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RESEARCH MEMORANDUM

COMPARISON OF ZERO-LIFT DRAGS DETERMINED BY FLIGHT TESTS AT TRANSONIC SPEEDS OF SYMMETRICALLY MOUNTED NACELLES IN VARIOUS CHORDWISE POSITIONS AT THE WING TIP OF A 45° SWEPTBACK WING AND BODY COMBINATION

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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COMPARISON OF ZERO-LIFT DRAGS DETERMINED BY FLIGHT TESTS AT TRANSONIC SPEEDS OF SYMMETRICALLY MOUNTED NACELLES IN VARIOUS CHORDWISE POSITIONS AT THE WING TIP OF A 45° SWEPTBACK WING AND BODY COMBINATION

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SUMMARY

The effect on drag of varying the chordwise position of a nacelle at the wing tip of a 45° sweptback wing and body combination has been determined through transonic flight tests at zero lift. The wing had a sweepback angle of 45° along the quarter-chord line, an aspect ratio of 6.0, a taper ratio of 0.6, and an NACA 65A009 airfoil section in the free-stream direction. The nacelle and fuselage fineness ratios were 9.66 and 10.0, respectively.

The drag of the configuration with nacelles located in the rear chordwise positions was either equal to or less than the drag of the configuration without nacelles over most of the speed range. The drag of the configuration with nacelles located in the forward chordwise position was about the same as that of the basic configuration up to a Mach number of 1.1. The lowest nacelle drag was obtained from the nacelle mounted in the rear chordwise position at Mach numbers from 0.99 to 1.20. The force-break Mach numbers of the models with nacelles were approximately equal to the force-break Mach number of 0.96 for the basic configuration.

INTRODUCTION

As part of a general transonic research program of the National Advisory Committee for Aeronautics to investigate the aerodynamic

properties of promising aircraft configurations, the Langley Pilotless Aircraft Research Division (at its testing station at Wallops Island, Va.), has tested a number of rocket-propelled free-flight models to determine the variations of zero-lift drag coefficient with Mach number for a high-aspect-ratio wing and body configuration with solid nacelles at various positions on the wing.

Reference 1 shows the effect on drag of varying the chordwise position of a nacelle located at 40 percent of the wing semispan; reference 2 shows the effect on drag of varying the spanwise location of the nacelle; and, reference 3 shows the effect on drag of varying the vertical position of the nacelle at 40 percent of the semispan. Because of the low drag obtained when nacelles were located at the wing tip (reference 2), especially near a Mach number of 1.0, the wing-tip nacelle location was selected for further investigation. The present investigation gives a comparison of the drags at zero lift obtained for three chordwise nacelle positions at the wing tip.

The wing-body configuration (basic configuration) and the nacelles were similar to that used in the previous tests (references 1, 2, and 3). The wing had a sweepback angle of 45° along the quarter-chord line, an aspect ratio of 6.0, a taper ratio of 0.6, and an NACA 65A009 airfoil section in the free-stream direction. The fuselage and nacelle fineness ratios were 10.0 and 9.66, respectively.

The nacelles were proportioned to house an axial-flow turbojet engine with an afterburner. The basic lines of the nacelle nose were designed to accommodate NACA 1-series inlets with critical Mach numbers above $M = 0.90$.

The tests were conducted without air flow through the nacelles to simplify the investigation. It was anticipated that, with the introduction of internal air flow, the resulting variations of drag with ducted-nacelle location would be similar to the variations found for solid nacelles.

Tests covered a continuous Mach number range from 0.80 to 1.25. The Reynolds number, based on the wing mean aerodynamic chord, varied from 3.8×10^{6} to 7.3×10^{6}.

SYMBOLS

a	longitudinal acceleration, feet per second per second
C_D	total drag coefficient, based on S_W
C_{D_N}	drag coefficient for nacelle plus interference, based on S_F
c	wing chord at 96 percent of the semispan, inches
e	distance between nacelle inlet and wing leading edge, inches
g	acceleration due to gravity, 32.2 feet per second per second
M	Mach number
q	free-stream dynamic pressure, pounds per square foot
R	Reynolds number, based on wing mean aerodynamic chord
S_F	frontal area of one nacelle, square feet
S_W	total wing plan-form area, square feet
W	model weight during deceleration, pounds
γ	angle between flight path and horizontal, degrees
x	station, inches
y	ordinate, inches

MODELS

The models used for this investigation were the same as those in references 1, 2, and 3, except for the location of the nacelles. Details and dimensions of the wing-body-fin combination, the nacelles, and the nacelle positions are given in figures 1 and 2. Photographs showing the general arrangements of the models flown are presented as figure 3.

The wing had a sweepback angle of 45° along the quarter-chord line, an aspect ratio of 6.0 (based on total wing plan-form area), a taper ratio of 0.6, and an NACA 65A009 airfoil section in the

free-stream direction. The wing leading edge intersected the maximum diameter of the fuselage. The fuselage fineness ratio was 10.0. The ratio of total wing plan-form area to fuselage frontal area was 16.0.

Each nacelle was a solid body of revolution having an NACA 1-50-250 nose-inlet profile, a cylindrical midsection, and an afterbody of NACA 111 proportions. The nacelle inlet was faired to a point making the nacelle solid. The fineness ratio of the solid nacelle was 9.66.

The center lines of the nacelles were located in the wing plane parallel to the free-stream direction at 96 percent of the semispan in order to make the outer portion of the nacelle flush with the wing tip. The chordwise nacelle location, measured with respect to the distance e between the nacelle inlet and the wing leading edge, was varied for the tests (fig. 2). The chordwise positions expressed in percent of the wing chord c at 96 percent of the semispan were 123, 82, and 48 percent.

TESTS AND MEASUREMENTS

Three rocket-propelled zero-lift models were tested at the Langley Pilotless Aircraft Research Station, Wallops Island, Va. Velocity and trajectory data were obtained from the CW Doppler velocimeter and the NACA modified SCR-584 tracking unit. A survey of atmospheric conditions for each test was made through radiosonde measurements from an ascending balloon.

