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# RESEARCH MEMORANDUM

## HINGE-MOMENT AND OTHER AERODYNAMIC CHARACTERISTICS AT TRANSONIC SPEEDS OF A QUARTER-SPAN SPOILER ON A TAPERED 45° SWEPTBACK WING OF ASPECT RATIO 3

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NATIONAL ADVISORY COMMITTEE
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# HINGE-MOMENT AND OTHER AERODYNAMIC CHARACTERISTICS AT TRANSONIC SPEEDS OF A QUARTER-SPAN SPOILER ON A TAPERED 45° SWEPTBACK WING OF ASPECT RATIO 3

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## SUMMARY

An investigation was made at transonic speeds in the Langley high-speed 7- by 10-foot tunnel to determine the hinge-moment and other aerodynamic characteristics of an inboard plug-type spoiler on a 45° sweptback wing of aspect ratio 3. Transonic speeds were obtained by testing in the high velocity field over a reflection plane on the side wall of the tunnel.

The results of the investigation indicated that the spoiler would be overbalanced at low projections (±2 percent chord) through the speed range investigated and that for the same rolling moment the spoiler hinge moments would be small in comparison with those of a plain-flap-type control. At high angles of attack, the spoiler became ineffective in producing changes in lift and rolling moment.

## INTRODUCTION

High-speed flight has brought forth many serious control problems; one of these problems is that of overcoming large control forces. This problem has been partially taken care of by the use of mechanical power boost systems incorporated into the control system of the aircraft. Although, mechanical boost systems have proven to be fairly satisfactory, a manually operated control system still remains desirable for many reasons, such as, weight saving, simplicity, and greater safety. To obtain manually operated controls requires either that a means be found to aerodynamically balance conventional controls or that controls having inherently low hinge moments be used.

From a study made by the NACA during the past decade, the spoiler appears to offer possibilities as a manual lateral-control device

because of desirably low hinge moments. (See references 1 to 28.) This study has been conducted mostly in the subsonic speed range but has included a large variation of possible shapes, types, and locations of spoilers. Recently some data have been obtained in the transonic and supersonic speed ranges. (See references 23 to 28.)

The purpose of this investigation was to determine the hinge-moment and other aerodynamic characteristics of a quarter-span inboard plug-type spoiler on a sweptback wing over a limited projection and angle-of-attack range from a Mach number of 0.70 to 1.10.

The spoiler tested does not represent the best possible spoiler configuration but was studied to provide an insight into the hinge-moment characteristics at transonic speeds.

## COEFFICIENTS AND SYMBOLS

$C_L$ lift coefficient (Twice semispan lift/qS)

$C_D$ drag coefficient (Twice semispan drag/qS)

$\Delta C_D$ increment of drag coefficient caused by spoiler projection

$C_m$ pitching-moment coefficient referred to $0.25\bar{c}$ (Twice semispan pitching moment/$qS\bar{c}$)

$C_l$ rolling-moment coefficient about axis parallel to relative wing and in plane of symmetry (Rolling moment of semispan model/qSb)

$C_h$ spoiler hinge-moment coefficient (Spoiler hinge moment about hinge line of spoiler/$q\mathcal{M}'$)

$C_n$ yawing-moment coefficient about axis through balance center perpendicular to relative wind and in plane of symmetry (Yawing-moment of semispan model/qSb)

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 $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$

$M'$ area moment of spoiler behind spoiler hinge line about spoiler hinge line for semispan wing (0.0000329 $ft^3$)

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

$c$ local wing chord parallel to plane of symmetry, feet

$y$ spanwise distance from plane of symmetry

$\rho$ 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 $\bar{c}$

$\alpha$ angle of attack, degrees

$\delta_s$ spoiler projection relative to wing surface, measured in a plane parallel to plane of symmetry (positive when projected below lower surface of wing), percent of local chord

$H$ hinge moment of control, foot-pounds

$p$ rolling velocity, degrees per second

## MODEL AND APPARATUS

The steel semispan model used in the investigation has a quarter-chord sweep angle of 45.58°, 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. The pertinent dimensions of the basic wing 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 an inboard quarter-span plug-type spoiler (fig. 3). The wing also had a full-span plain flap which was locked in the undeflected position for this

investigation. The gap between the flap nose and the spoiler was approximately 0.0018 chord and the gap between the spoiler and the wing was approximately 0.0007 chord. As a result of the flap, a small gap of 0.0018 to 0.0026 chord existed along the wing span at the nose of the flap.

The investigation was conducted in the Langley high-speed 7- by 10-foot tunnel using a small reflection plane setup on the side wall which gives local supersonic flow when the tunnel is near maximum velocity. The reflection plane is mounted a few inches from the side wall as shown in figure 1. The model was mounted through a turntable in the reflection plane and a gap of about 1/16 inch was maintained between the wing root chord section and the reflection-plane turntable. A sponge-wiper seal was fastened to the wing butt to minimize flow through the gap.

The model was mounted on an electrical strain-gage balance and the moments and forces were indicated by self-balancing potentiometers. A strain-gage beam was attached to the end of the spoiler shaft for measuring spoiler hinge moments.

## TESTS

The tests were conducted through an angle of attack range from $0^{\circ}$ to $16^{\circ}$ at spoiler projections of approximately 3.8 percent to -5.6 percent chord and over a Mach number range from 0.70 to 1.10. For Mach numbers below 0.95 there was practically no gradient in the vicinity of the reflection plane. At higher Mach numbers the presence of the reflection plane created a high local velocity field which allowed testing the model up to $M = 1.10$ before choking occurred in the tunnel. Typical variations of local Mach numbers are shown in figure 4. The effective test Mach numbers were obtained from contour charts similar to those shown in figure 4 by the relationship

$$M = \frac{2}{S}\int_{0}^{b/2} cM_a \, dy$$

For the investigation a Mach number gradient of generally less than 0.02 was obtained between Mach numbers of 0.95 and 1.04, increasing to about 0.06 at the highest test Mach number of 1.10.

A typical variation of Reynolds number with Mach number is shown in figure 5.

## RESULTS AND DISCUSSION

The variation of hinge-moment and other aerodynamic characteristics with spoiler projections are shown in figure 6 for several angles of attack and Mach numbers.

It should be noted again that this model does not represent the best possible spoiler configuration. However, the model is typical of high-speed wings and it was felt that an investigation on this configuration would give in general the trends of the hinge-moment and other aerodynamic characteristics of similiarly located spoilers through the transonic speed range.

Hinge-moment characteristics.- The data indicate a positive variation of $C_h$ with $\delta_s$ for low projections (approx. ±2 percent chord) through the Mach number and angle-of-attack range tested, except for a few small negative projections at $\alpha = 12^\circ$ and $16^\circ$ (fig. 6(a)). This positive variation of $C_h$ with $\delta_s$ at low projections is common of spoilers of this type at low speeds (references 5 and 6).

