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RESEARCH MEMORANDUM

DRAG CHARACTERISTICS OF RECTANGULAR AND SWEPT-BACK NACA 65-009 AIRFOILS HAVING ASPECT RATIOS OF 1.5 AND 2.7 AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

By

Sidney R. Alexander and Ellis Katz

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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DRAG CHARACTERISTICS OF RECTANGULAR AND SWEPT-BACK NACA 65-009 AIRFOILS HAVING ASPECT RATIOS OF 1.5 AND 2.7 AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

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SUMMARY

Tests were conducted to determine the effect of sweepback angle and aspect ratio on the drag of an NACA 65-009 airfoil at supersonic speeds. The data were obtained by tracking rocket-propelled bodies carrying wings of various plan forms. The following wing arrangements were investigated: (a) aspect ratio of 1.5, sweepback angles of 0°, 34°, 45°, and 52° and (b) aspect ratio of 2.7, sweepback angles of 0°, 34°, and 45°. The results showed that for the range of Mach number investigated (M = 1.05 to 1.35) increasing the sweepback angle and decreasing the aspect ratio reduced the value of the wing drag coefficient. Decreasing the aspect ratio always decreased the wing drag coefficient although this effect was observed to become very small at the higher sweepback angles.

INTRODUCTION

The aerodynamic characteristics of wings at sonic speeds become subject to marked adverse changes due to rapid discontinuities in the air flow over the wing precipitated by the formation of shock waves. These adverse effects could be appreciably delayed, as shown in reference 1, by sweeping the wing back.

The favorable relieving effects due to the three-dimensional flow around wings of finite span at supercritical speeds have been experimentally verified in reference 2. However, few systematic data exist on the combined effects of sweep angle and aspect ratio on drag in the transonic and supersonic speed range.

In order to obtain information relative to the drag of wings at supersonic speeds a series of tests are being conducted by the Langley Pilotless Aircraft Research Division at Wallops Island, Va., of rocket-propelled bodies carrying wings of various sweepback angles Λ and aspect ratios A. Results are presented herein of drag tests of rectangular and swept-back NACA 65-009 airfoils of aspect ratios 1.5 and 2.7. These values are based on the total wing span and area including the part blanketed by the fuselage. The NACA 65-009 airfoil is the same as that used in the freely falling body investigation of reference 3, although since the publication of reference 3 the subscript 1 has been deleted from the designation. The sweepback angles were selected to give ratios of free-stream velocity to velocity normal to the wing leading edge of 1.000, 1.207, 1.414, and 1.621.

MODELS AND TESTS

The rocket-propelled, winged test bodies were constructed of wood and were 5 inches in diameter and approximately 5 feet long. The airfoils were of aspect ratios 1.5 and 2.7 and were swept back 0°, 34°, and 45°. In addition, for the 1.5 aspect ratio, the airfoil was tested with a sweepback of 52°. The airfoils were mounted on the fuselage at zero angle of attack so as to have the midsemispan quarter-chord point at the same longitudinal station as the design center of gravity and had neither twist, taper, nor dihedral. The constant-chord sections were always normal to the leading edge. The fuselages were made hollow to accommodate the propulsion unit, a standard 3.25-inch Mk. 7 aircraft rocket motor developing about 2200 pounds of thrust for 0.87 second at an ambient preignition temperature of 69° F. The stabilizing fins were rotated 45° to the plane of the wings to minimize the effect of the wing wake on the tail. With the exception of the arrangement with 52° sweepback, there were two models of each configuration tested. A line drawing of the general body arrangement is shown as figure 1 and photographs of the test bodies are presented in figures 2 to 4.

The experimental data were obtained by launching the test bodies at an angle of 75° to the horizontal and determining its velocity along the flight path by the use of CW Doppler radar (AN/TPS-5). Photographs of the launcher and radar are shown in figures 5(a) and 5(b), respectively. A typical curve of velocity against flight time obtained from a radar record is given in figure 6. The drag data were obtained by differentiating the part of the curve corresponding to the time the bodies were coasting (after the propellant had been expended) and converting the values of deceleration into corresponding values of drag coefficient. The tests covered a Mach number range from approximately 1.0 to 1.37.

RESULTS AND DISCUSSION

Figure 7 presents curves of both total drag and wing drag against velocity for the two aspect ratios investigated. The curves of wing drag were derived by graphically taking the numerical difference between the total-drag curves of the winged configurations and that of the sharp-nose wingless body of reference 4 shown in figure 8. The values of wing drag determined by this method include any possible wing-fuselage interference effects. The body with wings of aspect ratio 1.5 and sweepback angle of 52° was not tracked to the low Mach number range obtained with the other test bodies.

Figure 9 presents corresponding plots of drag coefficient against Mach number for the wing arrangements investigated. The drag coefficients were based on the constant, exposed wing plan-form area of 200 square inches. The accuracy of the drag coefficient data, as experimentally determined from repeat tests, is approximately ±3 percent. Examination of figure 9(b) reveals that, for the wings of aspect ratio 2.7 and sweepback angles of 34° and 45°, the drag-coefficient reduction amounted to 50 percent and 69 percent, respectively, of the unswept wing values for a Mach number of 1.2. At the same value of Mach number for aspect ratio 1.5 the 34° and 45° swept-back wings reduced the drag coefficient of the unswept wing by 50 and 61 percent, respectively. The effect of decreasing the aspect ratio on the drag reduction is observed to remain constant with increasing sweepback angle until, at an angle of approximately 45°, this effect suddenly becomes very small. At sweepback angles of 0° and 34° for a Mach number of 1.2, the 1.5 aspect-ratio wing reduced the value of the drag coefficient obtained for the 2.7 aspect-ratio wing by 18 percent.

It should be remembered that since the constant-chord section was always normal to the leading edge for the wing configurations presented herein, the thickness ratio in the flight direction decreased with increasing sweep angle.

CONCLUSIONS

Flight tests to determine the drag of rectangular and swept-back NACA 65-009 airfoils having aspect ratios of 1.5 and 2.7, respectively, were conducted by the Langley Pilotless Aircraft Research Division at Wallops Island, Va. For the range of Mach number, sweepback angle, and aspect ratio investigated, the following general conclusions were reached:

1. Increasing the sweepback angle and decreasing the aspect ratio reduced the wing-drag coefficient.

2. Decreasing the aspect ratio always decreased the drag coefficient although this effect was observed to become very small at the higher sweepback angles.

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

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1. Jones, Robert T.: Wing Plan Forms for High-Speed Flight. NACA TN No. 1033, 1946.

2. Stack, John, and Lindsey, W. F.: Characteristics of Low-Aspect-Ratio Wings at Supercritical Mach Numbers. NACA ACR No. L5J16, 1945.

3. Mathews, Charles W., and Thompson, Jim Rogers: Comparative Drag Measurements at Transonic Speeds of Rectangular and Swept-Back NACA 65_1-009 Airfoils Mounted on a Freely Falling Body. NACA ACR No. L5G30, 1945.

4. Alexander, Sidney R.: Results of Tests to Determine the Effect of a Conical Windshield on the Drag of a Bluff Body at Supersonic Speeds. NACA RM No. L6K08a, 1947.

