Copy 5
RM L52F30

NACA RM L52F30

NACA

RESEARCH MEMORANDUM

FREE-FLIGHT TESTS AT MACH NUMBERS FROM 0.8 TO 1.4 TO DETERMINE THE EFFECT ON ZERO-LIFT DRAG OF INCREASING THE LEADING-EDGE BLUNTNESS OF A 45° SWEPTBACK WING HAVING AN NACA 65A009 AIRFOIL

By William B. Pepper, Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
August 19, 1952

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FREE-FLIGHT TESTS AT MACH NUMBERS FROM 0.8 TO 1.4 TO DETERMINE THE EFFECT ON ZERO-LIFT DRAG OF INCREASING THE LEADING-EDGE BLUNTNESS OF A 45° SWEPTBACK WING HAVING AN NACA 65A009 AIRFOIL

By William B. Pepper, Jr.

SUMMARY

Rocket-propelled models were flown at transonic and supersonic speeds to determine the effect on zero-lift drag of increasing the leading-edge bluntness of a sweptback wing. The basic wing-body configuration that was used for comparison consisted of a wing swept back 45° along the quarter-chord line with an aspect ratio of 6.0, a taper ratio of 0.6, an NACA 65A009 airfoil section in the free-stream direction, and a fuselage of fineness ratio 10.0. The blunt-wing configuration had a leading-edge profile modification consisting of a portion of the NACA 1-009 airfoil faired to the rearward 60 percent of the NACA 65A009 airfoil by a flat section.

Results from the tests showed that an increase in the wing leading-edge bluntness increased the wing-plus-interference drag coefficient approximately 0.002 at subsonic and supersonic speeds through a range of Mach numbers from 1.05 to 1.2. For Mach numbers between 1.2 and 1.37, the increment in drag coefficient was greater than at subsonic speeds and was equal to 0.006 at a Mach number of 1.37. A decrease of 0.02 in the force-break Mach number of the blunt wing as compared to the basic wing was indicated.

INTRODUCTION

The use of thin sweptback wings for high-speed aircraft has resulted in low maximum lift coefficients and unstable breaks in the pitching-moment curve at low speeds. Loftin and Von Doenhoff have made an analysis of the relationship of the airfoil pressure distribution to the low-speed maximum lift coefficient (ref. 1) and arrived at a series of thin symmetrical airfoils designed to give high maximum lift at low speeds. Tests of a half-span sweptback wing in the Langley low-turbulence pressure tunnel (ref. 2) by using one of the 6-percent-thick airfoils designed for high maximum lift showed that substantial improvements in the characteristics of the wing were obtained at low speeds without compromising the high-speed characteristics up to a Mach number of 0.95. As a result of the characteristic leading-edge bluntness of the new high-lift series of airfoils, however, an undue drag penalty may be encountered above Mach numbers of 0.95.

The tests discussed in this paper are intended to investigate the effect of leading-edge bluntness that would be encountered with the use of the high-lift series of airfoils on the zero-lift drag of a 45° sweptback wing throughout the transonic region and into the supersonic region.

The tests were conducted at the Langley Pilotless Aircraft Research Station at Wallops Island, Va., with the use of rocket-propelled models. Drag data were obtained through a range of Mach numbers from 0.8 to 1.40 corresponding to Reynolds numbers of 3.7×10^6 to 7.9×10^6 based on the mean aerodynamic chord of the wing.

SYMBOLS

C_{D_T} total drag coefficient (based on S_W)

C_{D_W} wing-plus-interference drag coefficient (based on S_W)

M Mach number

R Reynolds number (based on wing mean aerodynamic chord of 0.822 ft)

S_W total wing plan-form area (including part in fuselage), 3.878 sq ft

c wing chord, in.

x wing station, in.

y wing ordinate, in.

MODELS

Details and dimensions of the wing-body-fin configuration used for the tests are given in figure 1 and coordinates for the fuselage are given in reference 3. The basic configuration, which was the same as that used in reference 3, consisted of a fuselage of fineness ratio 10 with a 45° sweptback wing of aspect ratio 6.0, taper ratio 0.6, and NACA 65A009 airfoil sections in the free-stream direction.

The modified wing model had the same geometric characteristics as the basic configuration shown in figure 1 except that the leading edge of the airfoil was made more blunt by the use of the forward 12.049 percent of an NACA 1-009 airfoil with a constant thickness fairing back to the 40-percent chord. (See fig. 1.) The blunt leading-edge airfoil was the same as the NACA 65A009 airfoil rearward of the 40-percent chord. A geometrical comparison of the blunt leading-edge airfoil, the NACA 1-009 airfoil, and the high maximum lift NACA 2-006 airfoil used on the wing of reference 2 is shown in figure 2. The forward part of the two airfoils is similar, whereas the rearward part of the airfoil used in the present tests has considerably more thickness. Photographs of the blunt airfoil model are shown in figure 3. Coordinates of the two airfoils used are given in tables I and II.

TESTS AND MEASUREMENTS

The rocket-propelled zero-lift models were tested at the Langley Pilotless Aircraft Research Station at Wallops Island, Va.

