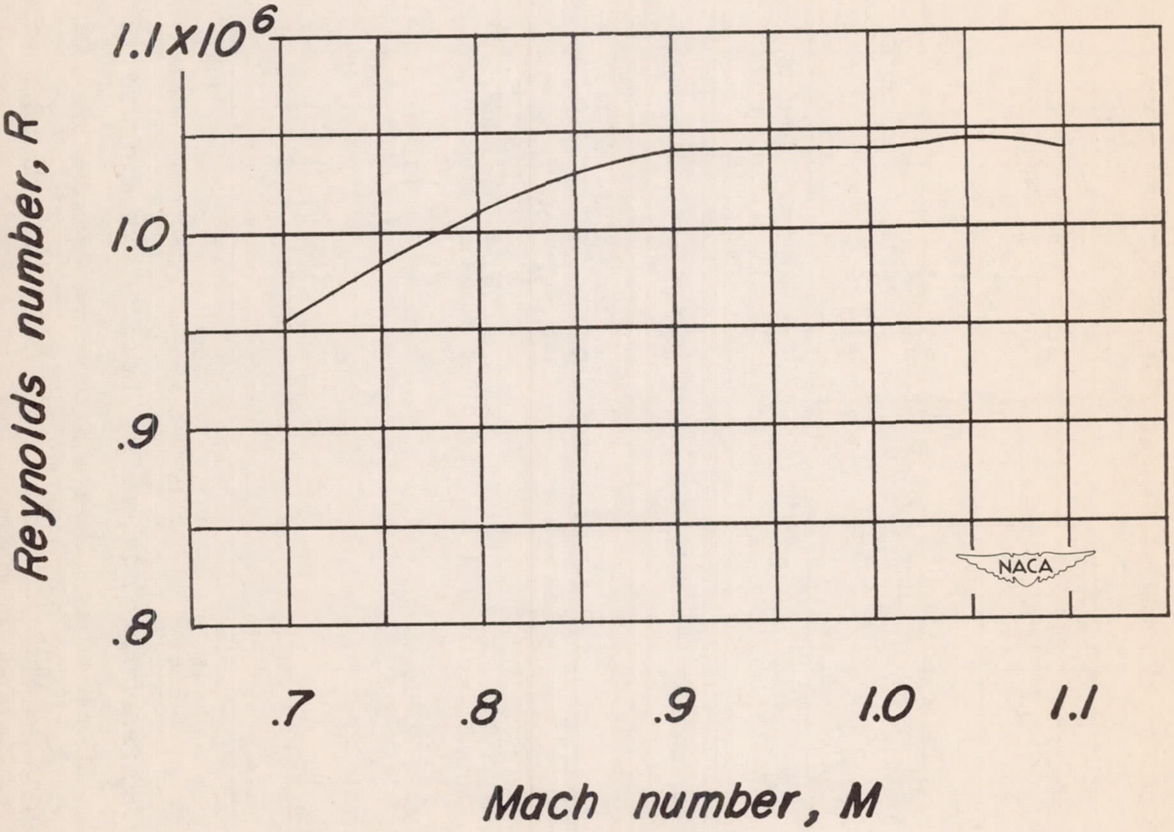
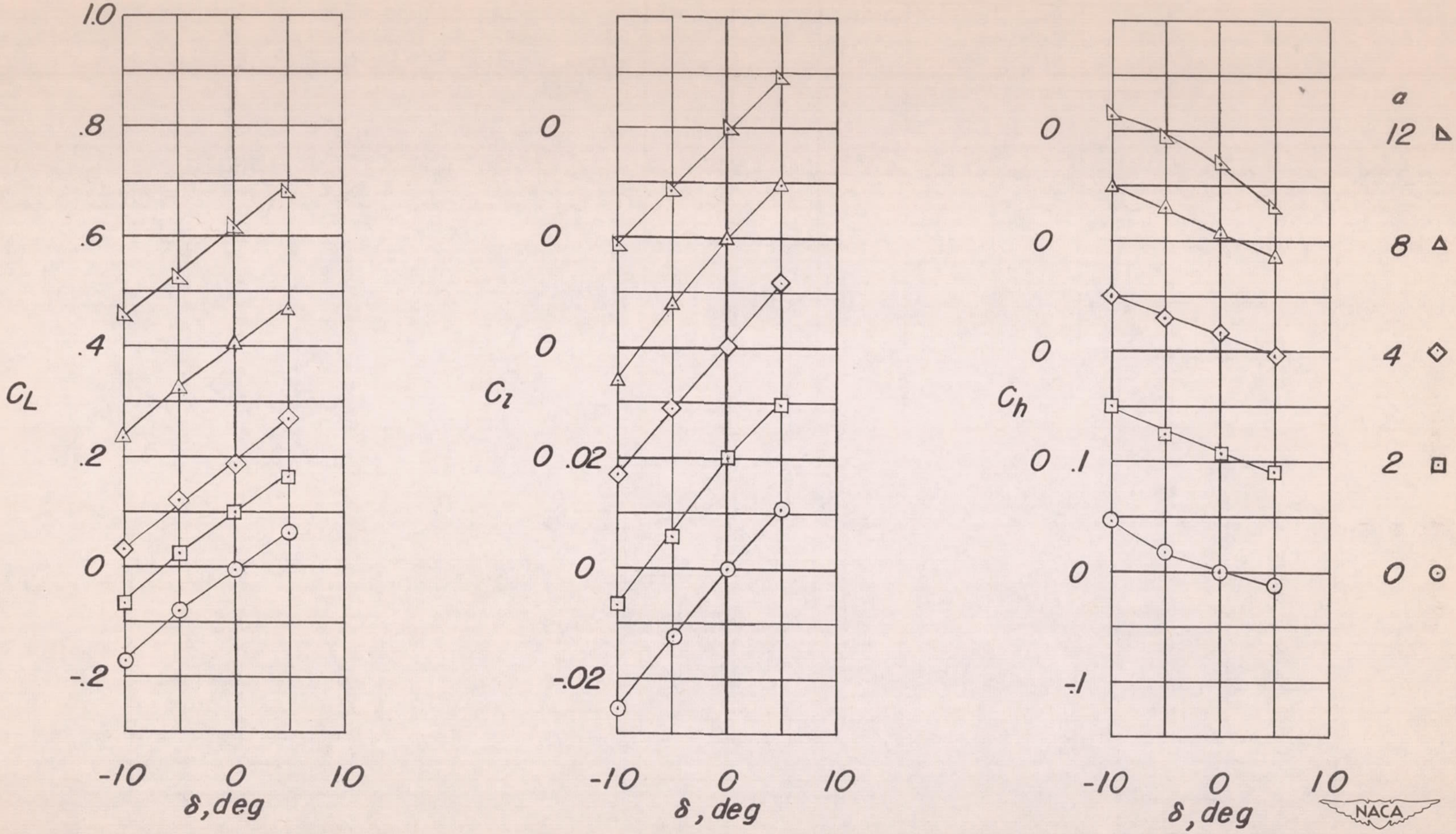
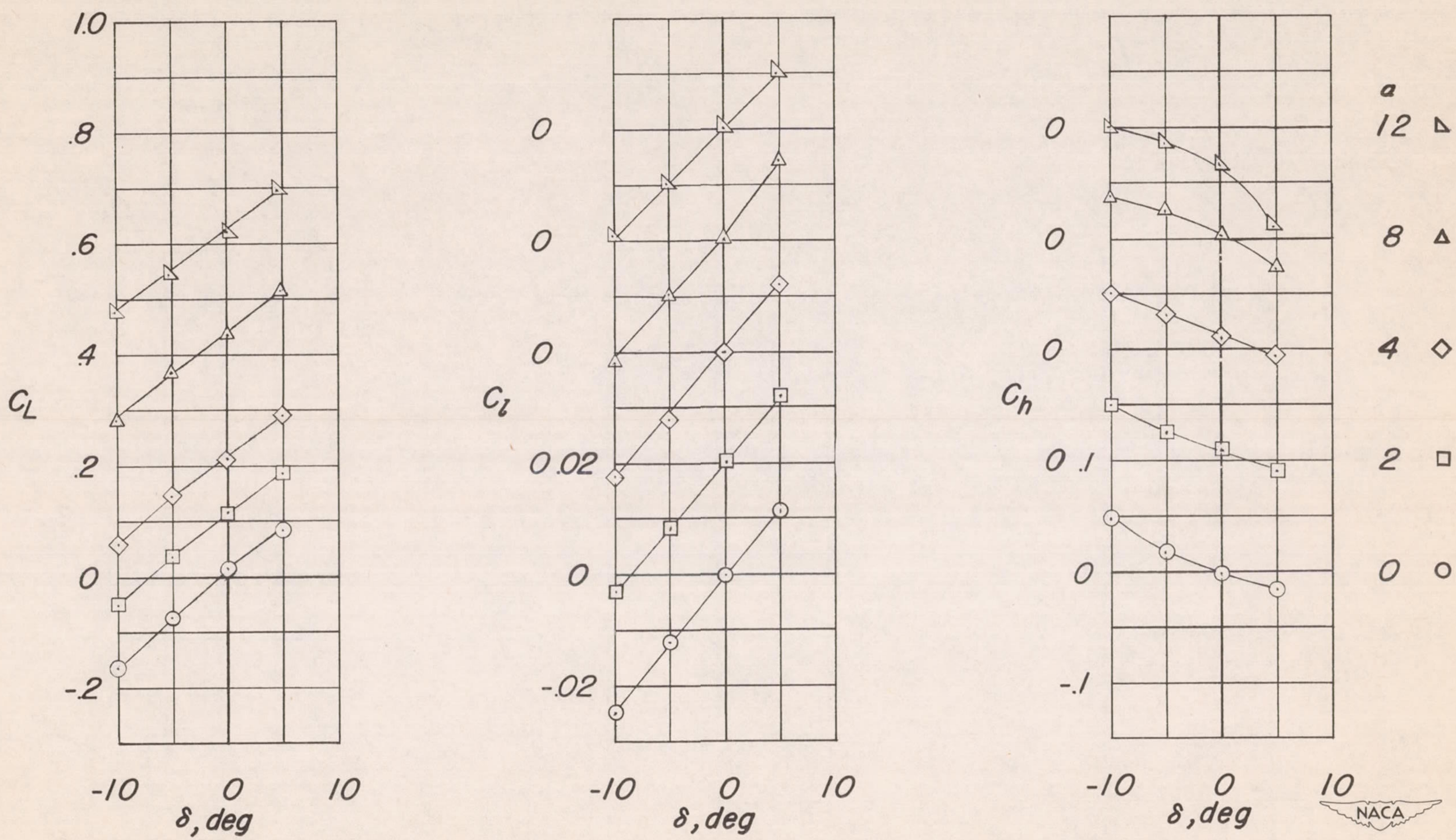