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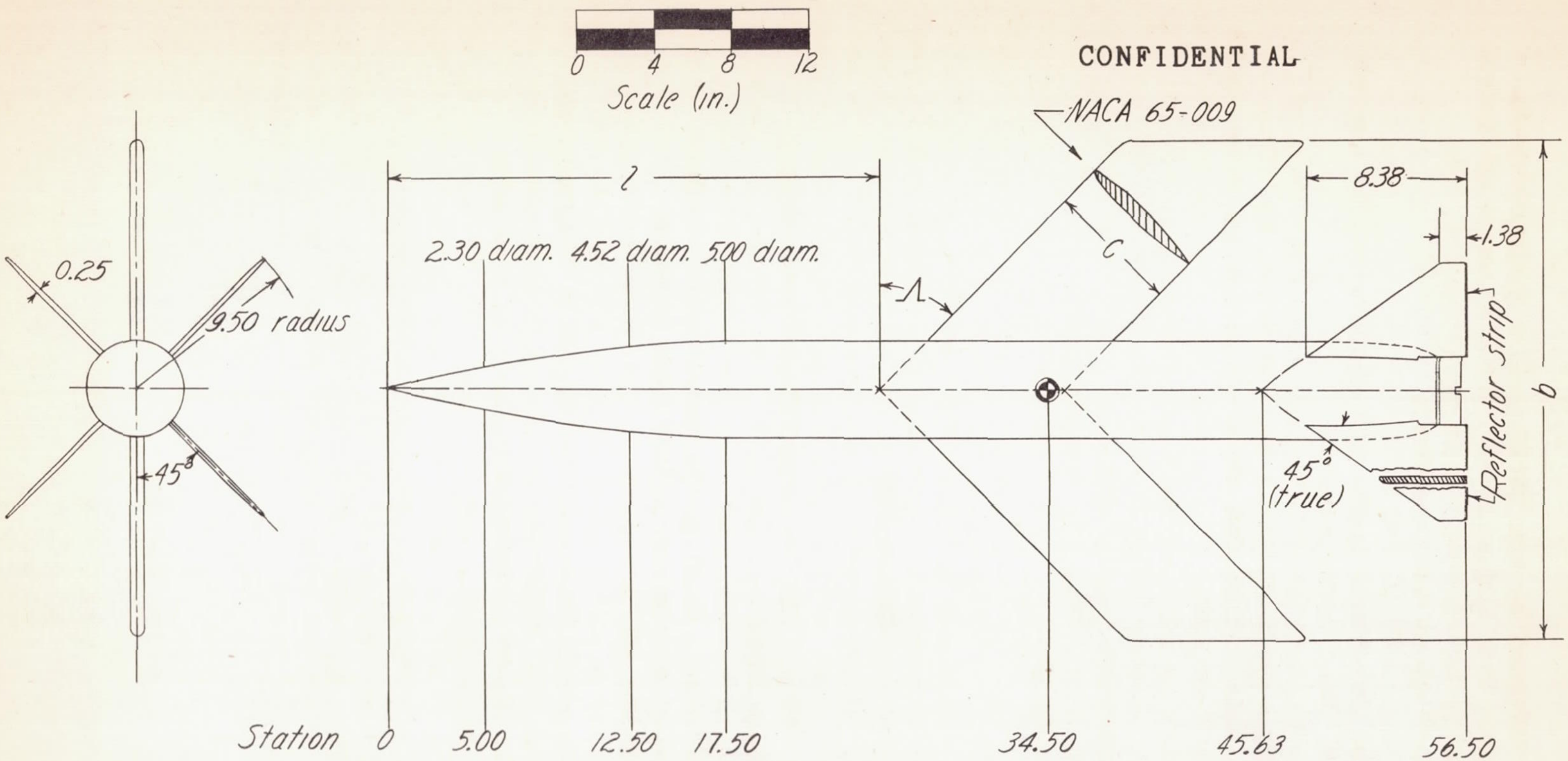

Configuration	Λ (deg)	A	b (in.)	c (in.)	l (in.)
1	0	1.5	20.00	13.33	31.28
2	34			11.05	28.02
3	45			9.43	26.46
4	52			8.21	25.13
5	0	2.7	25.73	9.65	32.09
6	34			8.00	27.74
7	45			6.88	25.76

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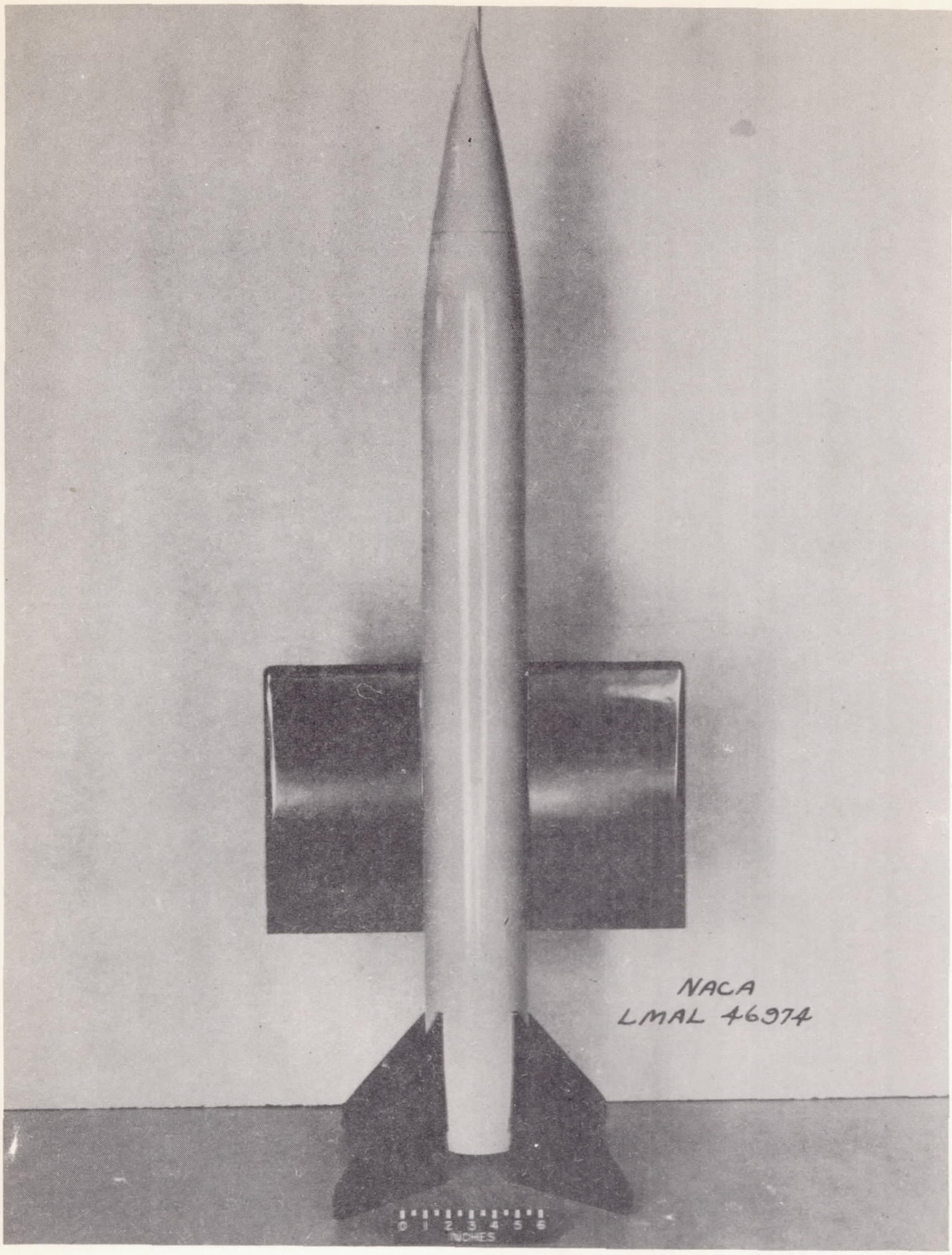
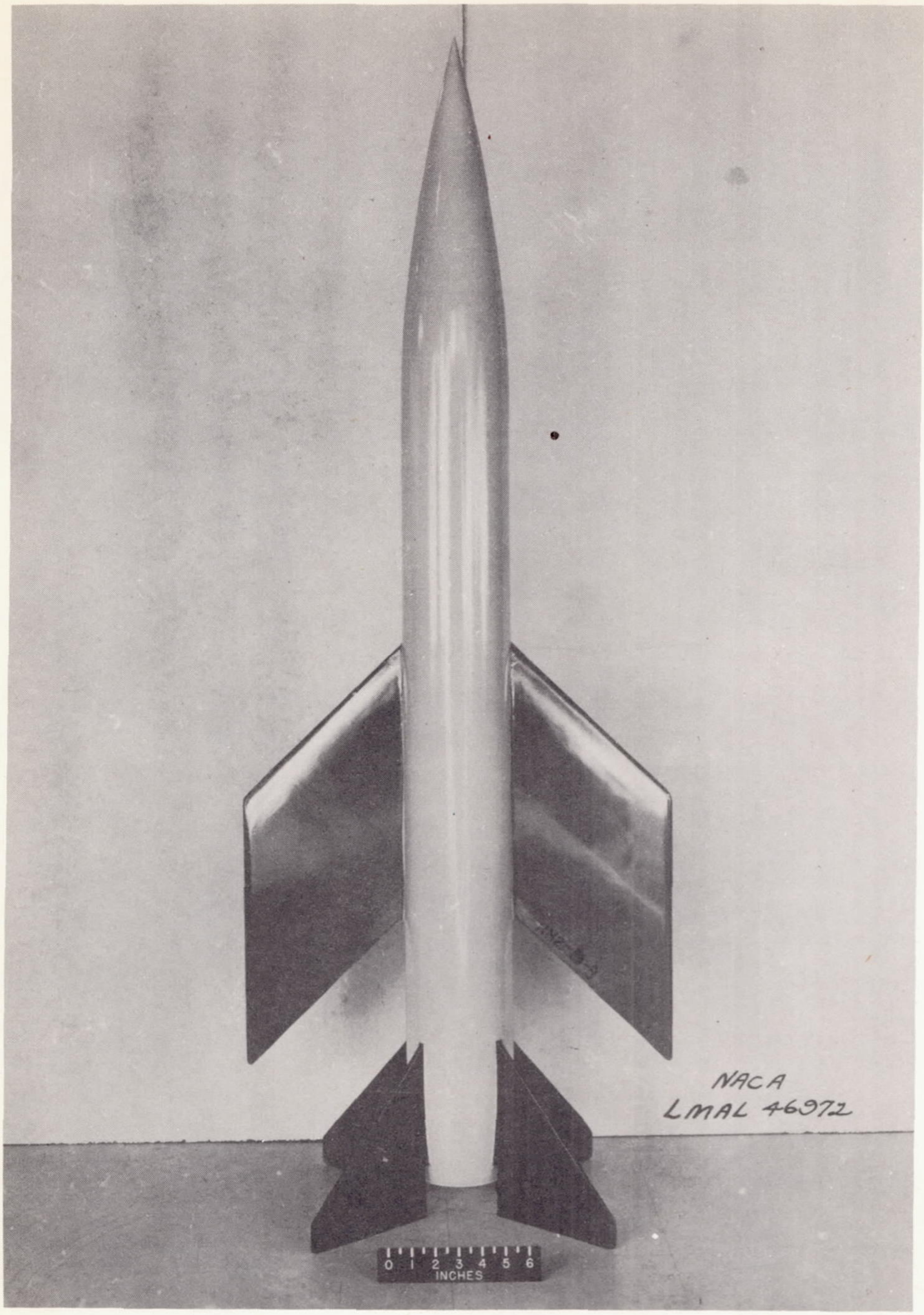
Figure 1.- General arrangement of test body indicating aspect ratios and sweepback angles investigated. Wing area (exposed), 200 sq in.; fin area (4 fins exposed), 136.5 sq in.; design weight (without propellant), 29.17 lb.



