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RESEARCH MEMORANDUM

SOME EFFECTS OF EXTERNAL WING TIP STORES ON THE ROLLING EFFECTIVENESS AND DRAG OF PLAIN AND HALF-DELTA TIP AILERONS ON A 4-PERCENT-THICK, TAPERED, UNSWEPT WING

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SOME EFFECTS OF EXTERNAL WING TIP STORES ON THE ROLLING EFFECTIVENESS AND DRAG OF PLAIN AND HALF-DELTA TIP AILERONS ON A 4-PERCENT-THICK, TAPERED, UNSWEPT WING

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SUMMARY

The Langley Pilotless Aircraft Research Division has made an investigation to determine some effects of external wing tip tanks on the rolling effectiveness and drag of plain and half-delta tip ailerons on a 4-percent-thick, tapered, unswept wing. The investigation was made by means of rocket-propelled models in free flight over a range of Mach numbers from 0.6 to 1.5.

The results of the investigation indicate that the addition of tip tanks reduces the rolling effectiveness of the plain aileron but slightly increases the rolling effectiveness of the tip aileron. The rolling effectiveness of the plain aileron was higher than that of the tip aileron up to a Mach number of about 1.22 for the wing without tip tanks. With the tip tanks on the wing, however, the rolling effectiveness of the plain aileron was less than that of the tip aileron at all Mach numbers above about 0.94. The addition of tip tanks increased the drag coefficient of the wing with both types of ailerons over the entire test Mach number range.

INTRODUCTION

One of the most common means of extending the range of modern fighter-type airplanes is the use of external fuel tanks. In order to determine some effects of external wing tip tanks on lateral control, the Langley Pilotless Aircraft Research Division has made an investigation of the rolling effectiveness and drag of plain and half-delta tip ailerons on a 4-percent-thick, tapered, unswept wing with and without tip tanks. The investigation was made by means of rocket-propelled models in free flight over a range of Mach number from 0.6 to 1.5.

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SYMBOLS

b	span of basic wing, ft
c	wing chord, ft
C_D	drag coefficient based on exposed wing area of 1.04 sq ft
M	Mach number
p	rolling velocity, radians/sec
R	Reynolds number based on mean geometric chord of exposed wing (0.550 ft)
V	flight-path velocity, ft/sec
pb/2V	wing tip helix angle, radians
L	length of tip tank, in.
x	coordinate along longitudinal axis from nose of tip tank, in.
y	coordinate normal to longitudinal axis of tip tank, in.
δ	deflection of each aileron, measured in a plane normal to the wing-chord plane and parallel to the free stream, deg

DESCRIPTION OF MODELS

Four models were tested in this investigation. The basic wings of all models had an aspect ratio of 4, a taper ratio of 0.6, and were unswept at the quarter-chord line. The airfoil section used was the NACA 65A004 in a plane parallel to the model center line, b/2 was 1.15 feet, and the exposed area of the basic wing was 1.04 square feet. The wings were constructed of solid aluminum alloy. Models 1 and 2 had plain sealed ailerons which extended over the outboard 41 percent of the semispan with the hinge line at 0.85c. Models 3 and 4 had half-delta tip ailerons of the same area as the plain ailerons of models 1 and 2 with the hinge line (two-thirds of the half-delta tip aileron root chord) at 0.43c. The deflection of each aileron was 5° measured in a plane normal to the wing-chord plane and parallel to the free stream.

Models 2 and 4 had external fuel tanks mounted near the wing tips with the center line of the tanks coinciding with the wing-chord plane.

Because of the difference in the controls of the two models, the tanks of model 2 were mounted with the inboard edges of the tanks at the tips of the basic wing whereas on model 4 the outboard edges of the tanks were at the basic wing tips. The difference in spanwise location of the tanks for the two models was about 0.11b/2. The tanks were the Douglas Aircraft Company, Inc., Store Shapes (for a wing span of 22.5 feet the corresponding tank capacity would be approximately 55 gallons for each tank); the coordinates of which are given in table I. Photographs of two of the models are shown in figure 1 and dimensioned sketches are presented in figure 2. As shown in figure 2, all models were equipped with free-spinning tails which contributed no appreciable resistance to roll but provided longitudinal and directional stability.

TEST METHOD

The models were propelled to a Mach number of approximately 1.5 by two-stage rocket-propulsion systems. During periods of free flight following burnout of the second propulsion stage, continuous records were made of rolling velocity by means of special radio equipment (spinsondes) and of flight-path velocity and space coordinates by means of radar. These data were used with atmospheric data from radiosondes to calculate the variation of the rolling effectiveness parameter pb/2V and drag coefficient C_D with Mach number. The range of test Reynolds numbers is presented in figure 3. A complete description of the test method is given in reference 1.

ACCURACY

From previous experience and mathematical analysis it is estimated that the data are accurate within the following limits:

	Subsonic	Supersonic
pb/2V	±0.003	±0.002
C_D	±0.003	±0.002
M	±0.01	±0.01

These values are point accuracies and represent the maximum possible error that might occur. The repeatability of test data for similar models indicates that a measured difference in pb/2V or C_D for two models would be accurate within much smaller limits.

