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RESEARCH MEMORANDUM

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

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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° swept-back 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

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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)
ΔC_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 $2M'$)
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
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 ₂	local Mach number
R	Reynolds number of wing based on \bar{c}
α	angle of attack, degrees
δ_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° to 16° 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

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

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.

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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 δ_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° (fig. 6(a)). This positive variation of C_h with δ_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 assymetry 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 δ_S was less in the low-projection range. At angles of attack of 12° and 16° , 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 $0.3C_{L\text{measured}}$, 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° and 4° . A small unfavorable yawing moment was also noted at the highest positive deflections for angles of attack of 8° , 12° , and 16° (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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REFERENCES

1. Shortal, J. A.: Effect of Retractable-Spoiler Location on Rolling- and Yawing-Moment Coefficients. NACA TN 499, 1934.
2. Soulé, H. A., and McAvoy, W. H.: Flight Investigation of Lateral Control Devices for Use with Full-Span Flaps. NACA Rep. 517, 1935.
3. Wetmore, J. W.: Flight Tests of Retractable Ailerons on a Highly Tapered Wing. NACA TN 714, 1939.
4. 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. 706, 1941.
5. 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.
6. Lowry, John G., and Liddell, Robert B.: Wind-Tunnel Investigation of a Tapered Wing with a Plug-Type Spoiler-Slot Aileron and Full-Span Slotted Flaps. NACA ARR, July 1942.
7. 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 1294, 1947.
8. Weick, Fred E., and Jones, Robert T.: Résumé and Analysis of N.A.C.A. Lateral Control Research. NACA Rep. 605, 1937.
9. Laitone, Edmund V., and Summers, James L.: An Additional Investigation of the High-Speed Lateral-Control Characteristics of Spoilers. NACA ACR 5D28, 1945.
10. Graham, Robert R., and Koven, William: Lateral-Control Investigations on a 37° Sweptback Wing of Aspect Ratio 6 at a Reynolds Number of 6,800,000. NACA RM L8K12, 1949.
11. Schneider, Leslie E., and Watson, James M.: Low-Speed Wind-Tunnel Investigation of Various Plain-Spoiler Configurations for Lateral Control on a 42° Sweptback Wing. NACA TN 1646, 1948.

12. Spooner, Stanley H., and Woods, Robert L.: Low-Speed Investigation of Aileron and Spoiler Characteristics of a Wing Having 42° Sweepback of the Leading Edge and Circular-Arc Airfoil Sections at Reynolds Numbers of Approximately 6.0×10^6 . NACA RM L9A07, 1949.
13. Fischel, Jack, and Ivey, Margaret F.: Collection of Test Data for Lateral Control with Full-Span Flaps. NACA TN 1404, 1948.
14. Bollech, Thomas V., and Pratt, George L.: Effects of Plain and Step Spoiler Location and Projection on the Lateral Control Characteristics of a Plain and Flapped 42° Sweptback Wing at a Reynolds Number of 6.8×10^6 . NACA RM L9L20a, 1950.
15. Fischel, Jack, and Vogler, Raymond D.: High-Lift and Lateral Control Characteristics of an NACA 65₂-215 Semispan Wing Equipped with Plug and Retractable Ailerons and A Full-Span Slotted Flap. NACA TN 1872, 1949.
16. Schneider, Leslie E., and Watson, James M.: Wind-Tunnel Investigation at Low Speeds of Various Plug-Aileron and Lift-Flap Configurations on a 42° Sweptback Wing. NACA RM L8K19, 1948.
17. Langley Research Staff (Compiled by Thomas A. Toll): Summary of Lateral-Control Research. NACA Rep. 868, 1947. (Formerly NACA TN 1245.)
18. Fischel, Jack: Wind-Tunnel Investigation of an NACA 65-210 Semispan Wing Equipped with Circular Plug Ailerons and A Full-Span Slotted Flap. NACA TN 1802, 1949.
19. Pasamanick, Jerome, and Sellers, Thomas B.: Low-Speed Investigation of the Effect of Several Flap and Spoiler Ailerons on the Lateral Characteristics of a 47.5° Sweptback-Wing - Fuselage Combination at a Reynolds Number of 4.4×10^6 . NACA RM L50J20, 1950.
20. Fischel, Jack, and Hammond, Alexander D.: Investigation of Effect of Span and Spanwise Location of Plain and Stepped Spoiler Ailerons on Lateral Control Characteristics of a Wing with Leading Edge Swept Back 51.3° . NACA RM L9K02, 1950.
21. Fischel, Jack, and Watson, James M.: Investigation of Spoiler Ailerons for Use as Speed Brakes or Glide-Path Controls on Two NACA 65-Series Wings Equipped with Full-Span Slotted Flaps. NACA Rep. 1034, 1951. (Formerly NACA TN 1933.)

22. Fischel, Jack, and Schneiter, Leslie E.: High-Speed Wind-Tunnel Investigation of an NACA 65-210 Semispan Wing Equipped with Plug and Retractable Ailerons and a Full-Span Slotted Flap. NACA TN 1663, 1948.
23. Schneiter, Leslie E., and Hagerman, John R.: Wind-Tunnel Investigation at High Subsonic Speeds of the Lateral-Control Characteristics of an Aileron and a Stepped Spoiler on a Wing with Leading Edge Swept Back 51.3° . NACA RM L9D06, 1949.
24. Hammond, Alexander D.: Lateral-Control Investigation of Flap-Type and Spoiler-Type Controls on a Wing with Quarter-Chord-Line Sweepback of 60° , Aspect Ratio 2, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L50E09, 1950.
25. Schneiter, Leslie E., and Ziff, Howard L.: Preliminary Investigation of Spoiler Lateral Control on a 42° Sweptback Wing at Transonic Speeds. NACA RM L7F19, 1947.
26. Olson, Robert N., and Mead, Merrill H.: Aerodynamic Study of a Wing-Fuselage Combination Employing a Wing Swept Back 63° - Effectiveness at Supersonic Speeds of a 30-Percent Chord, 50-Percent Semispan Elevon as a Lateral Control Device. NACA RM A50K07, 1951.
27. May, Ellery B., Jr.: Investigation of the Effects of Leading-Edge Chord-Extensions on the Aerodynamic and Control Characteristics of Two Sweptback Wings at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L50L06a, 1951.
28. Connor, D. William, and Mitchell, Mead H., Jr.: Effects of Spoiler on Airfoil Pressure Distribution and Effects of Size and Location of Spoilers on the Aerodynamic Characteristics of a Tapered Unswept Wing of Aspect Ratio 2.5 at a Mach Number of 1.90. NACA RM L50L20, 1951.

