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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION TO DETERMINE SOME EFFECTS OF TAIL DAMPING AND WING-TAIL INTERFERENCE ON THE ROLLING EFFECTIVENESS OF INBOARD AND OUTBOARD AILERONS ON AN UNTAPERED SWEPTBACK WING

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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FREE-FLIGHT INVESTIGATION TO DETERMINE SOME EFFECTS OF TAIL DAMPING AND WING-TAIL INTERFERENCE ON THE ROLLING EFFECTIVENESS OF INBOARD AND OUTBOARD AILERONS ON AN UNTAPERED SWEPTBACK WING

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SUMMARY

An investigation has been made of the rolling effectiveness of inboard and outboard ailerons on a sweptback wing. The investigation was made by means of rocket-propelled models in free flight over a Mach number range from 0.6 to 1.5. Tests were made on models with tails that were free to roll relative to the body so as to exclude the effects of tail damping and wing-tail interference and on models with tails fixed to the body at two different vertical locations. The results of the investigation indicate that the rolling effectiveness of the inboard aileron was decreased considerably over the entire test Mach number range by the substitution of fixed tail fins for a free-to-roll tail on a wing-body combination. Fixing the tail caused no consistent change in the rolling effectiveness of the outboard aileron.

INTRODUCTION

In previous investigations the common practice has been to use wings alone or wing-body combinations in determining the rolling effectiveness of lateral controls. The effects of tail damping and of downwash and sidewash have in most cases been neglected. In order to determine some of these effects on rolling effectiveness, an investigation has been made of the rolling effectiveness of inboard and outboard half-exposed-span ailerons on a sweptback wing. The investigation was made by means of rocket-propelled models in free flight over a Mach number range from 0.6 to 1.5. Tests were made on models with tail fins which were free to roll relative to the bodies in order to exclude the effects of tail damping and wing-tail interference and on models with tail fins fixed to the bodies, with the horizontal tail fins in two different vertical locations.

SYMBOLS

b	total wing span, ft
c	wing chord, ft
M	Mach number
p	rolling velocity, radians/sec
R	Reynolds number based on wing chord of 0.59 ft
V	model flight-path velocity, ft/sec
pb/2V	wing-tip helix angle, radians
δ	deflection of each aileron, measured parallel to the free stream, deg

DESCRIPTION OF MODELS

The models tested in this investigation consisted of a wing on a pointed body of revolution with four equally spaced tail fins. The wing had an aspect ratio of 3.71 and a taper ratio of 1.00 and was swept back 45°. The wing airfoil section was the NACA 65A009 in a plane parallel to the model center line. The wings were equipped with plain, sealed, trailing-edge ailerons deflected 5°. On models 1, 3, and 5 the ailerons extended over the inboard half and on models 2 and 4, the outboard half of the exposed semispan. Geometric details and dimensions of the models are given in figures 1 and 2. Wing construction details are shown in figure 3.

Models 1 and 2 were equipped with tail fins which were free to roll relative to the body in order that they might contribute to longitudinal and directional stability but exclude the effects of tail damping and wing-tail interference on rolling effectiveness. The tail fins of models 3, 4, and 5 were fixed to the body. On models 3 and 4, the horizontal tail was located in the wing-chord plane and on model 5, about 0.18c above the wing-chord plane. On models 3 and 4 the exposed tail area was about 25.8 percent and on model 5 about 29 percent of the exposed wing area. It should be noted that the difference in exposed tail area was due to the difference in vertical location of the horizontal tail fins. The total tail area and tail span were the same for models 3, 4, and 5. The tail length was 1.88c for all models.

TEST METHOD

The models were propelled to a Mach number of 1.5 by means of two-stage rocket-propulsion systems. During a period of free flight following burnout of the second propulsion stage, rolling velocity, flight-path velocity, range, and altitude were recorded continuously by means of special radio (spinsonde) and radar equipment. These data were used with atmospheric data from radiosondes to determine the variation of the rolling effectiveness parameter $pb/2V$ with Mach number. The range of test Reynolds numbers is presented in figure 4. A complete description of the test method is given in reference 1.

Accuracy

The following limits on the accuracy of the test data are estimated:

	Subsonic	Supersonic
$pb/2V$, radians	± 0.003	± 0.002
M	± 0.01	± 0.01

RESULTS AND DISCUSSION

The variation of the experimental rolling effectiveness parameter $pb/2V$ with Mach number is presented for the test configurations in figure 5. Experimental rolling effectiveness has been corrected by the method of reference 2 for the random wing- and tail-incidence errors resulting from construction tolerances. No corrections were made for the effects of moment of inertia in roll since these effects are shown in reference 1 to be negligible except where an abrupt change in $pb/2V$ occurs (inertia corrections for the models of the present investigation were less than 5 percent at the maximum). The resistance to roll of the free-to-roll tail was determined in static tests under simulated flight conditions and was found to be about 0.17 ft-lb, which is negligible compared to the wing damping moment (20 to 30 ft-lb). Models 1 and 2 were, therefore, effectively wing-body combinations as far as roll is concerned. Figure 5(a) shows that the substitution of fixed tail fins for the free-to-roll tail reduced the rolling effectiveness of the inboard aileron by a large amount over the entire test Mach number range. The reduction in rolling effectiveness was of the same order of magnitude at subsonic and supersonic speeds and was large enough to cause the control to become ineffective at a Mach number of approximately 1.30, with the horizontal tail in the plane of the wing.

The curves of figure 5(a) show a slight increase in rolling effectiveness at transonic and supersonic speeds when the horizontal tail is moved out of the plane of the wing; therefore, moving the horizontal tail out of the plane of the wing apparently reduced the effects of downwash slightly, above $M \approx 0.90$. In figure 5(b), the substitution of fixed tail for free-to-roll tail caused no consistent change in $pb/2V$ for the outboard aileron. The variation in rolling effectiveness for the free-to-roll tail and fixed tail is random and within experimental accuracy; therefore, the effect of substituting fixed tail fins for free-to-roll tail on the rolling effectiveness of the outboard aileron is negligible.

A comparison of the inboard and outboard ailerons is made in figure 6. The rolling effectiveness of the inboard aileron is considerably higher than that of the outboard aileron for the free-to-roll tail models in figure 6(a). In figure 6(b), after the substitution of fixed tail fins for the free-to-roll tail, the rolling effectiveness of the outboard aileron is the higher of the two, except in the transonic region. Apparently, there is an optimum aileron location where the effects of downwash from the aileron will be least harmful.

The changes in $pb/2V$ due to tail damping alone and wing-tail interference alone are shown in figure 7. The rolling effectiveness that the fixed-tail models would have if there were no downwash or sidewash was obtained by correcting the rolling effectiveness of the free-to-roll tail models for the additional damping of the tail by using the strip theory of reference 2. Figure 7 shows that wing-tail interference effects are responsible for the larger part of the total change in $pb/2V$ of the inboard aileron due to the substitution of fixed tail fins for the free-to-roll tail. Interference effects and the effects of tail damping were about equal and opposite for the outboard aileron.

