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RESEARCH MEMORANDUM

AERODYNAMIC CHARACTERISTICS AT TRANSONIC SPEEDS OF A TAPERED 45° SWEPTBACK WING OF ASPECT RATIO 3 HAVING A FULL-SPAN FLAP TYPE OF CONTROL WITH OVERHANG BALANCE

TRANSONIC-BUMP METHOD

By Vernard E. Lockwood and John R. Hagerman

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

The aerodynamic characteristics of a wing with a flap and overhanging balance have been determined through a Mach number range from 0.60 to 1.15. The model had a quarter-chord line sweep of 45.58°, an aspect ratio of 3.0, a taper ratio of 0.5, and an NACA 64A010 airfoil section measured in a plane at an angle of 45° to the plane of symmetry. The wing employed a 25.4-percent-chord full-span flap type of control with a 50-percent-chord elliptical-nose overhang for balancing action. The lift, hinge moments, pitching moments, and rolling moments were measured over an angle-of-attack range of -4° to 8° through a control deflection range from -28° to approximately 6°. The investigation was made in the Langley 7- by 10-foot tunnel by use of the transonic bump.

The results indicated that the elliptical overhang balance caused substantial reductions in the hinge moments resulting from angle-of-attack changes when compared with the results of flap without overhang. The overhang also reduced the hinge moments resulting from small deflections of the flap in the subsonic range but not at Mach numbers greater than 1.0. At large deflection, that is, 20°, the elliptical overhang was effective throughout the speed range in reducing the hinge moment due to deflection; appreciable hinge moment, however, still remains. The effects of the overhang on the lift, pitching moment, and aileron effectiveness parameters were small.

INTRODUCTION

Flight and wind-tunnel investigations at transonic speeds have indicated severe changes in control characteristics near sonic velocities. These changes have appeared in the form of large increases in hinge moments, flutter, loss of effectiveness, and, in extreme cases, control reversal (references 1 to 5). In order to find a solution to these problems, the National Advisory Committee for Aeronautics is currently investigating various types of controls and various methods of balancing controls at high subsonic and transonic speeds.

This paper presents the aerodynamic characteristics of low-aspect-ratio sweptback wing having a full-span flap type of control employing an overhanging balance of 50 percent of the flap chord. The main purpose of this investigation was to determine if overhang balances are an effective means of reducing the hinge moments of flap type of controls at transonic speeds. Besides the hinge moment, the lift, pitching-moment and rolling-moment characteristics are presented. The results are given through a flap-deflection range from -28° to approximately 6° for angles of attack of -4°, 0°, 4°, and 8°. The investigation utilized the transonic bump to obtain Mach numbers from 0.60 to 1.15. The results of this investigation are compared herein with the results of a previous investigation (reference 1) of the same wing with an open-gap full-span plain flap.

COEFFICIENTS AND SYMBOLS

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

C_m pitching-moment coefficient referred to $0.25\bar{c}$ $\left(\frac{\text{Twice semispan pitching moment}}{qS\bar{c}}\right)$

C_l rolling-moment coefficient about axis parallel to relative wind and in plane of symmetry $\left(\frac{\text{Rolling moment of semispan model}}{qSb}\right)$

C_h flap hinge-moment coefficient $\left(\frac{\text{Flap hinge moment about hinge line of flap}}{2qM'}\right)$

M' area moment of flap behind hinge line about hinge line for semispan wing, 0.000692 foot cubed

[redacted]

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

S twice wing area of semispan model, 0.202 square foot

b twice span of semispan model, 0.778 foot

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

c local wing chord parallel to plane of symmetry, feet

c_f local flap chord measured in a plane perpendicular to flap hinge line, feet

y spanwise distance from plane of symmetry

V free-stream velocity, feet per second

ρ mass density of air, slugs per cubic foot

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 wing mean aerodynamic chord

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

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

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

$$C_{m_{C_L}} = \left(\frac{\partial C_m}{\partial C_L}\right)_\delta$$

$$C_{m_\delta} = \left(\frac{\partial C_m}{\partial \delta}\right)_\alpha$$

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

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

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The subscripts outside the parentheses indicate the factors held constant during the measurements of the parameter. The slopes of the coefficient curves plotted against angle of attack were obtained from cross plots at zero flap deflection and in the angle-of-attack range of 0° to 4°. The slopes of the coefficient curves against angle of flap deflection were measured over a flap-deflection range of approximately $\pm 4^\circ$.

MODEL AND APPARATUS

The semispan wing used in the investigation had 45.58° of sweepback at the quarter-chord line, an aspect ratio of 3, a taper ratio of 0.5, and an NACA 64A010 airfoil section measured in a plane at 45° to the plane of symmetry. Pertinent dimensions of the basic wing are given in figure 1. The wing was equipped with a 0.254c full-span flap type of control. For balancing purposes a $0.50c_f$ elliptical-nose overhang was attached to the flap ahead of the hinge line. A gap of about 0.003 inch was maintained between wing and flap overhang. The flap was supported by two hinges along its span as shown in figure 1.

The model was constructed of steel and was mounted on an electrical strain-gage balance enclosed in the transonic bump. A strain-gage beam was attached to the end of the flap along the hinge line for measuring the hinge moments. A sponge rubber seal was fastened between the butt of the model and the lower surface of the bump turntable to reduce the flow of air through the slot in the turntable as shown in figure 2.

The model was tested in the Langley high-speed 7- by 10-foot tunnel by utilizing the flow field over the transonic bump to obtain Mach numbers from 0.6 to 1.15. Typical contours of local Mach numbers in the vicinity of the model location on the bump are shown in figure 3. The contours indicate a spanwise local Mach number variation of 0.02 at the lowest Mach numbers and 0.04 at the highest Mach numbers. The chordwise variation is generally less than 0.02. No attempt has been made to evaluate the effects of this chordwise and spanwise Mach number variation. The dashed lines near the root of the wing in figure 3 represent the estimated extent of the bump boundary layer. The effective test Mach number was obtained from contour charts similar to those presented in figure 3 by using the relationship

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

A typical variation of Reynolds number with test Mach number is shown in figure 4.

CORRECTIONS

The rolling-moment coefficients presented in this paper are uncorrected for reflection-plane effects. A reflection-plane correction, however, which accounts for the carry-over of load to the other wing, has been applied to the parameter C_{l_δ} throughout the range of test Mach numbers. The corrected value of C_{l_δ} was obtained by multiplying the measured value of C_{l_δ} by the correction factor 0.672 which was obtained from an unpublished theoretical investigation. The aileron effectiveness parameter C_{l_δ} presented herein represents the aerodynamic effects on a complete wing produced by the deflection of the control on only one semispan of the complete wing. Although the corrections are based on incompressible conditions, it is believed that the results obtained by applying the correction gives a better representation of true conditions than uncorrected data. Application of the correction factor to the data in the manner given results in the values of C_{l_δ} being undercorrected at subcritical Mach numbers and probably overcorrected in the transonic Mach number ($M > 0.95$) range. Flap deflections were corrected for angle change due to strain-gage deflections under load.

RESULTS AND DISCUSSION

Presentation of Data

The results of the investigation are presented in the following figures:

Hinge-Moment Characteristics

The flap of the present investigation (a 0.254c flap with a 50-percent flap-chord elliptical overhang) is shown in figure 6 to have a linear variation of hinge-moment coefficient against angle of attack over a considerable angle range for all Mach numbers tested. The values of the parameter C_{h_α} presented in figure 12 therefore provide a fairly accurate indication of the flap hinge-moment characteristics in pitch over a large range of angle of attack. For the convenience of determining the balancing effect of the overhang, both flap hinge-moment parameters C_{h_α} and C_{h_δ} of the plain flap (without overhang) taken from reference 1 are presented in figure 12. In the subsonic range, $M < 0.9$, the overhang reduced the magnitude of C_{h_α} from -0.0024 to 0. (A value of $C_{h_\alpha} = 0$ in the subsonic range is equivalent to triangular loading over the entire flap for this ratio of flap overhang to flap chord.) In the range of Mach numbers above $M = 0.9$, the overhang is more effective in reducing the magnitude of C_{h_α} but, because of the larger negative values of the plain flap, the hinge moments are not balanced out. It should be noted that for lighter stick forces in maneuvers, more negative values of C_{h_α} are desirable instead of the more positive values provided by the overhang.