RESULTS AND DISCUSSION

The variation of the rolling effectiveness parameter $pb/2V$ with Mach number is presented in figure 4. The experimental rolling effectiveness has been corrected by the method of reference 2 for the small wing incidence errors resulting from construction tolerances. No corrections were made for the effects of moment of inertia in roll since reference 1 shows that these corrections are negligible except in the transonic region when an abrupt change in $pb/2V$ occurs; the inertia effects do not materially change the conclusions that are drawn from the measured data. Theoretical rolling effectiveness of the models with tip tanks was obtained by the method of reference 3. The experimental curves indicate that the addition of tip tanks decreases $pb/2V$ for the plain aileron and slightly increases $pb/2V$ for the half-delta tip aileron over the entire test Mach number range. Theory agrees with experiment for the plain aileron, but shows a slight reduction in the rolling effectiveness of the tip aileron. The reason for the disagreement between experiment and theory for the tip aileron is not known. However, both experiment and theory indicate that the change in rolling effectiveness of the tip aileron with the addition of tip tanks is small. It is interesting to note that theory indicated an increase in both damping and aileron moments with the addition of tip tanks to the wing with plain ailerons. The increase in damping was about 44 percent whereas the increase in aileron moment was only 29 percent, giving a reduction in rolling effectiveness. The addition of tip tanks to the wing with tip ailerons, however, increased damping only 11 percent but decreased aileron moment by about 6 percent. It should be noted that the change in rolling moment due to the addition of tip tanks depends in part on the angle of attack of the tank, and the change in rolling moment due to the addition of tip tanks would vary with $pb/2V$. The experimental results of the present investigation are generally in agreement with previous experimental results (refs. 4 and 5 are typical).

A comparison of the rolling effectiveness of the plain and tip ailerons is made in figure 5. Whereas the rolling effectiveness of the plain aileron was approximately twice that of the tip aileron at subsonic speeds, the tip aileron did not undergo the large loss in rolling effectiveness experienced by the plain aileron in going from subsonic to supersonic speeds. However, the rolling effectiveness of the plain aileron was still higher than the rolling effectiveness of the tip aileron up to a Mach number of about 1.22 for the wing without tip tanks. Because of the reduction in rolling effectiveness of the plain aileron with the addition of tip tanks, the rolling effectiveness of the tip aileron was higher than that of the plain aileron at all Mach numbers above about 0.94 for the wing with tip tanks.

The variation of the drag coefficient C_D with Mach number is presented in figure 6. The drag of the body with tail is included in the figure for reference. The data of figure 6 indicate that the addition of tip tanks to the wing increases drag coefficient over the entire test Mach number range for the plain aileron models. The drag of the tip-aileron model without tip tanks is not included because no reliable wind correction data were obtained for that model. However, previous wind-tunnel tests at a Mach number of 1.4 on the configuration tested in the present investigation (ref. 6) showed about the same increase in drag with the addition of the tank to the wing with no control, so the control apparently has no appreciable effect on drag. Also, it may be seen from figure 6 that there is no appreciable difference in the drag of the plain- and tip-aileron models of the present investigation, with tip tanks on the wing.

CONCLUSIONS

From the results of an investigation of some effects of external wing tip stores on the rolling effectiveness and drag of plain and half-delta tip ailerons on a tapered, unswept wing for a Mach number range between 0.6 and 1.5, the following conclusions may be drawn:

1. The addition of tip tanks to the wing reduced the rolling effectiveness of the plain aileron but increased the rolling effectiveness of the tip aileron slightly over the entire test Mach number range.

2. The rolling effectiveness of the plain aileron was higher than that of the tip aileron up to a Mach number of approximately 1.22 for the wing without tip tanks. With tip tanks on the wing, however, the rolling effectiveness of the tip aileron was higher than that of the plain aileron at all Mach numbers above approximately 0.94.

3. The drag coefficient was increased over the entire test Mach number range by the addition of tip tanks. There was no appreciable difference in the drag coefficient for the two control configurations with tip tanks on the wing.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 16, 1954.

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4. Murray, Harry E., and Wells, Evalyn G.: Wind-Tunnel Investigation of the Effect of Wing-Tip Fuel Tanks on Characteristics of Unswept Wings in Steady Roll. NACA TN 1317, 1947.

