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RESEARCH MEMORANDUM

MAR 24 1947

DRAG OF A WING-BODY CONFIGURATION CONSISTING OF A SWEPT-FORWARD TAPERED WING MOUNTED ON A BODY OF FINENESS RATIO 12 MEASURED DURING FREE FALL AT TRANSONIC SPEEDS

By

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RESEARCH MEMORANDUM

DRAG OF A WING-BODY CONFIGURATION CONSISTING OF A SWEPT-FORWARD TAPERED WING MOUNTED ON A BODY OF FINENESS RATIO 12 MEASURED DURING FREE FALL AT TRANSONIC SPEEDS

By Jim Rogers Thompson and Charles W. Mathews

SUMMARY

The drag of a configuration consisting of a body of fineness ratio 12 with stabilizing tail surfaces and a 12-percent-thick, 30° swept-forward wing having an aspect ratio of 4 and a taper ratio of 2:1 has been measured at transonic speeds by the free-fall method. The total drag and the drag of the wing were measured separately. These measurements, which were made as part of the NACA research program to determine optimum aerodynamic shapes and configurations for use in the transonic and supersonic velocity ranges, show that the drag of the complete configuration rose almost linearly from 0.07 of atmospheric pressure per unit of frontal area at a Mach number of 0.90 to 0.30 of atmospheric pressure at a Mach number of 1.02. The drag of the wing rose similarly from 0.047 of atmospheric pressure per unit frontal area at a Mach number of 0.91 to 0.30 at 0.98 and then increased more slowly to 0.34 of atmospheric pressure at a Mach number of 1.02.

The presence of the swept-forward wing resulted in a large unfavorable interference effect on the drag of the body-tail combination. These parts experienced almost twice the drag measured in previous tests of an identical body-tail combination without wings.

INTRODUCTION

The NACA is testing a series of wing-body configurations by the free-fall method (references 1 and 2) to investigate the transonic drag characteristics of possible airplane arrangements having different combinations of wing sweep, taper, and thickness. To make the experimental data available as soon as possible, the results of each test are being published as soon as they have been evaluated.

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The present paper reports results obtained for one of the series; a configuration consisting of a 30° swept-forward wing mounted on a body of fineness ratio 12 whose transonic drag characteristics were known from previous tests.

The results obtained from this test are presented as curves showing the variation of drag coefficient with Mach number for the complete configuration and for its component parts. The results are compared with those for an identical body without wings reported in reference 3 and for rectangular and swept-back airfoils mounted on a cylindrical body reported in references 2 and 4.

APPARATUS AND METHOD

Test body.- The general arrangement of the test configuration is shown by the photographs (figs. 1 and 2), and its details and dimensions by the drawing (fig. 3). The body and tail were identical with the configuration of fineness ratio 12 whose tests were reported in reference 3. The wing had a sweepforward of 30°, measured at the quarter-chord line, and NACA 65-012 sections perpendicular to this line. The taper ratio was 2:1 and the aspect ratio, based on the wing area including that submerged within the body, was 4.0. The wing entered the body behind the maximum diameter through rectangular slots $2\frac{3}{4}$ by $20\frac{1}{4}$ inches and was attached to a spring balance within the body. These slots were filled by small wooden blocks mounted on the wing roots and shaped to preserve the body contour. Clearances of about $\frac{1}{32}$ inch were provided so that the end plates did not rub against the sides of the slots as the wing balance deflected under drag load.

Measurements.- Measurement of the desired quantities was accomplished as in the previous tests (references 1 and 2) through use of the NACA radio telemetering system and radar and photo-theodolite equipment. The following quantities were recorded at two separate ground stations by the telemetering system:

1. The force exerted on the body by the wing as measured by a spring balance

2. The total retardation of the complete configuration as measured by a sensitive accelerometer alined with the longitudinal axis of the body

3. The total pressure at an orifice located at the nose of the test body as measured by an aneroid cell

A time history of the position of the body with respect to ground axes during its fall was recorded by radar and phototheodolite equipment, and a survey of atmospheric conditions applying to the test was obtained from synchronized records of atmospheric pressure, temperature, and geometric altitude during the descent of the airplane from which the test body was dropped. The direction and velocity of the horizontal component of the wind in the range of altitude for which data are presented were obtained from radar and phototheodolite records of the path of the ascension of a free balloon.

Reduction of data.- As in the previous tests, the velocity of the body with respect to the ground, hereinafter referred to as ground velocity, during its fall was obtained both by differentiation of the flight path determined by radar and phototheodolite equipment and by integration of the vector sums of gravitional acceleration and the directed retardation measured by the longitudinal accelerometer. The true airspeed was obtained by vectorially adding the ground velocity and the horizontal wind velocity measured at the appropriate altitude.