The hinge-moment coefficient variation with flap deflection is not linear (fig. 7) and, therefore, the parameter C_{h_δ} presented in figure 12 provides an indication of the characteristics over only a very limited range of deflections, approximately $\pm 4^\circ$. For this small deflection range, the values of C_{h_δ} at subsonic Mach numbers are smaller in magnitude than those of the plain flap of reference 1 and indicate that the overhang is providing some balance as might be expected from experience with unswept wing configurations. At values of $M > 1.0$, however, the overhang produces no noteworthy balancing effects. It is thought that, as the Mach number increases, the balancing decreases as a result of the increased thickness of separation from the edge of the main part of the wing ahead of the flap combined with a change from subsonic flow over the flap to supersonic flow. A loss in balancing action with increased Mach number is also indicated for higher deflections (greater than 5°) in figure 11. These data, however, show that not all of the balancing effect is lost at the high deflections at transonic Mach numbers as $C_{h_{\delta}}$ near zero δ (fig. 12) had indicated. For example, the value of the hinge-moment coefficient for the plain flap for the condition ($\alpha = 0^{\circ}$, $\delta_f = -15^{\circ}$, and $M = 1.15$) is 0.230 as compared with a value of 0.152 for the elliptical overhang flap. This value is equivalent to about a 34-percent reduction in hinge moments. For a purely supersonic loading (that is, rectangular) a reduction of hinge moments of only 25 percent is possible for any 50-percent-chord overhang.

Other Aerodynamic Characteristics

The $0.50c_f$ elliptical overhang showed about the same variation in lift effectiveness with Mach number (fig. 13) as did the plain flap of reference 1. The values of $C_{L_{\delta}}$ were practically constant up to $M = 0.90$ and then decreased as the Mach number was increased to $M = 1.10$. The magnitude of $C_{L_{\delta}}$ was somewhat smaller, however, for the elliptical overhang than for the plain flap. The magnitude of $C_{L_{\alpha}}$ for the overhang flap was about the same as that of the plain flap except for a small range of Mach numbers.

The pitching-moment parameters for the overhang flap (fig. 14) showed a variation with Mach number similar to that of the plain flap of reference 1. The wing aerodynamic center as indicated by the parameters $C_{m_{C_L}}$ indicated a gradual rearward shift up to $M = 0.90$; above this Mach number the shift was more rapid, the center moving rearward about 10 percent of the mean aerodynamic chord in the range of Mach numbers from 0.87 to 1.10. Only a minor change in the flap pitching effectiveness $C_{m_{\delta}}$ with Mach number is shown.

The magnitude and the variation of the aileron effectiveness parameter with Mach number (fig. 15) is about the same for the overhang as for the plain flap of reference 1. The elliptical overhang flap, as for nearly all other flap type of lateral controls, has nearly constant effectiveness through the subsonic range ($M < 0.90$) with decreasing effectiveness through the transonic speed range.

CONCLUSIONS

An investigation at transonic speeds to determine the hinge-moment characteristics of a sweptback wing model equipped with a full-span flap having a 50-percent-chord elliptical overhang indicated the following results when compared with the flap without overhang:

1. The overhang balance was effective in reducing the hinge moment due to angle-of-attack changes throughout the Mach number range tested, the largest reductions being indicated at Mach numbers greater than 0.9.

2. The overhang also reduced the hinge-moments resulting from small deflections of the flap in the subsonic range but not for Mach numbers greater than 1.0. At large deflections, however, the overhang was effective throughout the speed range in reducing the hinge moments due to deflection.

3. The effects of the overhang on the lift, pitching-moment, and aileron effectiveness parameters were small.

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REFERENCES

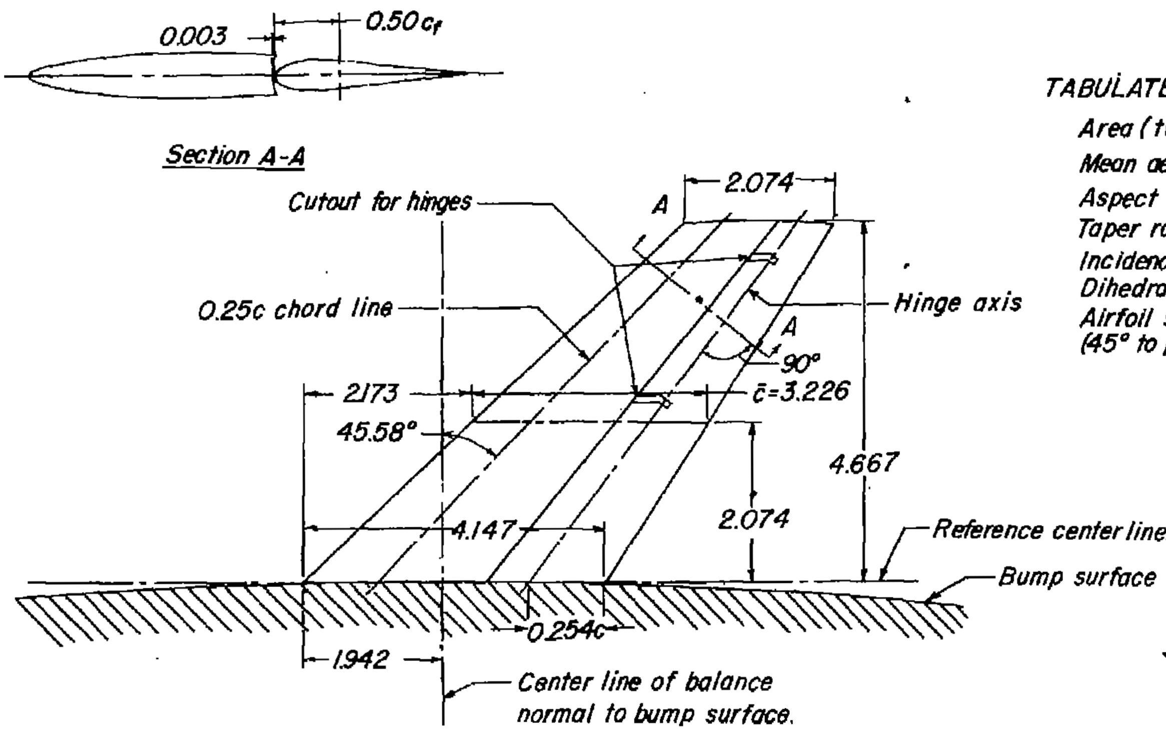
1. Lockwood, Vernard E., and Fikes, Joseph E.: Aerodynamic Characteristics at Transonic Speeds of a Tapered 45° Sweptback Wing of Aspect Ratio 3 Having a Full-Span Flap-Type Control. Transonic-Bump Method. NACA RM L51F06a, 1951.

2. Johnson, Harold I.: Measurements of Aerodynamic Characteristics of a 35° Sweptback NACA 65-009 Airfoil Model with $\frac{1}{4}$-Chord Plain Flap by the NACA Wing-Flow Method. NACA RM L7F13, 1947.

3. 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.

4. 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 Bevelled-Trailing-Edge Flap and Trim Tab by the NACA Wing-Flow Method. NACA RM L9K11, 1950.

5. Thompson, Robert F.: Investigation of a 42.7° Sweptback Wing Model to Determine the Effects of Trailing-Edge Thickness on the Aileron Hinge-Moment and Flutter Characteristics at Transonic Speeds. NACA RM L50J06, 1950.



TABULATED WING DATA

Area (twice semispan)	0.202 sq ft
Mean aerodynamic chord	0.269 ft
Aspect ratio	3.0
Taper ratio	0.5
Incidence	0.0°
Dihedral	0.0°
Airfoil section (45° to plane of symmetry)	NACA 64A010

Figure 1.- General arrangement of model. (All dimensions are in inches except where noted.)