(a) $\Lambda = 0^{\circ}$.

Figure 2.- General views of test bodies of aspect ratio 1.5.



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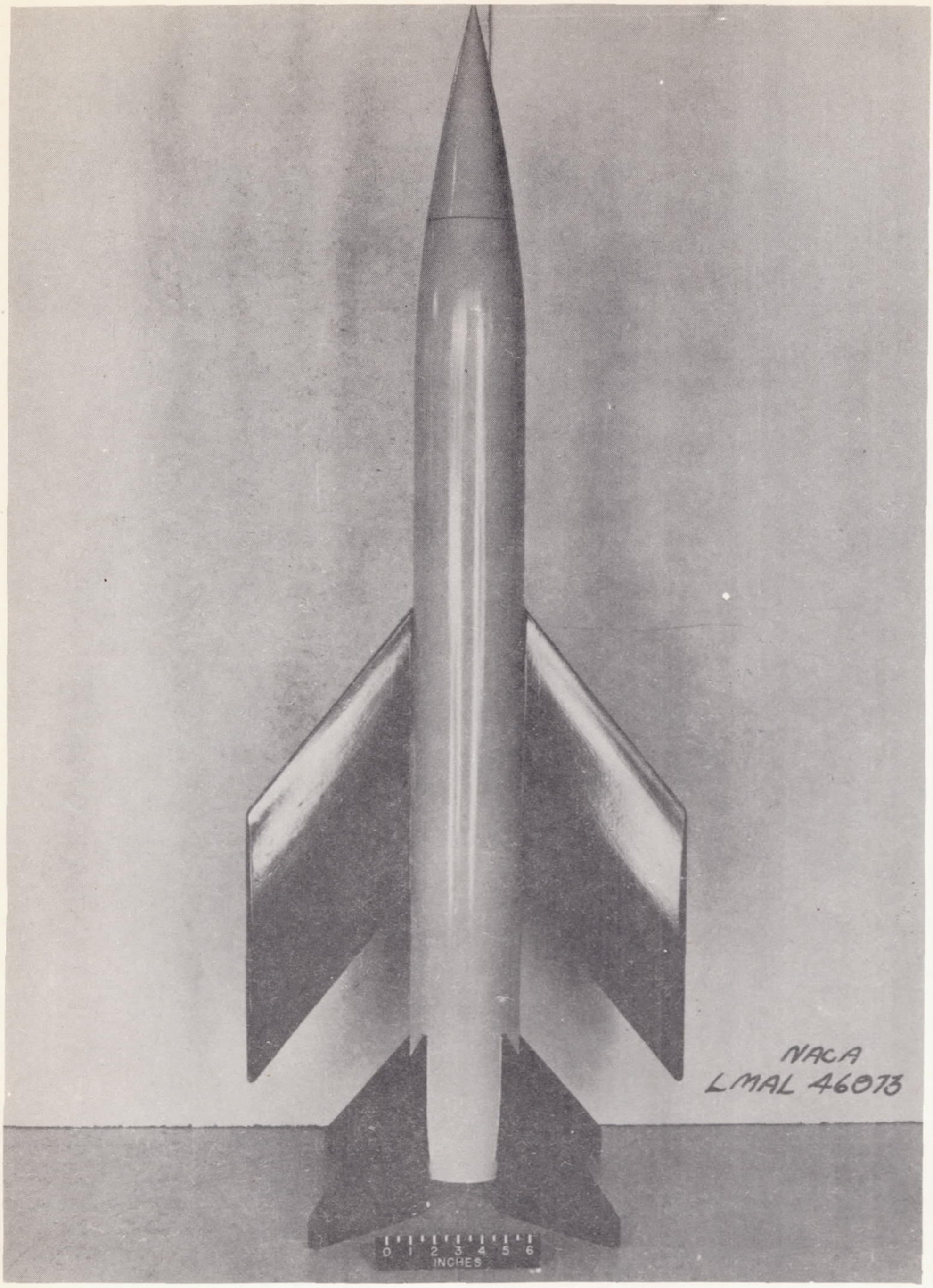
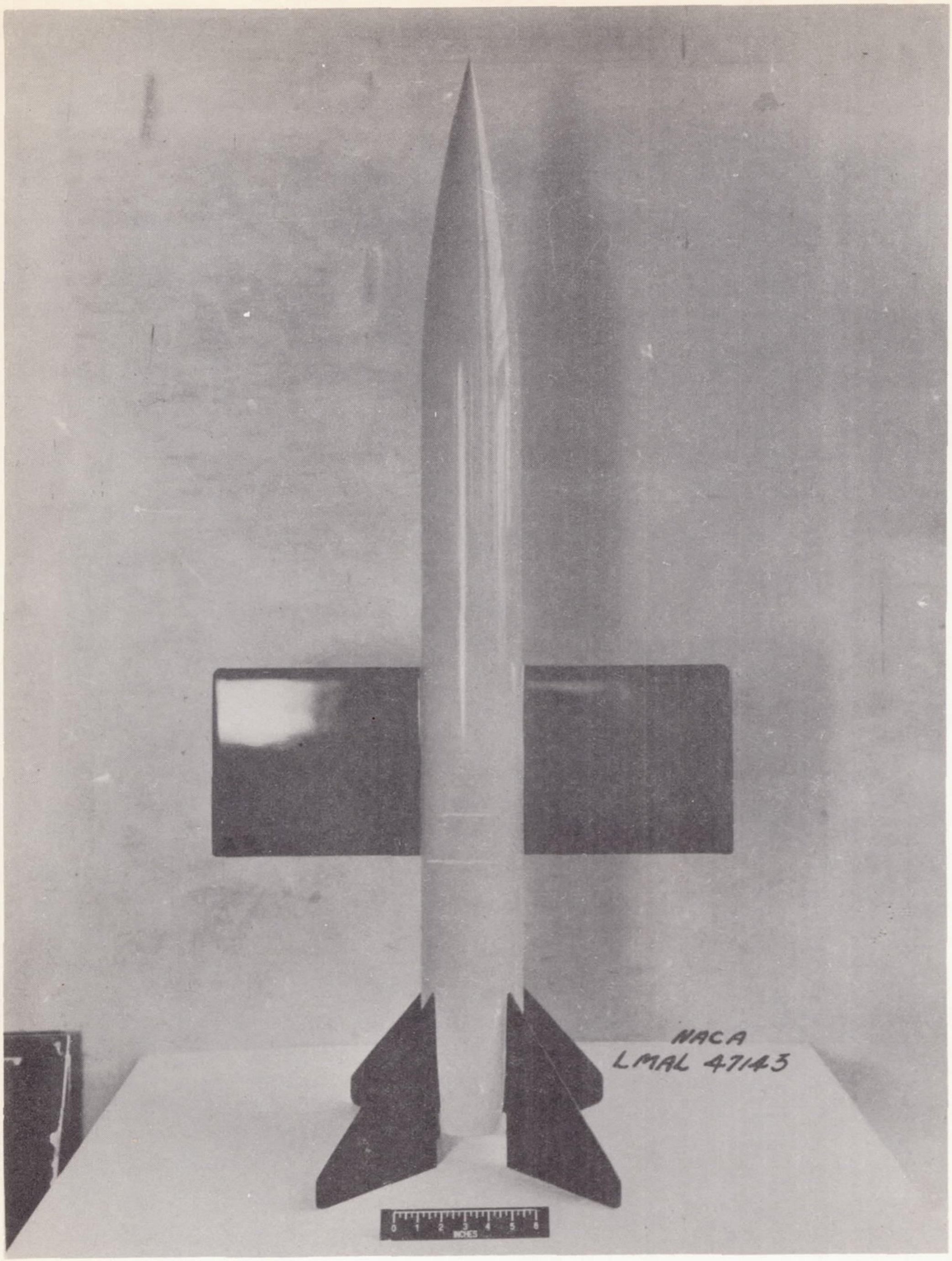
(b) $\Lambda = 45^{\circ}$.

