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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION OF THE ZERO-LIFT DRAG OF SEVERAL WINGS AT SUPERSONIC MACH NUMBERS EXTENDING TO 2.6

By Russell N. Hopko and Carl A. Sandahl

Langley Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION OF THE ZERO-LIFT DRAG OF SEVERAL WINGS AT SUPERSONIC MACH NUMBERS EXTENDING TO 2.6

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SUMMARY

The zero-lift drag of several wings of current interest has been obtained at supersonic Mach numbers extending to 2.6 in free flight with rocket-propelled models. The wings tested included a 60° delta wing having NACA 65A003 sections, a 60° delta wing of constant thickness 1.2 percent thick at the wing root, a 10° swept wing 4.5 percent thick, and a 63° sweptback tapered wing approximately 5.8 percent thick. Of those tested, the delta wings had the lowest drag over the entire Mach number range. At low supersonic Mach numbers, the drag of the 10° swept wing was considerably higher than that of the other wings. At the maximum Mach number attained, the 10° and the 63° swept wings had about equal drag.

INTRODUCTION

A considerable background of large-scale zero-lift wing drag information has been accumulated in the past 5 years by means of noninstrumented rocket-propelled free-flight test vehicles. Most of this information extends up to a Mach number of approximately 1.8. There exists an ever-increasing need for large-scale wing-drag measurements at Mach numbers well in excess of those so far attained. The present paper presents the results of a preliminary free-flight investigation at Mach numbers extending to 2.6 of the drag of four wings of current interest: (a) a 60° delta wing of constant thickness 1.2 percent thick at the wing root, (b) a 10° swept wing 4.5 percent thick, (c) a 63° swept tapered wing approximately 5.8 percent thick, and (d) a 60° delta wing having NACA 65A003 sections.

In the present tests, the total drag and the wing-plus-interference drag coefficients are presented for a Mach number range from low supersonic to approximately 2.6. The corresponding range in Reynolds number, based on the mean aerodynamic chord of the exposed wings, was from 2 to 12×10^6.

The flight tests were conducted at the Langley Pilotless Aircraft Research Station, Wallops Island, Va.

SYMBOLS

$C_D = \frac{\text{Drag}}{qS}$

q	dynamic pressure
S	area
c	chord
$\bar{c}$	mean aerodynamic chord of exposed wing
λ	taper ratio
t/c	thickness ratio
$\Lambda_{L.E.}$	sweep of leading edge
A	aspect ratio

Subscripts:

r	root
t	tip

MODELS AND TESTS

The general arrangement of the test vehicle and the test wings is shown in figure 1. A photograph of one of the test wings mounted on the model is shown in figure 2.

The bodies and test wings of the models were constructed of aluminum alloy. The bodies were cylinders with pointed ogival noses of fineness ratio 3.5 and conical afterbodies. The body-fin model had four 60° triangular stabilizing fins; the winged models had two 60° triangular fins and two test wings. More complete physical characteristics of the body and test wings are shown in tables I and II.

The models were boosted to approximately Mach number 2 utilizing a Deacon rocket motor. Following the boost period, a $3\frac{1}{4}$-inch rocket motor, contained in the body, accelerated the models to a Mach number of approximately 2.8. A photograph of one of the models and booster on the launcher is shown in figure 3.

During the flight the models were tracked with CW Doppler radar to determine velocity and with modified SCR 584 radar to determine the flight path. A typical flight path of the models tested is shown in figure 4. Atmospheric data at altitude were obtained by radiosonde. The velocity history was differentiated to obtain the acceleration history from which the drag was computed. A complete description of the technique may be found in reference 1.

The total errors of the results are estimated to be within the following limits:

Mach number	± 0.005
C_D, based on frontal area	± 0.010
C_D, based on wing area	± 0.001

Figure 5 is a data plot for one of the models tested.

RESULTS AND DISCUSSION

The variation of Reynolds number with Mach number is shown in figure 6. Curves of total drag coefficient C_D, based on body frontal area, are given in figure 7 for the wing-body-fin configurations tested.

The wing-plus-interference drag coefficients, presented in figure 8, were obtained by subtracting the drag coefficients of the body and two fins from the total drag coefficients of the winged models and therefore include any mutual interference effects. The drag coefficients of the body and two fins were obtained by linearly extrapolating to zero horizontal area the drag coefficients of the two-fin model having scaled-up fins as wings (model 2) and the four-fin wingless model (model 1).

The delta-wing plan forms had the lowest drag coefficients of those tested. At the lower supersonic Mach numbers investigated, the drag coefficients of the 10° swept wing 4.5 percent thick were considerably higher than those of the other wings tested. However, at Mach numbers above 2.1, the drag coefficients of the 4.5-percent-thick, 10° swept wing were equal to, or less than, those of the 5.8-percent-thick, 63° swept tapered wing. The results indicate that, with increasing Mach number, the wing drag coefficient becomes largely dependent on thickness ratio.

In figure 9 are shown curves of wing-plus-interference drag minus estimated skin friction drag for three of the present models and for three similar models from reference 2. The drag coefficients of reference 2 are based on total wing area and have been converted to exposed wing area in the present paper. The skin friction drag was estimated from reference 3 using Reynolds number values based on the exposed wing mean aerodynamic chords. The results are in excellent agreement.

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

REFERENCES

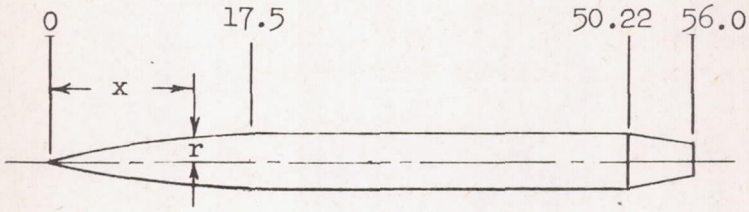
1. Morrow, John D., and Katz, Ellis: Flight Investigation at Mach Numbers from 0.6 to 1.7 to Determine Drag and Base Pressures on a Blunt-Trailing-Edge Airfoil and Drag of Diamond and Circular-Arc Airfoils at Zero Lift. NACA RM L50E19a, 1950.

2. Morrow, John D., and Nelson, Robert L.: Large-Scale Flight Measurements of Zero-Lift Drag of 10 Wing-Body Configurations at Mach Numbers from 0.8 to 1.6. NACA RM L52D18a, 1952.

3. Van Driest, E. R.: Turbulent Boundary Layer in Compressible Fluids. Jour. Aero. Sci., vol. 18, no. 3, Mar. 1951, pp. 145-160, 216.