Figure 5.- Typical variation of Reynolds number with test Mach number through the transonic speed range.



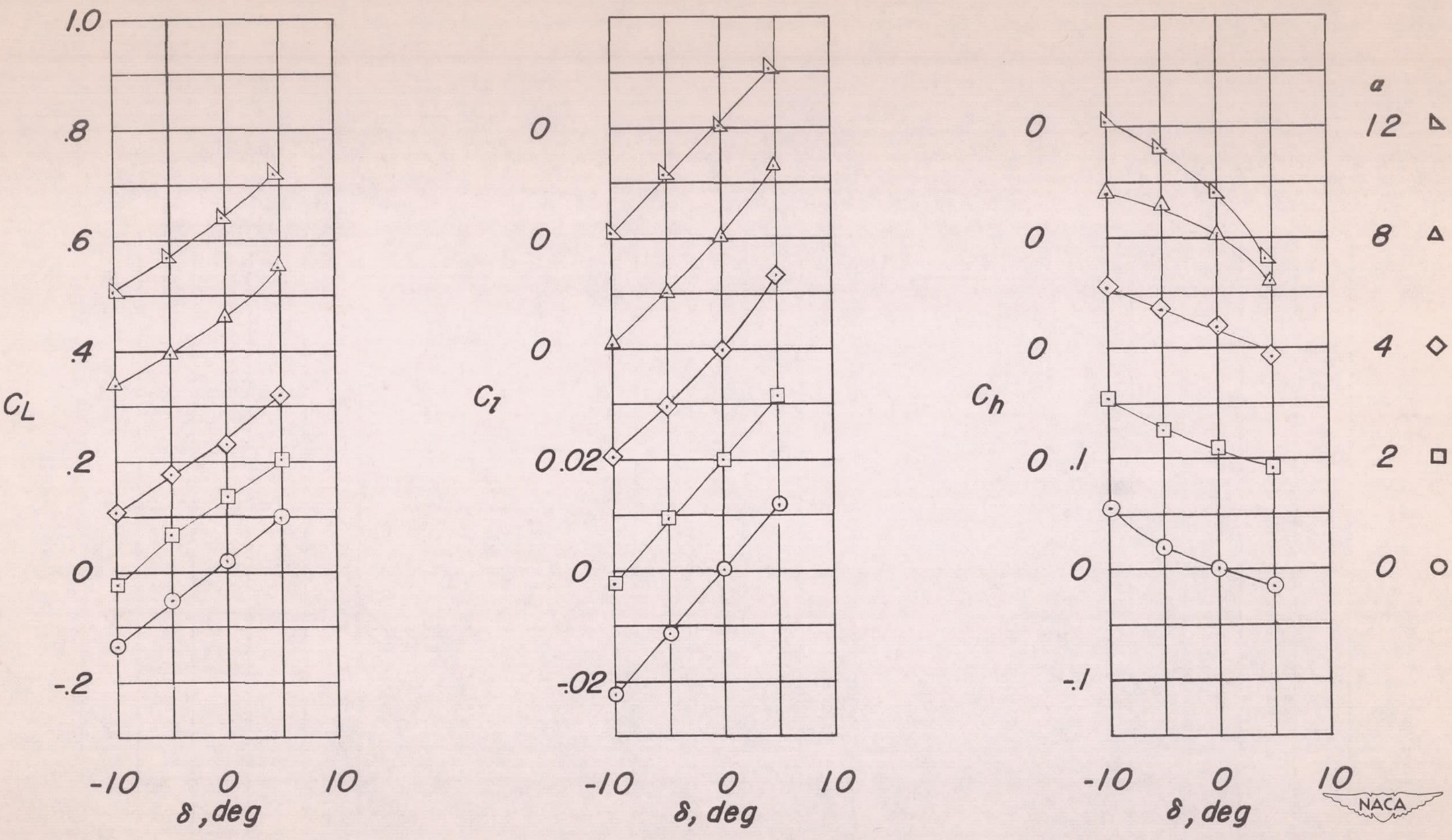
(a) M = 0.70.