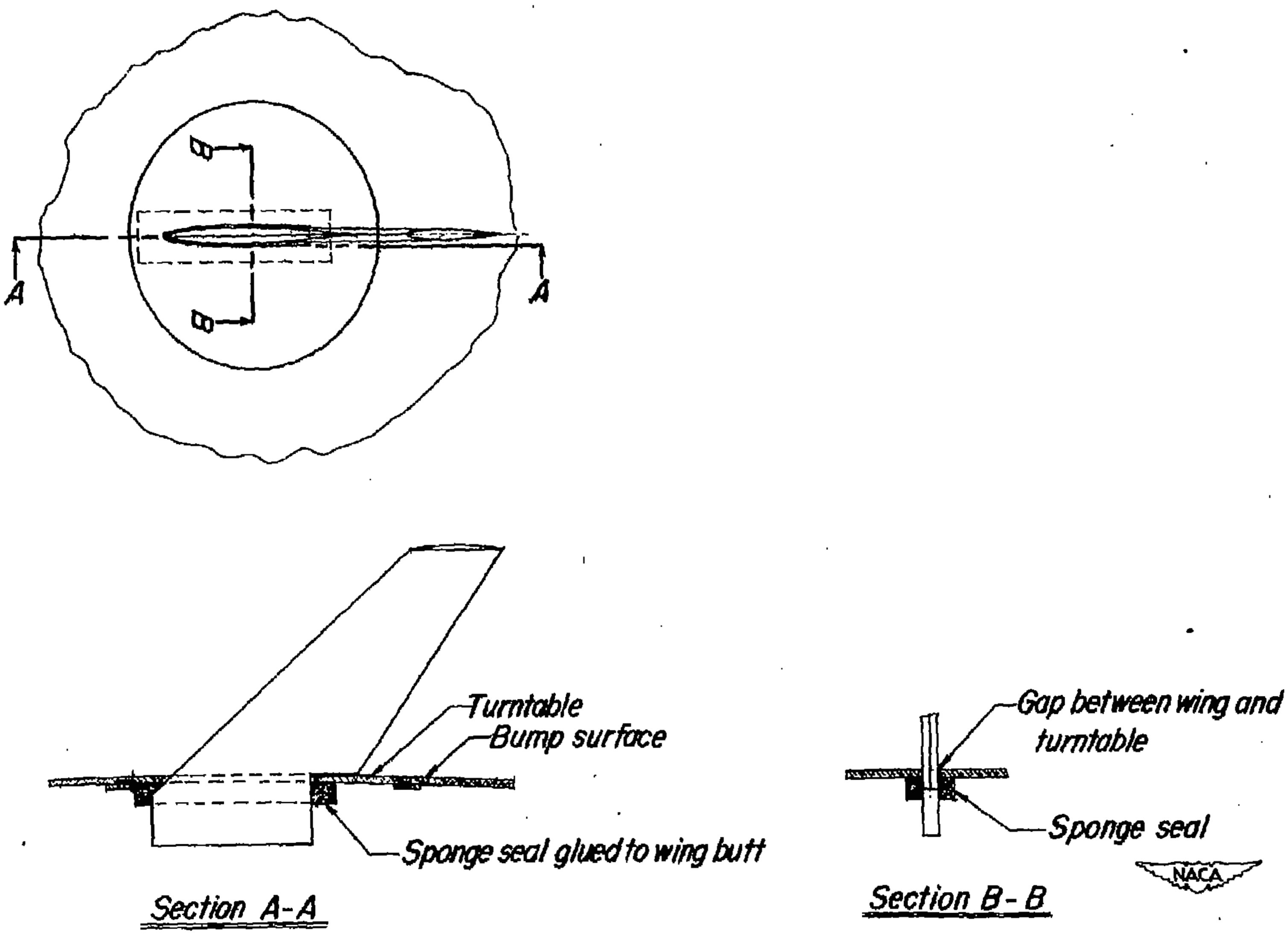


Figure 2.- Detail of sponge seal fastened to wing butt.

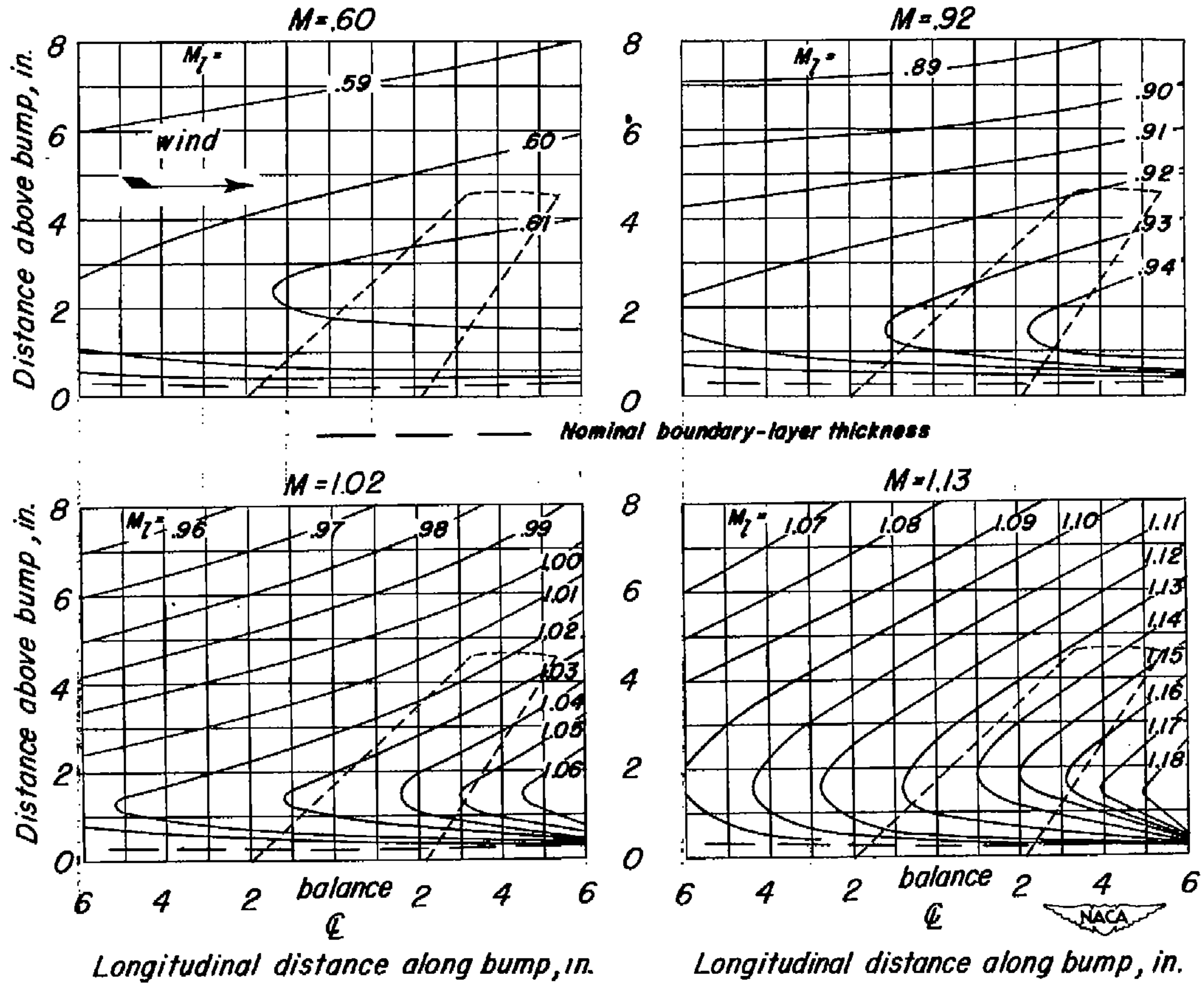


Figure 3.- Typical Mach number contour over transonic bump in region of model location.

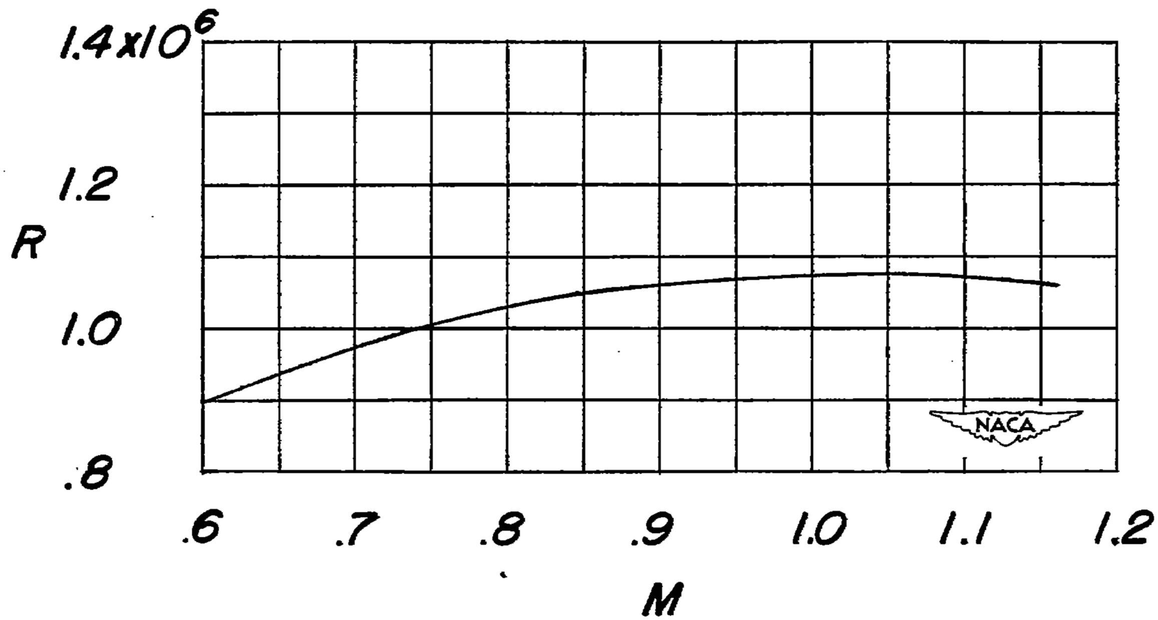


Figure 4.- Typical variation of Reynolds number with test Mach number through the transonic speed range.