TABLE I.- BODY COORDINATES FOR TEST MODELS

[Body coordinates in inches]



Body coordinates	
x	r
0	0
1.00	.250
2.00	.480
3.00	.710
4.25	.975
5.00	1.130
7.50	1.570
10.00	1.955
12.50	2.252
15.00	2.429
17.50	2.500
20.50	2.500
50.22	2.500
56.00	1.688

TABLE II

PHYSICAL PROPERTIES OF TEST WINGS

Wing	Model	$\Lambda_{L.E.}$	t/c	A	$\bar{c}$ (in.)	λ	Total included wing area	Total exposed wing area (sq in.)
Wingless	1	—	—	—	—	—	—	—
	2	60°	$\left(\frac{t}{c}\right)_r = 0.012$ $\left(\frac{t}{c}\right)_t = 0.128$	1.97	11.27	0.078	355	242
	3	10°	0.045	3	9.04	1	245	200
	4	62°47'	$\left(\frac{t}{c}\right)_r = 0.062$ $\left(\frac{t}{c}\right)_t = 0.049$	2.02	10.59	.381	278	200
	5	60°	0.030	2.31	9.31	0	304	200

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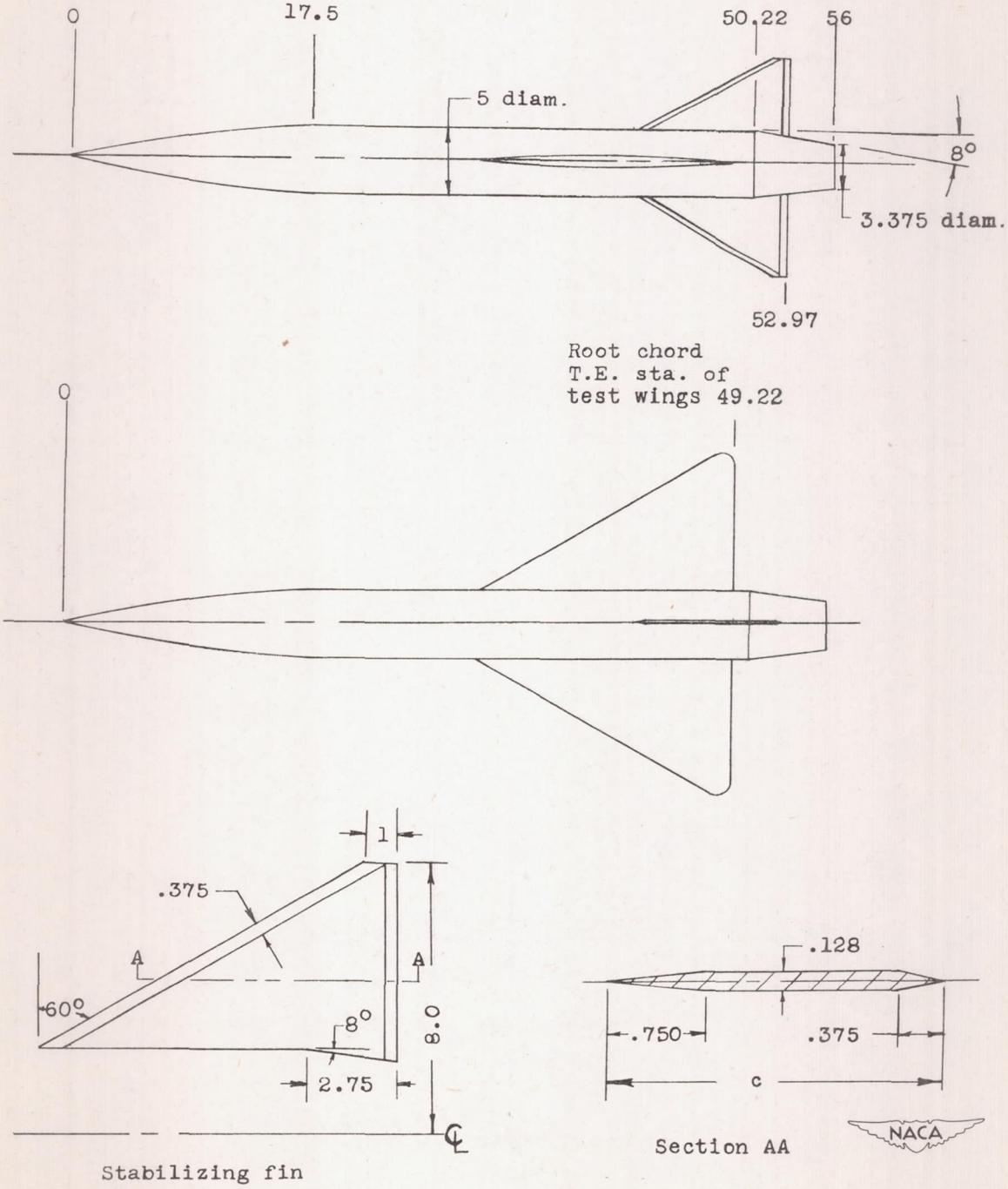
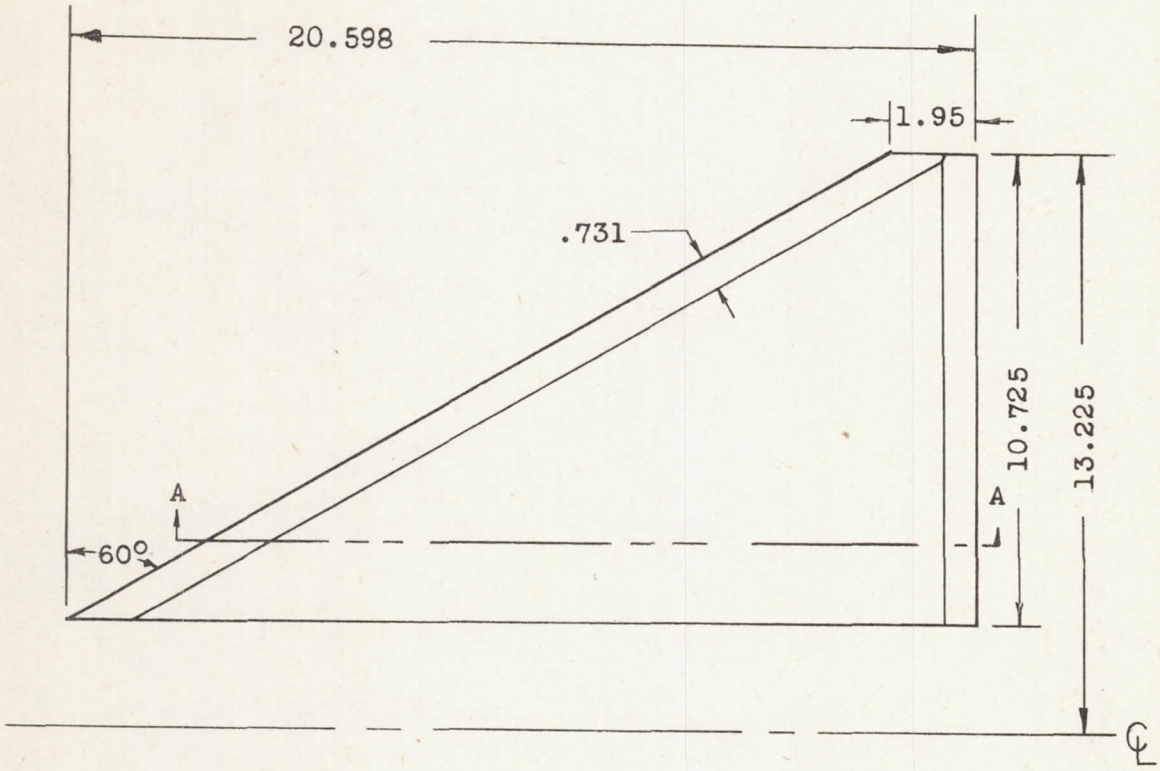
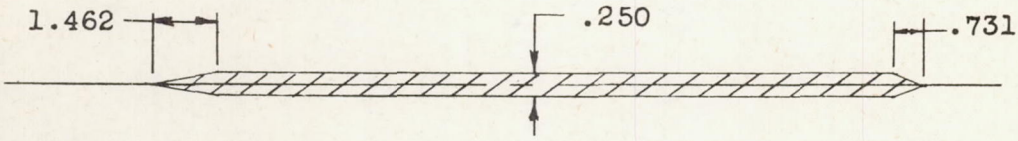


Figure 1.- General arrangement of test vehicle and test wings. All dimensions in inches.

