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RESEARCH MEMORANDUM

TRANSONIC DRAG CHARACTERISTICS OF A WING-BODY COMBINATION USING A THIN TAPERED WING OF 45° SWEEPBACK

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SUMMARY

A wing-body combination, which has been tested by the free-fall method, consisted of a fineness-ratio-12 body with a 45° sweptback wing measured from the 50-percent-chord line of 0.2 taper ratio (ratio of chord at tip to chord at the wing-body juncture), an aspect ratio of 3.75, and an NACA 65-003 airfoil section in the direction perpendicular to the 50-percent-chord line. The wing was chosen in order to investigate the possibilities of using a very thin wing to improve the zero-lift drag of a wing-body combination while using a high taper ratio to provide the wing with adequate strength and rigidity. The test covered a Mach number range of $M = 0.80$ to $M = 1.18$.

An abrupt drag rise of the complete configuration began at $M = 0.88$ and the total drag coefficient (based on wing plan area) rose to a value of 0.022 at a Mach number of 1.01. Above $M = 1.01$ the total and component drag coefficients remained effectively constant, the component drags being the following approximate percentages of the total drag: Wing, 30 percent; body, 50 percent; and tail, 20 percent. The drag coefficient of the wing above a Mach number of unity was approximately 70 percent greater than drag coefficients which existed prior to the drag rise. A comparison of the drag coefficients of the body-tail combination with those from a previous test of a model without wings indicates that within the accuracy of measurement the magnitude of the body-tail drag in the test range of supersonic Mach numbers was not appreciably affected by the presence of the wing.

INTRODUCTION

The Flight Research Division of the Langley Aeronautical Laboratory is conducting an investigation of the zero-lift drag of a series of wing-body combinations by the free-fall method. For all configurations so far

investigated either reduction of wing thickness ratio or increase in the sweepback angle produced large reductions in the wing and total drags at supersonic speeds and delayed the occurrence of the drag rise to higher Mach numbers. (See reference 1.) The results presented in references 1 and 2, however, indicate that increasing the taper of sweptback wings holding a constant section thickness ratio and angle of sweep increased the drag of these configurations at low supersonic speeds and caused a slight decrease in the Mach number at which the drag rise occurred. Although the use of taper gives this apparent detrimental effect on the zero-lift drag for a given section thickness ratio, the use of taper enables a reduction in the section thickness ratio without sacrificing the strength or rigidity of the wing structure. On the basis of this consideration, it appears that the over-all results of reduction of wing thickness ratio through use of a high taper may be beneficial from the standpoint of zero-lift drag. Accordingly, tests are being conducted to investigate the effects of variations in these wing geometric parameters where structural effects such as bending stiffness and stress are considered.

Results are presented herein of a test of a wing-body combination where the wing external geometry did incorporate high taper and extremely low section thickness ratio. These results are presented as curves showing the variations of drag coefficient with Mach number for the test model and each of its components. The Mach number range covered by the test was from 0.80 to 1.18. The Reynolds number range covered by the test was from 2.0×10^6 to 7.9×10^6 per foot of length.

APPARATUS AND METHOD

Test configuration.- The general arrangement of the wing-body configuration tested is shown in figure 1 and its details and dimensions given in figure 2. The body and tail of the wing-body combination were identical to those of the models described in references 1 and 3, these models differing only in wing geometry. The wing of the test model was located on the body so that the intersection of the 50-percent-chord line with the body surface was approximately 15 inches to the rear of the maximum body diameter. The wing had a taper ratio of 0.2, an aspect ratio of 3.75, and a midchord sweepback of 45°. The coordinates of the airfoil were interpolated from the NACA 65-series so as to give approximately a 65-003 airfoil section in a direction perpendicular to the 50-percent-chord line. The wing and tail surfaces were mounted on separate force-measuring balances within the model and entered the body through rectangular slots slightly wider than the maximum thickness of the airfoils. To prevent leakage, wood blocks were attached to the wing roots and contoured to the body. Small clearances were provided so that the filler blocks did not rub on the walls of the slot.