Figure 6.- Variation of aerodynamic characteristics with flap deflection for various angles of attack and Mach numbers.



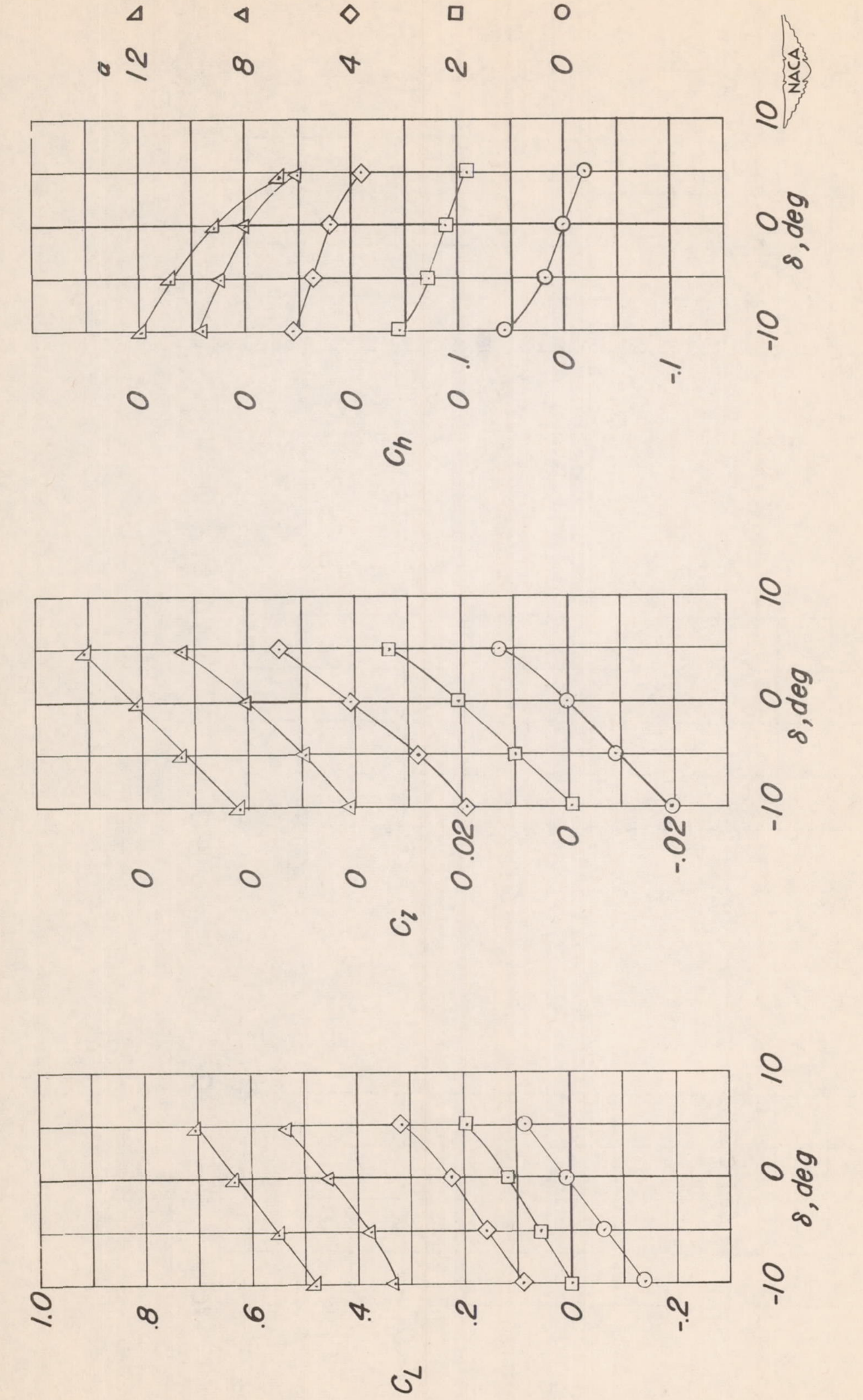
(b) M = 0.80.

Figure 6.- Continued.



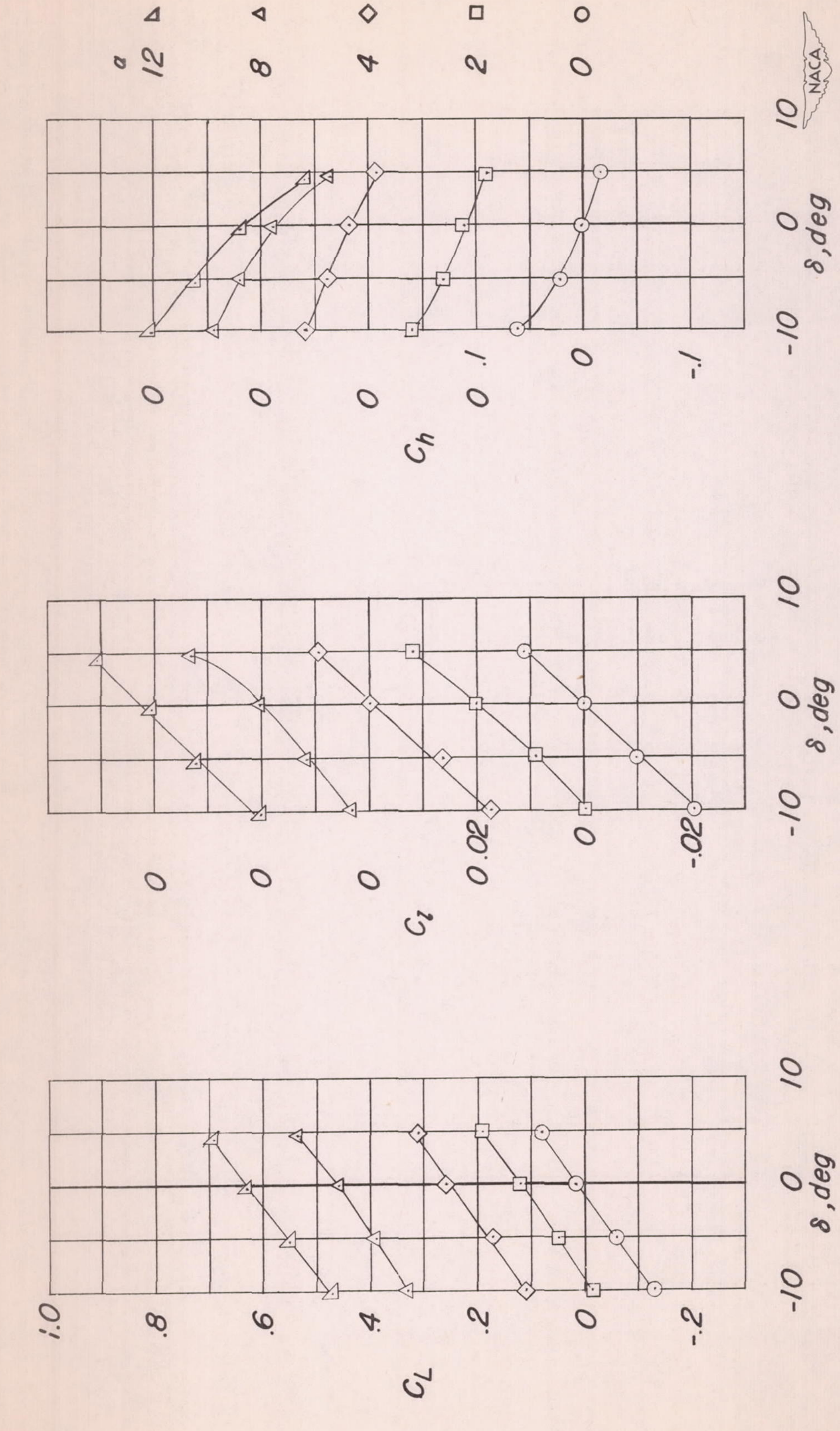
(c) M = 0.90.