Experimental rolling effectiveness is compared with theoretical rolling effectiveness in figure 8. Theoretical rolling effectiveness and wing spanwise loadings were calculated at subsonic speeds by the lifting-line method of reference 3. Subsonic downwash angles were calculated by the method of reference 4 and sidewash angles, by the method of reference 5. At supersonic speeds, rolling effectiveness was calculated by the strip theory of reference 2 and downwash and sidewash angles were calculated by the method of reference 6 by using two-dimensional spanwise loadings. The presence of the body was neglected in the calculations. The theories used are for rigid wings but the model wings were stiff enough to make flexibility effects negligible. Good agreement is shown between experiment and theory for the inboard aileron, except for the fixed-tail model with the horizontal tail mounted above the wing-chord plane at subsonic speeds. Theory predicted an appreciable increase in rolling effectiveness when the tail was moved out of the plane of the wing at both subsonic and supersonic speeds. Experiment showed the increase predicted by theory at transonic and supersonic speeds but showed no appreciable change at subsonic speeds. For the case of the outboard aileron, theory indicated much higher rolling effectiveness than was obtained by experiment. The high predictions are probably due to the fact that theory did not take into account the effects of separation. Reference 7 shows separation to be quite appreciable over the outboard half of a 45° sweptback wing. It is interesting to note, however, that the change in rolling effectiveness due to fixing the tail was predicted by theory.

CONCLUSIONS

The following conclusions may be drawn from the results of an investigation of the effects of tail damping and wing-tail interference on the rolling effectiveness of inboard and outboard ailerons on sweptback wings:

1. The substitution of fixed tail fins for a free-to-roll tail on a wing-body combination reduced the rolling effectiveness of the inboard aileron by a large amount over the entire test Mach number range (0.6 to 1.5). The rolling effectiveness of the outboard aileron was not appreciably changed by the substitution of the fixed tail for the free-to-roll tail. Apparently, there is an optimum aileron location where the effects of wing-tail interference will be least harmful.

2. Changing the location of the horizontal tail fins from the wing-chord plane to 18 percent of the wing chord above the wing-chord plane caused a slight increase in the rolling effectiveness of the inboard aileron at transonic and supersonic speeds.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 30, 1954.

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1. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds To Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM L7D02, 1947.

2. Strass, H. Kurt, and Marley, Edward T.: Rolling Effectiveness of All-Movable Wings at Small Angles of Incidence at Mach Numbers From 0.6 to 1.6. NACA RM L51H03, 1951.

3. Weissinger, J.: The Lift Distribution of Swept-Back Wings. NACA TM 1120, 1947.

4. Diederich, Franklin W.: Charts and Tables for Use in Calculations of Downwash of Wings of Arbitrary Plan Form. NACA TN 2353, 1951.

5. Michael, William H., Jr.: Analysis of the Effects of Wing Interference on the Tail Contributions to the Rolling Derivatives. NACA Rep. 1086, 1952. (Supersedes NACA TN 2332.)

6. Martin, John C.: The Calculation of Downwash Behind Wings of Arbitrary Plan Form at Supersonic Speeds. NACA TN 2135, 1950.

7. Whitcomb, Richard T.: An Experimental Study at Moderate and High Subsonic Speeds of the Flow Over Wings With 30° and 45° of Sweepback in Conjunction With a Fuselage. NACA RM L50K27, 1951.

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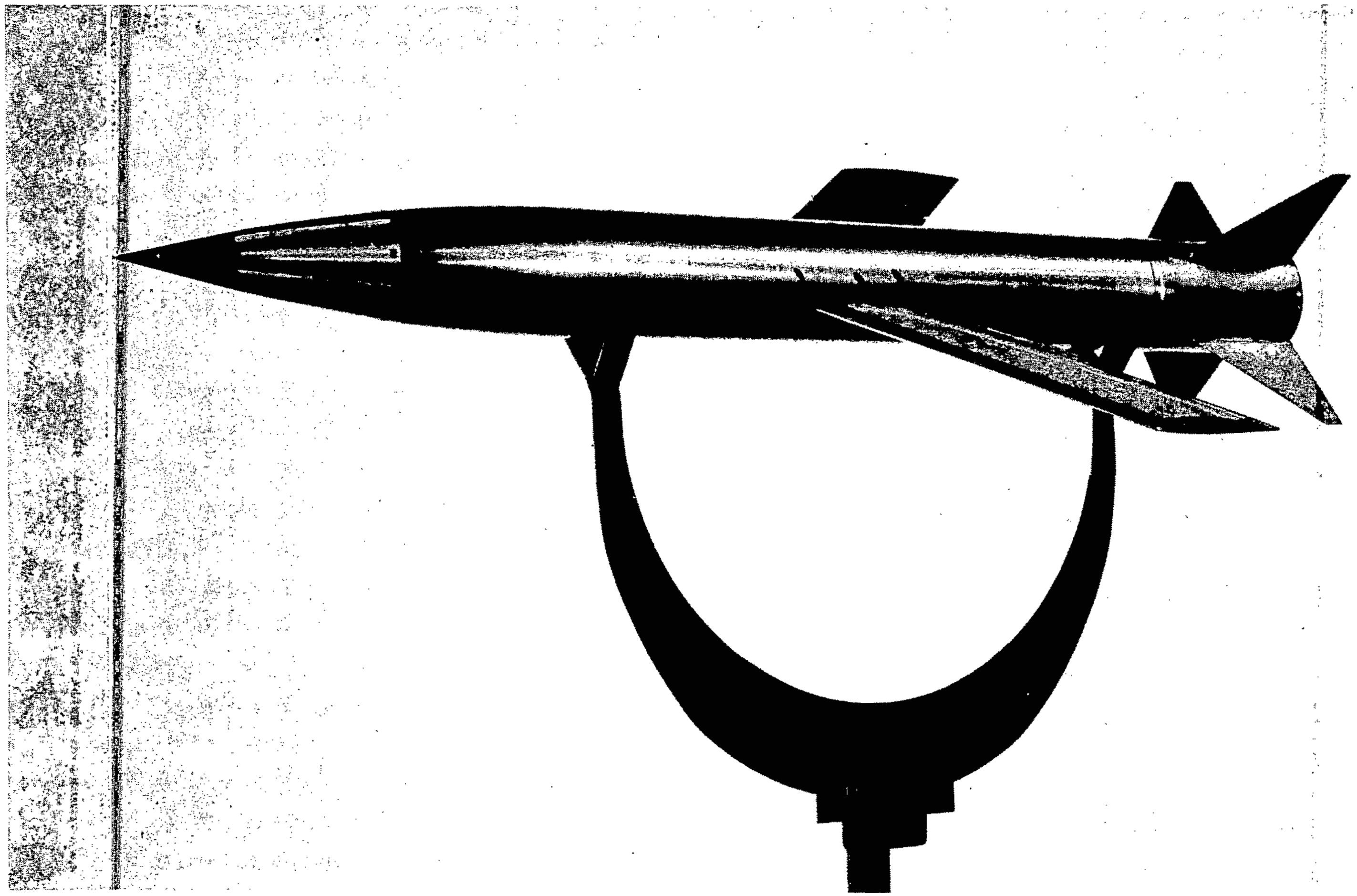

L-76733.1

(a) Model 1. Inboard aileron; free-to-roll tail.