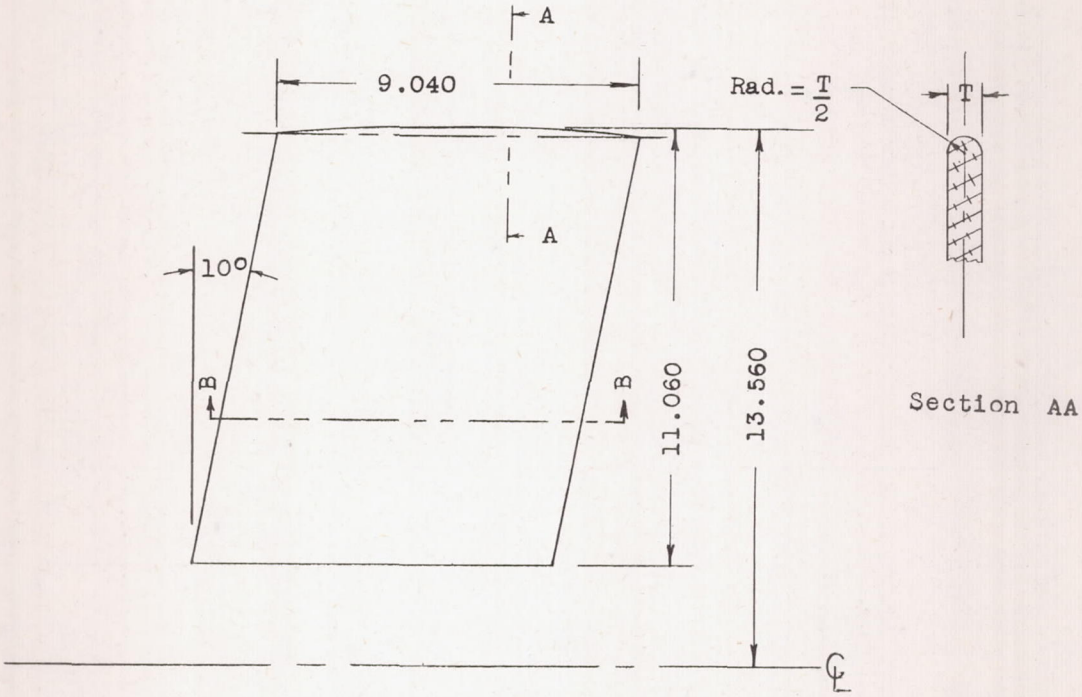


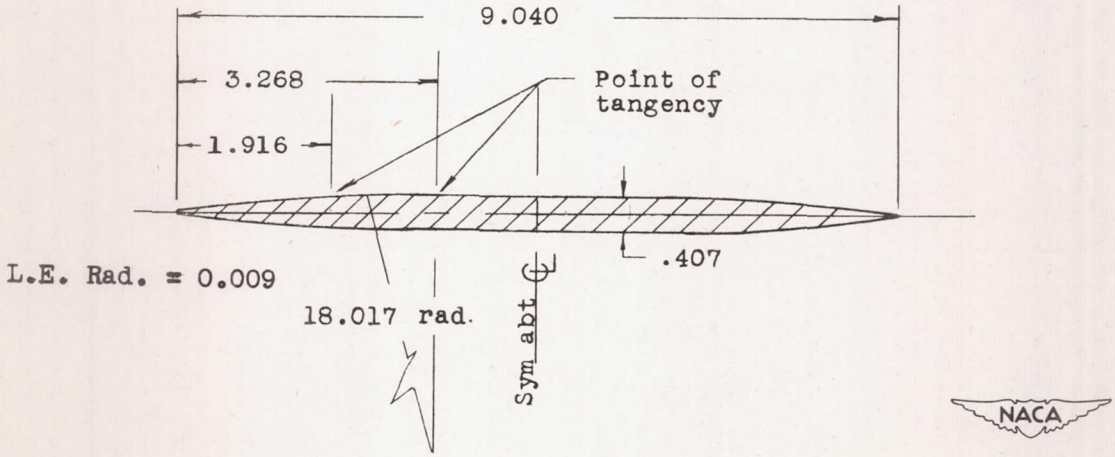


Section AA

Wing on Model 2

Figure 1.- Continued.

