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DRAG MEASUREMENTS OF SYMMETRICAL CIRCULAR-ARC AND NACA 65-009 RECTANGULAR AIRFOILS HAVING AN ASPECT RATIO OF 2.7 AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

By

Sidney R. Alexander

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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RESEARCH MEMORANDUM

DRAG MEASUREMENTS OF SYMMETRICAL CIRCULAR-ARC AND NACA 65-009 RECTANGULAR AIRFOILS HAVING AN ASPECT RATIO OF 2.7 AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

By Sidney R. Alexander

SUMMARY

Flight tests have been conducted at supersonic speeds to determine the drag characteristics at zero lift of a wing having a circular-arc airfoil section with a maximum thickness of 9 percent chord. The wing plan form was rectangular and had an aspect ratio of 2.7. Included for comparison are results of similar tests previously conducted on an NACA 65-009 airfoil. For the Mach number range investigated (0.85 to 1.22), the NACA 65-009 airfoil produced lower values of drag coefficient than the circular-arc airfoil. The difference in drag coefficients of the two airfoils was greatest at Mach numbers near 1.0.

INTRODUCTION

The possibility of practical flight at supersonic speeds has led to the study of airfoil shapes that differ basically in profile from conventional round-nose types. Comparisons of the characteristics of round-nose and sharp-nose airfoil sections at subsonic and supersonic speeds, respectively, have been reported in references 1 and 2. No theoretical data and only extremely meager experimental data on this general subject, however, are available for the transonic speed range (the region of mixed flow). Tests have therefore been conducted at the test station of the Langley Pilotless Aircraft Research Division at Wallops Island, Va., to determine the zero-lift drag of a rectangular, 9-percent circular-arc airfoil of aspect ratio 2.7 mounted on a rocket-propelled body. This value of aspect ratio is based on the total wing span and area including the part enclosed by the body. For comparison, the results of tests of the rectangular NACA 65-009 airfoil, which has the same aspect ratio, presented in reference 3 are included.

BODY AND TESTS

A photograph of the test body is shown as figure 1. The body was approximately 5 feet long and 5 inches in diameter and was of wooden construction. The 9-percent circular-arc airfoil, of 25.73-inch span, was mounted on the body so as to have the quarter-chord point at the same longitudinal station as the design center of gravity. The airfoil had neither taper, twist, nor dihedral. The leading and trailing edges were rounded off to a $\frac{1}{64}$-inch radius which was about 30 percent of the leading-edge radius of the NACA 65-series airfoil section. Except for airfoil section, the test body with the circular-arc airfoil and the comparable test body with the NACA 65-009 airfoil of reference 3 were alike. A comparison of the airfoil sections investigated is presented in figure 2. Although the conventional section has a rounded nose, the slope of the surface of the front part of the airfoil is much more gradual and the rear part is much finer than for the circular-arc airfoil. Two models of each configuration were fired under similar atmospheric conditions.

All the test bodies were propelled by 3.25-inch-diameter Mk. 7 aircraft rocket motors enclosed within the bodies. At a preignition temperature of 69° F, the rocket motor provides about 2200 pounds of thrust for approximately 0.87 second.

The test bodies, as well as the test bodies of reference 3, were launched at an elevation angle of 75° to the horizontal. Because of the high elevation angle and the short duration of burning of the rocket motor, the trajectory of the bodies during their supersonic coasting flight (after the propellant was expended) was approximately a straight line. The flight velocity was measured during this coasting period by means of a CW Doppler radar set (AN/TPS-5) located at the point of launching. The values of temperature and static pressure used in calculating drag coefficients and Mach number were obtained from radiosonde observations made at the time of firing.

RESULTS AND DISCUSSION

The variation of velocity with flight time for one of the circular-arc airfoil models, as measured with the radar unit, is presented in figure 3. The part of the velocity curve corresponding to the time during which coasting flight was attained (after the end of burning) was graphically differentiated to obtain the deceleration.

The values thus obtained are presented in figure 4 as a function of the flight velocity for two identical test bodies with circular-arc airfoils. Since these models were fired under identical atmospheric conditions, the difference between the curves can be partly attributed to the weight difference between the two models.