Each model was propelled by a two-stage rocket system and launched from a rail launcher (fig. 4). The first stage or booster consisted of a 5.0-inch rocket motor that served to accelerate the model from zero velocity to high subsonic speeds. After the drag separation of the booster, a 3.25-inch Mk 7 rocket motor which was installed in the model accelerated it to supersonic speeds. A CW Doppler radar set and an NACA modified SCR 584 radar set was used to determine the flight path and deceleration during the coasting flight. A survey of atmospheric conditions at the time of each launching was made through radiosonde measurements from an ascending balloon. A more detailed description of the test technique and instruments may be found in reference 4.

The values of drag coefficient were calculated as in reference 3. The order of accuracy of the total drag coefficient as determined by tests of three identical models (ref. 3) is ±0.0004. At Mach numbers near 1.0 where the increased rate of change in slope of the drag curve may cause larger inaccuracies, the total drag coefficient is estimated to be accurate within ±0.0017. The Mach number was determined from the velocity of each model and the speed of sound at the altitude from corresponding radiosonde records. The accuracy of the Mach number determination is estimated to be within ±0.005.

RESULTS AND DISCUSSION

Flight tests of the models covered a Reynolds number range from 3.7×10^6 at $M = 0.8$ to 7.9×10^6 at $M = 1.40$. (See fig. 5.)

The variations of total drag coefficient with Mach number for the test configurations are presented in figure 6(a). The curve for the model with the NACA 65A009 airfoil wings is the average for three identical models of reference 3. The estimated curve for the fuselage and two fins was obtained in reference 5 by subtracting the estimated drag of two fins from the value obtained from tests of two fuselage models having four fins. By subtracting the drag coefficients for the fuselage and two fins from the total drag coefficients in figure 6(a), the wing-plus-interference drag coefficient of the two wings was obtained.

The wing-plus-interference drag coefficients for the wing with an NACA 65A009 airfoil and for the wing having the same airfoil modified with a blunt leading edge are shown in figure 6(b). The accuracy of the absolute level of wing-plus-interference drag coefficients is dependent upon the estimation of drag for the body with two fins and is believed to be within ±0.001. A comparison of the drag coefficients of the two wings up to a Mach number of 0.955 showed that the blunt leading-edge modification caused an increase of 0.002. Wind-tunnel tests (ref. 2) of two swept wings, one with NACA 65A006 airfoil sections and the other with NACA 2-006 airfoil sections, also showed the same increase in drag coefficient at a Mach number of 0.9. A decrease of 0.02 in the force-break Mach number of the blunt wing as compared to the basic wing was indicated by the curves in figure 6. The drag increment due to blunting the leading edge was the same (0.002) between Mach numbers of 1.05 and 1.2 as at subsonic speeds; therefore, no increase in wing pressure drag was indicated. At a Mach number above 1.2, however, the drag increment caused by blunting the leading edge increased and was equal to 0.006 at a Mach number of 1.37. This larger drag increment can probably be attributed in large measure to an increase in wing pressure drag.

It, therefore, appears that no large adverse drag effects result from blunting the leading edge of the configuration tested between Mach numbers of 0.8 and 1.2. The percentage increase in drag coefficient caused by blunting the leading edge for Mach numbers greater than 1.2

may be much reduced for sections of lower thickness ratio. Also, the drag of the high lift series sections may be less than the blunt leading-edge section tested herein because of differences in shape and thickness to the rear of the 12.044-percent-chord station.

CONCLUSIONS

The effect of leading-edge bluntness on zero-lift drag of a wing has been measured by rocket-propelled free-flight models. The basic configuration consisted of a 45° sweptback wing of aspect ratio 6 having NACA 65A009 airfoil sections in the free-stream direction mounted on a fuselage of fineness ratio 10. The blunt-wing configuration had a leading-edge profile modification consisting of a portion of the NACA 1-009 airfoil faired by a flat section to the rearward 60 percent of the NACA 65A009 airfoil. The following conclusions were made:

1. An increase in the wing leading-edge bluntness increased the wing-plus-interference drag coefficient approximately 0.002 at subsonic and supersonic speeds through a Mach number range from 1.05 to 1.2.

2. For Mach numbers between 1.2 and 1.37 the increment in drag coefficient caused by blunting the wing leading edge was greater than at subsonic speeds and was equal to 0.006 at a Mach number of 1.37.

3. A decrease of 0.02 in the force-break Mach number of the blunt wing as compared to the basic wing was indicated.

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

REFERENCES

1. Loftin, Laurence K., Jr., and Von Doenhoff, Albert E.: Exploratory Investigation at High and Low Subsonic Mach Numbers of Two Experimental 6-Percent-Thick Airfoil Sections Designed to Have High Maximum Lift Coefficients. NACA RM L51F06, 1951.

2. Racisz, Stanley F., and Paradiso, Nicholas J.: Wind-Tunnel Investigation at High and Low Subsonic Mach Numbers of a Thin Sweptback Wing Having an Airfoil Section Designed for High Maximum Lift. NACA RM L51L04, 1952.