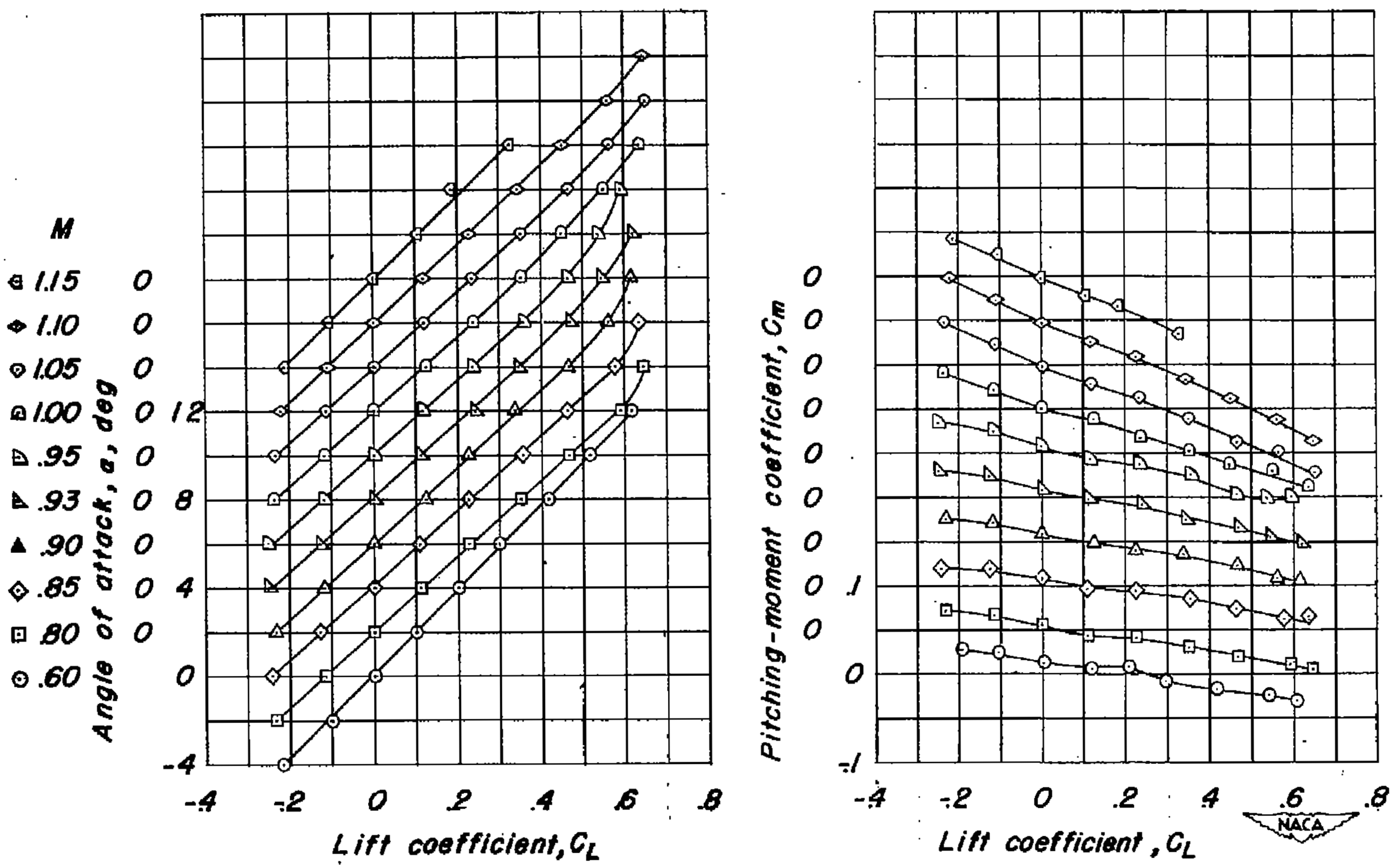


Figure 5.- Variation of angle of attack and pitching-moment coefficient with lift coefficient for various Mach numbers. $\delta = 0°$.

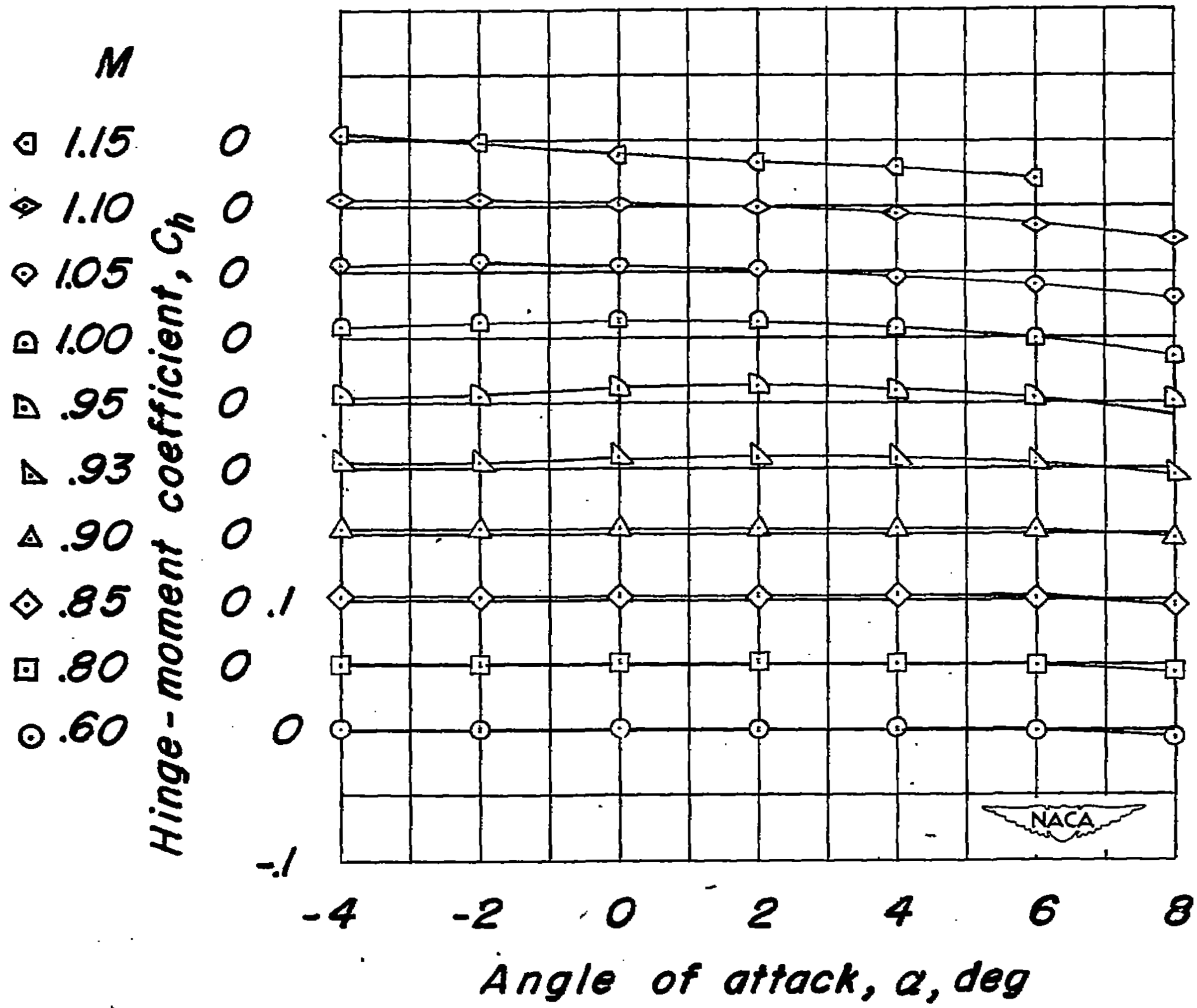
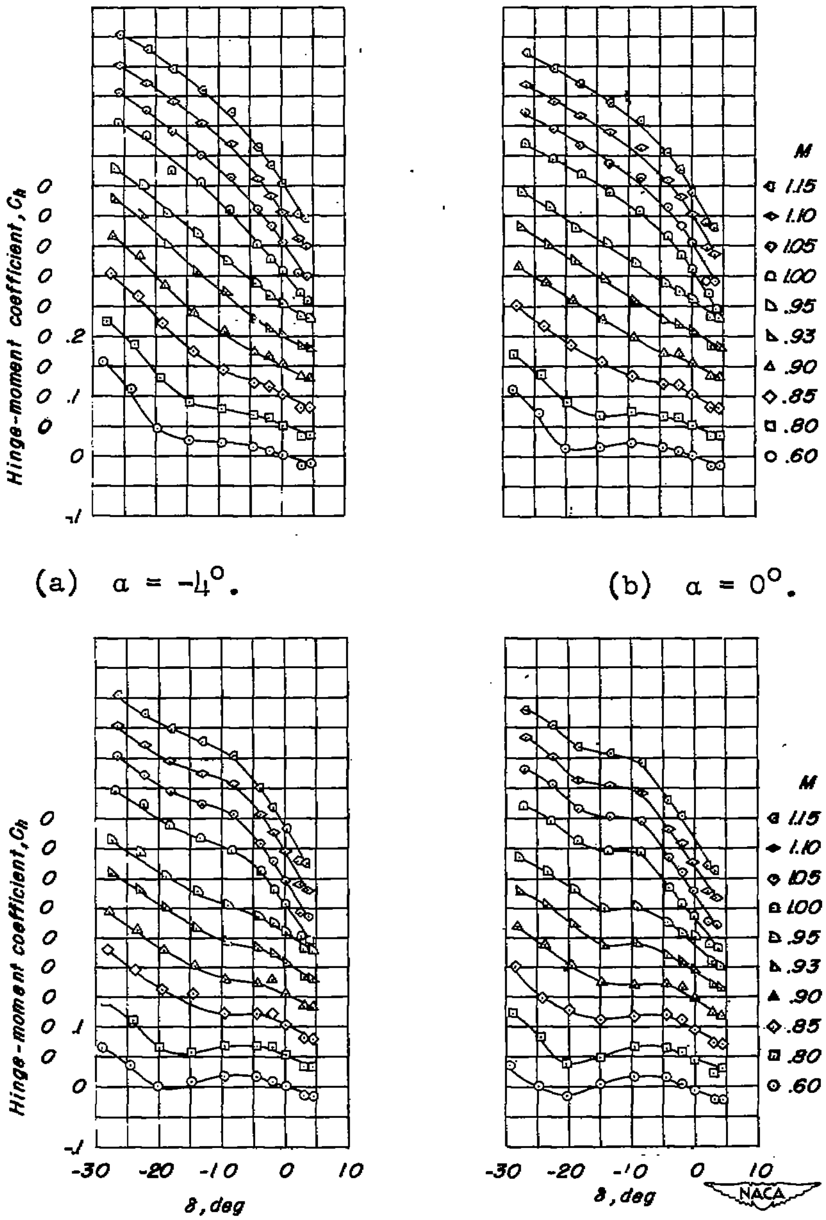