From the curves of figure 4, the total drag has been computed and is presented in figure 5 plotted against Mach number. With the model weight now taken into account, the variation of drag with Mach number should be the same, and consequently one curve was faired through the results of both tests, the average scatter of the calculated points from the faired line being approximately ±3 percent. Drag coefficients calculated from the data of figure 5 and based on an exposed wing area of 200 square inches are presented in figure 6(a). The corresponding curves for the test body with the NACA 65-009 airfoil and for an identical test body without wings are included for comparison. Figure 6(a) shows that, for Mach numbers between 0.85 and 1.22, the body with the NACA 65-009 wing produced lower values of total drag coefficient than did the body with the circular-arc wing. Generally similar results have been obtained recently by the Langley Flight Research Division using freely-falling-body technique. The greatest difference between the drags of the two wings can be seen to occur near a Mach number of 1.0. Corresponding curves of wing drag coefficient, derived by taking the difference between the winged and wingless bodies of figure 6(a), are presented in figure 6(b). The values of wing drag coefficient determined by this method include wing-fuselage-interference effects. Information concerning the variation of the drag-coefficient curves of the NACA 65-009 and the symmetrical circular-arc airfoils beyond the tested Mach number range could be established only by further investigation at higher speeds.

CONCLUDING REMARKS

The results of supersonic flight tests to determine the drag of a rectangular, 9-percent circular-arc airfoil of aspect ratio 2.7 mounted on a rocket-propelled body are presented. The drag coefficients of a similar test body with an NACA 65-009 airfoil obtained in the same manner have also been included for comparison. For Mach numbers between 0.85 and 1.22, the values of drag coefficient of the NACA 65-009 airfoil were lower than those produced by the circular-

arc airfoil. The difference in drag coefficients of the two airfoils was greatest near a Mach number of 1.0.

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

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1. Lindsey, W. F., Daley, Bernard N., and Humphreys, Milton D.: The Flow and Force Characteristics of Supersonic Airfoils at High Subsonic Speeds. NACA TN No. 1211, 1947.

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3. Alexander, Sidney R., and Katz, Ellis: 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. NACA RM No. L6J16, 1946.