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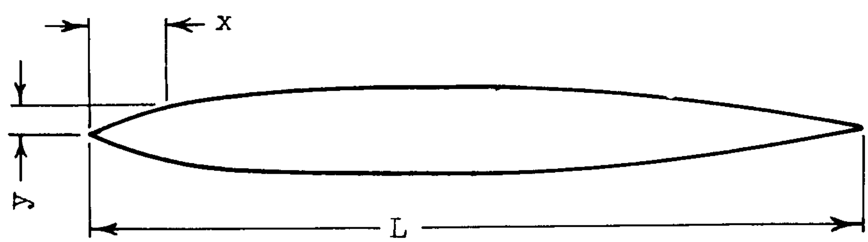
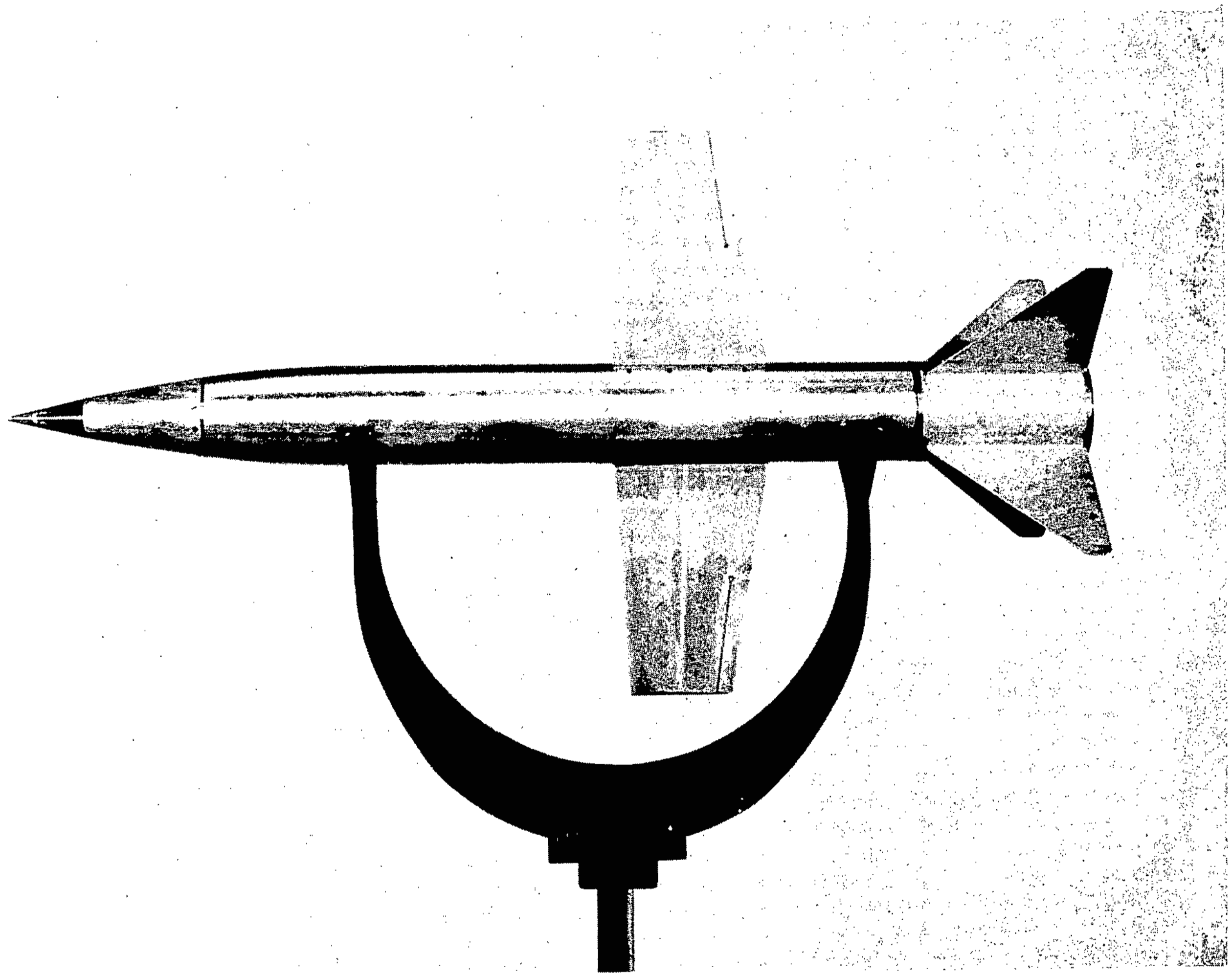
TABLE I