Figure 1.- Photographs of typical models.

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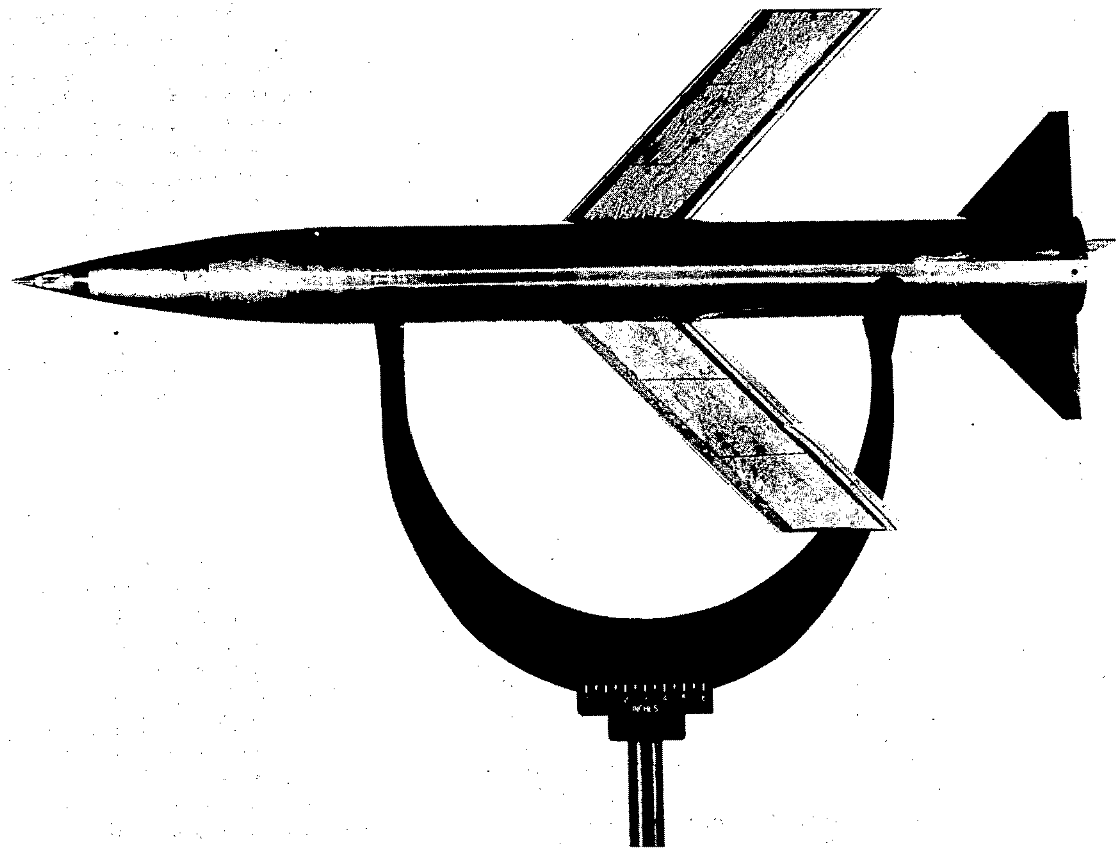

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(b) Model 4. Outboard aileron; fixed tail in wing-chord plane.

Figure 1.- Continued.

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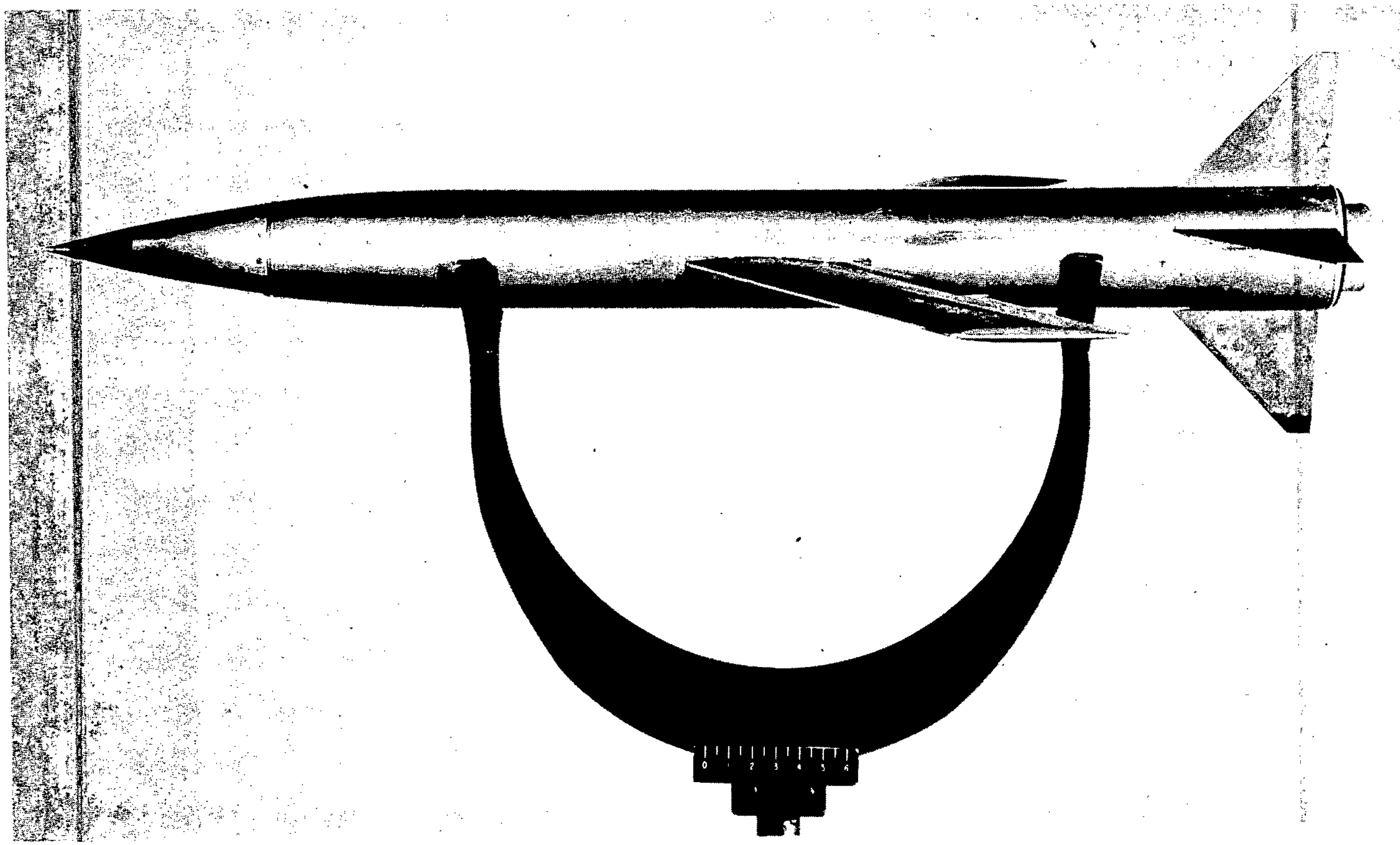

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(c) Model 5. Inboard aileron; fixed tail above the wing-chord plane.