Measurements.- Measurements of the desired quantities were accomplished as in previous free-fall tests (references 1 and 3) through use of the NACA radio-telemetering system and radar and phototheodolite equipment. The following quantities were recorded at two ground stations by the telemetering system:

1. The chordwise force exerted by the wings on the body measured by a spring balance. Range 0 to 180 pounds.

2. The chordwise force exerted by the tail on the tailboom as measured by a spring balance. Range 0 to 120 pounds.

3. The longitudinal acceleration due to drag of the configuration (retardation) as measured by three sensitive accelerometers each covering a partial range as follows: 0g to 0.2g, 0.2g to 0.4g, and 0.4g to 0.75g.

4. The total, static, and impact pressures at the airspeed head as measured by aneroid cells. Ranges as follows: 0 to 5400 pounds per square foot, 0 to 2150 pounds per square foot, and 0 to 2800 pounds per square foot, respectively.

A device was incorporated into the acceleration-measuring equipment which accurately switched a higher range accelerometer into the telemeter transmitting system whenever the maximum range point of the preceding accelerometer was attained. As the magnitude of the acceleration of the switch points was accurately known and as these switch points could be detected on the telemeter records, two acceleration points were determined during the test by a method independent of the telemetering system and, therefore, enabled a check on the accuracy of the telemetered accelerations. The known acceleration points checked the corresponding telemetered accelerations within 0.002g.

A survey of atmospheric conditions at the time of the test was obtained from synchronized records of static pressure, temperature, and geometric altitude during the descent of the airplane from which the configuration was dropped. The direction and velocity of the horizontal component of the wind were determined from radar and phototheodolite tracking records of the ascent of a free balloon immediately after the test.

Reduction of data.- The velocity variation of the model with respect to the ground, hereinafter referred to as ground velocity, was obtained by a step-by-step integration of the vector sums of gravitational acceleration and the directed retardation as measured by the accelerometer. True airspeed was obtained by vector summation of ground velocity and horizontal wind velocity at appropriate altitudes and was converted to Mach number through use of the atmospheric temperature data.

The telemetered static, total, and impact pressures were also measured and the Mach numbers obtained from these pressure measurements checked the Mach numbers obtained through use of the radar and atmospheric temperature data to within the accuracy of the pressure measurements. Since the primary purpose of the pressure measurements is to provide an alternate means of obtaining Mach number, which is not needed in this case, telemetered pressure measurements are not presented herein.

The force measurements for the complete configuration and each component were reduced to the form of drag per unit frontal area as a fraction of static pressure and drag coefficient by the method outlined in references 1 and 3. The total drag coefficient C_D used in this test is based on the wing plan area, the wing drag coefficient C_{D_W} is based on the exposed wing plan area and the body and tail drag coefficient C_{D_F} is based on the body frontal area.

Precision of measurements.- The Mach number variation as computed from the accelerometer, wind, and temperature data is considered to be accurate to ±0.01. Considerable evidence has been obtained which indicates that the possible inaccuracy in the telemetered quantities is the order of ±1 percent of the full range of the particular instrument involved. The accuracy with which the drag parameters were determined varied through the fall due to the possible inaccuracy in the telemetered quantities and in the case of drag coefficients the accuracy was also affected by the Mach number. The estimated maximum inaccuracy of the drag parameters at several Mach numbers is presented in table I.

RESULTS AND DISCUSSION

The results of this test are presented in figures 3 to 5 as curves showing the variations with Mach number of the parameter D/F_p and the drag coefficients for the complete configuration and each component. The Mach number range covered by the test was from 0.80 to 1.18. The Reynolds number range covered by the test was from 2.0×10^6 to 7.9×10^6 per foot of length.