ORDINATES OF THE DOUGLAS AIRCRAFT

COMPANY, INC., STORE SHAPE



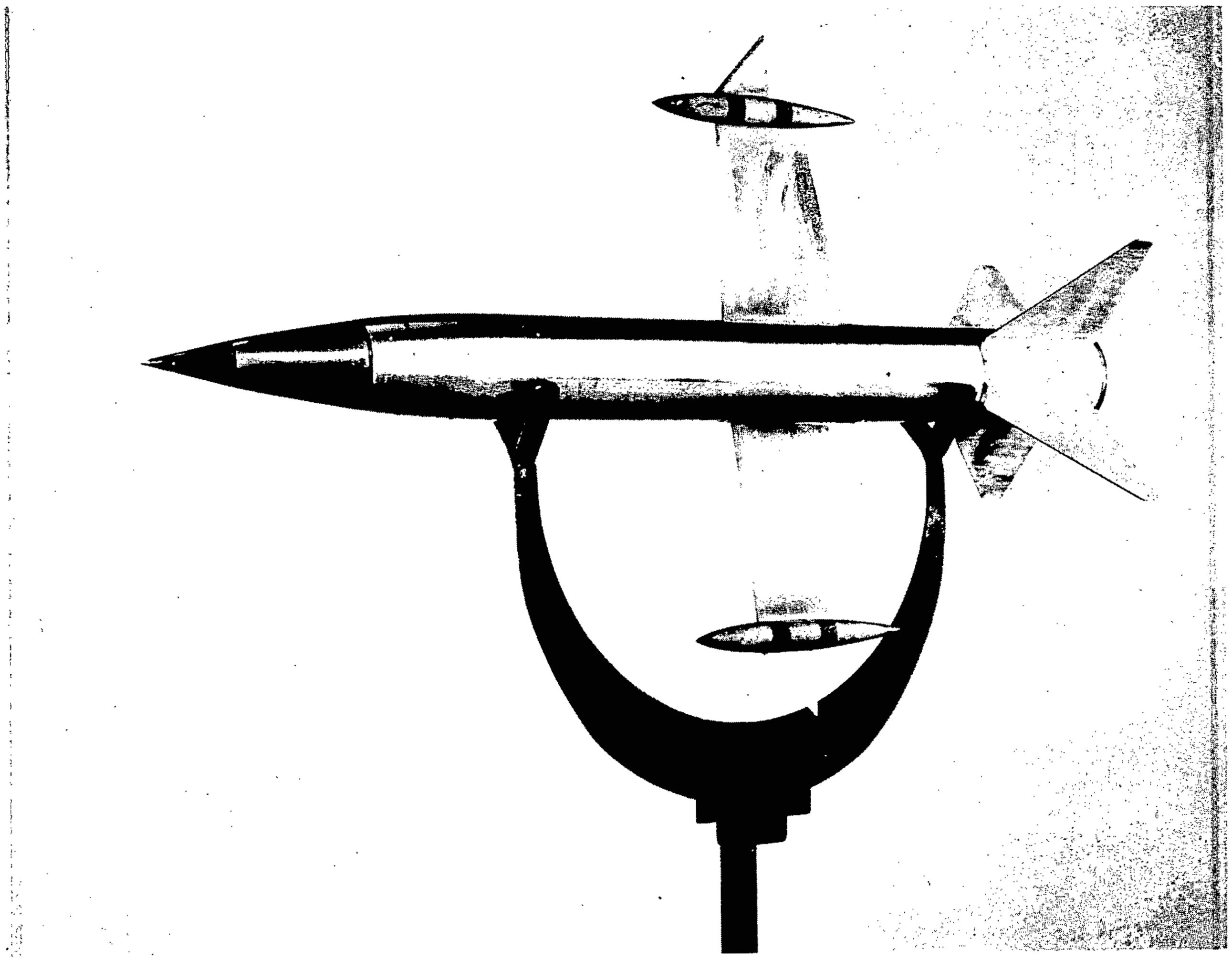
x/L	y/L	x/L	y/L
0	0	0.5806	0.0565
.0194	.0095	.6083	.0551
.0472	.0203	.6361	.0533
.0750	.0287	.6639	.0513
.1028	.0351	.6917	.0489
.1306	.0402	.7194	.0462
.1583	.0442	.7472	.0433
.1861	.0475	.7750	.0402
.2139	.0503	.8028	.0369
.2417	.0527	.8306	.0335
.2694	.0549	.8583	.0299
.2972	.0566	.8861	.0262
.3250	.0579	.9139	.0225
.3528	.0583	.9361	.0194
.4250	.0583	.9583	.0163
.4972	.0583	.9806	.0121
.5250	.0581	1.0000	0
.5528	.0575	T.E. rad. = 0.0056 L	



(a) Model 1.