The total drag was obtained by multiplying the retardation a_e (in g units) by the weight of the configuration. The wing drag D_w was obtained from the relation

$$D_w = R + W_w a_e$$

where

R measured reaction between wing and body, pounds

W_w weight of wing assembly supported on spring balances, pounds

The drag of the body-tail combination was obtained by subtracting the drag of the wing from the total

The atmospheric pressure p, the temperature T, and the appropriate frontal area F were combined with simultaneous values of true airspeed and drag to obtain $\frac{D}{Fp}$ ratios for the complete configuration and its component parts and the Mach number M.

Values of conventional drag coefficient based on frontal area C_{D_F} were obtained from the relation

$$C_{D_F} = \frac{\frac{D}{Fp}}{\frac{\gamma}{2} M^2}$$

where the ratio of specific heats γ was taken as 1.4. Wing drag coefficients based on plan area C_D were obtained by multiplying C_{D_F} by the ratio of wing frontal area (projected from the line of maximum thickness) to plan area. Areas used did not include those enclosed by the body.

Mach number was also obtained from the total-pressure measurement by use of the relation

$$M = \sqrt{\frac{\left(\frac{H}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1}{\frac{\gamma - 1}{2}}}$$

where H is the measured total pressure and the other symbols are as previously defined. This expression does not include a correction for the loss in total pressure through the normal shock wave which would appear in front of the orifice at supersonic speeds, as at the low supersonic speeds attained by this test body the correction would be negligible.

RESULTS AND DISCUSSION

A time history of important quantities obtained in the present test is presented as figure 4.

The ground velocity obtained for the test body from the accelerometer data is shown on figure 4 as a dashed line. The test body was tracked by the radar and phototheodolite equipment during the entire drop; however, due to relatively poor visibility conditions and rough tracking the theodolite photographs, which normally allow the data to be corrected for small tracking errors, were obtained only for about 6 seconds near the end of the drop. The ground

velocity computed from the radar and phototheodolite data during this period is shown by the test points. The data from the two different sources agree and the accelerometer data, corrected to true airspeed by use of the wind data, were used to compute the Mach number. Both this Mach number and the Mach number determined from total-pressure measurements are plotted on the time history. They differ by a maximum of ±0.02, which is within the expected limit of accuracy of the pressure measurement. The Mach number determined from the true airspeed data was used in the remainder of this paper and is believed accurate within ±0.01.

The results of the tests are summarized on figure 5 where curves are presented which show the variations obtained for $\frac{D}{Fp}$ and C_{D_F} for the complete configuration, for the wing, and for the body and tail. The wing drag coefficient C_D is also presented on this figure.

As the spring balance with which the wing drag force was measured must withstand the high drag forces occurring at supersonic Mach numbers and high static pressures (low altitudes), it is necessarily relatively insensitive to the small drags occurring at subcritical Mach numbers at low static pressures (high altitudes). The drag parameters are therefore less accurate at the lowest Mach numbers for which data are presented than at the highest speeds attained. At $M = 0.85$ the $\frac{D}{Fp}$ data of figure 5 are believed accurate within ±0.008, ±0.006, and ±0.02 for the complete configuration, the wing, and the body and tail, respectively. Corresponding values at $M = 1.02$ are ±0.004, ±0.003, and ±0.01. The C_{D_F} and C_D values are somewhat less accurate due to the introduction of the Mach number values into the computation, the uncertainty in C_D for the wing being about ±0.001 from $M = 0.85$ to $M = 1.02$.

In an effort to obtain the drag data as accurately as possible, the maximum balance deflection was chosen to correspond closely to maximum drag estimated from available information. The actual wing drags obtained were considerably larger than estimated and as a result full balance deflection occurred at $M = 1.02$ at an altitude of 12,600 feet. (See fig. 4.) No significant data were lost, however, as the high drag of the test configuration prevented it from attaining a Mach number greater than 1.03.

Figure 5 shows that for the complete configuration the drag rose almost linearly from 0.07 of atmospheric pressure per unit frontal

area at $M = 0.9$ to 0.30 of atmospheric pressure at $M = 1.02$. The wing drag rose similarly from 0.047 of atmospheric pressure per unit frontal area at $M = 0.91$ to 0.30 at $M = 0.98$ and then increased more slowly to 0.34 of atmospheric pressure at $M = 1.02$. The drag of the body and tail, which was determined by subtracting the wing drag from the total drag, rose linearly from 0.08 of atmospheric pressure at $M = 0.85$ to 0.16 at $M = 0.975$, then increased abruptly to 0.25 of atmospheric pressure at $M = 1.01$. Considerable unsteadiness was present in the drag values at Mach numbers between 0.90 and 1.00. This unsteadiness is believed due to disturbed flow conditions at the wing-body juncture.

