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RESEARCH MEMORANDUM

PRELIMINARY FREE-FLIGHT INVESTIGATION OF THE EFFECTS OF
RIVETS AND LAP JOINTS ON THE DRAG OF BODIES AT
ZERO LIFT AT SUPERSONIC MACH NUMBERS TO 2.1

By Russell N. Hopko

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
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RESEARCH MEMORANDUM

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SUMMARY

The effects of rivets and lap joints on the drag of bodies at zero lift at supersonic Mach numbers to 2.1 have been obtained in free flight with rocket-propelled models. Four forward-facing lap joints 0.064 inch high, four similar lap joints facing rearward, and four double rows of $\frac{1}{8}$ -inch-diameter brazier head rivets were tested on a 5-inch-diameter body 56 inches long. The brazier head rivets caused the smallest drag increases while the lap joints facing forward caused the largest drag increases. At a Mach number of 2.0 the increases in drag coefficient due to the rivets and lap joints ranged from 20 to 80 percent of the estimated smooth-body skin-friction drag coefficient.

INTRODUCTION

At the present time there are little data on the additional body drag produced by surface-roughness elements at supersonic Mach numbers and large Reynolds numbers. A research program has been initiated by the Pilotless Aircraft Research Division to ascertain, experimentally, the effects of some surface irregularities on the drag of bodies at zero lift at supersonic speeds. In the investigation reported in reference 1, the effects on drag of over-all surface conditions consisting of small protuberances and depressions were obtained. The results indicated that the protuberances produced substantial drag increases but that some surface roughness produced by depressions did not increase the drag. The present investigation is concerned with the drag penalties arising from surface-roughness conditions resulting from practical manufacturing procedures. In this paper, results are presented for forward- and backward-facing lap joints and for protruding rivet heads.

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The Mach number range was from 0.9 to approximately 2.1. The corresponding range in Reynolds number, based on body length, was from 20×10^6 to 60×10^6 .

The flight tests were conducted at the Pilotless Aircraft Research Station, Wallops Island, Va. The results are presented without complete analysis in order to expedite publication and because the investigation is still in the exploratory stages.

SYMBOLS

C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
q	dynamic pressure
S	frontal area of basic body, 0.136 sq ft
l	body length
R	Reynolds number

MODELS AND TESTS

The general arrangement of the models is shown in figure 1. A photograph of the test models is shown in figure 2.

The models were constructed of aluminum alloy. The bodies were 56 inches in length with pointed ogival noses of fineness ratio 3.5 and conical afterbodies. Body coordinates for the smooth body (model 1) are shown in table I.

Surface conditions were varied at four body stations: 18.5, 29.0, 39.5, and 50.22. At these stations model 2 had four staggered double rows of $\frac{1}{8}$ -inch-diameter modified AN 456 brazier head rivets with a longitudinal spacing of $\frac{5}{8}$ inches. Each row had 16 rivets except the forward row at station 50.22 which had 12. Model 3 had 0.064-inch-high backward-facing lap joints with conical sections between the joints. Model 4 had 0.064-inch forward-facing lap joints with conical sections between the joints.

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The models were accelerated to a Mach number of approximately 2.1 by means of a two-stage propulsion system. A photograph of one of the models on the launcher is shown in figure 3.

During flight, the models were tracked with CW Doppler radar to determine the velocity and with modified SCR 584 radar to determine the flight path. A typical trajectory of the models tested is shown in figure 4. The variation of Reynolds number with Mach number is shown in figure 5. 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 2.

ACCURACY

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

M	±0.005
C _D	±0.005

Figure 6 is a data plot for one of the models tested.

RESULTS AND DISCUSSION

The variation of total drag coefficient based on the smooth-body frontal area with Mach number is given in figure 7. Also shown in figure 7 are the fin drag coefficients obtained from reference 3 and the smooth-body skin-friction coefficients estimated from reference 4. Each of the surface irregularities investigated increased the drag coefficients over those of the smooth-body-fin configuration. The additional drag is due to the pressure drag of the roughness element and the change in the surface-friction drag of the body. The rivets caused the smallest drag increase while the forward-facing lap joints caused the largest drag increase. The percentage increase in drag, due to the irregularities, decreased as the Mach number was increased. At a Mach number of 2.0 the increase, due to the surface irregularities, ranged