Figure 6.- Variation of hinge-moment coefficient with angle of attack for various Mach numbers. $\delta = 0^{\circ}$.



(a) $\alpha = -4^{\circ}$. (b) $\alpha = 0^{\circ}$.

(c) $\alpha = 4^{\circ}$. (d) $\alpha = 8^{\circ}$.

Figure 7.- Variation of hinge-moment coefficient with flap deflection for various Mach numbers and angles of attack.

[redacted]

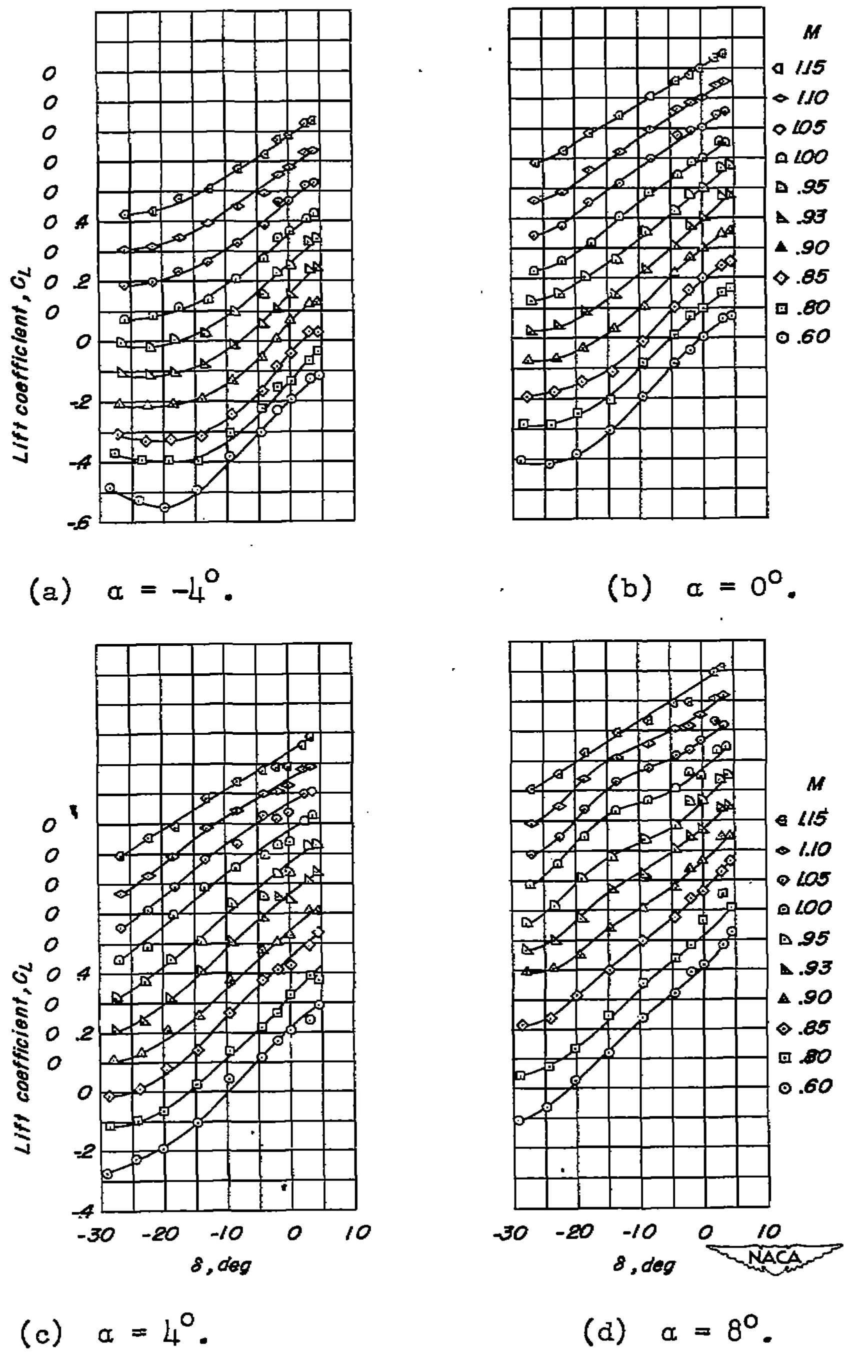


Figure 8.- Variation of lift coefficient with flap deflection for various Mach numbers and angles of attack.