The drag results obtained for the swept-forward wing and results of previous tests of rectangular plan form and 45° swept-back plan-form airfoils mounted on cylindrical test bodies are compared in figure 6. The airfoil section normal to the quarter-chord line, the sweep angle, the aspect ratio, and the reference from which the data were taken are given in the figure. The drag rise measured in the present tests for the 30° swept forward, 12-percent-thick airfoil of aspect ratio 4 and taper ratio 2:1 agrees closely with the drag rise for the unswept 9-percent-thick airfoil of aspect ratio 5.1 (reference 2).

The results of previous tests presented in figure 6 illustrate the effects of thickness and aspect ratio for rectangular plan-form airfoils and the effect of 45° sweepback for an untapered airfoil. These results are not directly comparable with the results of the present test, however, because these airfoils were untapered, were of different thickness, and were mounted on long cylindrical bodies which they entered through open rectangular slots. Consideration of the flow about the body shows that in the present test a portion of the wing near the root was in a region of increased velocity due to the curvature of the fineness ratio 12 body. The drag of this portion of the wing would therefore begin to rise at a lower free-stream Mach number than the drag of an identical wing mounted on a long cylindrical body where the excess velocities are negligible. For configurations similar to that tested, the drag of a tapered wing would tend to rise more abruptly than the drag of an untapered wing since a larger part of the wing area would be located in the region of appreciable excess velocities.

The drag of the body-tail combination, obtained by subtracting the drag of the wing from the measured total drag, is compared in figure 7 with the drag of an identical body-tail combination tested without wings (reference 3). This comparison shows a large unfavorable interference effect, the drag of the body-tail combination

being almost doubled due to the presence of the wing. Presumably this large, rather unsteady interference drag results from disturbed flow conditions at the wing-fuselage juncture.

CONCLUSIONS

The drag of a configuration consisting of a body of fineness ratio 12 with stabilizing tail surfaces and a 30° swept-forward wing has been measured at transonic speeds by the free-fall method. The total drag and the drag of the wing were measured separately. The drag of the complete configuration rose almost linearly from 0.07 of atmospheric pressure per unit frontal area at a Mach number of 0.90 to 0.30 of atmospheric pressure at a Mach number of 1.02. The drag of the wing rose similarly from 0.047 of atmospheric pressure per unit frontal area at a Mach number of 0.91 to 0.30 at 0.98 and then increased more slowly to 0.34 of atmospheric pressure at a Mach number of 1.02.

The presence of the swept-forward wing resulted in a large unfavorable interference effect on the drag of the body-tail combination; these parts experienced almost twice the drag measured in previous tests of an identical body-tail combination without wings.

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REFERENCES

1. Bailey, F. J., Jr., Mathews, Charles W., and Thompson, Jim Rogers: Drag Measurements at Transonic Speeds on a Freely Falling Body. NACA ACR No. L5E03, 1945.

2. Mathews, Charles W., and Thompson, Jim Rogers: Comparative Drag Measurements at Transonic Speeds of Rectangular and Swept-Back NACA 65_1-009 Airfoils Mounted on a Freely Falling Body. NACA ACR No. L5G30, 1945.

3. Thompson, Jim Rogers, and Mathews, Charles W.: Total Drag of a Body of Fineness Ratio 12 and Its Stabilizing Tail Surfaces Measured During Free Fall at Transonic Speeds. NACA CB No. L6D08, 1946.

4. Mathews, Charles W., and Thompson, Jim Rogers: Drag Measurements at Transonic Speeds of NACA 65-009 Airfoils Mounted on a Freely Falling Body to Determine the Effects of Sweepback and Aspect Ratio. NACA RM No. L6K08c, 1947.

5. Thompson, Jim Rogers, and Marschner, Bernard W.: Comparative Drag Measurements at Transonic Speeds of an NACA 65-006 Airfoil and a Symmetrical Circular-Arc Airfoil. NACA RM No. L6J30, 1946.