It was thought that the model wing and spoiler were symmetrical in section but as evidenced by the large positive value of $C_h$, at $\alpha = 0^\circ$ and $\delta_s = 0$, there was probably some assymmetry in the model. Spoiler hinge moments are very critical of small changes in the angle of the exposed faces of the spoiler (reference 5) and their use might require special care in design and construction if desirably low hinge moments are obtained. Although the hinge moments do not pass through zero for $\alpha = 0^\circ$ and $\delta_s = 0$ the variation of hinge-moment coefficient is almost symmetrical with positive and negative spoiler projections for all Mach numbers.

An evaluation of the spoiler hinge-moment coefficient is more clearly illustrated in figure 7, which shows the value of hinge moments in foot-pounds for a spoiler of this type and for a full-span plain-flap-type control on a full-scale airplane. The forces of the spoiler are small in comparison with those of the flap but are still too large for manual operation. The magnitude of the spoiler hinge moments could be considerably reduced by redesigning the spoiler. One design change would be a reduction in thickness of the spoiler and supporting arms which for this test configuration was considerably thicker than necessary.

Rolling-moment characteristics.- At low angles of attack the spoiler was effective in producing rolling moment at all projections, that is positive increments of $C_l$ for positive projections and negative

increments for negative projections (fig. 6(b)). It should be noted, however, that the variation of $C_l$ with $\delta_s$ was less in the low-projection range. At angles of attack of $12^\circ$ and $16^\circ$, the spoiler became ineffective in roll with reversal indicated for some positive projections.

The rolling-moment coefficients have not been corrected for the effects of reflection plane. Available correction factors are from unpublished data derived from a limited low-speed investigation and from theoretical considerations and are only approximate. The low-speed ($M \approx 0$) corrected $C_l$ would be about $0.3C_{l_{measured}}$, but at high-subsonic and transonic speeds it is believed that the corrected $C_l$ would be much nearer the measured value.

Yawing-moment characteristics.- In general, the spoiler gave small favorable yawing moments at negative deflections and unfavorable yawing moments at positive deflections at angles of attack of $0^\circ$ and $4^\circ$. A small unfavorable yawing moment was also noted at the highest positive deflections for angles of attack of $8^\circ$, $12^\circ$, and $16^\circ$ (fig. 6(c)).

Lift characteristics.- At low angles of attack positive spoiler projections gave an increase in lift and negative projections gave a decrease in lift for all Mach numbers but at high angles of attack the spoiler became ineffective or showed signs of reversal for positive projections (fig. 6(d)).

Pitching-moment characteristics.- Only slight changes in pitching moment with spoiler projection occurred at the low angles of attack through the Mach number range tested, but at the high angles of attack, some variations of pitching moment with spoiler projection were indicated (fig. 6(e)).

Drag characteristics.- The incremental drag coefficient varied almost symmetrically with positive and negative spoiler projections at $\alpha = 0^\circ$, but negative spoiler projections progressively produced less drag as the angle of attack was increased until at $\alpha = 16^\circ$ and Mach numbers up to 0.96 there was practically no additional drag caused by negative spoiler projections (fig. 6(f)).

These data along with the lift and pitching moment might be useful for considerations of dive or speed brakes (reference 21).

## CONCLUDING REMARKS

An investigation at transonic speeds of a 45° sweptback wing of aspect ratio 3 having an inboard quarter-span plug-spoiler control indicated an overbalance of the spoiler hinge moments at low projections (±2 percent chord) through the transonic Mach range. For the same rolling moment the spoiler hinge moments would be small in comparison with those of a full-span plain-flap-type control but are still too large for manual operation for this specific spoiler configurations. It is considered possible that with redesign and relocation a spoiler could be produced with considerably less hinge moment. At low angles of attack, the positive spoiler projections were similar to a split flap and gave positive increments of lift and rolling moment. At high angles of attack (12° and 16°), this spoiler became ineffective or showed signs of reversal in lift and roll for positive spoiler projections.

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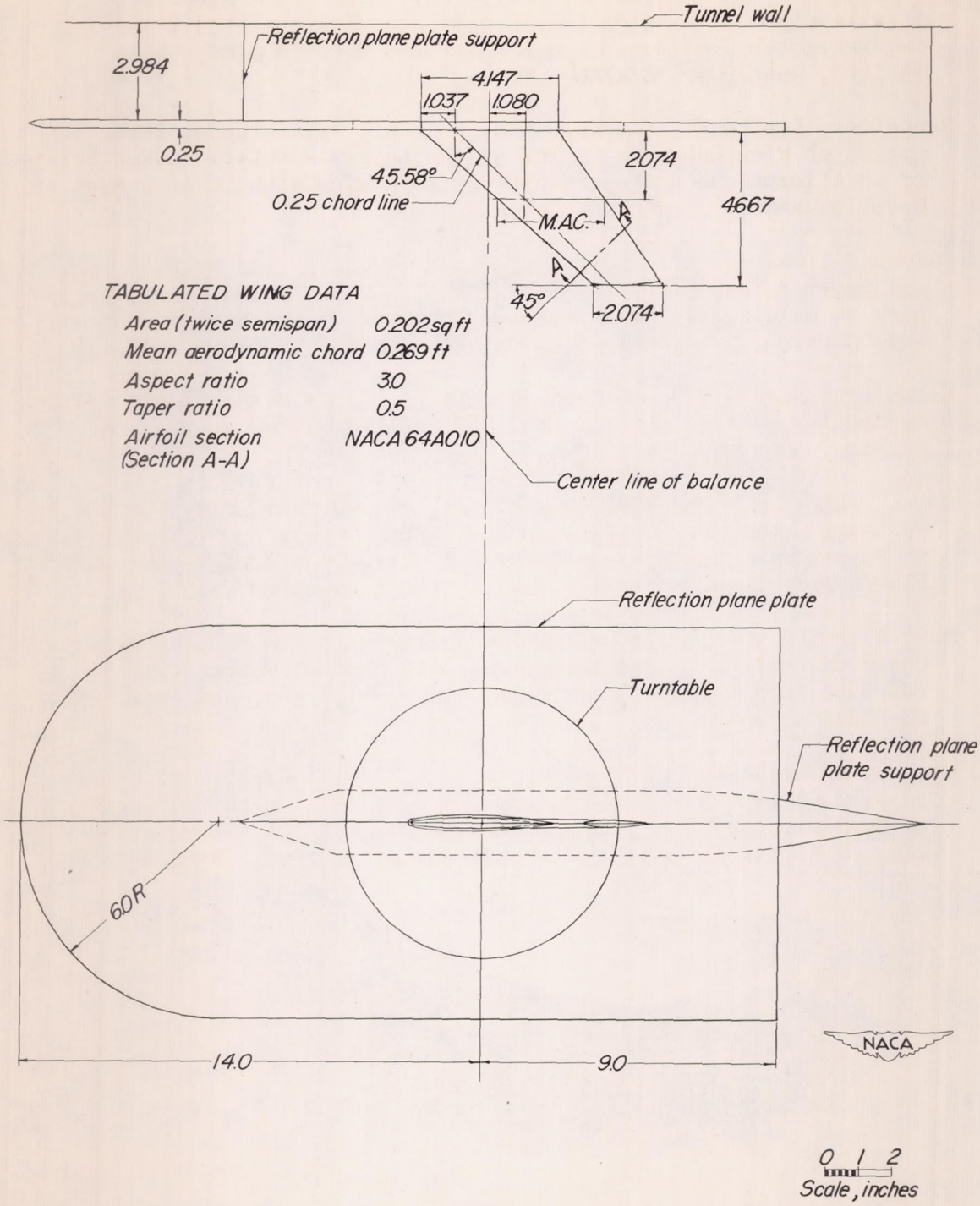



Figure 1.- Basic wing model mounted on the reflection plane in the Langley high-speed 7- by 10-foot tunnel.