Figure 6.- Continued.



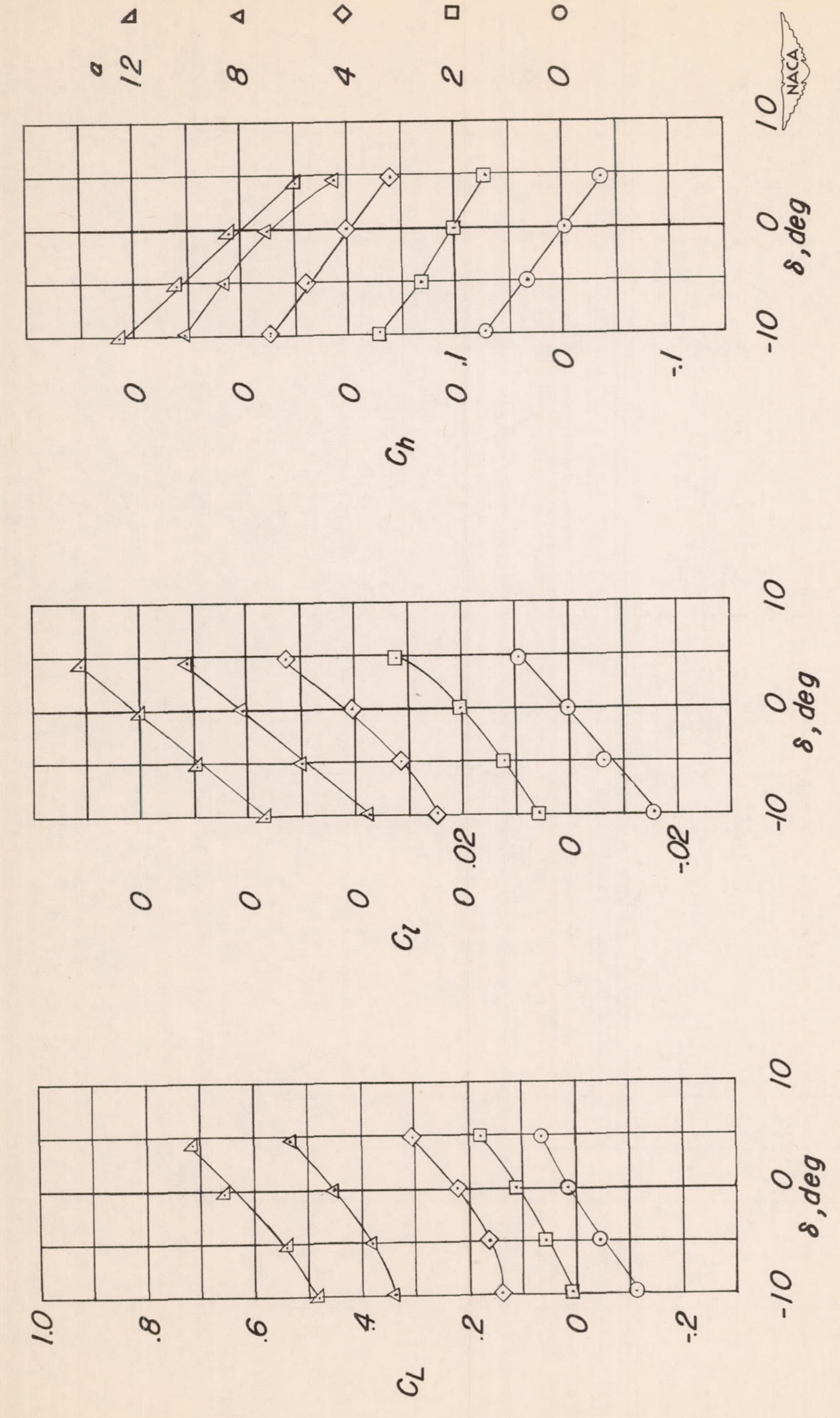
(d) M = 0.93.

Figure 6.- Continued.



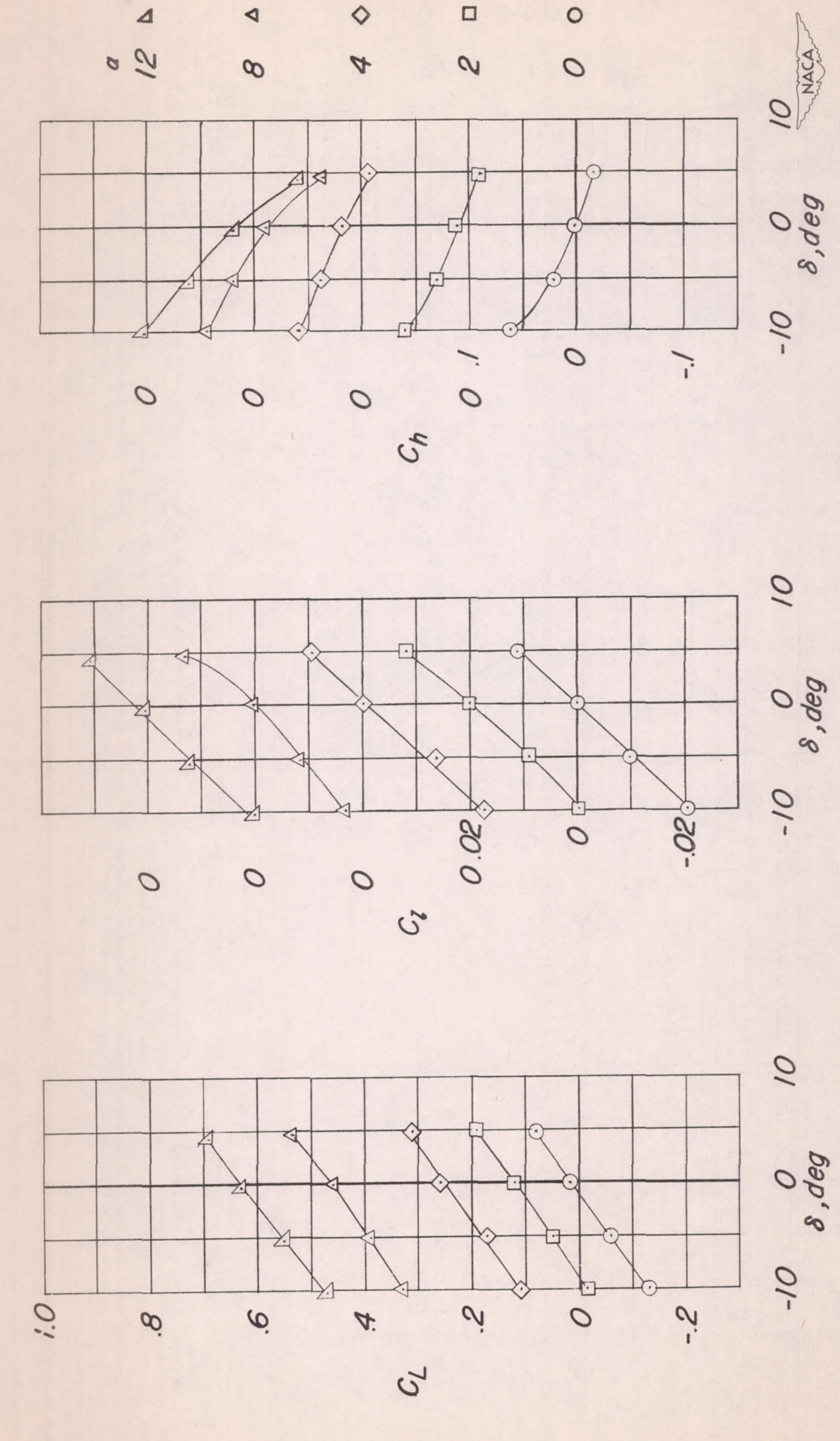
(e) M = 0.96.

