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RESEARCH MEMORANDUM

FREE-FLIGHT MEASUREMENTS OF THE ROLLING EFFECTIVENESS AND DRAG OF TRAILING-EDGE SPOILERS ON A TAPERED SWEPTBACK WING AT MACH NUMBERS BETWEEN 0.6 AND 1.4

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
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RESEARCH MEMORANDUM

FREE-FLIGHT MEASUREMENTS OF THE ROLLING EFFECTIVENESS AND DRAG OF TRAILING-EDGE SPOILERS ON A TAPERED SWEPTBACK WING AT MACH NUMBERS BETWEEN 0.6 AND 1.4

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SUMMARY

A limited free-flight investigation of the rolling effectiveness and drag of 0.02-chord trailing-edge spoilers has been conducted between Mach numbers of 0.6 and 1.4 by use of the rocket-model technique. The test wings were swept back 45° at the quarter chord, had a taper ratio of 0.6, an aspect ratio of 4.0, and an NACA 65A006 profile parallel to the free stream. Solid, sharp-edged, half-span spoilers were tested at both inboard and outboard spanwise locations.

The inboard spoiler produced considerably more rolling effectiveness but higher drag than the outboard spoiler. Compared with the same spoiler located at the 0.70-chord position, the trailing-edge spoiler had more rolling effectiveness at subsonic speeds but less rolling effectiveness at supersonic speeds. Less drag was obtained with the trailing-edge spoiler than with the same spoiler located at the 0.70-chord position throughout the speed range tested.

INTRODUCTION

Trailing-edge spoilers have previously been considered as a means of reducing the time lag of conventional spoilers (ref. 1). In addition, trailing-edge spoilers might be expected to reduce the region of flow expansion known to exist behind the spoiler (ref. 2) and thus increase the spoiler effectiveness. The present limited investigation was made to determine the steady-state rolling effectiveness and drag of 0.02-chord spoilers at the 0.98-chord position at two spanwise locations (outboard and inboard) on a tapered 45° sweptback wing. The results are compared with those for identical spoilers located at the 0.70-chord position (ref. 3).

The flight tests were made at the Pilotless Aircraft Research Station at Wallops Island, Va., using rocket-propelled test vehicles in free flight. Data were obtained continuously over the Mach number range from 0.6 to 1.4 by means of the technique described in reference 4.

SYMBOLS

A	aspect ratio, b^2/S, 4.0
b	diameter of circle swept by wing tips, 3.0 ft
S	area of two wings measured to model center line, 2.25 sq ft
S'	exposed area of three wings, 2.80 sq ft
c	local wing chord measured parallel to model center line
M	Mach number
q	dynamic pressure, lb/sq ft
V	flight-path velocity, ft/sec
R	Reynolds number based on average exposed wing chord of 0.72 ft
p	rolling velocity, positive for right wing moving downward as seen from rear, radians/sec
$pb/2V$	wing-tip helix angle, radians
h	local spoiler height above wing measured normal to wing-chord plane (test configuration represents right wing with spoiler on upper surface and left wing with spoiler on lower surface), ft
i_w	average wing incidence per wing, measured in a plane normal to wing-chord plane and parallel to free-stream direction, positive if tending to produce positive p, deg
y	spanwise distance, measured from and normal to model center line, ft
s	control span measured in direction of y, ft
m	concentrated static couple applied near wing tip in the plane of i_w, ft-lb

θ	wing twist produced by m (measured in planes parallel to the plane of m), radians
θ/m	wing torsional-stiffness parameter, radians/ft-lb
λ	wing taper ratio, 0.6
P	concentrated static load applied near wing tip, lb
δ	wing bending deflection due to concentrated load P, ft
δ/P	wing bending-stiffness parameter, ft/lb
C_D	test-vehicle drag coefficient, Drag/qS'

MODELS AND TECHNIQUE

A typical three-wing test vehicle used in the present investigation is illustrated in the photographs presented as figure 1 and the sketches presented as figure 2. The wings of the two models used were swept back 45° along the quarter-chord line, had an aspect ratio of 4.0, a taper ratio of 0.6, and NACA 65A006 airfoil sections parallel to the model center line. The solid, sharp-edged, half-span spoilers had projections of 2 percent of the local wing chord and were tested at inboard and outboard locations along the 0.98-chord line of each of the test wings.

Measured values of the wing torsion and bending characteristics are shown in figure 3 to give the magnitude and spanwise variation of the wing flexibility parameters. Values shown are the average for one wing from each of the two test vehicles.

The variation of Reynolds number R and dynamic pressure q with Mach number is shown in figure 4, at a given Mach number, the maximum deviation of q from the mean value was of the order of ±40 pounds per square foot.

The wing angle of attack, other than that due to rolling, was approximately zero.

ACCURACY AND CORRECTIONS

From previous experience and mathematical analysis, the experimental uncertainties in the test variables are believed to be within the following limits:

i_w, deg . . . . ±0.05
h/c . . . . ±0.001

	Subsonic	Supersonic
M	±0.010	±0.005
C_D	±0.003	±0.002
pb/2V	±0.003	±0.002

The sensitivity of the measuring technique, however, is such that small irregularities in the variation of pb/2V with Mach number, of the order of one-half the magnitude shown in the preceding table may be detected.