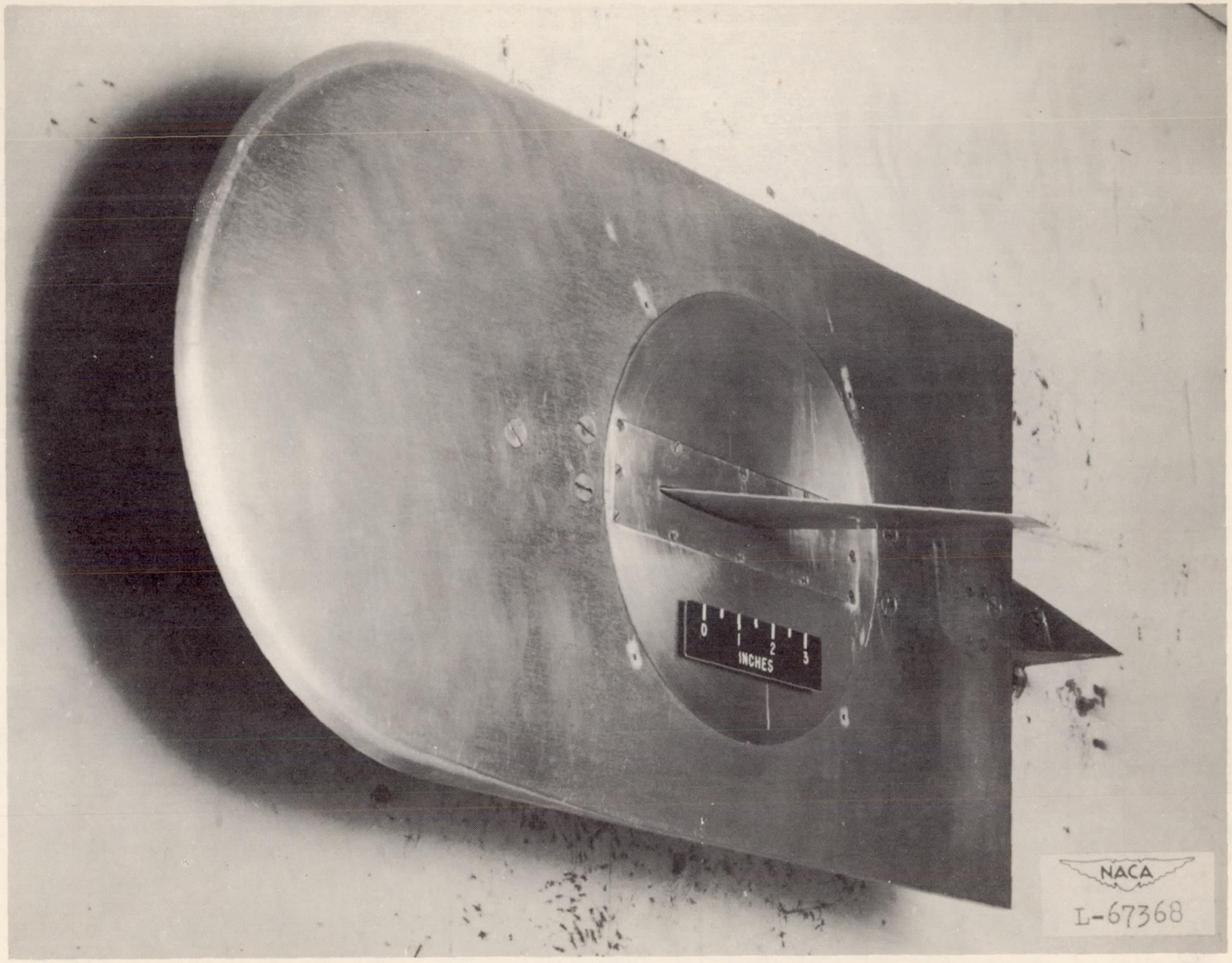



Figure 2.- View of typical model mounted on the reflection plane in the Langley high-speed 7- by 10-foot tunnel.

