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RESEARCH MEMORANDUM

LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF A SEMISPAN AIRPLANE MODEL WITH A SWEPTBACK WING AND TAIL FROM TESTS AT TRANSONIC SPEEDS BY THE NACA WING-FLOW METHOD

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF A SEMISPAN AIRPLANE MODEL WITH A SWEPTBACK WING AND TAIL FROM TESTS AT TRANSONIC SPEEDS BY THE NACA WING-FLOW METHOD

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SUMMARY

An investigation was made by the NACA wing-flow method to determine the longitudinal stability and control characteristics at transonic speeds of a semispan airplane model having a 45° sweptback wing and tail. The airfoil sections parallel to the axis of symmetry were NACA 65-series with thicknesses of 10 and 8 percent of the chord, respectively, for the wing and tail. The model was mounted to pivot freely about the center of gravity at 27 percent of the mean aerodynamic chord. Measurements were made of lift and angle of attack for trim for several stabilizer and elevator settings. Additional tests were made to investigate the effects of transition wires mounted on the wing and tail of the model, the effect of increasing the boundary-layer thickness on the test surface, and the effectiveness of a wing flap having a sweepback of 45°.

Because of the chordwise variation of Mach number in the test region, the effective Mach number for the wing of the model was lower than that for the tail of the model. The effective Mach numbers at the wing of the model ranged from 0.50 to 1.07. The interpretation of the results in terms of full-scale flight conditions is subject to some uncertainty because of the difference in the Mach number of the flow at the wing and at the tail and of the low Reynolds number of the tests.

The results of the tests are compared with the results of previous tests of a model with an unswept wing and tail and with a model with an unswept wing and sweptback tail. Reynolds number effects on the trim characteristics of the model were generally greater than those noted in the previous tests. A smoother and more gradual variation of the lift coefficient and angle of attack for trim with Mach number up to a Mach number of about 0.9 was obtained than with the configurations previously tested. At higher Mach numbers, a sudden decrease in the lift coefficient and angle of attack for trim occurred at about the same Mach number (0.95 to 0.98) and was of about the same magnitude as the trim changes encountered with the unswept wing and sweptback tail configuration. The variation of lift coefficient for trim with stabilizer setting indicated that the model had stick-fixed stability for stabilizer settings

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of 0.7° to 2.8°, but was unstable for a stabilizer setting of −0.2° over most of the Mach number range. No such instability was noted in the previous tests over the range of stabilizer deflection tested (−2° to 4°). As in the tests of the unswept wing and sweptback tail configuration, the elevator was ineffective at low deflections (1° to −3°) over the entire Mach number range probably as a result of the low Reynolds number of the tests. The change in trim obtained by deflecting the elevator from −3° to −5° was large at low speeds but decreased steadily with increase in Mach number to 1.0. A sweptback flap on the lower surface of the wing (similar to a dive-recovery flap) was found to be ineffective in changing the trim of the model at Mach numbers up to about 0.95. At a Mach number of about 1.0, a small adverse effect was noted.

INTRODUCTION

Modern military and experimental aircraft are being designed to fly at speeds closely approaching and passing through the speed of sound. Serious stability and control problems are anticipated for this flight region because of compressibility effects on the aerodynamic characteristics of airfoils and control surfaces. In order to provide some information on these problems, tests have been made in the transonic-speed range by the NACA wing-flow method to investigate the longitudinal stability and control characteristics of a semispan airplane model. In the first of these tests (reference 1), the model was equipped with a low-drag unswept wing and tail configuration. The results of these tests indicated that large and abrupt changes in trim occurred at Mach numbers from 0.90 to 0.95, probably as a result of compressibility effects on the tail. Inasmuch as tests of sweptback airfoils have shown a delay in the onset and magnitude of compressibility effects, the unswept tail was replaced with a 45° sweptback tail for the second of these tests (reference 2). This change resulted in increasing the Mach number at which the major changes in trim first occurred by about 0.05 and in decreasing the magnitude of the trim changes. In an effort to improve further the longitudinal stability and control characteristics of the model, the unswept wing was replaced for the present tests with a sweptback wing of the same airfoil section in a plane normal to the wing span, with the same span and aspect ratio, but with no taper and with a sweepback of 45°. The results of the tests with this configuration (sweptback wing and tail) are presented herein. Measurements were made of lift and angle of attack for trim for several stabilizer and elevator settings. Some data were obtained with transition wires on the wing of the model and on the wing and tail of the model. The effect on the model tests of the thickness of the boundary layer on the test region of the P-51D airplane wing was investigated. A brief investigation was also made to determine the effectiveness of a wing flap which was similar to a dive-recovery flap on an unswept wing.

SYMBOLS

α_{trim}	angle of attack of fuselage for trim
i_t	incidence of stabilizer
δ_e	deflection of elevator in plane normal to tail span
x	chordwise distance along wing surface of P-51D airplane
M_x	local Mach number at distance x along wing surface of P-51D airplane
M_w	effective Mach number at wing (average at semispan)
M_t	effective Mach number at tail (average at semispan)
M_o	free-stream Mach number
q_w	effective dynamic pressure at wing (average at semispan)
S	wing area (semispan), 6 square inches
L_{trim}	lift for trim
$C_{L_{trim}}$	lift coefficient for trim $\left(\frac{L_{trim}}{q_w S}\right)$
C_{L_a}	lift coefficient of P-51D airplane
R_w	Reynolds number of wing based on mean aerodynamic chord of wing, 1.5 inches
R_t	Reynolds number of tail based on the mean aerodynamic chord of tail, 0.94 inch

APPARATUS AND TECHNIQUE

The tests were made, as described in reference 1, by the NACA wing-flow method in which the model is mounted in the high-speed flow over the wing of a P-51D airplane.

Model.- The semispan model equipped with a sweptback wing and a sweptback horizontal tail is shown in figures 1 to 3. Except for the wing, the model was the same as that used for the tests of reference 2. The wings in both cases were made of steel and had the same area, aspect ratio, and airfoil section (NACA $65_{(112)}$-110) in a plane normal to the wing span. The arrangement of the unswept wing of references 1 and 2 is shown in figure 3 for comparison with the present wing. Also shown in figure 3 is the unswept horizontal tail of reference 1 for comparison with the present tail. The unswept and sweptback tails were also made of steel and had the same area, aspect ratio, and airfoil section (NACA $65_{(112)}$-110) in a plane normal to the tail span. The elevator chords, however, were 20 and 30 percent of the unswept and sweptback tails, respectively. The geometric characteristics of the model with the sweptback wing and tail are given in table I. Dimensions of a corresponding full-scale airplane with a scale 50:1 relative to the model are also shown in table I in order that the proportions of the airplane may be more easily visualized. The horizontal tail was arranged to permit adjustment of the stabilizer angle and was grooved at 70 percent chord so that it could be bent sharply to simulate deflection of the elevator. The tail and elevator chords and the stabilizer and elevator deflections are considered in planes normal to the span of the tail. Other details of the model and testing technique are described in references 1 and 2.

<u>Tests</u>.- The model was mounted in such a way as to permit it to assume a position of zero pitching moment about the center of gravity at 27 percent of the mean aerodynamic chord. Measurements of lift and angle of attack at trim were made with elevator neutral and stabilizer settings of -0.2°, 0.7°, 1.8°, 2.3°, and 2.8°, and with a stabilizer setting of 2.3° and elevator deflections of 2°, -2°, -3.9°, and -5.1°.

Additional measurements of lift and angle of attack at trim for a stabilizer setting of 2.8° with elevator neutral were made with transition wires 0.0025 inch in diameter mounted at 5 percent of the chord on the upper and lower surfaces of the wing of the model. With the transition wires on the wing and with transition wires 0.0015 inch in diameter on both surfaces of the tail at 5 percent of the chord, tests were made with the stabilizer set at 2.8° and with elevator deflections of 0°, -1.9°, and -4.05°.

The thickness of the boundary layer in the test region was increased by taping a transition thread of 0.036-inch diameter at 5 percent chord on the wing of the P-51D airplane forward of the test region. Lift and angle of attack at trim for a stabilizer setting of 2.8° and elevator neutral were thus obtained with the displacement thickness of the boundary layer increased 50 percent. The boundary-layer thickness was measured by a rack of total-pressure tubes.

A dive-recovery type of wing flap deflected 30° was simulated by a wooden wedge glued to the lower surface of the wing as indicated in figures 1(b) and 4. Tests with this arrangement were made with a stabilizer setting of 2.8° and elevator neutral.

In order to cover a range of Reynolds number independently of Mach number, the tests were made in three runs consisting of two dives, one at high and one at medium altitude, and in a level-flight run at low altitude. The average relation of Reynolds number at the wing R_w and at the tail R_t with Mach number at the wing M_w is shown for the three altitude conditions in figure 5. The Reynolds number corresponding to a given Mach number in a given nominal altitude range varied somewhat between different tests but the variations did not exceed 5 percent. The variation of the Mach number at the tail M_t with Mach number at the wing M_w is shown in figure 6. The Mach number was higher at the tail than at the wing because of the chordwise variation in the test region. Typical chordwise distributions of Mach number over the test region are shown in figure 7 for several flight Mach numbers M_o and P-51D airplane lift coefficients C_{L_a}. A small gradient of Mach number normal to the P-51D wing surface of approximately three-fourths of 1 percent per inch (decreasing Mach number with distance above the wing surface) also existed and was taken into account in determining the effective Mach numbers at the wing and tail of the model.

Accuracy.- The probable error in the measurements from a consideration of the sensitivity of the measuring instruments is estimated to be within the following limits:

$C_{L_{trim}}$	±0.02
α_{trim}	±0.1
M_w	±0.005

PRESENTATION OF RESULTS

The results of the investigation are given in figures 6 to 18. The variation of lift coefficient and of angle of attack for trim with Mach number is presented in figures 8 to 11 for the following test conditions of the model:

Figure 8: Elevator neutral with several stabilizer settings.

Figure 9: Stabilizer set at 2.3° with several elevator deflections.

Figure 10: Transition wires on wing and transition wires on wing and tail of model. Stabilizer set at 2.8° with elevator neutral.

Figure 11: Transition wires on wing and tail of model. Stabilizer set at 2.8° with two elevator deflections.

Figure 12 shows the variation of lift coefficient for trim with Mach number with the stabilizer of the model set at 2.8° and elevator neutral for the original test condition and with boundary-layer thickness increased on the wing of the P-51D airplane.

The data shown in figures 8 to 11 are also given in figures 13 to 18 in the following form:

Figure 13: Variation of lift coefficient with angle of attack at several Mach numbers.

Figure 14: Variation of lift-curve slope and the angle of attack for zero lift with Mach number.

Figure 15: Variation of lift coefficient for trim with stabilizer deflection at several Mach numbers. Results of previously tested configurations of model shown for comparison.

Figure 16: Variation of lift coefficient for trim with elevator deflection at several Mach numbers.

Figure 17: Variation of lift coefficient for trim with elevator deflection at several Mach numbers with transition wires on wing and tail of model.

Figure 18: Variation of lift coefficient for trim with elevator deflection at several Mach numbers, with and without transition wires, compared with results for previously tested configurations of the model.

The variation of lift coefficient and angle of attack for trim with Mach number for the model with and without the wing flap is shown in figure 19. From the data of figures 15, 16, and 17, the stabilizer deflections (elevator neutral) and the elevator deflections (stabilizer fixed) required for trim throughout the Mach number range have been determined for an airplane of the same configuration as the model and are shown in figure 20. Elevator trim curves are given for configurations with and without transition wires. The wing loading was taken as 50 and the altitude as 30,000 feet. The corresponding variation of lift coefficient C_L with Mach number is also shown in figure 20. For comparison, the results obtained in reference 1 for the model with unswept wing and tail and in reference 2 for the model with unswept wing and sweptback tail are included in figure 20.

DISCUSSION OF RESULTS

Effects of test conditions on results.- Substantial differences in the lift coefficient and the angle of attack at which the model trimmed (figs. 8 and 9) were obtained from the tests at different altitudes apparently as a result of the variation of Reynolds number (fig. 5). This effect occurred, in general, at all Mach numbers (0.5 to 1.02) for which data at different altitudes were obtained except for some small ranges at high Mach numbers. Previous tests of the model with unswept wing and tail (reference 1) and with unswept wing and sweptback tail (reference 2) also indicated Reynolds number effects on the trim characteristics of the model but these effects were generally smaller than those for the present tests. With transition wires fixed to the wing of the model, the variation of the trim condition with Reynolds number was practically eliminated at all Mach numbers (compare fig. 10(a) with fig. 8(c)). Although the addition of transition wires to the wing apparently eliminated the differences in flow characteristics at the different altitudes, the resulting flow probably does not represent full-scale conditions.

As in the tests of reference 2, the elevator of the sweptback tail was ineffective at small deflections (1° to -3°) even at the lowest Mach numbers of the tests (figs. 9 and 16). This ineffectiveness was apparently a result of the low Reynolds number because the elevator had substantial effectiveness under the same conditions when transition wires were mounted on the tail of the model (figs. 10(b), 11, and 17).

In view of the foregoing results, only the data for the highest Reynolds numbers obtained at a given Mach number (using only the low-altitude level-flight run and the medium-altitude dive) are considered in the following discussion and in the fairing of the data except in the variation of lift coefficient with angle of attack which showed no consistent effects of Reynolds number.

No appreciable differences in the characteristics of the model resulted from the 50-percent increase in the thickness of the boundary layer over the test region effected by the transition strip on the wing of the P-51D airplane (fig. 12). This result indicates that the normal variations in boundary-layer thickness over the test region did not contribute appreciably to the aforementioned differences in the model data from the tests at the different altitudes.