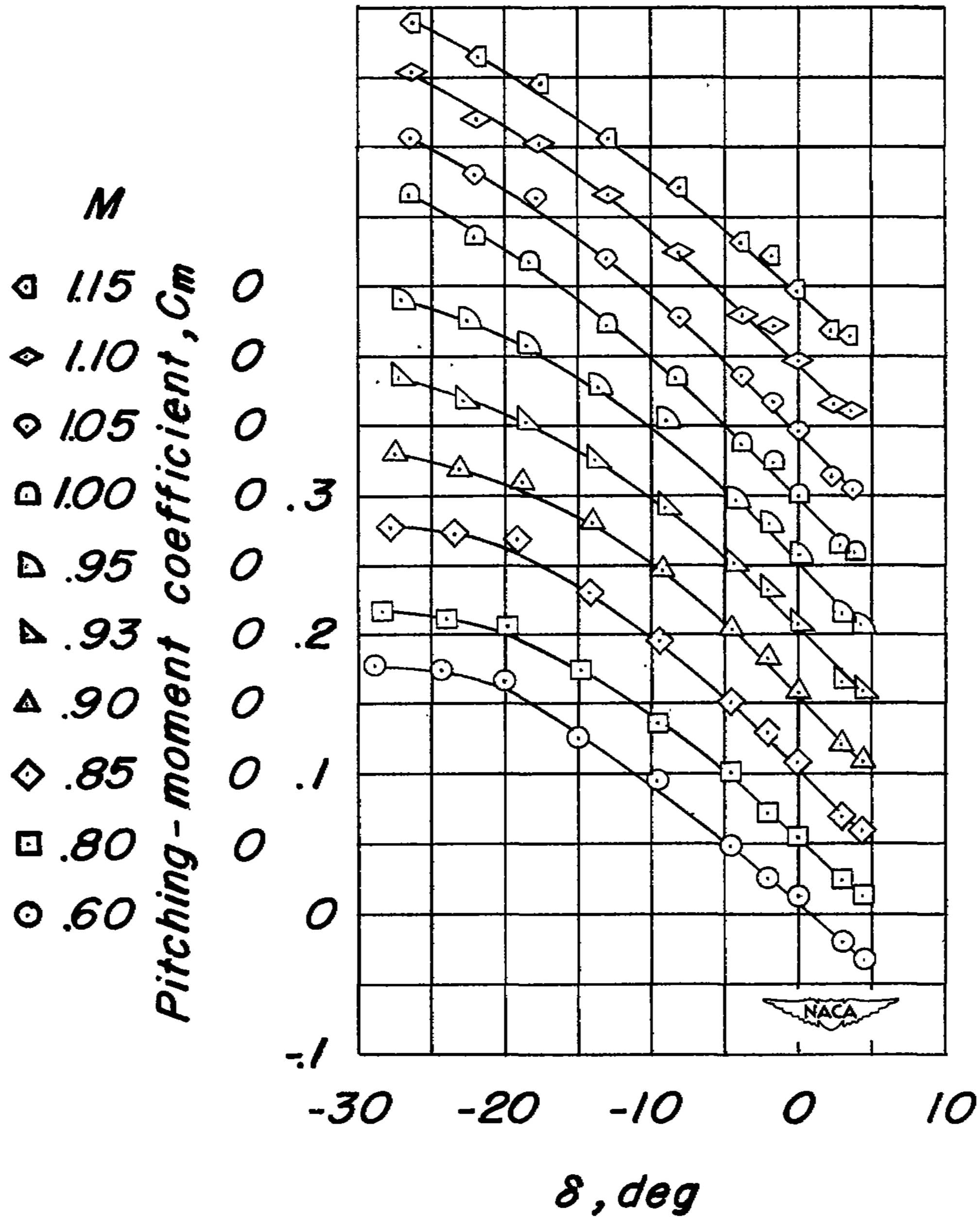


Figure 9.- Variation of pitching-moment coefficient with flap deflection for various Mach numbers. $\alpha = 0^{\circ}$.

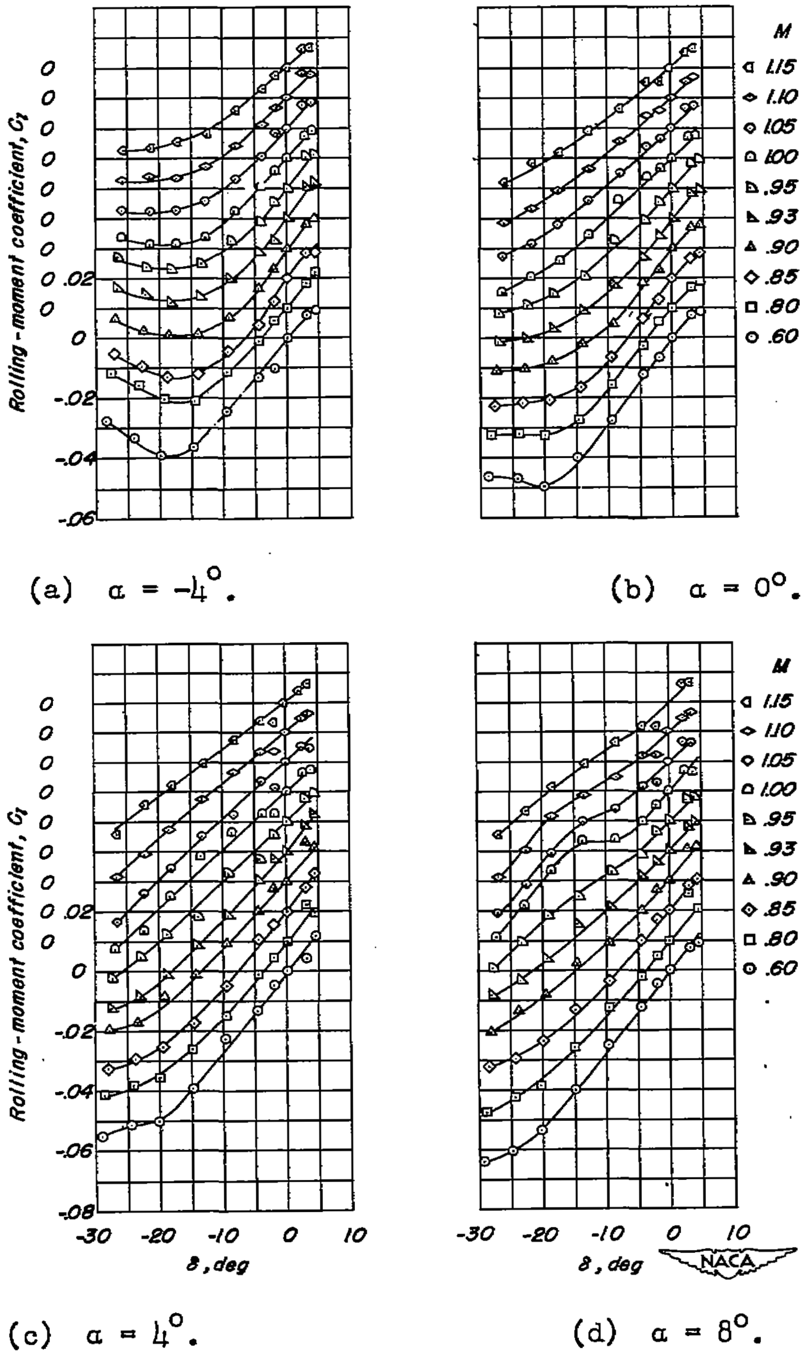


Figure 10.- Variation of rolling-moment coefficient with flap deflection for various Mach numbers and angles of attack. Uncorrected for reflection-plane effects.

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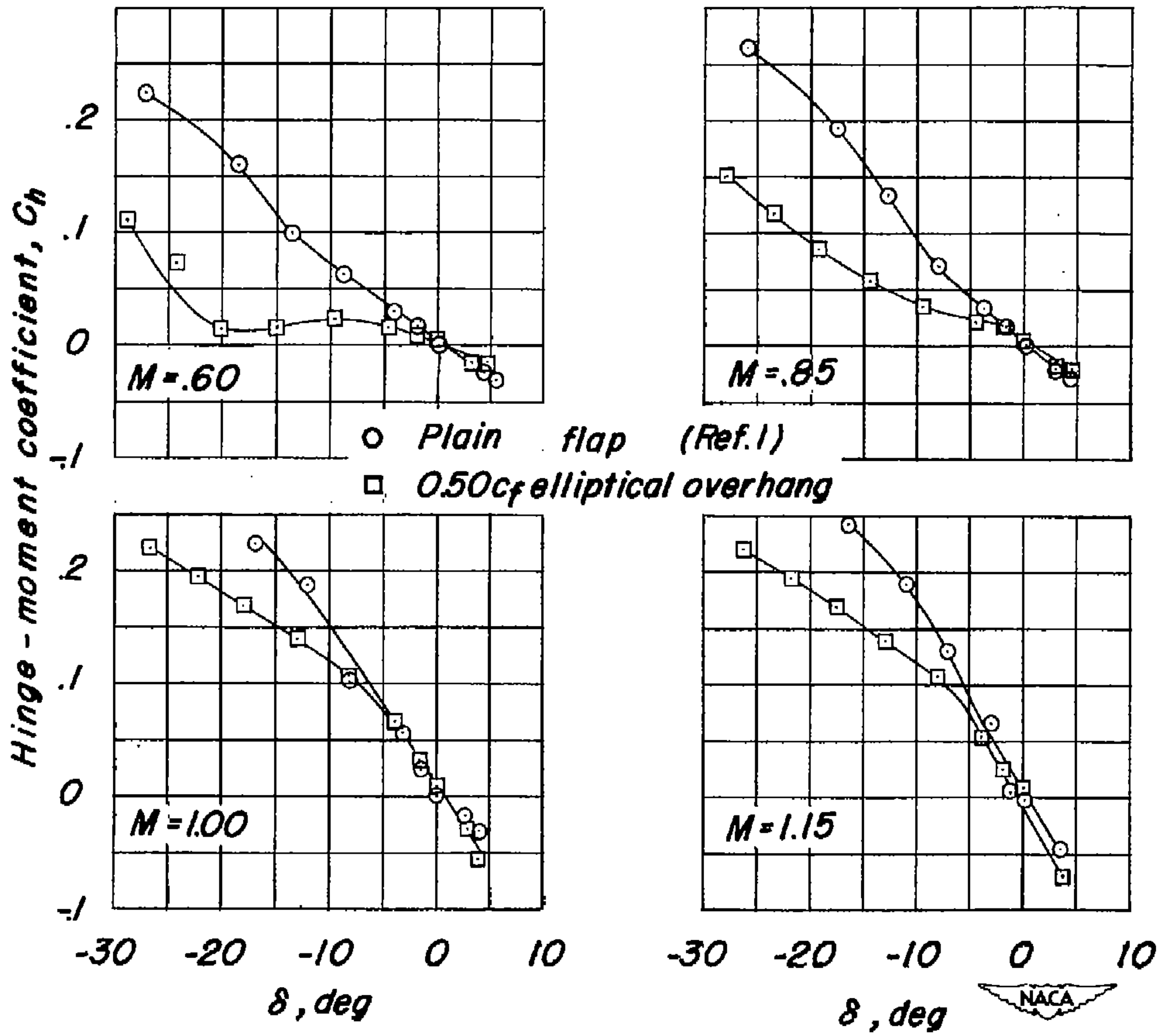