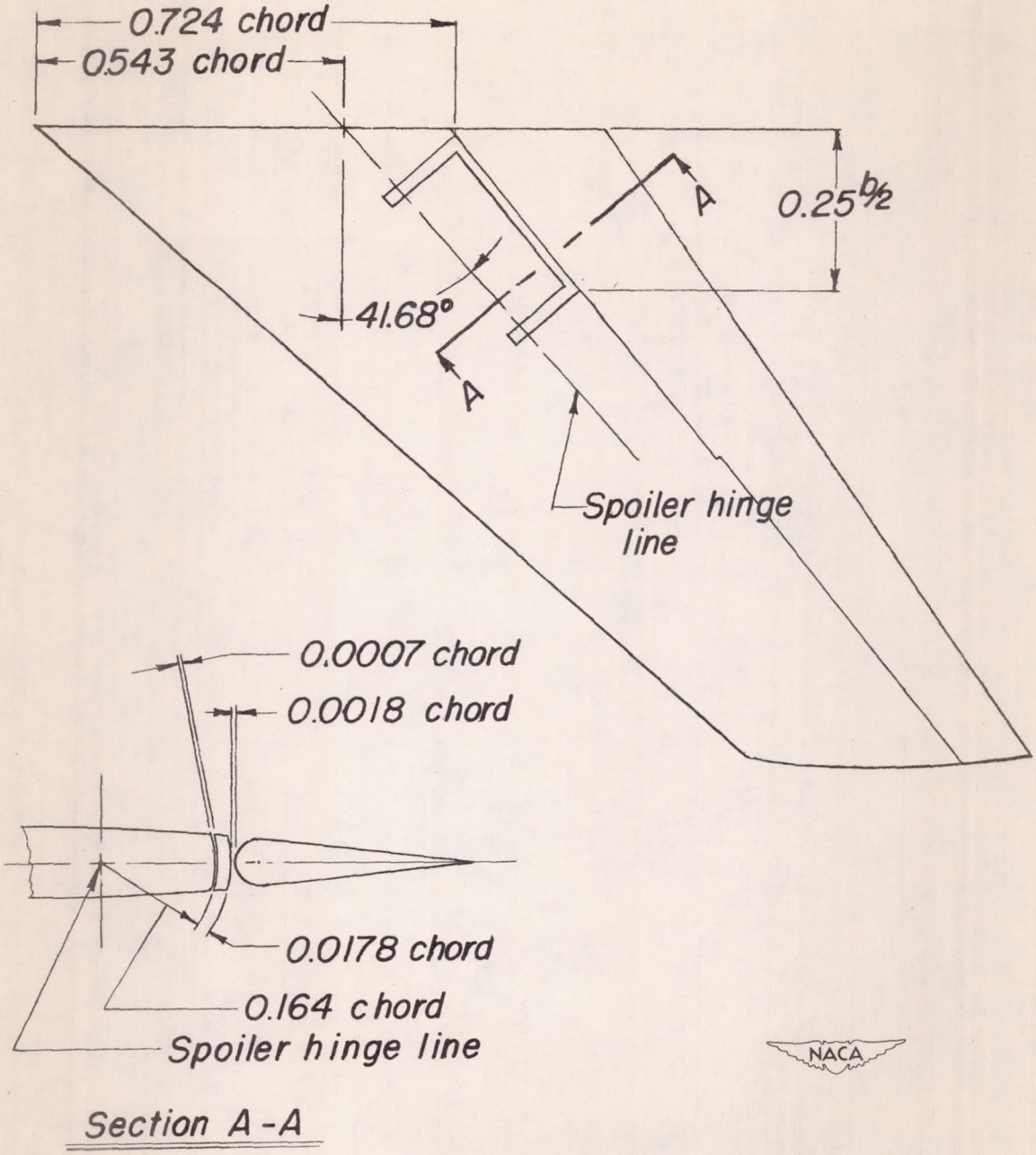



Figure 3.- Details of spoiler control.

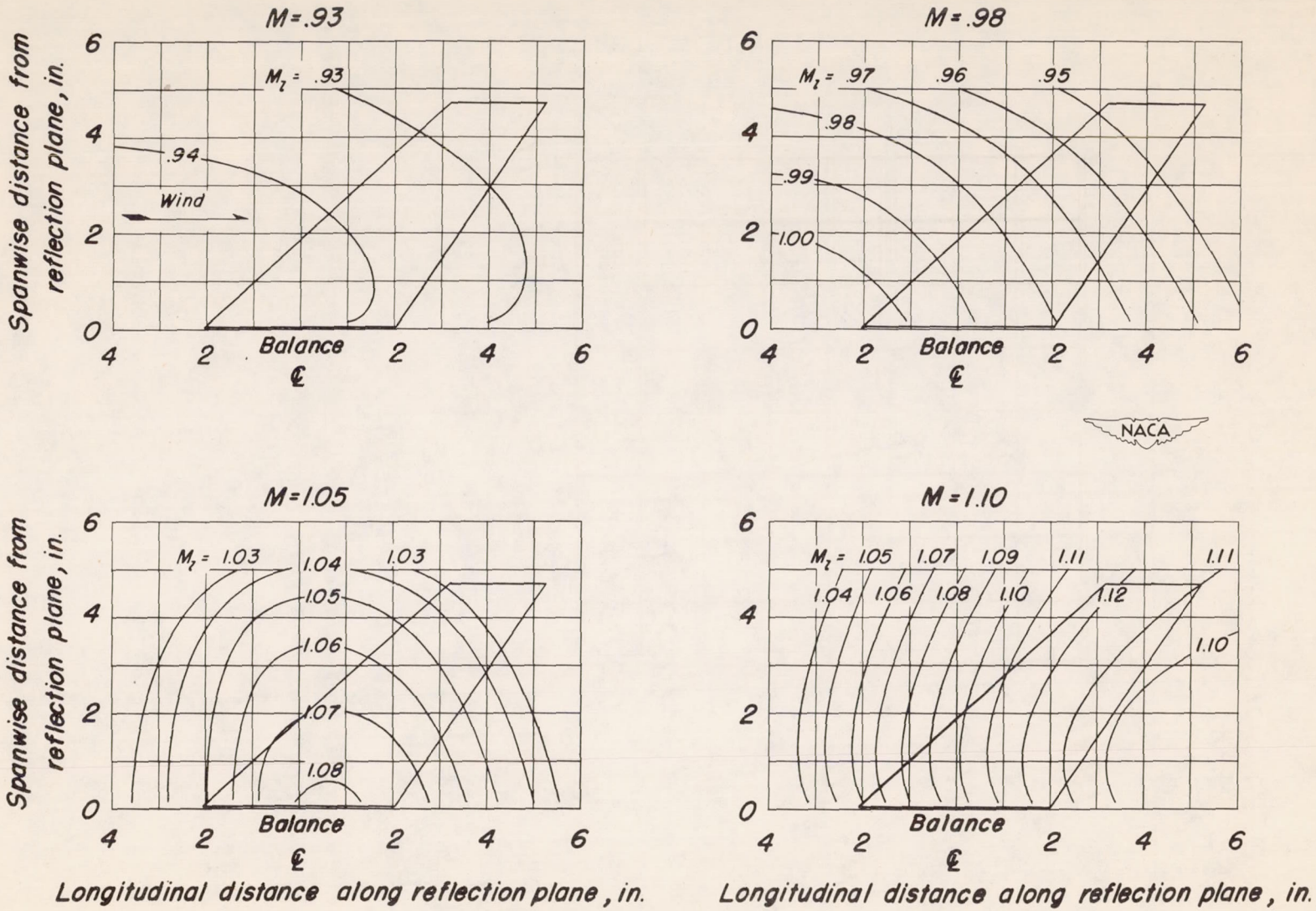



Figure 4.- Typical Mach number contours over the side-wall reflection plane in region of model location.