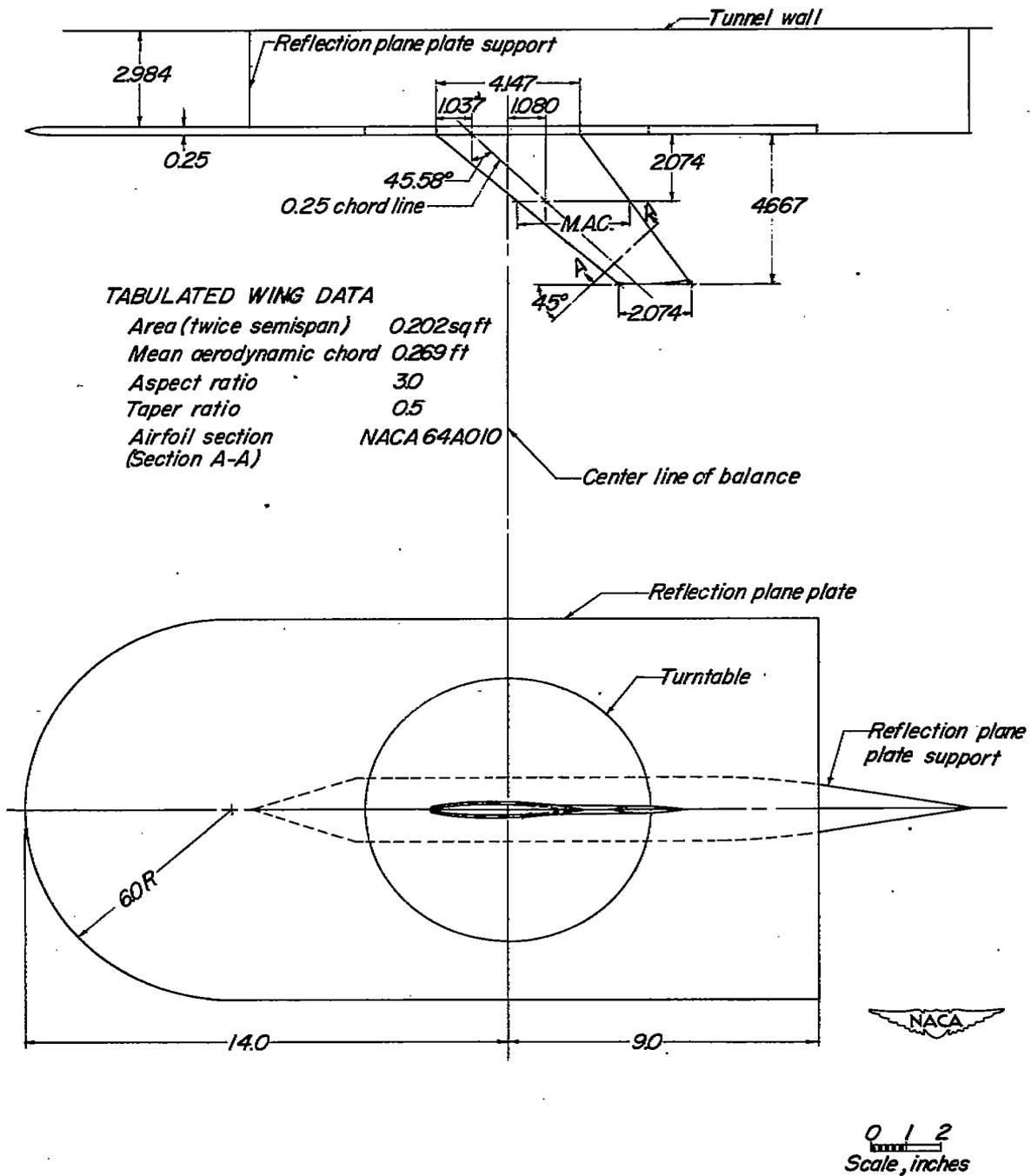


Figure 1.- Basic wing model mounted on the reflection plane in the Langley high-speed 7- by 10-foot tunnel.