Figure 2.- Continued.



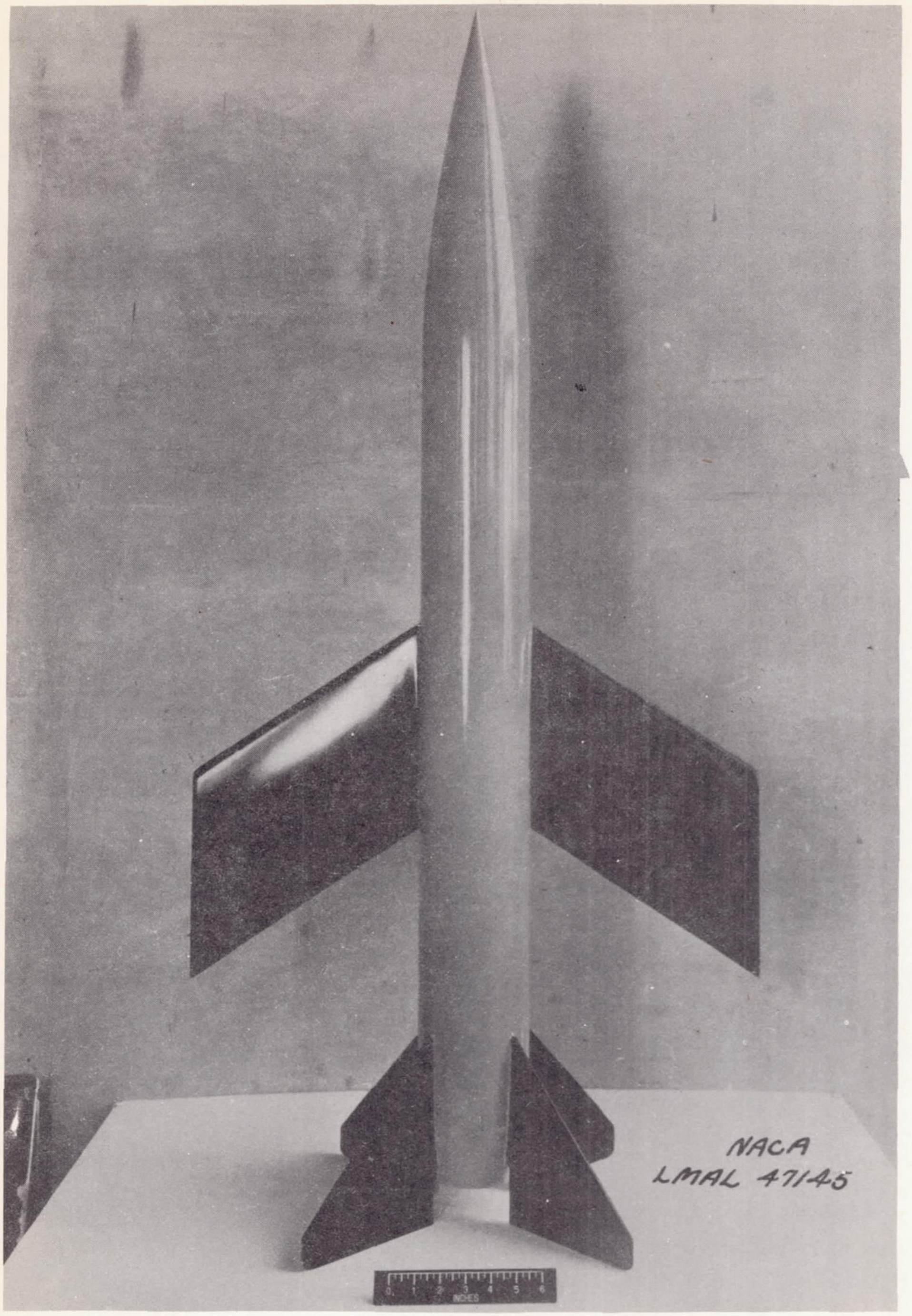
(c) $\Lambda = 52^{\circ}$.

Figure 2.- Concluded.