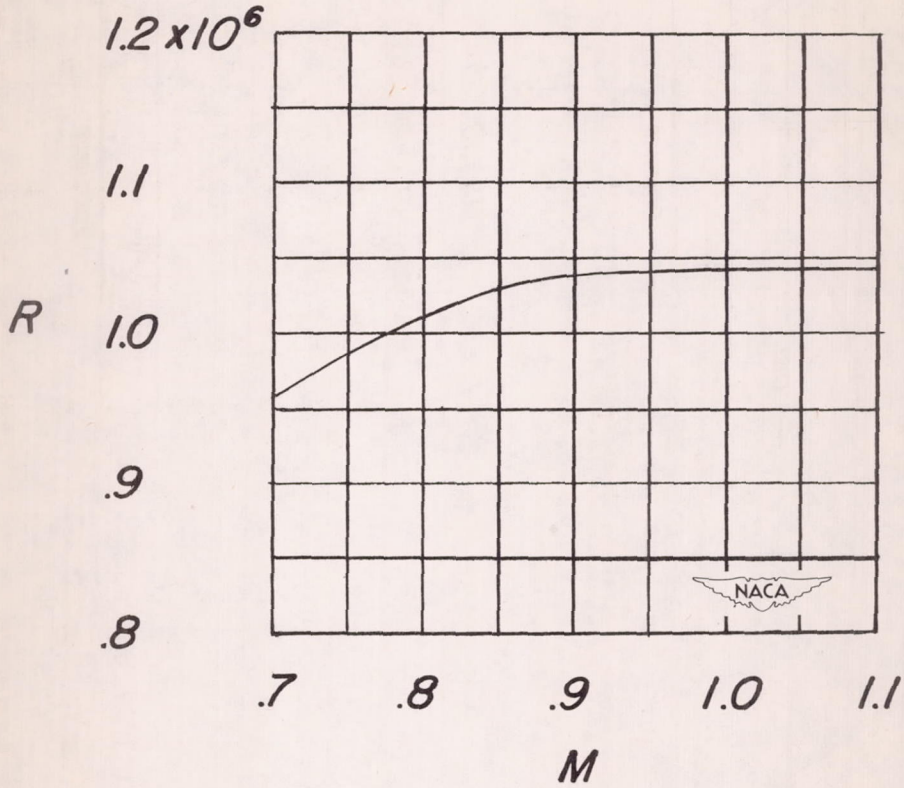
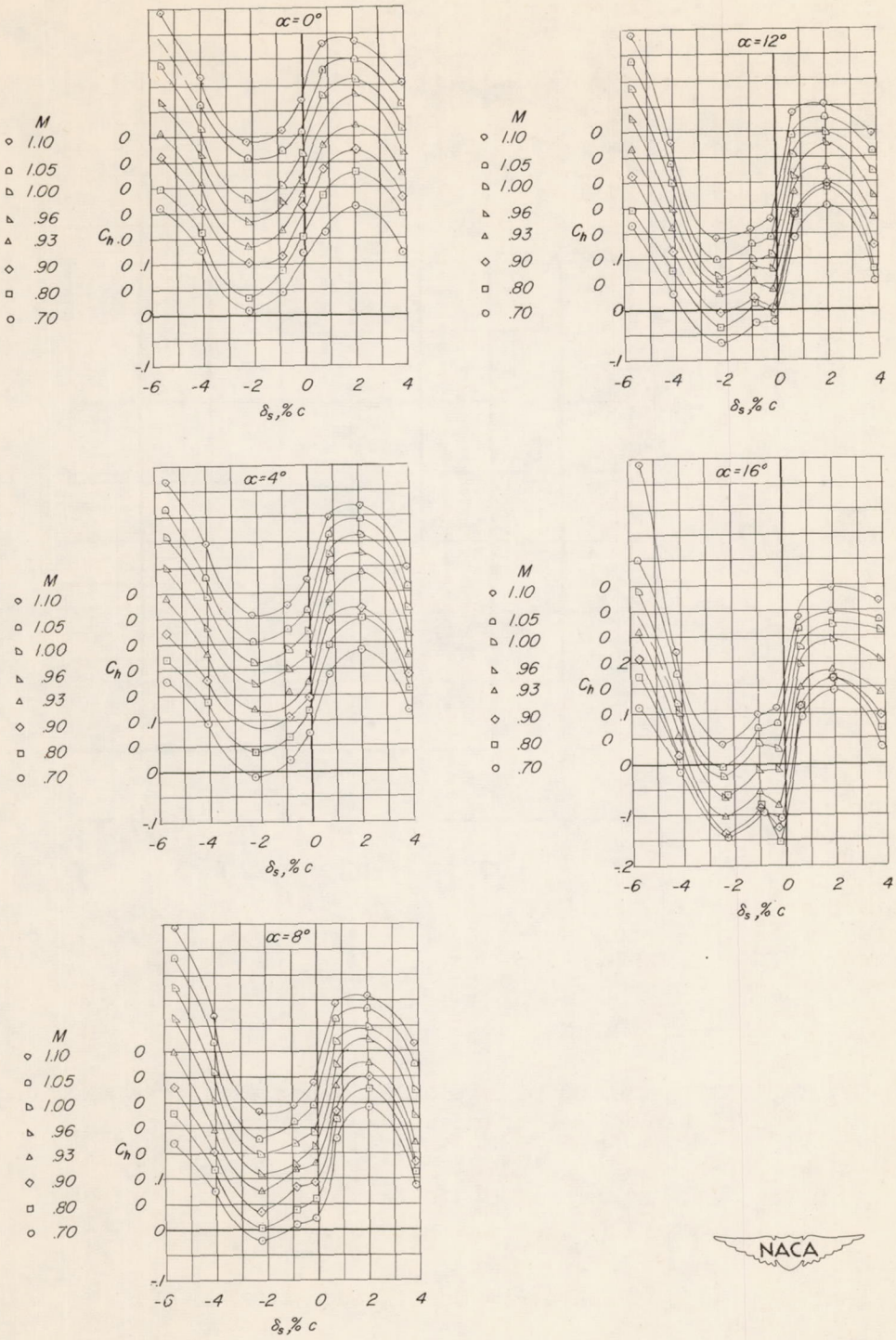
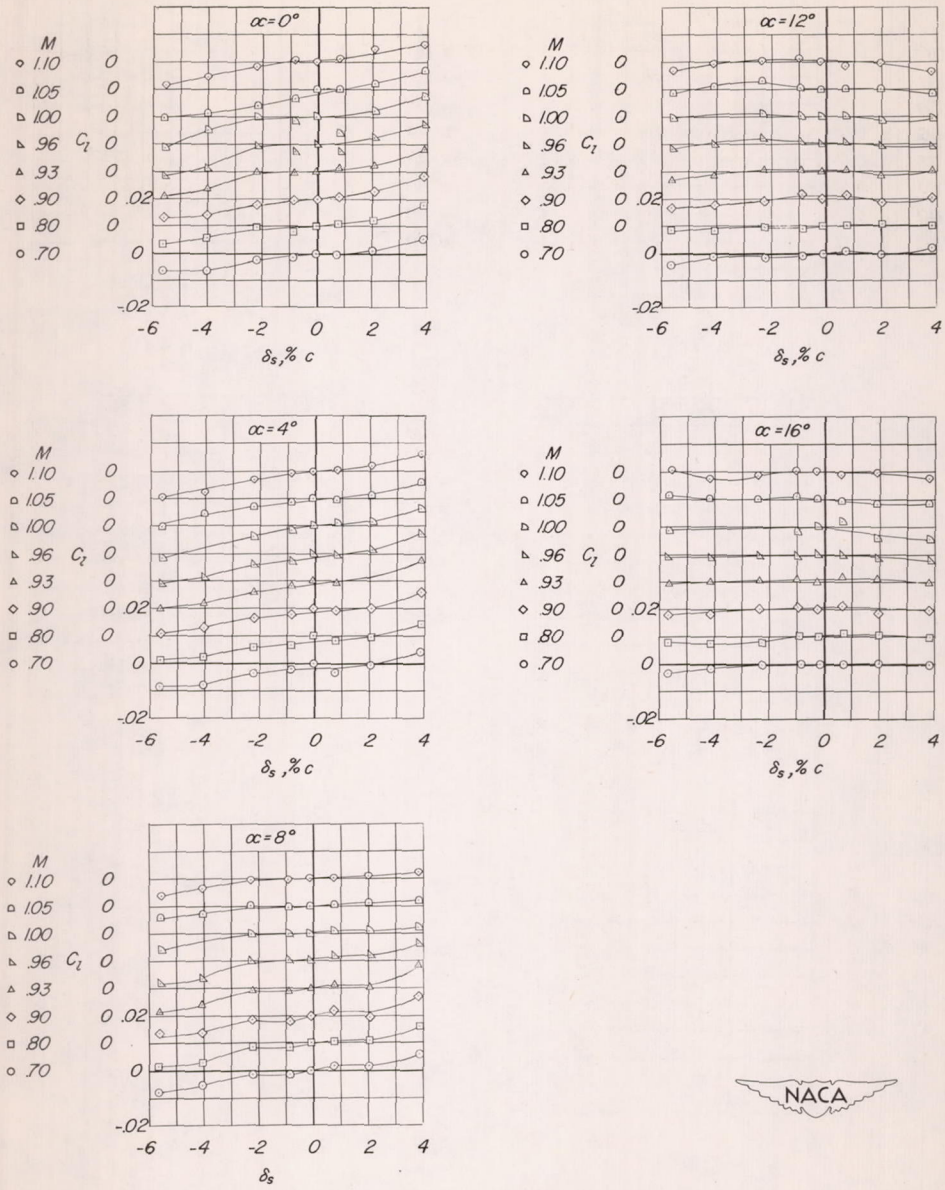