No correction has been applied to the data to account for the effects of wing flexibility on rolling effectiveness because of the lack of twisting-moment data for this wing-spoiler combination.

RESULTS AND DISCUSSION

The results of this investigation are presented in figures 5 to 7. The test-vehicle total drag coefficient C_D and the flexible-wing rolling effectiveness pb/2V at essentially zero angle of attack are plotted against Mach number in figure 5 for the inboard and outboard half-span 0.02-chord spoilers located at the 0.98-chord position. The inboard spoiler is shown to have more drag and considerably more rolling effectiveness than the outboard spoiler; this is substantially true regardless of whether pb/2V and C_D are compared on the basis of equal control spans, equal control frontal areas, or equal moments of the control frontal areas about the roll axis. However, in comparing the effectiveness of inboard and outboard controls, it should be pointed out that the over-all rolling effectiveness of a given control may be radically changed with the addition of a fixed tail surface behind the test wings. Preliminary results (unpublished) of a current investigation of the effects of fixed tail surfaces behind an untapered sweptback wing show that an inboard half-span aileron may be inferior to the outboard half-span aileron when a fixed tail surface is used, whereas the reverse is true if no fixed tail surface is present. No data are at present available concerning the effects of a fixed tail surface on spoiler rolling effectiveness.

The rolling-effectiveness data of figure 5 have been compared in figure 6 with rolling-effectiveness data from reference 3, where the 0.02-chord spoilers were located at the 0.70-chord position. It can be seen that the trailing-edge location is superior at subsonic speeds but inferior at supersonic speeds. These results at supersonic speeds were somewhat unexpected in view of the data of references 5 and 6 which indicate that, generally, higher rolling moments were obtained by moving the spoiler toward the wing trailing edge. The wings of references 5 and 6 were untapered, had lower aspect ratios than the wings of the present test, and were relatively thick at the trailing edge. Calculations show that approximately one-half the rolling-effectiveness difference between the 0.70-chord location and the trailing-edge location for the present tests at low supersonic speeds may be due to wing flexibility for the outboard location, but that only a small part of the difference is due to wing flexibility for the inboard location. From a comparison of the results of the present tests with those of reference 3, it must be concluded that at low supersonic speeds the trailing-edge location for an $h/c = 0.02$ spoiler is aerodynamically inferior to the 0.70-chord location for a sweptback, tapered, thin-trailing-edge wing.

A drag comparison for the two chordwise locations is made in figure 7 and it can be seen that the trailing-edge spoiler has the lower drag throughout the speed range tested. The data of figures 6 and 7 show that moving the spoiler from the 0.70-chord location to the trailing edge results in more rolling effectiveness and less drag at subsonic speeds but results in less rolling effectiveness with less drag at supersonic speeds.

CONCLUSIONS

A limited free-flight investigation employing the rocket-model technique was made over the Mach number range from 0.6 to 1.4, utilizing 0.02-chord inboard and outboard spoilers located at the trailing edge of a 45° tapered sweptback wing. The test vehicles did not have fixed tail surfaces and were flown at essentially zero angle of attack. From a comparison of the results with those of a previous investigation, the following conclusions have been drawn:

1. The inboard spoiler gave considerably more rolling effectiveness and more drag than the outboard spoiler.

2. In terms of rolling effectiveness, the trailing-edge location is superior to the 0.70-chord location at subsonic speeds but inferior at low supersonic speeds.

3. The trailing-edge location exhibited less drag than the 0.70-chord location throughout the Mach number range from 0.6 to 1.4.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 25, 1953.