The values of total drag coefficient, based on total wing plan-form area, were calculated for decelerating flight (reference 1) with the formula

$$C_D = -\frac{W}{qgS_W}(a + g \sin \gamma)$$

The variations of nacelle-plus-interference drag coefficient with Mach number were obtained from the difference in drag coefficient of faired C_D curves of a model without nacelles and a model with nacelles. This coefficient, based on nacelle frontal area, is

$$C_{D_N} = \left(C_{D_{\text{nacelles on}}} - C_{D_{\text{nacelles off}}}\right)\frac{S_W}{2S_F}$$

The magnitude of the error in drag was established by testing three identical models without nacelles in reference 1 and was based on the maximum deviation found between C_D curves faired through experimental points. The error in total drag coefficient was within ±0.0004. The error in nacelle-plus-interference drag coefficient was within ±0.046 at subsonic and supersonic speeds and about ±0.1 near $M = 1.0$. The accuracy of the flight Mach number was estimated to be within ±0.005.

Flight tests of the models covered a Reynolds number range from 3.8×10^6 at $M = 0.80$ to 7.3×10^6 at $M = 1.25$ as shown on figure 4.

RESULTS AND DISCUSSION

Faired curves showing the variations of total drag coefficient with Mach number for the models tested are presented in figure 5 and are summarized in figure 6. A comparison of the C_D curves for the models shows that the drag of the configuration with nacelles at the 82- and 48-percent-chordwise positions was either equal to or less than the drag of the wing-body configuration near a Mach number 1.0. The drag of the model with nacelles at the 123-percent station was approximately the same as that of the configuration without nacelles up to $M = 1.1$. In regard to the effect of chordwise nacelle location on drag, the model with nacelles located in the rear chordwise position at the wing tip had less drag than each of the other models with nacelles between $M = 0.99$ to $M = 1.2$.

In general, the variation of drag with chordwise nacelle location at the wing tip was similar to that given in reference 1 for the chordwise nacelle locations at 40 percent semispan. Although the nacelle-plus-interference drags referred to in reference 1 were higher than those of this investigation, especially near $M = 1$, the rear nacelle positions on the wing chord also had less drag than the forward nacelle positions.

The force-break Mach numbers of the models with nacelles were approximately equal to the force-break Mach number of 0.96 of the basic configuration without nacelles.

The variations of C_{D_N} with Mach number are shown in figure 5 and are summarized in figure 6. The nacelle-plus-interference drag coefficients are compared with the drag coefficient of an isolated nacelle, which was estimated in reference 1. A comparison between the estimated isolated nacelle drag and the measured nacelle drag is indicative of the interference drag.

From a comparison of the C_{D_N} with M curves, it is evident that the low nacelle drags were due to the favorable interference that was present over the entire Mach number test range. The negative values of C_{D_N} indicate that the nacelle arrangements used herein may have improved the flow over the wing to give low drag.

CONCLUSIONS

The effect on drag of varying the chordwise location of a nacelle at the wing tip of a 45° sweptback wing and body combination has been determined through transonic flight tests at zero lift. The following effects were noted:

1. The drag of the configuration with nacelles located in the rear chordwise positions was either equal to or less than the drag of the configuration without nacelles over most of the speed range. The drag of the configuration with nacelles located in the forward chordwise position was about the same as that of the basic configuration up to a Mach number of 1.1.

2. The lowest nacelle drag was obtained from the nacelle mounted in the rear chordwise position at Mach numbers from 0.99 to 1.20. Low nacelle drags that were due to favorable interference occurred over the speed range for all the nacelle positions tested.

3. The force-break Mach numbers of the models with nacelles were approximately equal to the force-break Mach number of 0.96 of the basic configuration.

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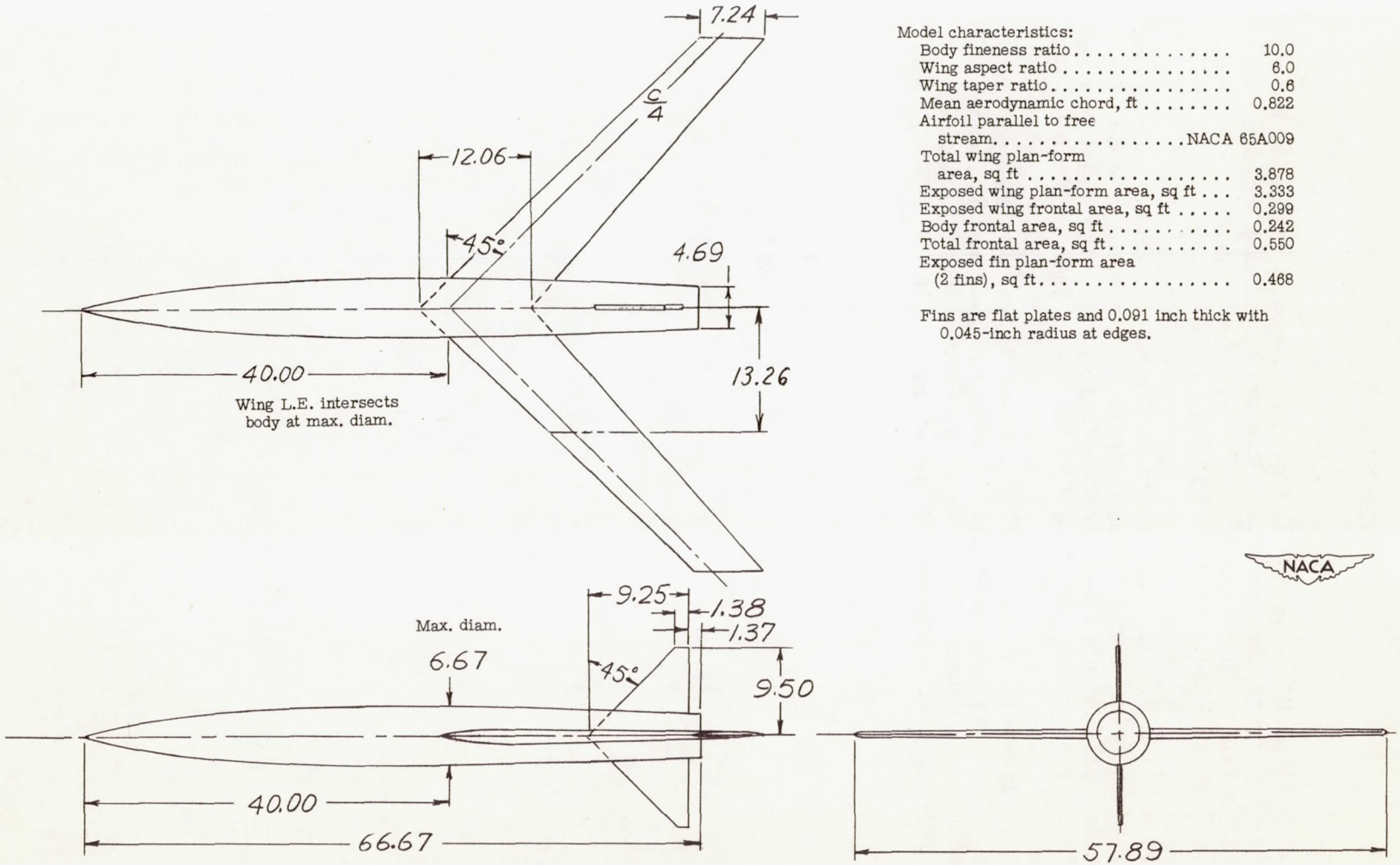
REFERENCES