Because of the chordwise variation of Mach number in the test region (fig. 7), the Mach number of the flow at the tail may be greater than the values quoted in the following discussion by the amount shown in figure 6. No appreciable difference in the Mach number between the root and tip of the wing due to the sweep of the wing existed, however, because the spanwise variation of Mach number almost fully compensated for the small chordwise variation. It should be noted that the difference in Mach number at the wing and tail is of an order of magnitude comparable to the Mach number range within which abrupt reversals in trim characteristic in some instances have been found to occur. Therefore, it is possible that the difference in Mach number at the wing and tail might result in distorting the true trim changes that would occur if the model were tested in a uniform flow field. If the effects of the nonuniform flow field are actually small, then the changes in the trim characteristics of the model attributed to the effects of compressibility on the tail would probably occur in free air at somewhat higher Mach numbers than the values quoted.

Trim with fixed controls.- The lift coefficient and angle of attack for trim with various stabilizer and elevator settings (figs. 8 and 9) showed a smoother and more gradual variation with Mach number up to a Mach number of about 0.9 than either the model with unswept wing and tail (reference 1) or the model with unswept wing and sweptback tail (reference 2). Between Mach numbers of about 0.95 to 0.98, a sudden decrease in the lift coefficient and angle of attack for trim occurred. This sudden change occurred at about the same Mach number and was of about the same magnitude as the trim changes encountered with the unswept wing and sweptback tail of reference 2. Comparison with the unswept wing and tail configuration of reference 1 showed that the trim changes for the sweptback tail configurations (present tests and tests of reference 2) were considerably smaller and occurred on the average at 0.05 higher Mach number.

Lift results.- The slope of the lift curve and the angle of zero lift (fig. 14) showed smaller and more gradual variations with Mach number than the results obtained for the unswept wing of references 1 and 2.

Stabilizer effectiveness.- The variation of lift coefficient for trim with stabilizer setting (fig. 15) indicated that the model had stick-fixed stability for stabilizer settings of 0.7° to 2.8°. With a stabilizer setting of -0.2°, the model trimmed at an angle of attack greater than 11.6° (limit of measurements) when the Mach number was increased up to about 0.94 (fig. 8) in the high-altitude dive. The model then trimmed down and was stable for Mach numbers increasing from about 0.94 to 1.07 and for Mach numbers decreasing from 1.07 to 0.85. In the medium and low-altitude runs up to the highest test Mach numbers, 1.02 and 0.94, respectively, the angle of attack for trim for a stabilizer setting of -0.2° exceeded 11.6°. In cases where the angle of attack for trim was greater than the limit of measurements, large and violent pitching oscillations were noted at some Mach numbers. The results for the high-altitude dive indicated that the pitching-moment variation with lift coefficient was nonlinear and that the model was unstable for some range of higher lift coefficients. Such pitching-moment curves are characteristic of wings with too high an aspect ratio for the amount of sweepback or too large a sweepback for the aspect ratio (reference 3). The unswept-wing configurations of references 1 and 2 did not indicate such an instability for the range of stabilizer settings investigated (-2° to 4°).

Elevator effectiveness.- As mentioned previously, the elevator was ineffective in changing the lift over the entire range of Mach numbers tested for deflections of 1° to −3° (figs. 9 and 16). For larger deflections (−3° to −5°) the elevator was very effective at low speeds but steadily decreased in effectiveness as the Mach number was increased to 1.0. The ineffectiveness of the elevator at low deflections was apparently due to the low Reynolds number since it was eliminated by the addition of transition wires to the tail (figs. 10(b), 11, and 17).

Effectiveness of dive-recovery type of wing flap.– The effect on the trim of the model due to the flap on the lower surface of the wing was not appreciable at Mach numbers lower than 0.95 (fig. 19); a small adverse effect was noted near a Mach number of 1.0. Although flaps of similar proportions on unswept wings have been found effective for executing emergency pull-outs from high-speed dives, a sweptback configuration such as that tested apparently would be useless in effecting a trim change.

Trim of full-scale airplane.– The stabilizer deflection (elevator neutral) required to trim an airplane of a configuration similar to the model throughout the Mach number range investigated (fig. 20) indicated that the deflection range required to trim with stabilizer alone was slightly greater than the range required for the unswept wing and sweptback tail configuration (reference 2) and considerably less than that required for the unswept wing and tail configuration (reference 1). The elevator deflection (stabilizer fixed) required to trim an airplane of a configuration similar to the model throughout the Mach number range investigated (fig. 20) indicated that the deflection range required to trim with elevator alone was slightly less than the range required for the unswept wing and sweptback tail configuration (reference 2) and considerably less than that required for the unswept wing and tail configuration (reference 1). The variations of stabilizer and elevator angles required for trim with Mach number were stable up to a much higher Mach number for the configuration of the present tests than for the unswept wing tests of references 1 and 2. It should be noted that these comparative results are subject to some uncertainty because of the difference in the Mach number at the wing and tail of the model and the differences in Reynolds number effects noted between the present tests and the tests of references 1 and 2.

CONCLUSIONS

The results of NACA wing-flow tests of the longitudinal stability and control characteristics in the transonic speed range of a semispan airplane model having a sweptback wing and tail are summarized and compared[1] with previous tests of the same model equipped first with an

[1]It should be noted that this comparison is subject to some uncertainty because of differences in Reynolds number effects noted between the present and previous tests and because of the difference in Mach number of the flow at the wing and tail of the model.

unswept wing and tail and second with an unswept wing and sweptback tail as follows:

1. Reynolds number effects on the trim characteristics of the model were, in general, greater than those noted in the previous tests.

2. A smoother and more gradual variation of the lift coefficient and angle of attack for trim with Mach number with fixed controls up to a Mach number of about 0.9 was obtained than with the configurations previously tested. At higher Mach numbers a sudden decrease in the lift coefficient and angle of attack for trim occurred at about the same Mach number (0.95 to 0.98) and was of about the same magnitude as the trim changes encountered with the unswept wing and sweptback tail configuration.

3. The variation of lift coefficient for trim with stabilizer setting indicated that the model had stick-fixed stability for stabilizer settings of 0.7° to 2.8°, but was unstable for a stabilizer setting of −0.2° over most of the Mach number range. No such instability was indicated in the previous tests over the range of stabilizer deflections tested (−2° to 4°).

4. As in the tests of the unswept wing and sweptback tail configuration, the elevator was ineffective at low deflections (1° to −3°) over the entire Mach number range, probably as a result of the low Reynolds number of the tests. The change in trim obtained by deflecting the elevator from −3° to −5° was large at low speeds but decreased steadily with increase in Mach number to 1.0.

5. A sweptback flap on the lower surface of the wing (similar to a dive-recovery flap on an unswept wing) was found to be ineffective in changing the trim of the model at Mach numbers up to about 0.95. At a Mach number of about 1.0, a small adverse effect was noted.

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1. Zalovcik, John A., and Sawyer, Richard H.: Longitudinal Stability and Control Characteristics of a Semispan Airplane Model at Transonic Speeds from Tests by the NACA Wing-Flow Method. NACA ACR No. L6E15, 1946.

2. Zalovcik, John A., and Sawyer, Richard H.: Longitudinal Stability and Control Characteristics of a Semispan Airplane Model with a Swept-Back Tail from Tests at Transonic Speeds by the NACA Wing-Flow Method. NACA RM No. L6K21, 1946.

3. Shortal, Joseph A., and Maggin, Bernard: Effect of Sweepback and Aspect Ratio on Longitudinal Stability Characteristics of Wings at Low Speeds. NACA TN No. 1093, 1946.

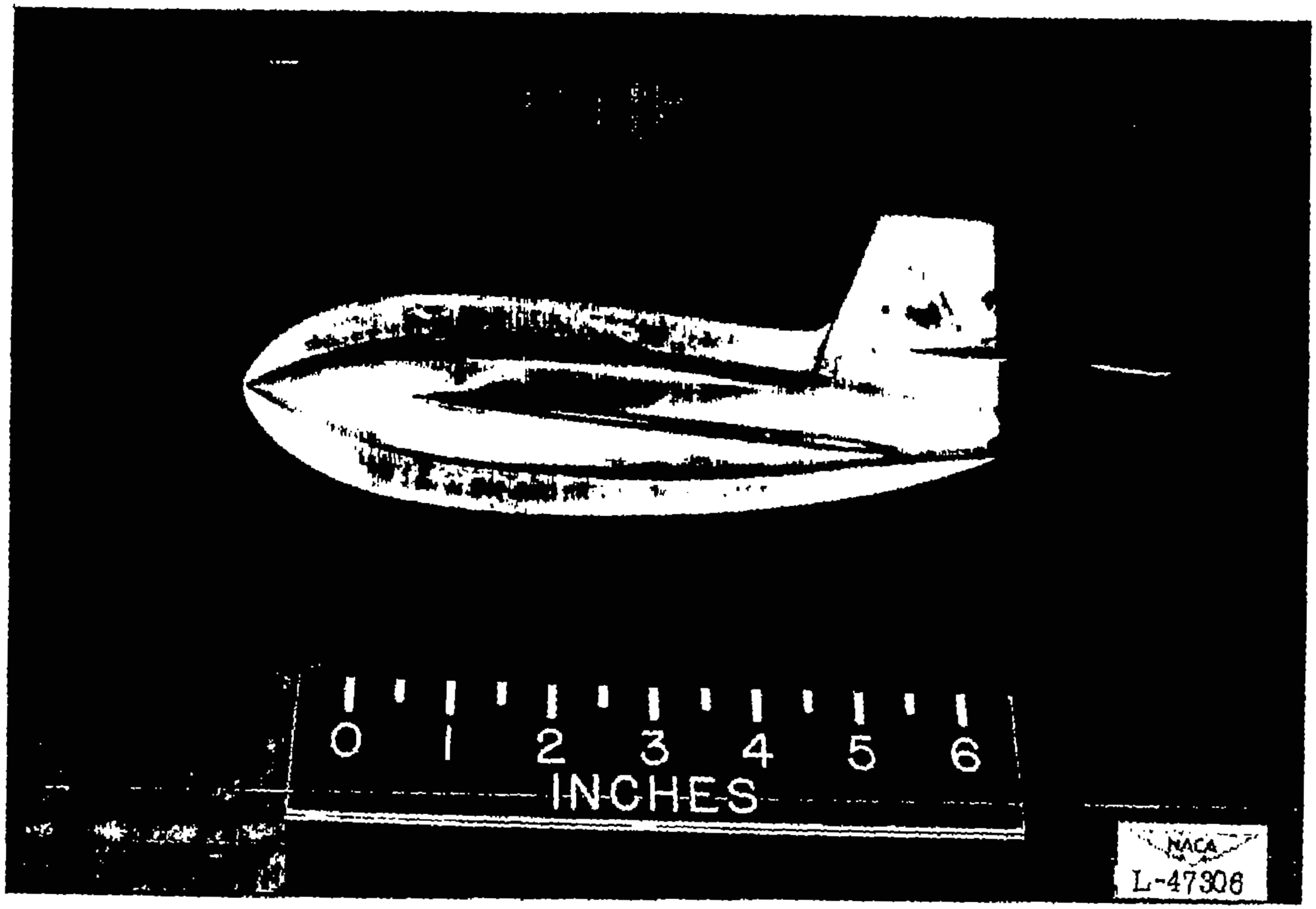
[redacted]

TABLE I

GEOMETRIC CHARACTERISTICS OF MODEL AND CORRESPONDING FULL-SCALE AIRPLANE

	Model	Full-scale airplane
Wing:		
Section (normal to span)	NACA $65_{(112)}$-110	NACA $65_{(112)}$-110
Semispan	4.00 in.	16 ft 8 in.
Chord	1.50 in.	75.0 in.
Area (of semispan wing)	6 sq in.	104 sq ft
Aspect ratio	5.33	5.33
Taper ratio	1:1	1:1
Incidence	$2^{\circ}30'$	$2^{\circ}30'$
Dihedral	0°	0°
Sweepback	45°	45°
Horizontal tail:		
Section (normal to span)	NACA $65_{(112)}$-008	NACA $65_{(112)}$-008
Semispan	1.66 in.	6 ft 11 in.
Chord	0.94 in.	47 in.
Area (of semispan tail)	1.56 sq in.	27.0 sq ft
Aspect ratio	3.5	3.5
Taper ratio	1:1	1:1
Chord of elevator	0.28 in.	14.1 in.
Sweepback	45°	45°
Fuselage length	7.97 in.	33 ft 2 in.
Maximum fuselage diameter	1.20 in.	60 in.
Fuselage fineness ratio	6.64	6.64
Tail length (c.g. to one-fourth M.A.C. of horizontal tail)	4.29 in.	17 ft 10 in.
Location of center of gravity	27 percent M.A.C.	27 percent M.A.C.

[redacted]



(a) Side view.

Figure 1.- Semispan airplane model.