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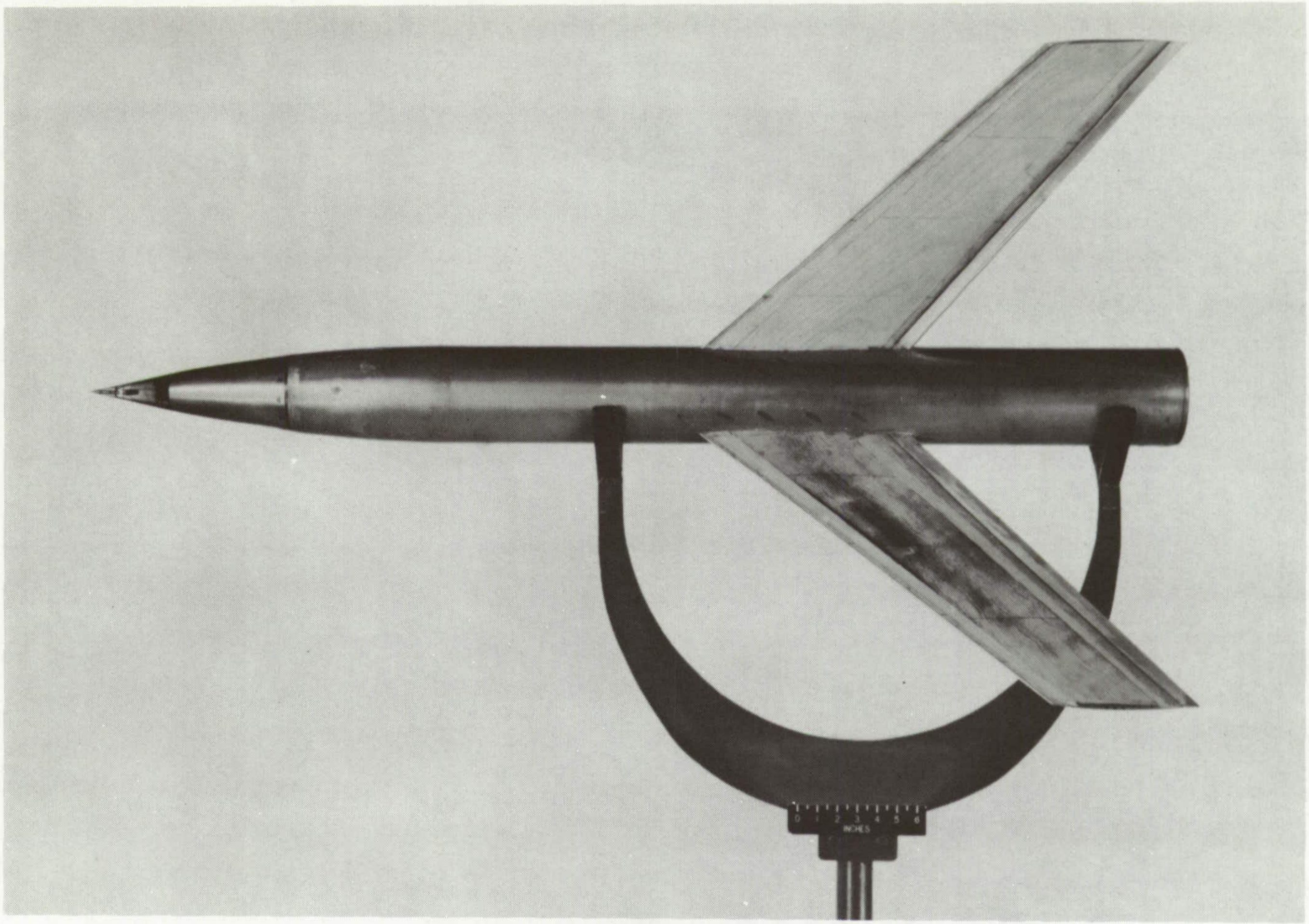

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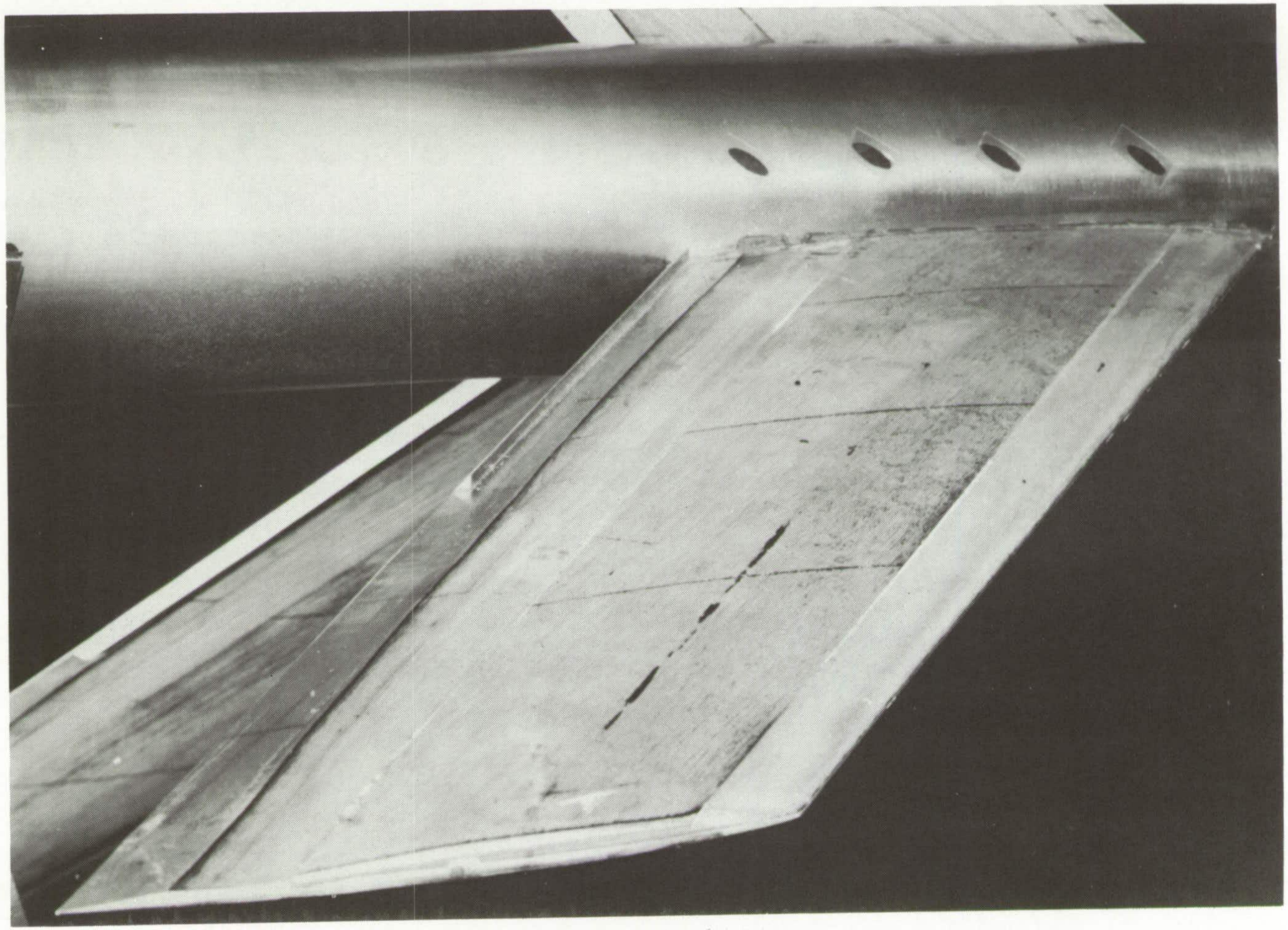
(a) Test vehicle with inboard spoiler.