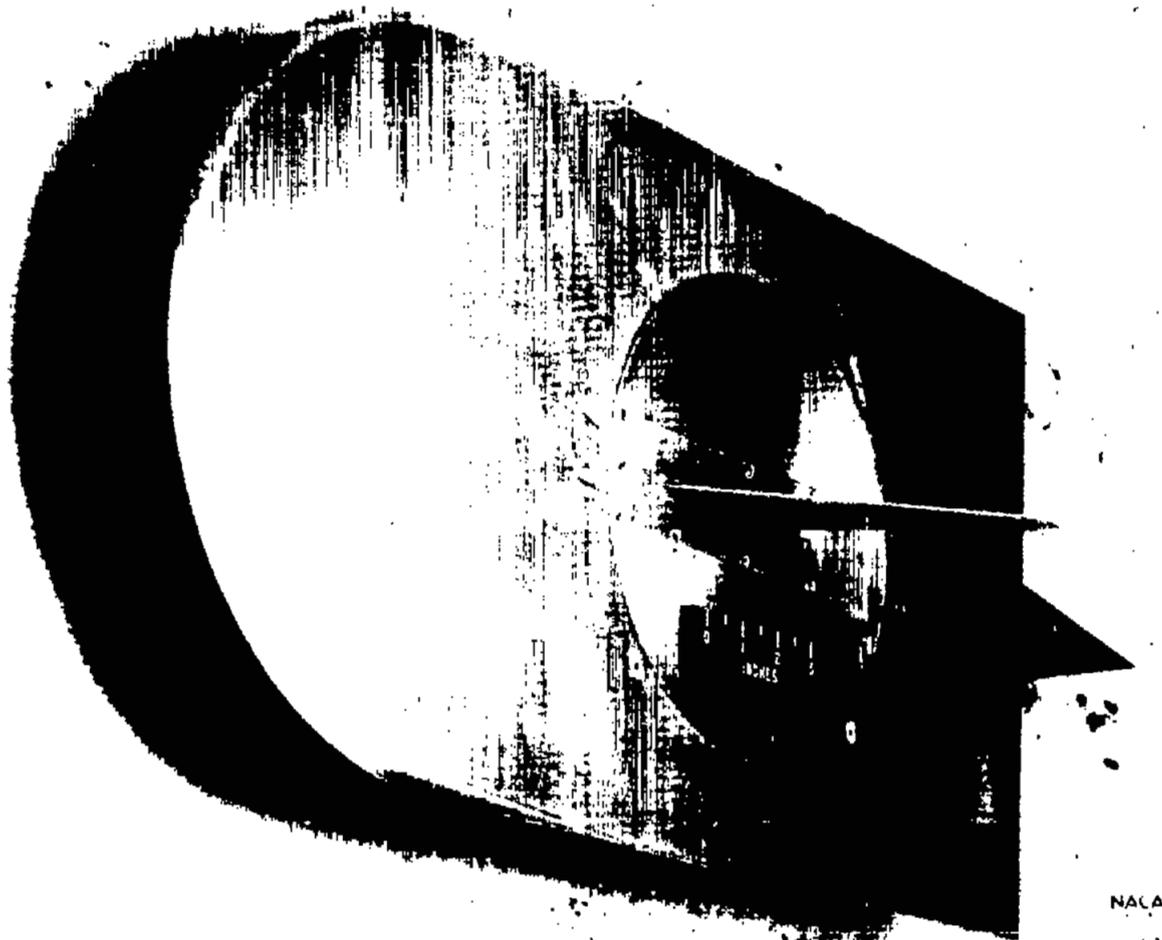


Figure 2.- View of typical model mounted on the reflection plane in the Langley high-speed 7- by 10-foot tunnel.

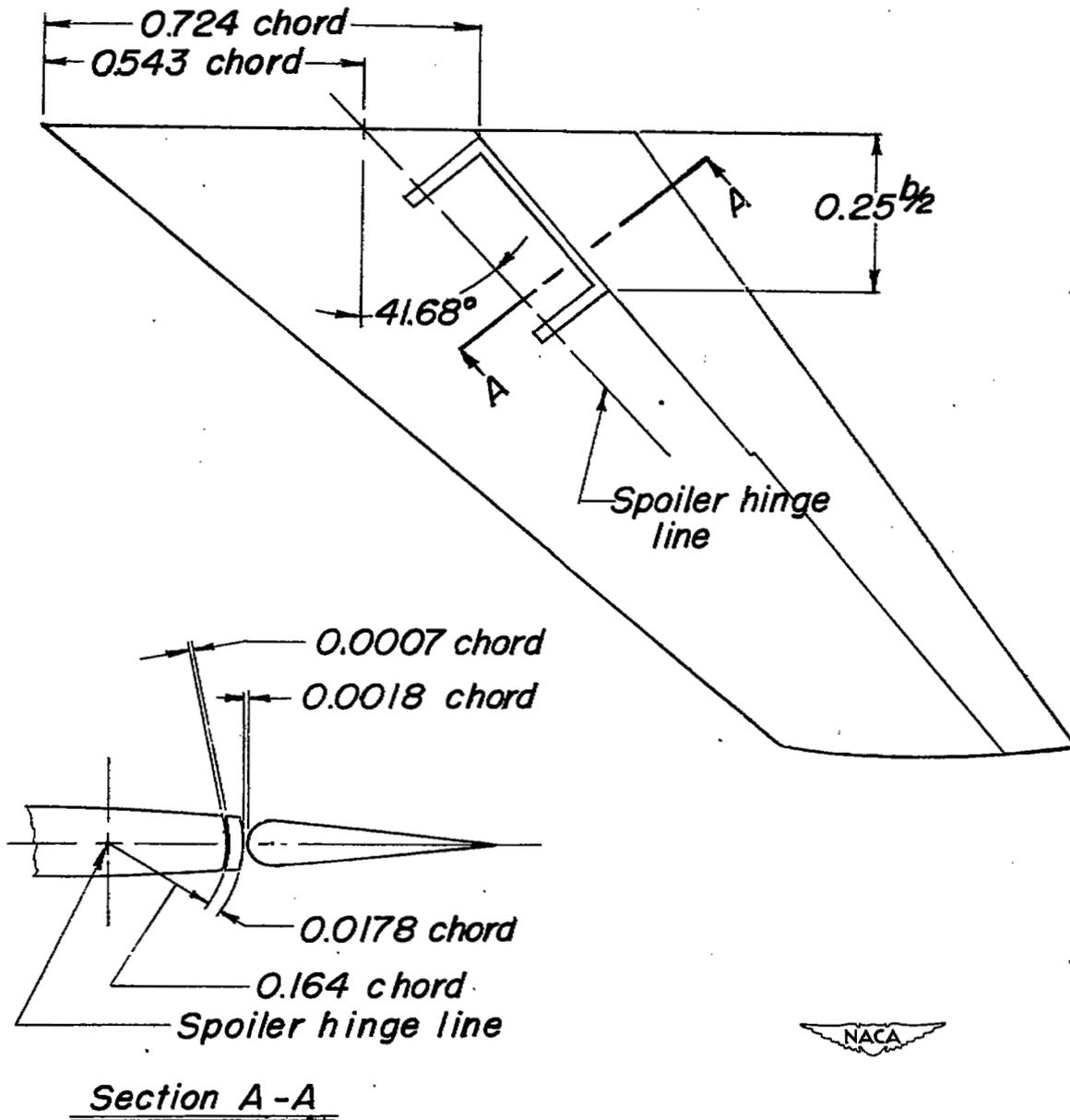