1. Pepper, William B., Jr., and Hoffman, Sherwood: Transonic Flight Tests to Compare the Zero-Lift Drag of Underslung and Symmetrical Nacelles Varied Chordwise at 40 Percent Semispan of a 45° Sweptback, Tapered Wing. NACA RM L50G17a, 1950.

2. Pepper, William B., Jr., and Hoffman, Sherwood: Comparison of Zero-Lift Drags Determined by Flight Tests at Transonic Speeds of Symmetrically Mounted Nacelles in Various Spanwise Positions on a 45° Sweptback Wing and Body Combination. NACA RM L51D06, 1951.

3. Hoffman, Sherwood: Comparison of Zero-Lift Drag Determined by Flight Tests at Transonic Speeds of Pylon, Underslung, and Symmetrically Mounted Nacelles at 40 Percent Semispan of a 45° Sweptback Wing and Body Combination. NACA RM L51D26, 1951.

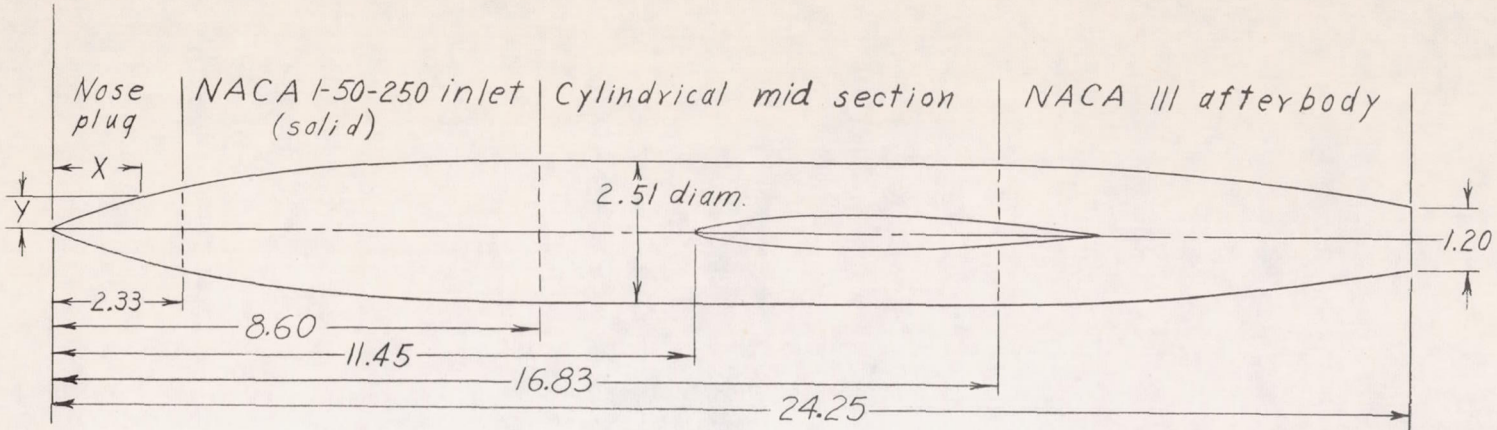


Model characteristics:

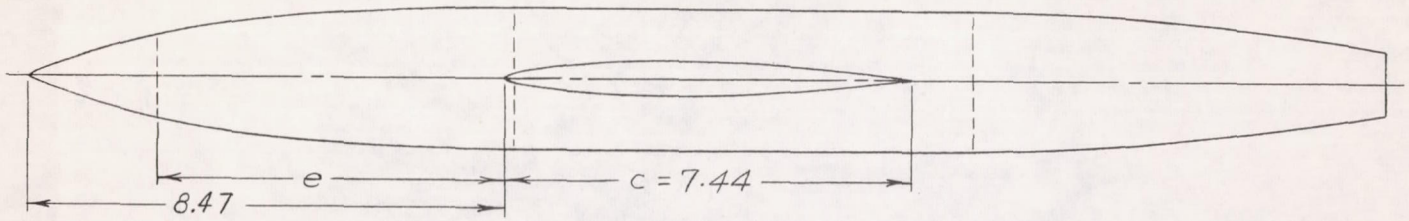
Body fineness ratio	10.0
Wing aspect ratio	6.0
Wing taper ratio	0.6
Mean aerodynamic chord, ft	0.822
Airfoil parallel to free stream	NACA 65A009
Total wing plan-form area, sq ft	3.878
Exposed wing plan-form area, sq ft	3.333
Exposed wing frontal area, sq ft	0.299
Body frontal area, sq ft	0.242
Total frontal area, sq ft	0.550
Exposed fin plan-form area (2 fins), sq ft	0.468

Fins are flat plates and 0.091 inch thick with 0.045-inch radius at edges.