Figure 1.- Photographs of test configuration.



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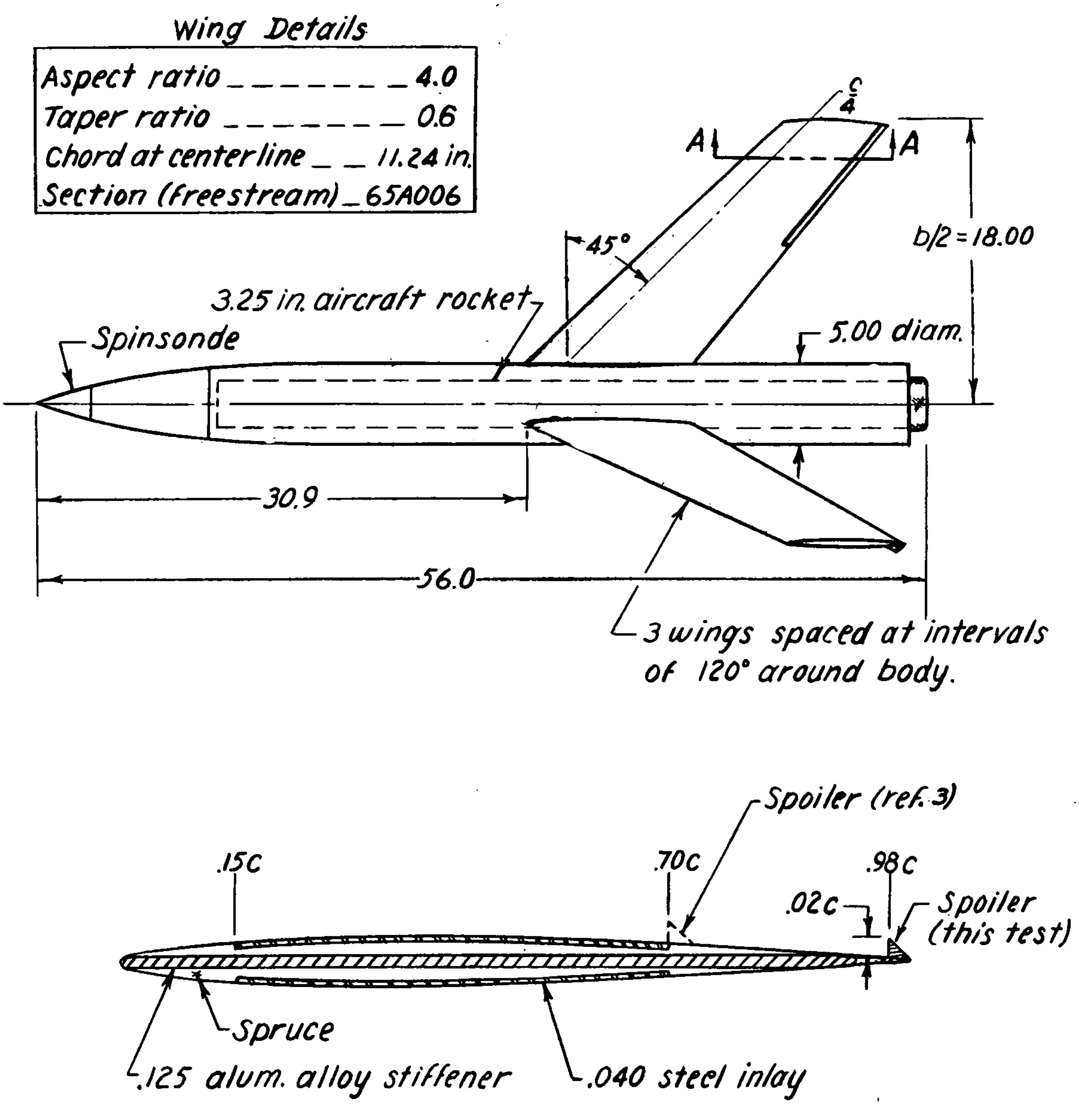
(b) Closeup of inboard spoiler on a typical wing.

Figure 1.- Concluded.



Typical Section A-A

Figure 2.- Geometric details of a typical test vehicle. All dimensions are in inches.