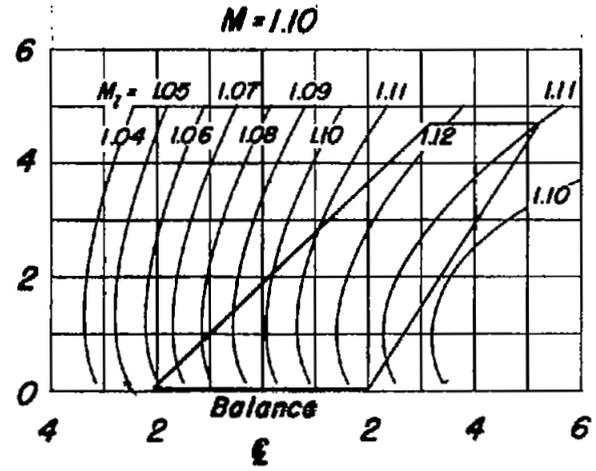
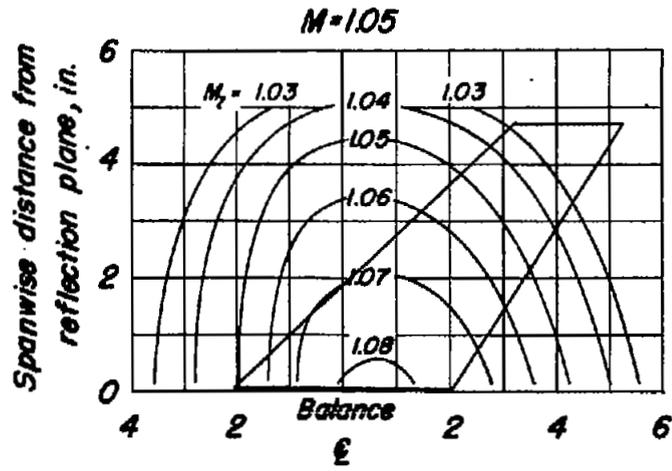
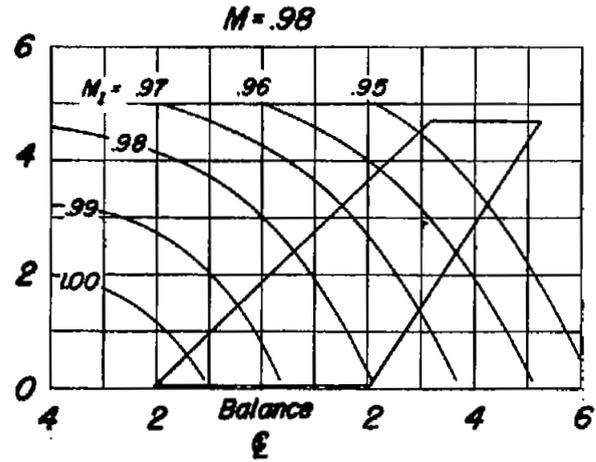
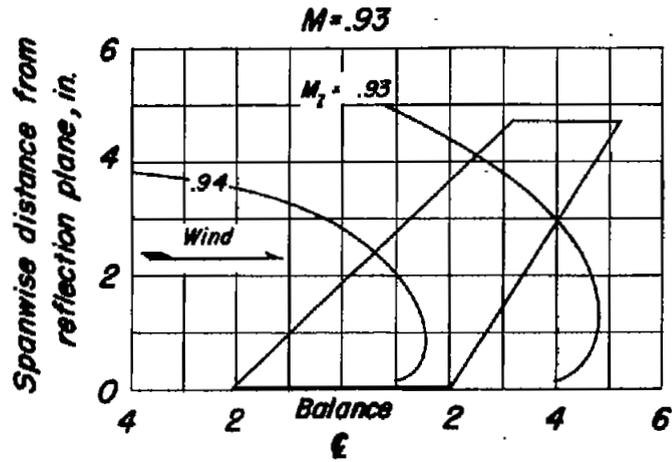