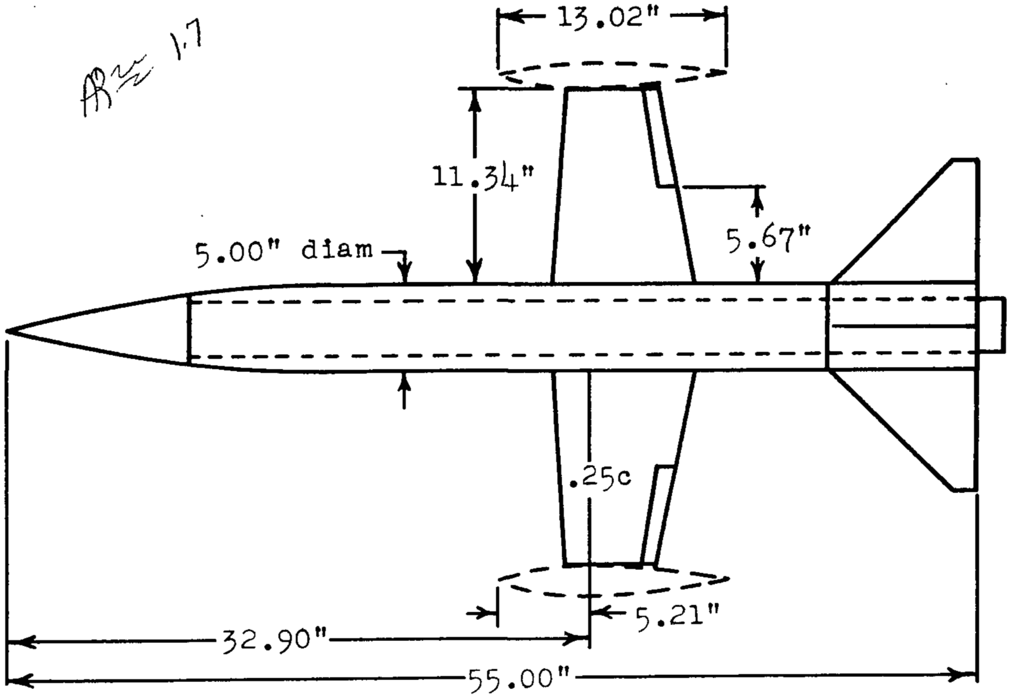
L-81092.1

Figure 1.- Photographs of typical test models.

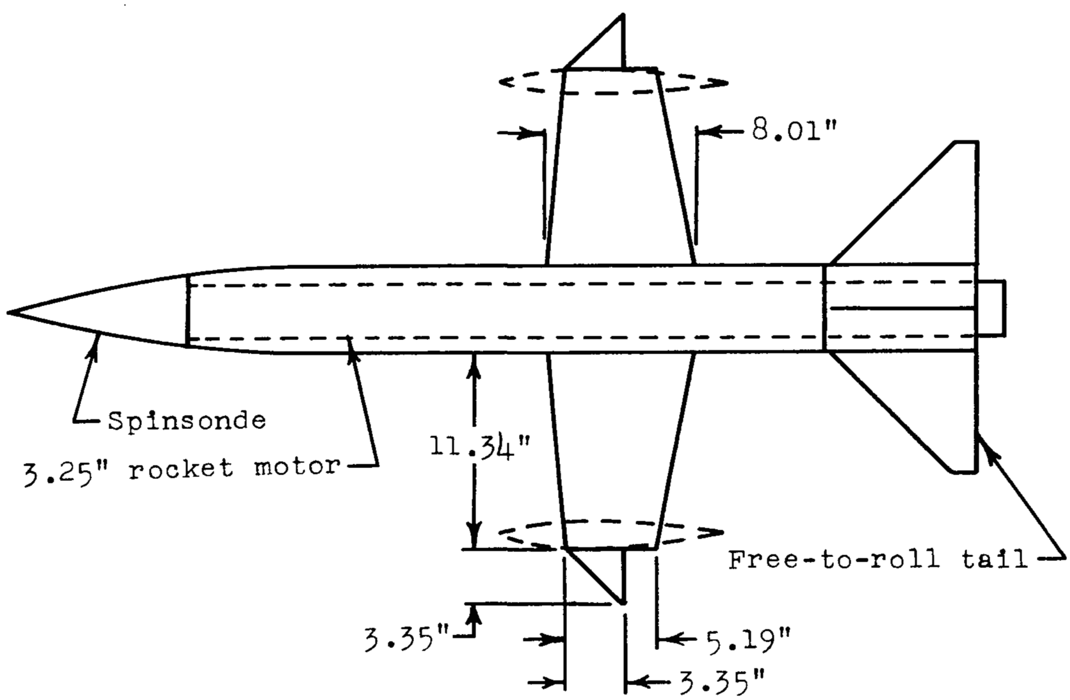


(b) Model 4. L-81354.1

Figure 1.- Concluded.



Models 1(without tank) and 2(with tank)



Models 3(without tank) and 4(with tank)

Figure 2.- Sketches of test models.