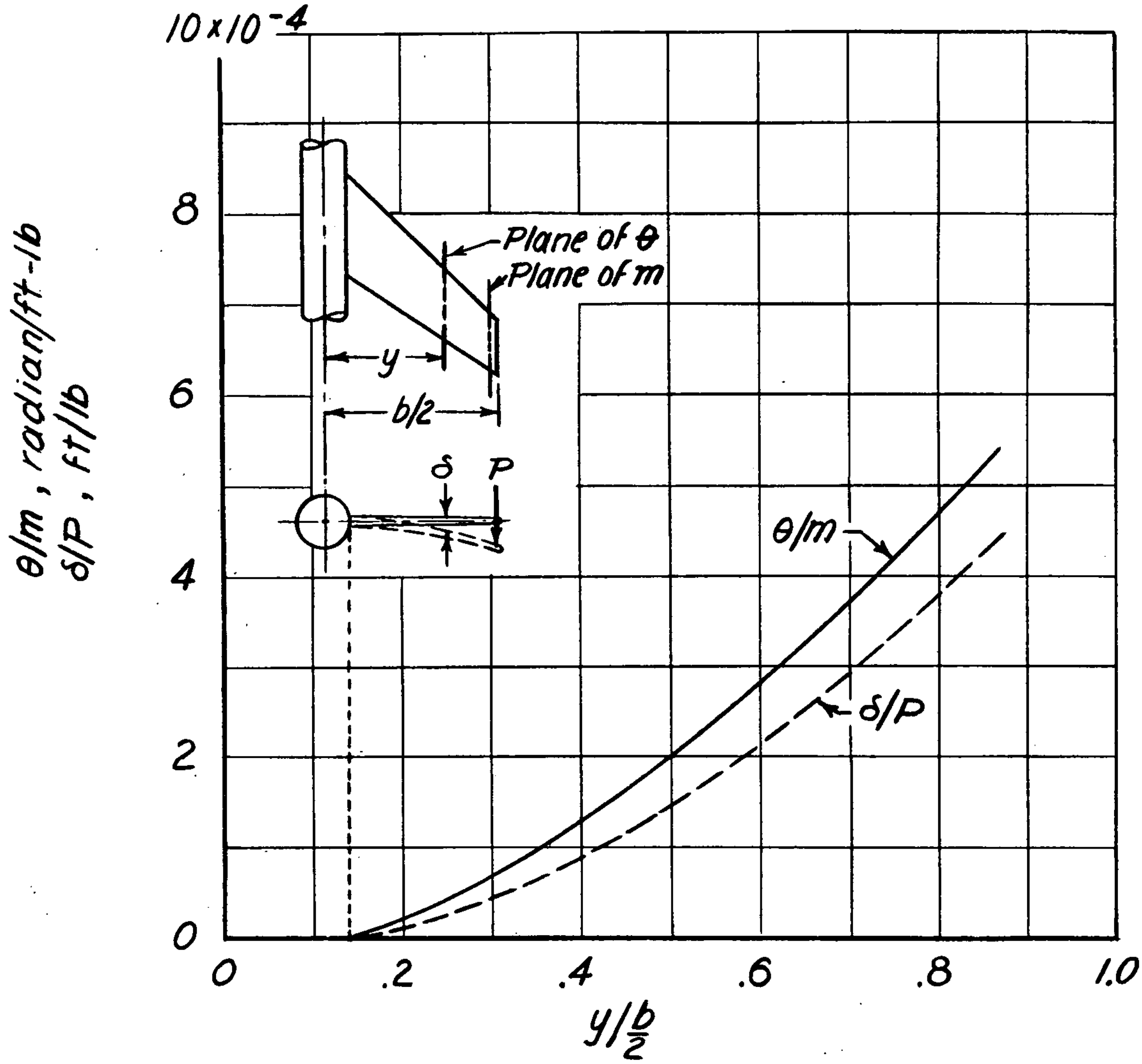


Figure 3.- The torsion and bending characteristics of a typical test wing.