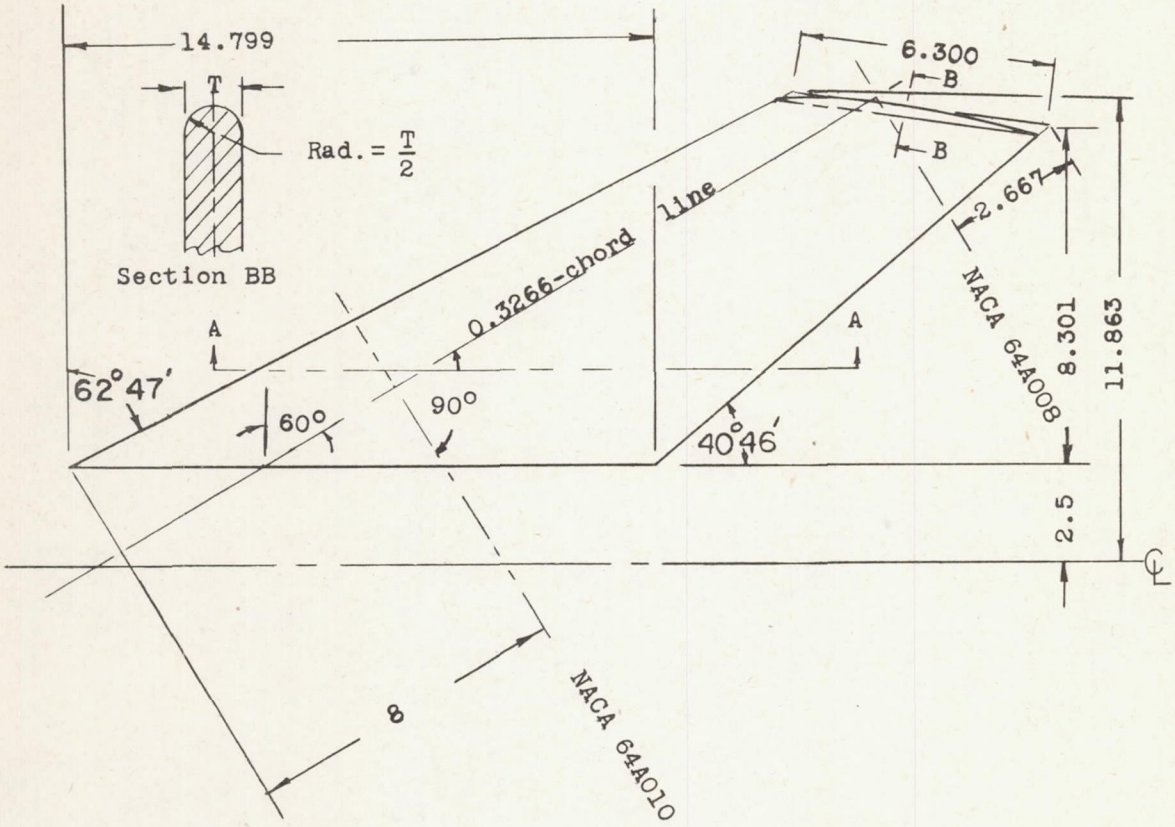


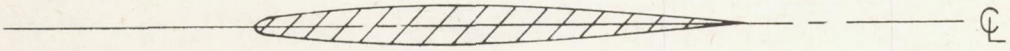


Section BB

Wing on Model 3.

Figure 1.- Continued.

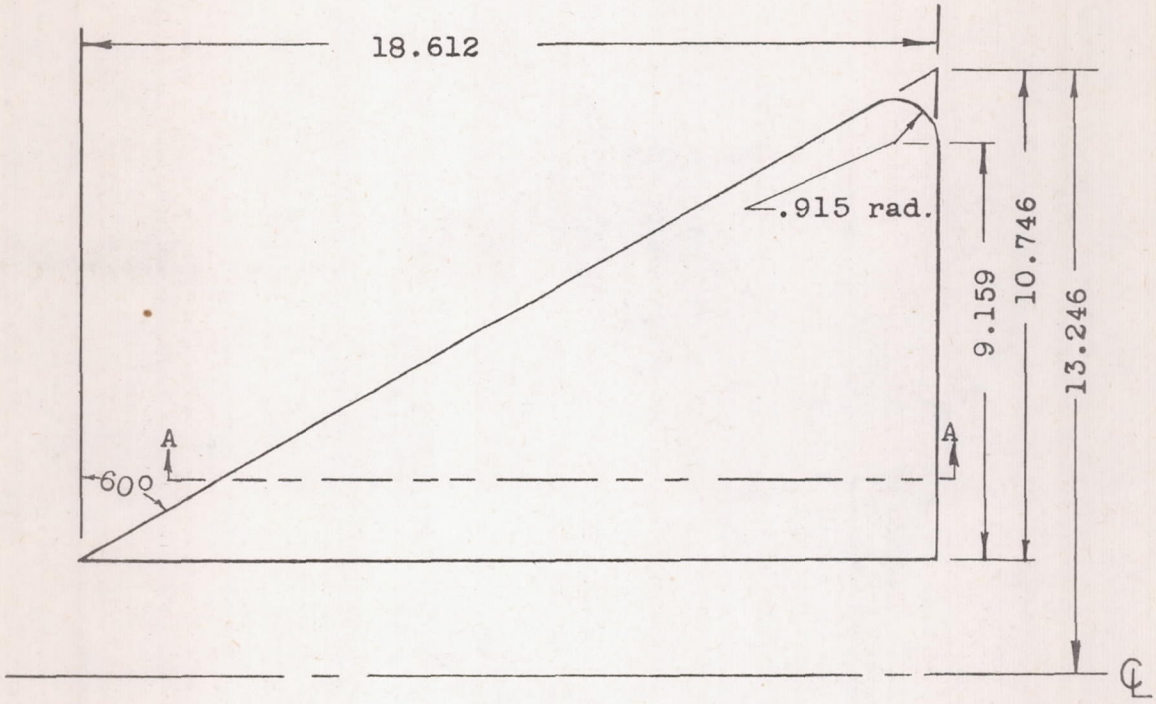


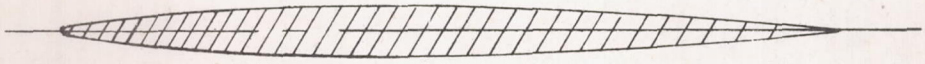


Section AA

Wing on Model 4.

Figure 1.- Continued.





Section AA NACA 65A003

Wing on Model 5.

Figure 1.- Concluded.