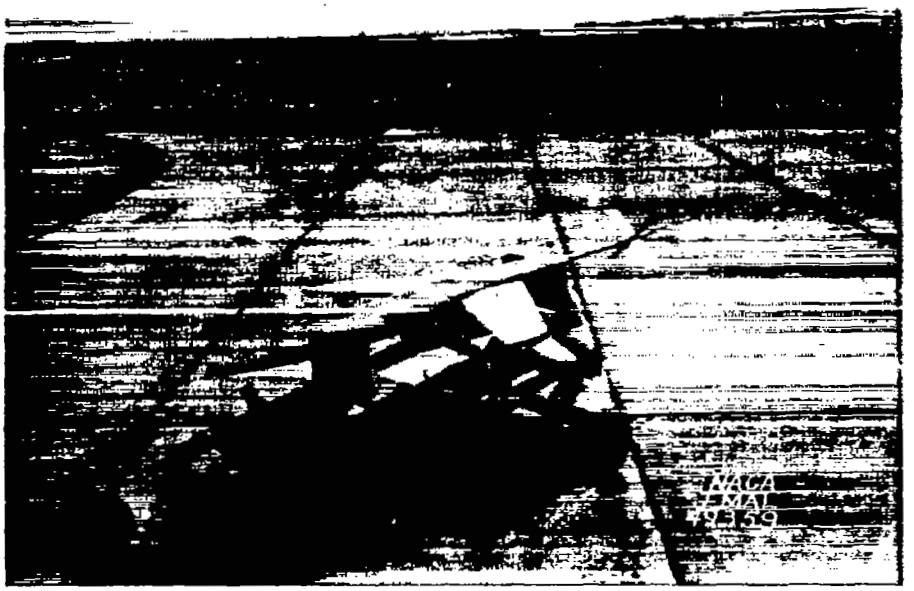

Figure 1.- Three-quarter front view of test configuration.

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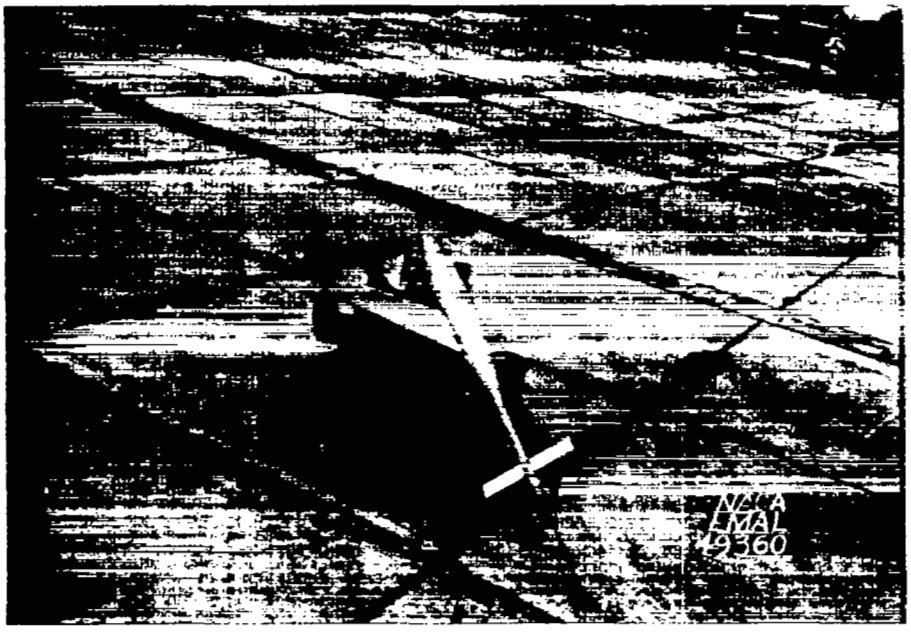

Figure 2.- Top rear view of test configuration.

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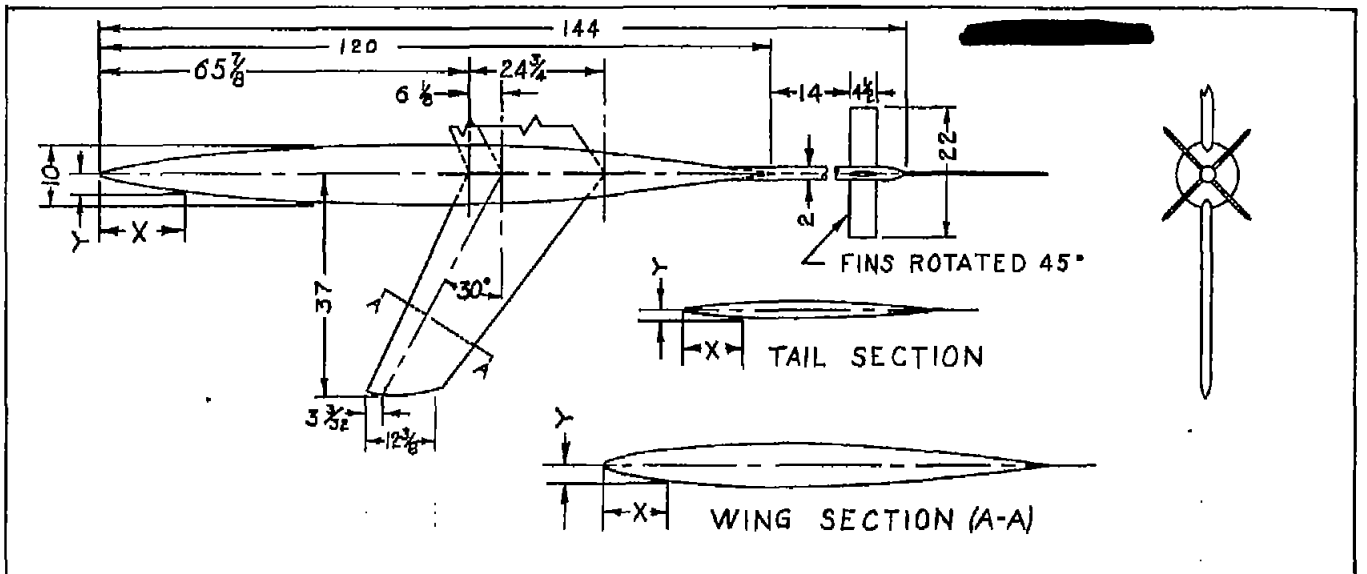