Complete configuration.- Figure 3 presents the variation with Mach number of the parameter D/F_p and the drag coefficient for the complete configuration. The total drag coefficient (based on wing plan area) rose from a value of about 0.012 at a Mach number of 0.88 to a value of about 0.022 at a Mach number of 1.01 where the drag rise was completed. The total drag coefficient remained effectively constant at higher Mach numbers. Figure 3 also shows the distribution of the total drag between

components of the model. Above Mach number 1.01, the component drag coefficients remained effectively constant and the division of the total drag among the component drags was in about the following percentages: Wings, 30 percent; body, 50 percent; and tail, 20 percent.

Wing.- The variation with Mach number of D/F_p and C_{D_W} (based on exposed wing plan area) for the wing of the test model is presented in figure 4. The drag of the wing begins an abrupt rise at a Mach number of 0.95 from a drag coefficient of 0.005 to a drag coefficient of 0.0085 at a Mach number of 1.0. Above Mach number 1.0, the drag coefficient remains nearly constant at a value of 0.0085. The drag coefficient of the test wing at supersonic speeds is only about 70 percent greater than the drag coefficient at subcritical speeds. The drag rise is relatively small due both to the sweepback and the use of a very thin wing section.

Body-tail combination.- The variation with Mach number of drag coefficient of the body-tail combination of the test model and of a body-tail combination, identical with that of the model, but which was tested without wings (reference 3) is shown in figure 5. In addition, the tail drag coefficients (based on body frontal area) of the two models are presented.

The drag coefficient (based on body frontal area) of the body-tail combination of the test model began to rise from a value of 0.135 at a Mach number of 0.9. As can be seen from figure 5, this initial drag rise resulted from the drag rise of the tail. The drag rise of the body-tail combination was completed at a Mach number of about 1.01, and above this Mach number, the drag coefficient of the body-tail combination remained nearly constant at a value of 0.255. A comparison of these results with the results of a similar body-tail combination without wings that was tested previously indicates that within the accuracy of the test the drag coefficient was not affected appreciably by the presence of the wing.

Component effects on total drag.- Comparing the variation of total drag coefficient (fig. 3) with the component variations (figs. 4 and 5) it is seen that the initial drag rise, which occurred at a Mach number of 0.90, was due primarily to the drag rise of the tail (fig. 5). Above $M = 0.95$, the drag of the wing (fig. 4) increased abruptly and this combined with the abrupt increase in drag of the body-tail combination at a slightly higher Mach number served to steepen the drag rise of the complete configuration up to $M = 1.01$. Above a Mach number of 1.01, the drag coefficients of all the components had little variation and thus the total drag coefficient remained nearly constant in this Mach number range.

CONCLUDING REMARKS

Measurements have been made of the transonic drag characteristics at zero lift of a configuration consisting of a fineness-ratio-12 body with a 45° sweptback wing measured from the 50-percent-chord line having a 0.2 taper ratio, a 3.75 aspect ratio, and an NACA 65-003 airfoil section perpendicular to the 50-percent-chord line.

Results of the test show that the drag rise for the complete configuration began at $M = 0.88$. The drag coefficient rose from a value of 0.012 (based on wing plan area) to a value of 0.022 at $M = 1.01$. Above a Mach number of 1.01, the total and component drag coefficients remained effectively constant, the component drags being the following approximate percentages of the total drag: Wing, 30 percent; body, 50 percent; and tail, 20 percent. The drag of the test wing began an abrupt rise at a Mach number of 0.95 and rose from a drag coefficient (based on exposed plan area) of 0.005 to a value of 0.0085 at a Mach number of unity. The drag rise was relatively small due to sweepback and the use of a very thin wing section.

A comparison of the drag results of the body-tail combination with those from a previous test of a model without wings indicates that within the accuracy of measurement the magnitude of the drag of the body-tail combination and the tail drag in the test range of supersonic Mach numbers was not appreciably affected by the presence of the wing.

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REFERENCES

1. Thompson, Jim Rogers, and Mathews, Charles W.: Effect of Wing Sweep, Taper, and Thickness Ratio on the Transonic Drag Characteristics of Wing-Body Combinations. NACA RM L8K01, 1948.

