Copy No. 133
RM No. L8K23

CONFIDENTIAL

NACA

RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION AT TRANSONIC AND SUPERSONIC SPEEDS OF THE ROLLING EFFECTIVENESS OF SEVERAL AILERON CONFIGURATIONS ON A TAPERED WING HAVING 42.7° SWEEPBACK

By

Carl A. Sandahl

Langley Aeronautical Laboratory
Langley Field, Va.

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

January 11, 1949

CONFIDENTIAL

Classification cancelled (or changed to Unclassified

By Authority of NASA Tech Pub Announcement 92 15 NOV 55
(OFFICER AUTHORIZED TO CHANGE)

By NK

GRADE OF OFFICER MAKING CHANGE)

21 Apr. 61
DATE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION AT TRANSONIC AND SUPERSONIC SPEEDS OF THE ROLLING EFFECTIVENESS OF SEVERAL AILERON CONFIGURATIONS ON A TAPERED WING HAVING 42.7° SWEEPBACK

By Carl A. Sandahl

SUMMARY

An investigation was made of several aileron modifications in conjunction with a tapered, sweptback wing having circular-arc airfoil sections of relatively large thickness ratio. The modifications, all of which effectively reduced the aileron trailing-edge angle, included a straight-side extended-chord aileron, a parallel-side aileron of thickness equal to the wing thickness at the hinge line and having blunt trailing edges, and a straight-side aileron having a blunt trailing edge of thickness equal to one-half of the wing thickness at the hinge line. The modified ailerons eliminated the reversal of rolling effectiveness obtained with the true-contour ailerons at small deflections.

INTRODUCTION

In the early part of 1948, as part of an investigation of wing-aileron rolling effectiveness utilizing rocket-propelled test vehicles in free flight, tests were made of an 0.2-chord, outboard half-semispan, true-contour aileron in conjunction with a wing which had an aspect ratio of 4.00, a taper ratio of 0.5, a sweepback angle of 40° measured at the quarter-chord line, and circular-arc airfoil sections of 10-percent-thickness ratio normal to the quarter-chord line. The above tests, which are reported in reference 1, indicated reversal of the rolling effectiveness in the Mach number range from 0.94 to 1.00 for small aileron deflections. It was believed that the relatively large trailing-edge angle of the circular-arc sections contributed to the observed reversal of effectiveness.

Following the previously mentioned tests, an investigation was conducted by means of the "transonic bump" technique in the Langley 7- by 10-foot high-speed tunnel for the purpose of developing an aileron for the wing configuration used in the free-flight tests which would not produce reversal at transonic speeds. It was desired that the modifications be limited to the aileron only; the remainder of the wing was to be unmodified. Several satisfactory aileron configurations were developed in the "transonic bump" tests which are reported in reference 2. Confirmatory free-flight tests of these configurations were subsequently performed at larger scale and are the subject of the present paper.

In the present investigation, outboard, inboard, and full-span ailerons were tested. The inboard and full-span ailerons had true-contour profiles. The outboard ailerons were tested with several profile modifications including straight-side extended-chord ailerons, parallel-side ailerons of thickness equal to the wing thickness at the hinge line having blunt trailing edges, and straight-side ailerons having a blunt trailing edge of thickness equal to one-half of the wing thickness at the hinge line.

The present investigation, which was made by means of the technique described in references 3 and 4, permits the evaluation of the wing-aileron rolling effectiveness over the Mach number range from about 0.6 to 1.9 at relatively large scale. The variation of drag coefficient with Mach number was also obtained.

SYMBOLS

$\frac{pb}{2V}$	wing-tip helix angle, radians
p	rolling velocity, radians per second
b	diameter of circle swept by wing tips, feet
V	flight-path velocity, feet per second
C_D	total-drag coefficient based on total exposed area of basic wing (1.563 sq ft)
M	Mach number
R	Reynolds number based on average exposed chord of basic wing (0.55 ft)
c	wing chord parallel to model center line
δ_a	aileron deflection measured in plane normal to chord plane and to aileron hinge line

$\frac{\theta}{m}$ wing torsional-stiffness parameter

m concentrated couple applied near wing tip in plane parallel to model center line and normal to wing chord plane, inch-pounds

θ angle of twist produced by m at any section along wing span in plane parallel to that of m, radians

TEST VEHICLES AND TESTS

The general arrangement of the test vehicles is shown in figures 1 and 2. Further pertinent information is contained in table I. The test vehicles, which were relatively simple, inexpensive, and expendable, consisted of a pointed cylindrical wooden body to which the particular wing-aileron configuration under investigation was attached in a three-panel arrangement. Unpublished tests of 3- and 4-panel arrangements indicate that, with regard to the rolling-effectiveness characteristics, the interference effects between the wings were negligible. A small radio transmitter, designated spinsonde, which produced a plane polarized signal was enclosed in the pointed nose of the body for the measurement of rolling velocity. The wings, which were constructed mainly of wood, were stiffened by means of steel plates cycle-welded into the upper and lower wing surfaces as shown in figure 1. The measured torsional-stiffness characteristics of two typical wings are shown in figure 3. The degree of torsional stiffness indicated by the curves of figure 3 has been shown by tests reported in reference 4 to be sufficient to make the effects of wing twisting negligible.

The geometric details of the wing-aileron configurations tested are shown in figure 4. The configuration shown in figure 4(a) is that of reference 1. The ailerons were formed by deflecting the chord line of the basic section at the indicated hinge line. This method of construction simulates plain, sealed ailerons in actual aircraft construction. For the majority of the test flights the aileron deflection was 5°.

The test vehicles were propelled by a two-stage rocket-propulsion system to a Mach number of about 1.9. During coasting flight following burnout of the rocket motor, time histories of the rolling velocity produced by the ailerons (obtained with spinsonde radio equipment) and the flight-path velocity (obtained with Doppler radar) were recorded. These data, in conjunction with atmospheric data obtained with radiosondes, permitted the evaluation of the rolling-effectiveness parameter $pb/2V$ as a function of Mach number. Also the drag coefficient of the test vehicles was obtained by a process involving the graphic differentiation of the curve of flight-path velocity against time. The scale of the tests is indicated by the curve of Reynolds number against Mach number shown in figure 5. A more complete description of the technique is given in references 3 and 4.

ACCURACY

The accuracy of the test results is estimated to be within the following limits:

$\frac{pb}{2V}$ (due to limitations on model constructional accuracy) . . . . ±0.005

$\frac{pb}{2V}$ (due to limitations on instrumentation) . . . . ±0.0005

C_D . . . . ±0.002

M . . . . ±0.005

In figure 6 is shown the effect of the moment of inertia about the roll axis on the measured variation of $pb/2V$ with Mach number. The correction was made by the method described in reference 3 using an arbitrarily estimated value of −0.2 for the damping-in-roll derivative over the entire Mach number range. The value of −0.2 is probably very approximate; it was simply chosen to show that the magnitude of the correction is small for any reasonable negative value of the damping-in-roll derivative. The data presented herein have not been corrected for inertia effects.

RESULTS AND DISCUSSION

The results of the present investigation are shown in figure 4 as curves of the wing-tip helix angle $pb/2V$ and total-drag coefficient C_D against Mach number. In each part of figure 4 is shown a drawing of the particular wing-aileron configuration for which the experimental results are presented.

True-contour ailerons.- The experimental results for the outboard, inboard, and full-span true-contour ailerons are shown in figures 4(a), 4(b), and 4(c), respectively, and are summarized in figure 7. The results shown in figure 4(a) are from reference 1 and were obtained with two pairs of models. The pairs differed nominally only in the aileron deflection.