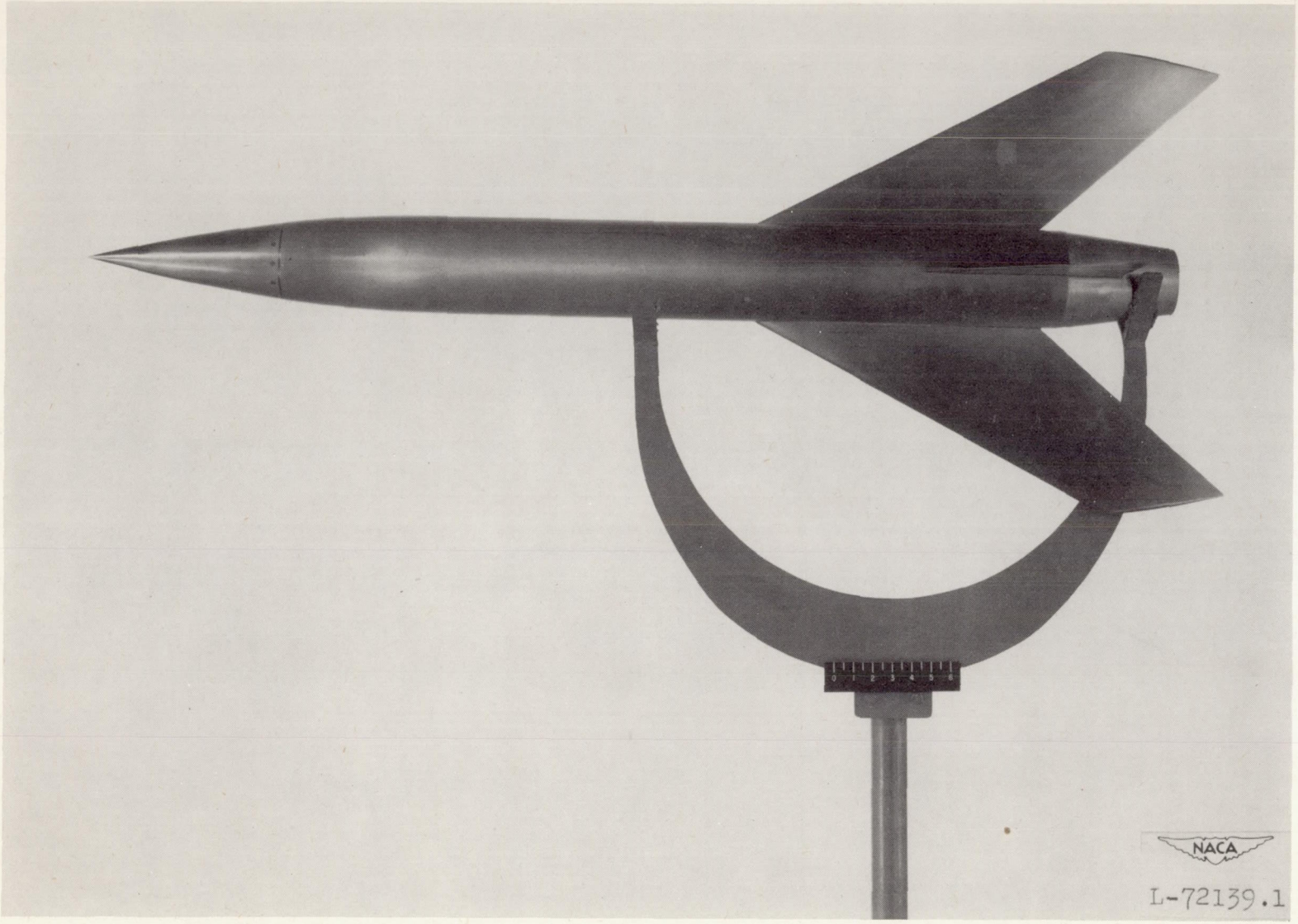


Figure 2.- Photograph of one of the test wings mounted on research body.

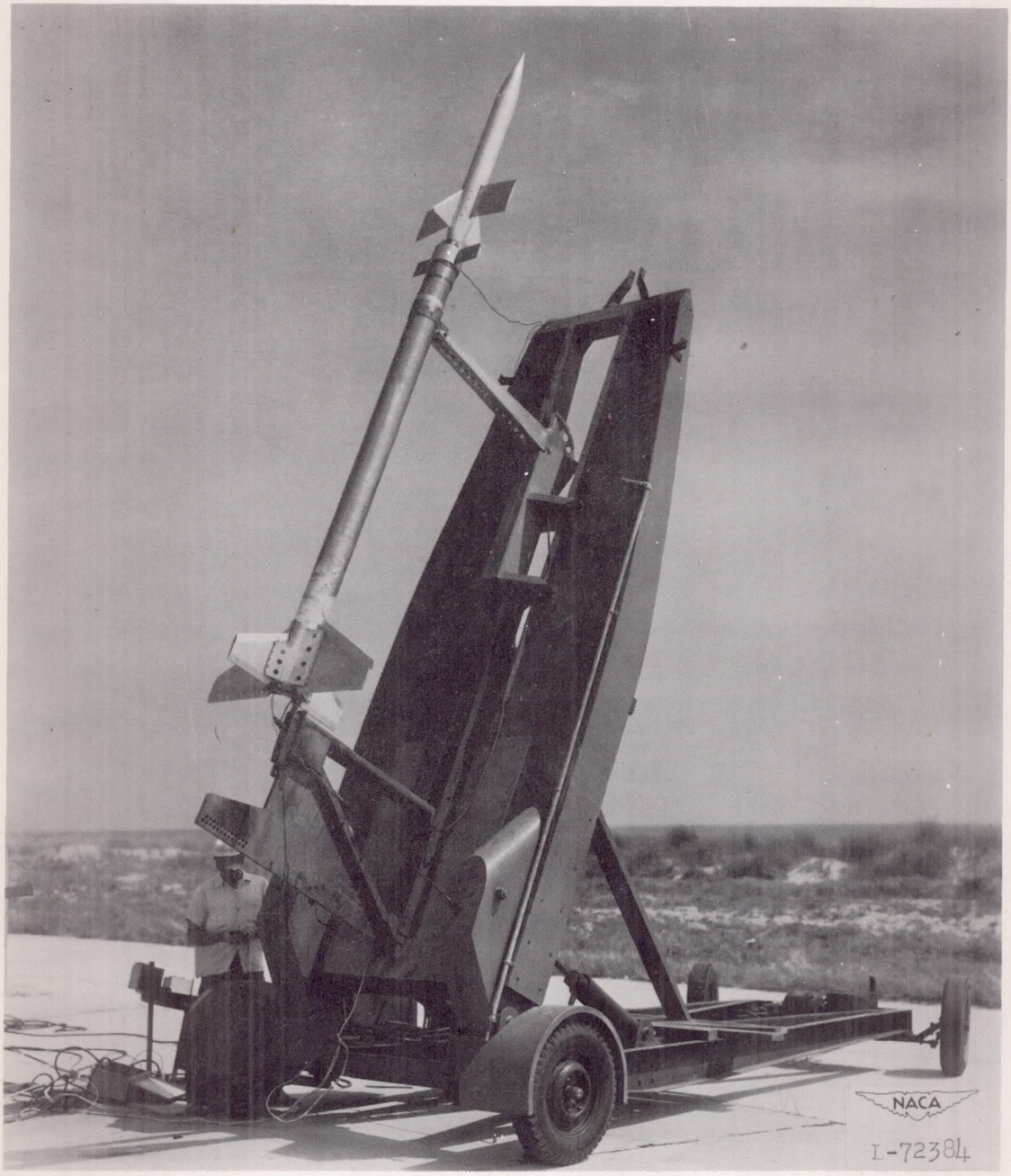


Figure 3.- Photograph showing one of the models in launching position.