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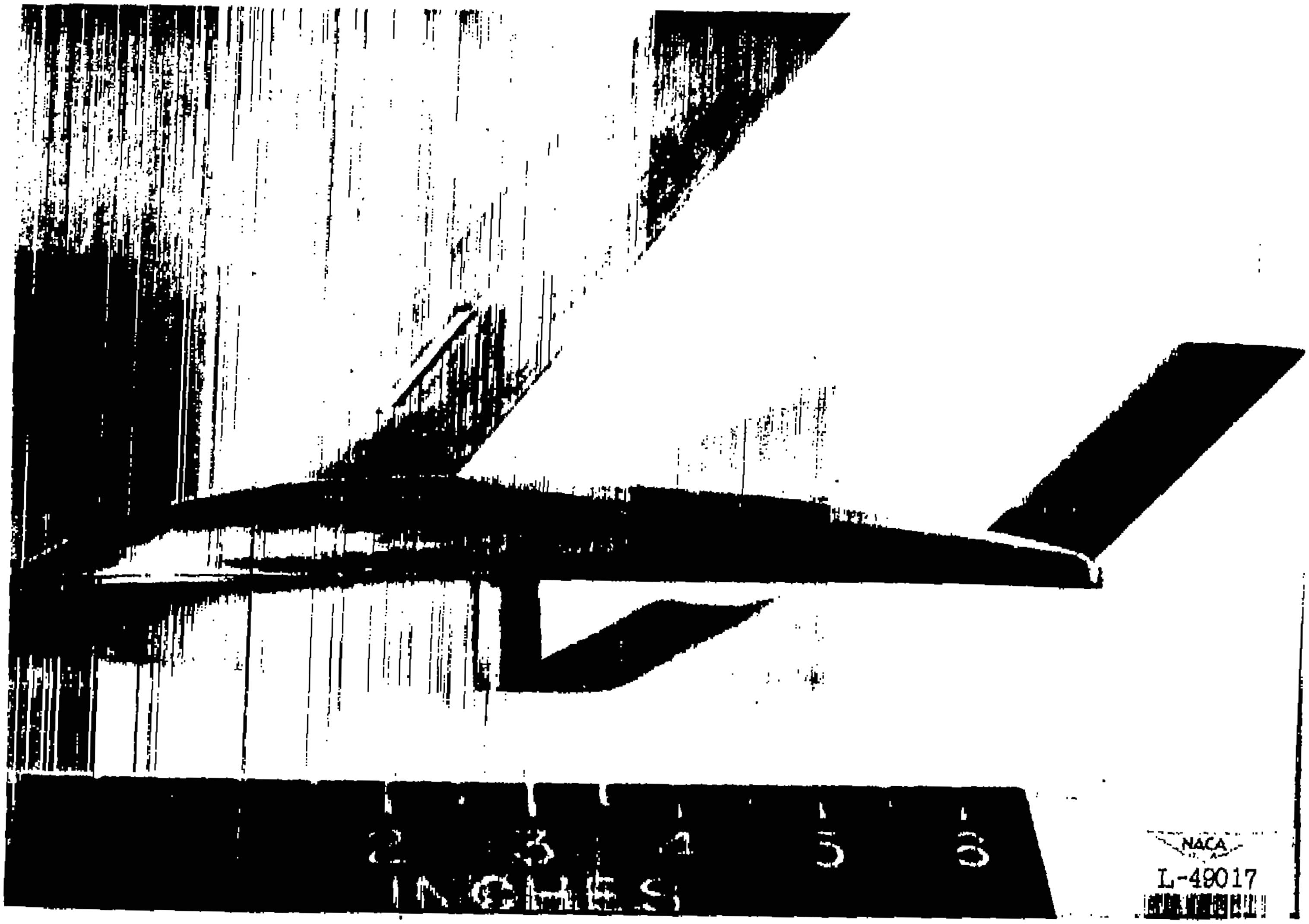

(b) Bottom view showing sweptback wing flap.

Figure 1.- Concluded.

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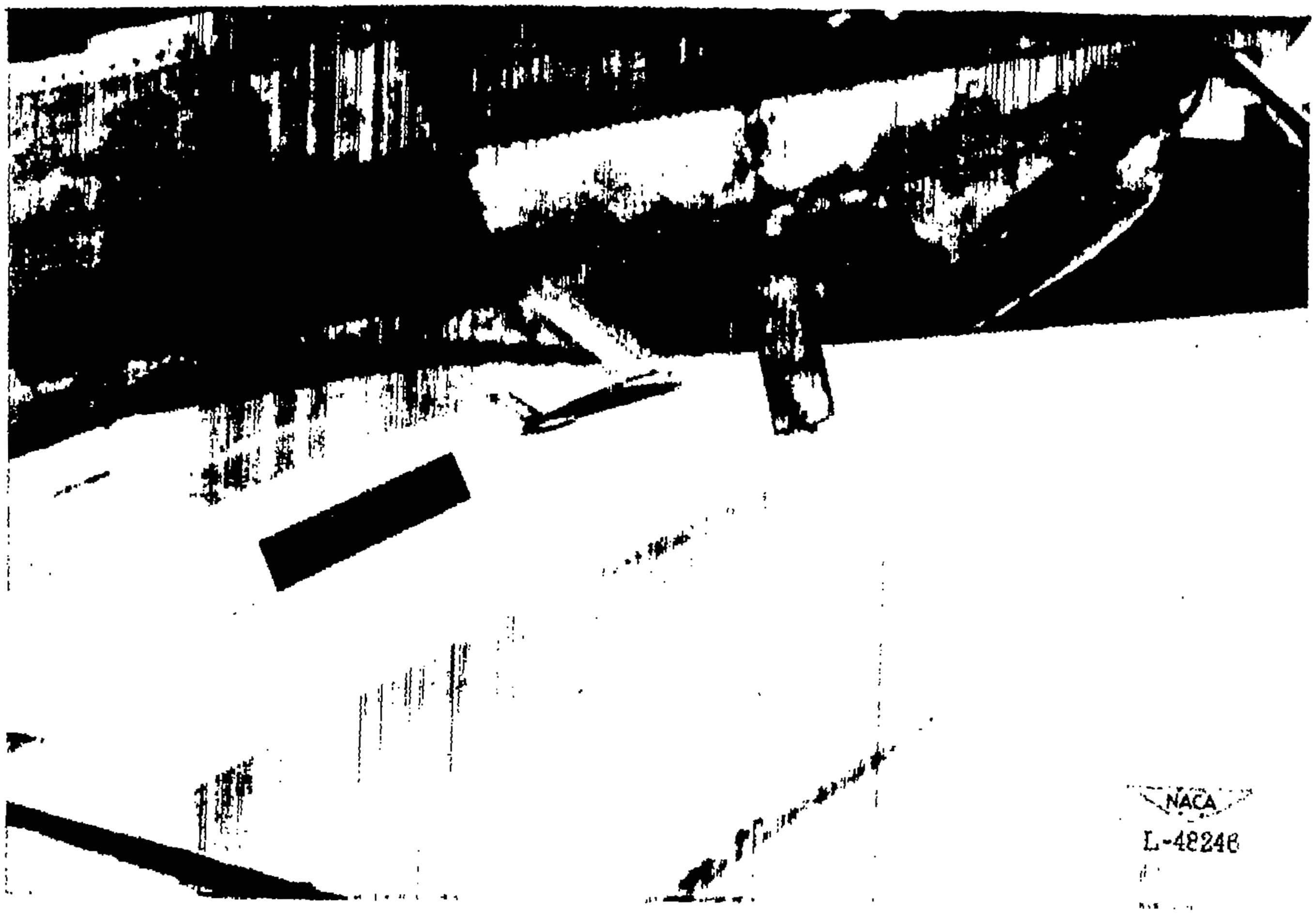

Figure 2.- Semispan airplane model mounted above wing of P-51D airplane. Reference vane in foreground.

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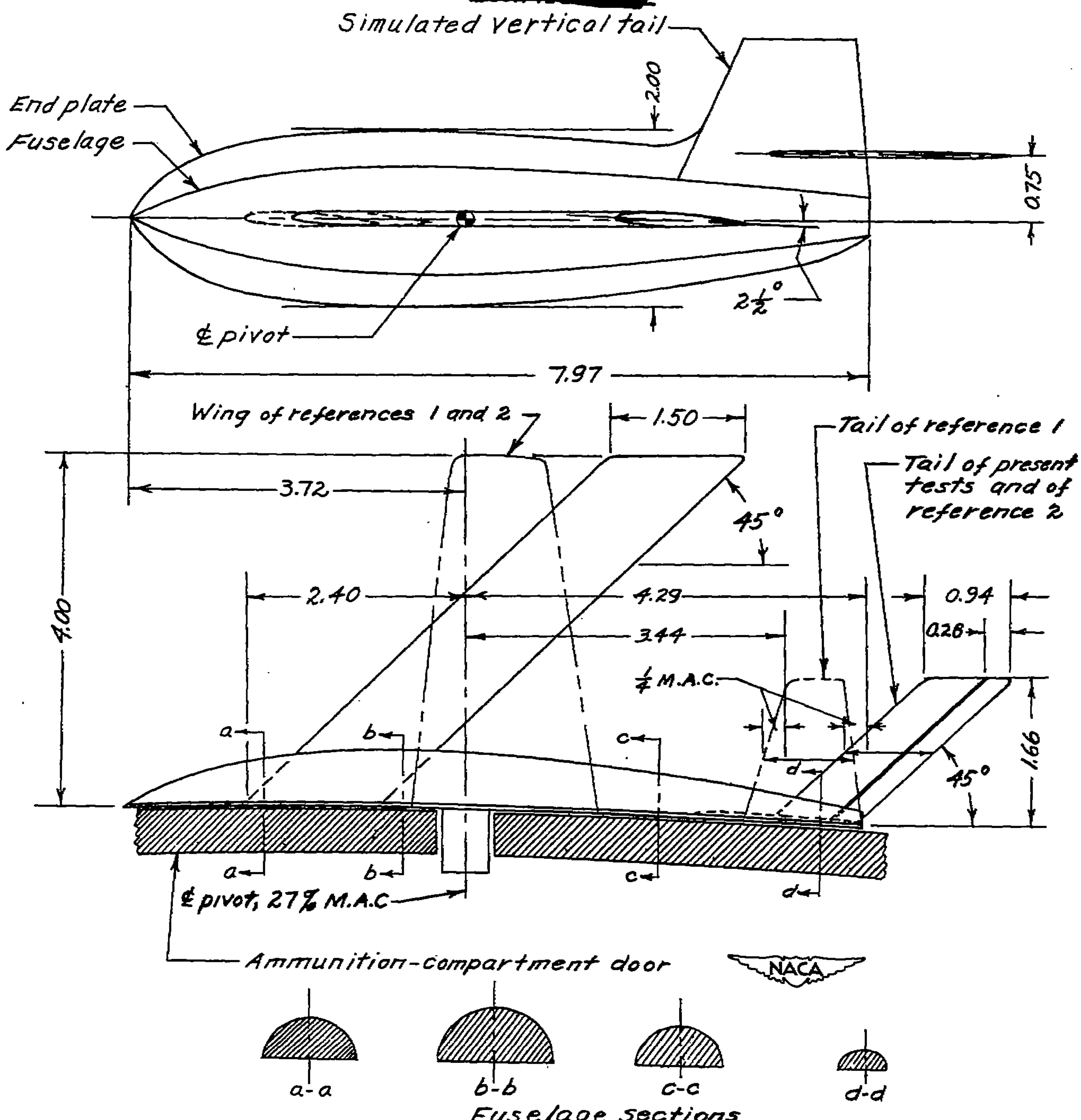

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Figure 3.- Details of semispan airplane model. All dimensions are in inches.

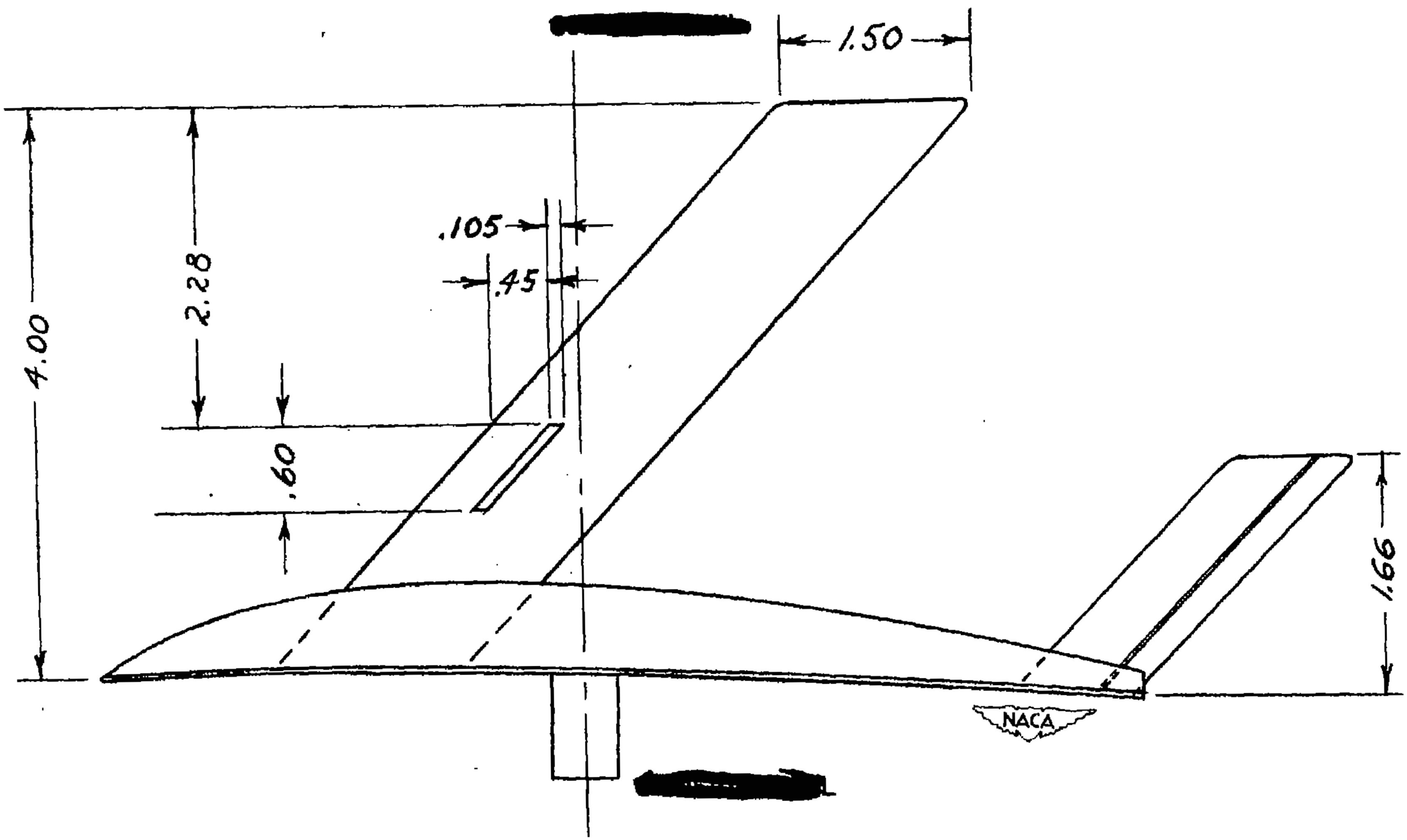


Figure 4.- Detail of semispan model showing location of sweptback wing flap. All dimensions are in inches.