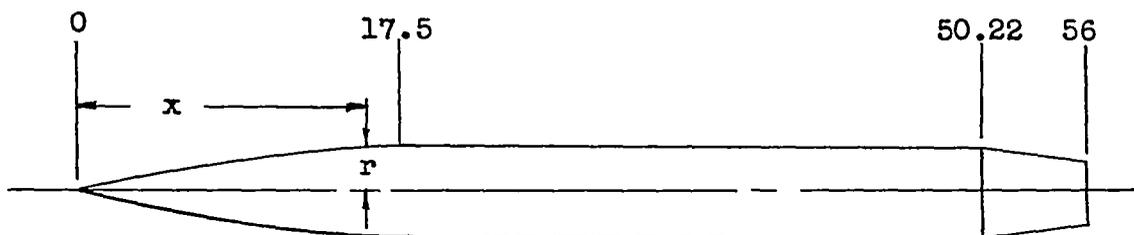
from approximately 20 percent to 80 percent of the estimated smooth-body skin-friction drag coefficient.

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National Advisory Committee for Aeronautics
Langley Field, Va.

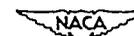
REFERENCES

1. Jackson, H. Herbert: Flight Measurements of the Effects of Surface Condition on the Supersonic Drag of Fin-Stabilized Parabolic Bodies of Revolution. NACA RM L52B26, 1952.
2. 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.
3. Hopko, Russell N., and Sandahl, Carl A.: Free Flight Investigation of the Zero-Lift Drag of Several Wings at Supersonic Mach Numbers Extending to 2.6. NACA RM L52D29, 1952.
4. 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 MODEL 1



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



Body coordinates in inches.