The effectiveness of the outboard ailerons was reversed in the Mach number range from about 0.94 to 1.0 for $\delta_a = 5^{\circ}$; no reversal was obtained with $\delta_a = 10^{\circ}$. The effectiveness of the inboard ailerons also reversed but at slightly lower Mach numbers than for the outboard ailerons. No reversal was obtained for the full-span ailerons, and except for the Mach number range for which reversal was obtained for the partial-span ailerons the sum of the measured values of effectiveness for the inboard and outboard partial-span ailerons was approximately equal to the effectiveness measured for the full-span ailerons.

Extended-chord ailerons.- The results obtained for the extended-chord aileron deflected 5° are shown in figure 4(d). The rolling effectiveness of this configuration was higher than that obtained for the original ailerons over the Mach number range investigated and no reversal was obtained. A small jog in the effectiveness curve, similar to that obtained for the true-contour ailerons, was encountered just below a Mach number of 1.

Blunt trailing-edge ailerons.- The experimental results for the blunt trailing-edge ailerons, deflected 5°, are shown in figure 4(e). The effectiveness of the parallel-side ailerons varied smoothly and continuously over the entire Mach number range investigated. A small loss in effectiveness just below a Mach number of 1 was obtained for the flat-side aileron having a trailing-edge thickness equal to one-half of that of the parallel-side aileron. At the extremities of the investigated Mach number range, the effectiveness for both blunt trailing-edge ailerons was only slightly less than that of the original true-contour ailerons. At supersonic velocities the drag of the blunt trailing-edge-aileron configurations was only slightly larger than that of the original ailerons; at subsonic velocities a measurable increase in drag was obtained for the blunt trailing-edge configurations. The results obtained for the blunt trailing-edge ailerons indicate that separation of the boundary layer over the rearward part of the airfoil section was partly responsible for the reversal of effectiveness obtained for the true-contour ailerons.

The results obtained in the present investigation are in agreement with those of reference 2 as regards the relative effectiveness of the various configurations tested.

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

REFERENCES

1. Sandahl, Carl A.: Free-Flight Investigation at Transonic and Supersonic Speeds of the Rolling Effectiveness of a 42.7° Sweptback Wing Having Partial-Span Ailerons. NACA RM No. L8E25, 1948.

2. Turner, Thomas R., Lockwood, Vernard E., and Vogler, Raymond D.: Preliminary Investigation of Various Ailerons on a 42° Sweptback Wing for Lateral Control at Transonic Speeds. NACA RM No. L8D21, 1948.

3. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM No. L7D02, 1947.

4. Sandahl, Carl A.: Free-Flight Investigation of Control Effectiveness of Full-Span, 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Wing Sweepback, Taper, Aspect Ratio, and Section Thickness Ratio. NACA RM No. L7F30, 1947.

TABLE I

PHYSICAL CHARACTERISTICS OF TEST VEHICLES WITH ORIGINAL AILERONS

Total exposed wing area, sq ft	1.563
Aspect ratio	[a]4.00
Taper ratio	[a]0.50
Sweepback of wing leading edge, deg	42.7
Sweepback of wing trailing edge, deg	30.5
Moment of inertia about roll axis, slug-ft^2	0.056

[a]Obtained by extending leading and trailing edges to center line of test vehicle.

CONFIDENTIAL

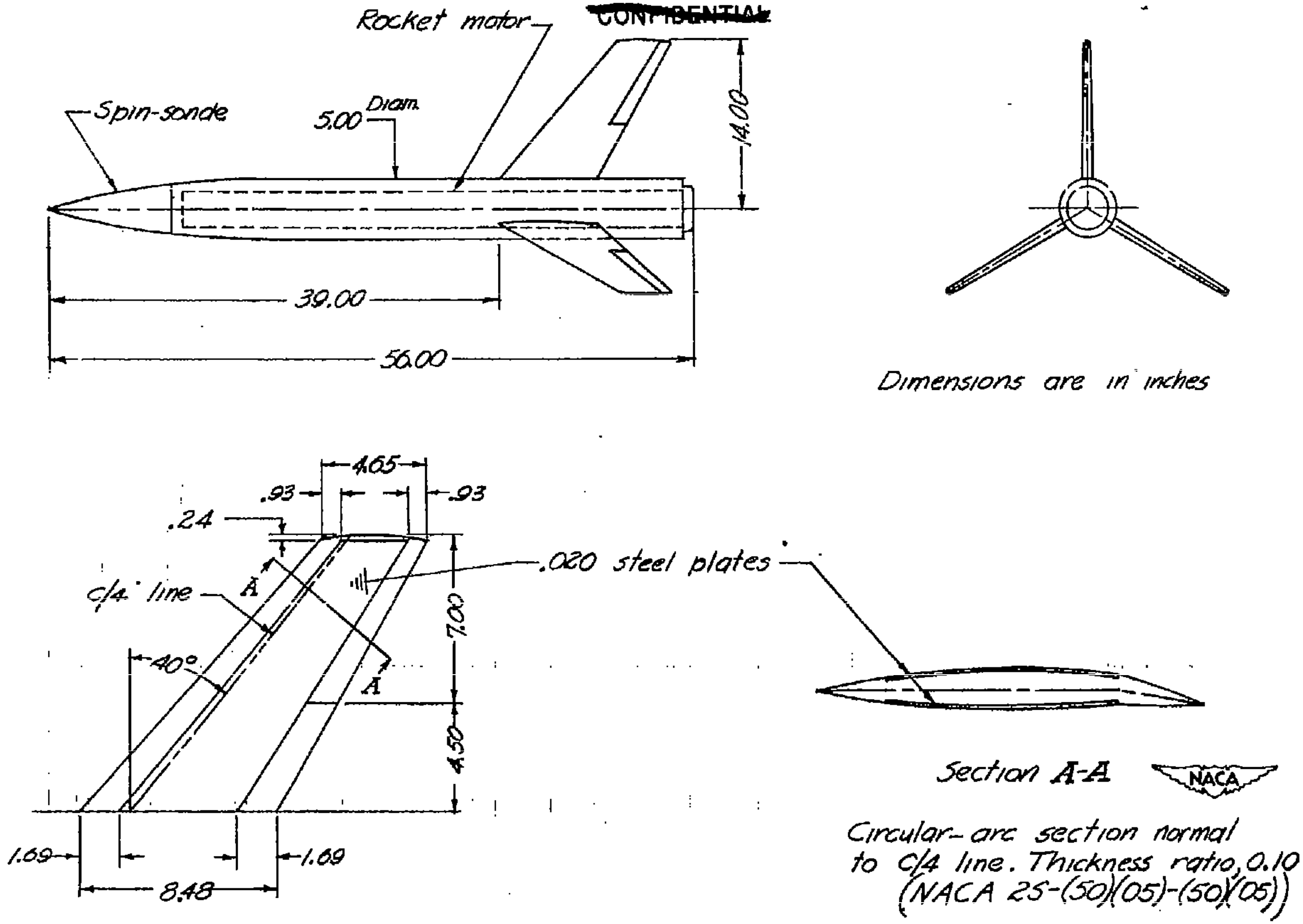
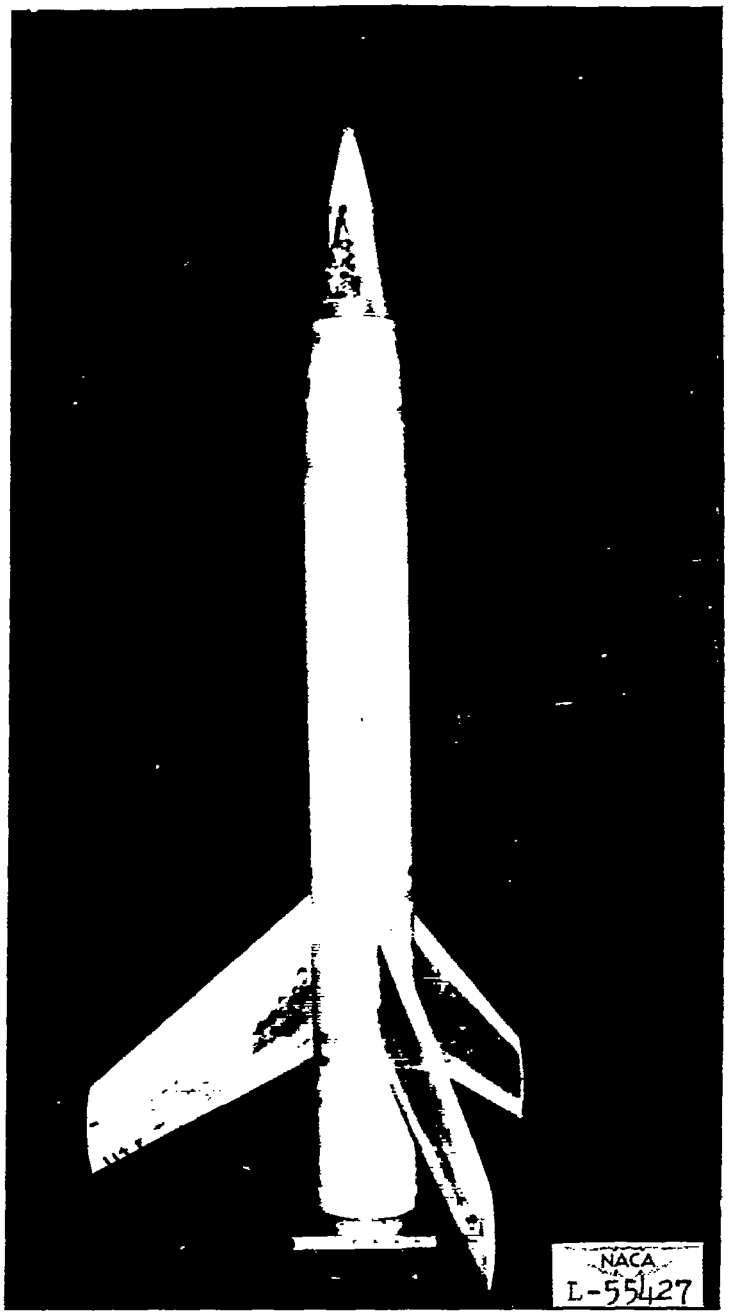