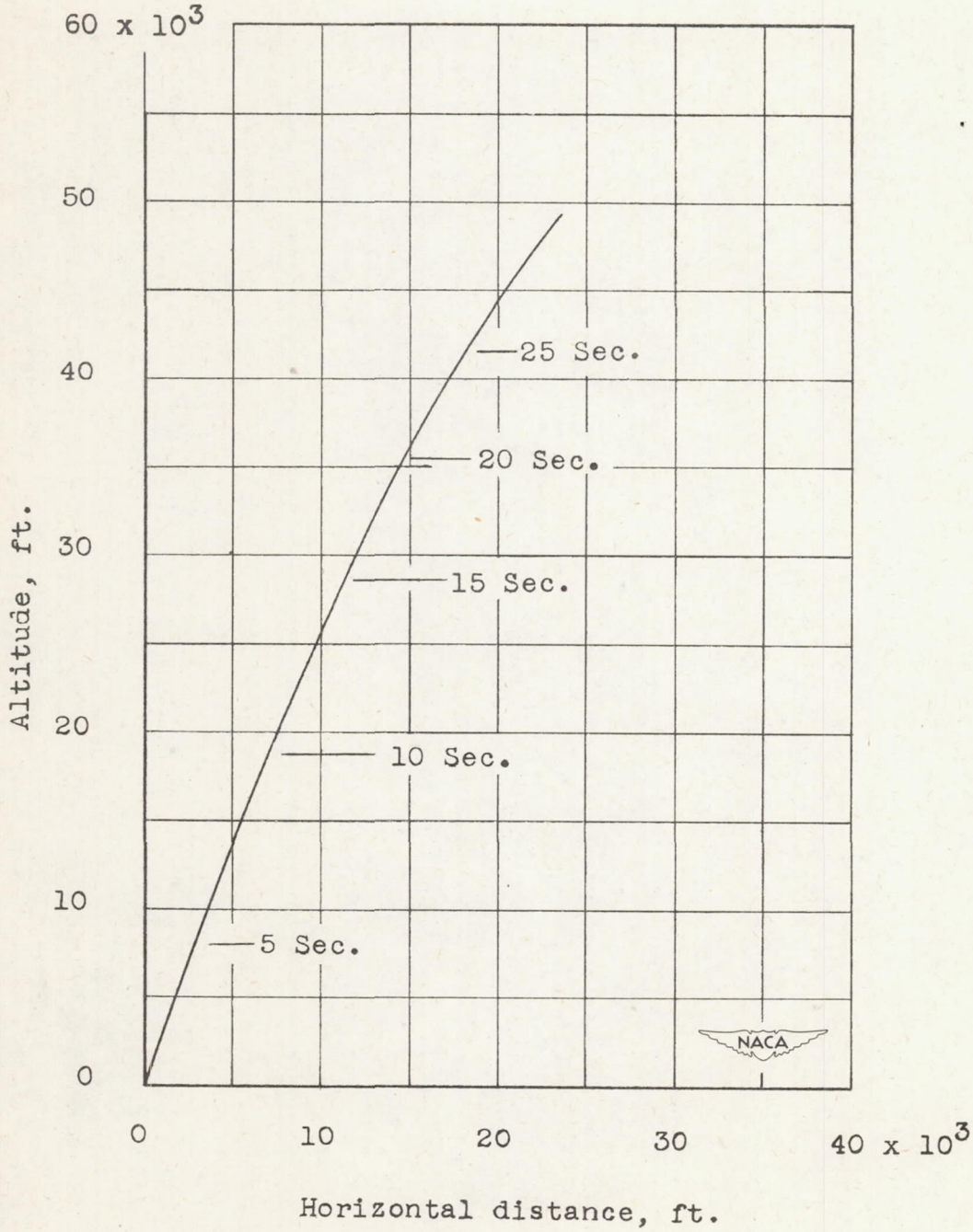


Figure 4.- Typical trajectory of test models.

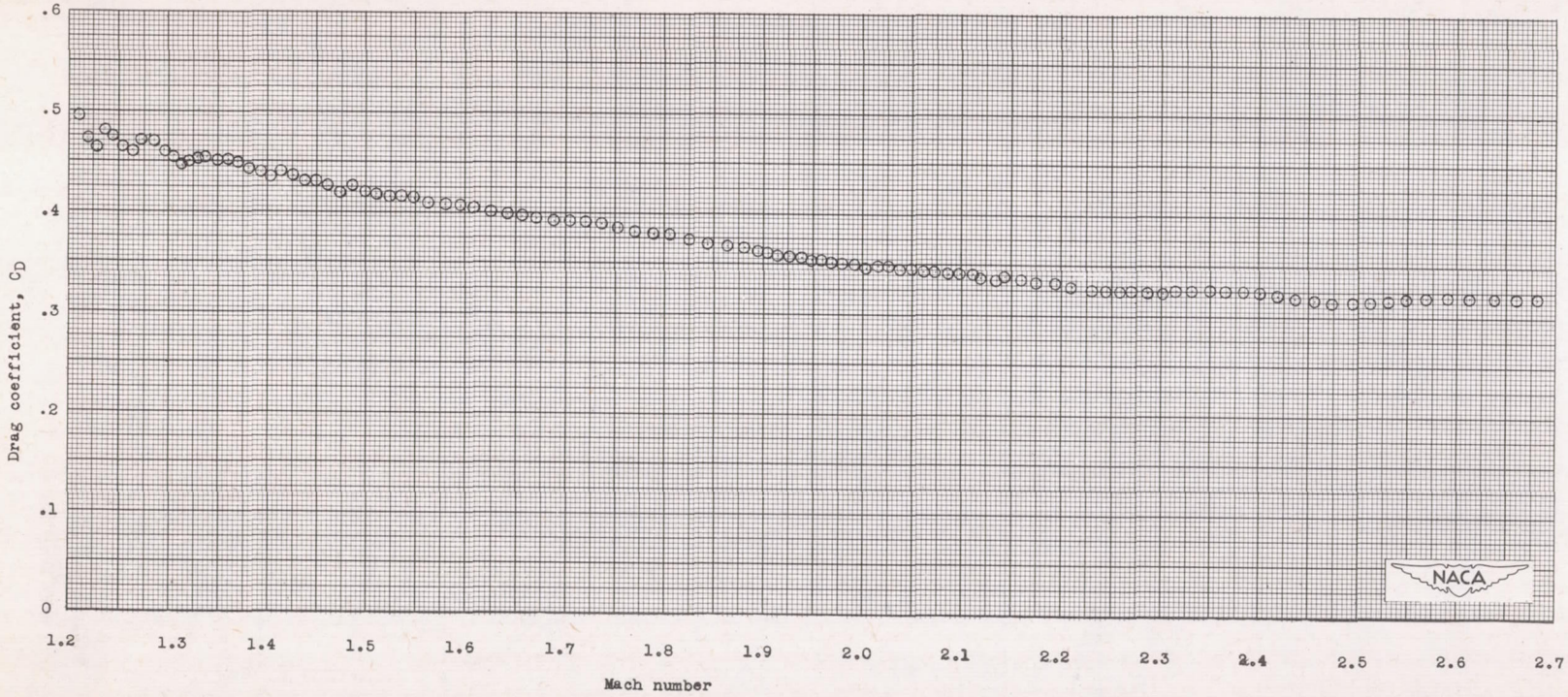


Figure 5.- Typical data plot for one of the test models. Drag coefficient C_D based on body frontal area.