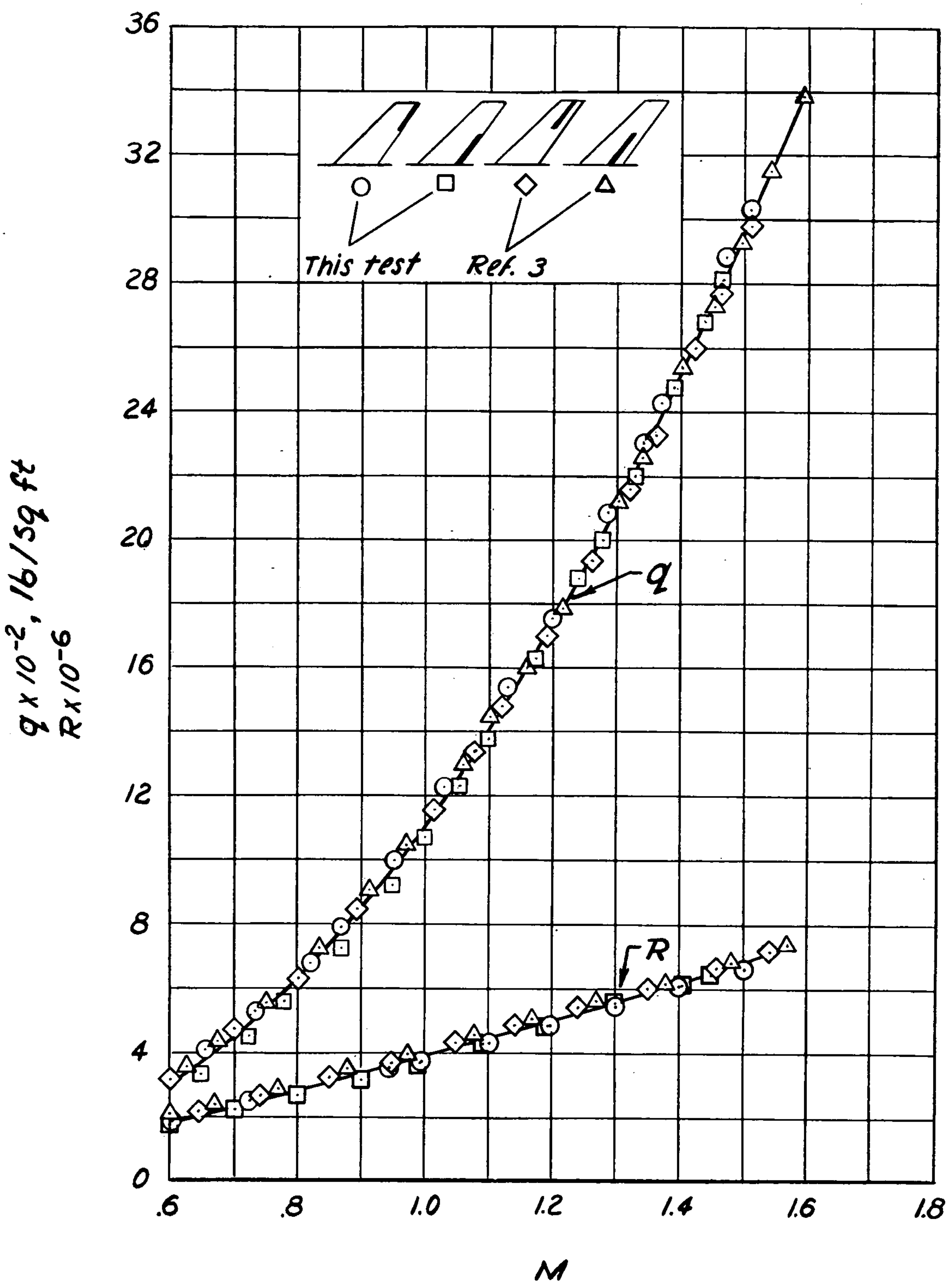


Figure 4.- Variation of test dynamic pressure q and test Reynolds number R with Mach number for this test and reference 3.