Figure 1.– General arrangement of test vehicles. Original aileron configuration.

CONFIDENTIAL

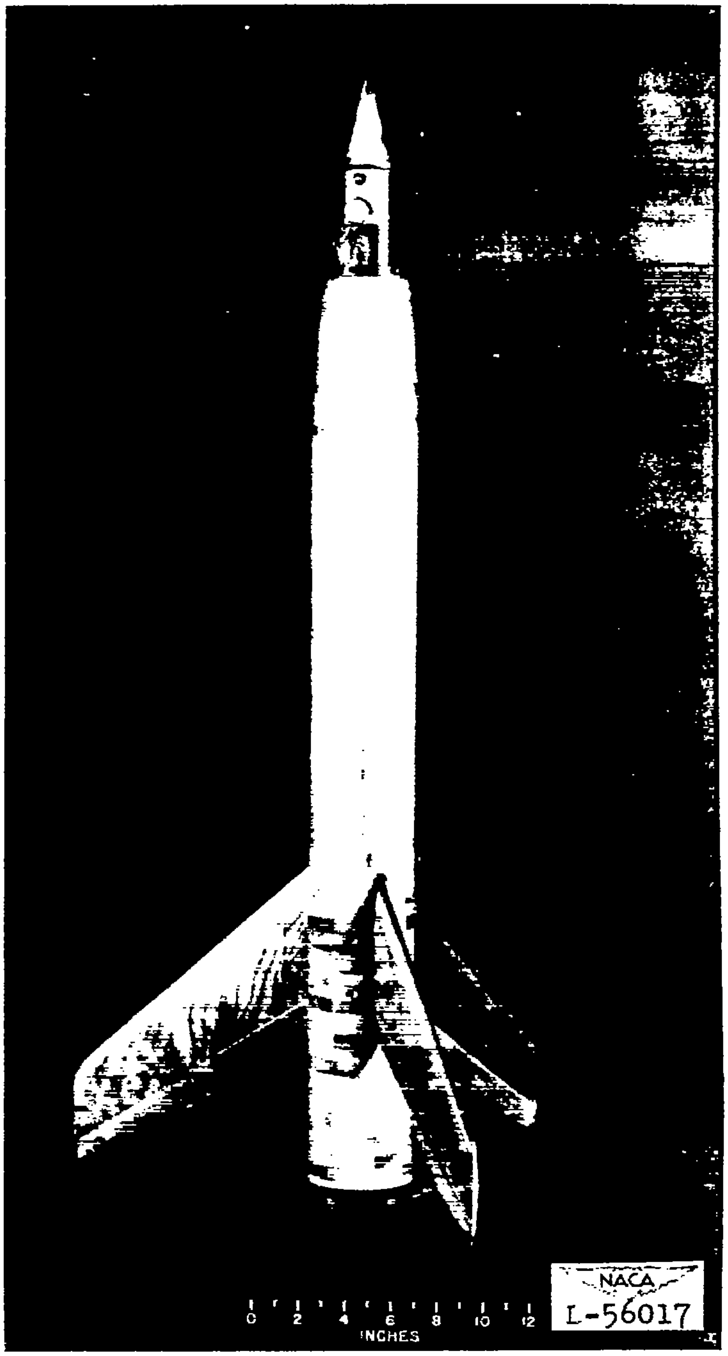
CONFIDENTIAL



(a) Original aileron configuration.