Figure 3.- Details of spoiler control.



Longitudinal distance along reflection plane, in.

Longitudinal distance along reflection plane, in.

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

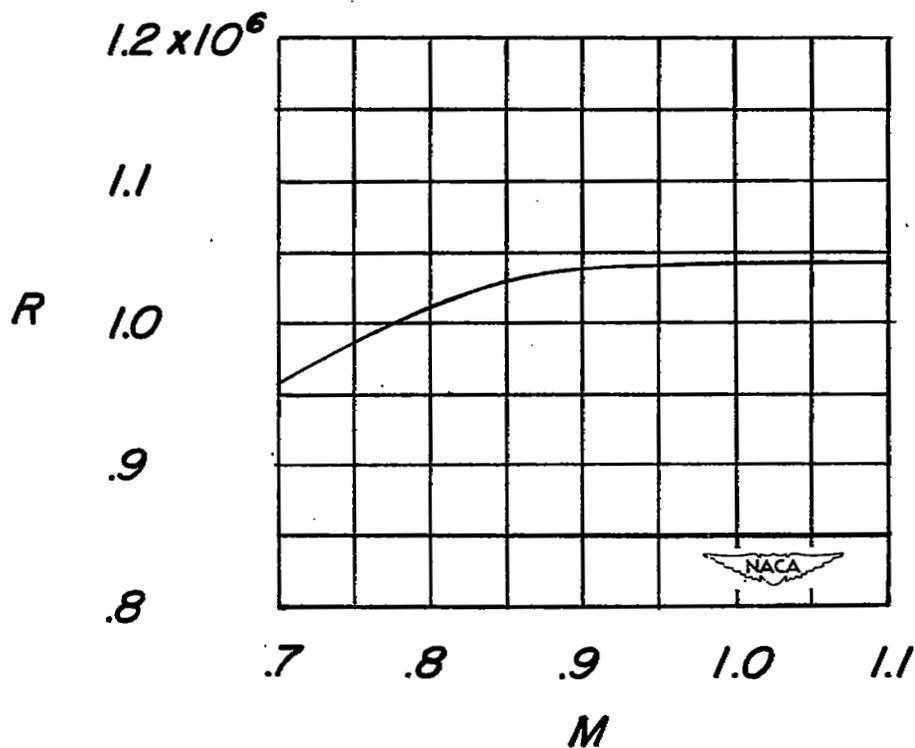
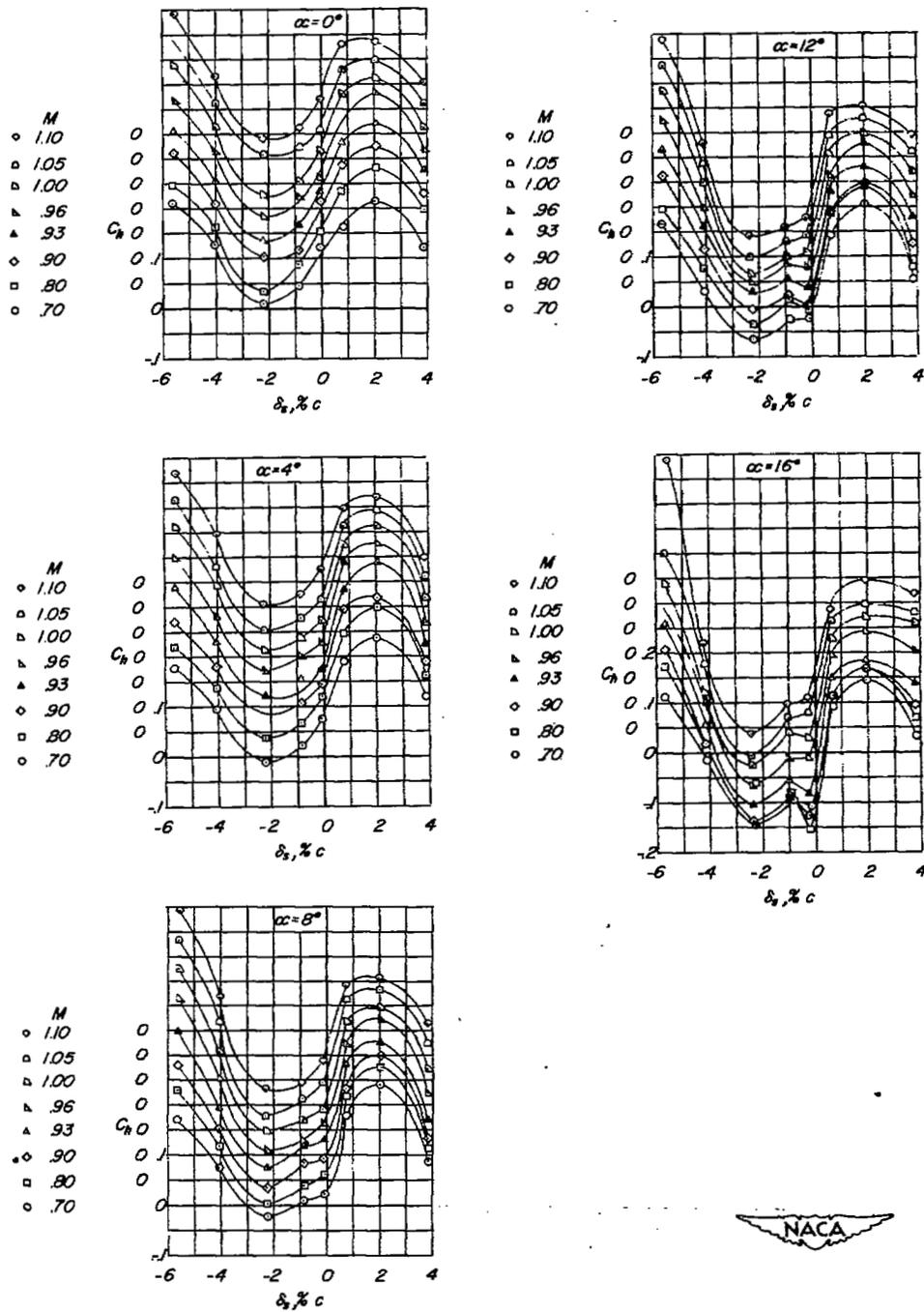


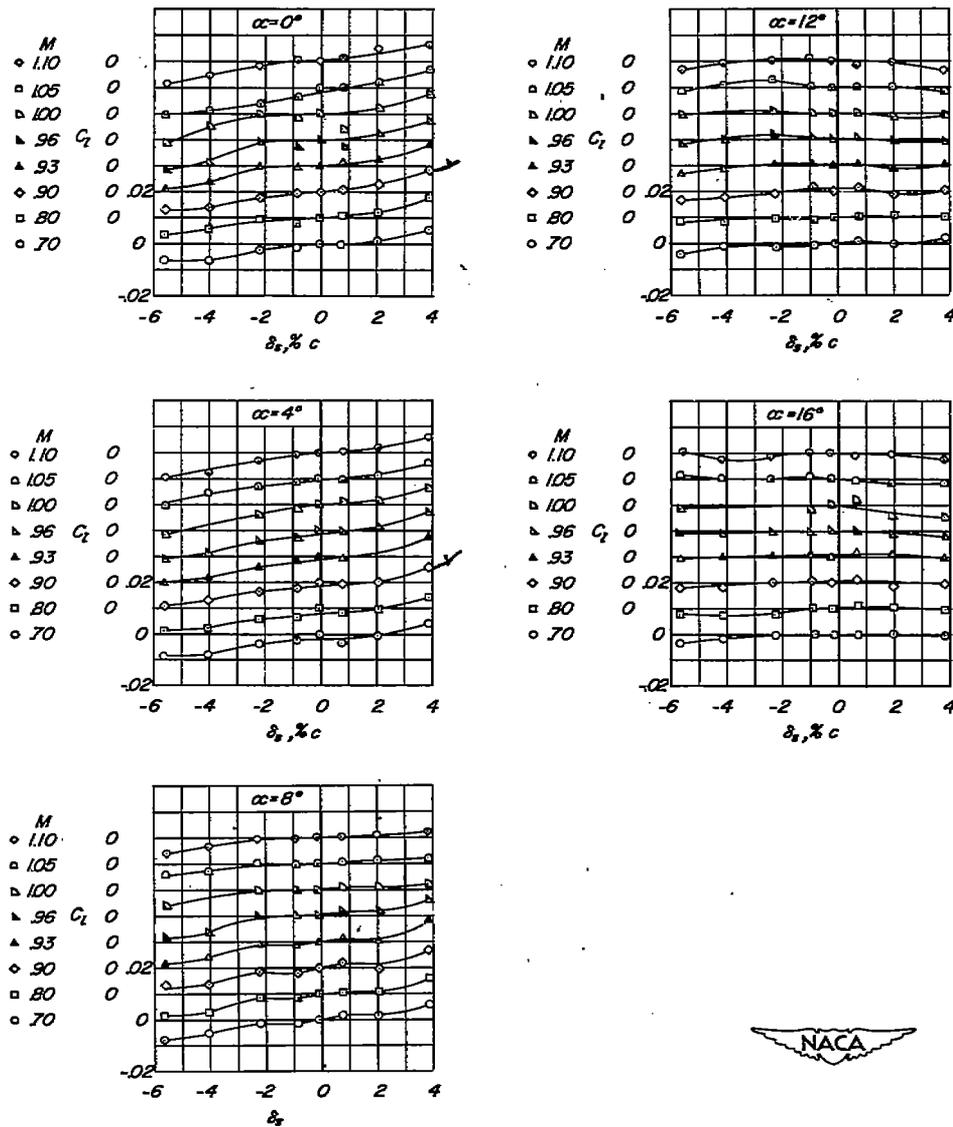
Figure 5.- Typical variation of Reynolds number with test Mach number through the transonic speed range.