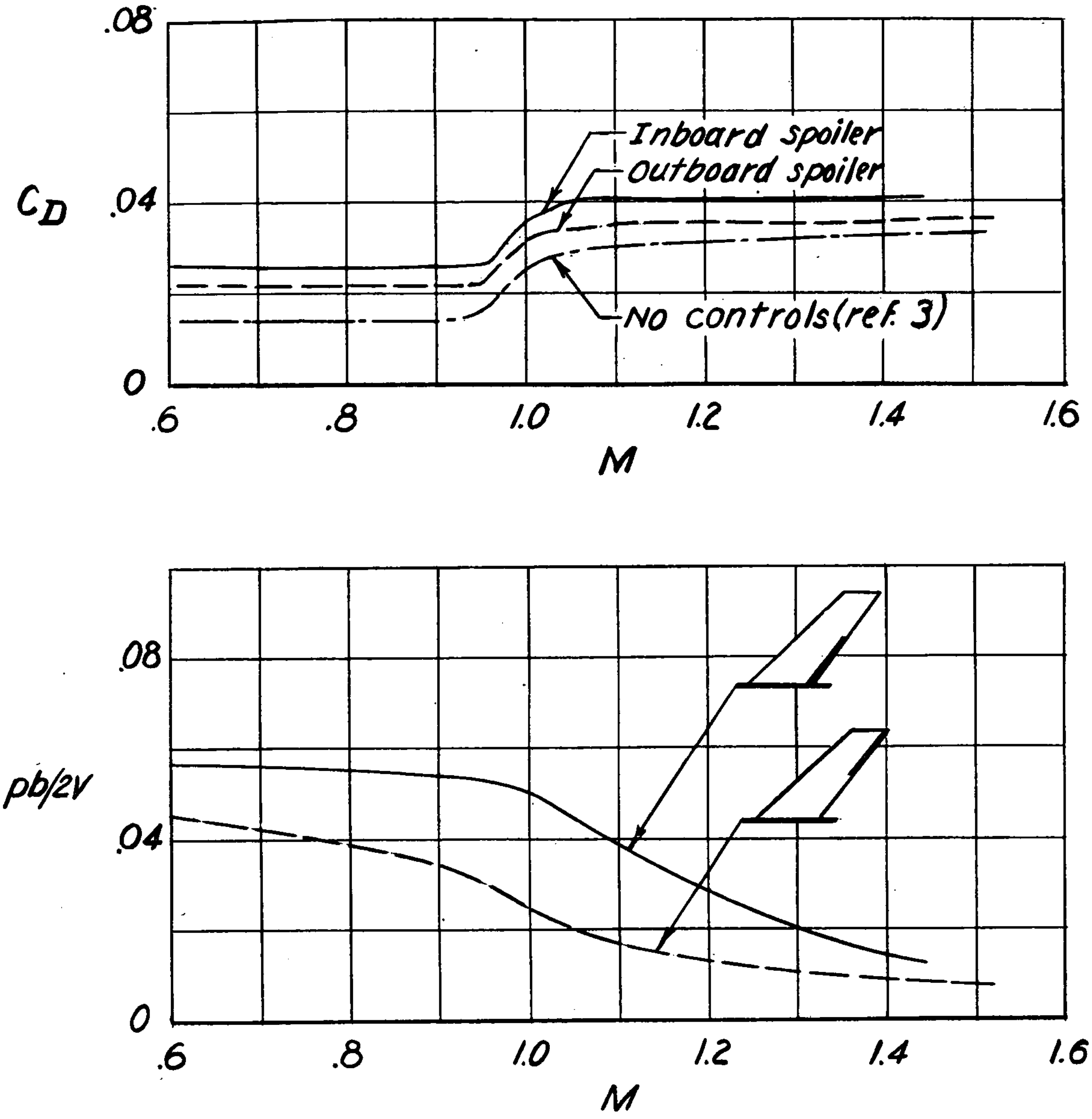
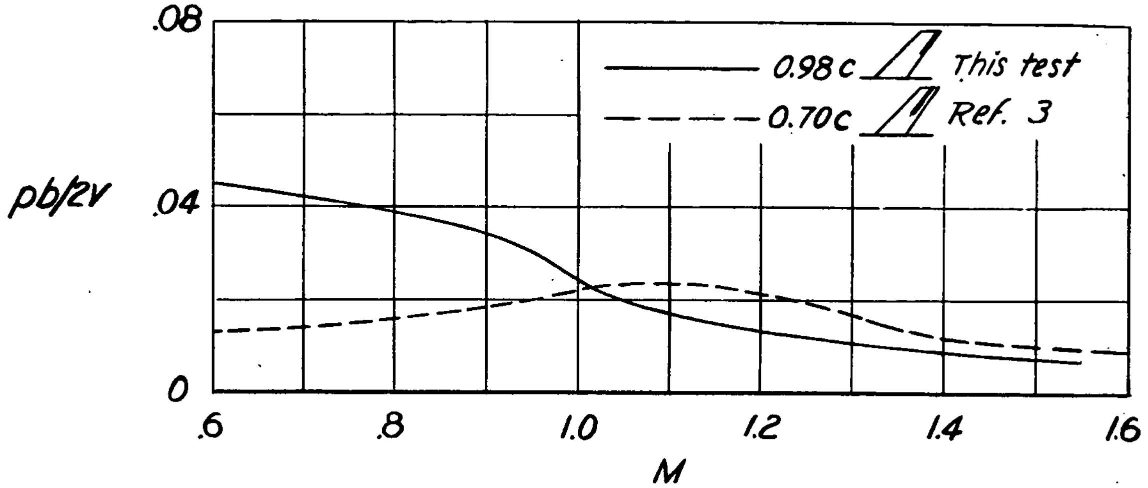
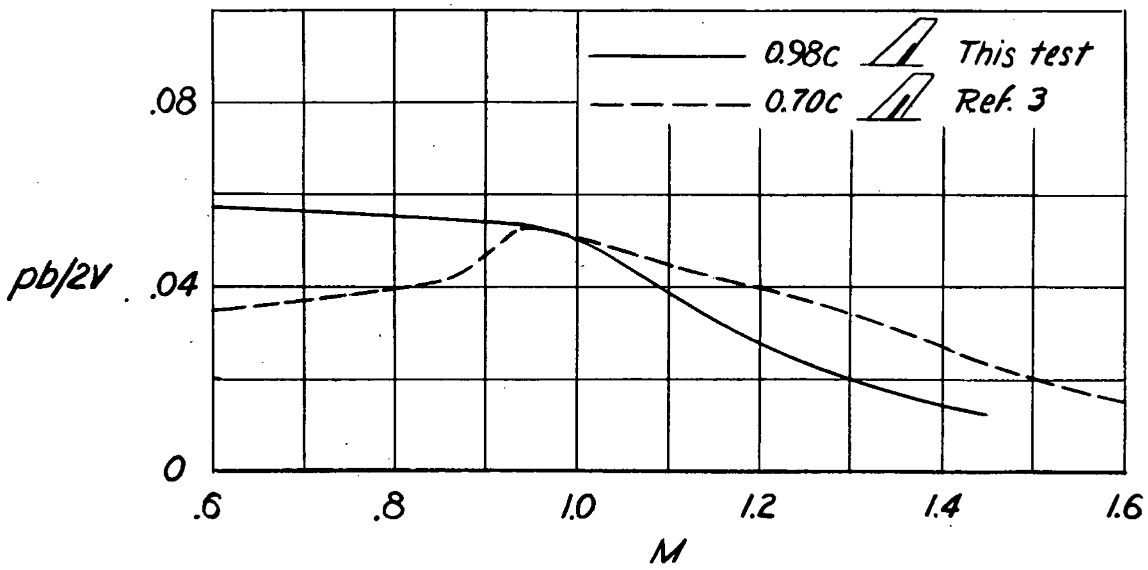


Figure 5.- Variation of drag coefficient and rolling effectiveness with Mach number for inboard and outboard spoilers located along the 0.98-chord line; $\frac{h}{c} = 0.02$; $\frac{s}{b/2} = 0.43$; $i_w = 0^\circ$.