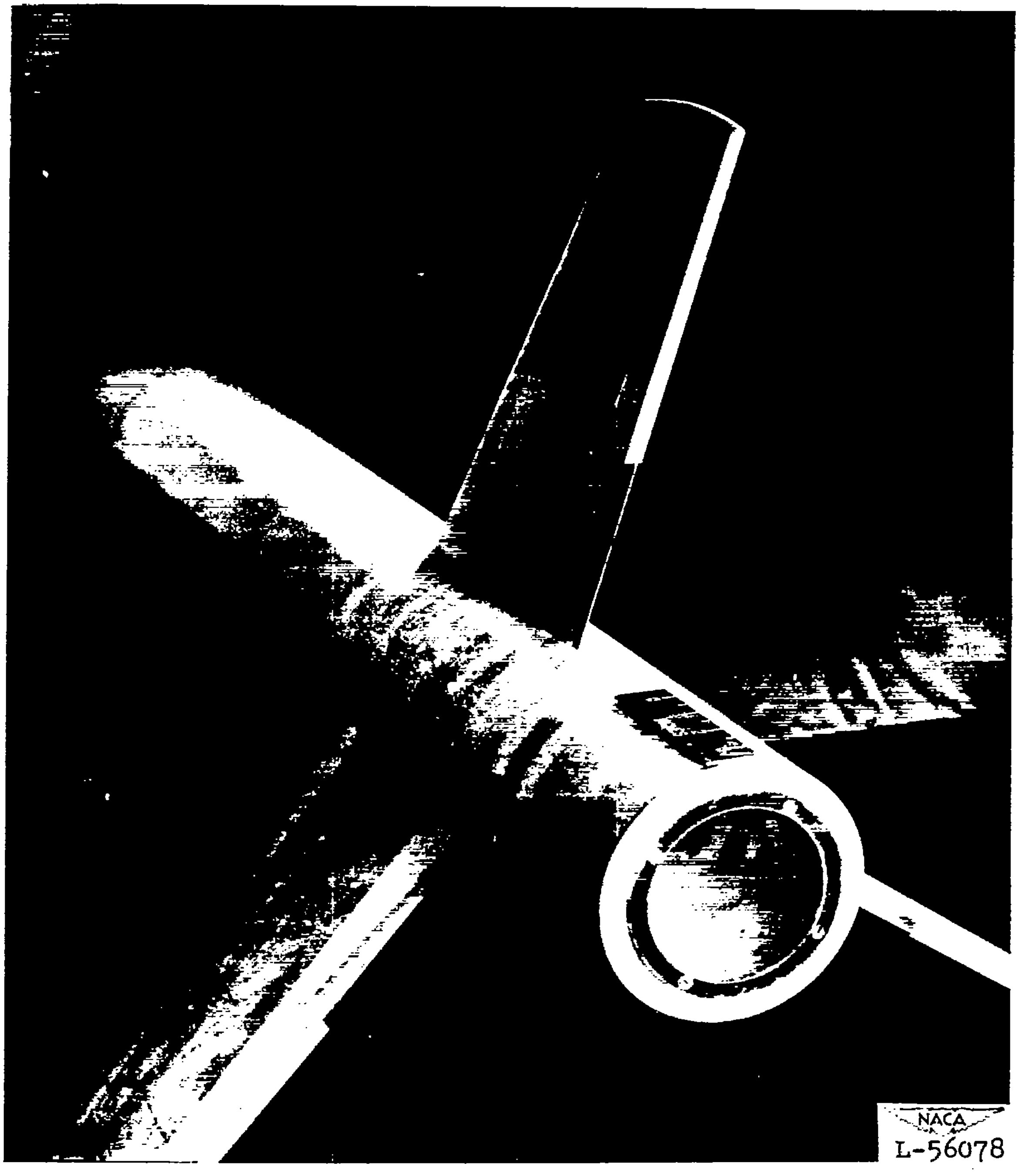
Figure 2.— Photographs of test vehicles.

CONFIDENTIAL



(b) Extended chord aileron configuration.

Figure 2.– Continued.



(c) Parallel-sided aileron configuration.

Figure 2.- Concluded.

CONFIDENTIAL

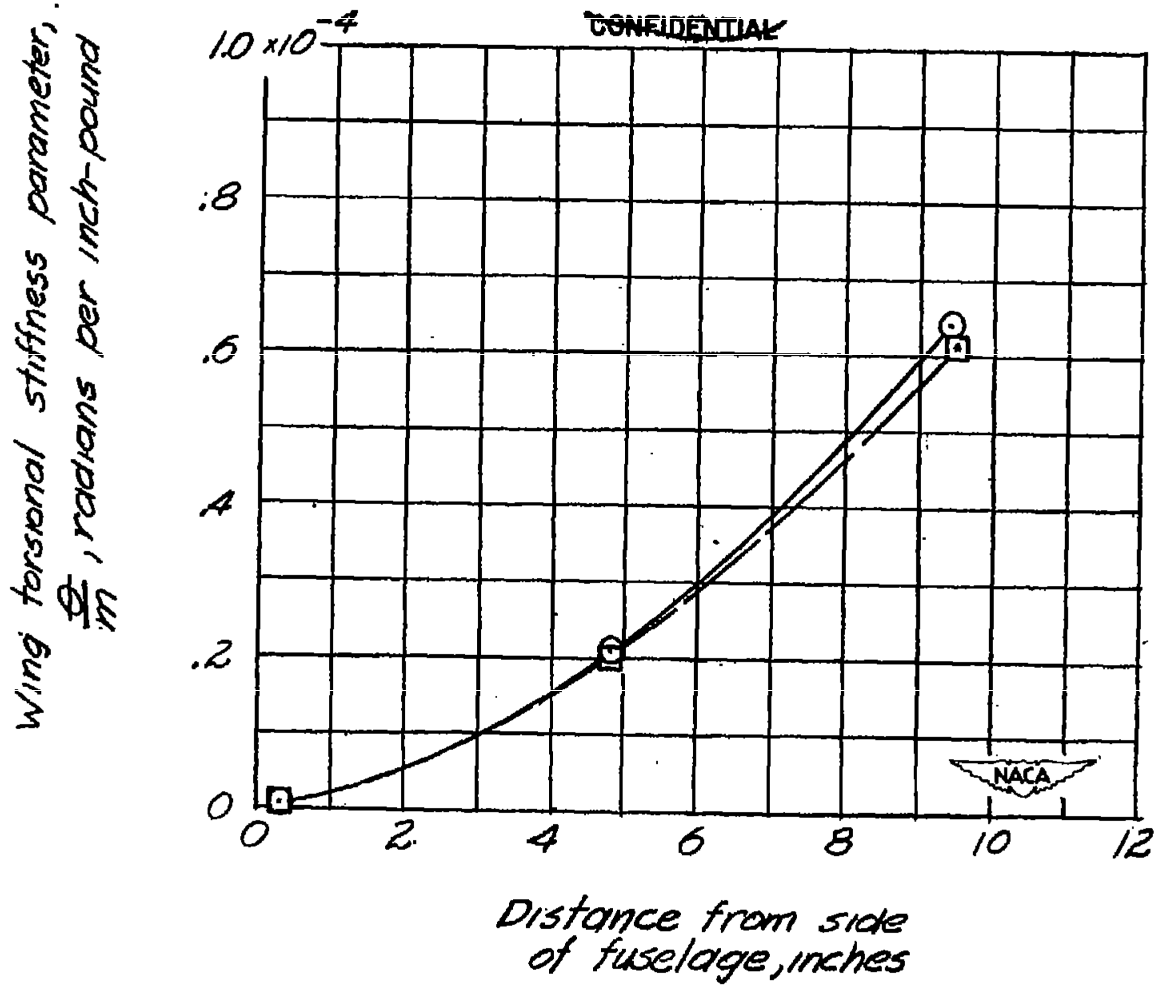
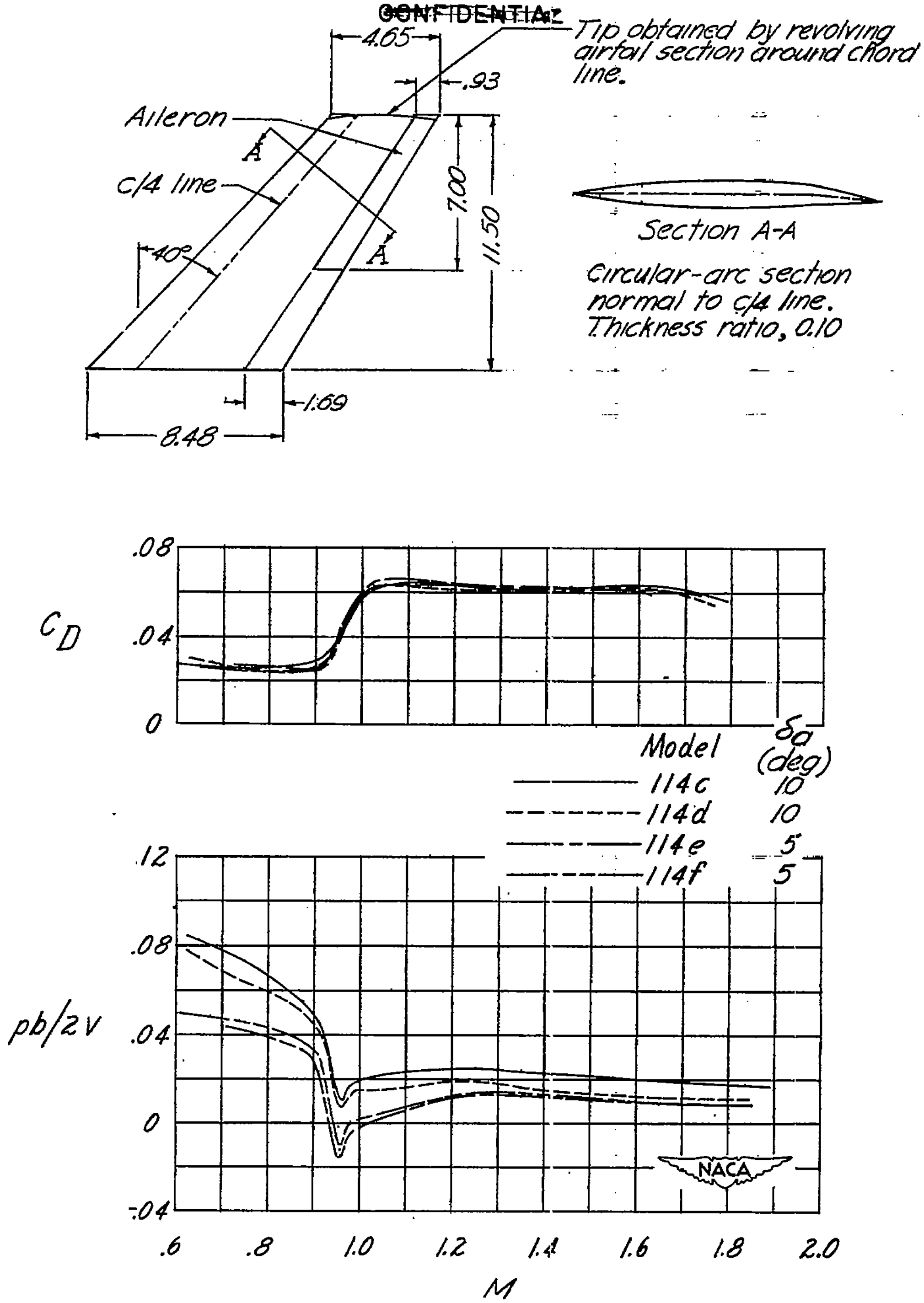