2. Pittel, Murray: Flight Tests at Supersonic Speeds to Determine the Effect of Taper on Zero-Lift Drag of Sweptback Low-Aspect-Ratio Wings. NACA RM L50F30A, 1950.

3. Thompson, Jim Rogers: Measurements of the Drag and Pressure Distribution on a Body of Revolution throughout Transition from Subsonic to Supersonic Speeds. NACA RM L9J27, 1950.

TABLE I

ESTIMATED MAXIMUM UNCERTAINTIES OF THE DRAG

PARAMETERS AT SEVERAL MACH NUMBERS

[Percent values are errors in percent of measured values.]

Parameter	M = 0.90	M = 1.00	M = 1.17
D/Fp total	±0.004 3.4 percent	±0.005 1.8 percent	±0.004 1.1 percent
D/Fp wings	±0.017 12.3 percent	±0.015 5.6 percent	±0.010 2.5 percent
C_{D_W} (wing)	±0.0008 14.8 percent	±0.0006 7.8 percent	±0.0004 5.2 percent
C_{D_F} (body and tail)	±0.024 17.5 percent	±0.016 6.3 percent	±0.010 4.0 percent
C_D (total)	±0.0010 5.7 percent	±0.0012 3.9 percent	±0.00094 2.9 percent

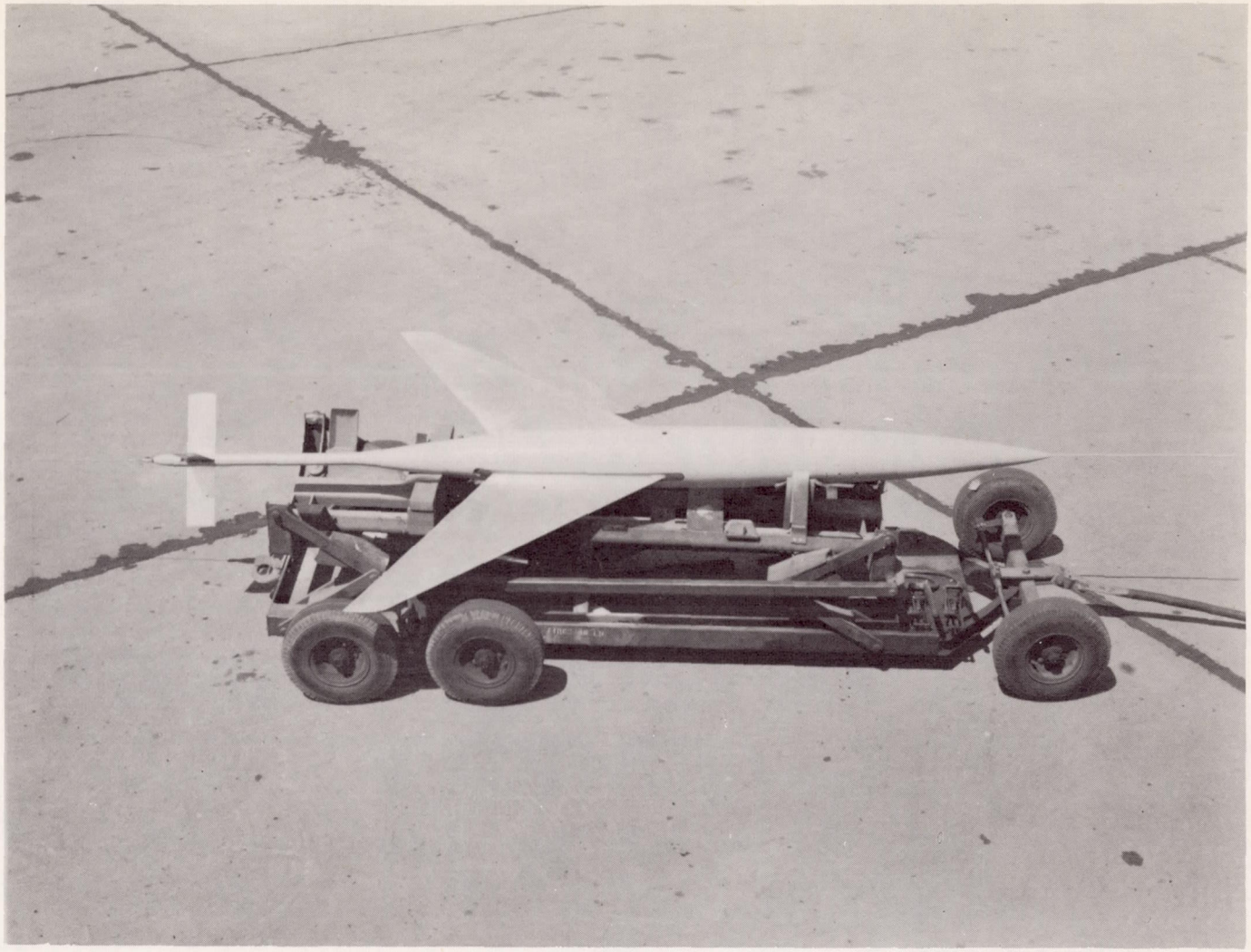

Figure 1.- General view of the wing-body configuration tested.