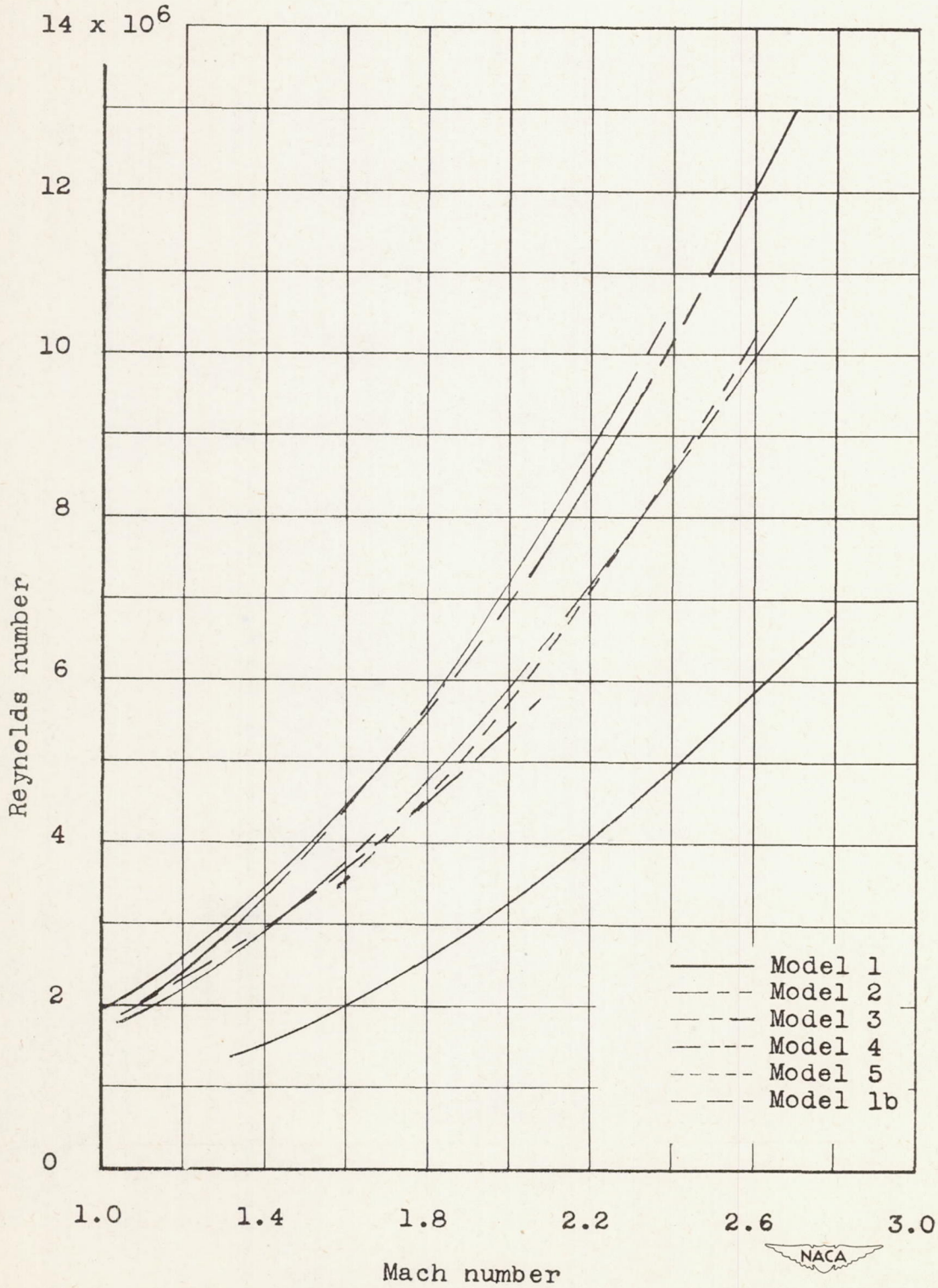
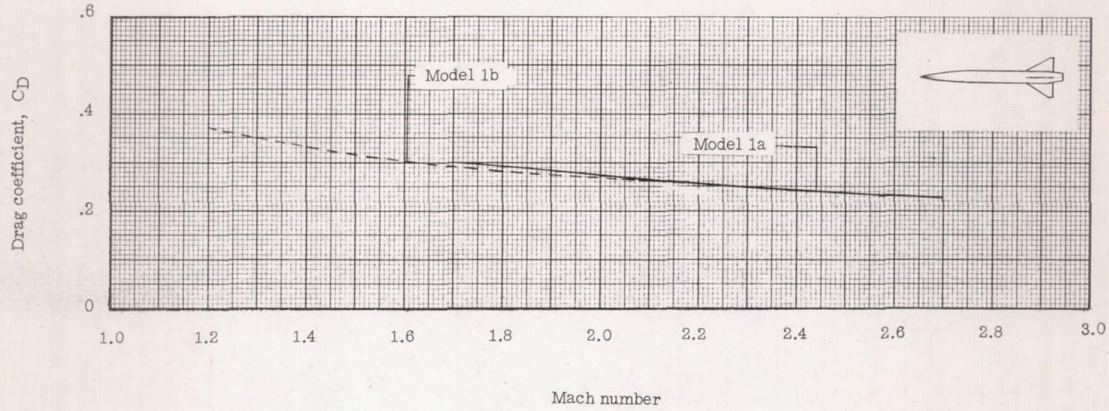
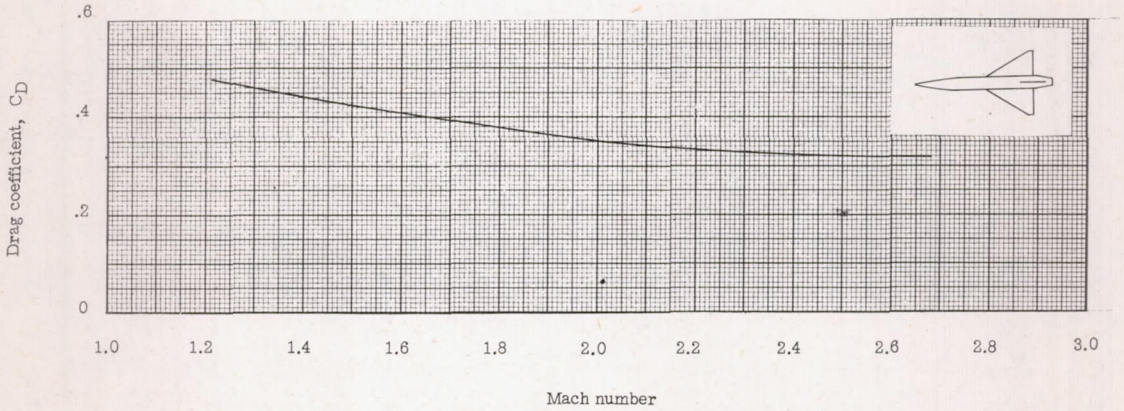


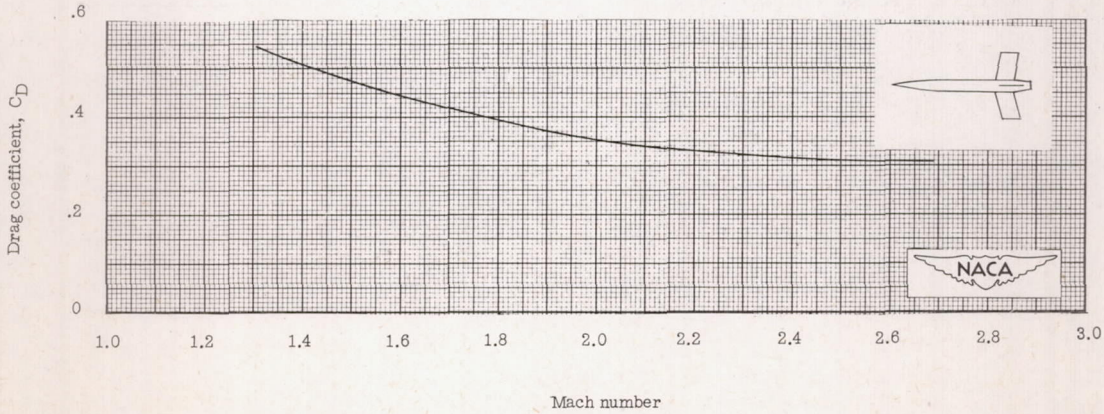
Figure 6.- Variation of Reynolds number with Mach number, based on mean aerodynamic chord of exposed wing.



(a) Model 1.