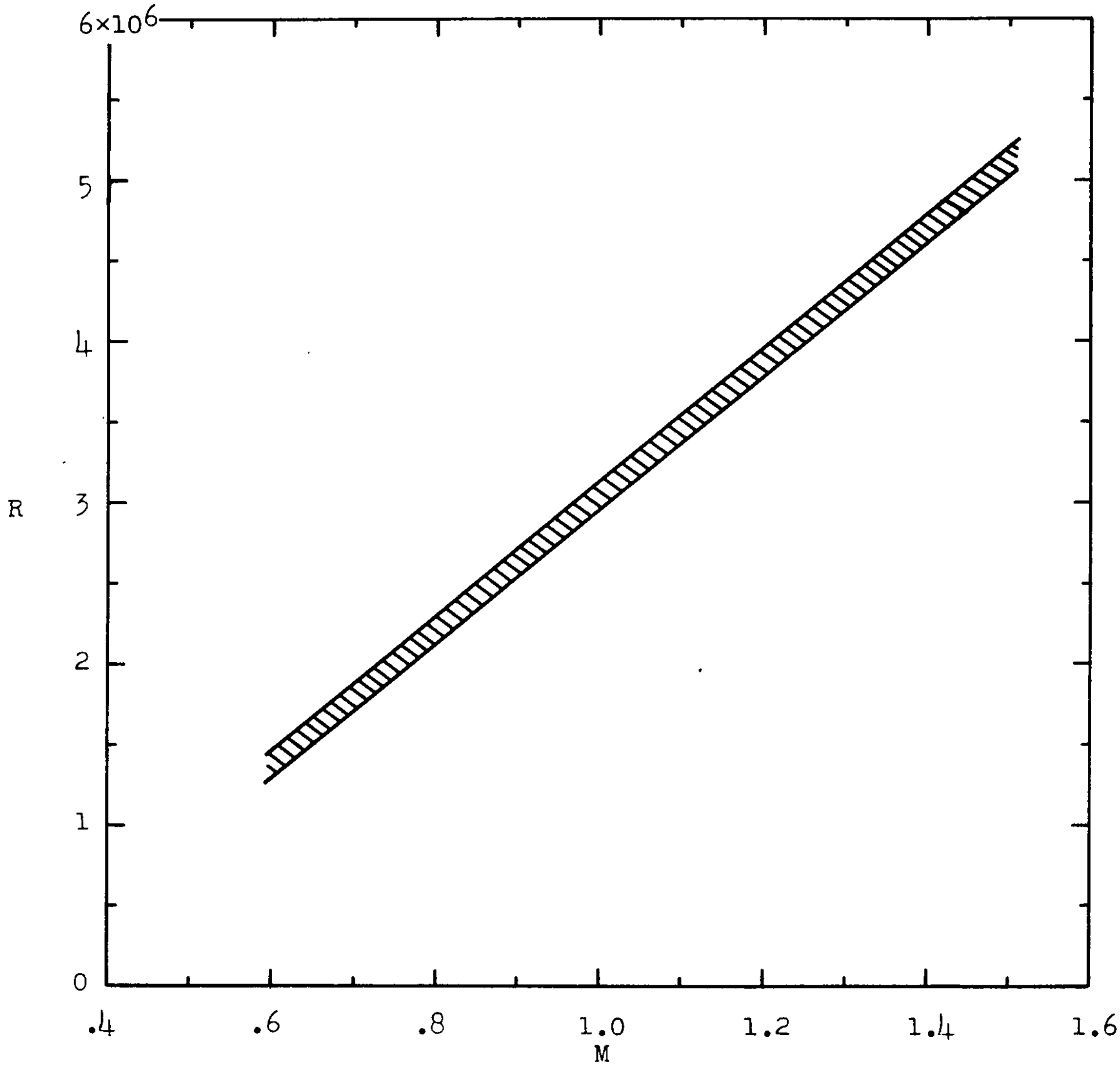
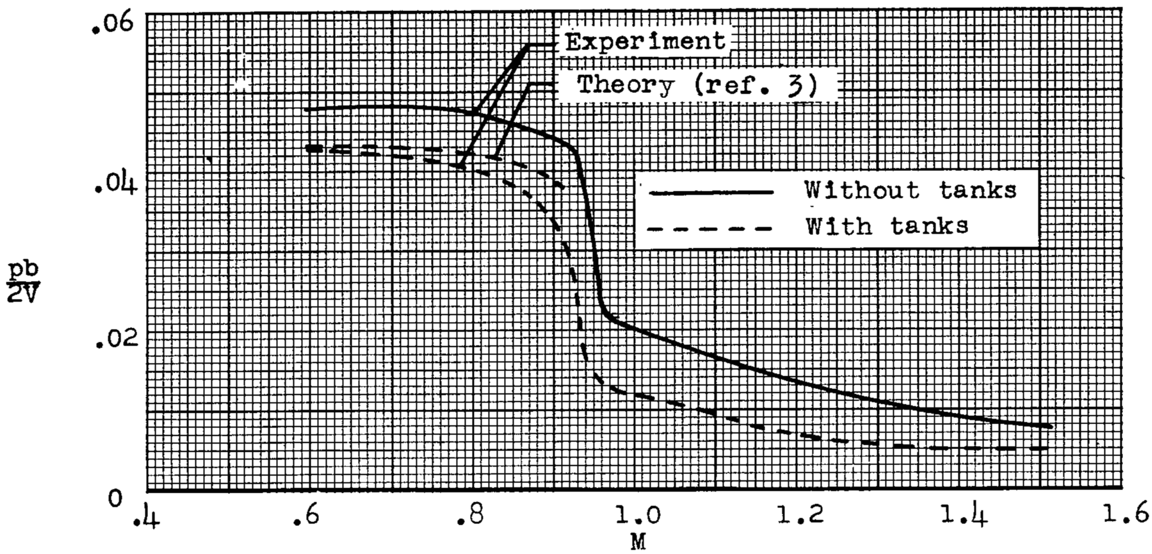
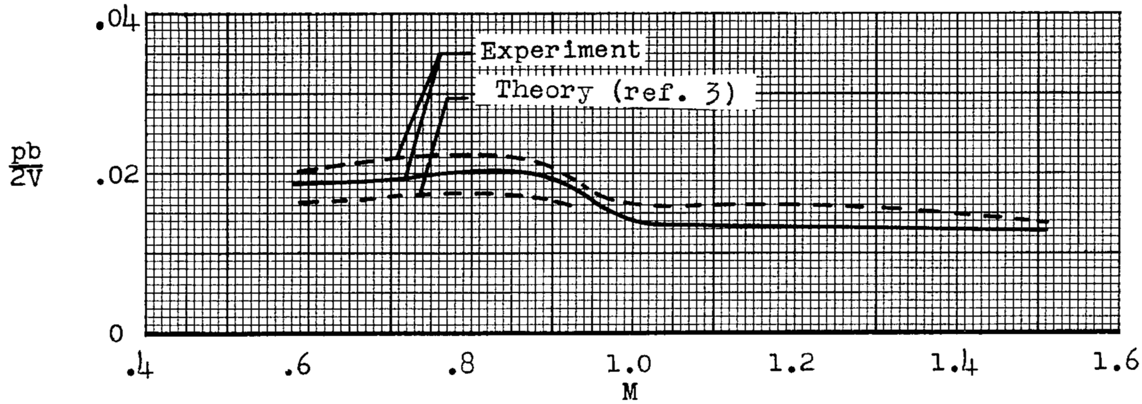