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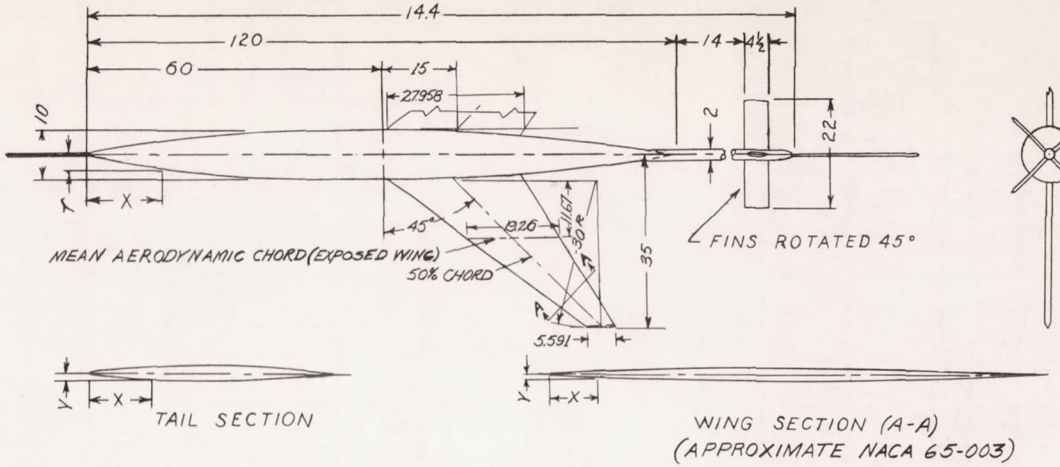

DIMENSIONS SQ. FT.

BODY FRONTAL AREA	0.545	WING PLAN AREA	9.062
WING FRONTAL AREA	.152	TAIL PLAN AREA	1.232
EXPOSED WING AREA	7.065	TOTAL FRONTAL AREA	.771

WING - SECTION COORDINATES

X %C	Y %C	X %C	Y %C	X %C	Y %C
0	0.	20	1.241	65	1.135
.5	.238	25	1.349	70	.978
.75	.287	30	1.426	75	.805
1.25	.358	35	1.476	80	.628
2.5	.478	40	1.499	85	.440
5.0	.655	45	1.495	90	.265
7.5	.795	50	1.455	95	.115
10.	.912	55	1.380	100	0.
15	1.099	60	1.273		

L.E. RADIUS 0.055 %C

TAIL-SECTION COORDINATES
(NACA 16-SECTION 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

X	T	X	T
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 2.- Details and dimensions of the wing-body configuration tested. All dimensions except wing coordinates are in inches. Wing section coordinates are in percent chord and are measured perpendicular to the 50-percent-chord line.