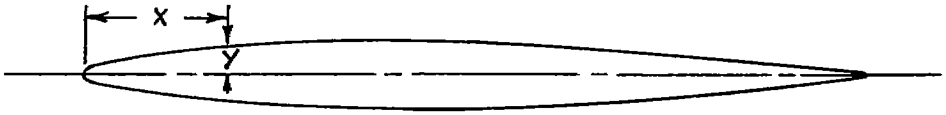
3. Pepper, William B., Jr., and Hoffman, Sherwood: Transonic Flight Tests To Compare the Zero-Lift Drag of Underslung and Symmetrical Nacelles Varied Chordwise at 40 Percent Semispan of a 45° Sweptback, Tapered Wing. NACA RM L50G17a, 1950.

4. Hoffman, Sherwood: Transonic Flight Tests To Compare the Drag at Zero-Lift of Nacelles Located in Various Positions on the Wing of a Sweptback Wing and Body Configuration. Univ. Va. Thesis, 1951.

5. Pepper, William B.: The Effect on Zero-Lift Drag of an Indented Fuselage or a Thickened Wing-Root Modification to a 45° Sweptback Wing-Body Configuration as Determined by Flight Tests at Transonic Speeds. NACA RM L51F15, 1951.

TABLE I

COORDINATES OF THE NACA 65A009 AIRFOIL

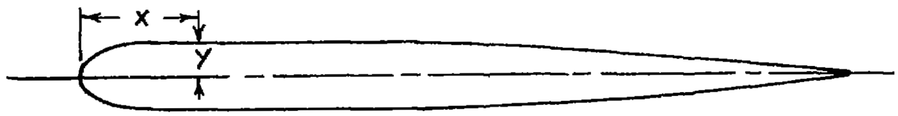


x/c (percent)	y/c (percent)
0	0
.5	.688
.75	.835
1.25	1.065
2.5	1.460
5.0	1.964
7.5	2.385
10.0	2.736
15.0	3.292
20.0	3.714
25.0	4.036
30.0	4.268
35.0	4.421
40.0	4.495
45.0	4.485
50.0	4.377
55.0	4.169
60.0	3.874
65.0	3.509
70.0	3.089
75.0	2.620
80.0	2.117
85.0	1.594
90.0	1.069
95.0	.544
100.0	.019
Leading-edge radius, 0.575 percent c Trailing-edge radius, 0.021 percent c	

NACA

TABLE II

COORDINATES OF BLUNT LEADING-EDGE AIRFOIL



x/c (percent)	y/c (percent)
0	0
.468	1.383
1.879	2.617
4.261	3.587
7.648	4.214
12.049	4.500
40	4.500
45	4.485
50	4.377
55	4.169
60	3.874
65	3.509
70	3.089
75	2.620
80	2.117
85	1.594
90	1.069
95	.544
100	.019
Leading-edge radius, 2.13 percent c	