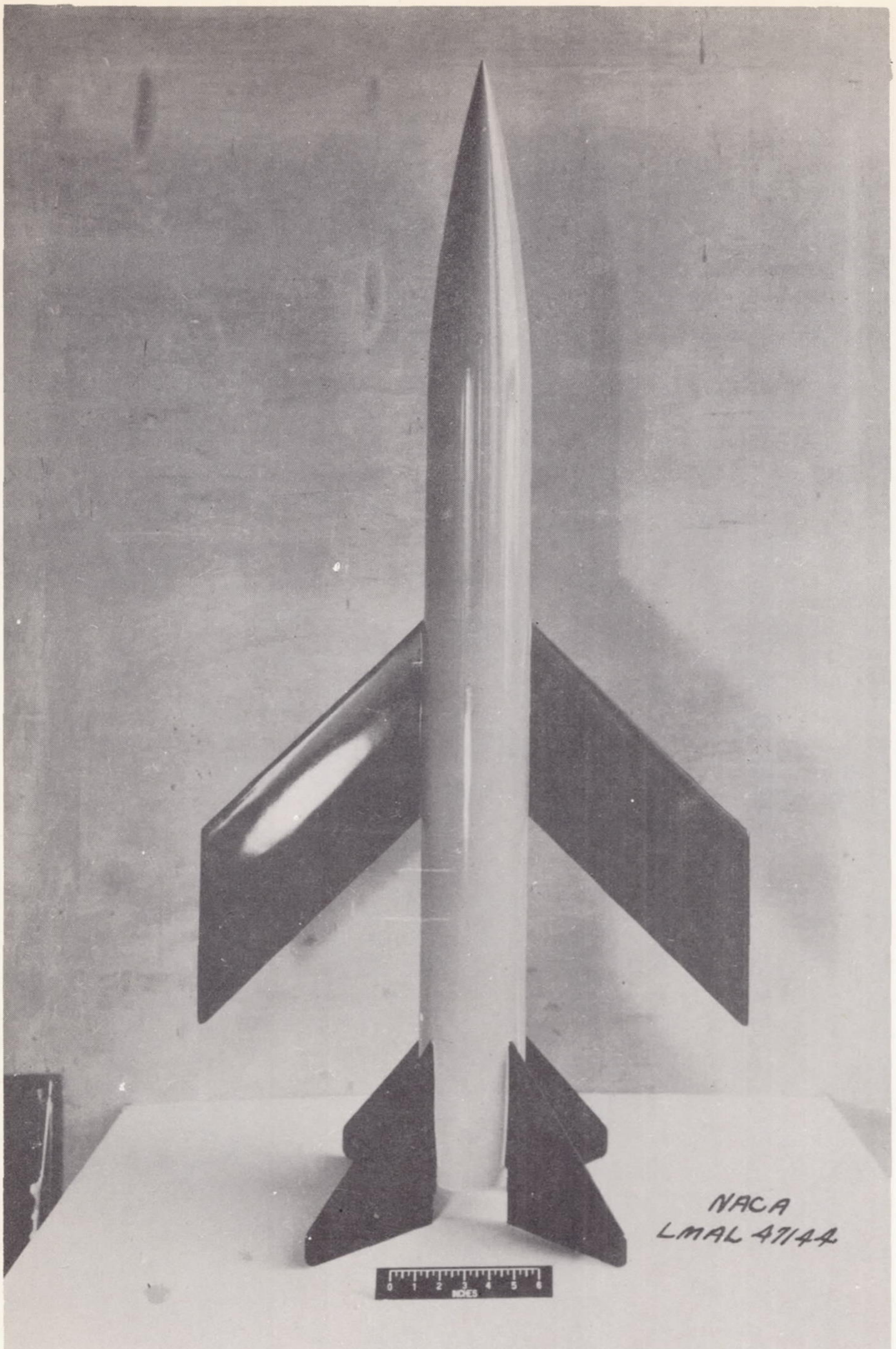
(a) $\Lambda = 0^{\circ}$.

Figure 3.- General views of test bodies of aspect ratio 2.7.



(b) $\Lambda = 34^{\circ}$.

Figure 3.- Continued.



(c) $\Lambda = 45^{\circ}$.

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Figure 3.- Concluded.

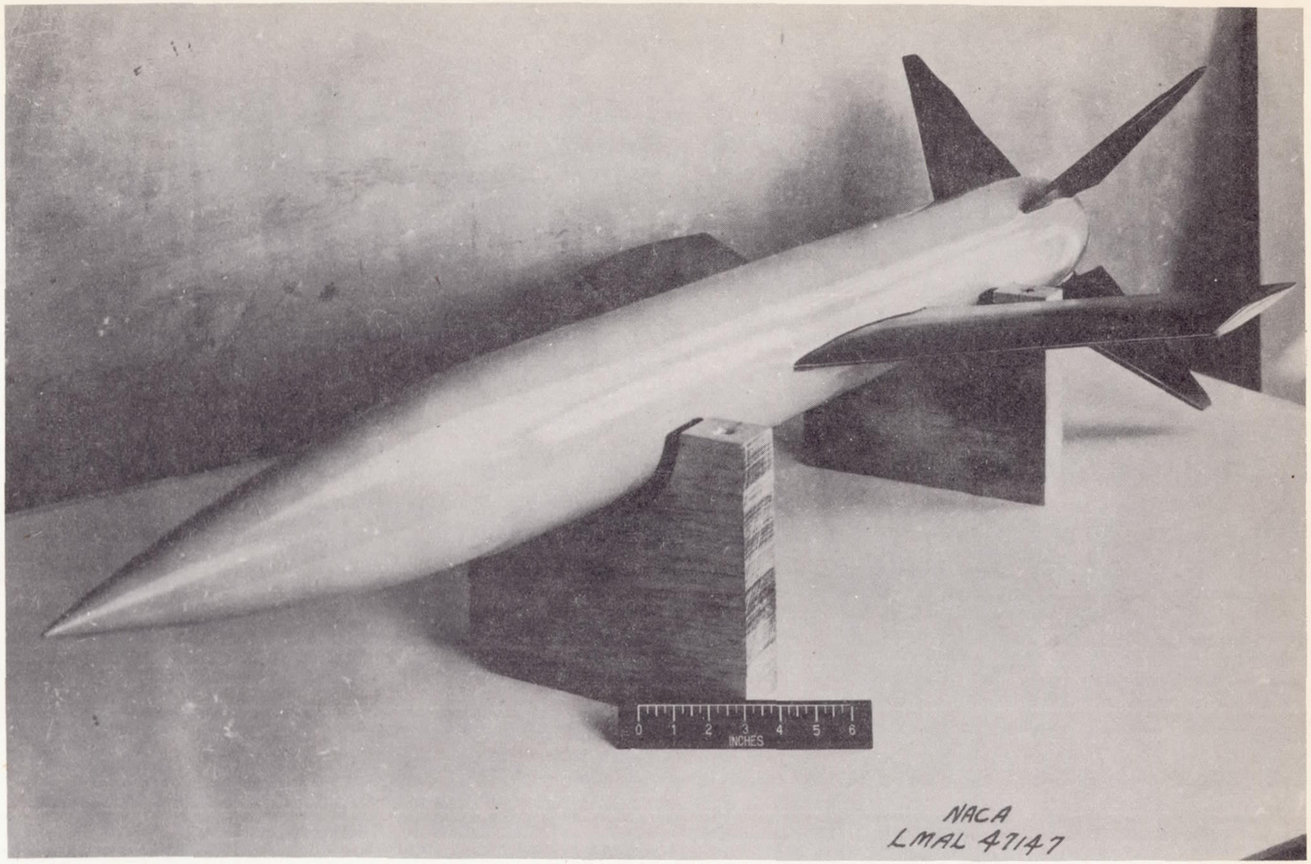
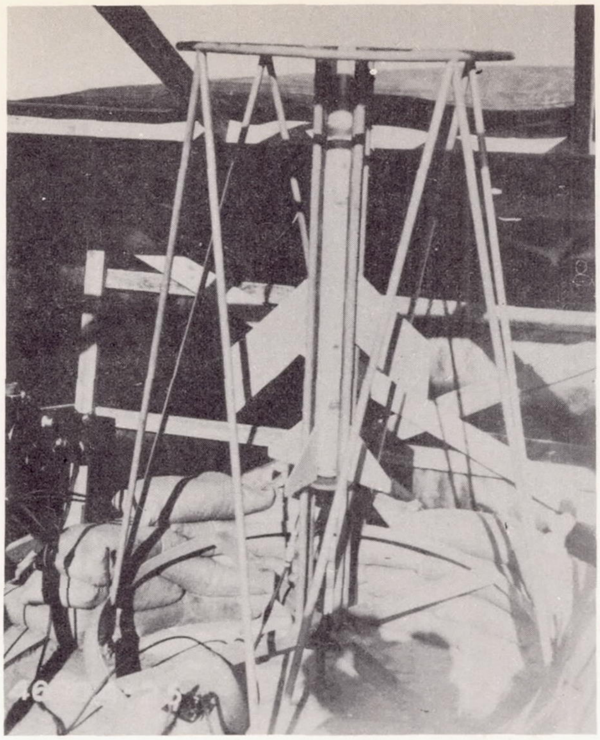
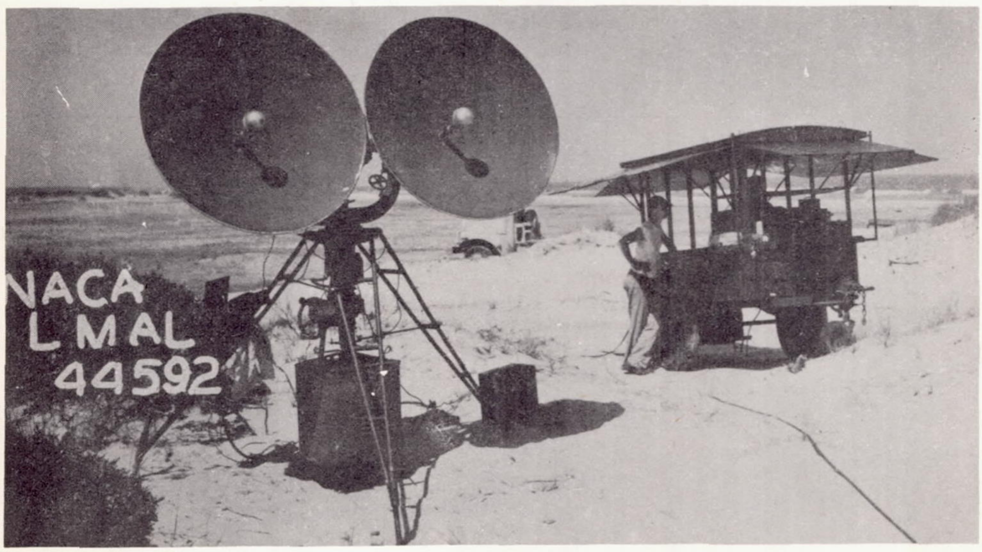


Figure 4.- Three-quarter front view of typical swept-back body arrangement.