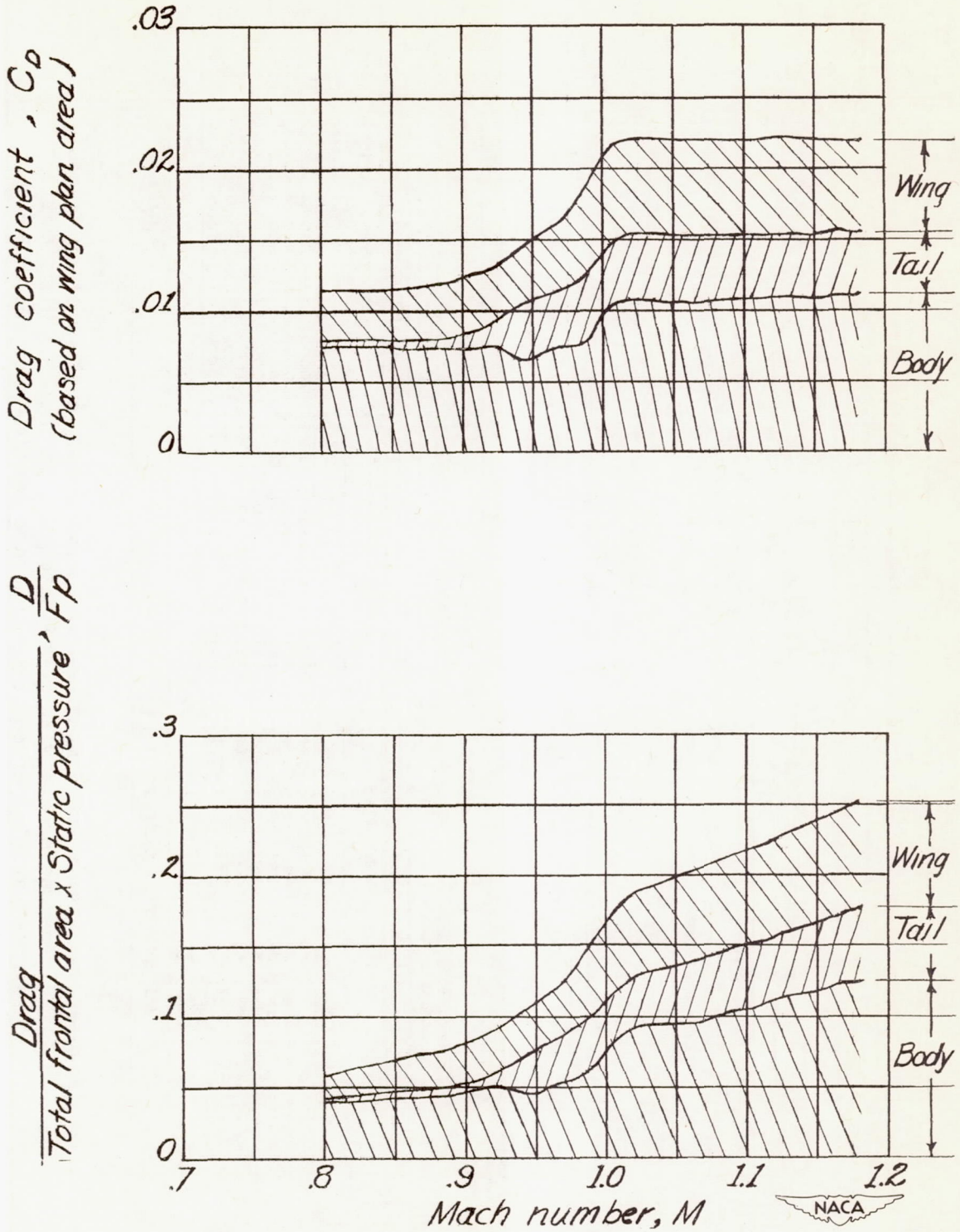

Figure 3.- Variation with Mach number of drag coefficient and D/F_p for the test configuration.