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DIMENSIONS, SQ.FT			
BODY FRONTAL AREA	0.545	WING PLAN AREA	8.000
WING FRONTAL AREA	.767	TAIL PLAN AREA	1.232
TAIL FRONTAL AREA	.074	TOTAL FRONTAL AREA	1.386

WING-SECTION COORDINATES, %C (NACA 65-012 SECTION)					
X	Y	X	Y	X	Y
0.000	0.000	20.000	4.975	65.000	4.381
.500	.923	25.000	5.406	70.000	3.743
.750	1.109	30.000	5.716	75.000	3.059
1.250	1.387	35.000	5.912	80.000	2.345
2.500	1.875	40.000	5.997	85.000	1.630
5.000	2.606	45.000	5.949	90.000	.947
7.500	3.172	50.000	5.757	95.000	.356
10.000	3.647	55.000	5.412	100.000	.000
15.000	4.402	60.000	4.943		
L.E. RADIUS 1.000					

TAIL-SECTION COORDINATES, IN. (NACA 16 SERIES AIRFOIL)			
X	Y	X	Y
0.000	0.000	1.350	.122
.052	.029	1.800	.132
.113	.041	2.250	.135
.225	.056	2.700	.131
.338	.068	3.150	.118
.450	.078	3.600	.094
.675	.093	4.050	.057
.900	.105	4.275	.032
1.125	.115	4.500	.003
L.E. RADIUS 0.008			

BODY COORDINATES, IN.			
X	Y	X	Y
0.000	0.000	48.000	4.876
.600	.277	54.000	4.971
.900	.358	60.000	5.000
1.500	.514	66.000	4.955
3.000	.866	72.000	4.828
6.000	1.446	78.000	4.610
9.000	1.936	84.000	4.274
12.000	2.365	90.000	3.754
18.000	3.112	96.000	3.031
24.000	3.708	102.000	2.222
30.000	4.158	108.000	1.350
36.000	4.489	114.000	.526
42.000	4.719	120.000	.000
NOSE RADIUS 0.060			

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Figure 3.- General arrangement and dimensions of test configuration. All dimensions are in inches.