Figure 3.- Variation of Reynolds number with Mach number. Reynolds number based on mean geometric chord of exposed wing (0.550 ft).

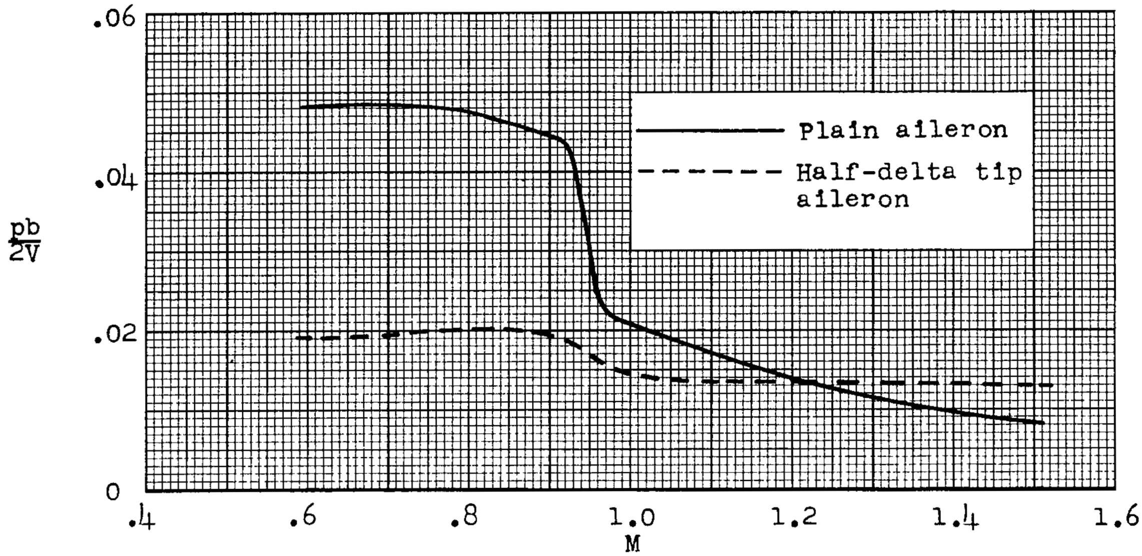


(a) Plain ailerons.

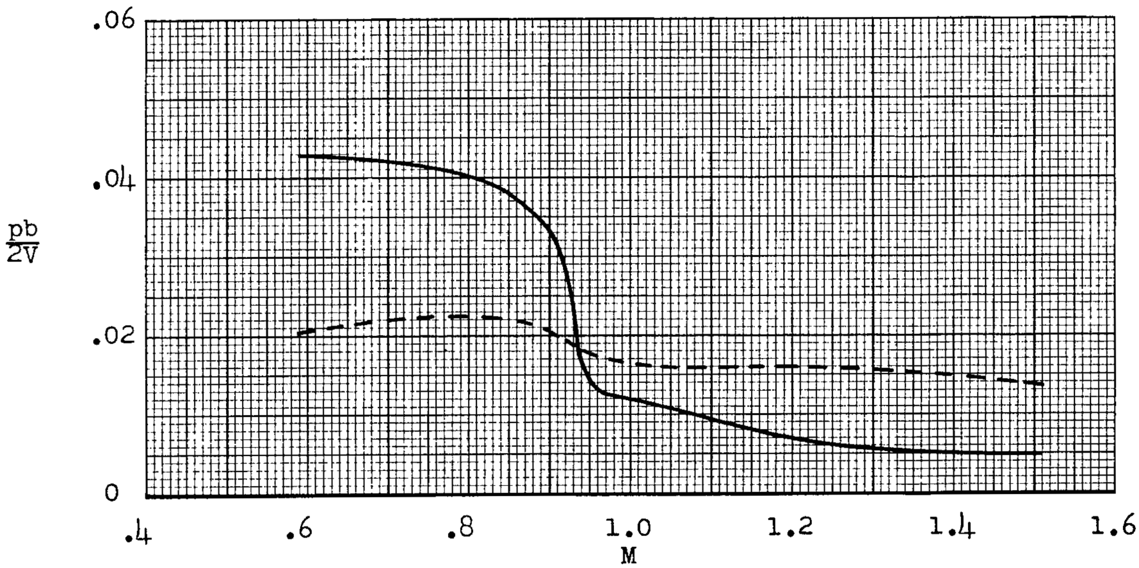


(b) Half-delta tip ailerons.