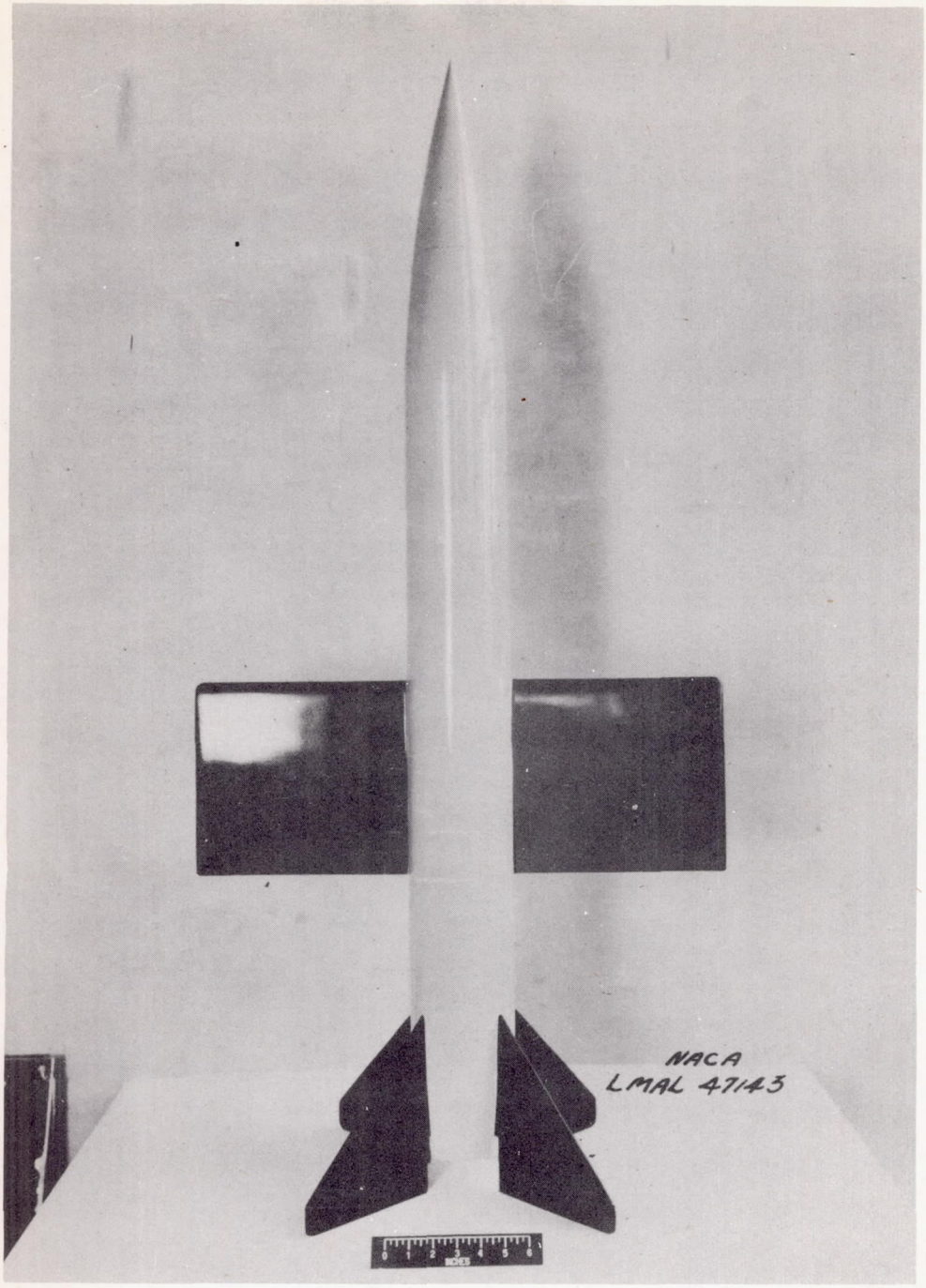
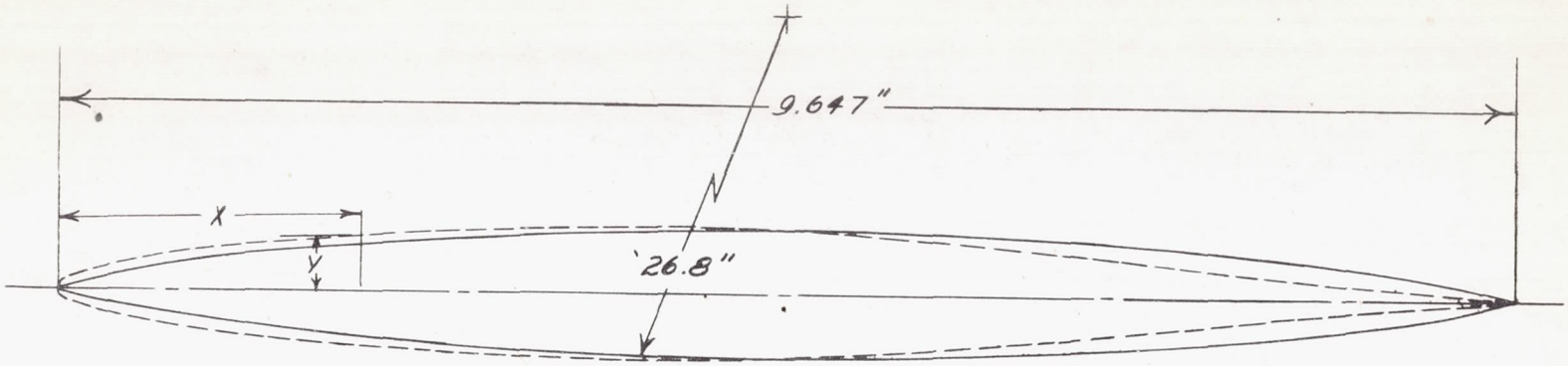


Figure 1.- General arrangement of test body with 9-percent circular-arc airfoil with an aspect ratio of 2.7.



NACA 65-009 airfoil coordinates in percent chord			
X	Y	X	Y
0	0	40	4.496
0.5	.700	45	4.469
0.75	.845	50	4.336
1.25	1.058	55	4.086
2.5	1.421	60	3.743
5.0	1.961	65	3.328
7.5	2.383	70	2.856
10	2.736	75	2.342
15	3.299	80	1.805
20	3.727	85	1.260
25	4.050	90	.738
30	4.282	95	.280
35	4.431	100	0
Leading-edge radius; 0.552			

——— Circular-arc airfoil

- - - - - - NACA 65-009 airfoil

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Figure 2.- Comparison of NACA 65-009 and circular-arc airfoil sections of equal thickness ratio.