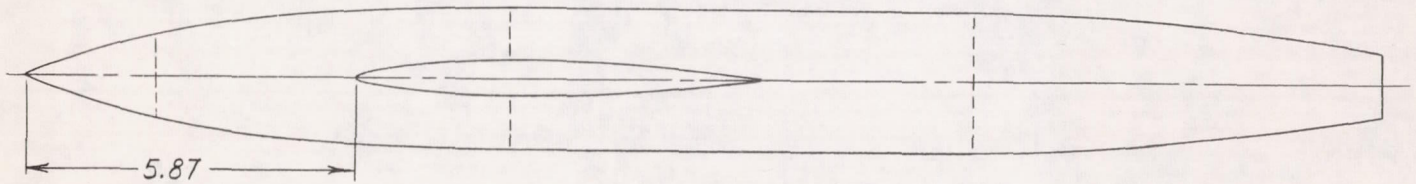
Figure 1.- General arrangement and dimensions of test model. All dimensions are in inches.



(a) Model B; e/c = 1.23



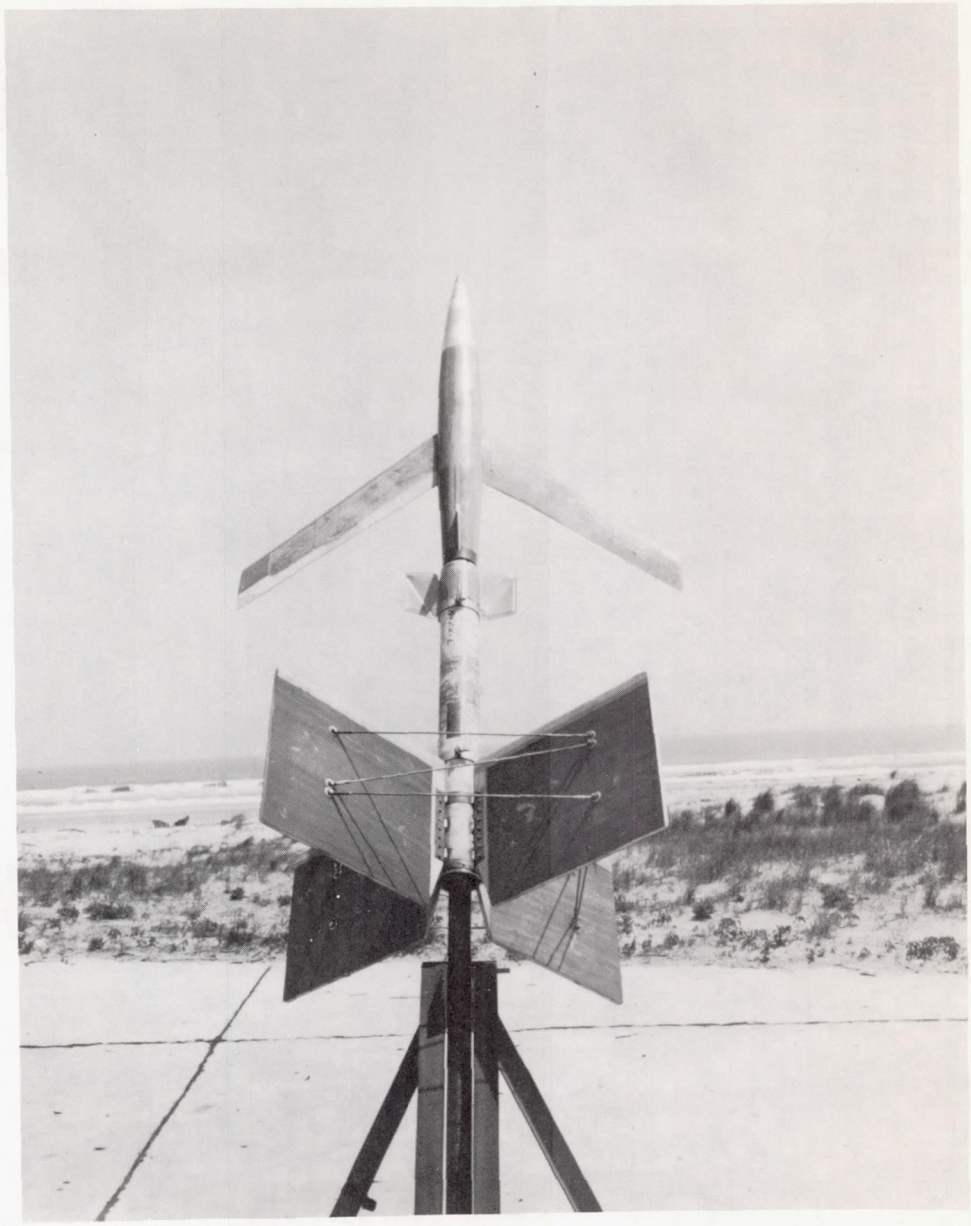
(b) Model C; e/c = 0.82



(c) Model D; e/c = 0.48

Nacelle fineness ratio = 9.66
Nacelle frontal area = 0.034 sq ft

Figure 2.- Cross-sectional views showing chordwise location of nacelles mounted at 96 percent of the semispan. All dimensions are in inches.