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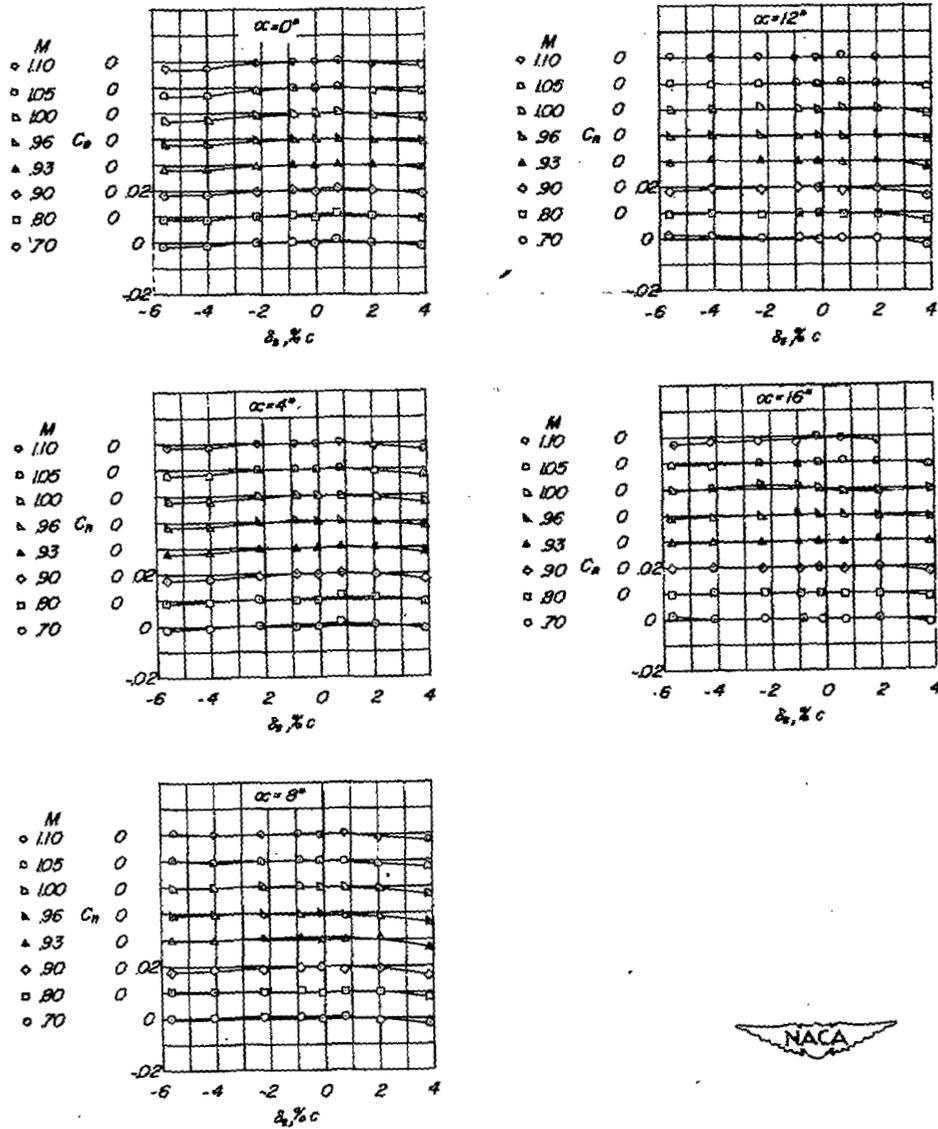
(a) C_h against δ_s .

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



(b) C_l against δ_s .