Figure 1.- Concluded.

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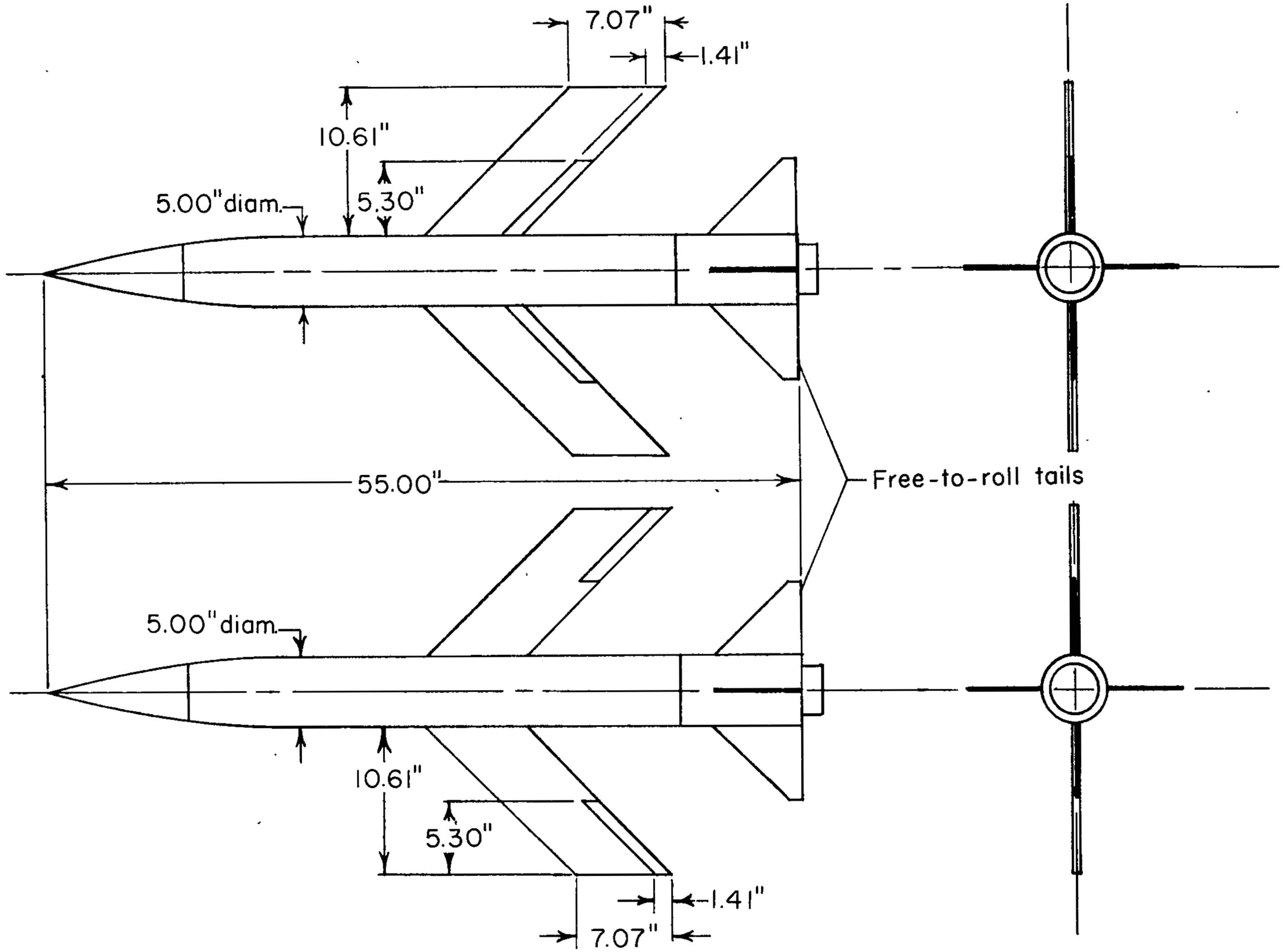

Models 1 (top) and 2 (bottom)

Figure 2.- Sketches of test models.

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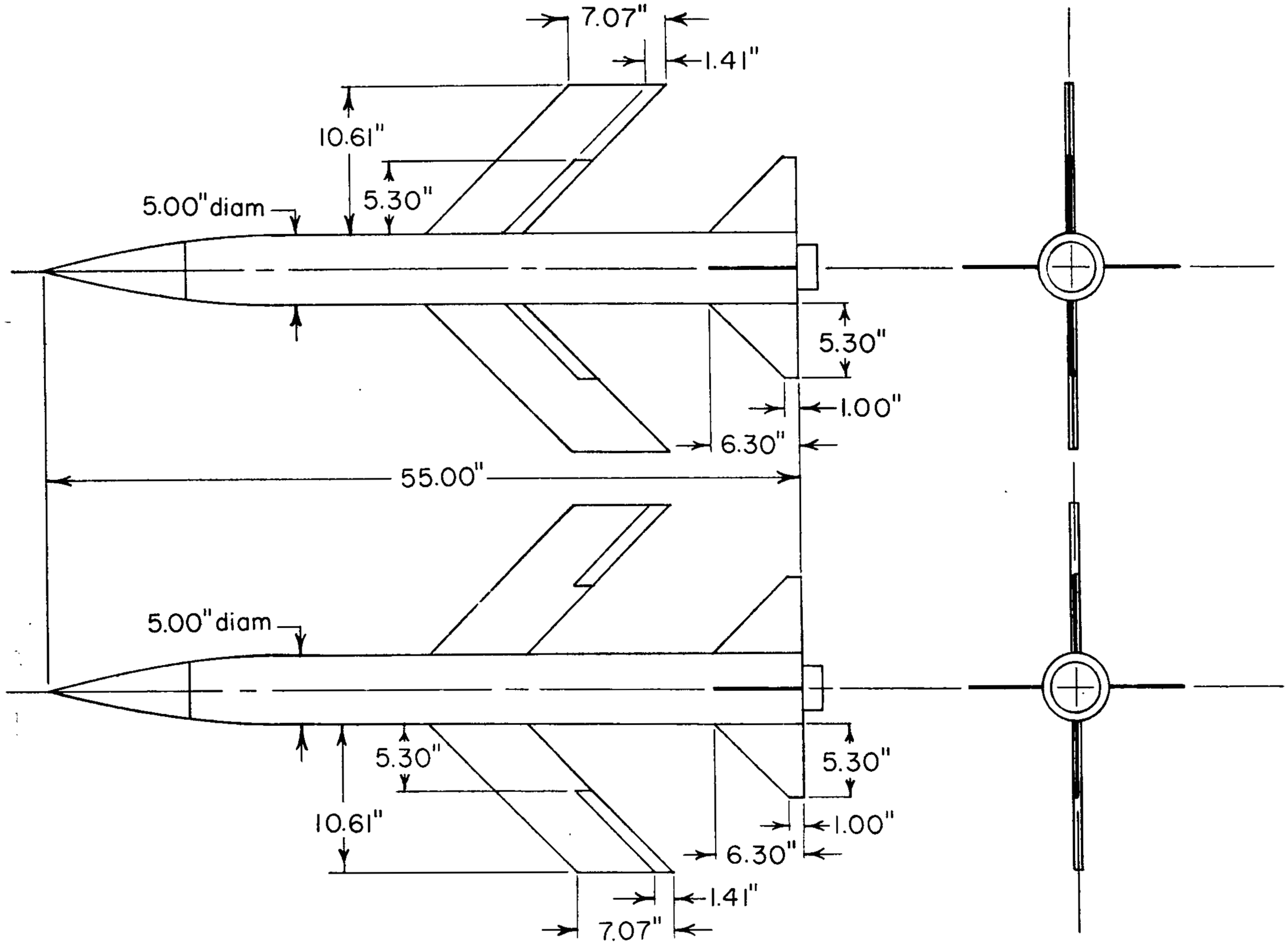

Models 3 (top) and 4 (bottom)

Figure 2.- Continued.