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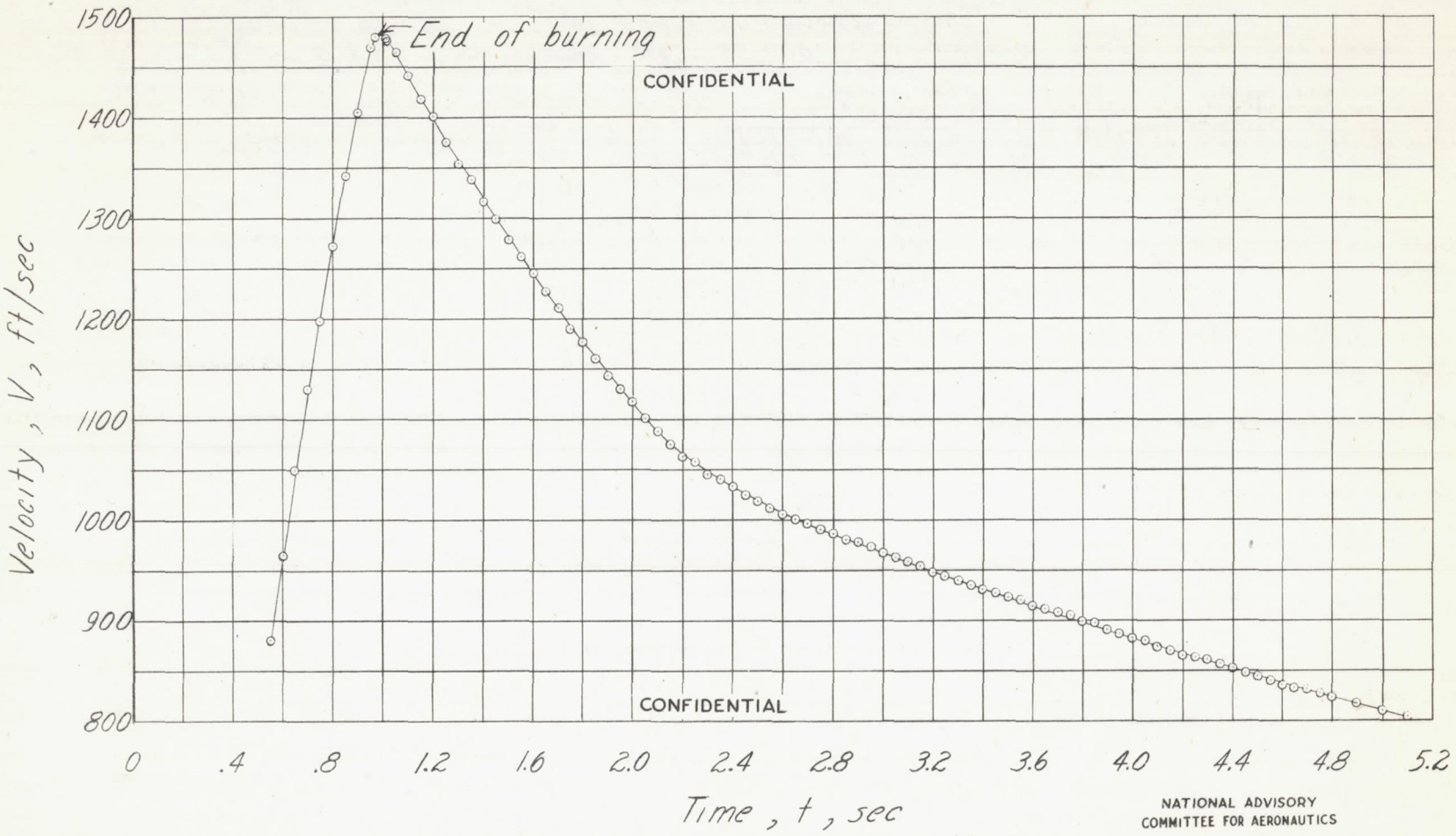

Figure 3.- Velocity-time curve. Test body with circular-arc airfoil of aspect ratio 2.7 and zero sweep.