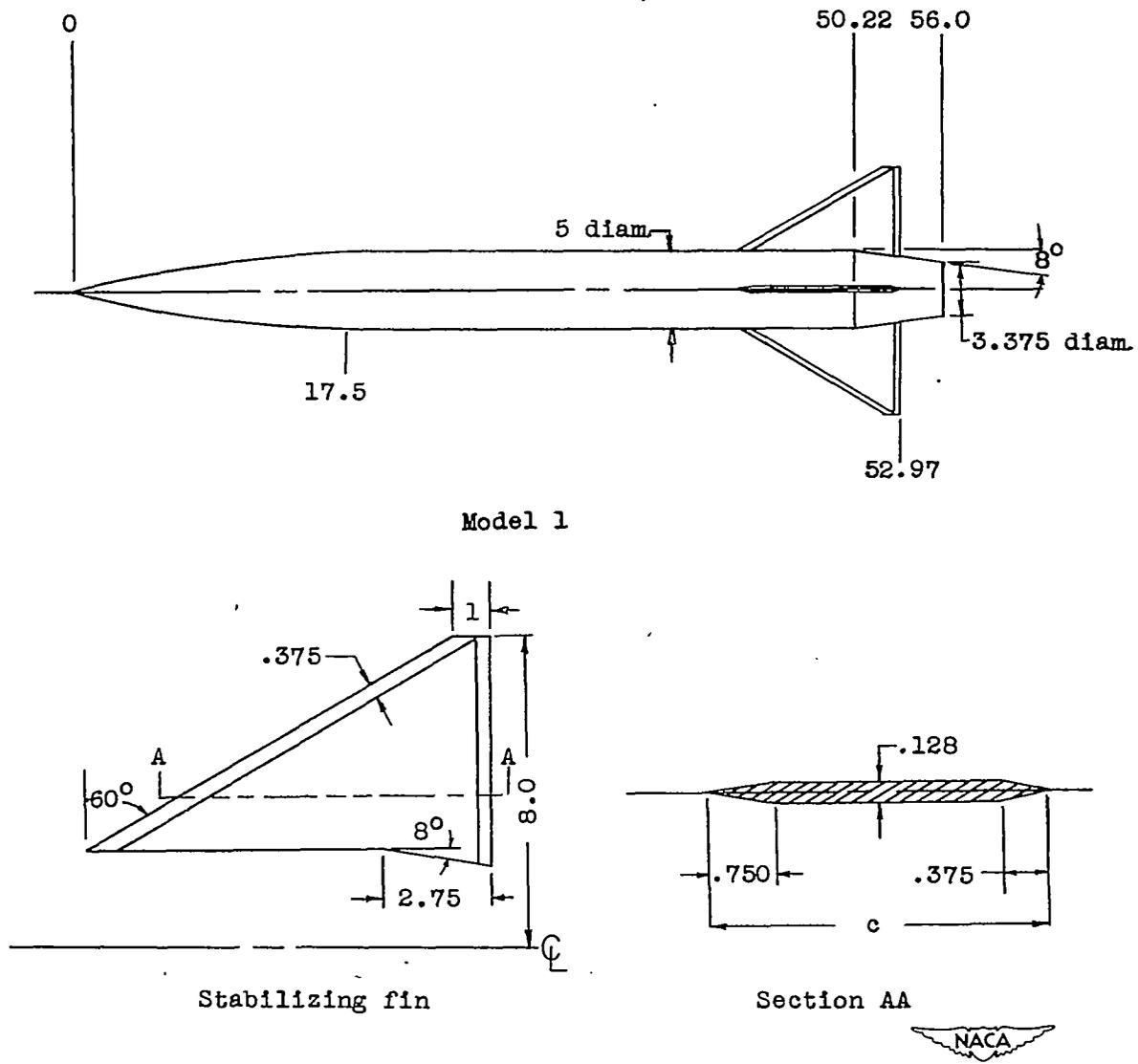
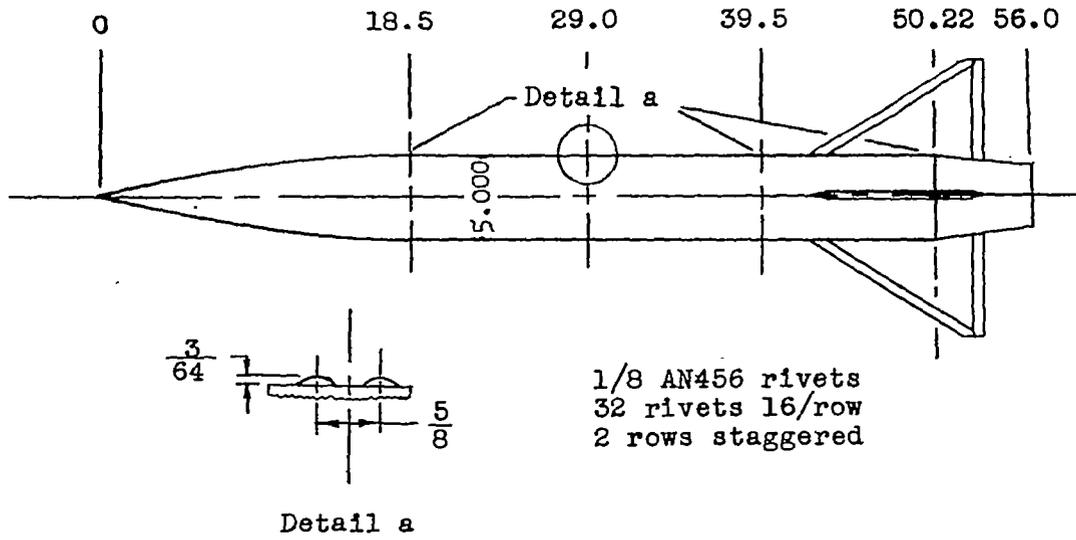
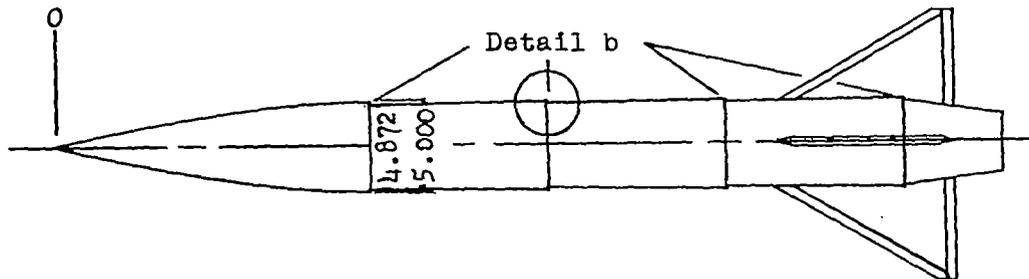