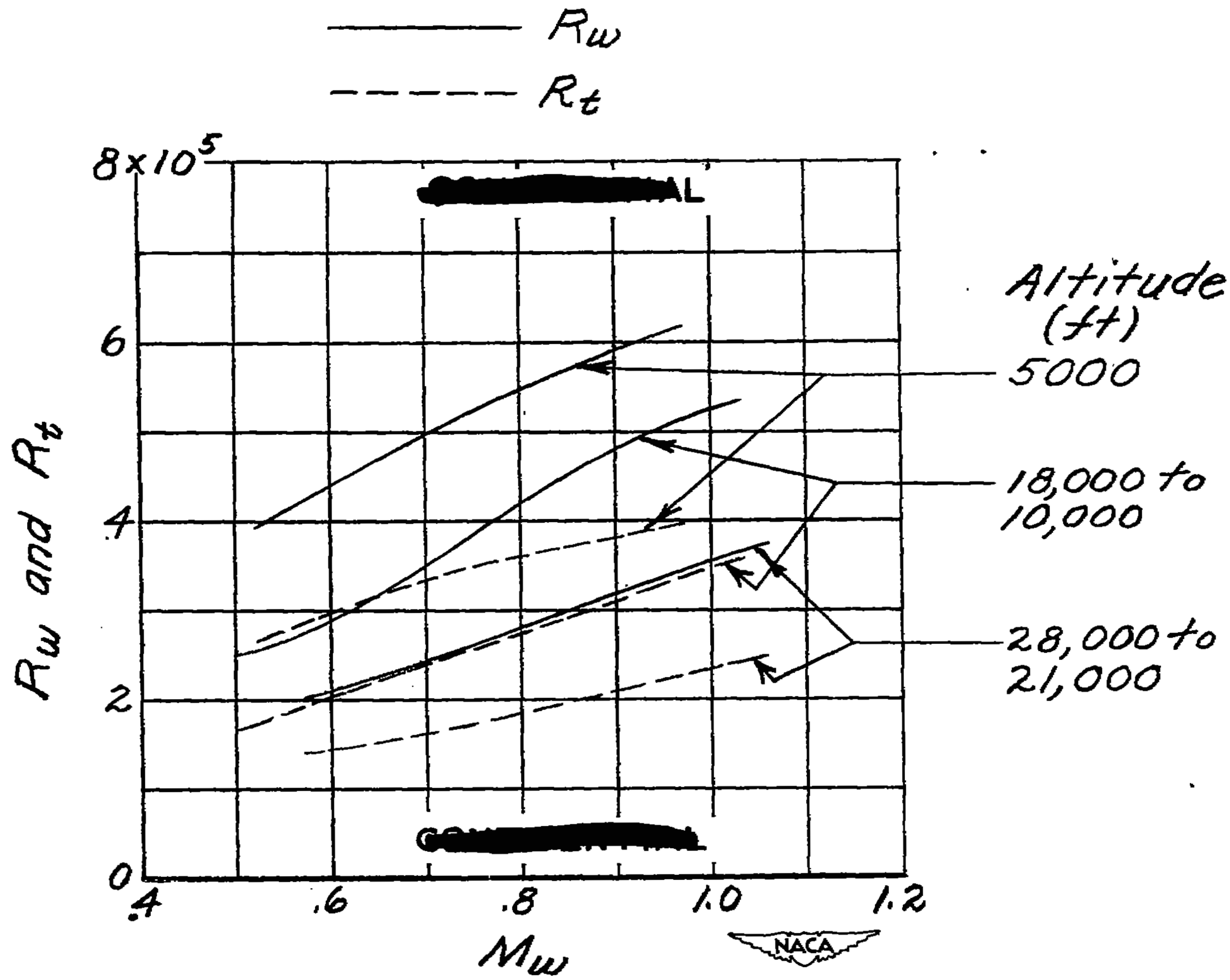


Figure 5.- Variation of Reynolds number of wing R_w and Reynolds number of tail R_t with Mach number for tests at three ranges of altitude.

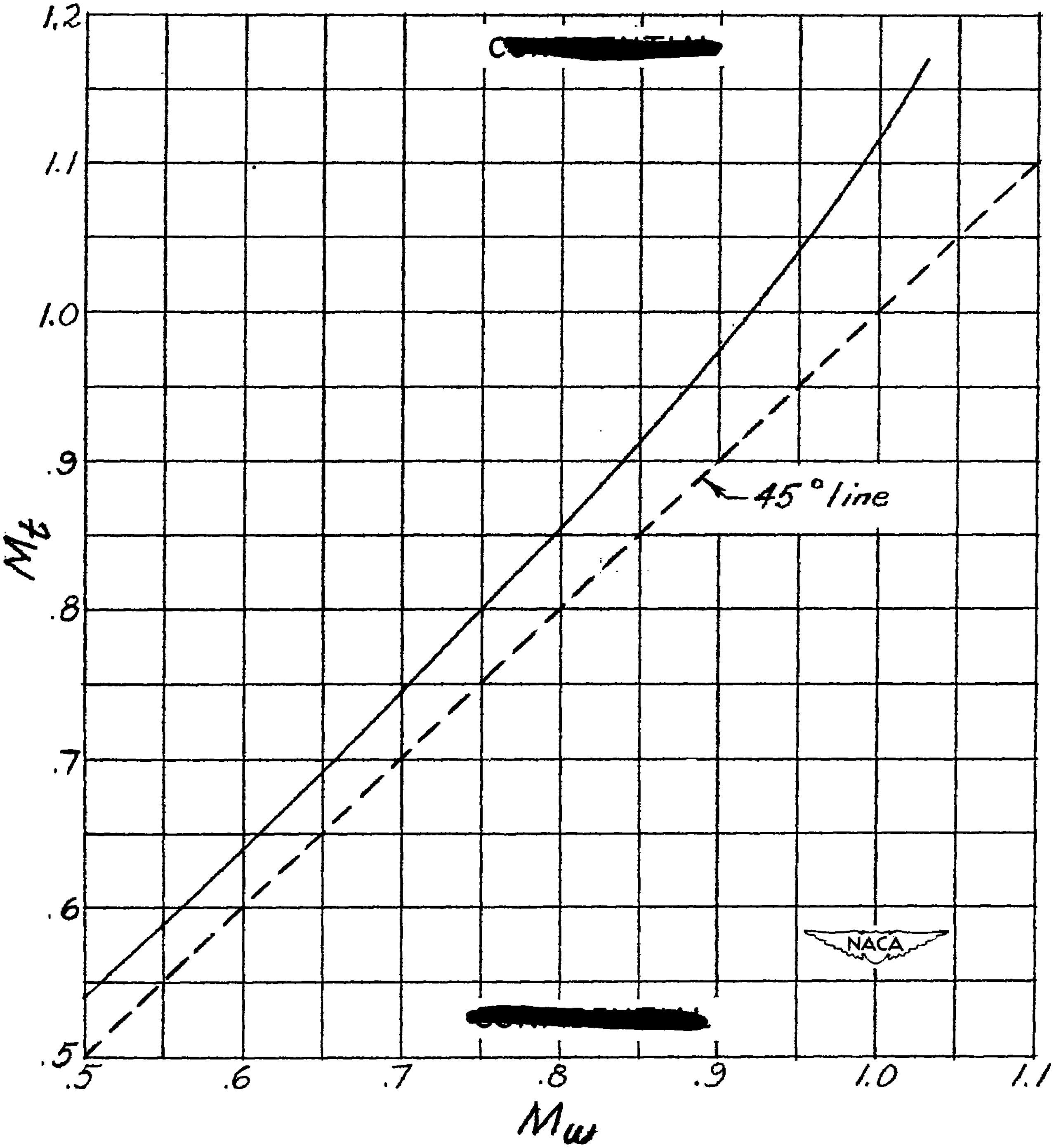


Figure 6.- Relation of Mach number at tail M_t to Mach number at wing M_w.

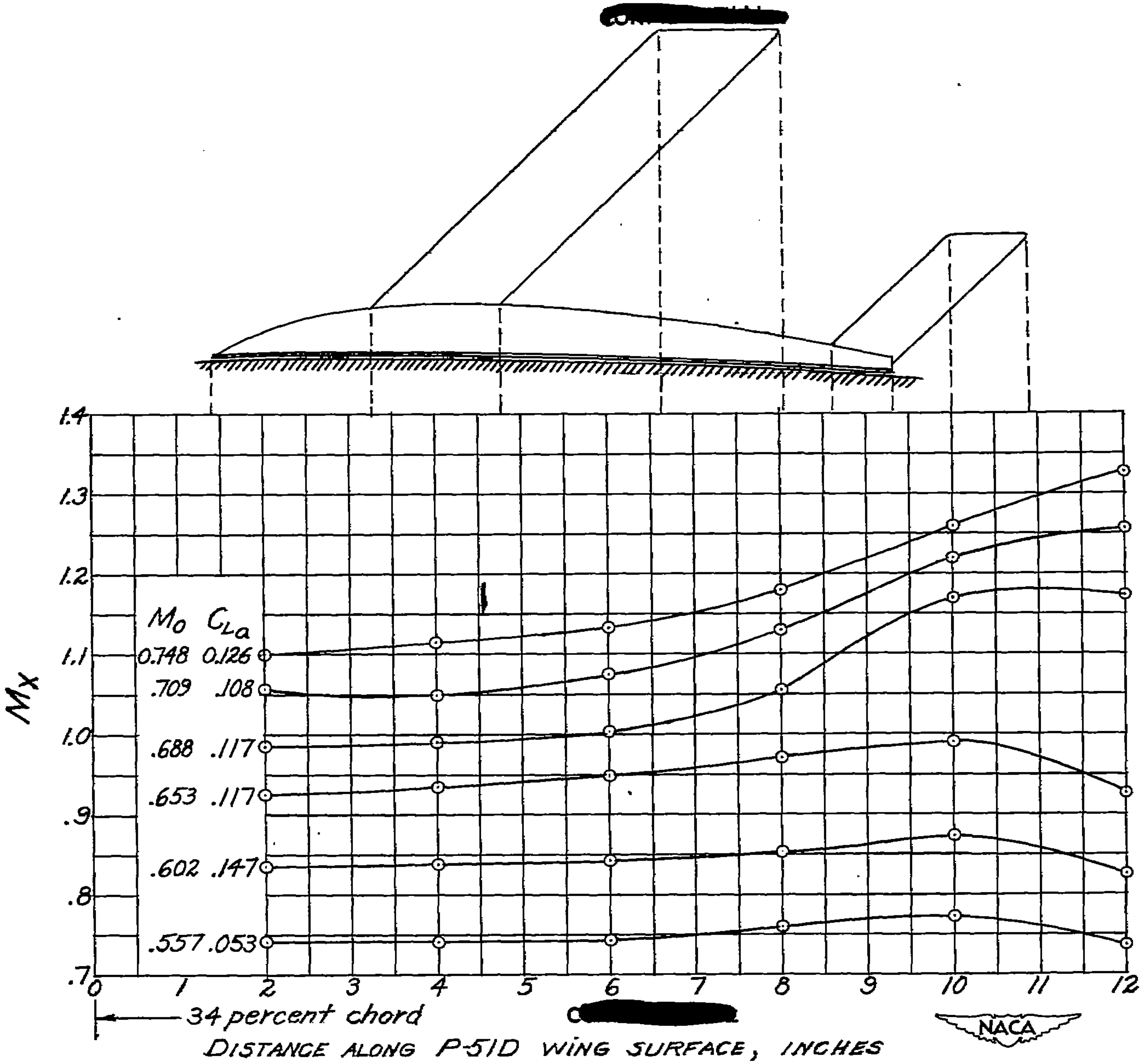
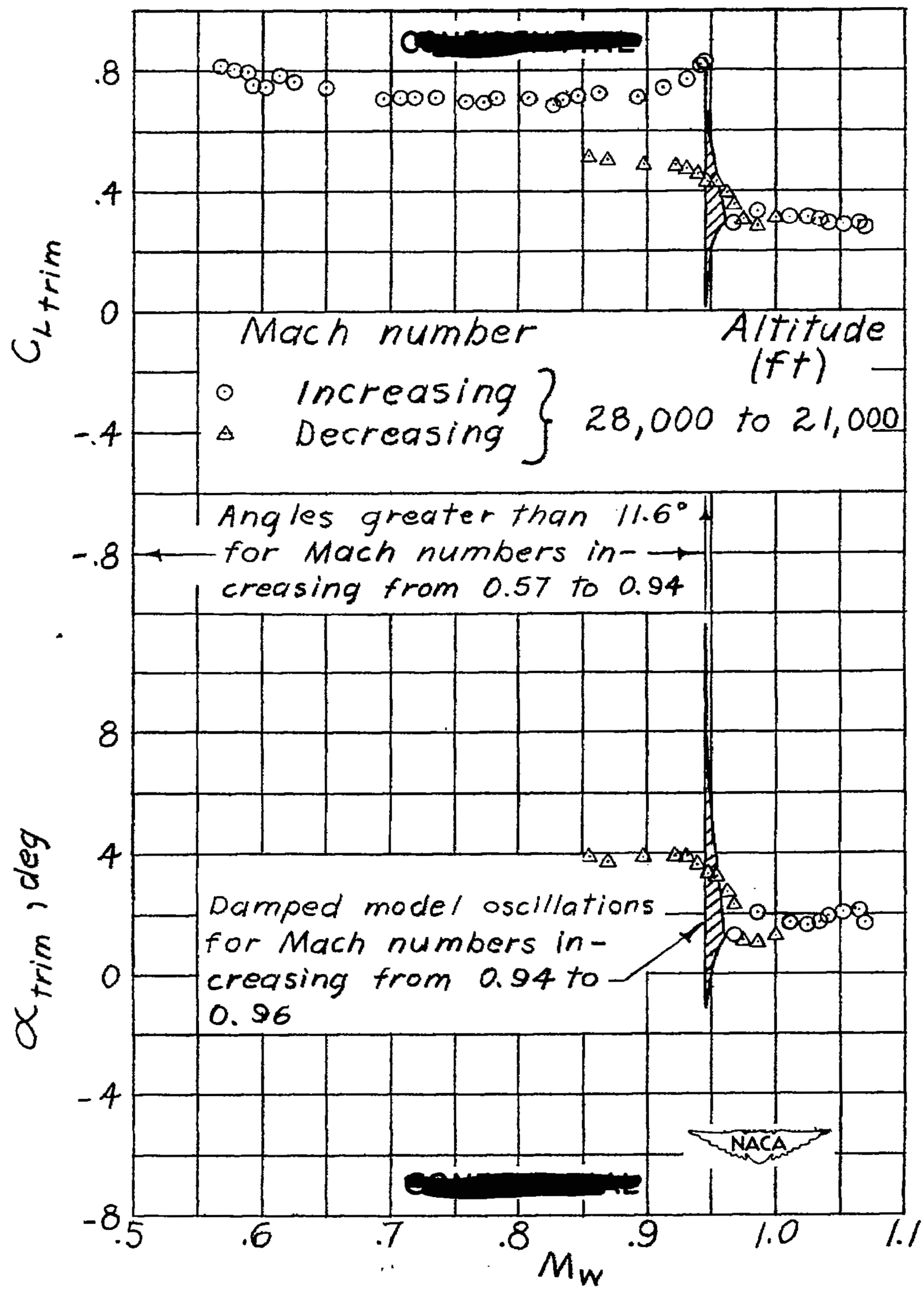