(a) Close-up of body in launcher.



(b) CW Doppler radar unit (AN/TPS-5).

Figure 5.- General views of launcher and radar.

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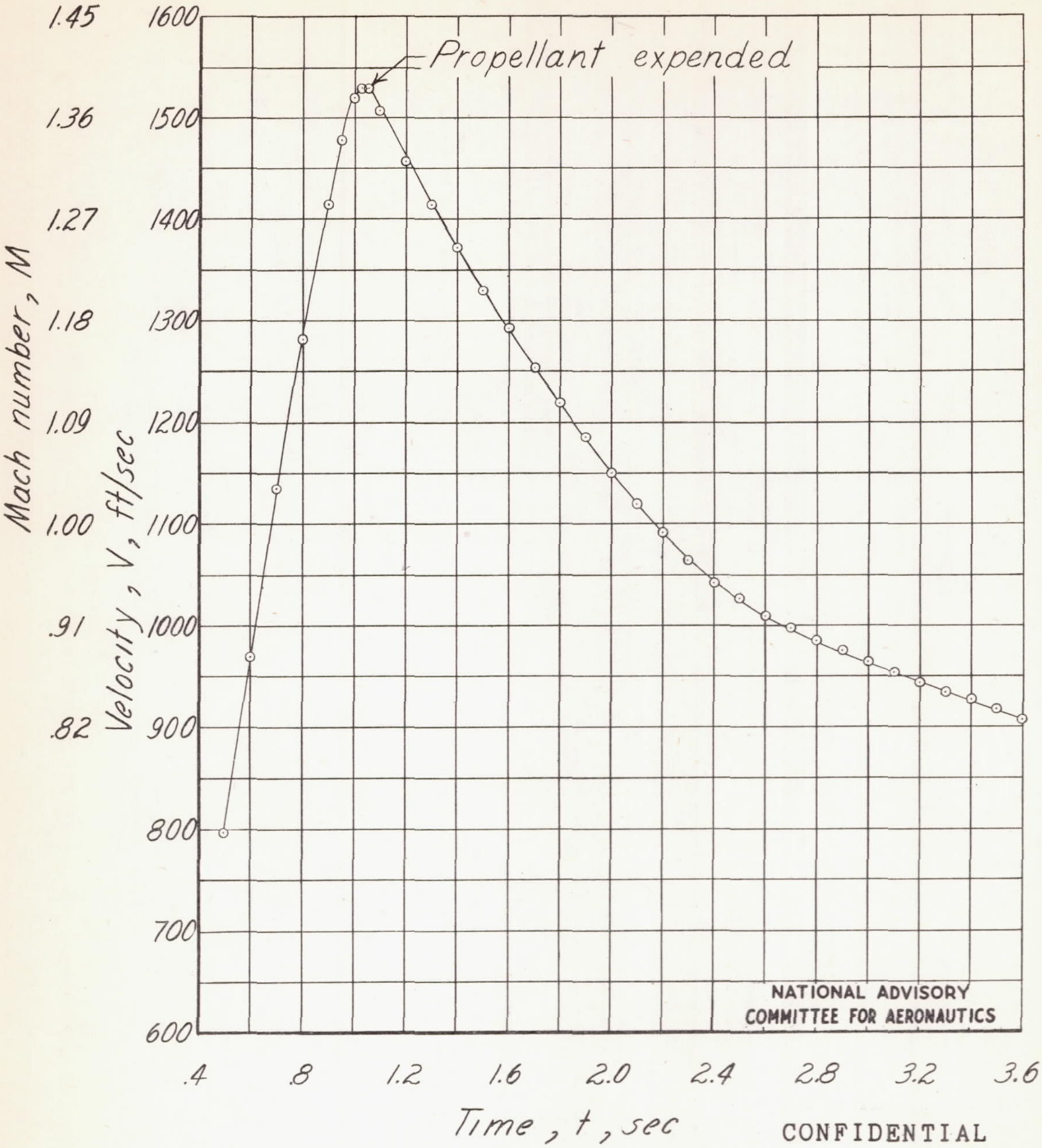