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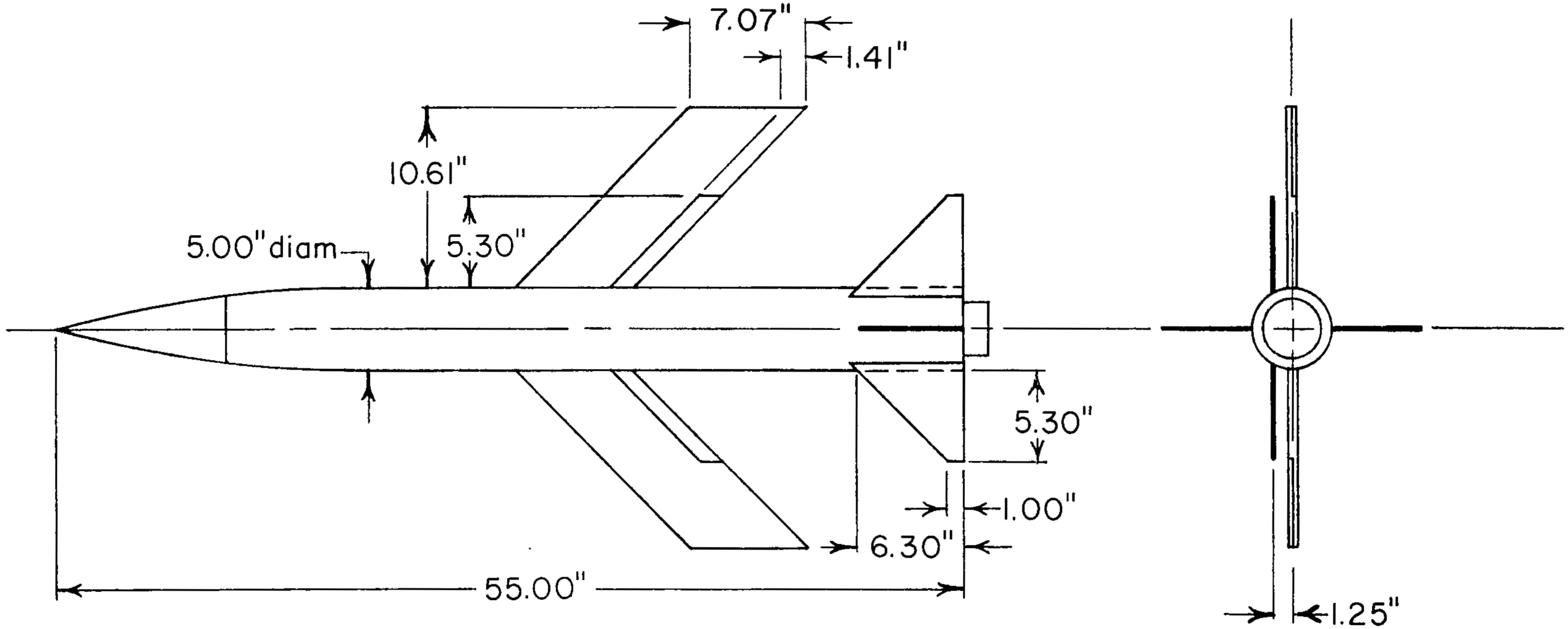

Model 5

Figure 2.- Concluded.

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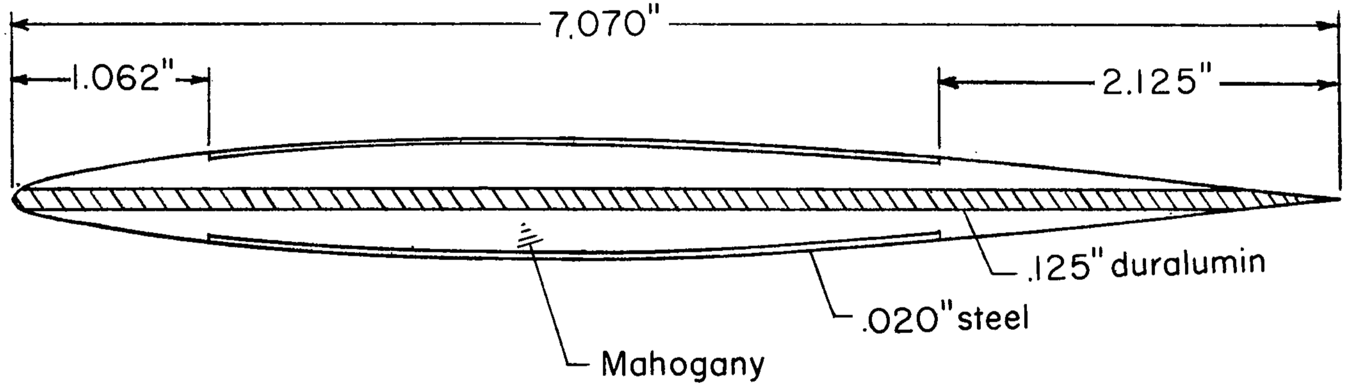

Figure 3.- Wing construction details.