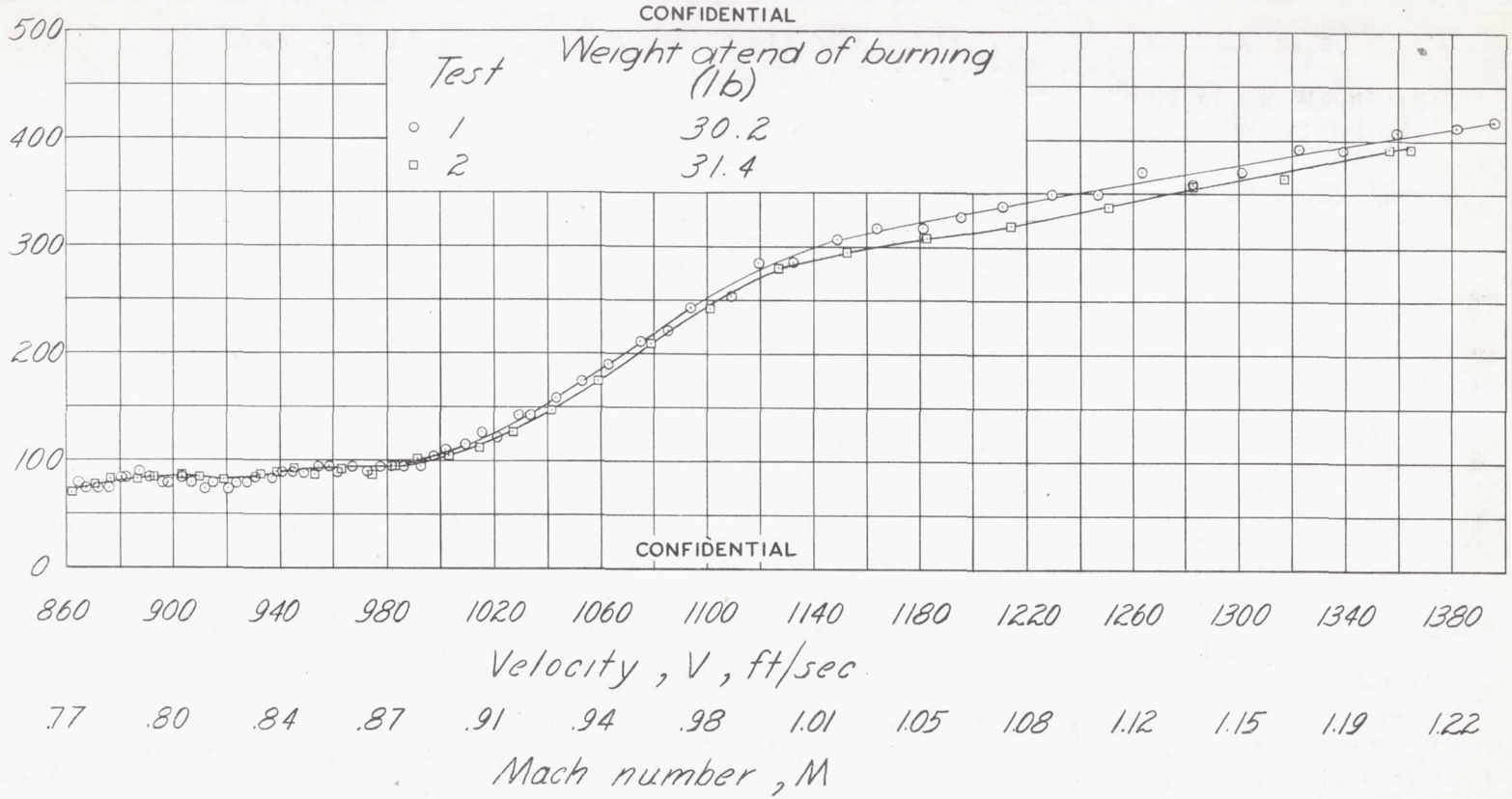

Figure 4.- Comparison of deceleration data for two identical test bodies with circular-arc airfoils of aspect ratio 2.7 and zero sweep.