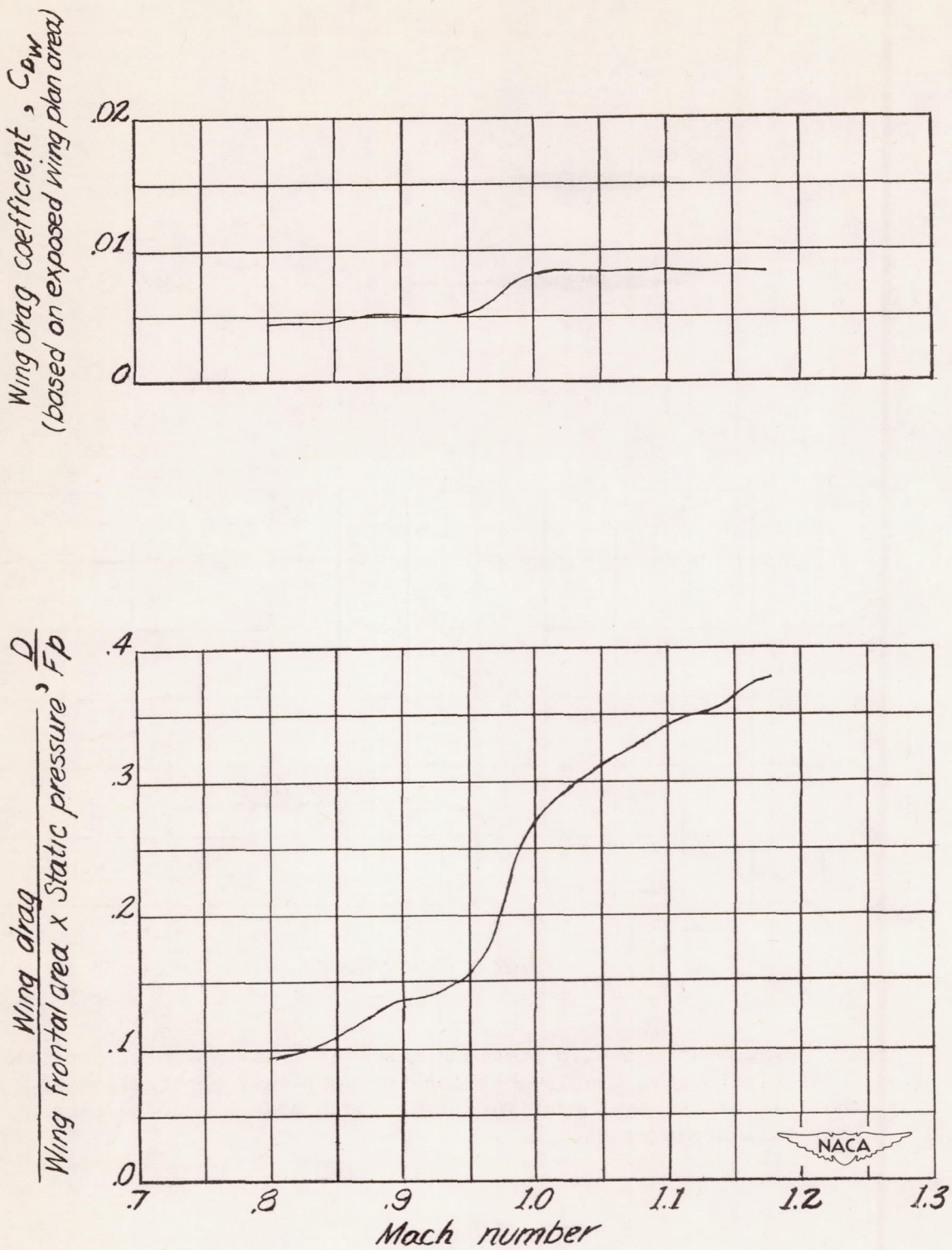

Figure 4.- Variation with Mach number of wing drag coefficient and D/F_p for the test configuration.