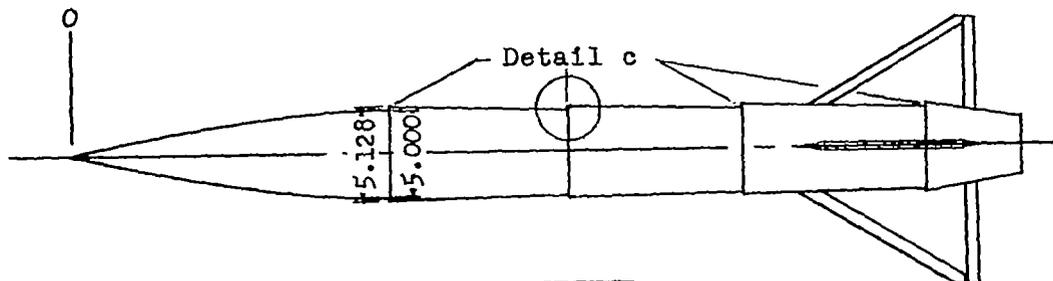
Figure 1.- General arrangement of test vehicle. All dimensions in inches.



Model 2



Detail b 0.064 lap joint
Model 3



Detail c 0.064 lap joint
Model 4

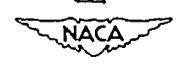


Figure 1.- Concluded.

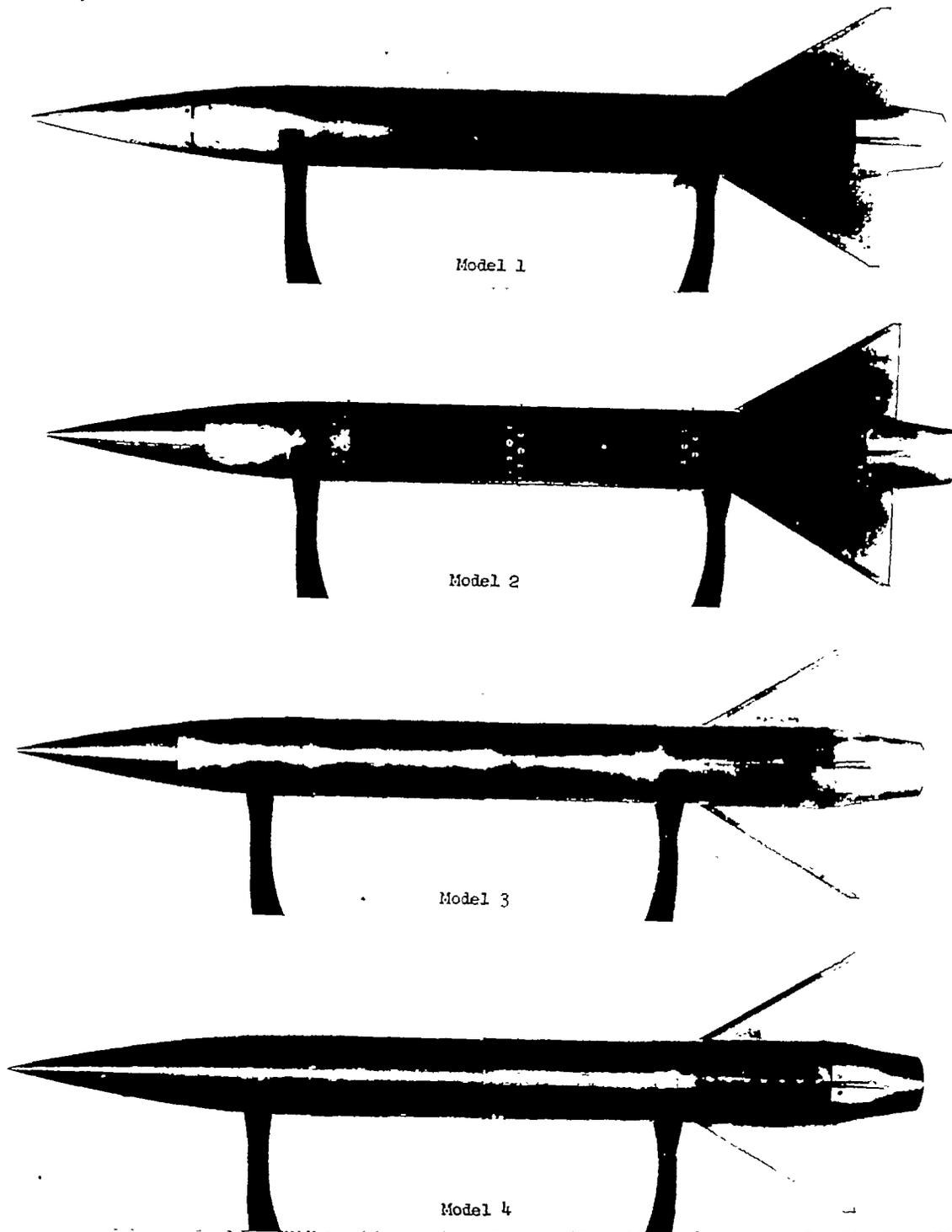


Figure 2.- Photograph of the test models.