Figure 4.- Variation of the rolling effectiveness parameter pb/2V with Mach number. $\delta = 5^{\circ}$.



(a) Without tanks.



(b) With tanks.

Figure 5.- Comparison of the rolling effectiveness of the plain aileron and the half-delta tip aileron. $\delta = 5^{\circ}$.

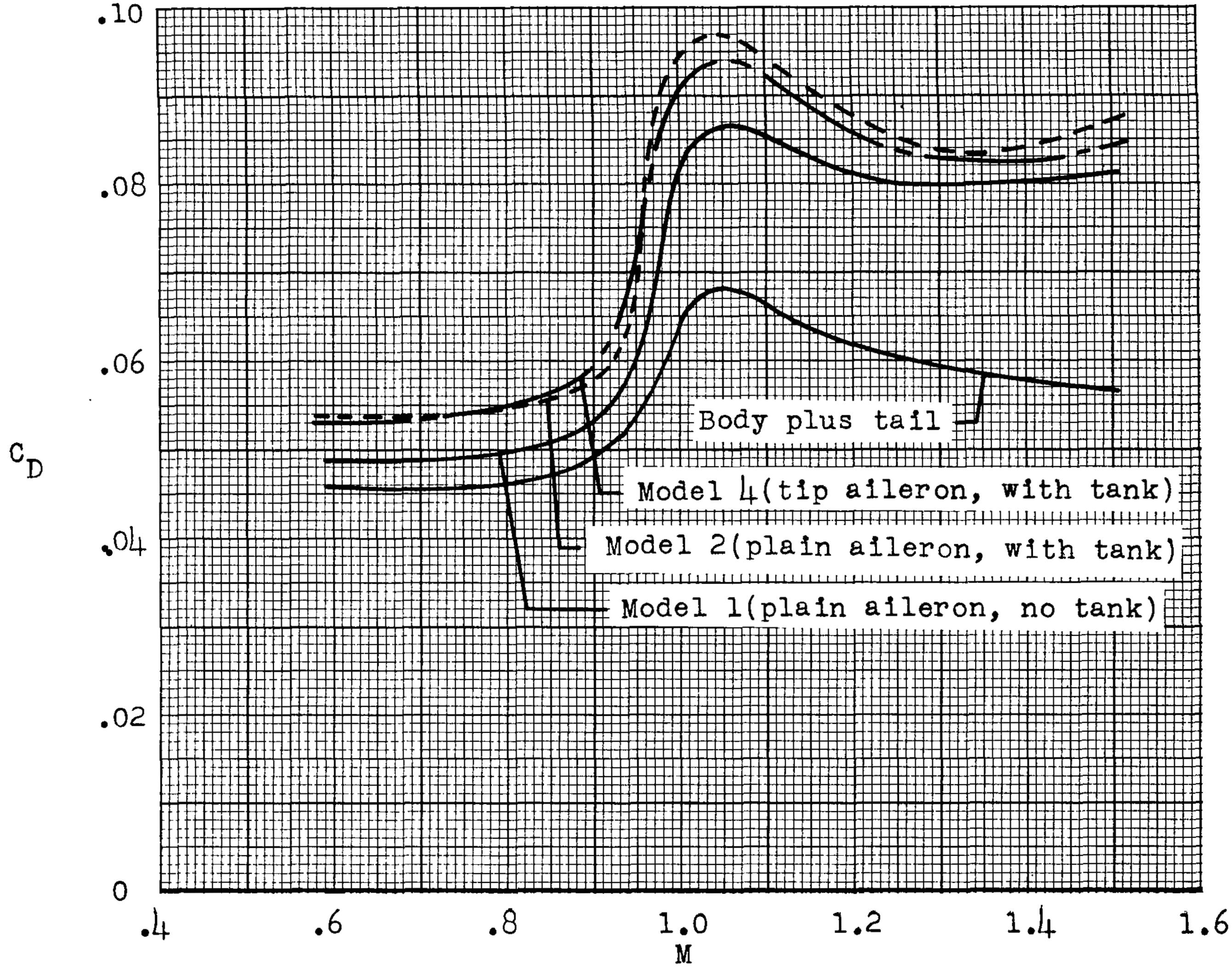


Figure 6.- Variation of drag coefficient C_D with Mach number. $\delta = 5^{\circ}$.

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