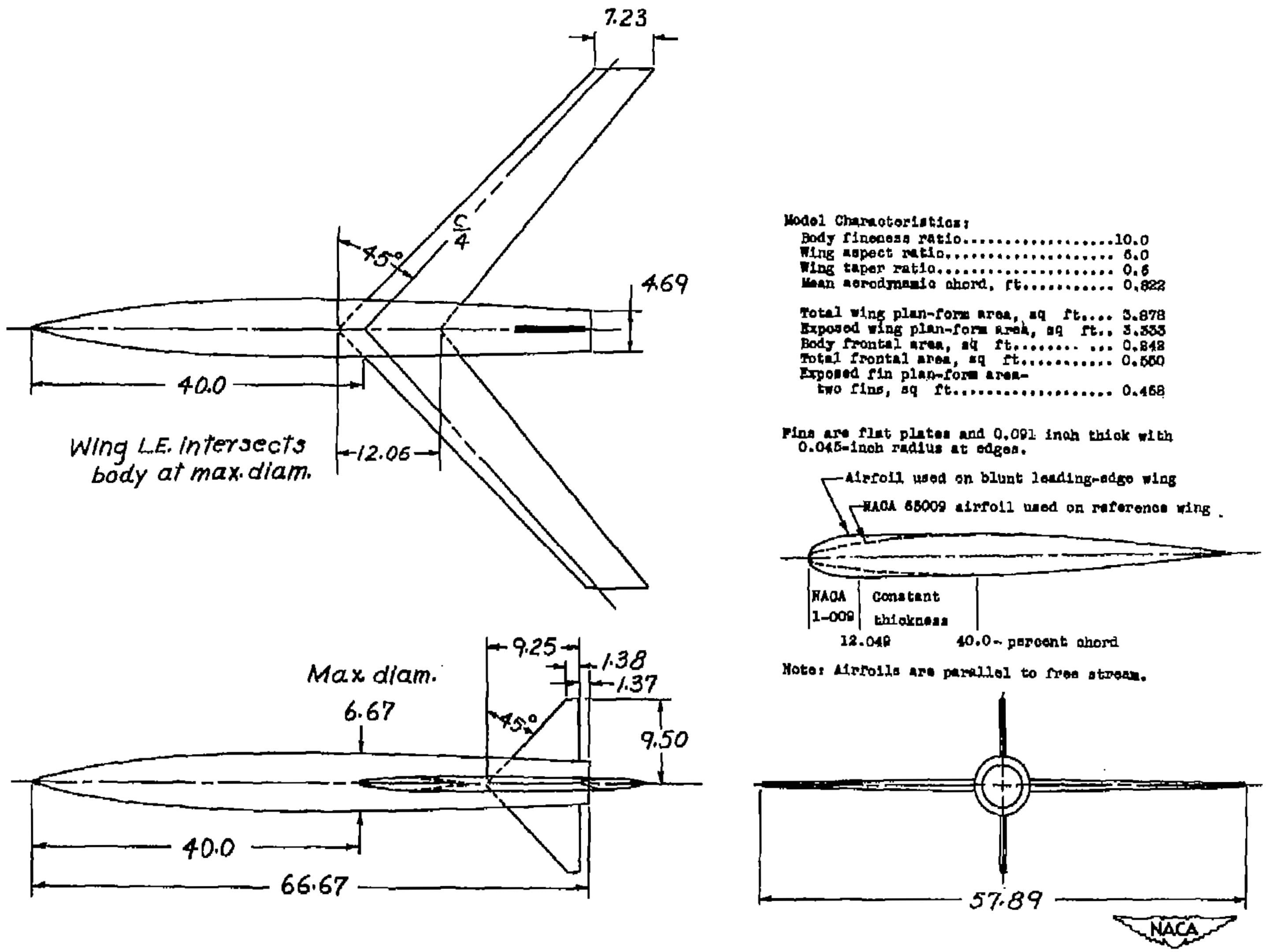


Figure 1.- General arrangement and dimensions of test models. All dimensions are in inches.