Figure 5.- Typical variation of Reynolds number with test Mach number through the transonic speed range.



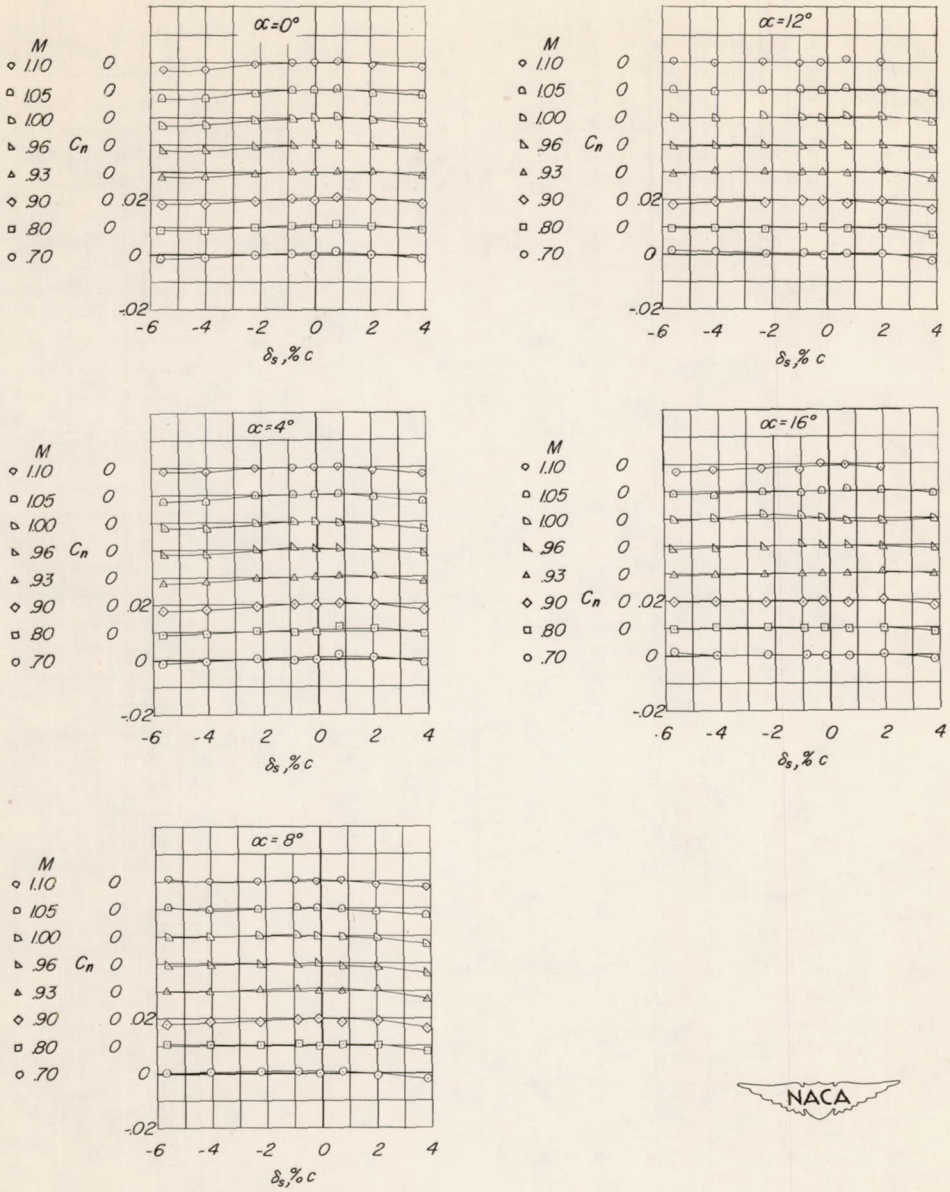

(a) $C_h$ against $\delta_s$.