Figure 7.- Variation of local Mach number M_x with distance along P-51D wing surface for several airplane lift coefficients C_{L_a} and airplane Mach numbers M_o. Chordwise location of model also shown.



(a) $i_t = -0.2^{\circ}$.

Figure 8.- Variation with Mach number of lift coefficient and angle of attack for trim for several stabilizer settings. $\delta_e = 0^{\circ}$.

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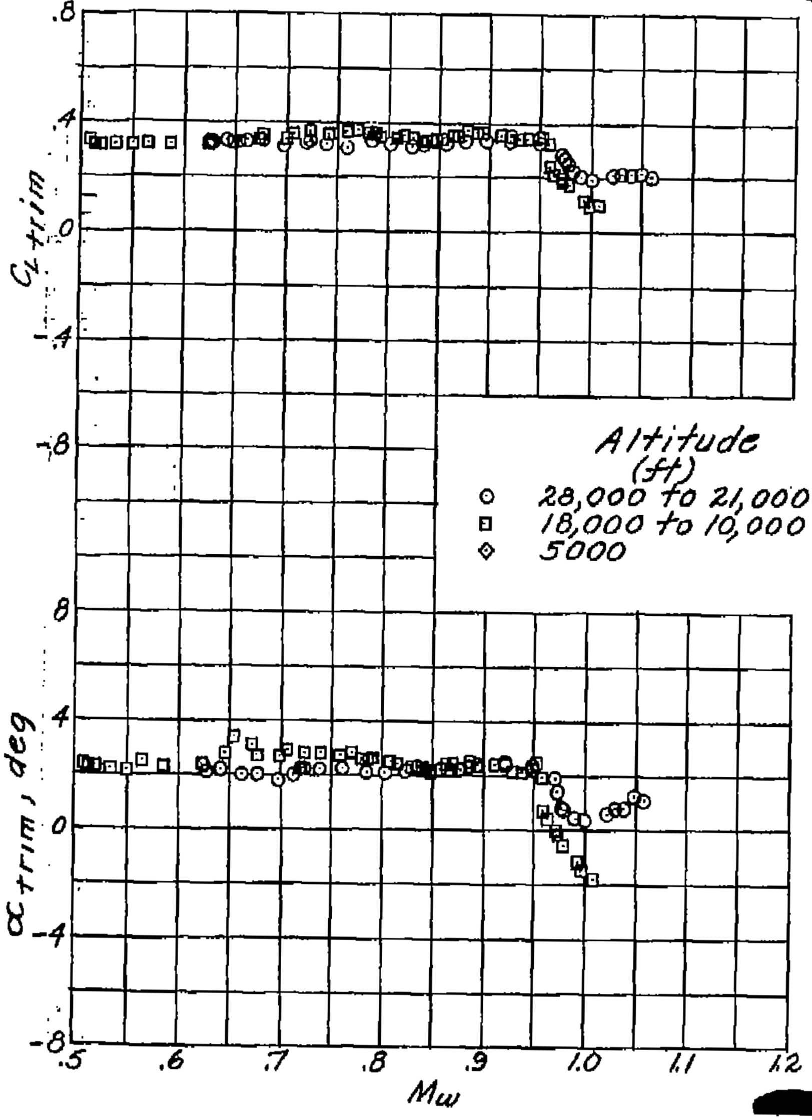
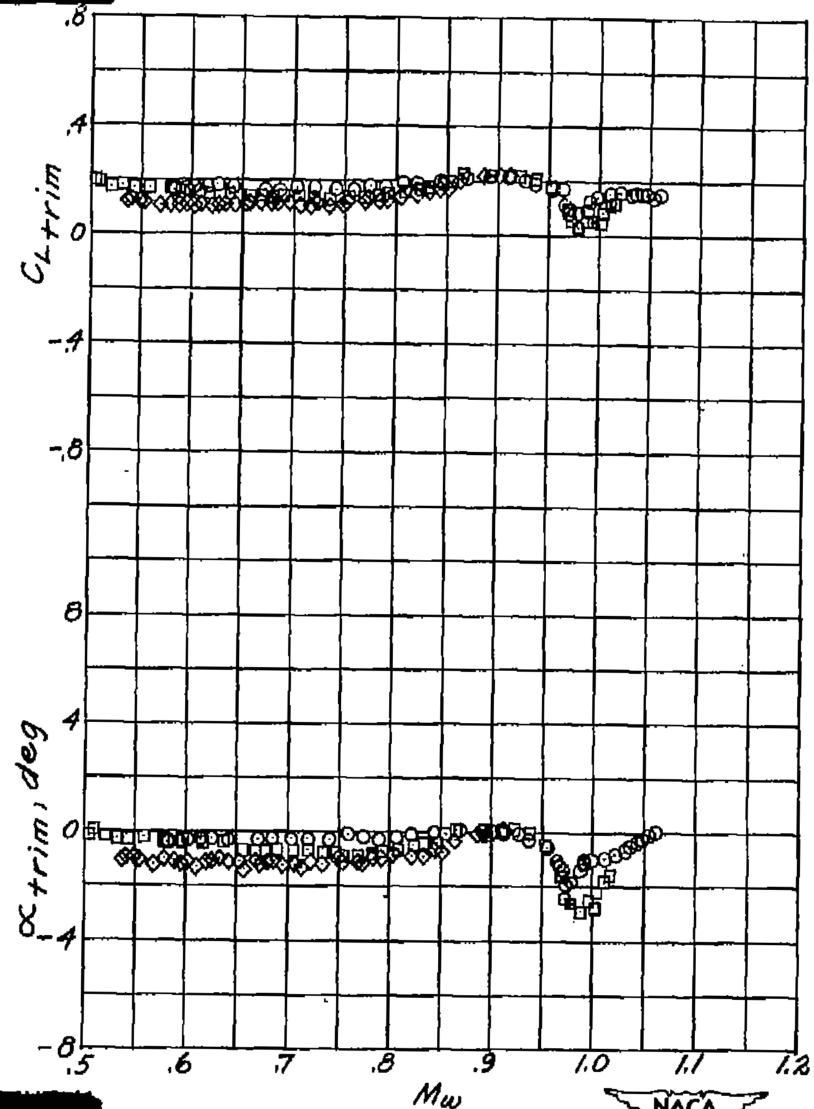


(b) $i_t = 0.7^\circ$.



(c) $i_t = 1.85^\circ$.

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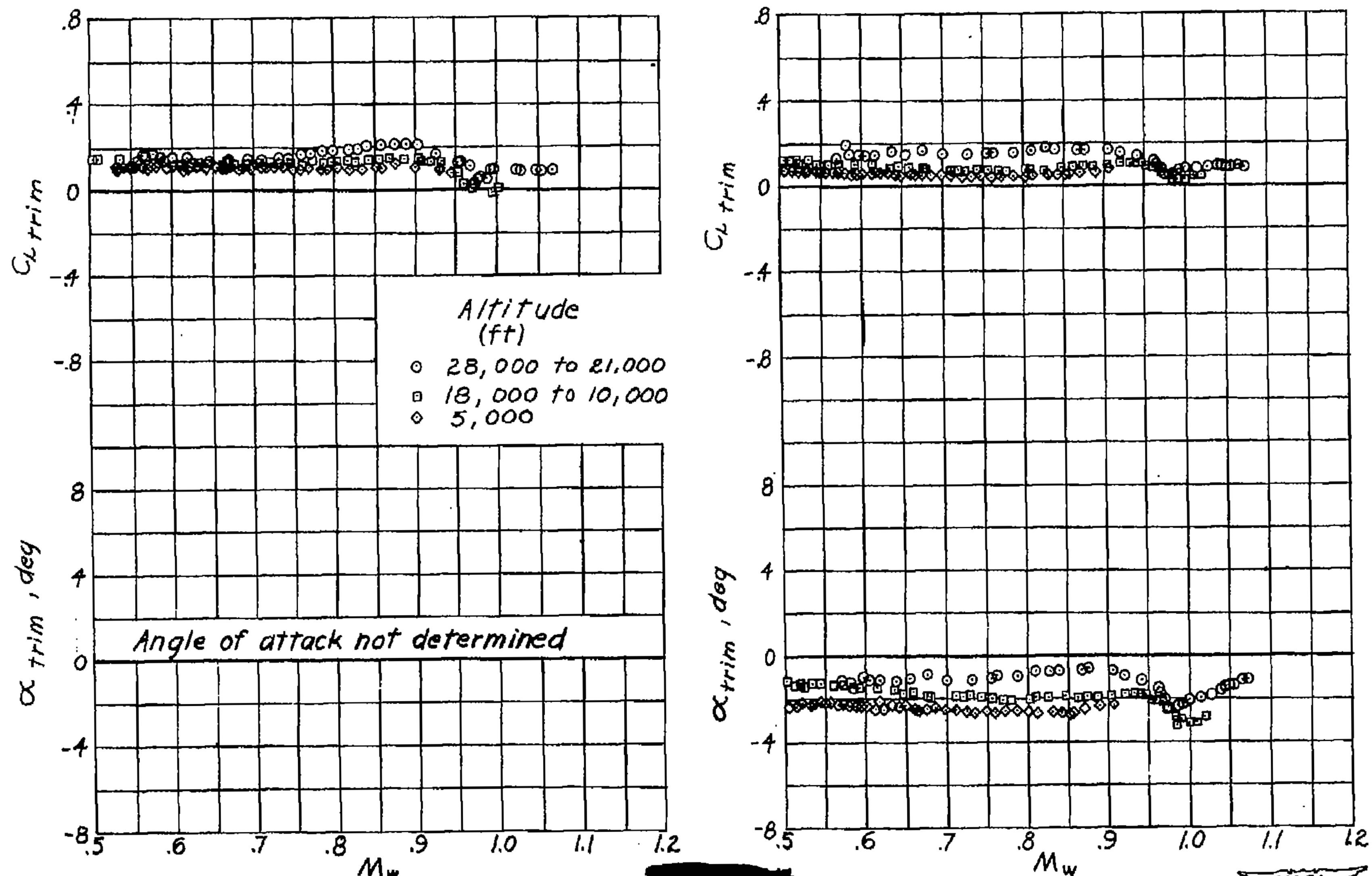
Figure 8.- Continued.