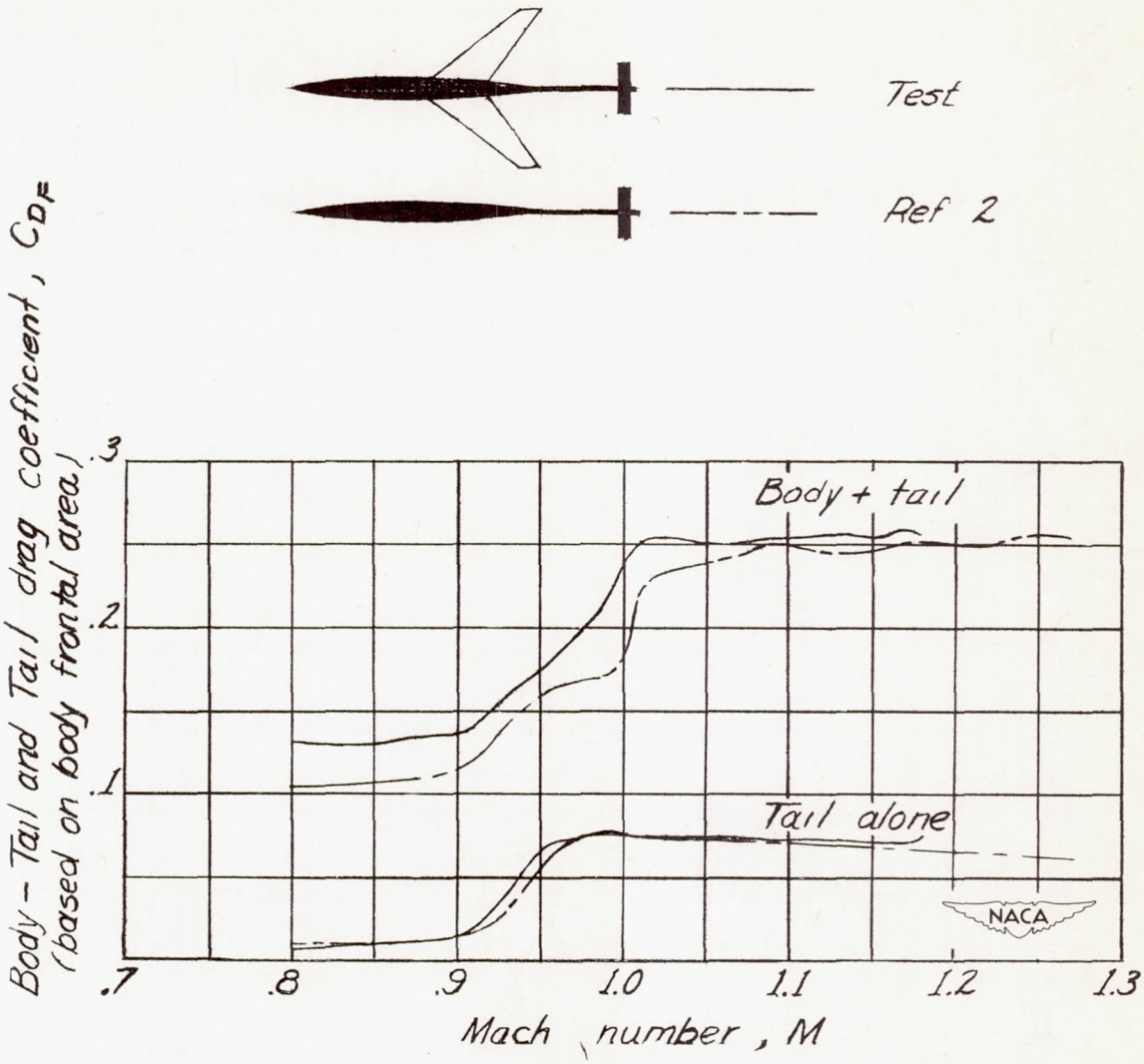

Figure 5.- Comparison with previous results of variation of the drag coefficients with Mach number for the body-tail combination and the tail of the test configuration. Both models had the same body-tail arrangement.