Model A

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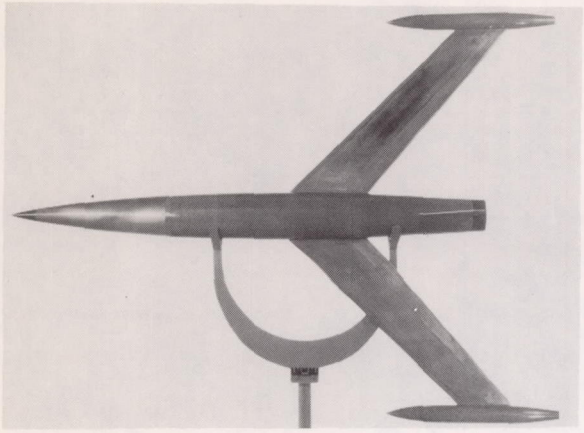
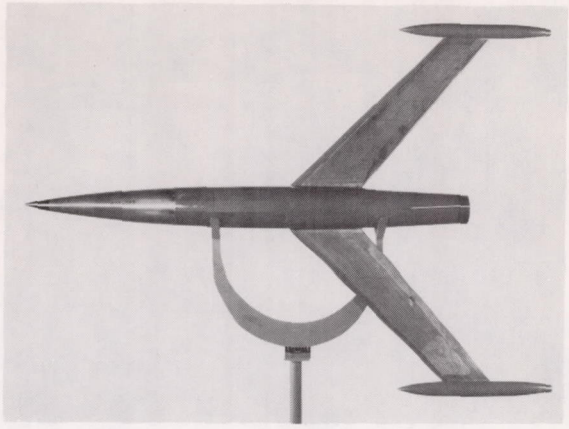
L-61049

(a) Test model without nacelles. Model and booster arrangement on rail launcher.

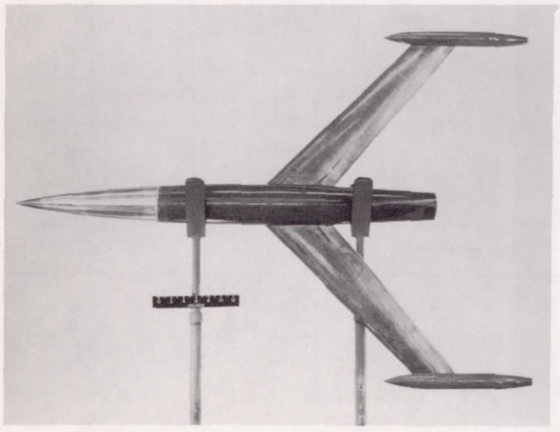
Figure 3.- General views of test models.



Model B; $\frac{e}{c} = 1.23$. NACA L-66600



Model C; $\frac{e}{c} = 0.82$. NACA L-67573



Model D; $\frac{e}{c} = 0.48$. NACA L-68749

(b) Test models with nacelles.

Figure 3.- Concluded.