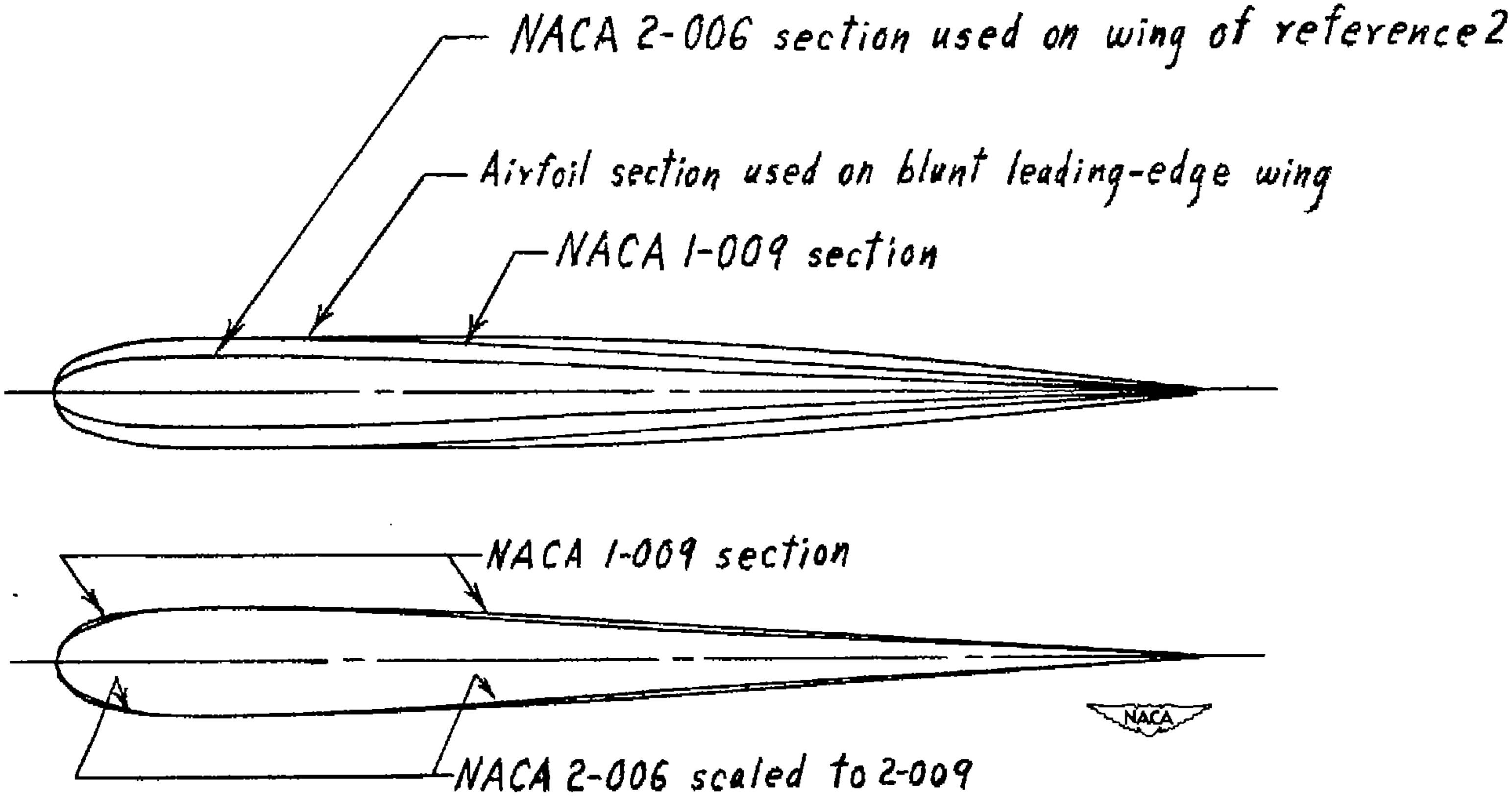
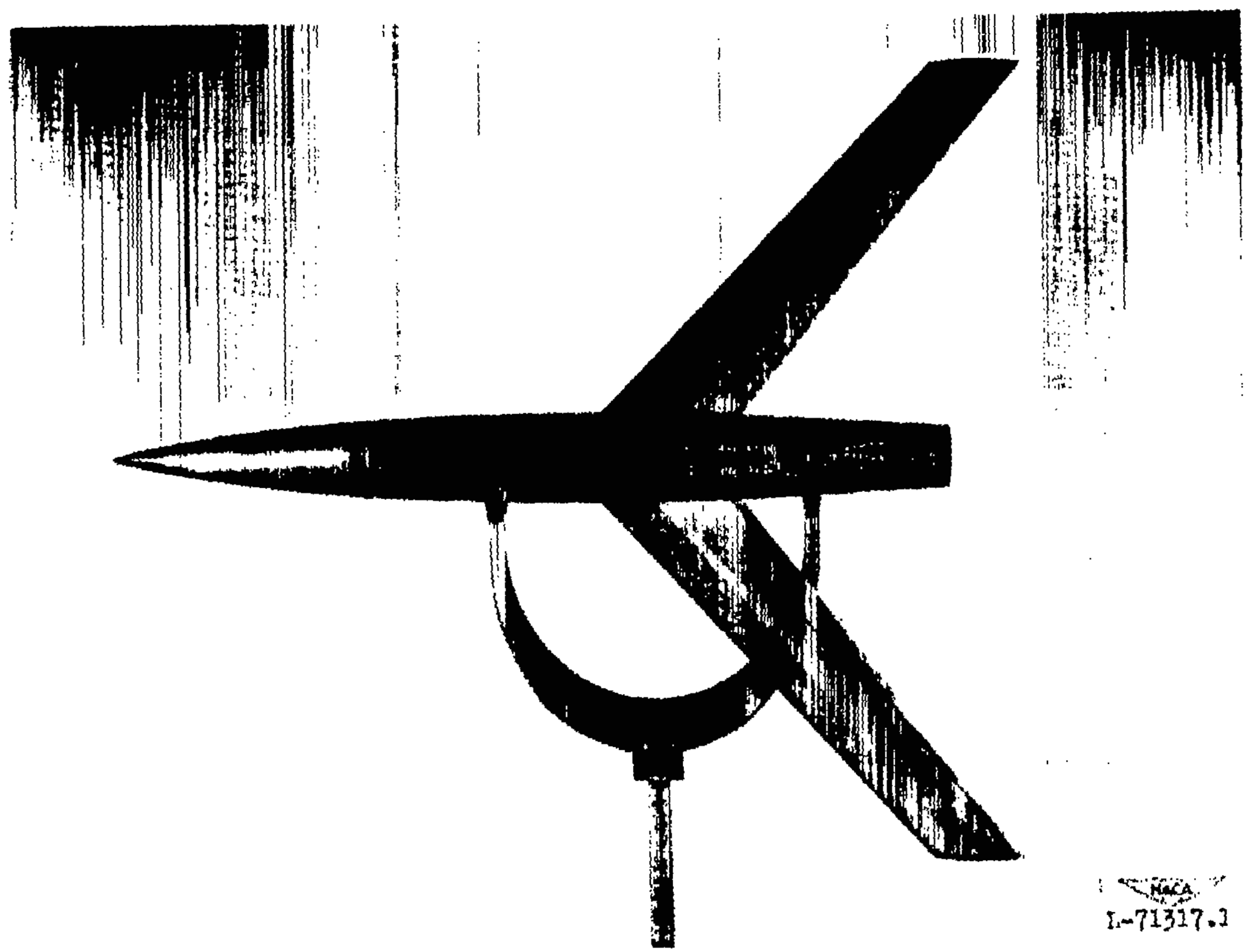