Figure 3.– Stiffness characteristics of two typical wings of the present tests.

CONFIDENTIAL

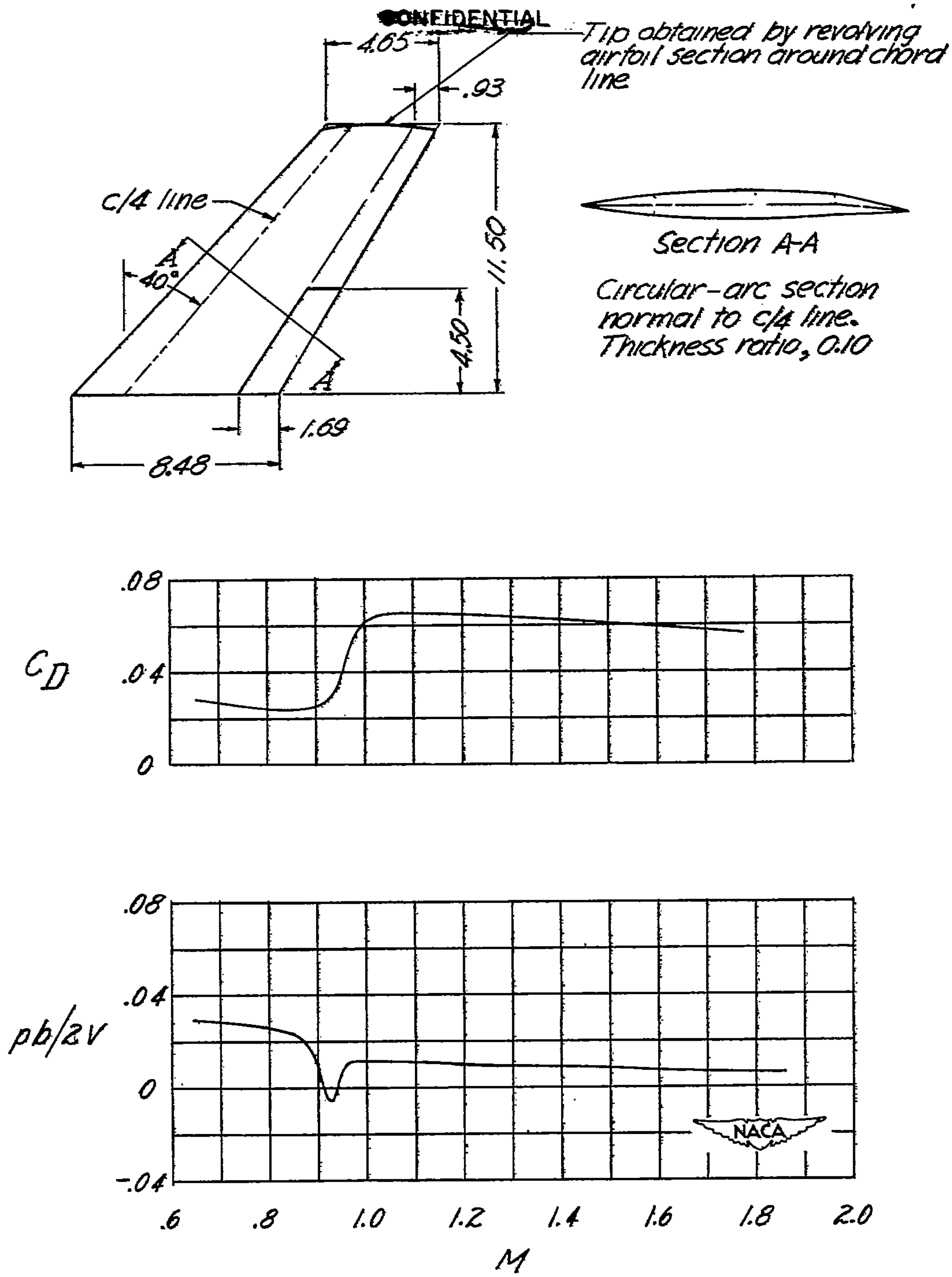
CONFIDENTIAL



(a) Original aileron configuration.