[redacted]



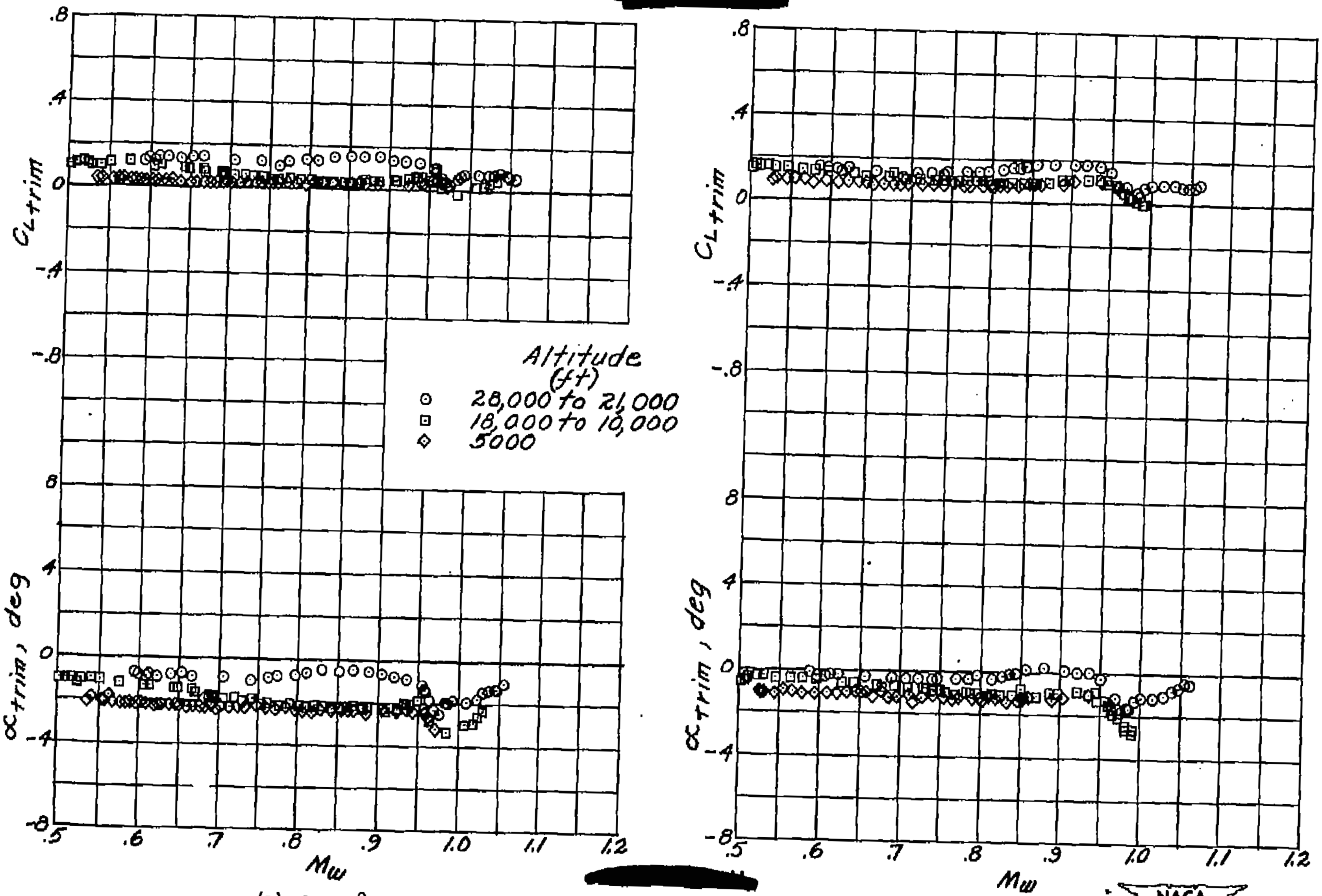
[redacted]

(d) $i_t = 2.3^{\circ}$.

(e) $i_t = 2.8^{\circ}$.

Figure 8.- Concluded.

[redacted]



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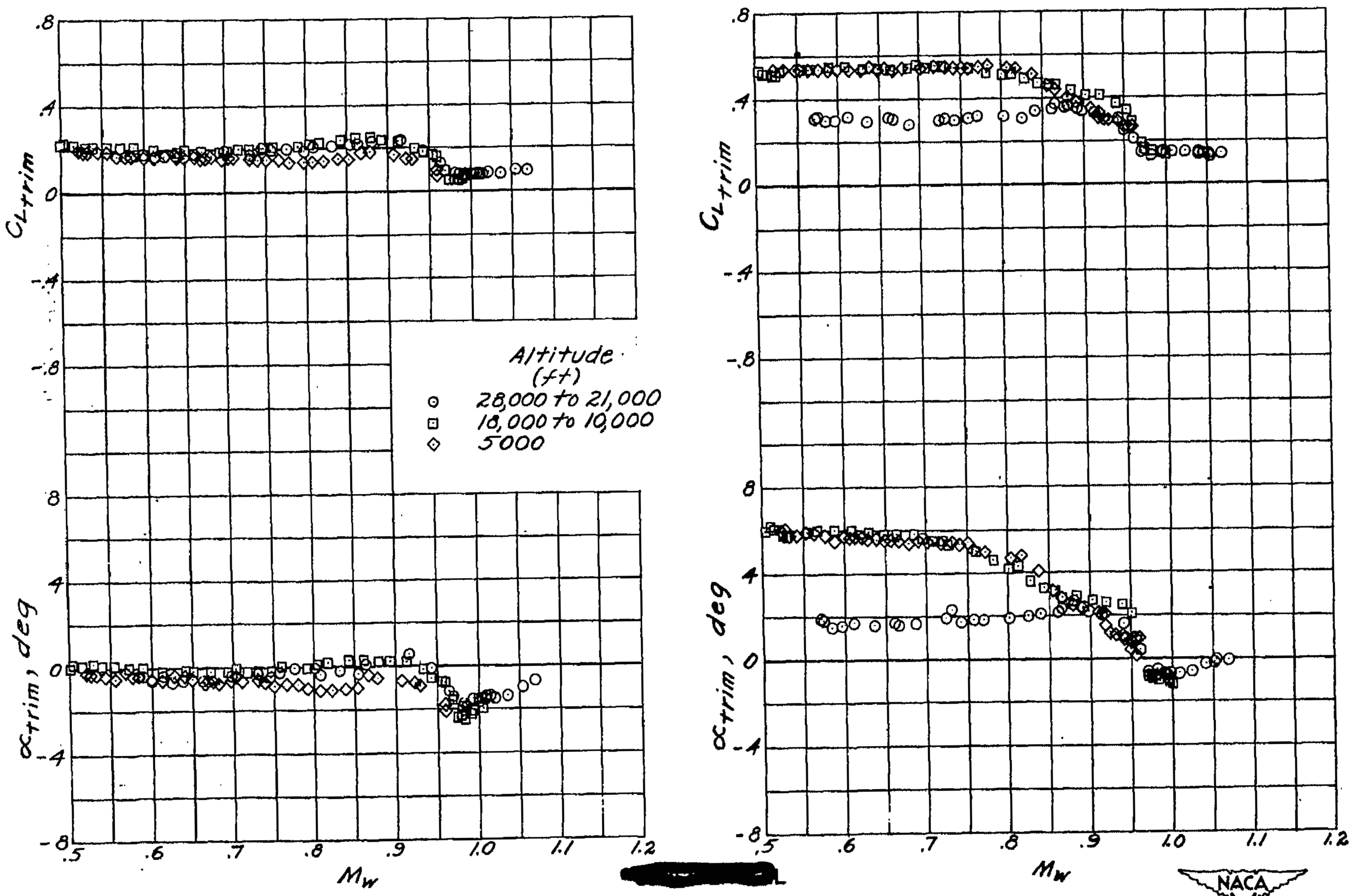
(a) $\delta_e = 2^{\circ}$.

(b) $\delta_e = -2^{\circ}$.

Figure 9.- Variation with Mach number of lift coefficient and angle of attack for trim with various elevator deflections. $i_t = 2.3^{\circ}$.

[redacted]



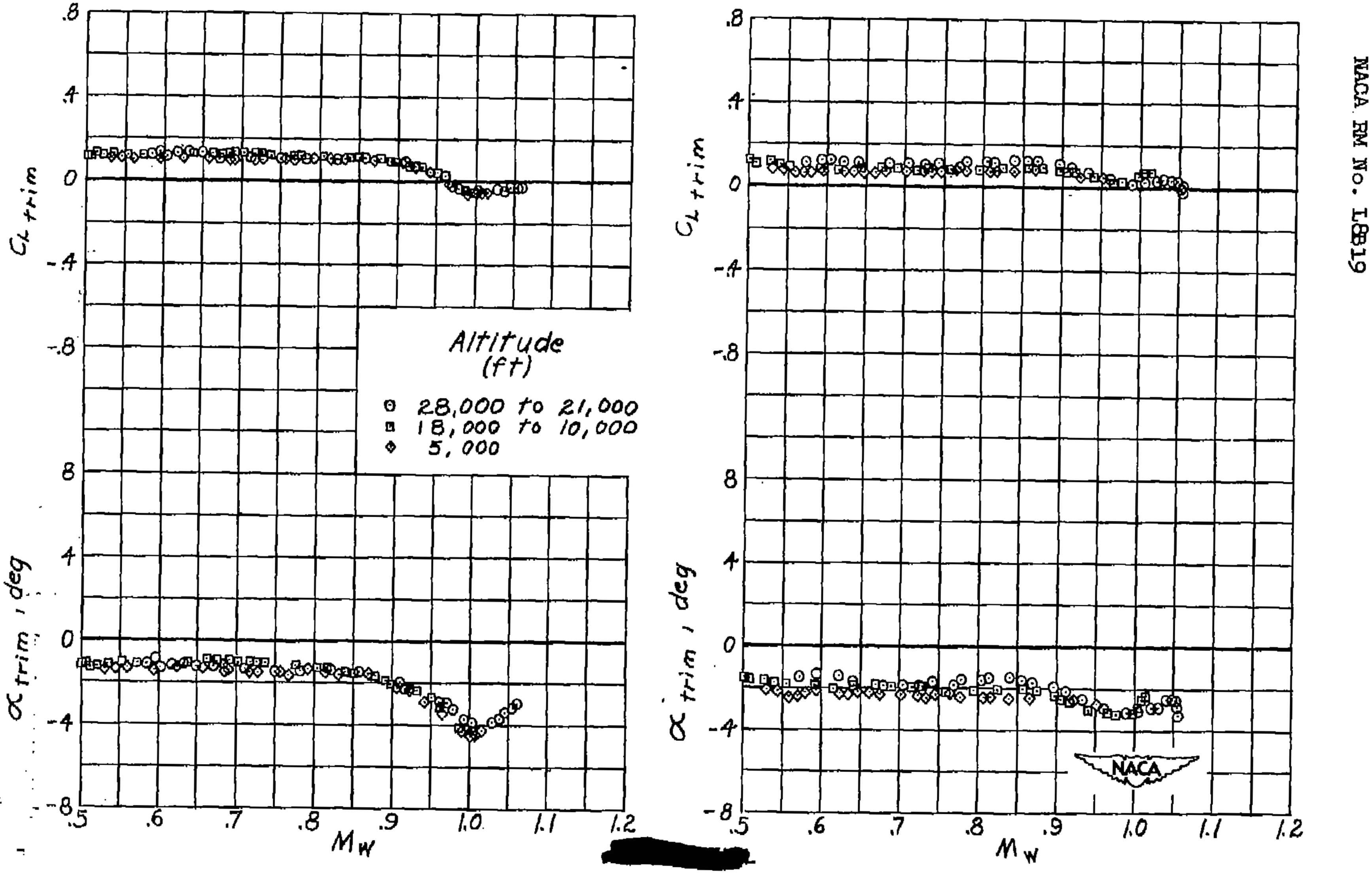
[redacted]

(c) δ_e = -3.9°.

(d) δ_e = -5.1°.

Figure 9.- Concluded.