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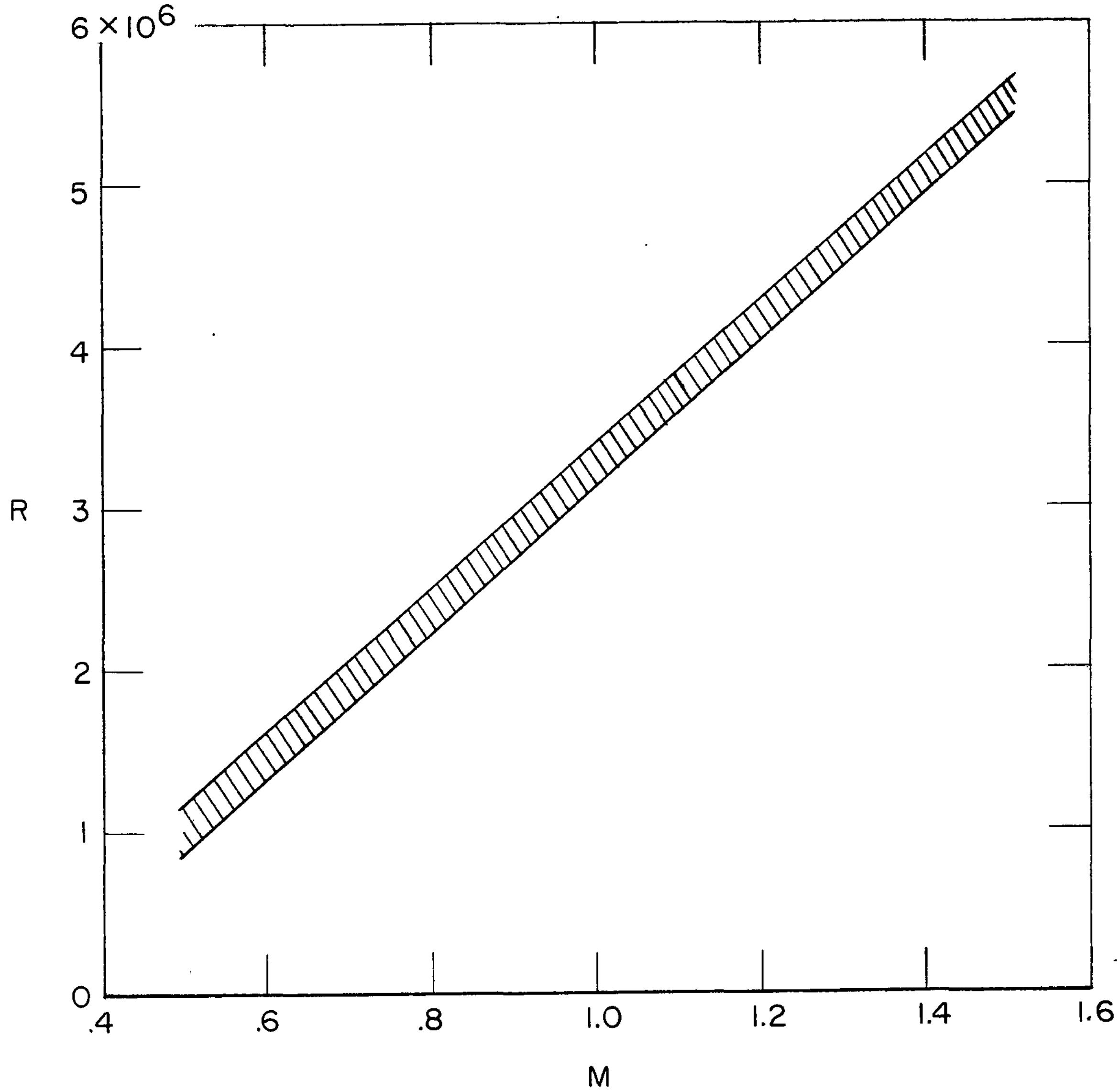
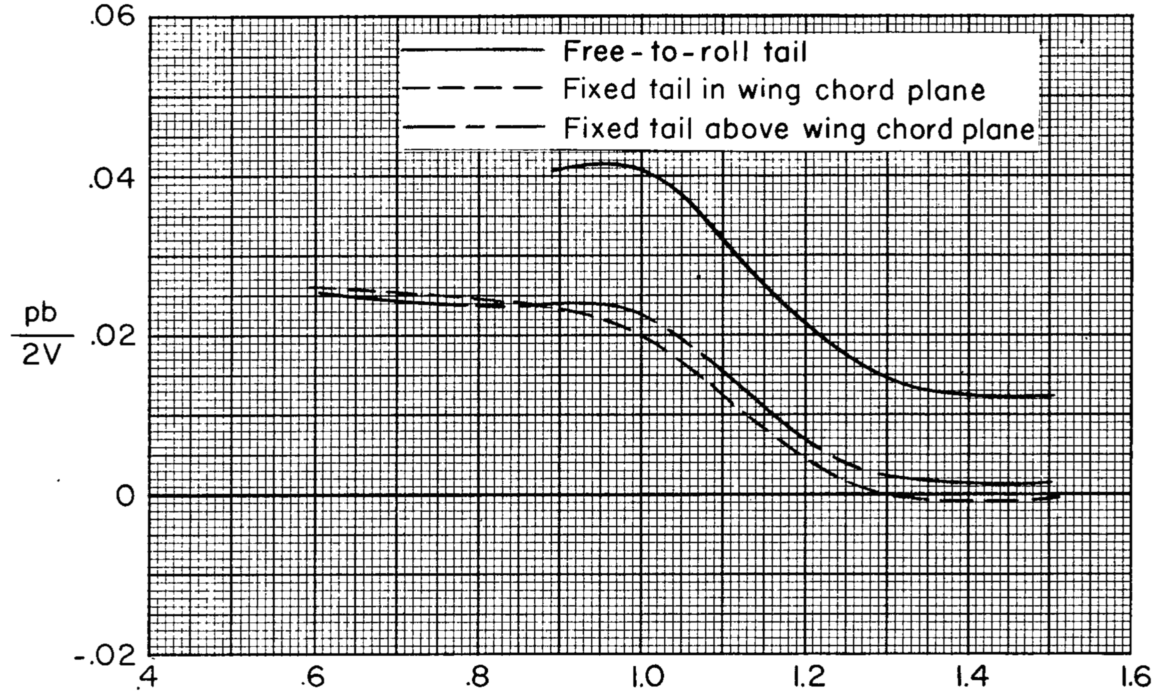
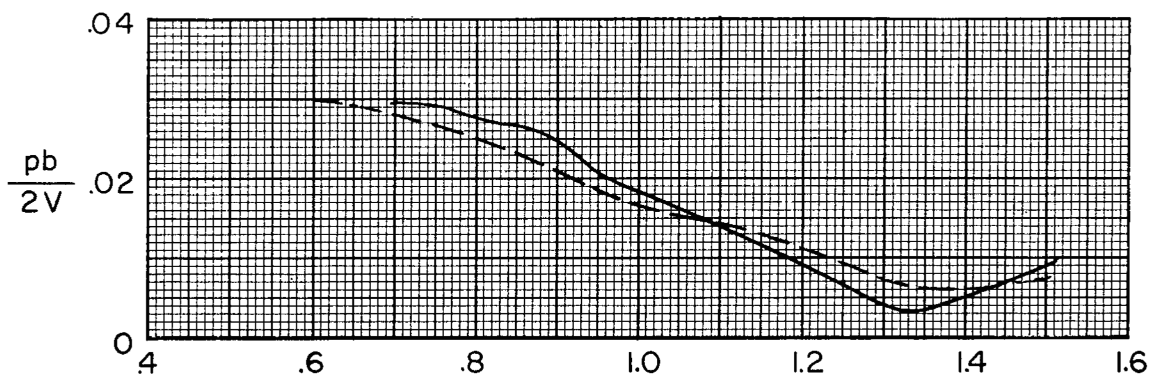


Figure 4.- Variation of test Reynolds numbers with Mach number. Reynolds numbers based on wing chord, 0.59 foot.