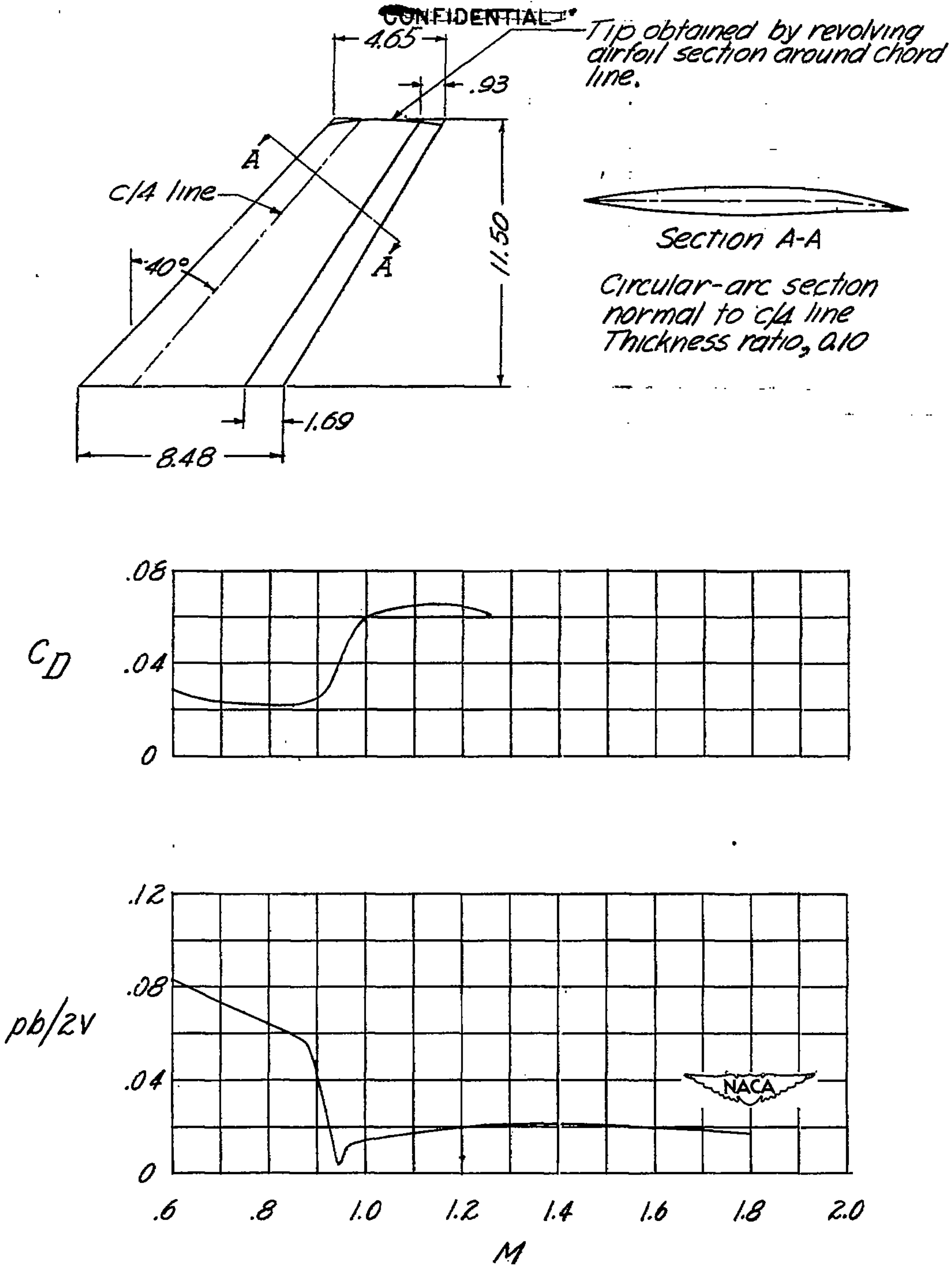
Figure 4.– Details of configurations tested and experimental results.

CONFIDENTIAL



(b) Inboard aileron configuration. $\delta_a = 5^{\circ}$.

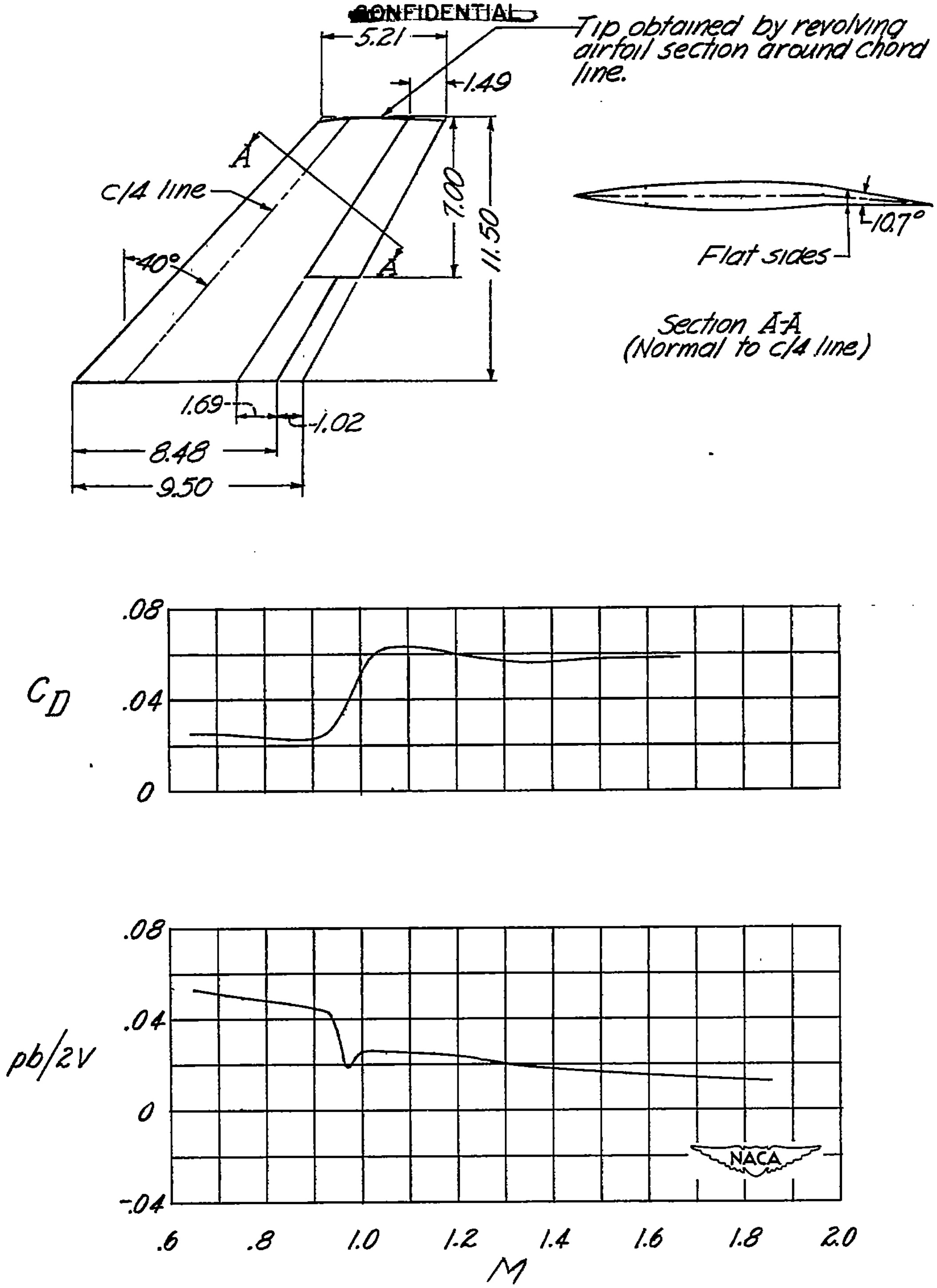
Figure 4.– Continued.



(c) Full-span aileron configuration. $\delta_a = 5^{\circ}$.

Figure 4.– Continued.