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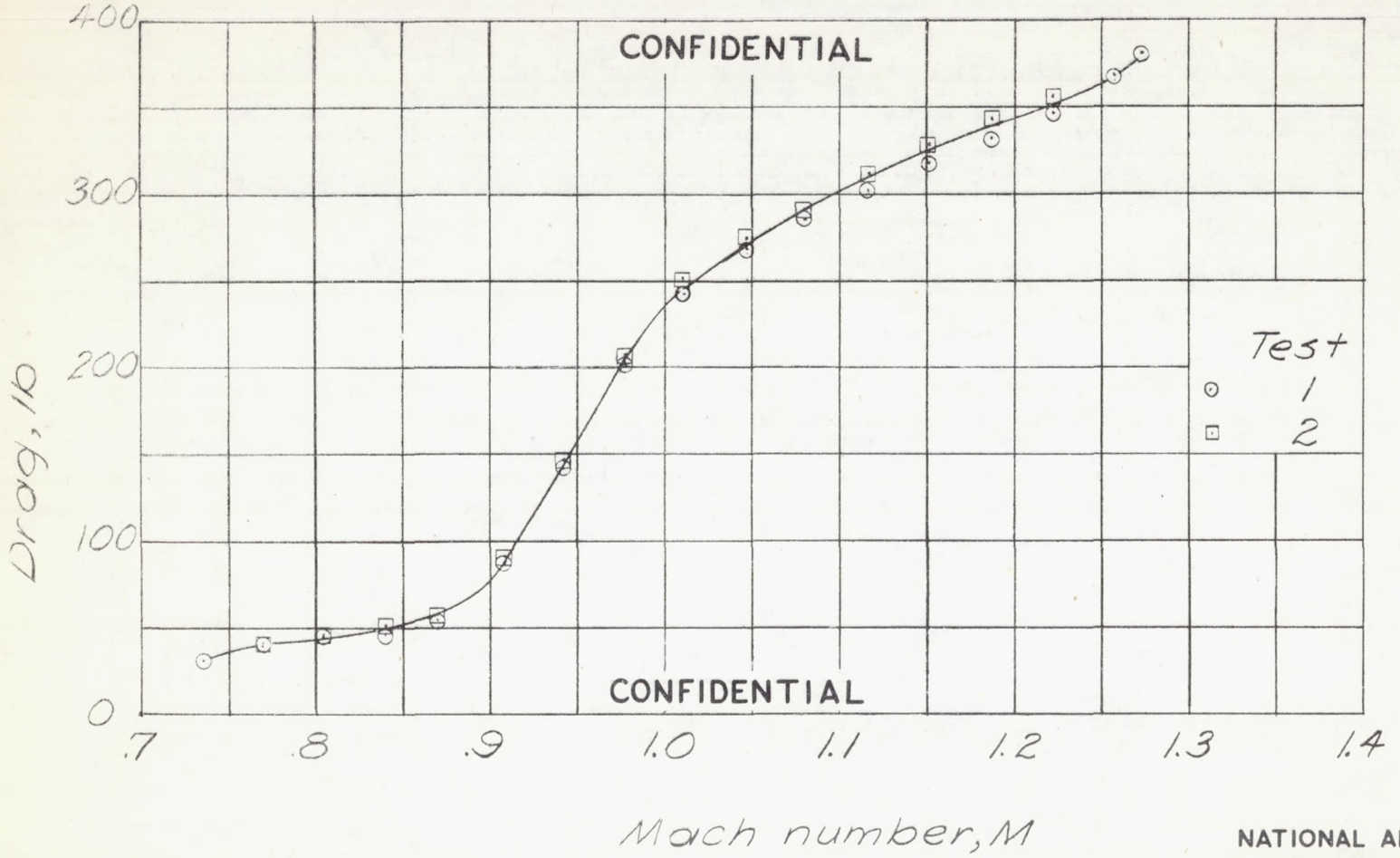

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Figure 5.- Drag curves for two identical test bodies with circular-arc airfoils of aspect ratio 2.7 and zero sweep