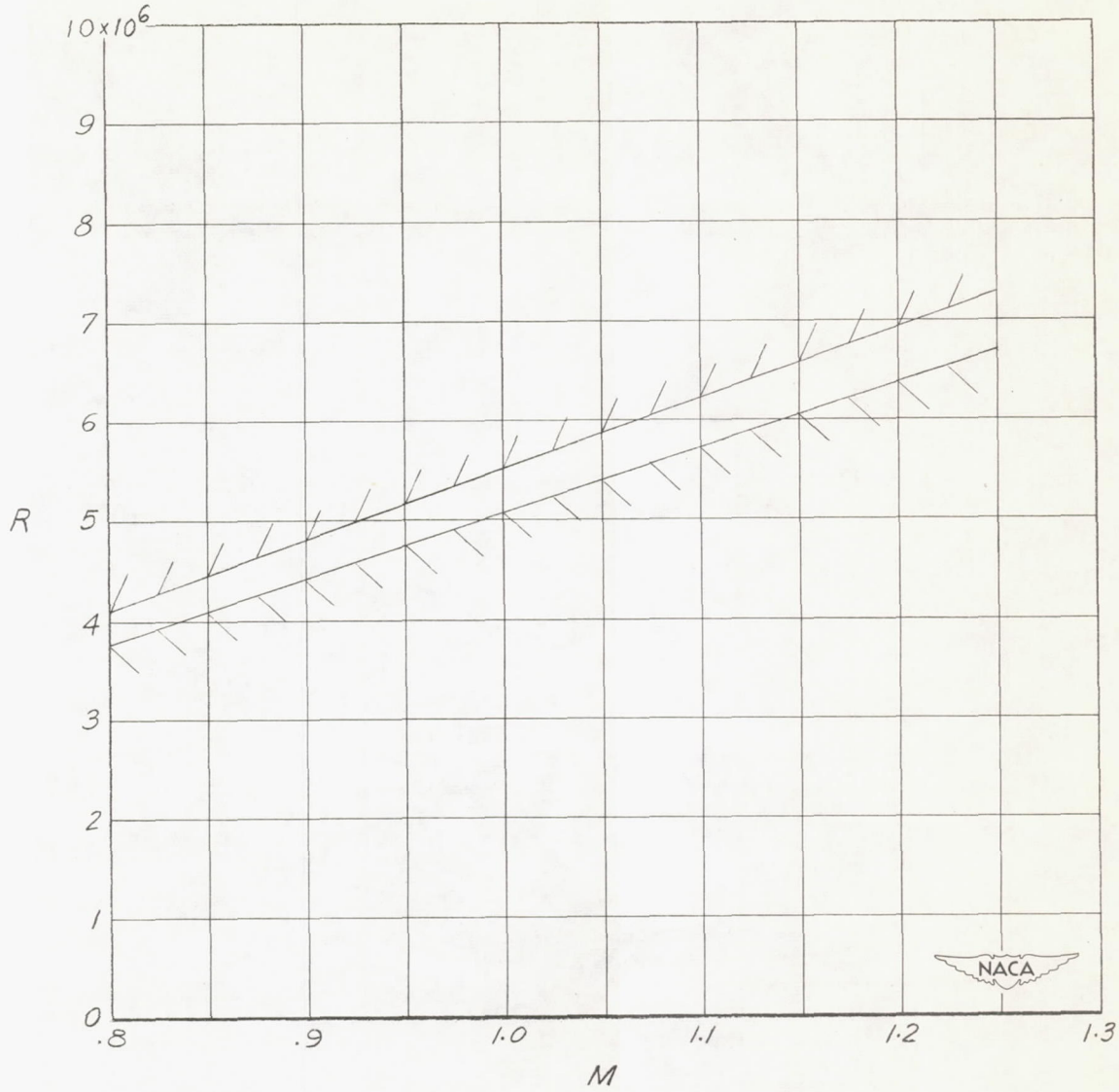
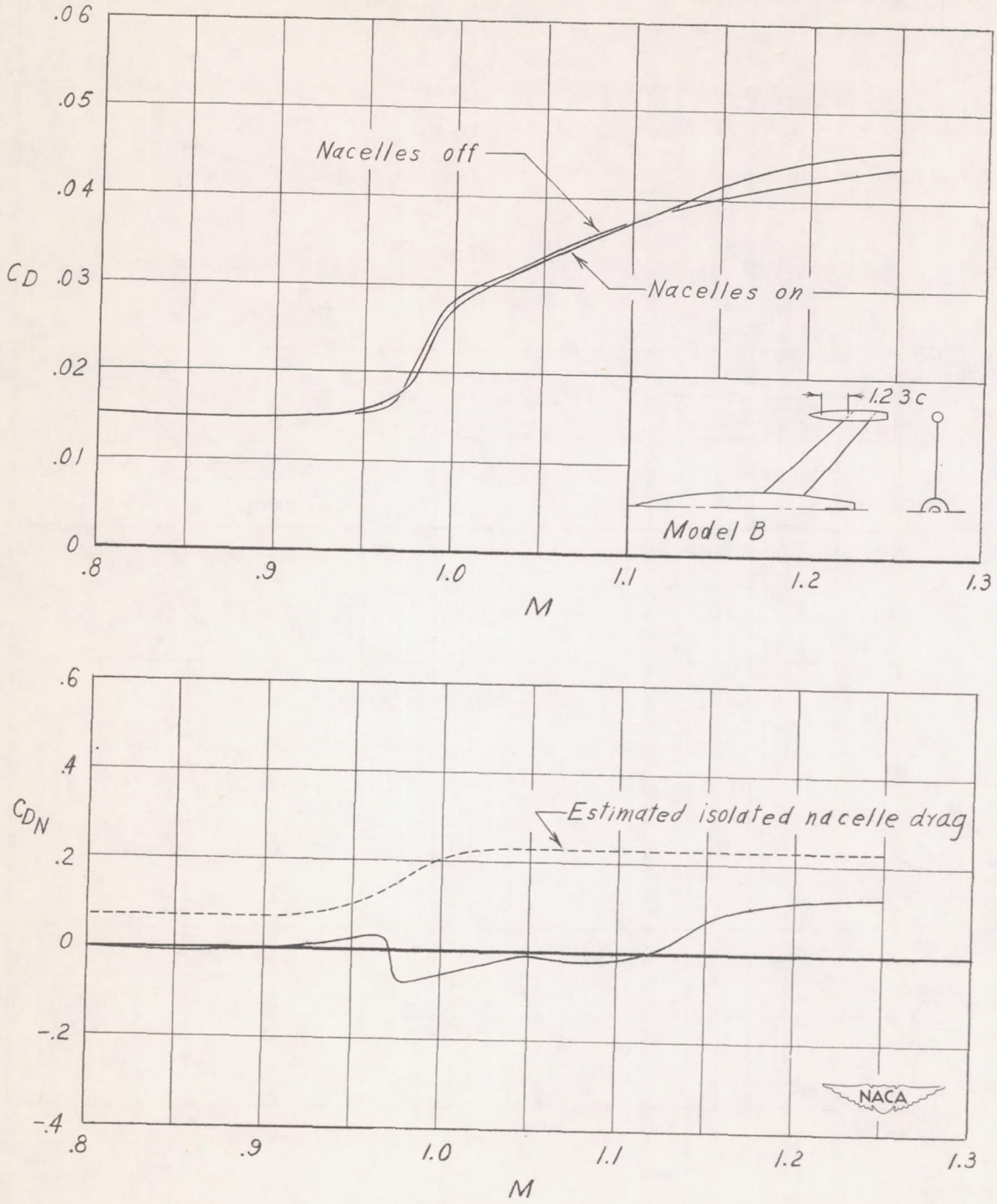
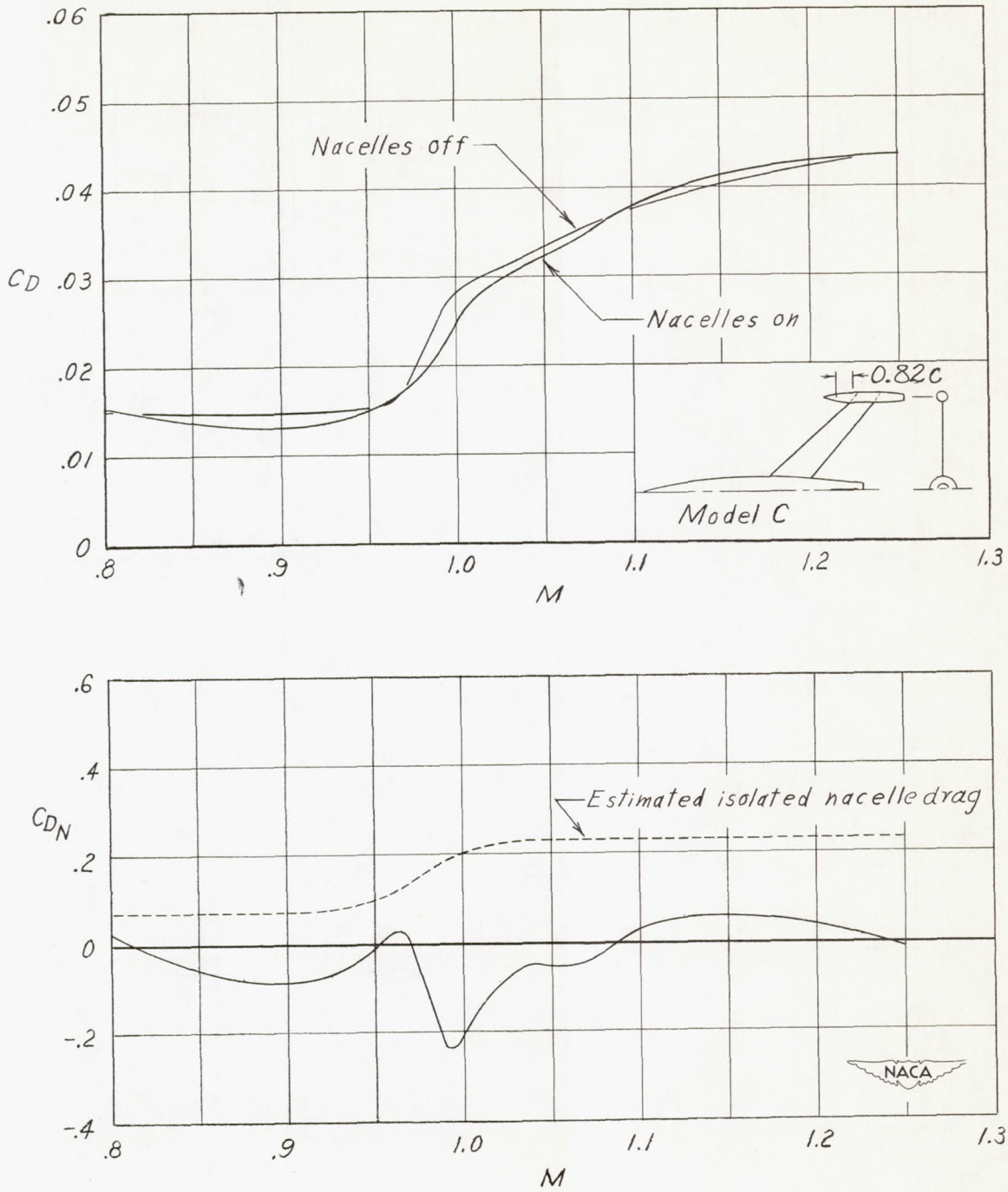