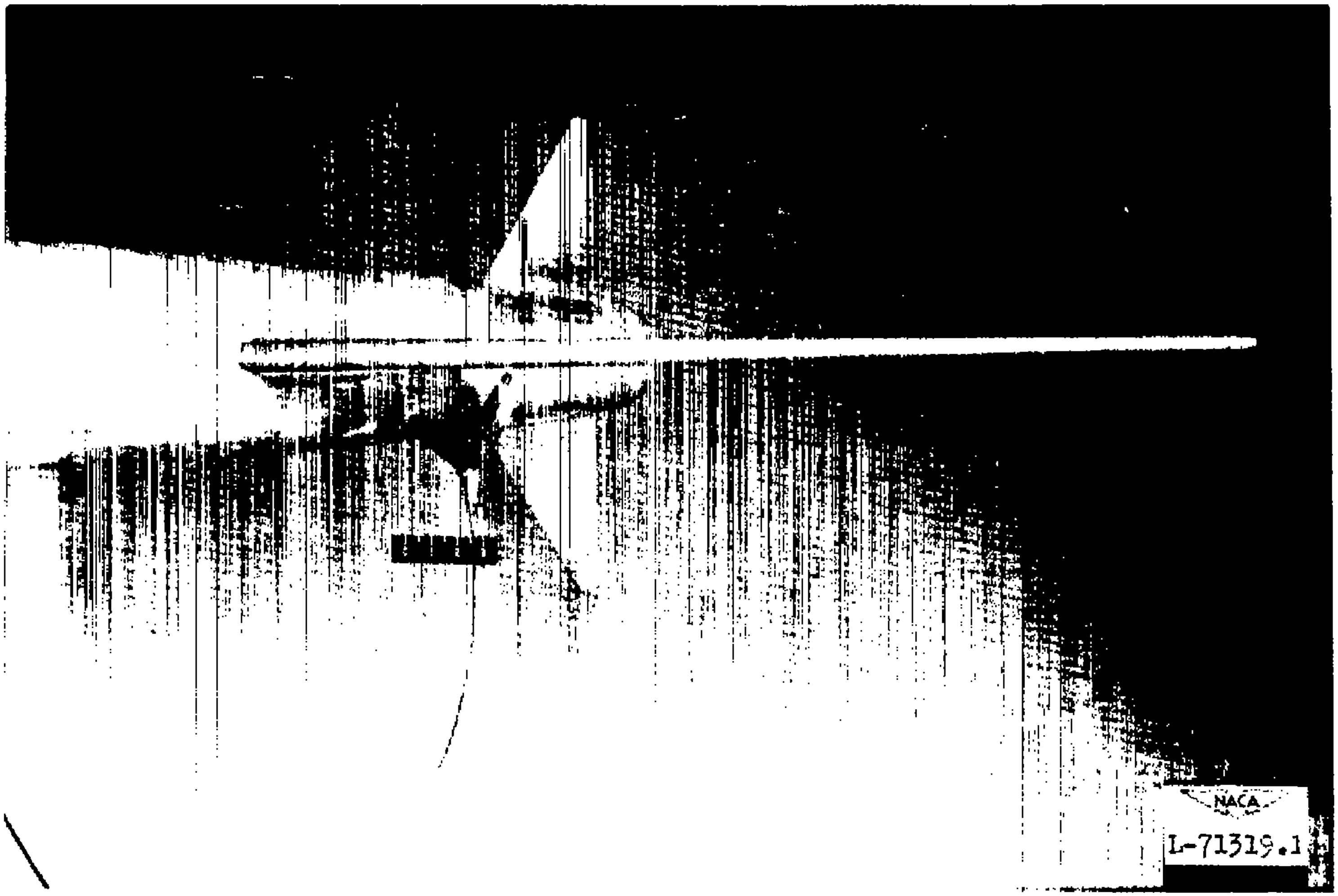