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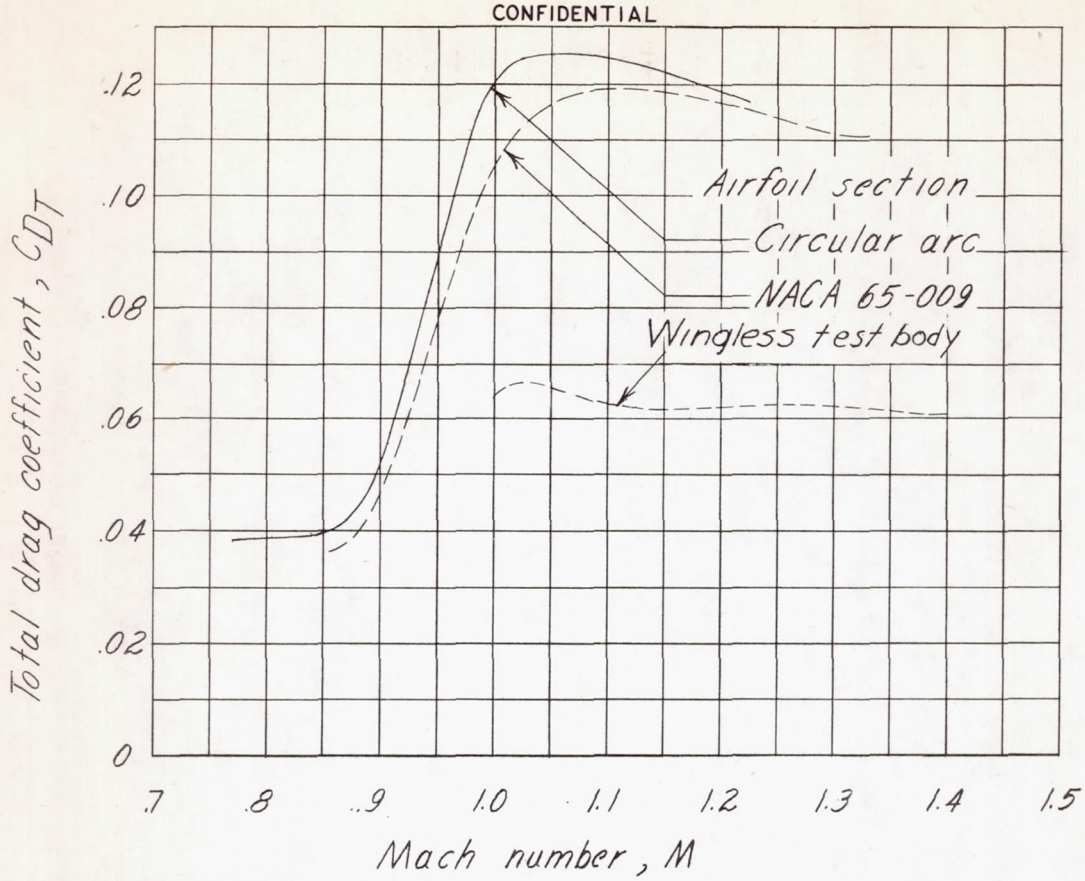
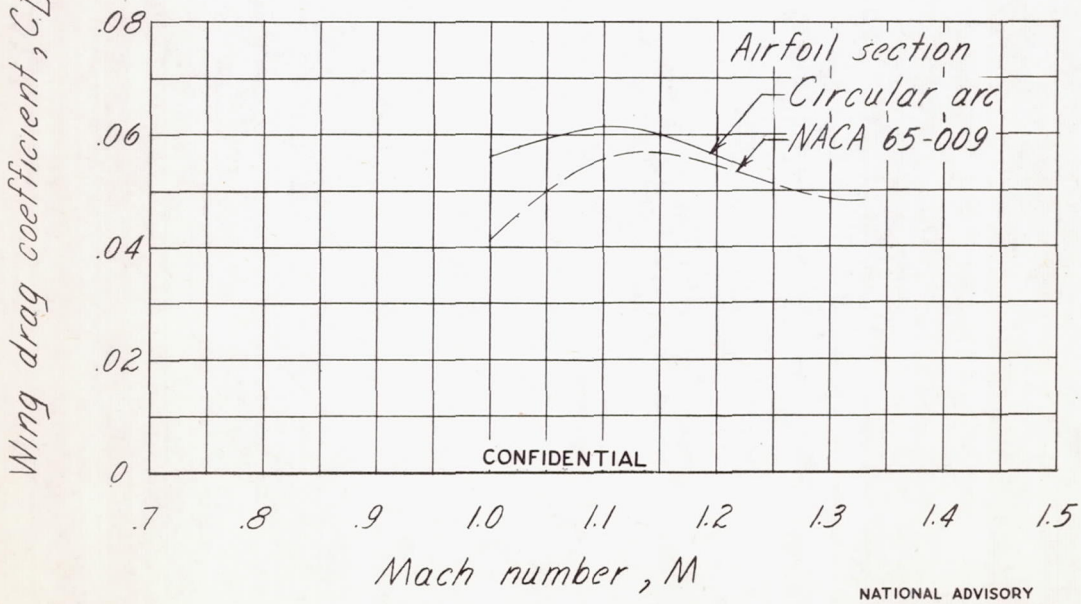


(a) Total drag coefficient.



(b) Wing drag coefficient.

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Figure 6.- Comparison of drag coefficients at zero lift for the test bodies with circular-arc and NACA 65-009 airfoils of aspect ratio 2.7 and zero sweep.