Figure 6.- Continued.



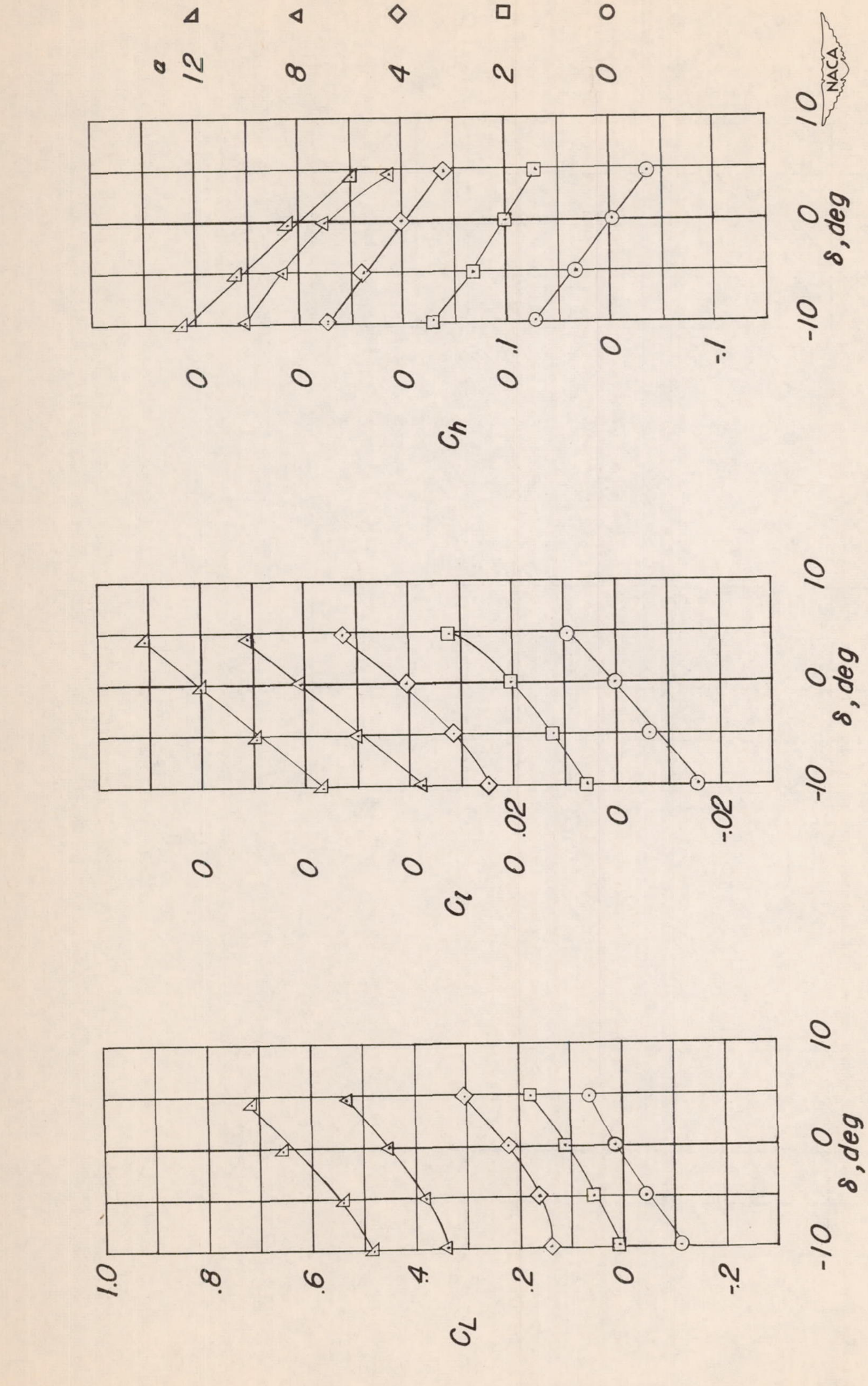
(f) M = 1.00.

Figure 6.- Continued.