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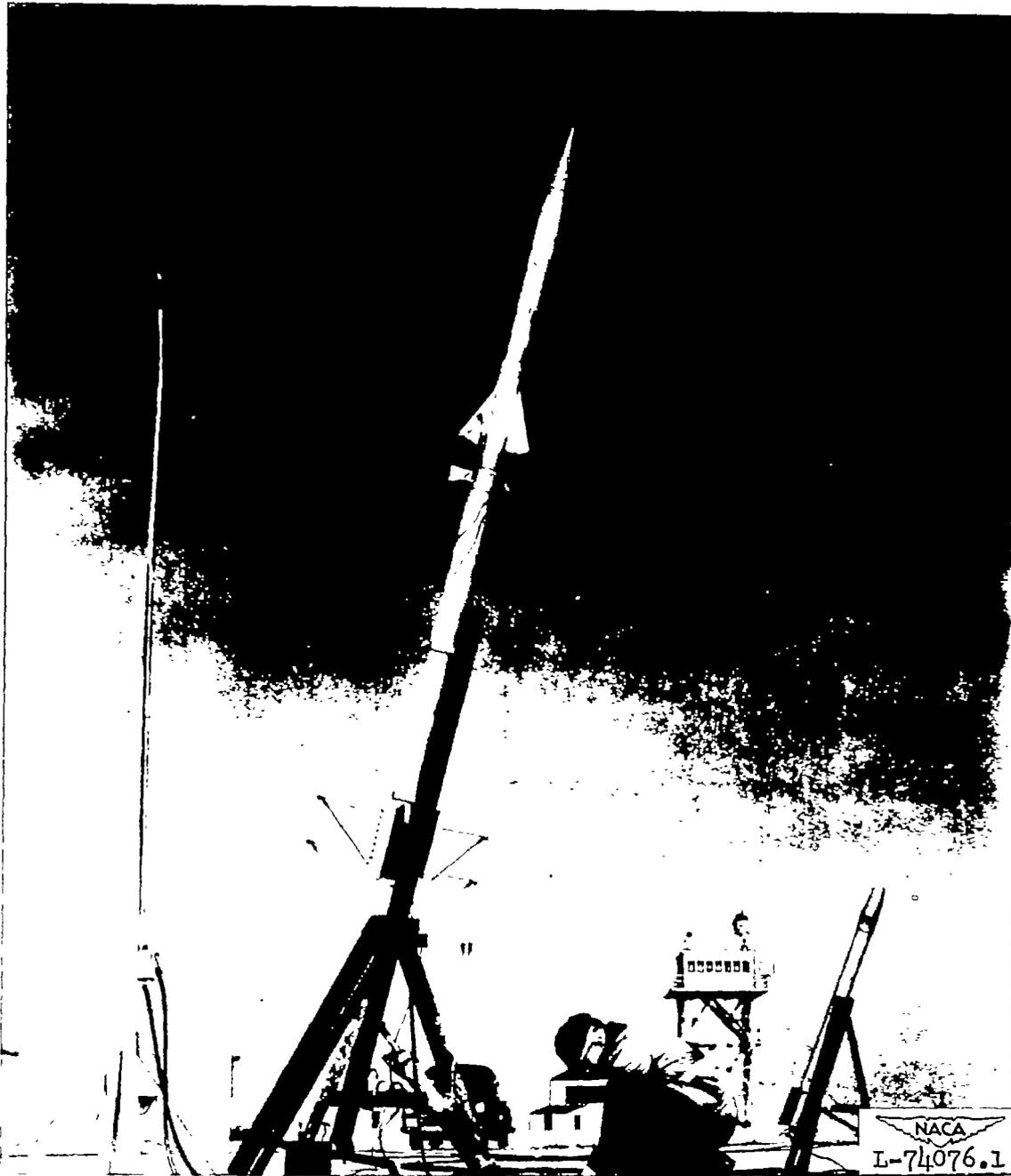


Figure 3.- One of the models in launching position.