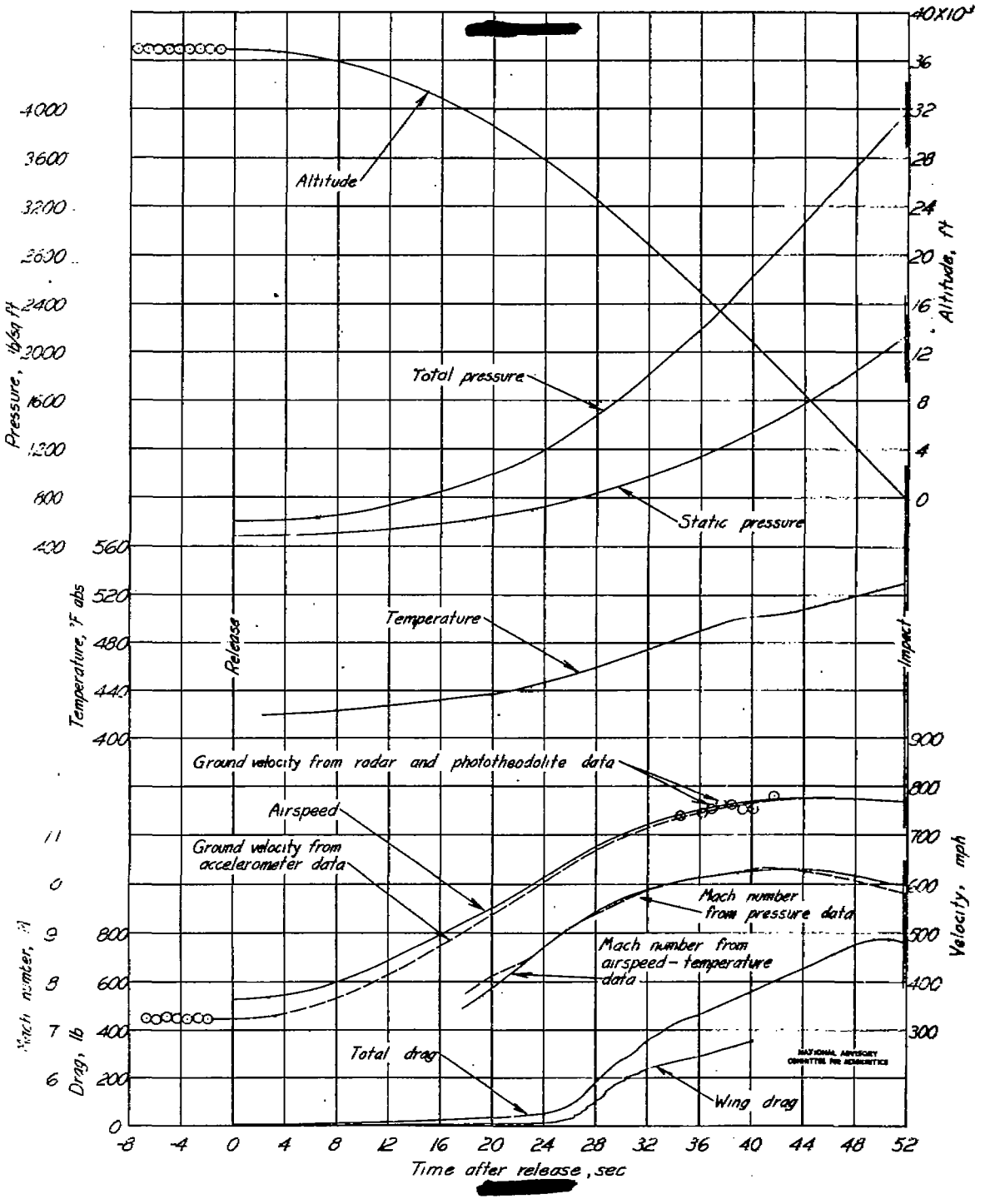

Figure 4.- Time history of free fall of test configuration.