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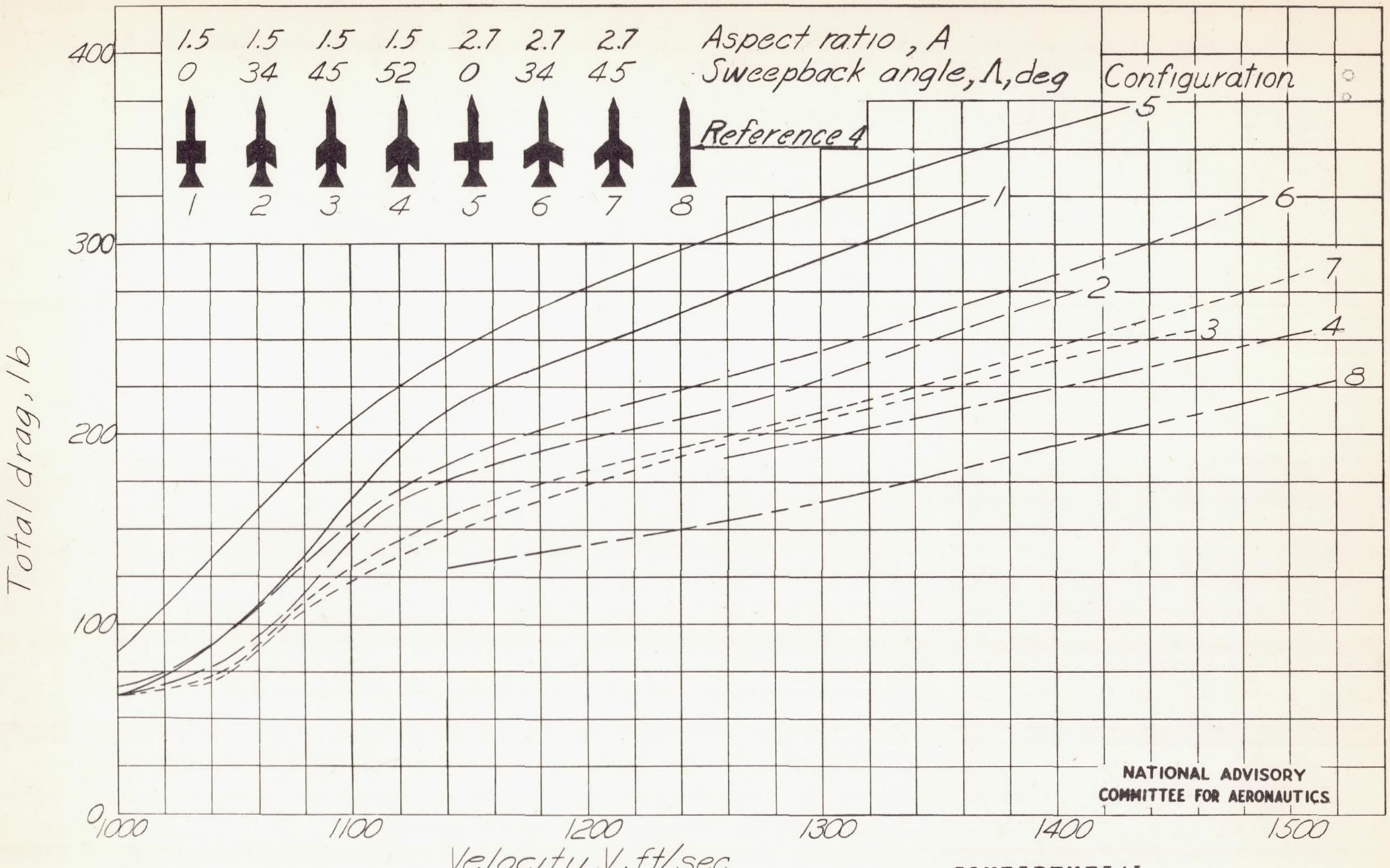
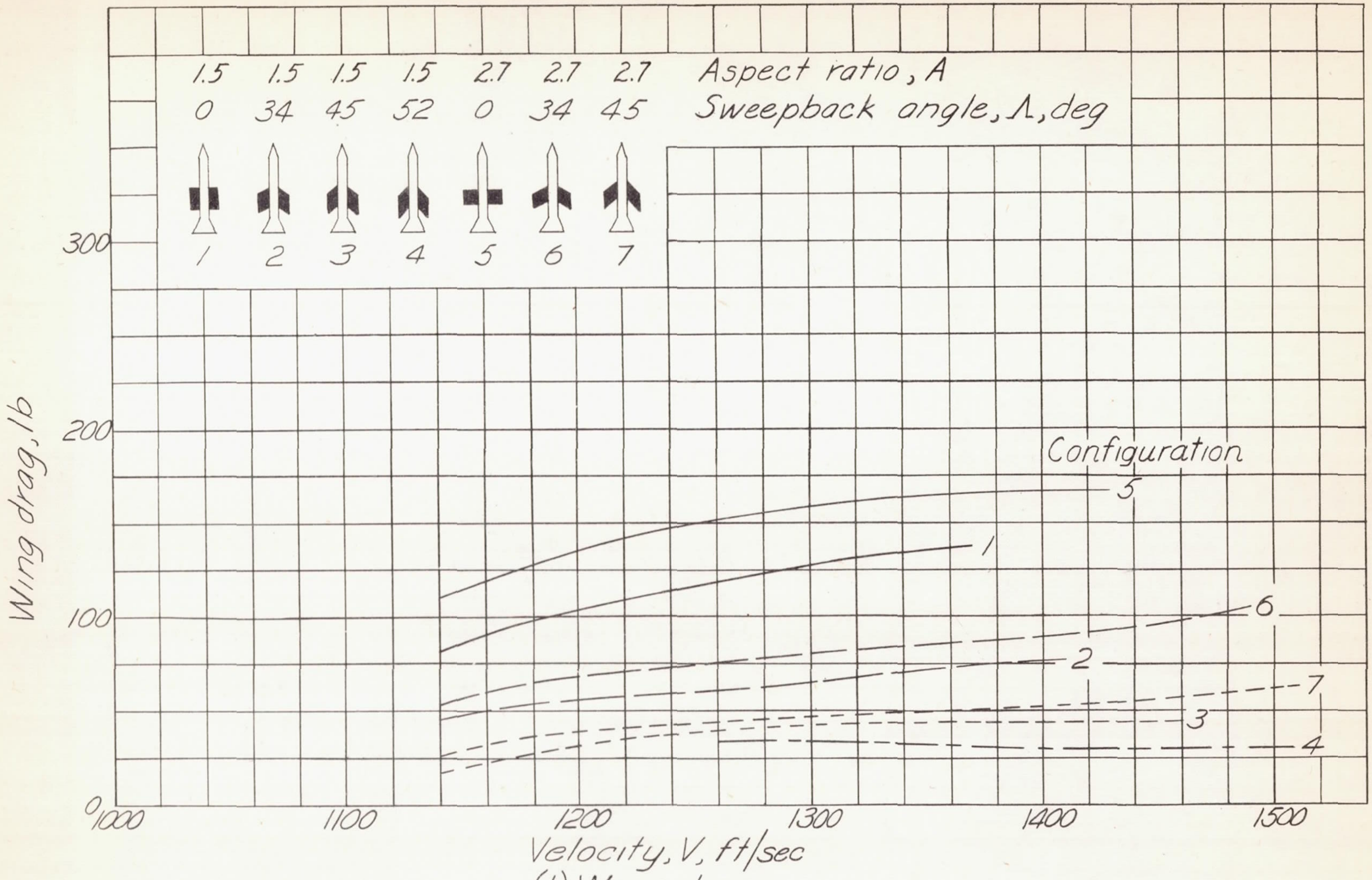
Figure 6.- Typical velocity-time curve.



(a) Total drag.

Figure 7.- Curves of total drag and wing drag for the sweepback angles and aspect ratios investigated.



(b) Wing drag.

Figure 7.-Concluded.