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



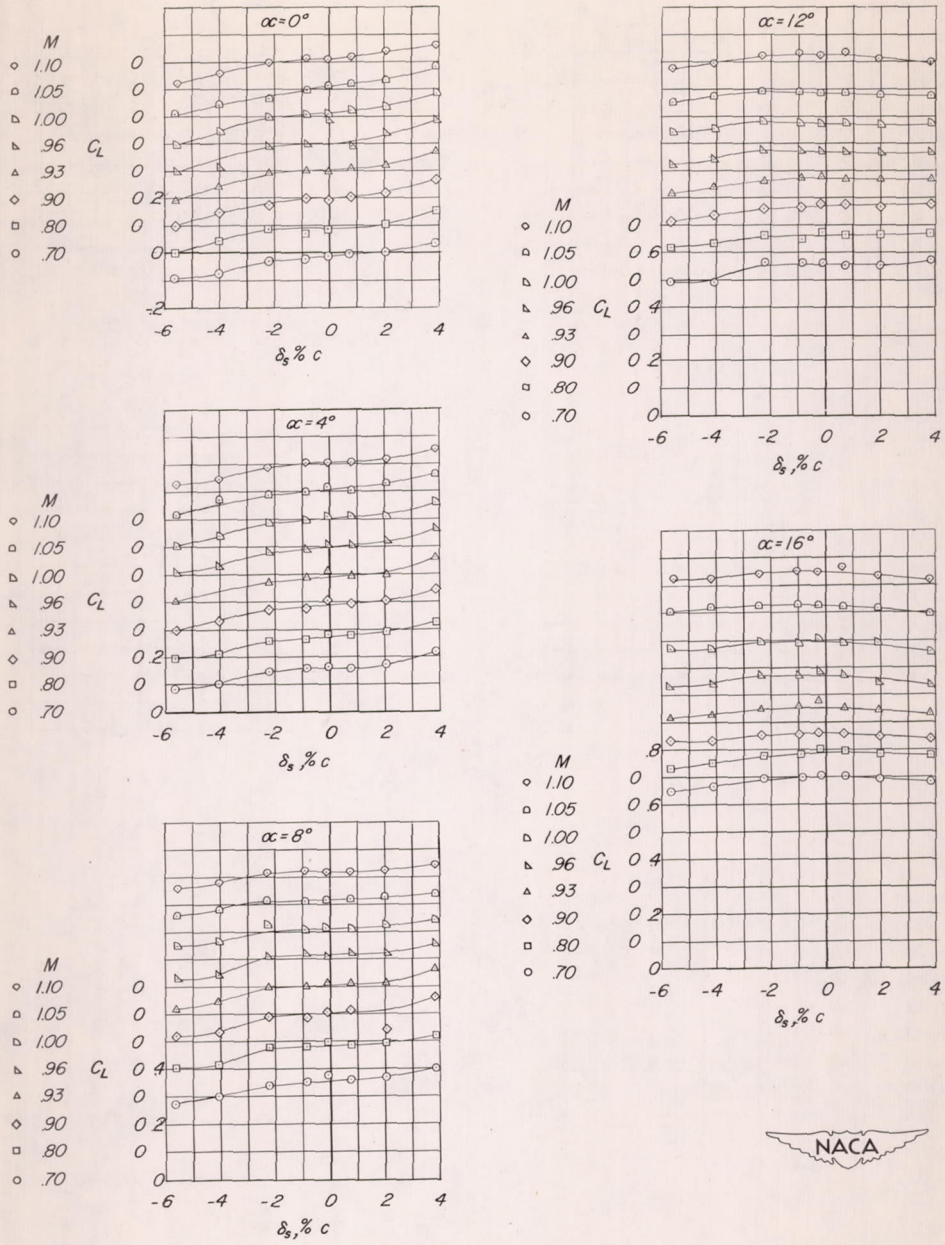

(b) $C_l$ against $\delta_s$.

Figure 6.- Continued.



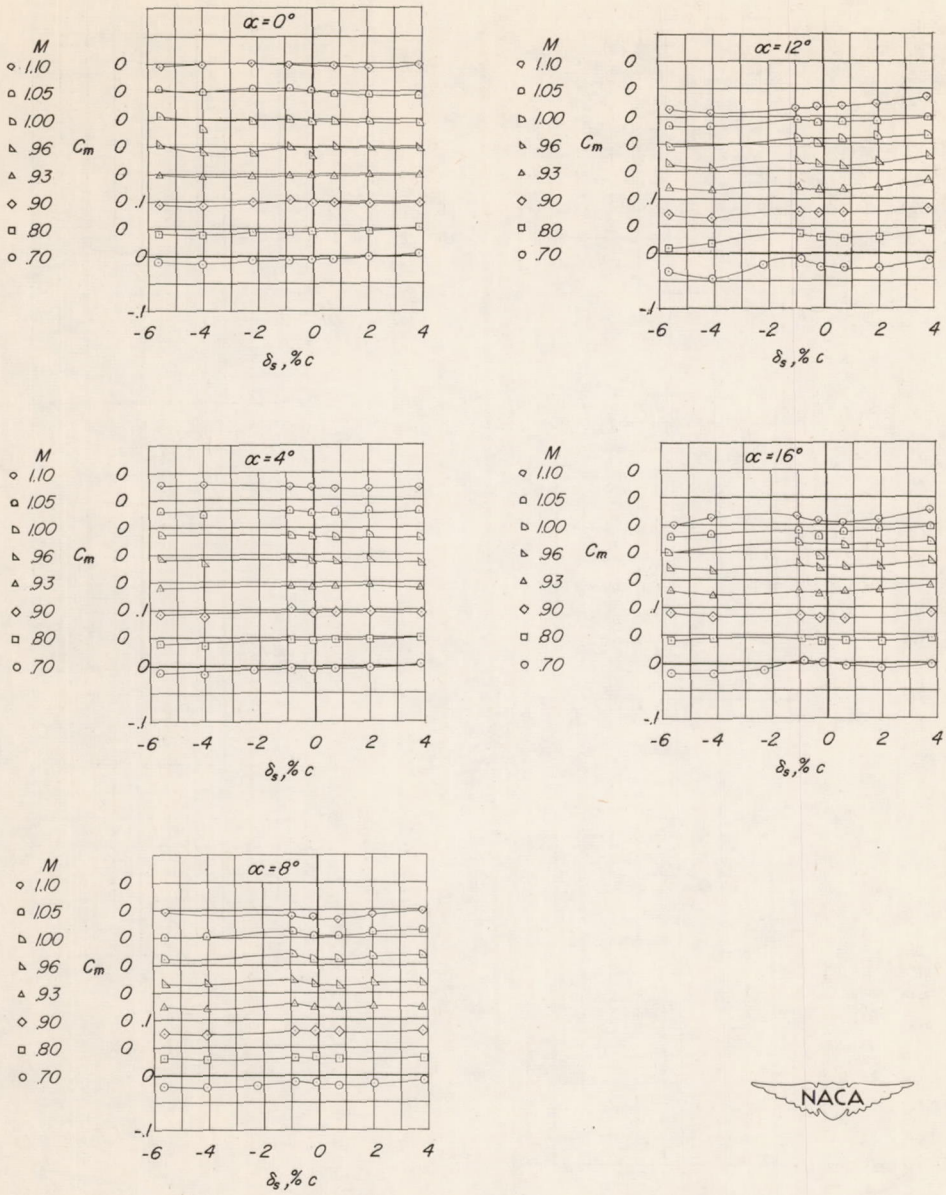

(c) $C_n$ against $\delta_s$.

Figure 6.- Continued.