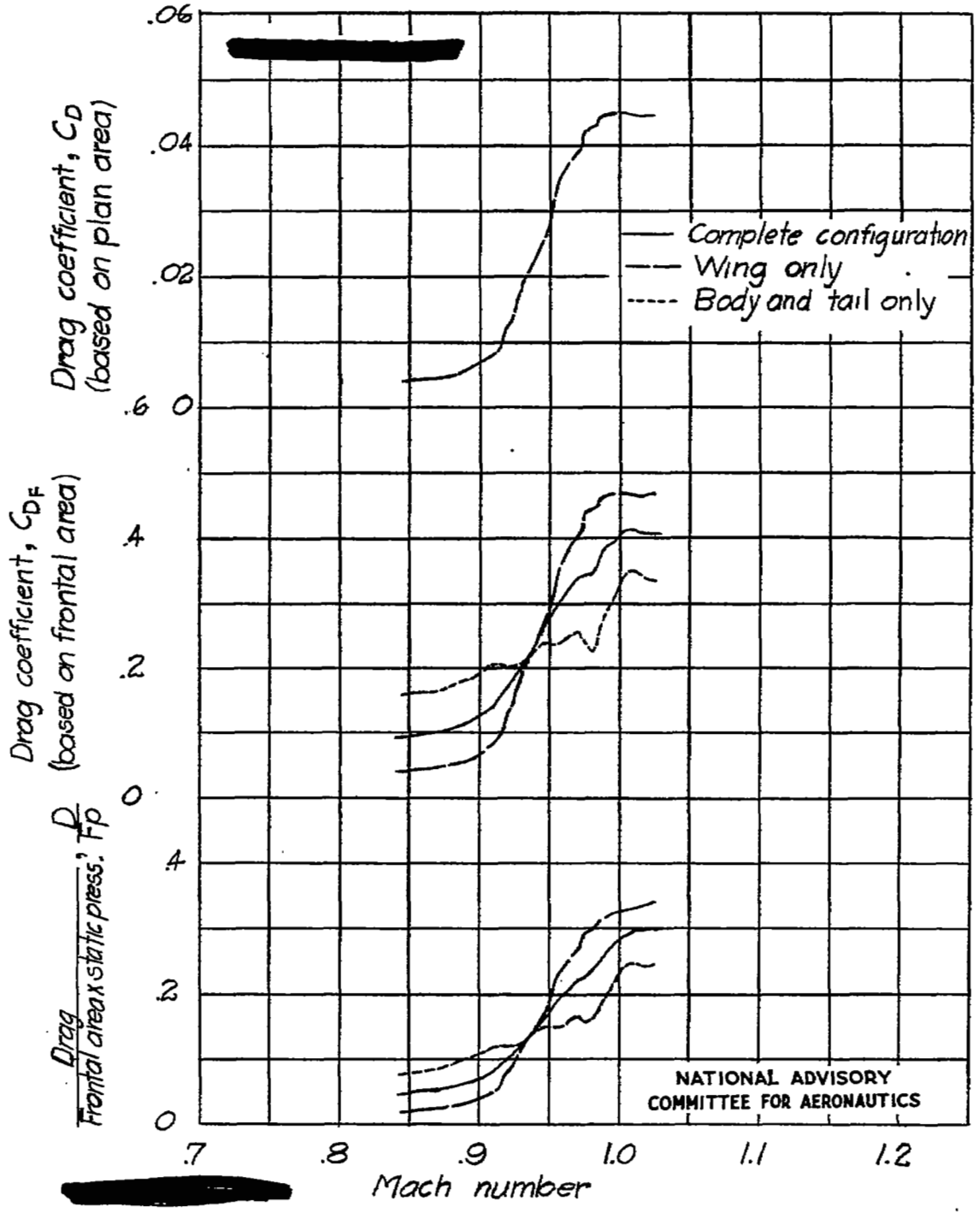

Figure 5.- Variation with Mach number of drag coefficients and D/F_p ratios for the complete configuration and its component parts. For each curve the drag parameter is based on the area of the specified component.

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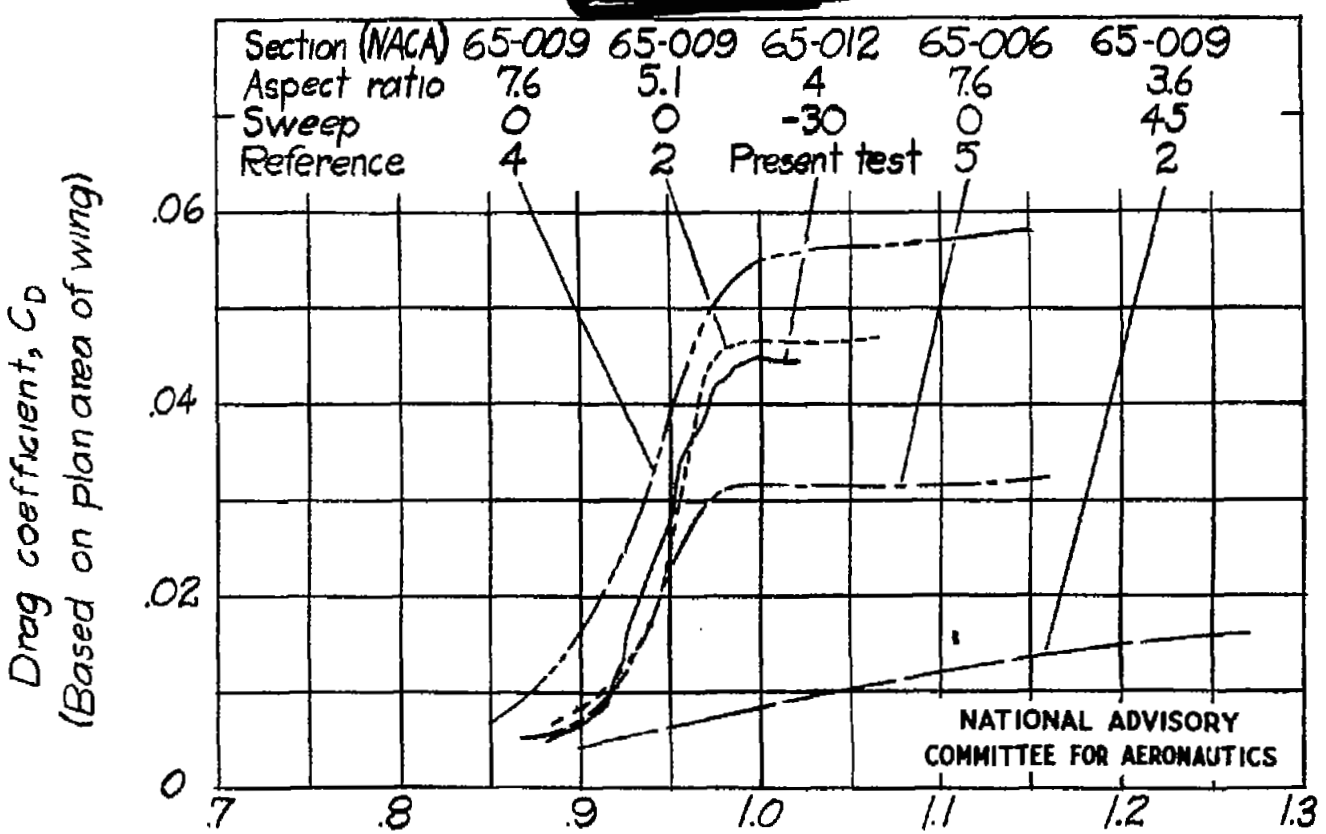