Figure 2.- Comparison of airfoil sections used on blunt leading-edge wing with the high-lift-series airfoil used in reference 2.



(a) Plan view.

Figure 3.- Photographs of model with blunt leading-edge wing.



(b) Front three-quarter view.

Figure 3.- Concluded.

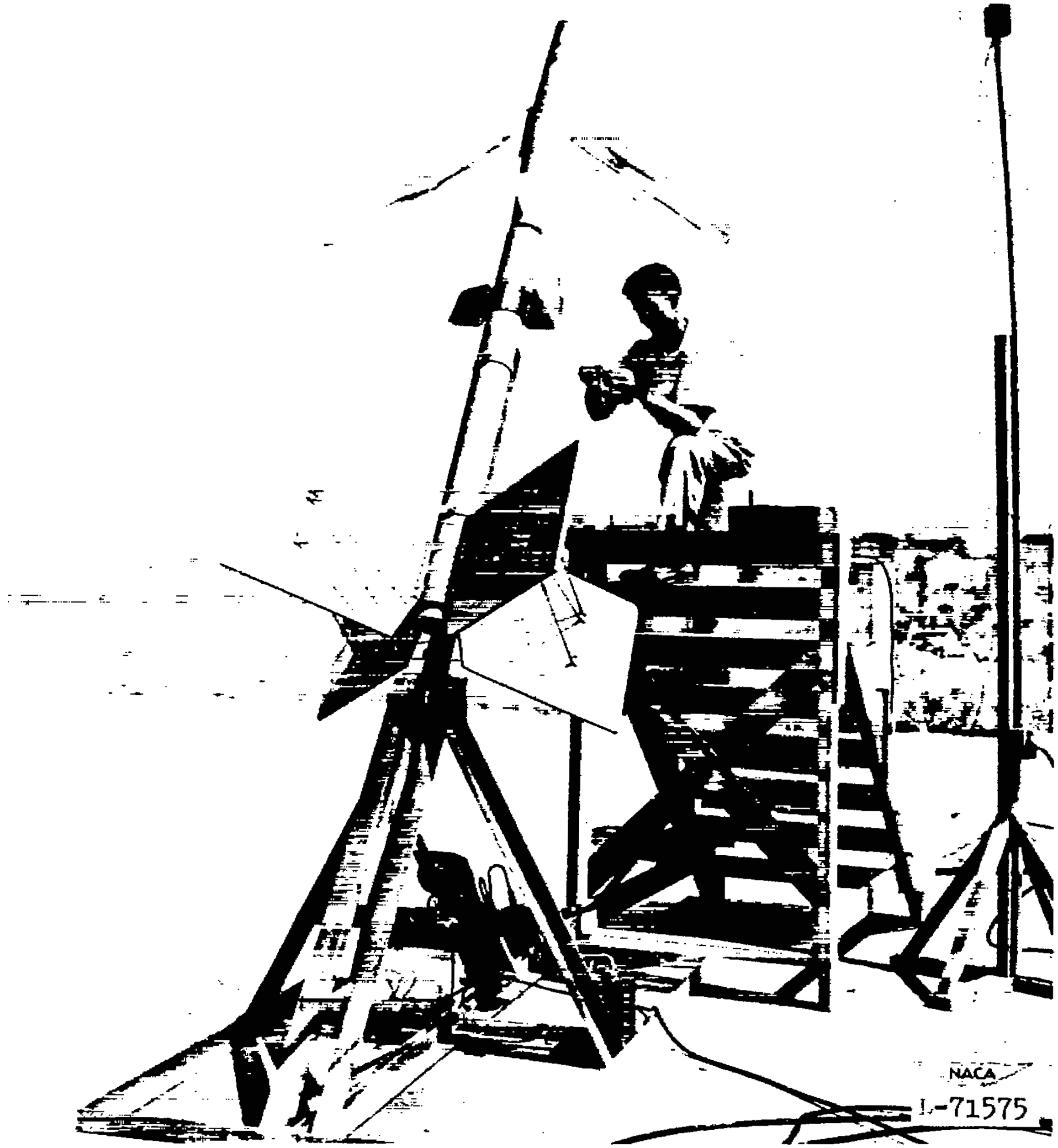


Figure 4.- Model and booster on rail launcher.