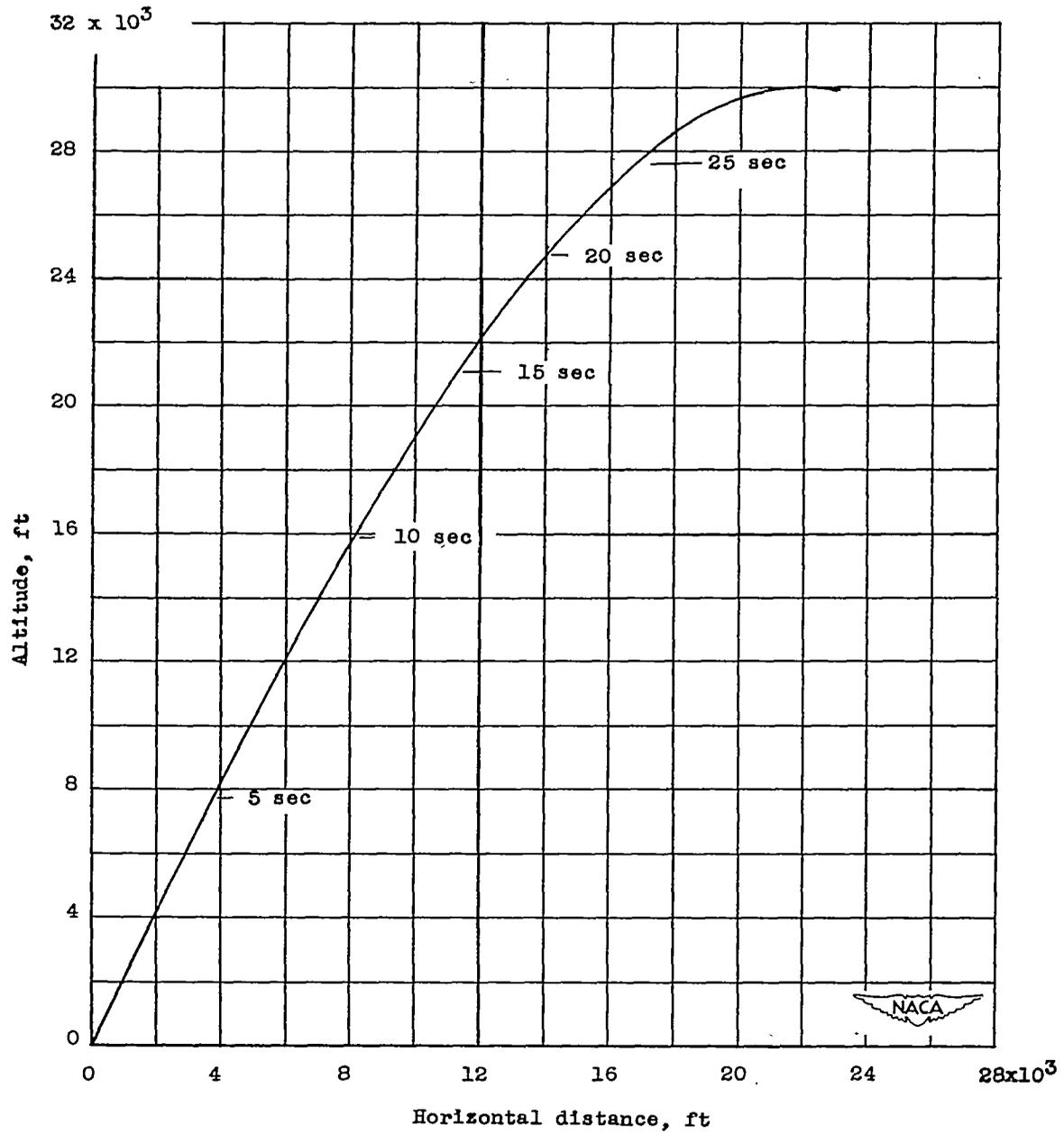


Figure 4.- Typical flight path of test models.