Figure 11.- Variation of hinge-moment coefficients with flap deflection for the plain and $0.50c_f$ elliptical-overhang flaps. $\alpha = 0^{\circ}$.

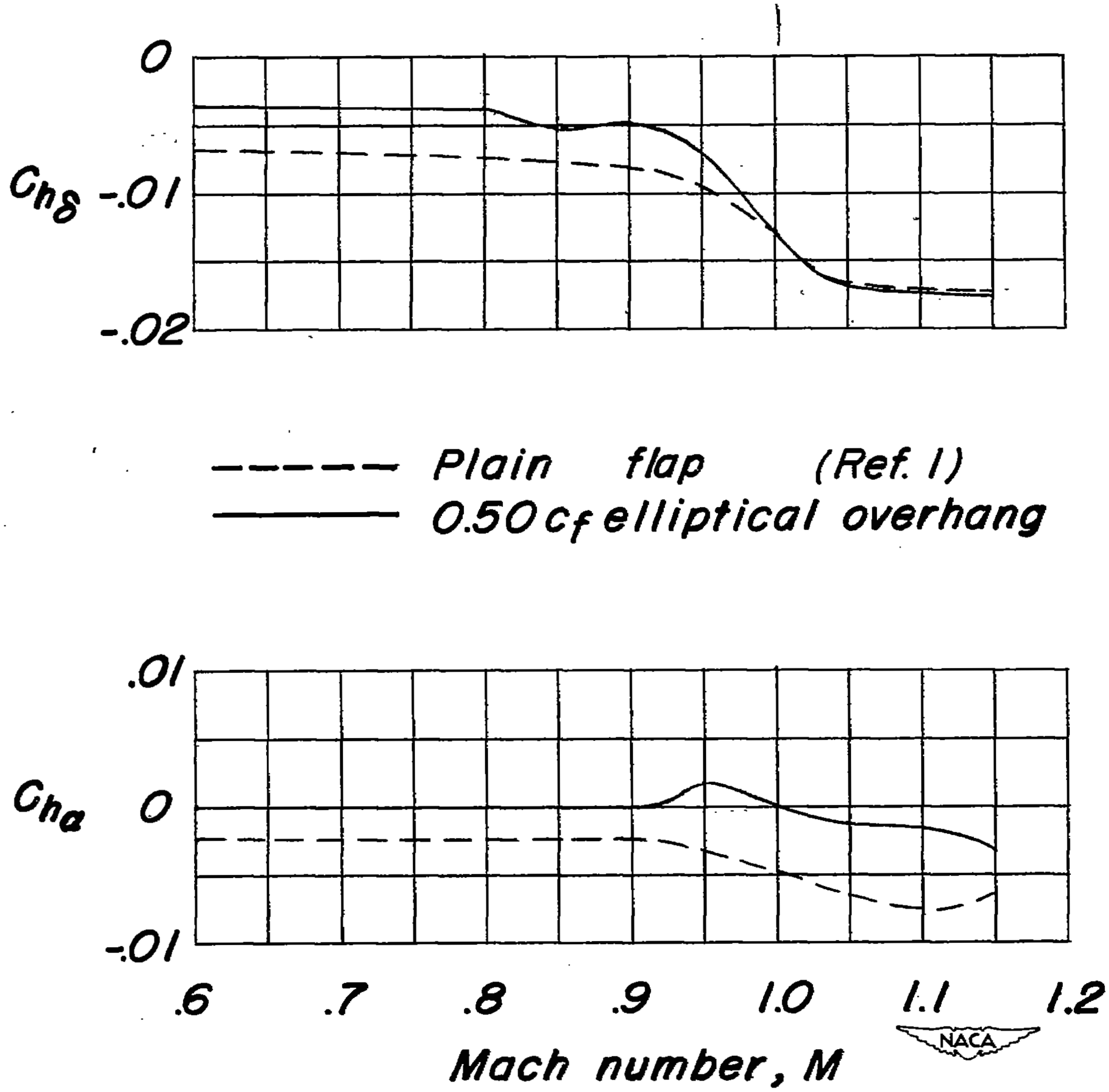

Figure 12.- Variation of the hinge-moment parameters with Mach number for the plain and 0.50c_f elliptical-overhang flaps.