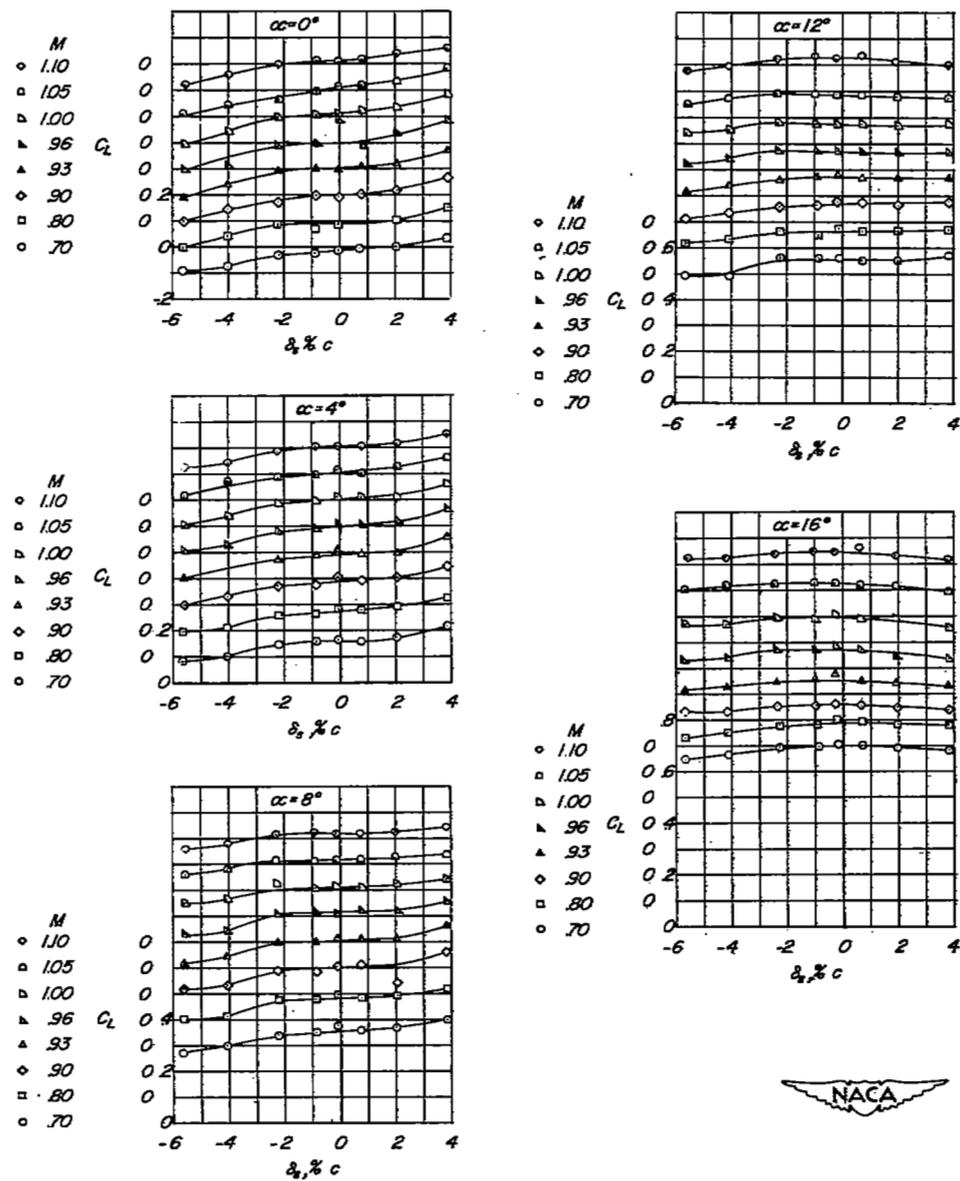
Figure 6.- Continued.



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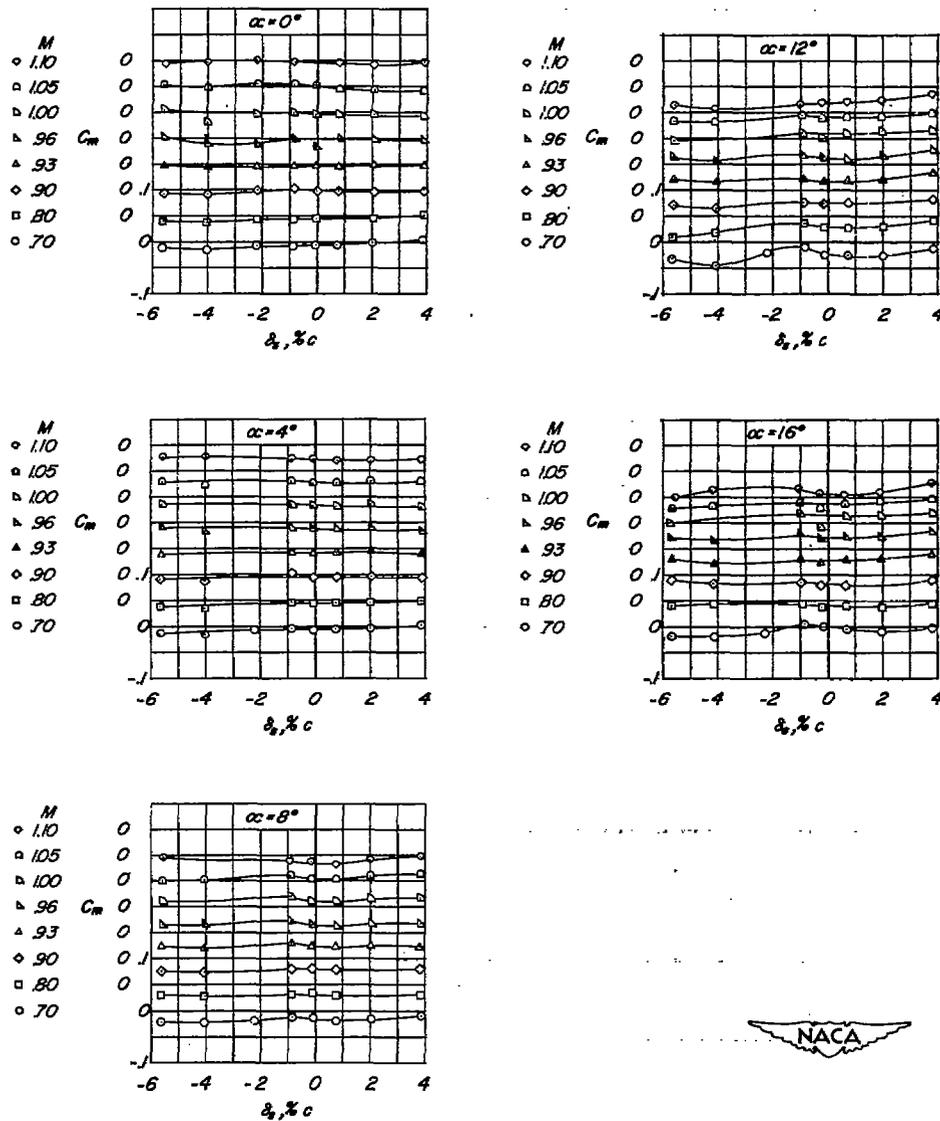
(c) C_n against δ_s .

Figure 6.- Continued.