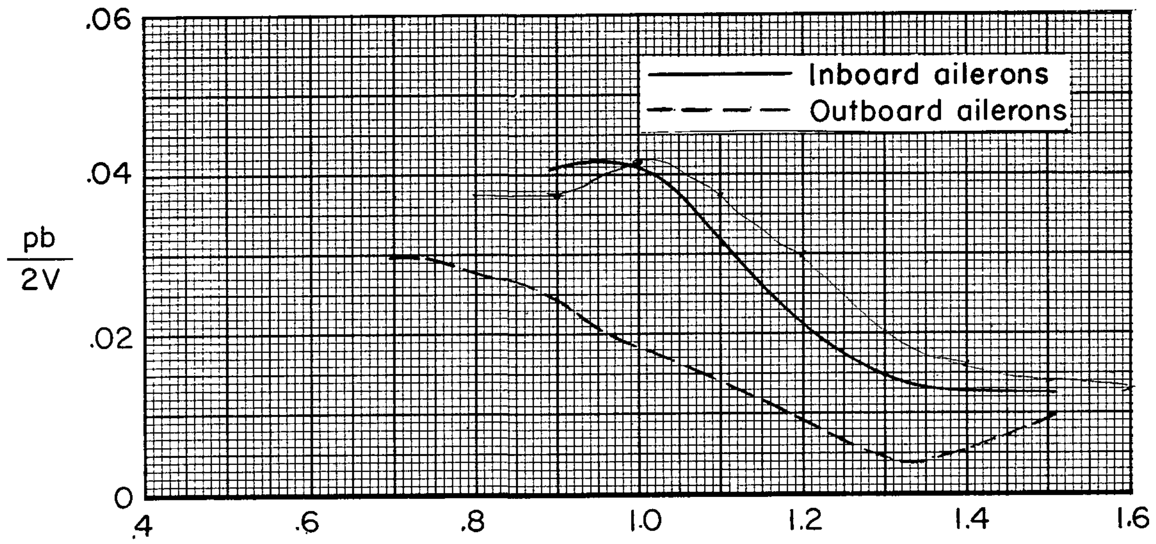


(a) Inboard ailerons.

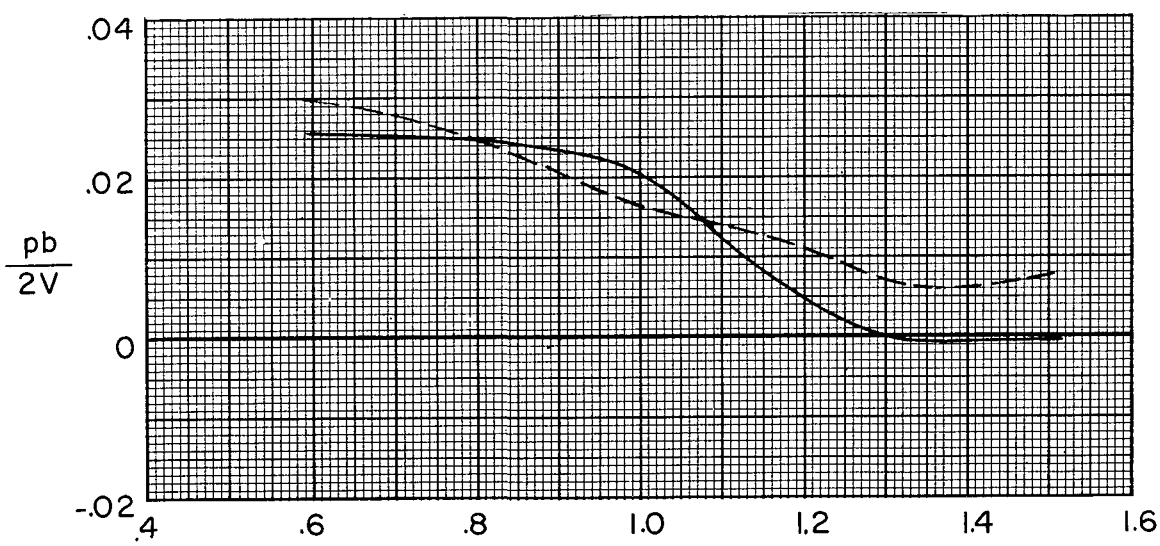


(b) Outboard ailerons.

Figure 5.- Variation of rolling effectiveness parameter pb/2V with Mach number. $\delta = 5^\circ$.

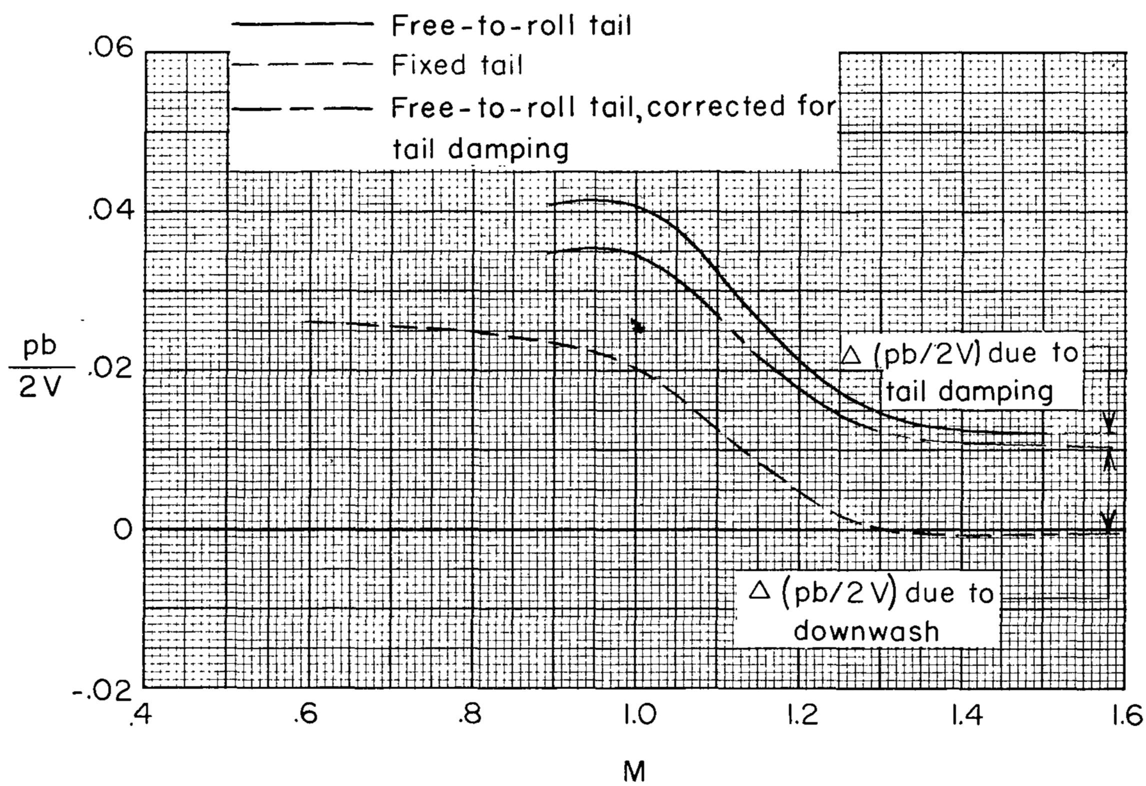


(a) Free-to-roll tail.