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Figure 6.- Comparison of wing drag results with those of previous tests.

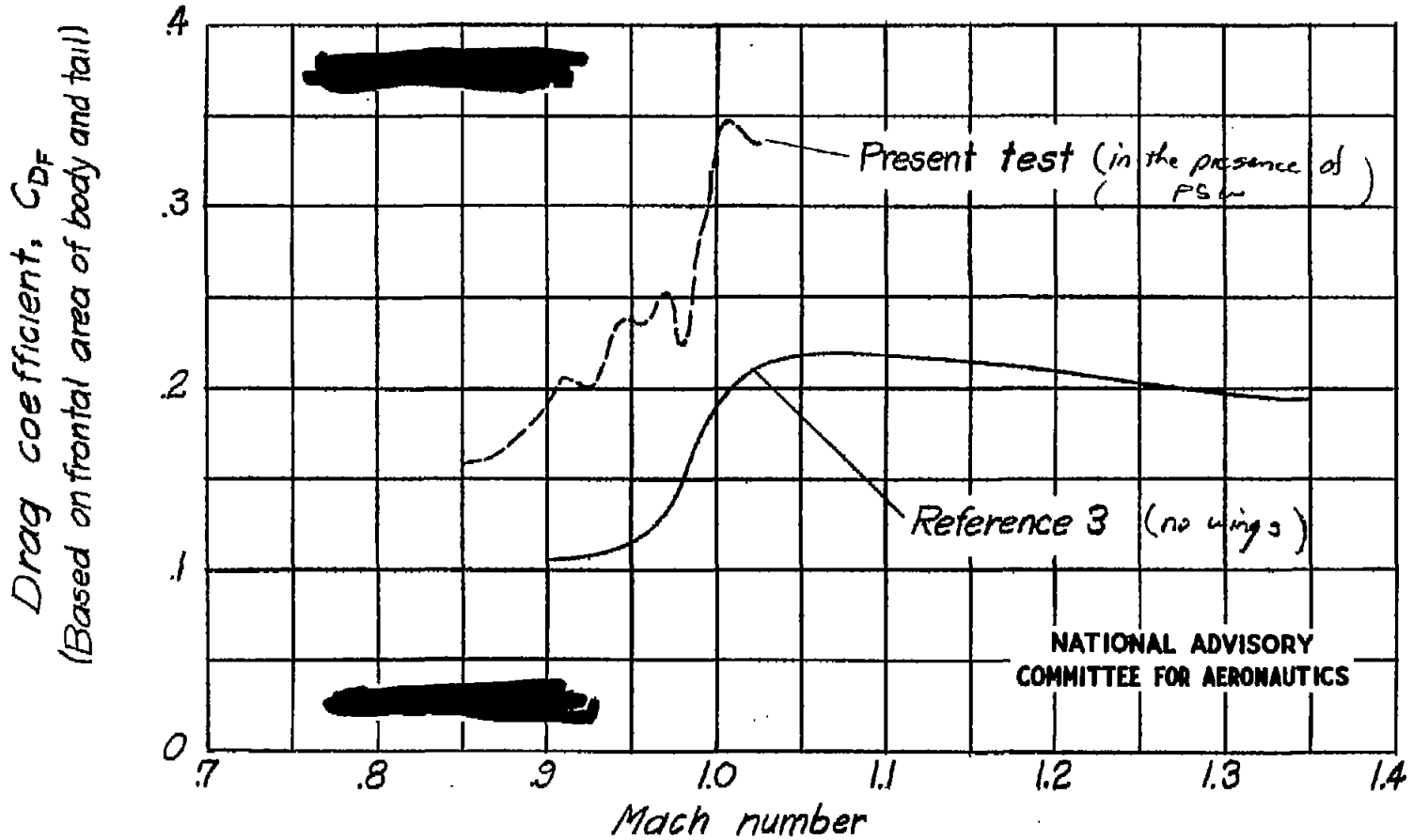

Figure 7.- Comparison of drag results for the body-tail combination with those of previous tests.