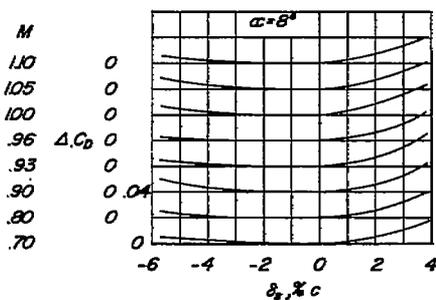
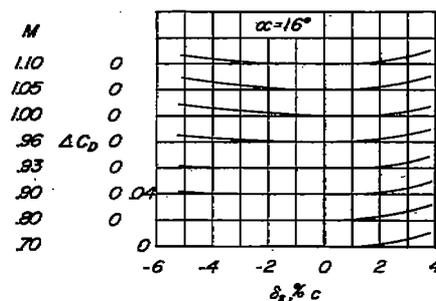
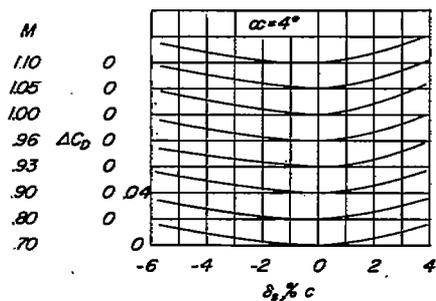
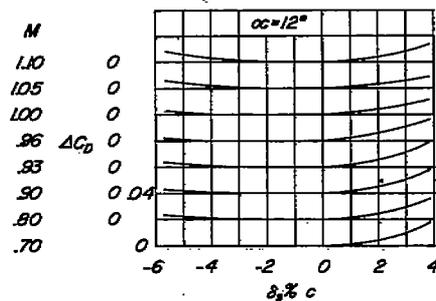
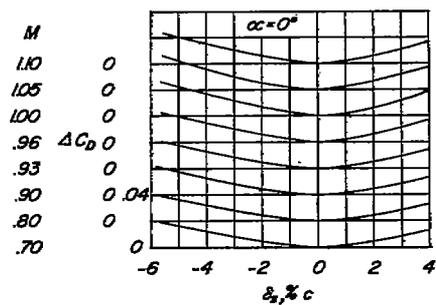
(d) C_L against δ_s .

Figure 6.- Continued.



(e) C_m against δ_g .

Figure 6.- Continued.



(f) ΔC_D against δ_g .

Figure 6.- Concluded.

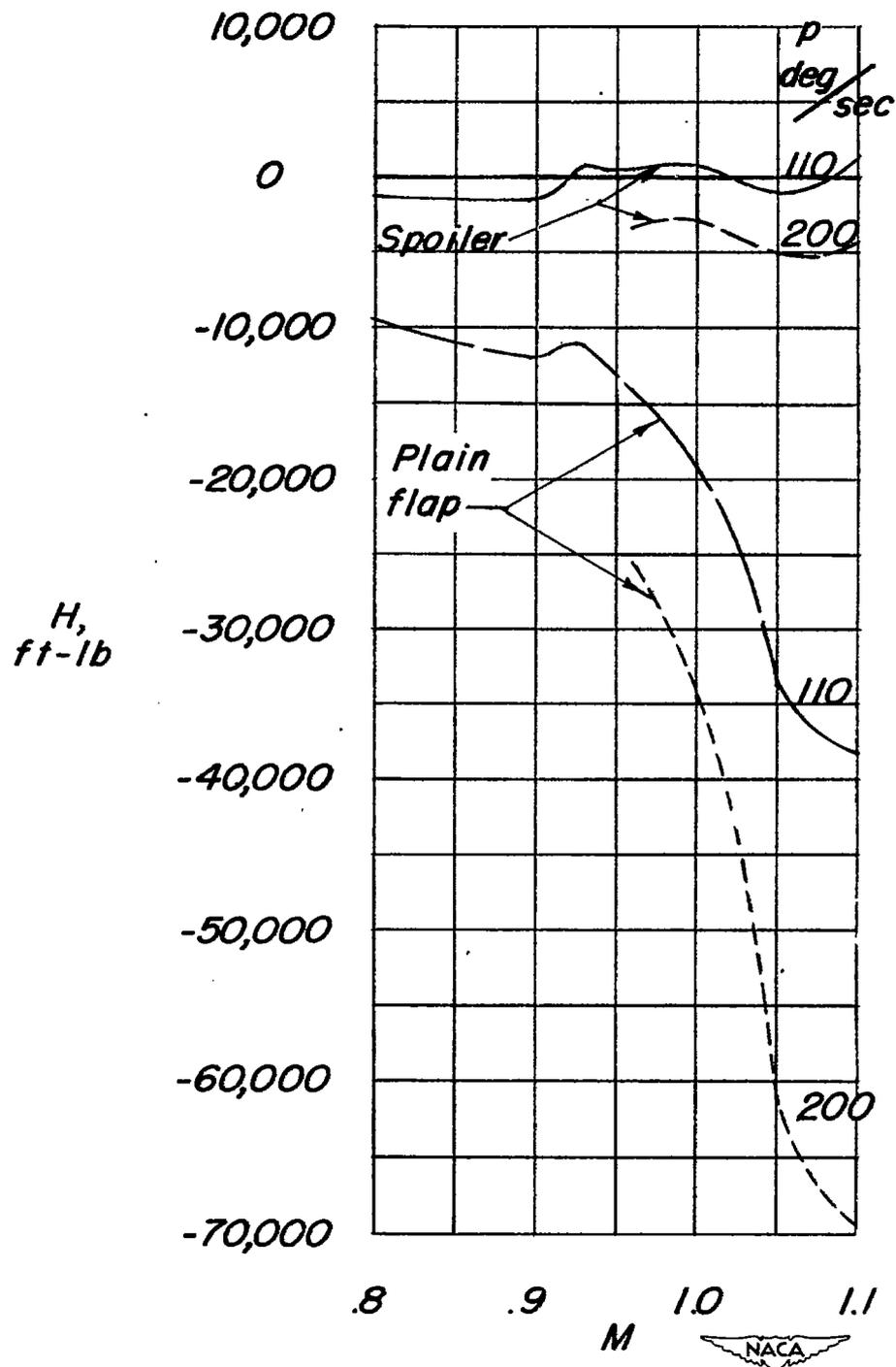


Figure 7.- Variation of hinge moment with Mach number for various rates of roll for a spoiler and for a full-span 25.4-percent-chord plain flap on an airplane of 38.90-foot span at sea-level conditions.

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