Figure 4.- Variation of Reynolds number with Mach number for models tested. Reynolds number based on wing mean aerodynamic chord.



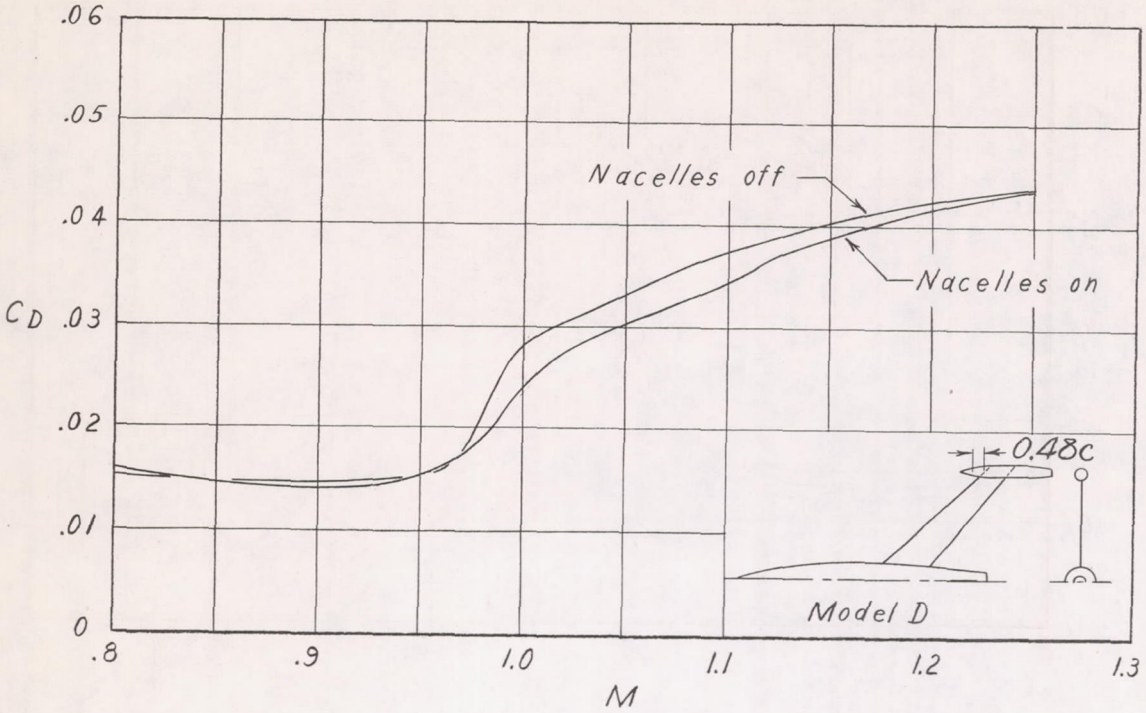
(a) Wing-tip nacelles at 1.23c.