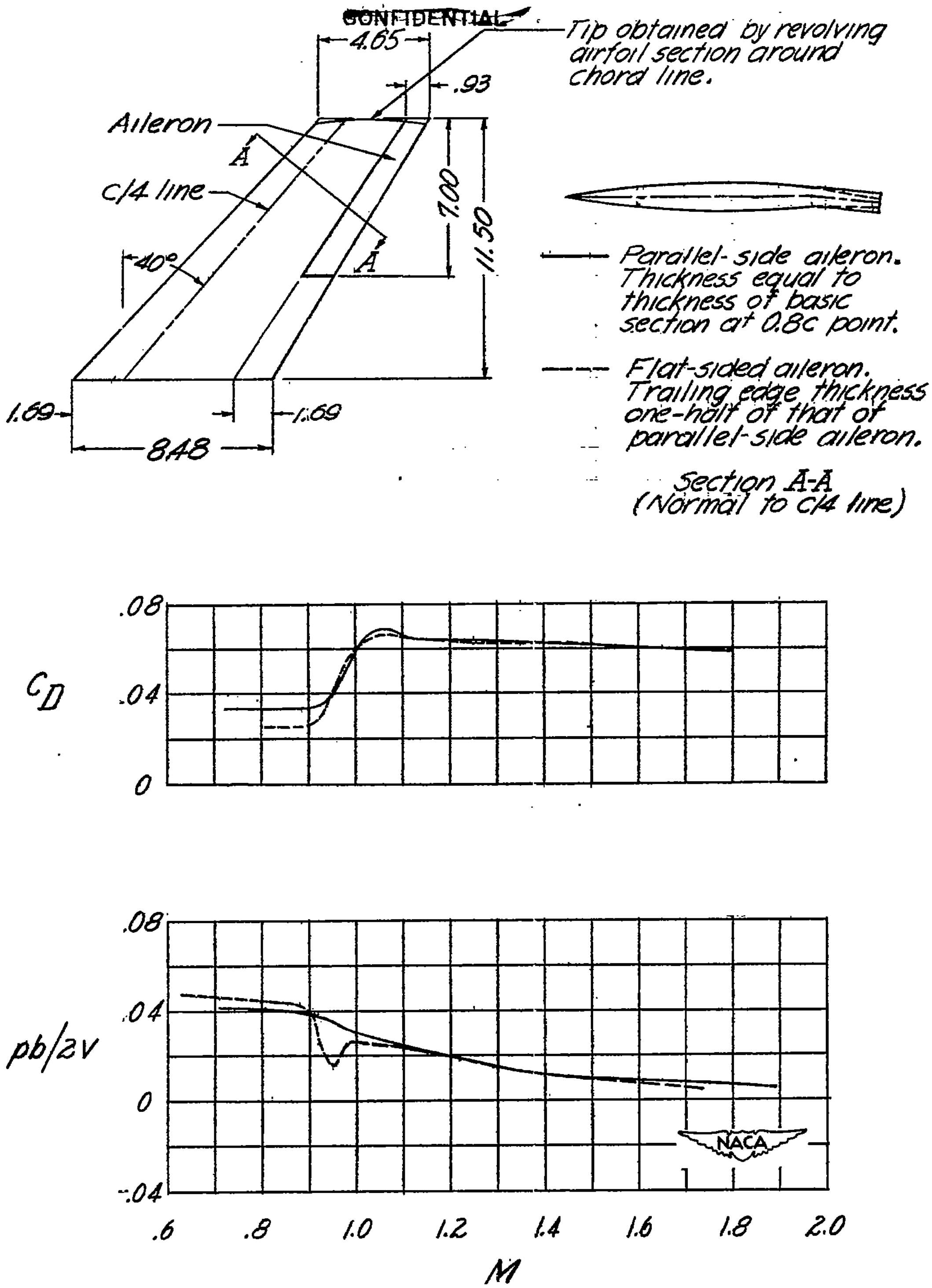
CONFIDENTIAL



(d) Extended-chord aileron configuration. $\delta_a = 5^{\circ}$.

Figure 4.— Continued.

CONFIDENTIAL



(e) Blunt trailing-edge aileron configurations. $\delta_a = 5^\circ$.

Figure 4.– Concluded.

CONFIDENTIAL

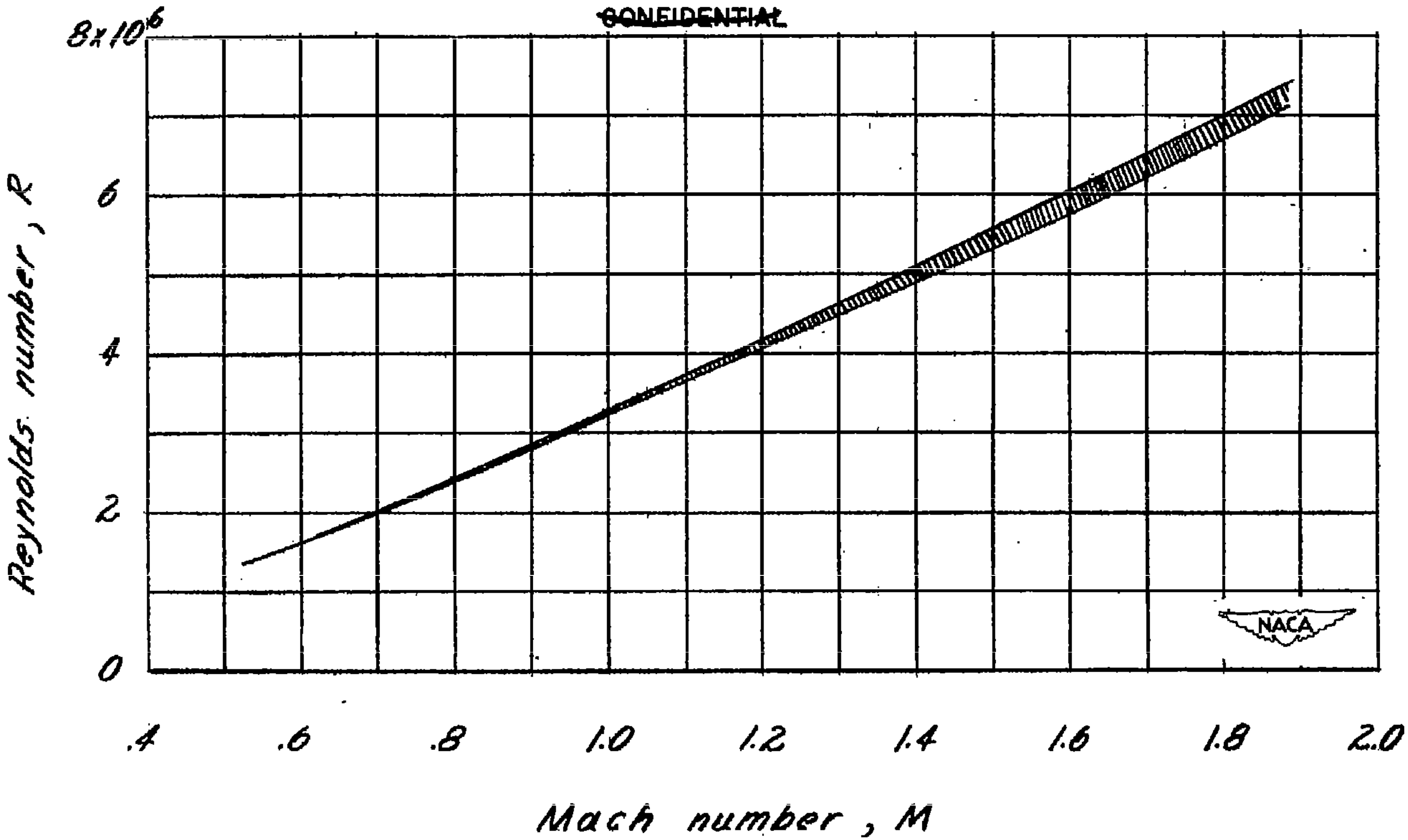


Figure 5.– Variation of Reynolds number with Mach number for range of test conditions.