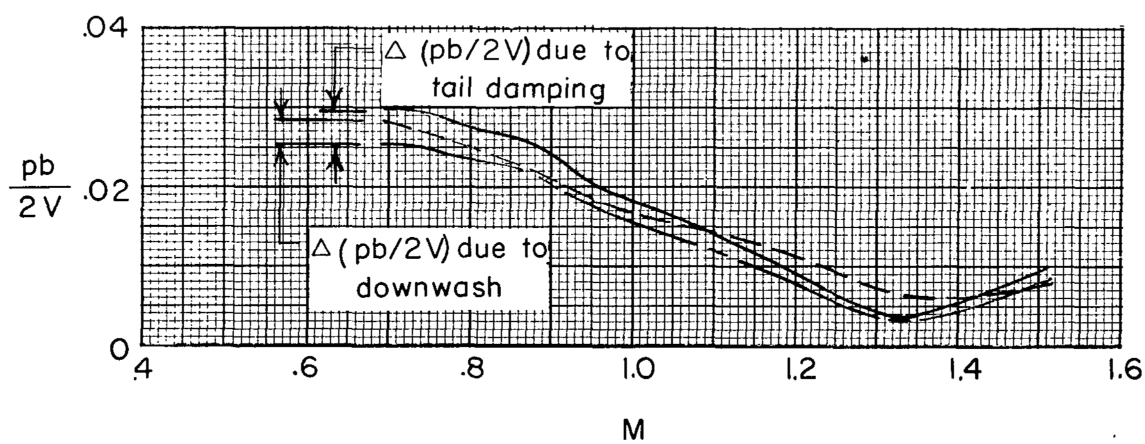


(b) Fixed tail.

Figure 6.- Comparison of the rolling effectiveness of inboard and outboard ailerons. $\delta = 5^\circ$

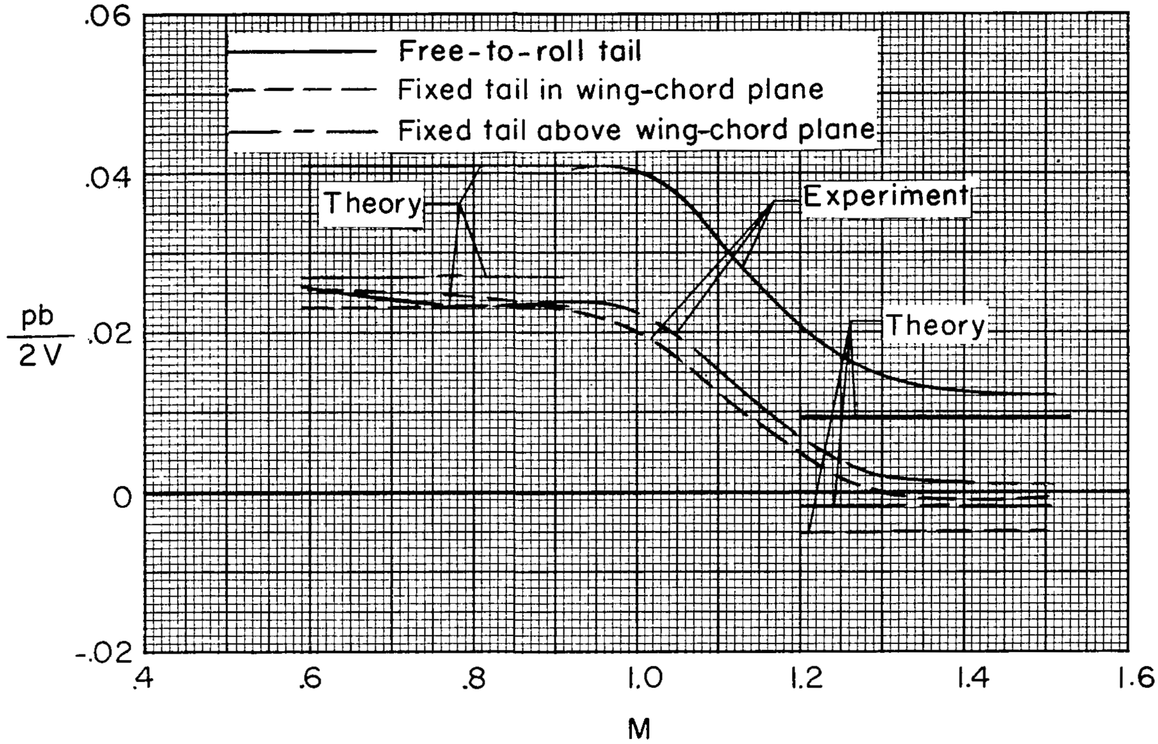


(a) Inboard ailerons.

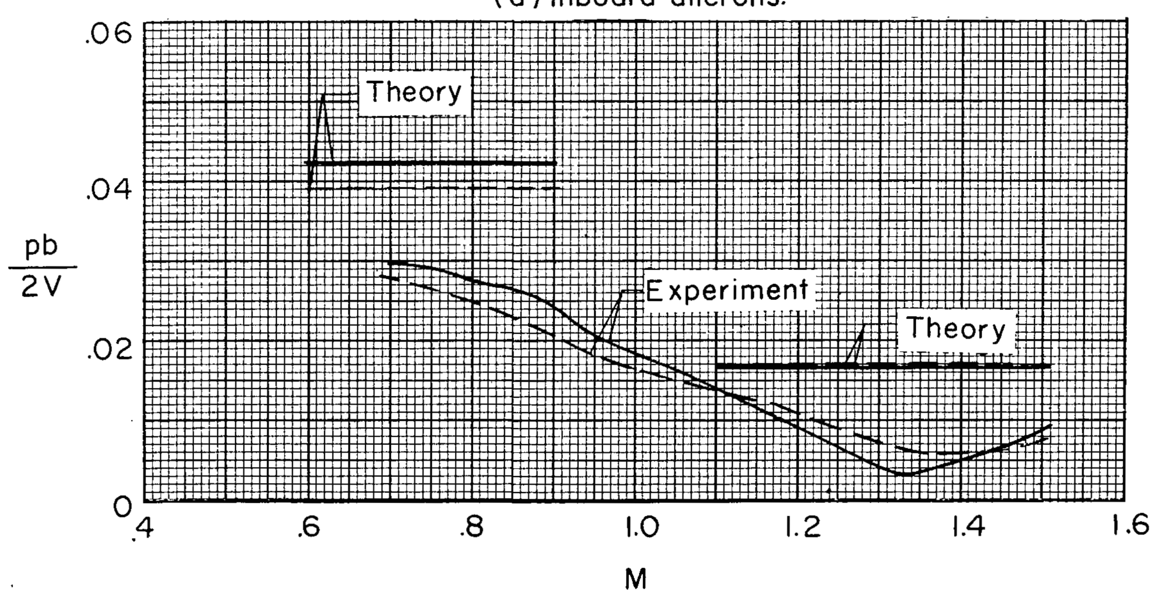


(b) Outboard ailerons.

Figure 7.- Changes in pb/2V due to tail damping alone and downwash alone. $\delta = 5^{\circ}$



(a) Inboard ailerons.



(b) Outboard ailerons.

Figure 8.- Comparison of theoretical and experimental rolling effectiveness. $\delta = 5^\circ$

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