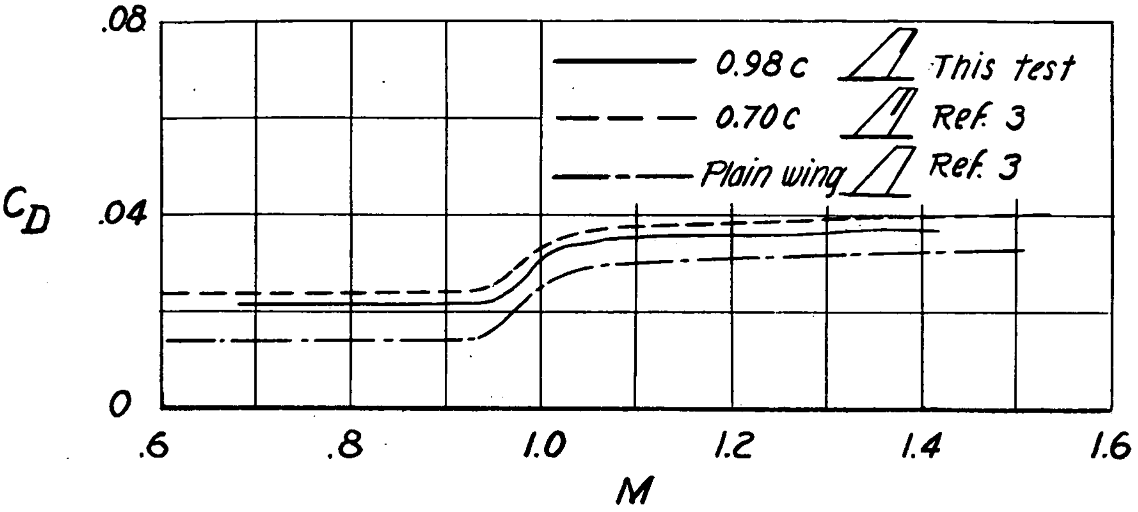


(a) Outboard spoiler.

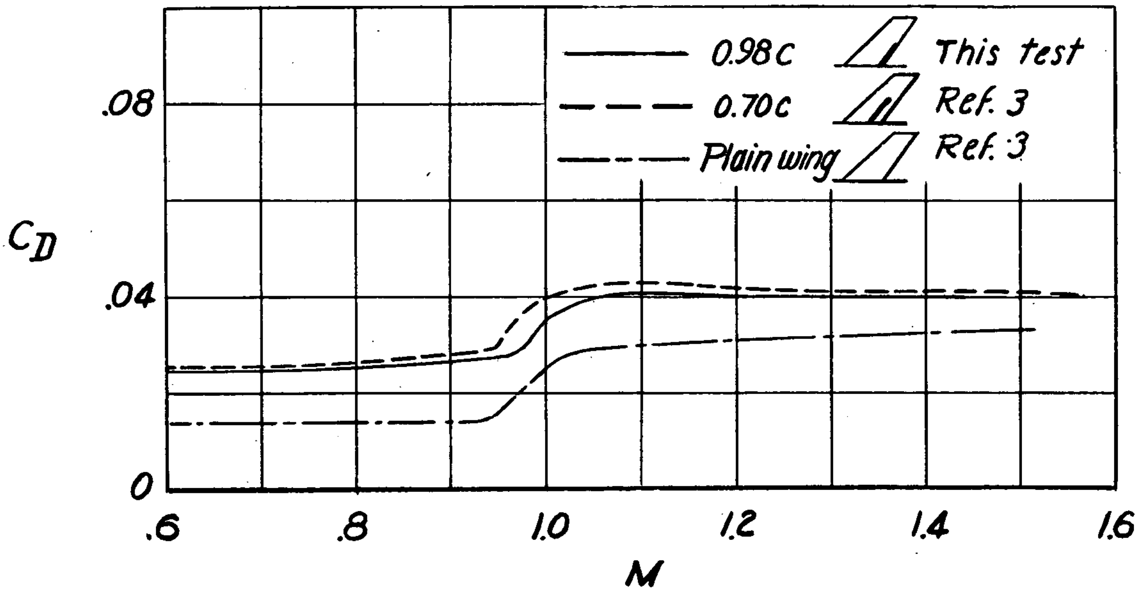


(b) Inboard spoiler.

Figure 6.- Effect of chordwise location on the variation of rolling effectiveness with Mach number for outboard and inboard spoilers; $\frac{h}{c} = 0.02$; $\frac{s}{b/2} = 0.43$; $i_w = 0^{\circ}$.



(a) Outboard spoiler.



(b) Inboard spoiler.

Figure 7.- Effect of chordwise location on the variation of drag coefficient with Mach number for outboard and inboard spoilers; $\frac{h}{c} = 0.02$; $\frac{s}{b/2} = 0.43$; $i_w = 0^\circ$.

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