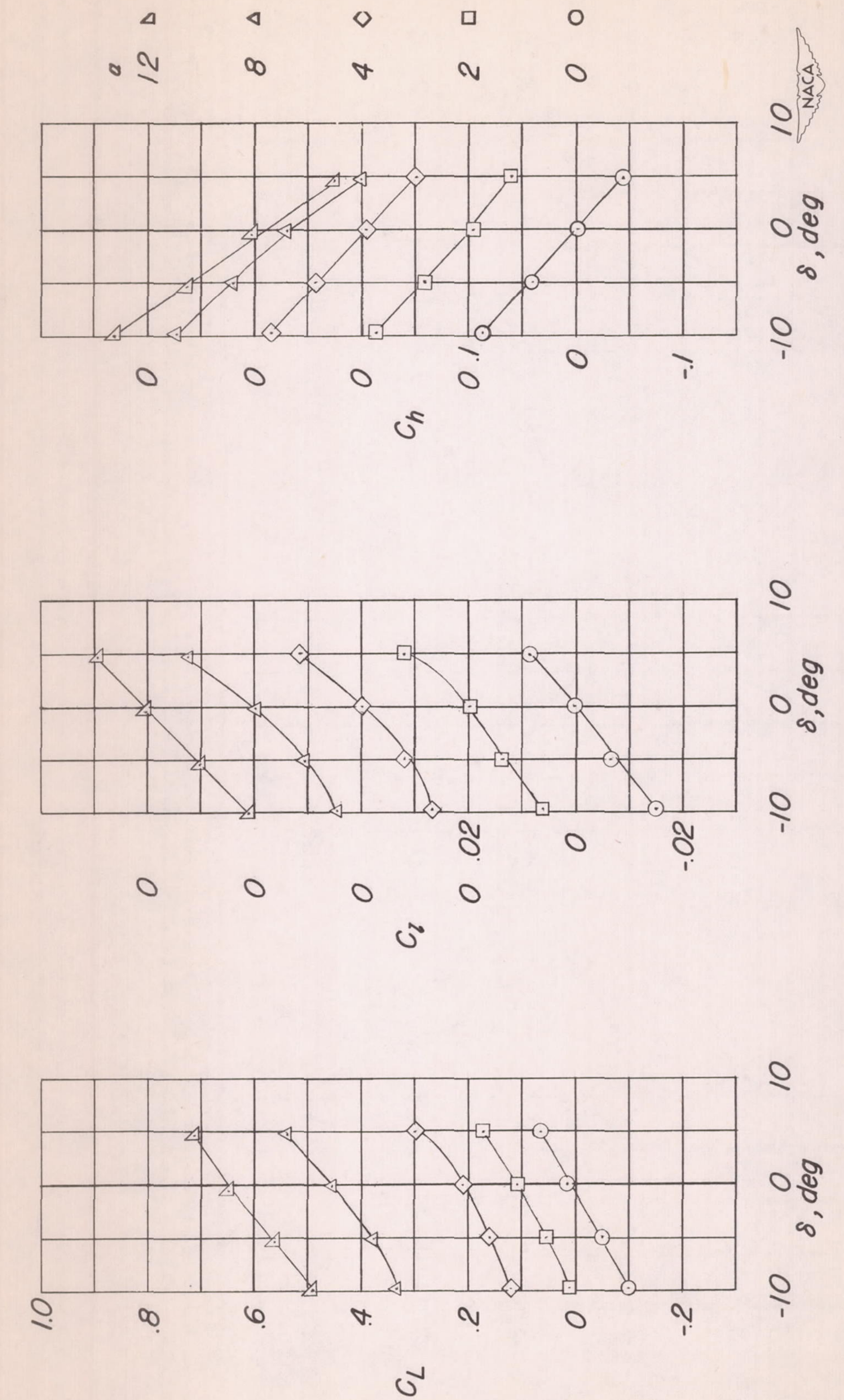
(e) M = 0.96.

Figure 6.- Continued.



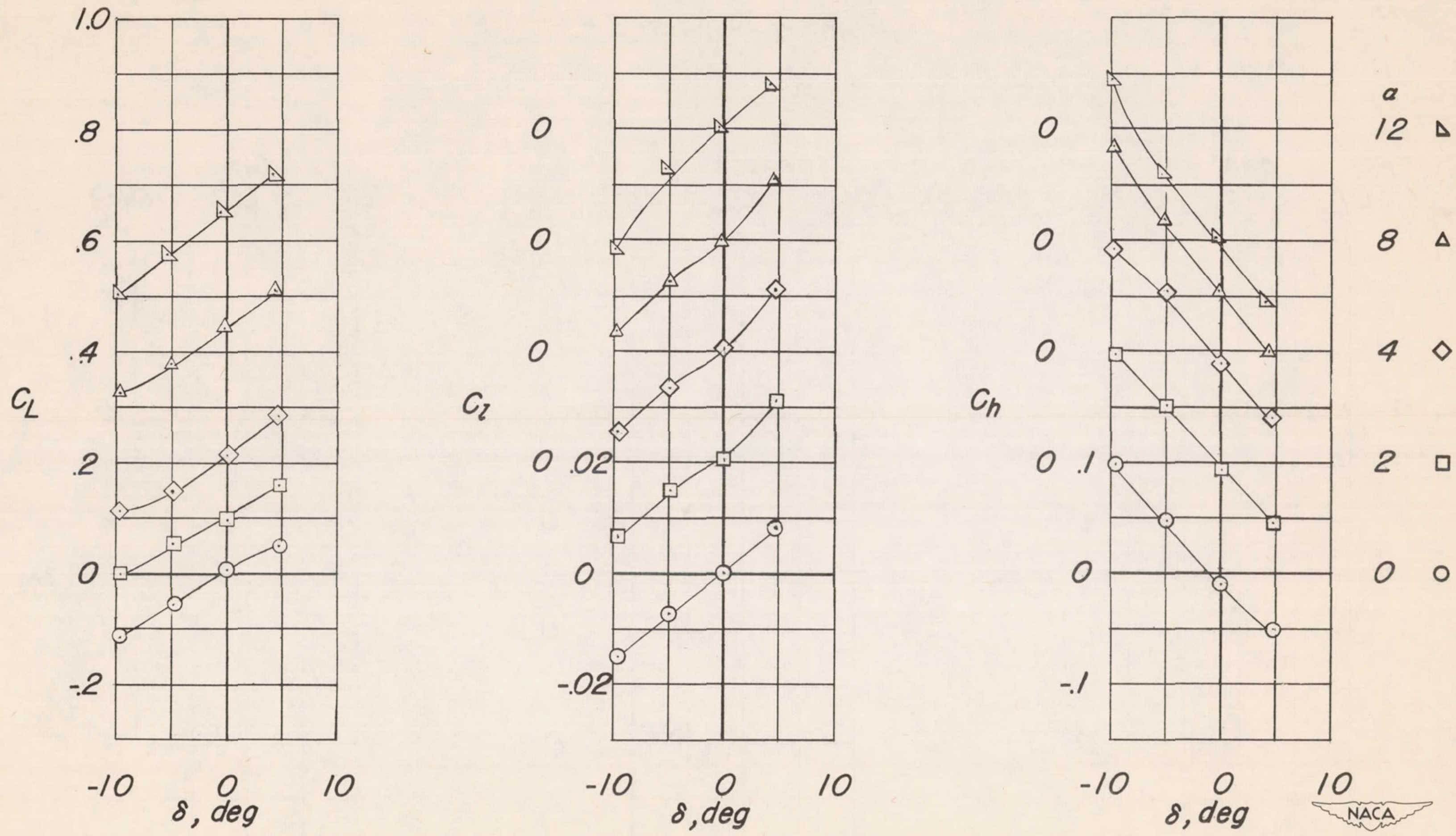
(f) M = 1.00.

Figure 6.- Continued.