[redacted]



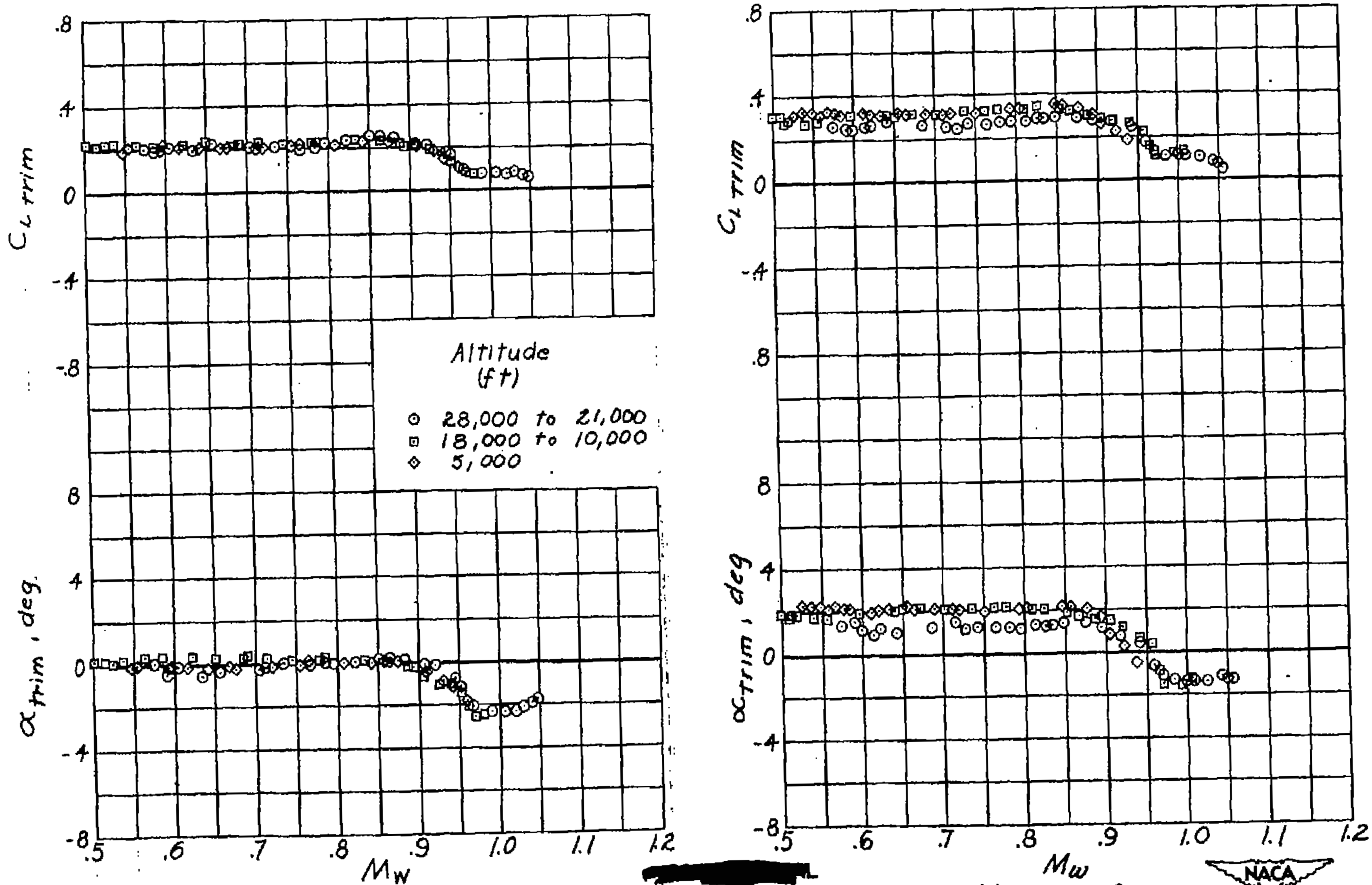
[redacted]

(a) Transition wires on wing of model.

(b) Transition wires on wing and tail of model.

Figure 10.- Variation with Mach number of lift coefficient and angle of attack for trim with transition wires on wing of model and transition wires on wing and tail of model; $i_t = 2.8^\circ$, $\delta_e = 0^\circ$.

[redacted]



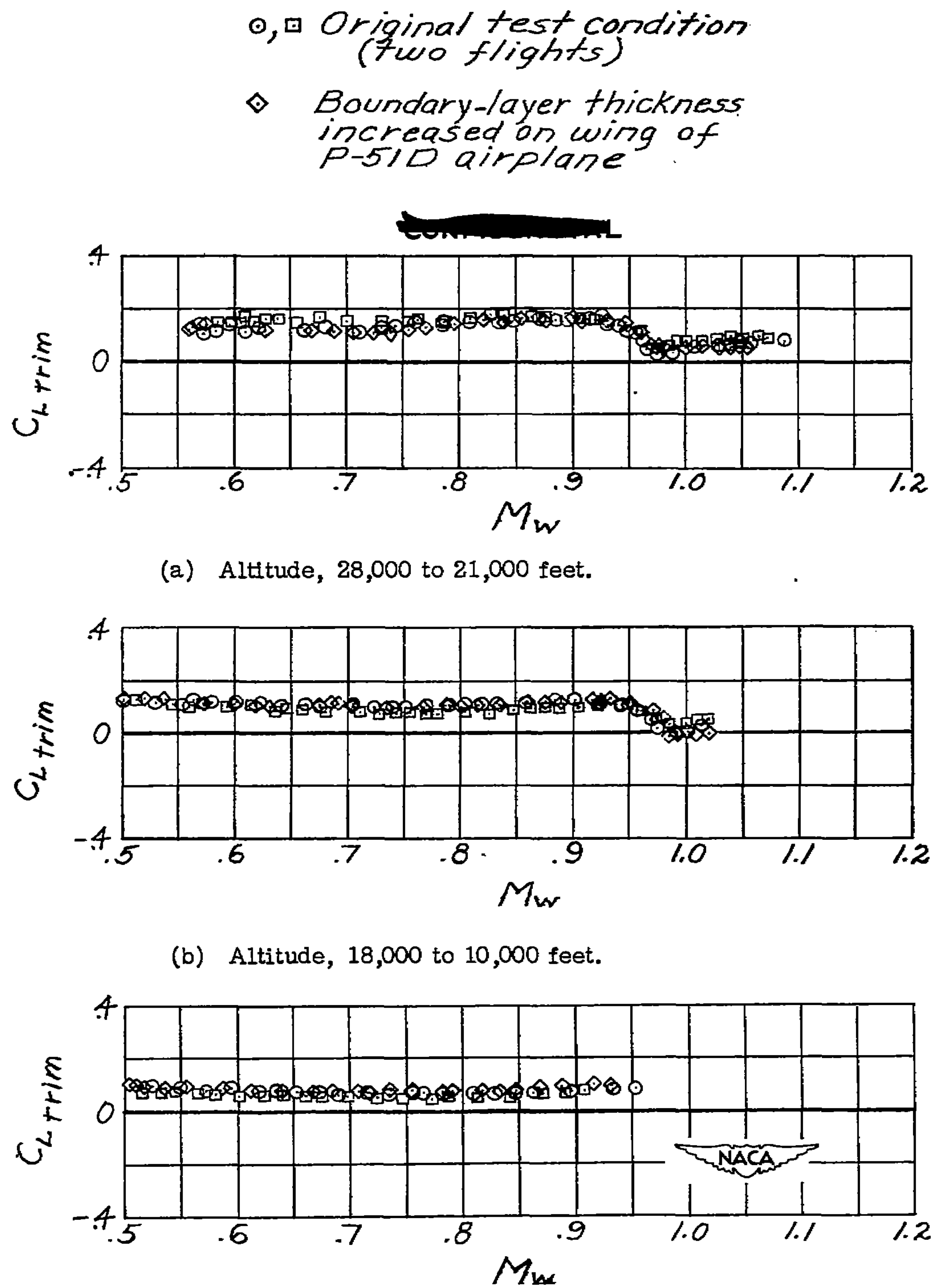
(a) $\delta_e = -1.9°$.

(b) $\delta_e = -4.05°$.

[redacted]

Figure 11.- Variation with Mach number of lift coefficient and angle of attack for trim for two elevator deflections with transition wires on both model wing and tail; $i_t = 2.8°$.

[redacted]



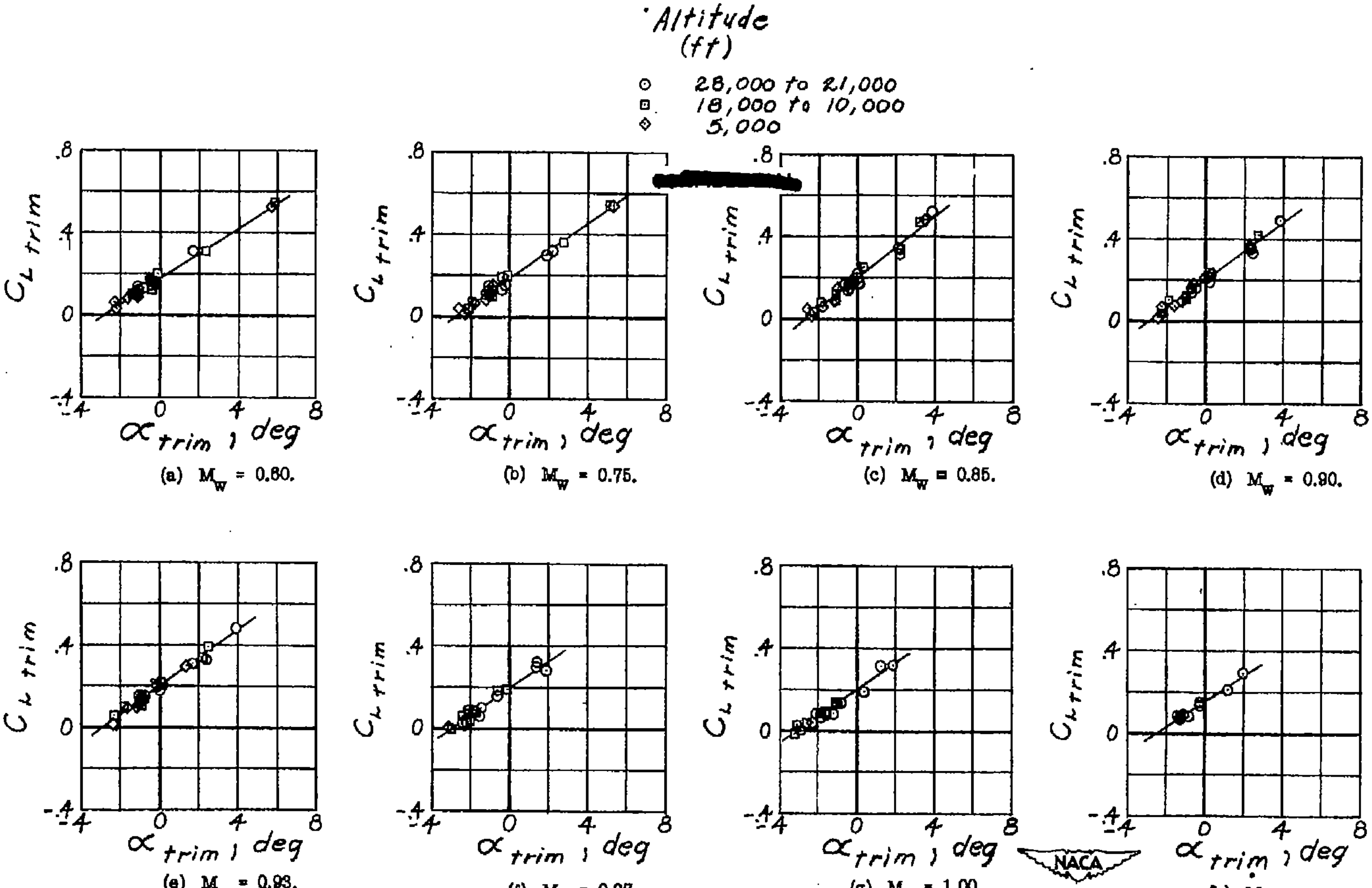
(a) Altitude, 28,000 to 21,000 feet.

(b) Altitude, 18,000 to 10,000 feet.

(c) Altitude, 5,000 feet.

[redacted]

Figure 12.- Variation with Mach number of lift coefficient for trim with original test condition and with boundary-layer thickness increased on wing of P-51D airplane. $i_t = 2.8^\circ$, $\delta_e = 0^\circ$.



[redacted]

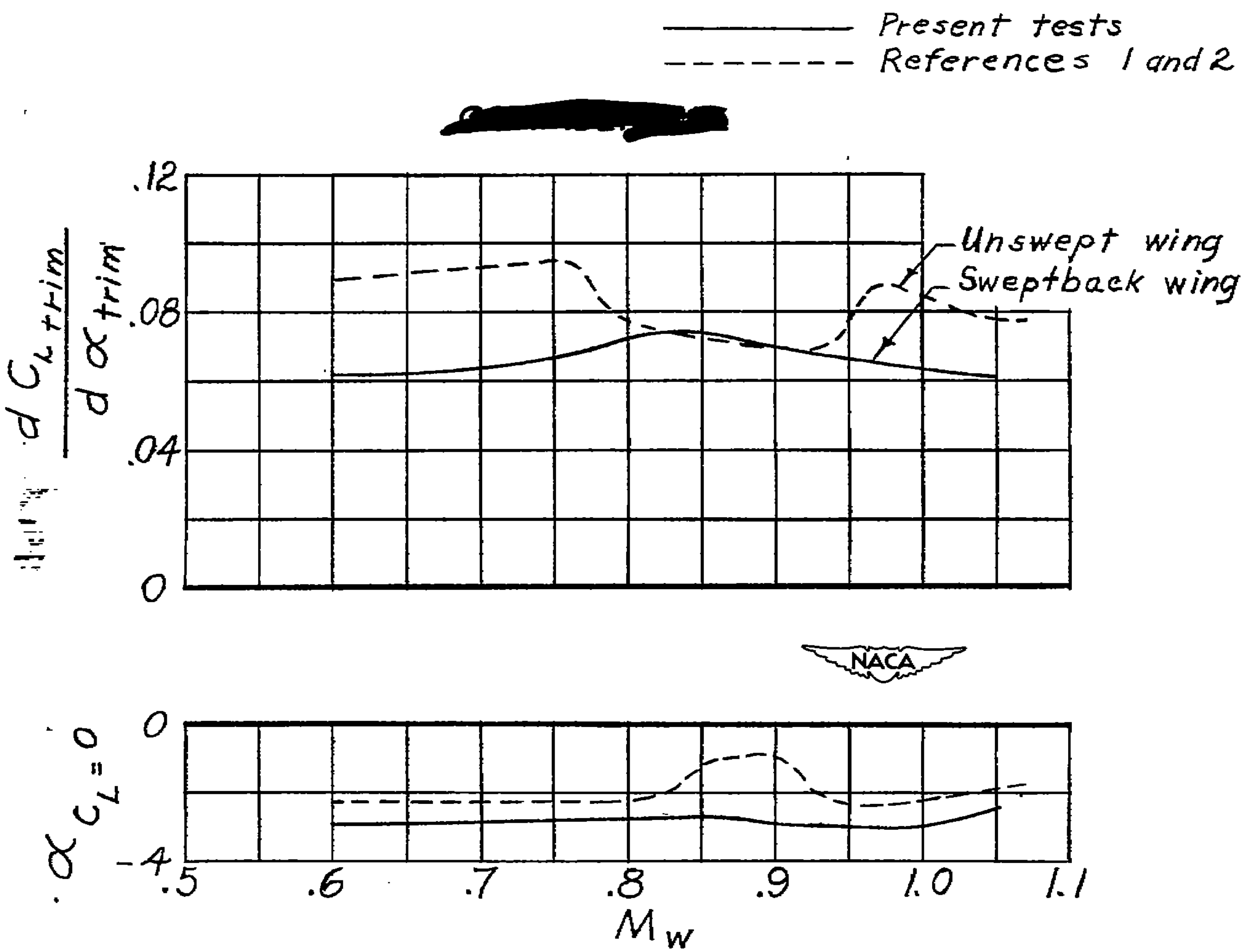
(a) M_W = 0.60. (b) M_W = 0.75. (c) M_W = 0.85. (d) M_W = 0.90.