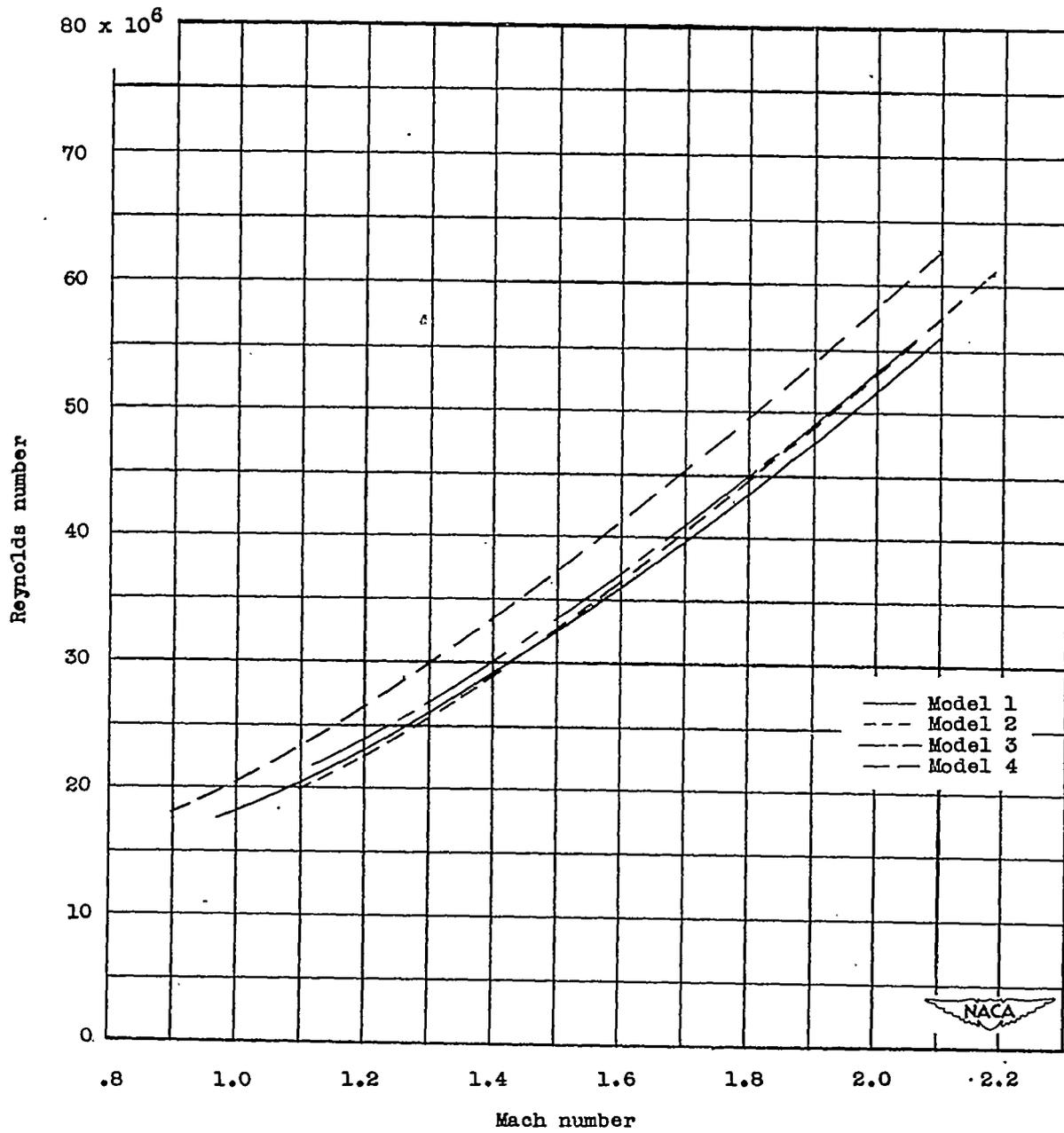


Figure 5.- Variation of Reynolds number with Mach number based on body length.