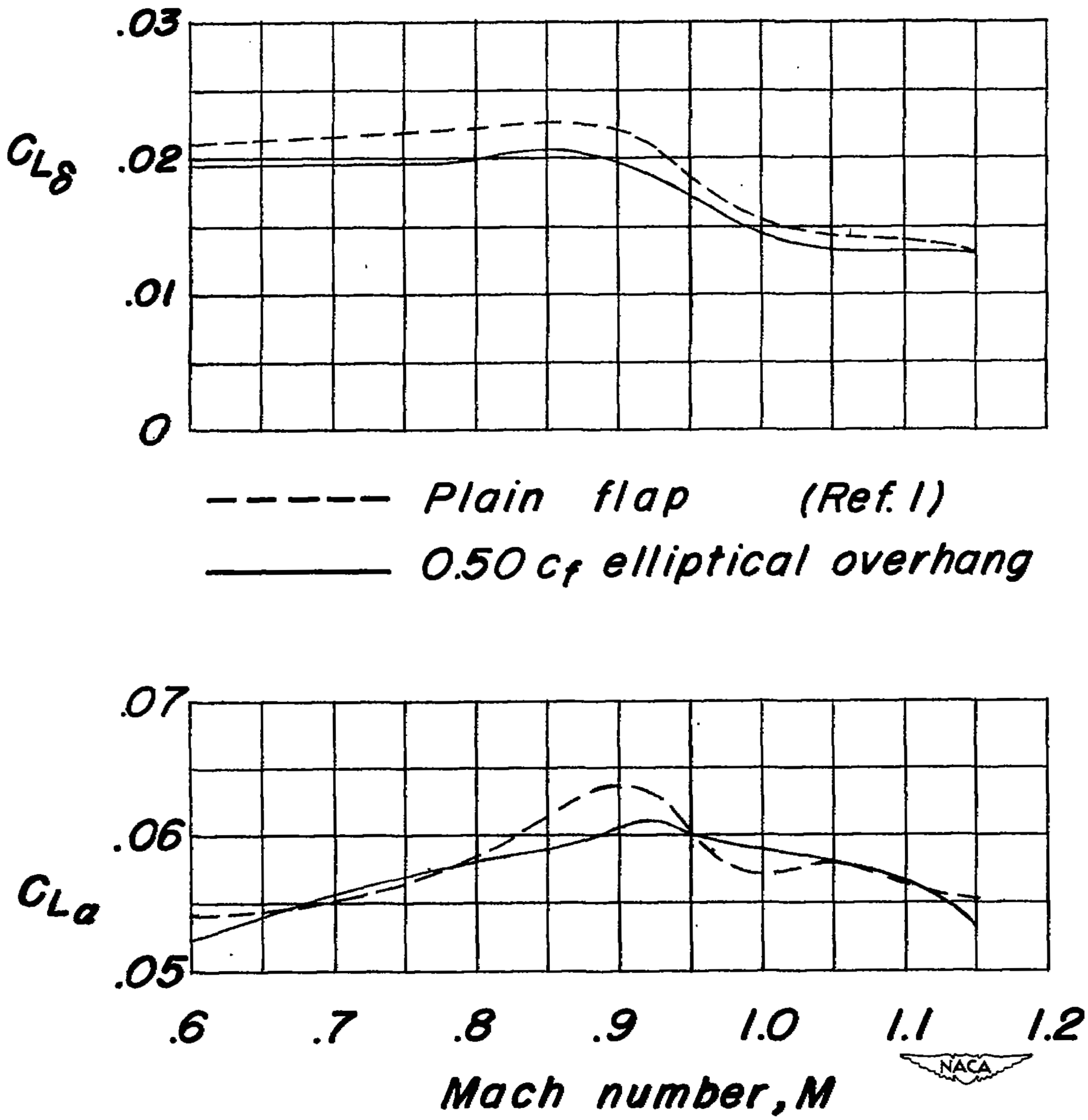

Figure 13.- Variation of the lift parameters with Mach number for the plain and 0.50c_f elliptical-overhang flaps.

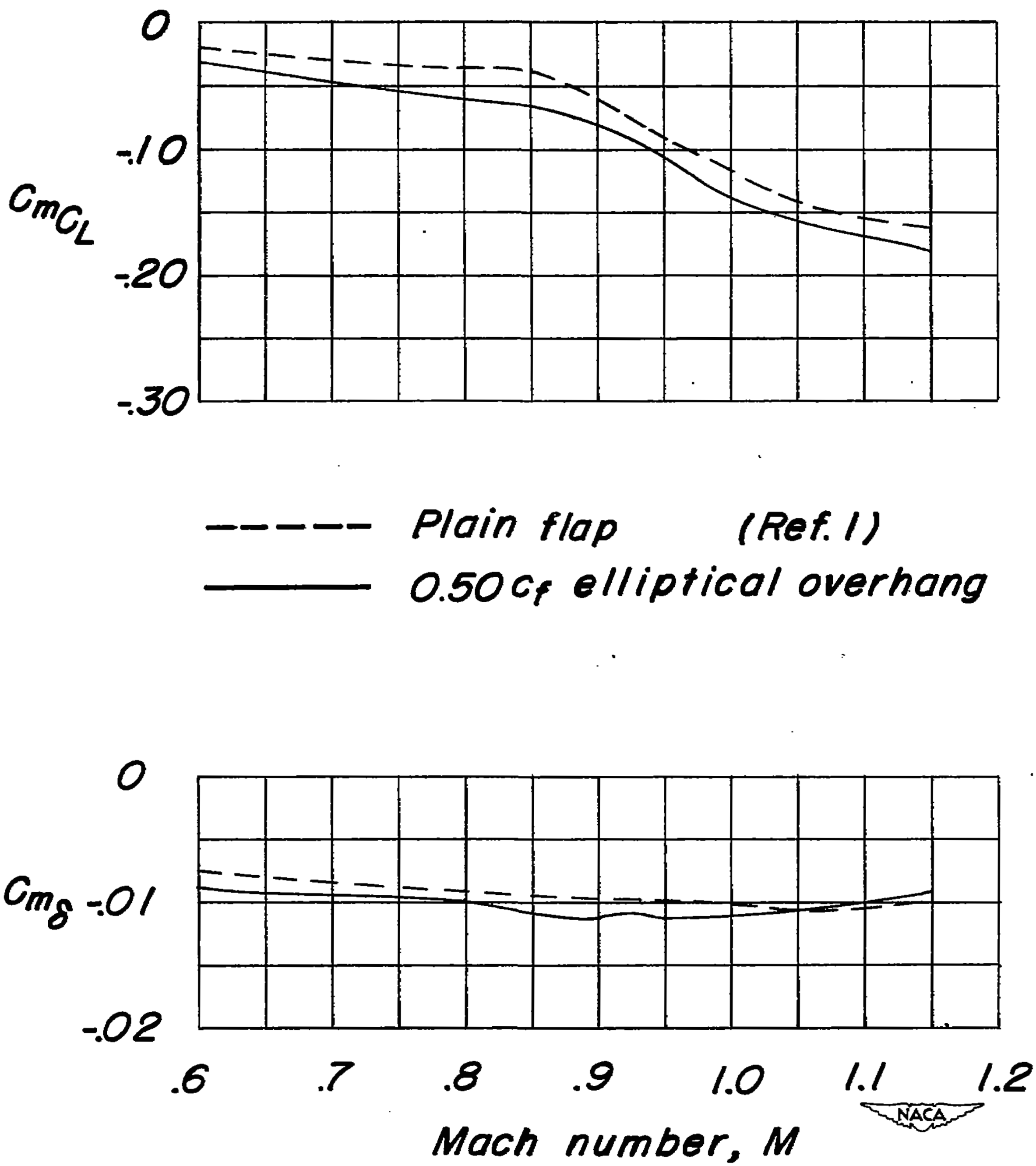

Figure 14.- Variation of the pitching-moment parameters with Mach number for the plain and 0.50c_f elliptical-overhang flaps.

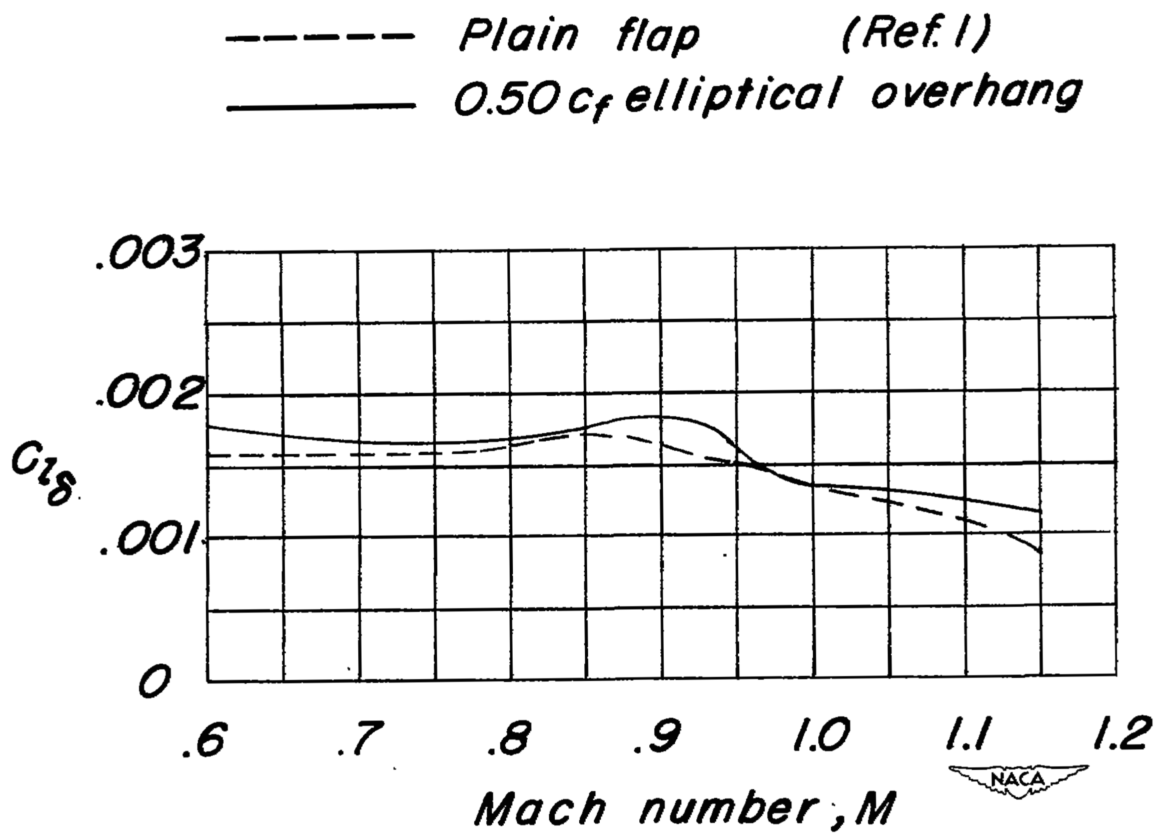

Figure 15.- Variation of the rolling-moment parameter with Mach number for the plain and $0.50c_f$ elliptical-overhang flaps. Corrected for reflection-plane effects.

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