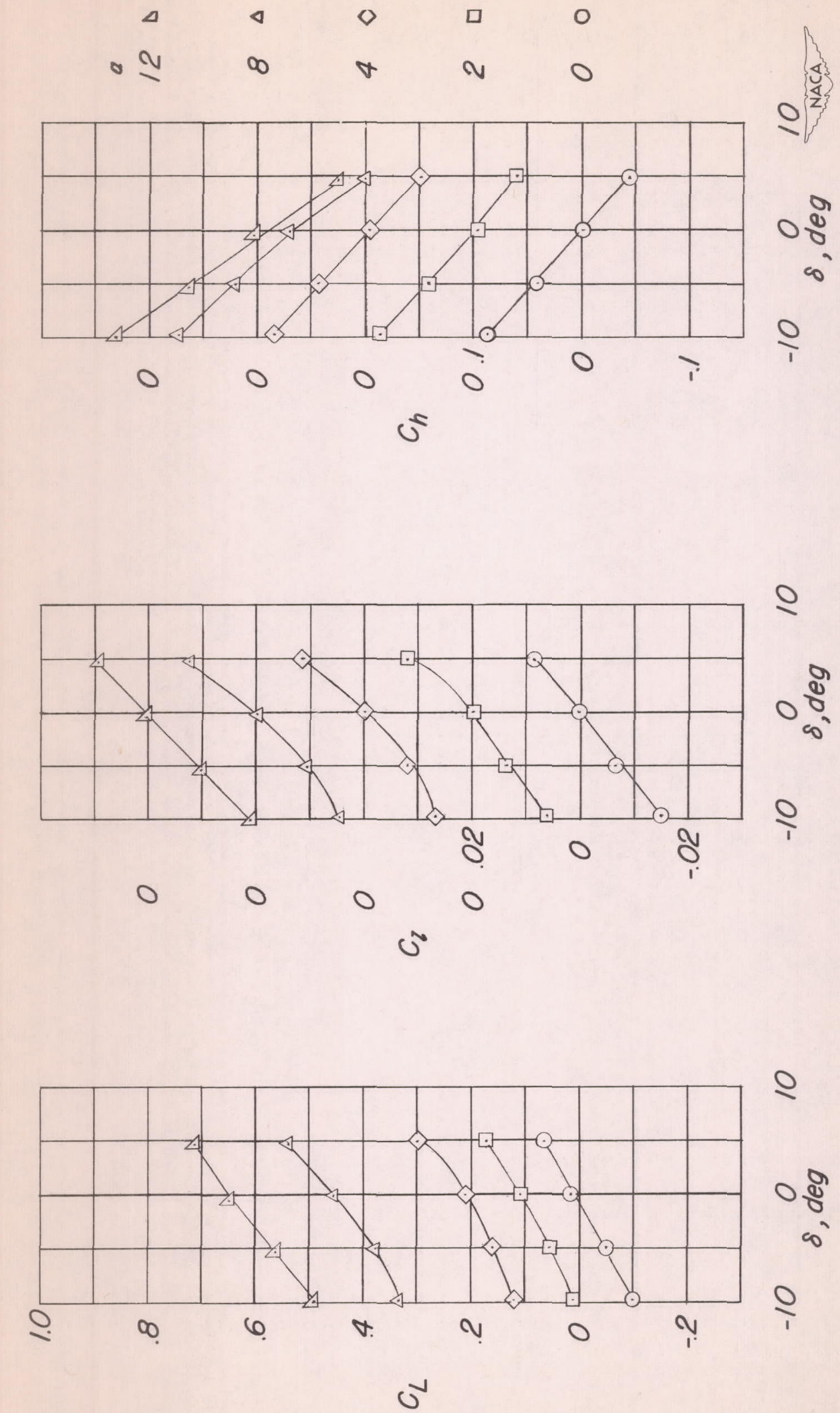
(g) M = 1.05.

Figure 6.- Continued.



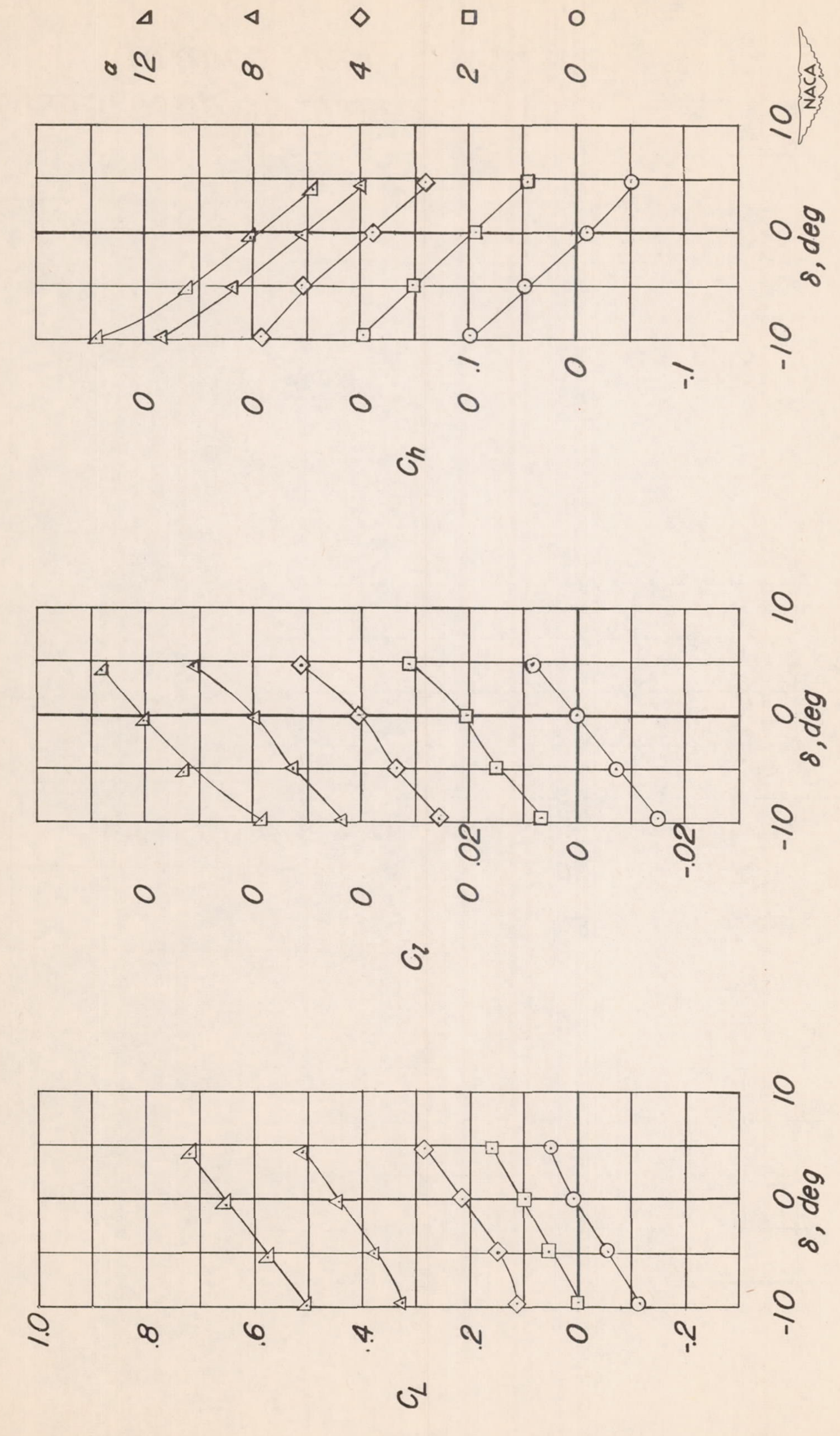
(h) M = 1.10.

Figure 6.- Concluded.



(g) M = 1.05.

Figure 6.- Continued.



(h) M = 1.10.

Figure 6.- Concluded.