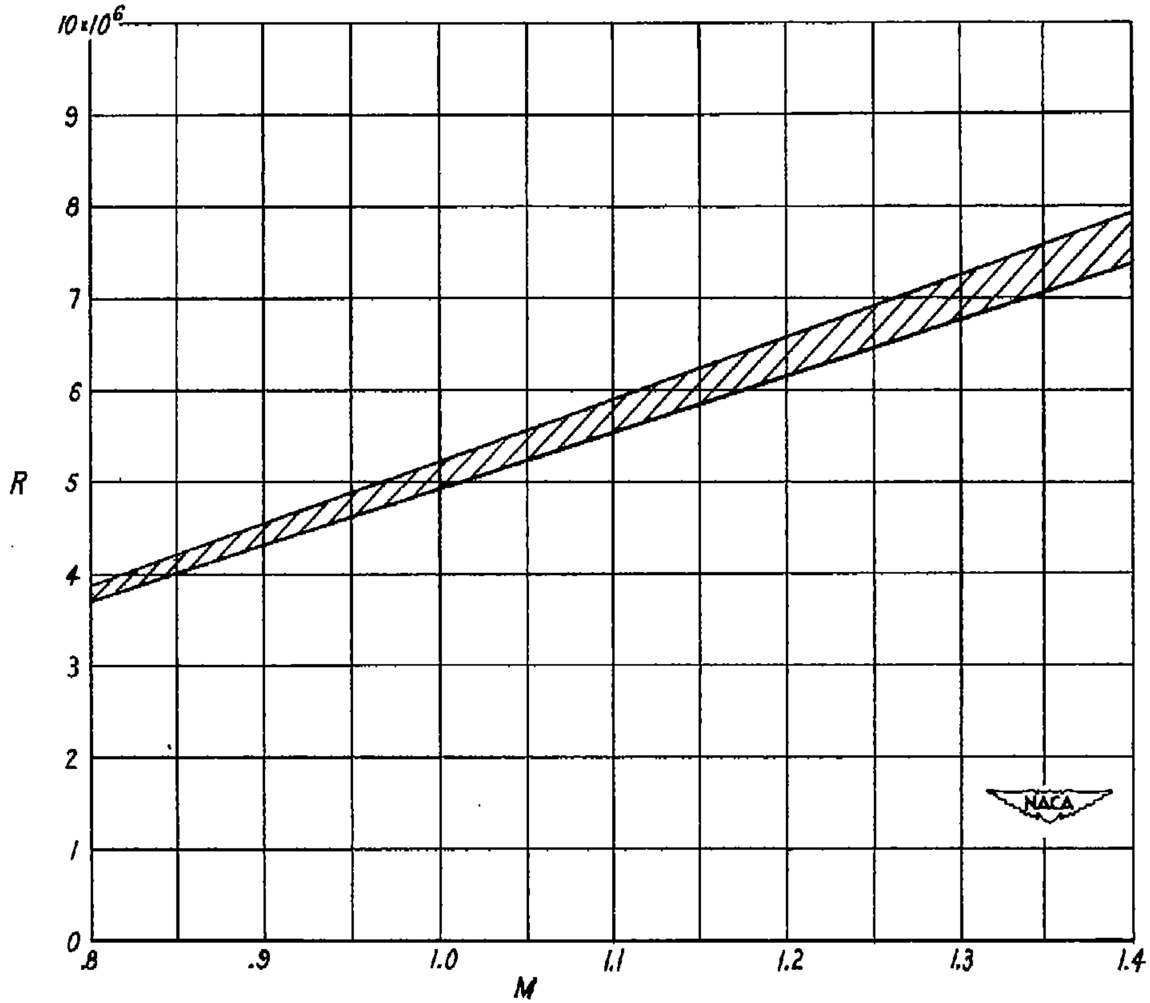
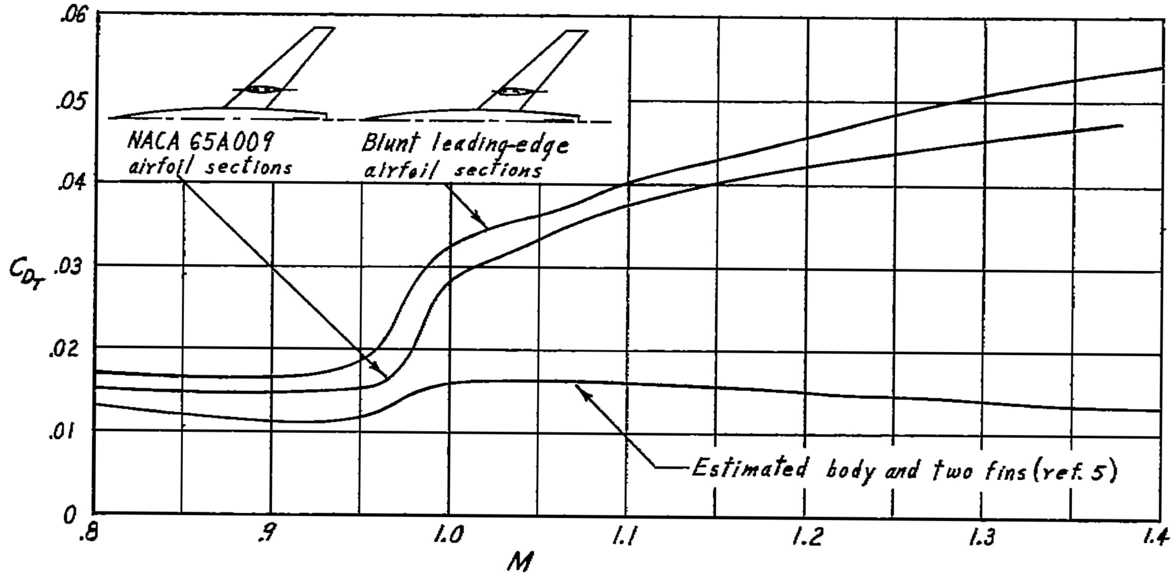
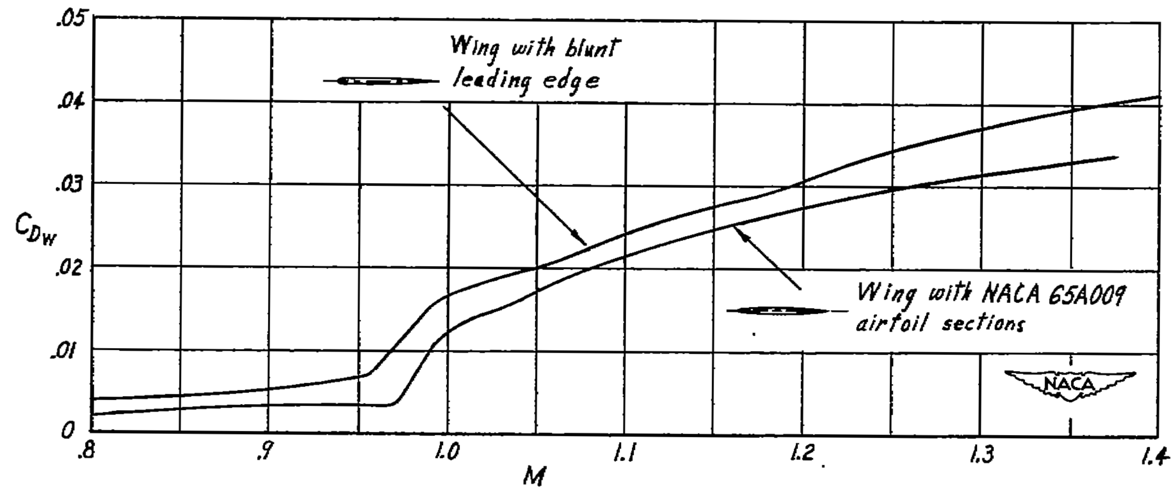


Figure 5.- Variation of Reynolds number range with Mach number for models tested. Reynolds number based on mean aerodynamic wing chord.



(a) Total drag coefficient.



(b) Wing-plus-interference drag coefficient.

Figure 6.- Variations of total drag and wing-plus-interference drag coefficients with Mach number for the basic- and blunt-wing leading-edge models. (Based on wing plan-form area.)

SECURITY INFORMATION

[redacted]