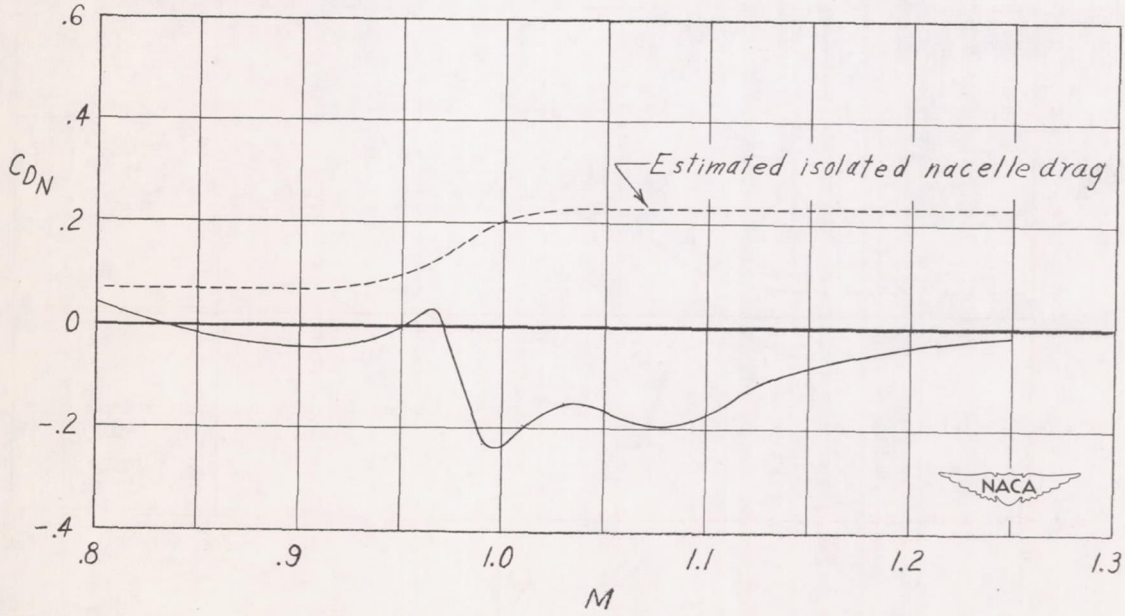
Figure 5.- Variations of total drag, wing-body drag, and nacelle drag coefficients with Mach number for nacelles located at 96 percent of the wing semispan.



(b) Wing-tip nacelles at 0.82c.

Figure 5.- Continued.





(c) Wing-tip nacelles at 0.48c.

Figure 5.- Concluded.

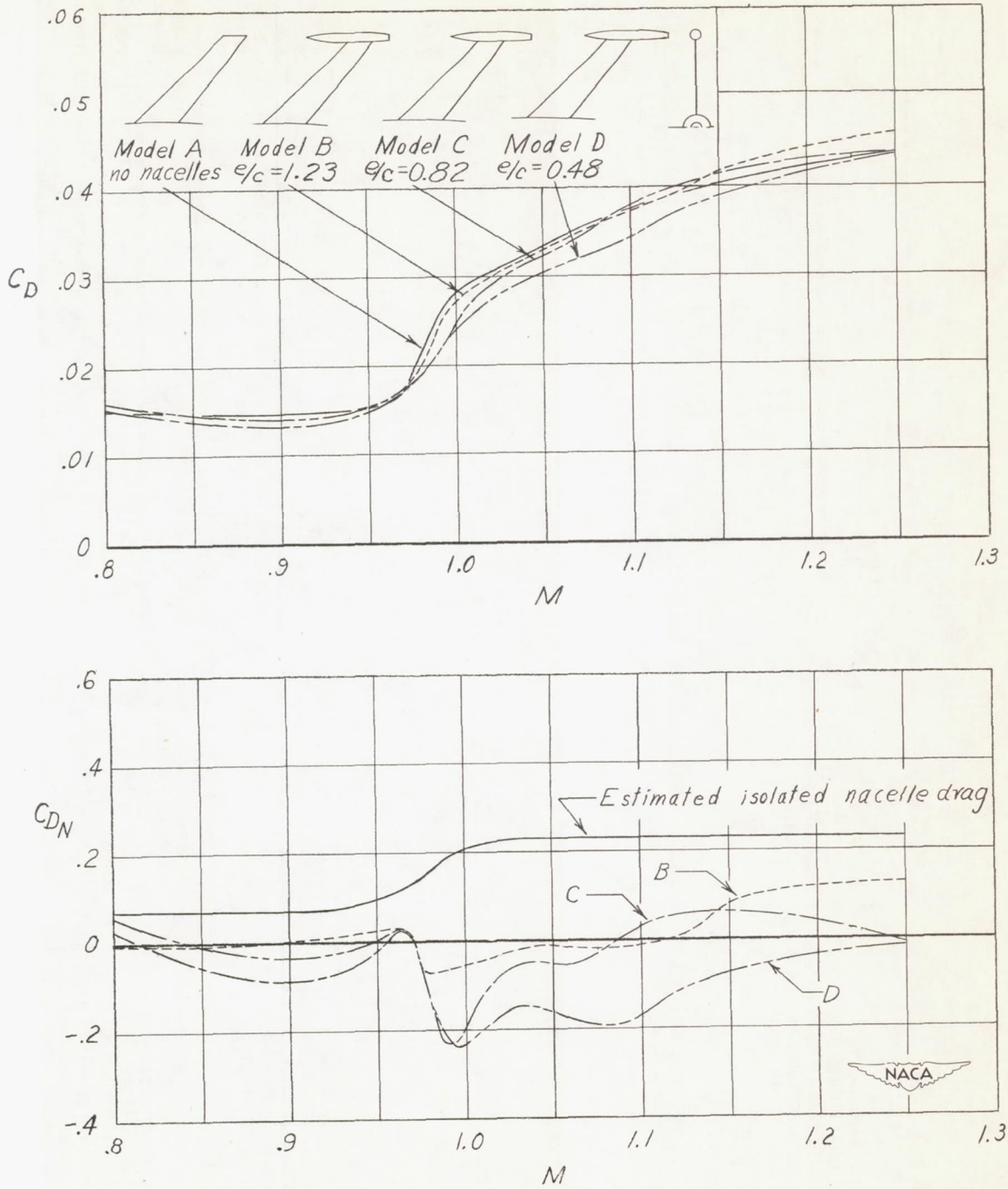


Figure 6.- Comparison of total drag, wing-body drag, and nacelle-plus-interference drag coefficients with Mach number for nacelles located at 96 percent of the semispan.