CONFIDENTIAL

CONFIDENTIAL

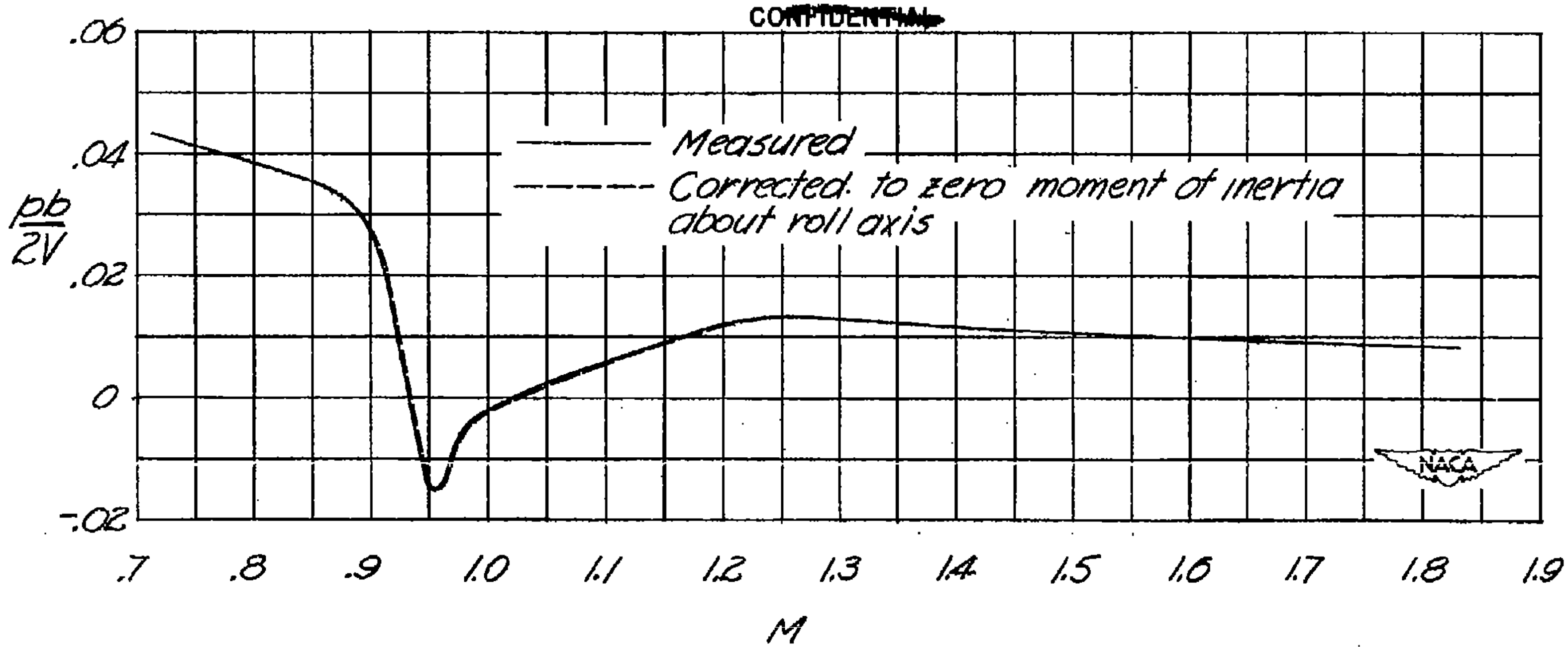


Figure 6.– Effect of moment of inertia about roll axis on measured variation of pb/2V with Mach number.

CONFIDENTIAL

CONFIDENTIAL

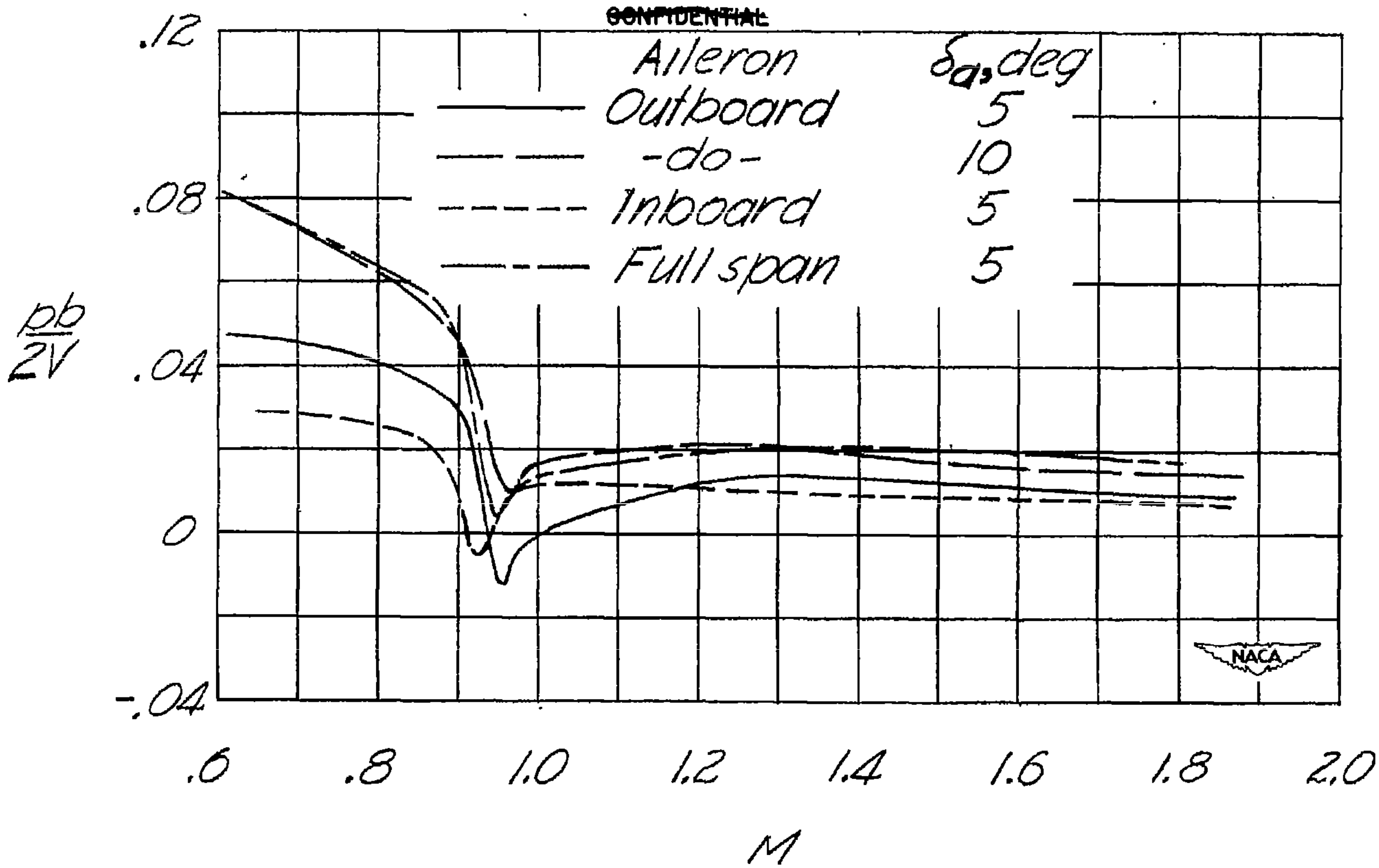


Figure 7.- Summary of results for true-contour ailerons. Curves for outboard ailerons obtained by averaging results shown in figure 4(a).

CONFIDENTIAL