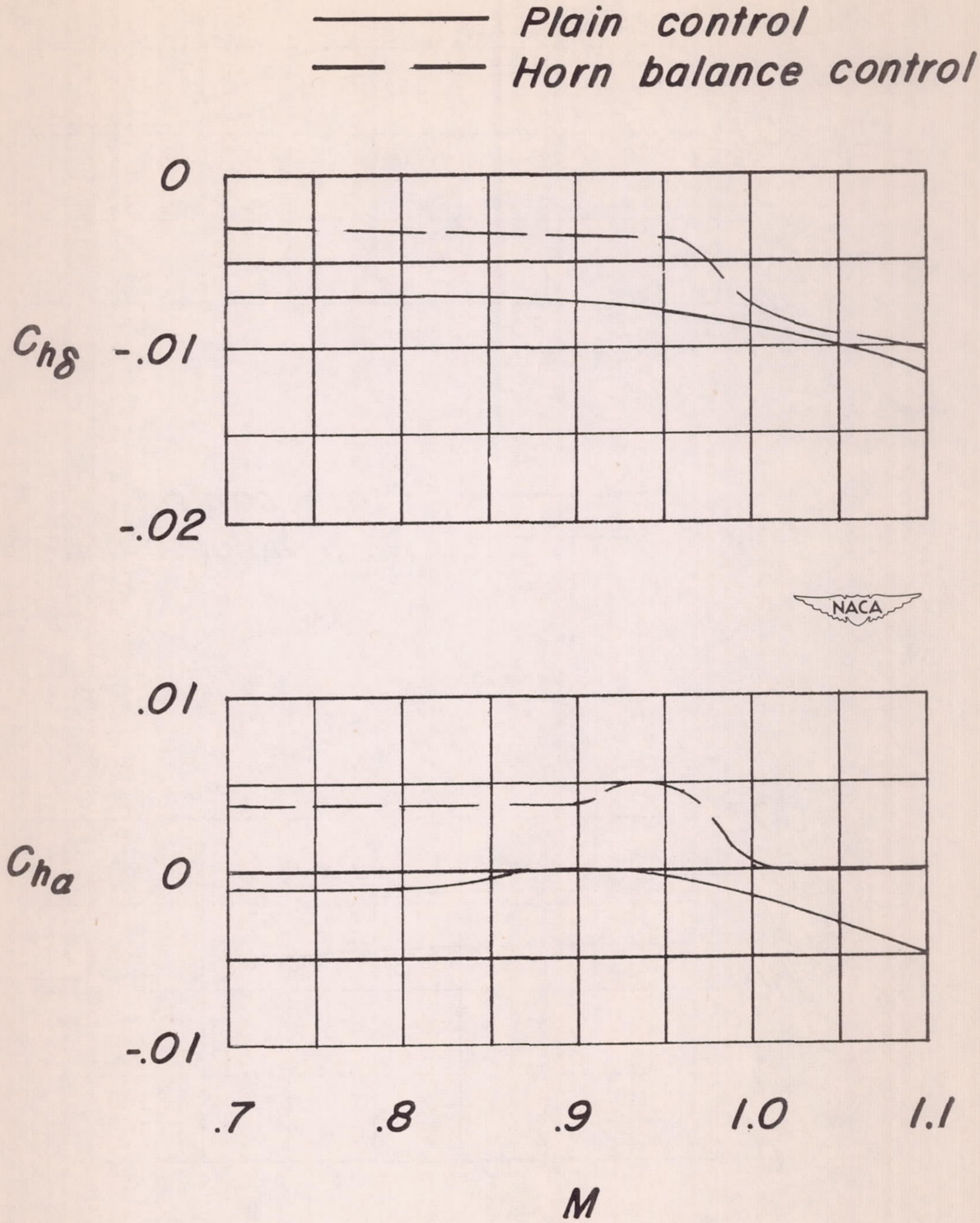


Figure 7.- Variation of hinge-moment parameters with Mach number.

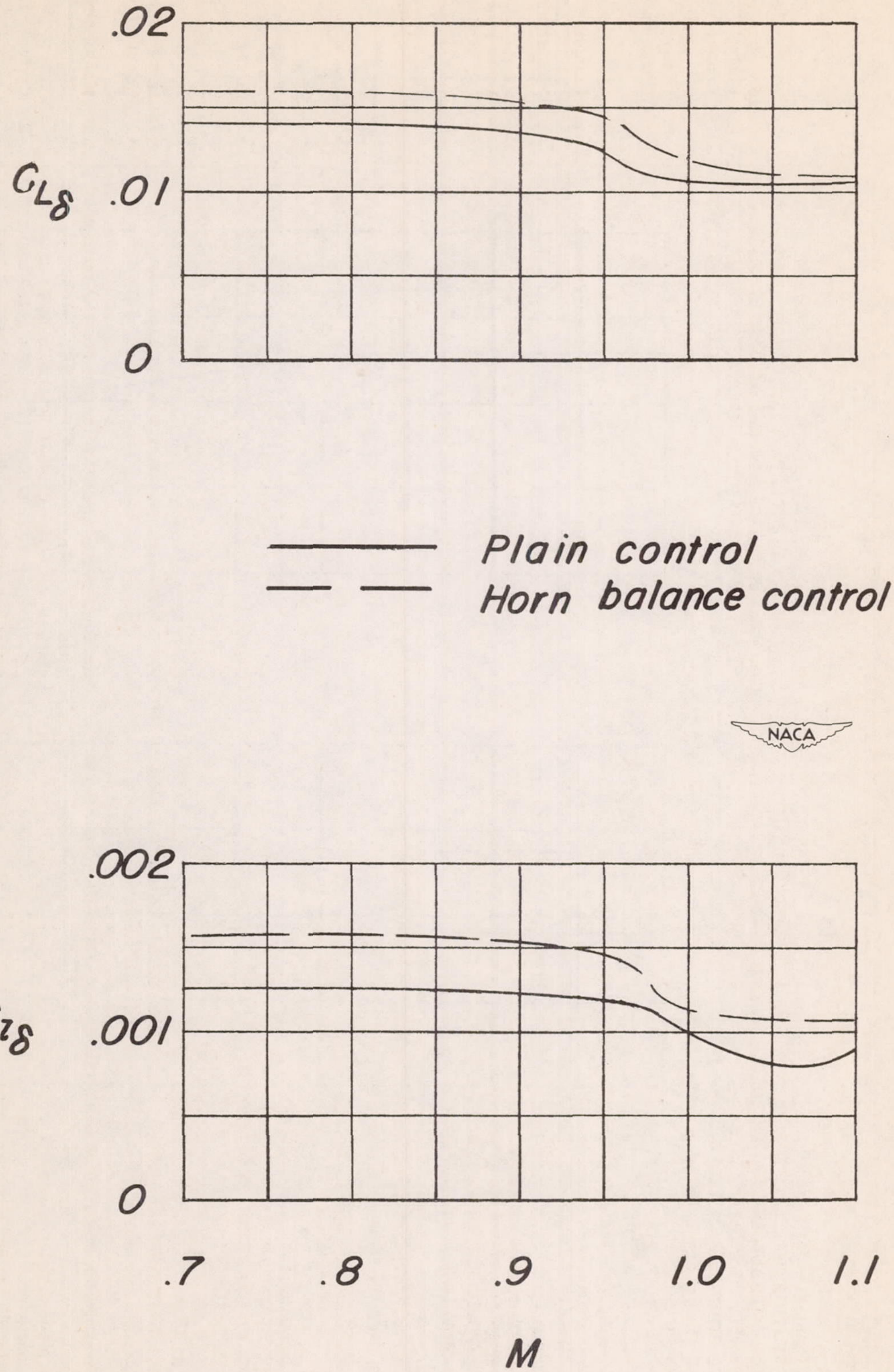


Figure 8.- Variation of lift parameter and aileron-effectiveness parameter with Mach number.