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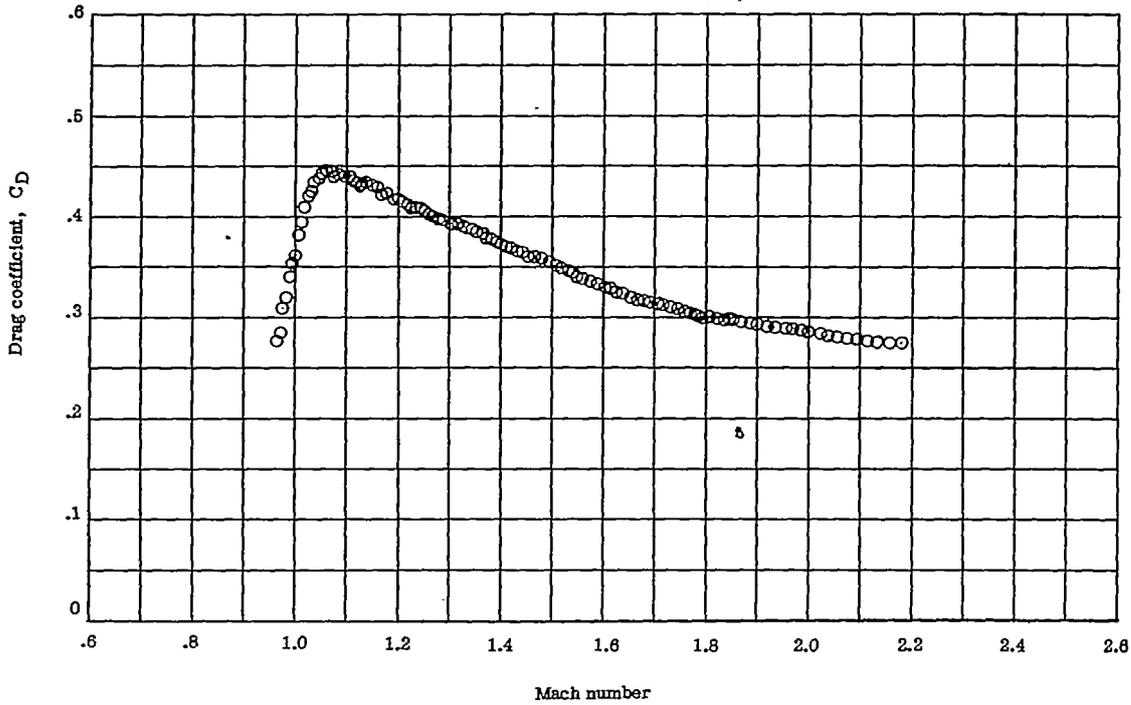


Figure 6.- Typical data plot for one of the test models.

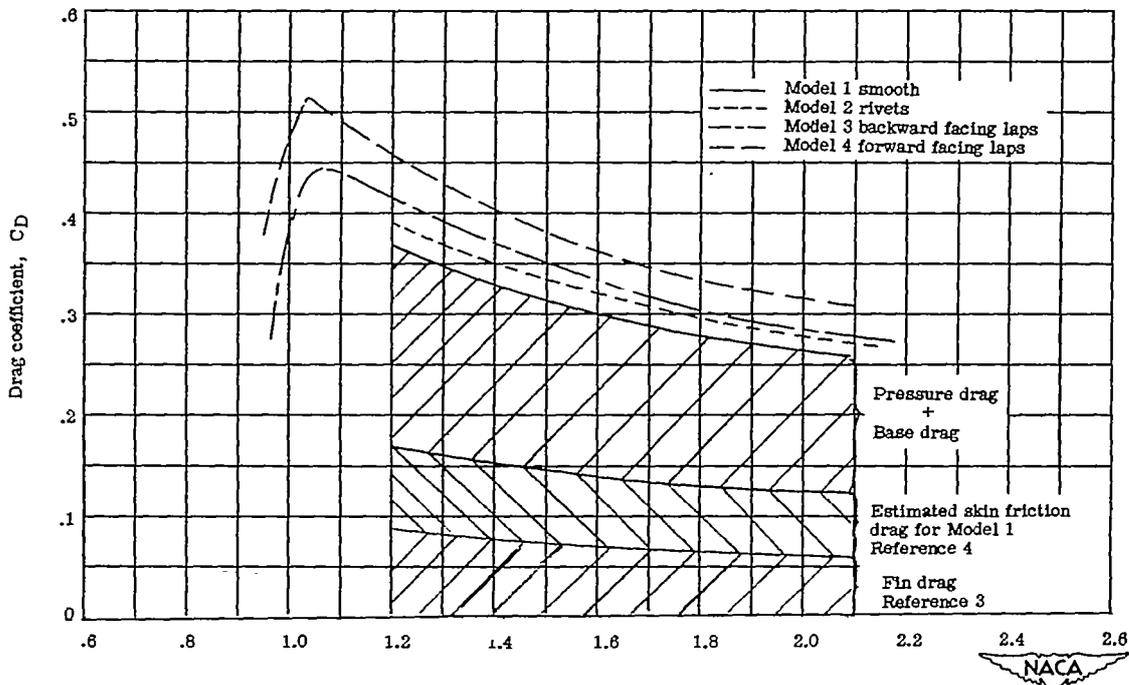


Figure 7.- Variation of drag coefficient C_D with Mach number based on body frontal area.

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