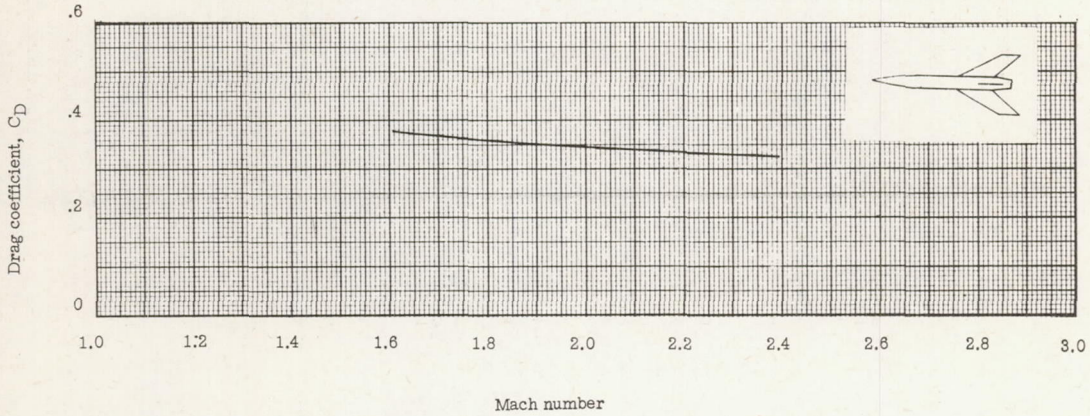


(b) Model 2.

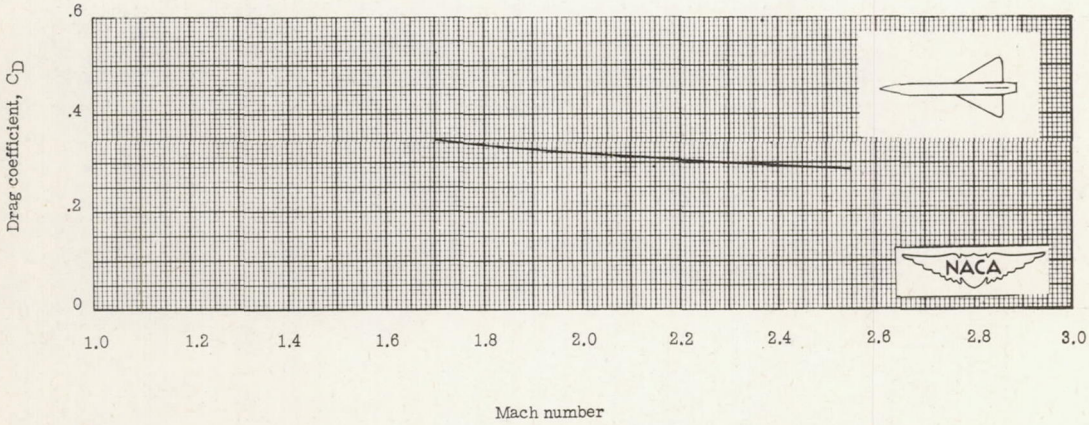


(c) Model 3.

Figure 7.- Variation of drag coefficient C_D with Mach number, based on body frontal area.



(d) Model 4.



(e) Model 5.

Figure 7.- Concluded.

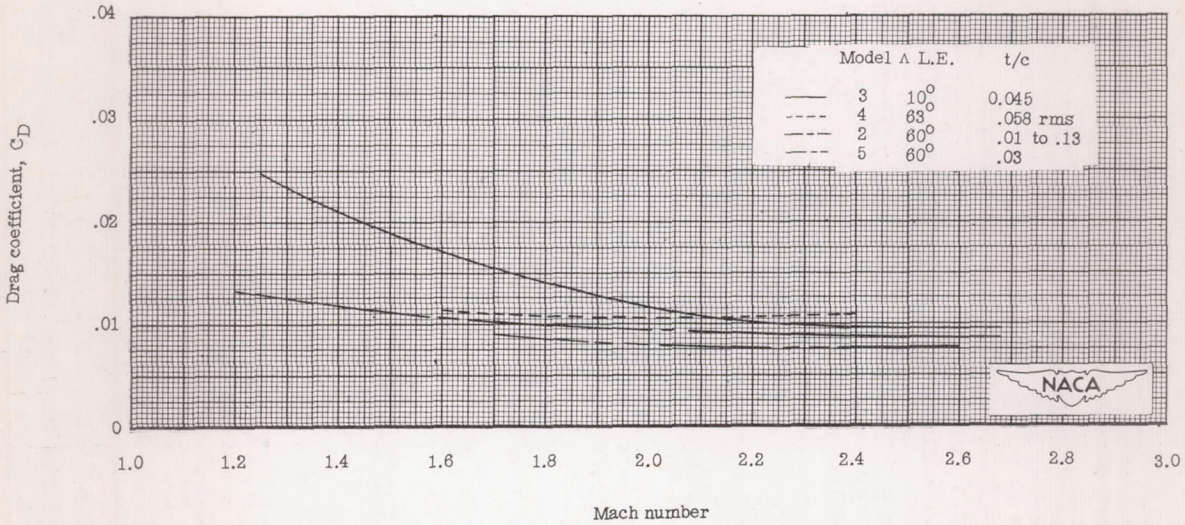


Figure 8.- Variation of wing-plus-interference drag with Mach number, based on exposed wing area.

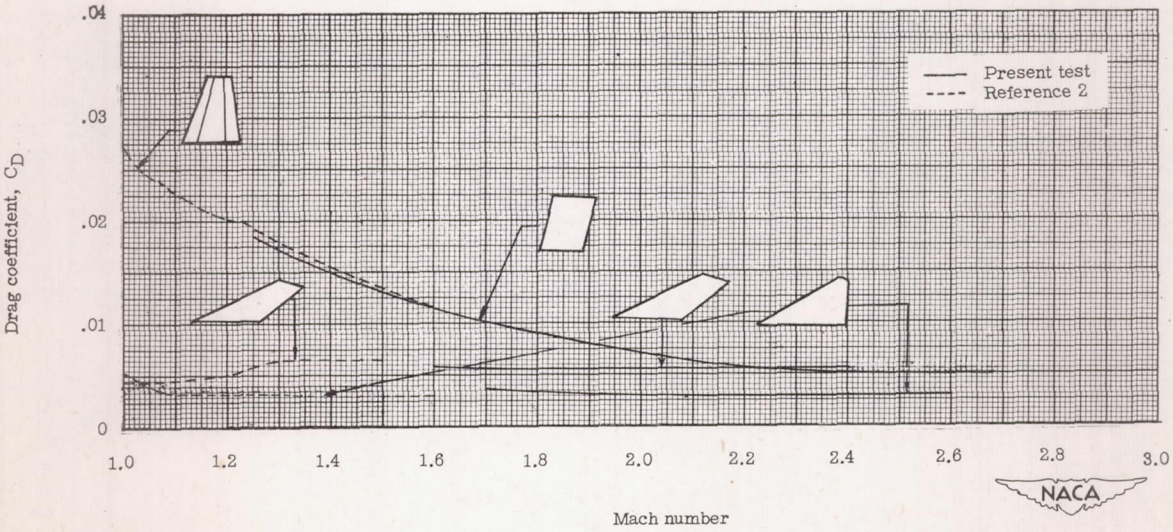


Figure 9.- Variation of wing-plus-interference drag minus estimated skin-friction drag with Mach number, based on exposed wing area.

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