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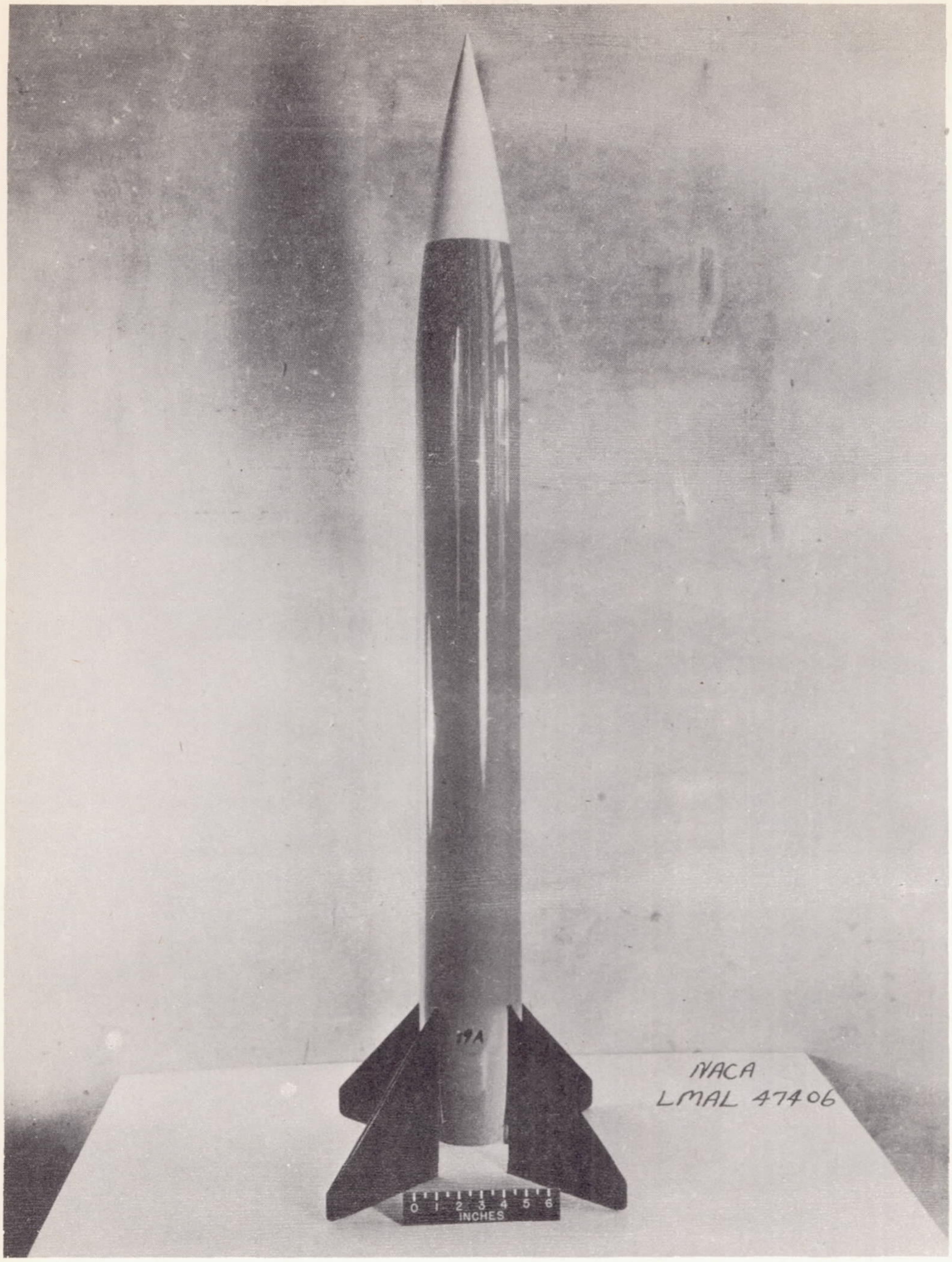
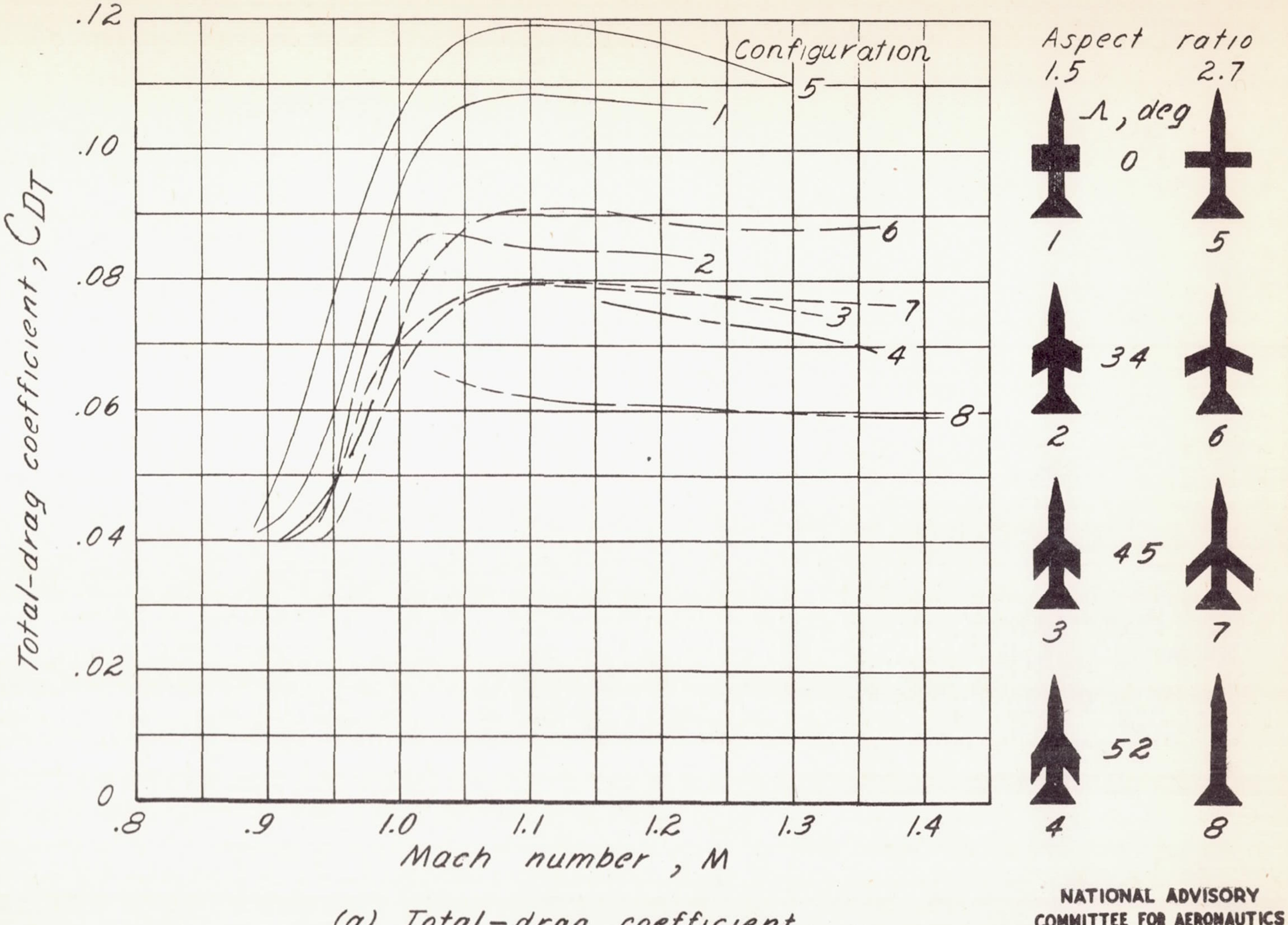
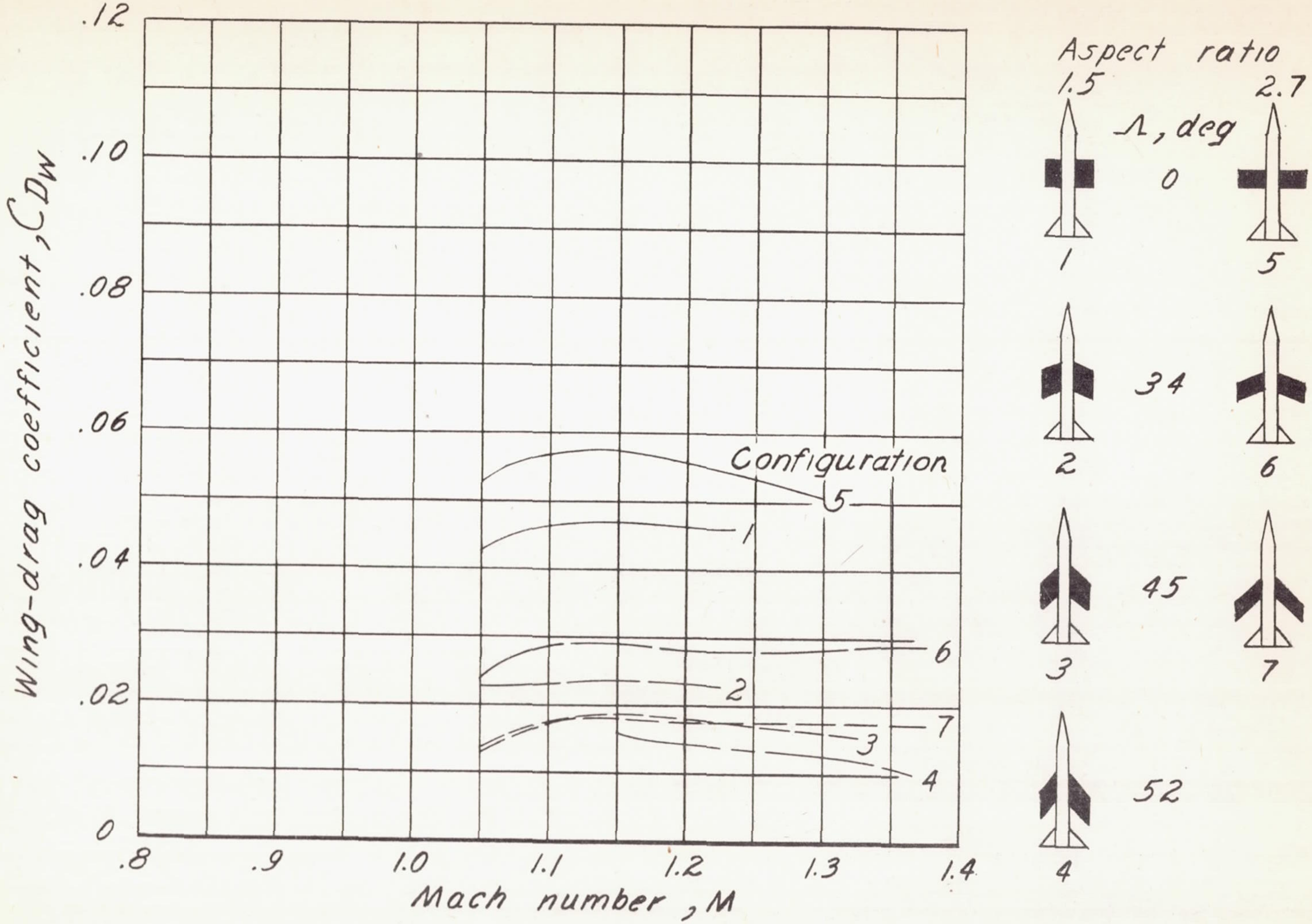


Figure 8.- The sharp-nose wingless body of reference 4.



(a) Total-drag coefficient.

Figure 9 .- Effect of sweepback angle and aspect ratio on total-drag coefficient and wing-drag coefficient.



(b) Wing-drag coefficient.

Figure 9.- Concluded.