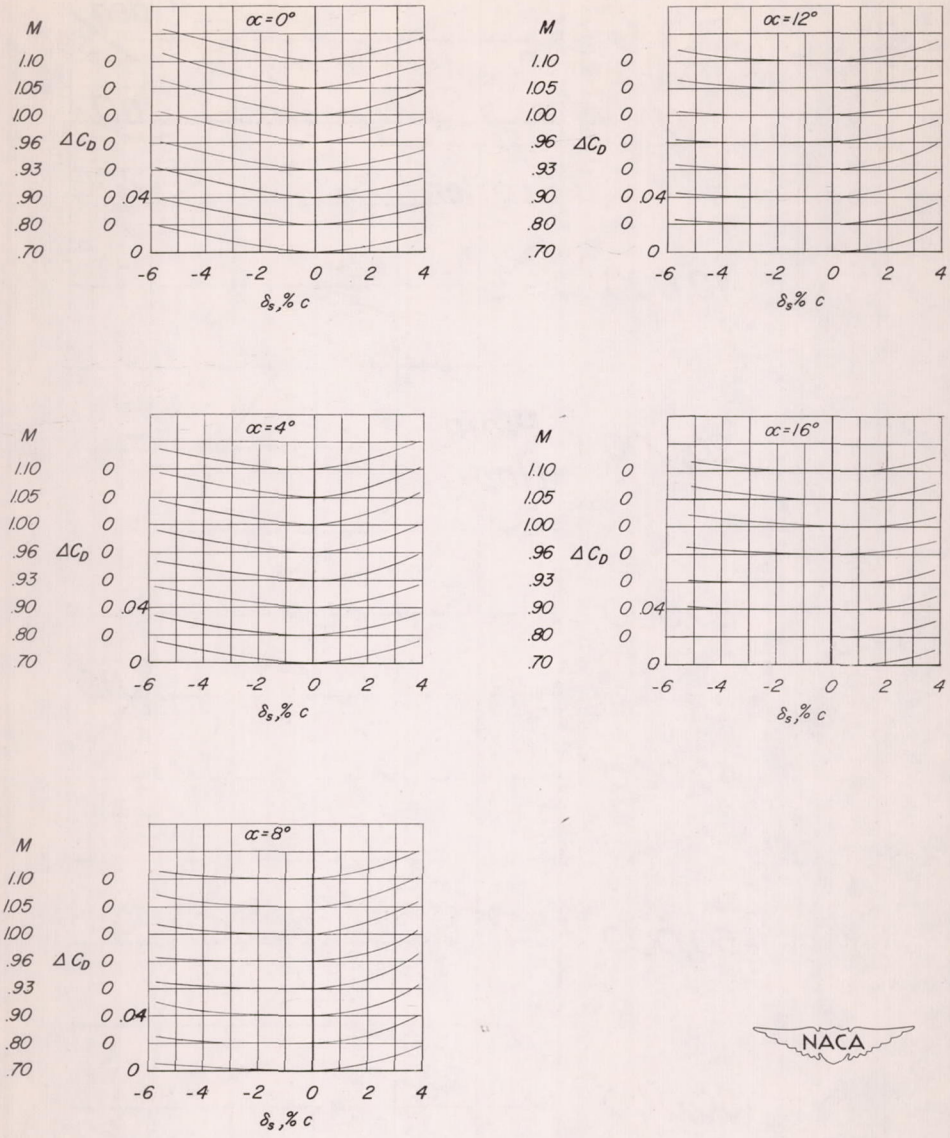

(d) $C_L$ against $\delta_s$.

Figure 6.- Continued.




(e) $C_m$ against $\delta_s$.

Figure 6.- Continued.




(f) $\Delta C_D$ against $\delta_s$.

Figure 6.- Concluded.

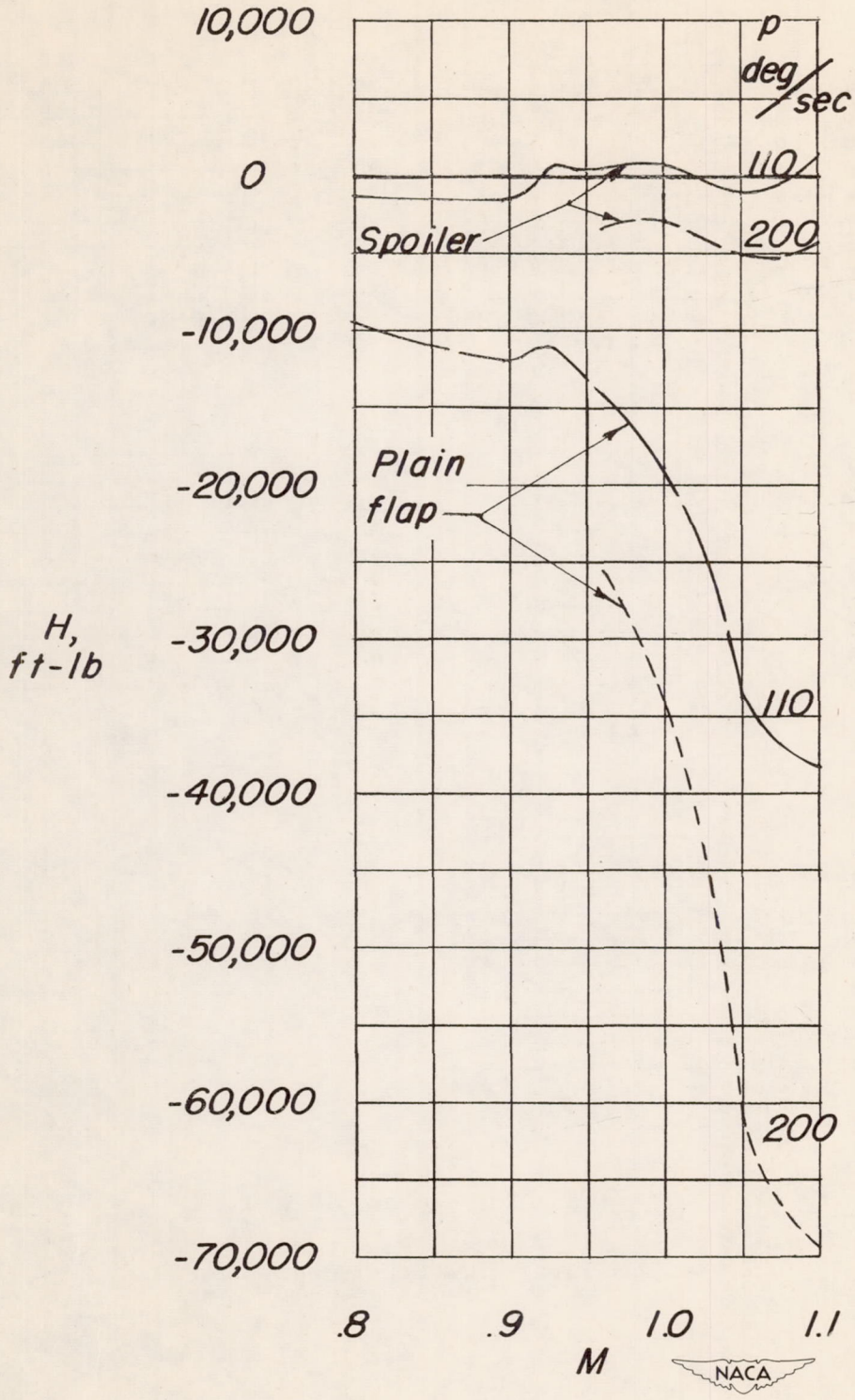



Figure 7.- Variation of hinge moment with Mach number for various rates of roll for a spoiler and for a full-span 25.4-percent-chord plain flap on an airplane of 38.90-foot span at sea-level conditions.