(e) M_W = 0.93. (f) M_W = 0.97. (g) M_W = 1.00. (h) M_W = 1.05.

[redacted]

Figure 13.- Variation of lift coefficient with angle of attack for various Mach numbers.

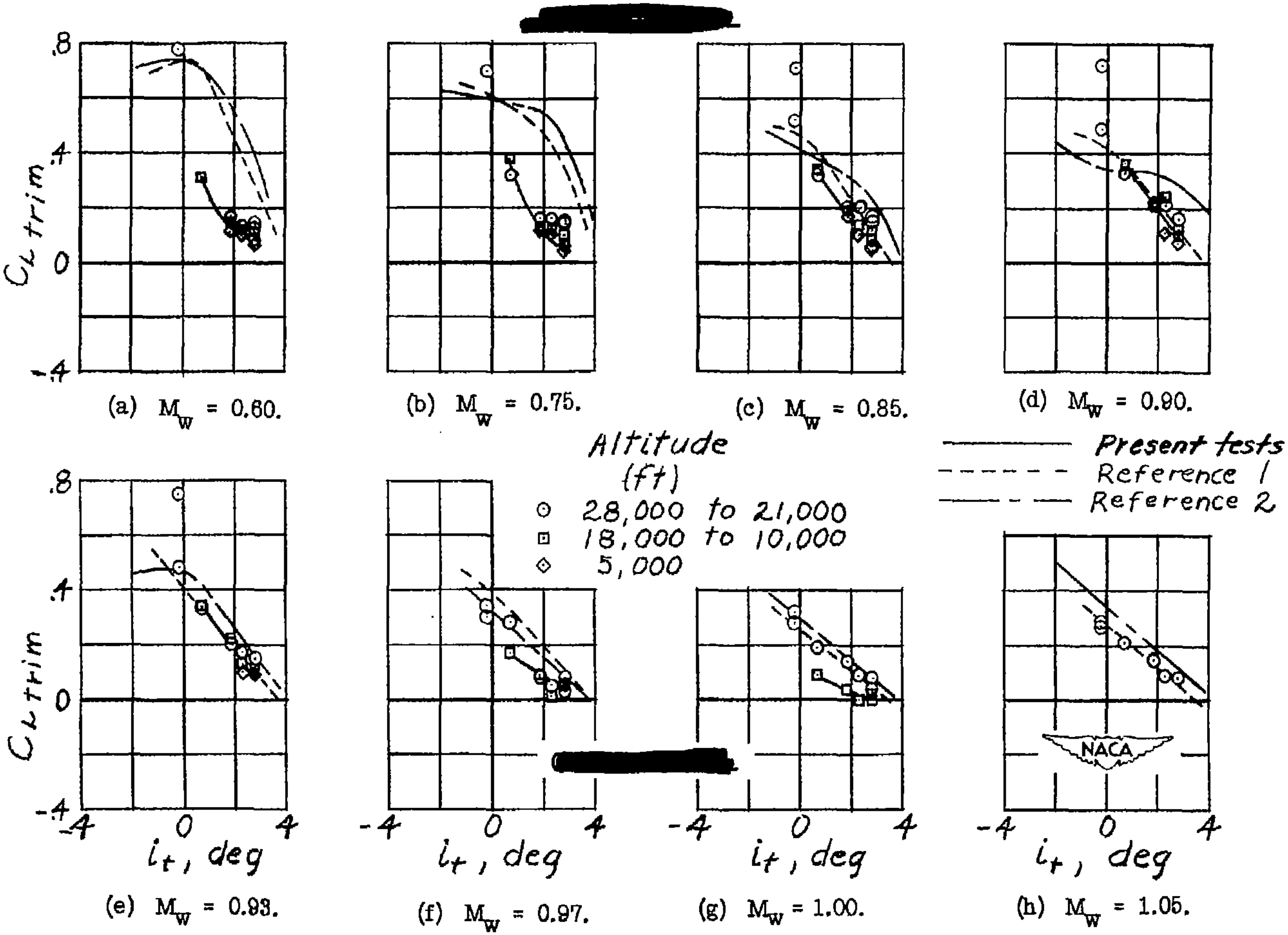
[redacted]



[redacted]

Figure 14.- Variation with Mach number of slope of trim lift curve and angle of zero lift.

[redacted]

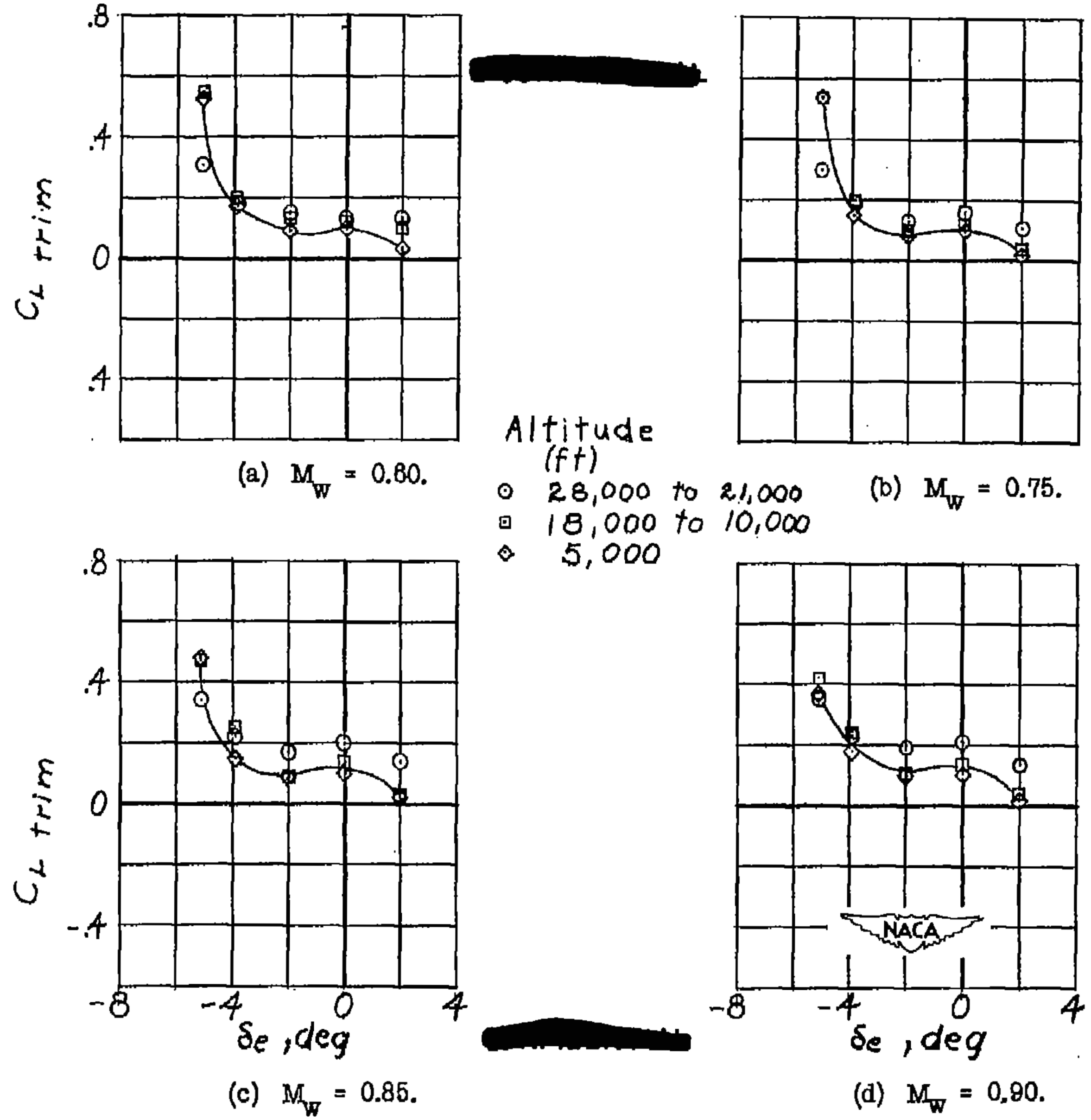


(a) M_W = 0.60.
(b) M_W = 0.75.
(c) M_W = 0.85.
(d) M_W = 0.90.
(e) M_W = 0.93.
(f) M_W = 0.97.
(g) M_W = 1.00.
(h) M_W = 1.05.

[redacted]

Figure 15.- Variation of lift coefficient for trim with stabilizer setting for various Mach numbers and $\delta_e = 0^{\circ}$. Results for unswept tail of reference 1 and for sweptback tail of reference 2 shown for comparison.

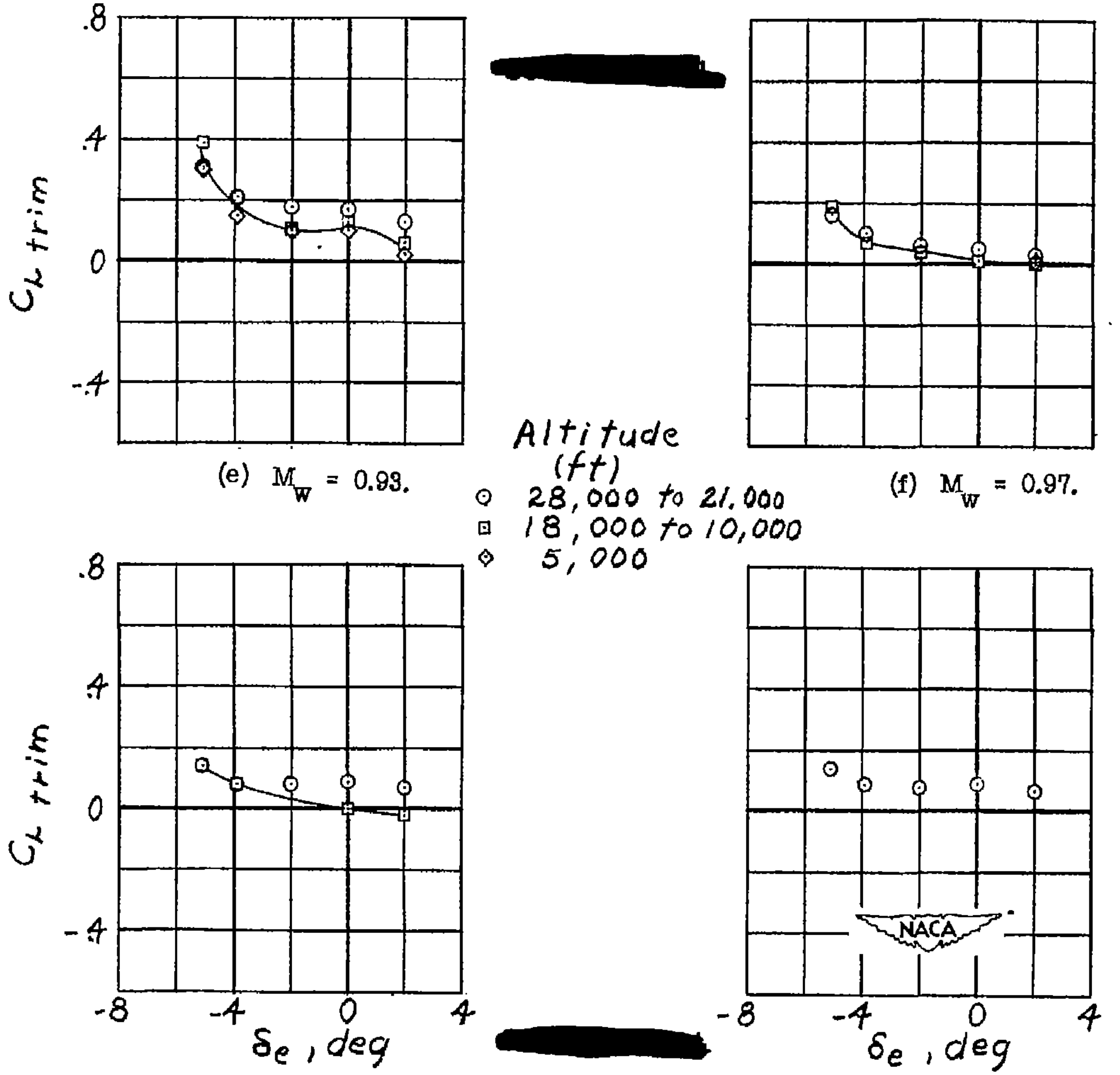
[redacted]



[redacted]

Figure 16.- Variation of lift coefficient for trim with elevator deflection for various Mach numbers. i_t = 2.3°.

[redacted]



(e) M_W = 0.93.

(f) M_W = 0.97.

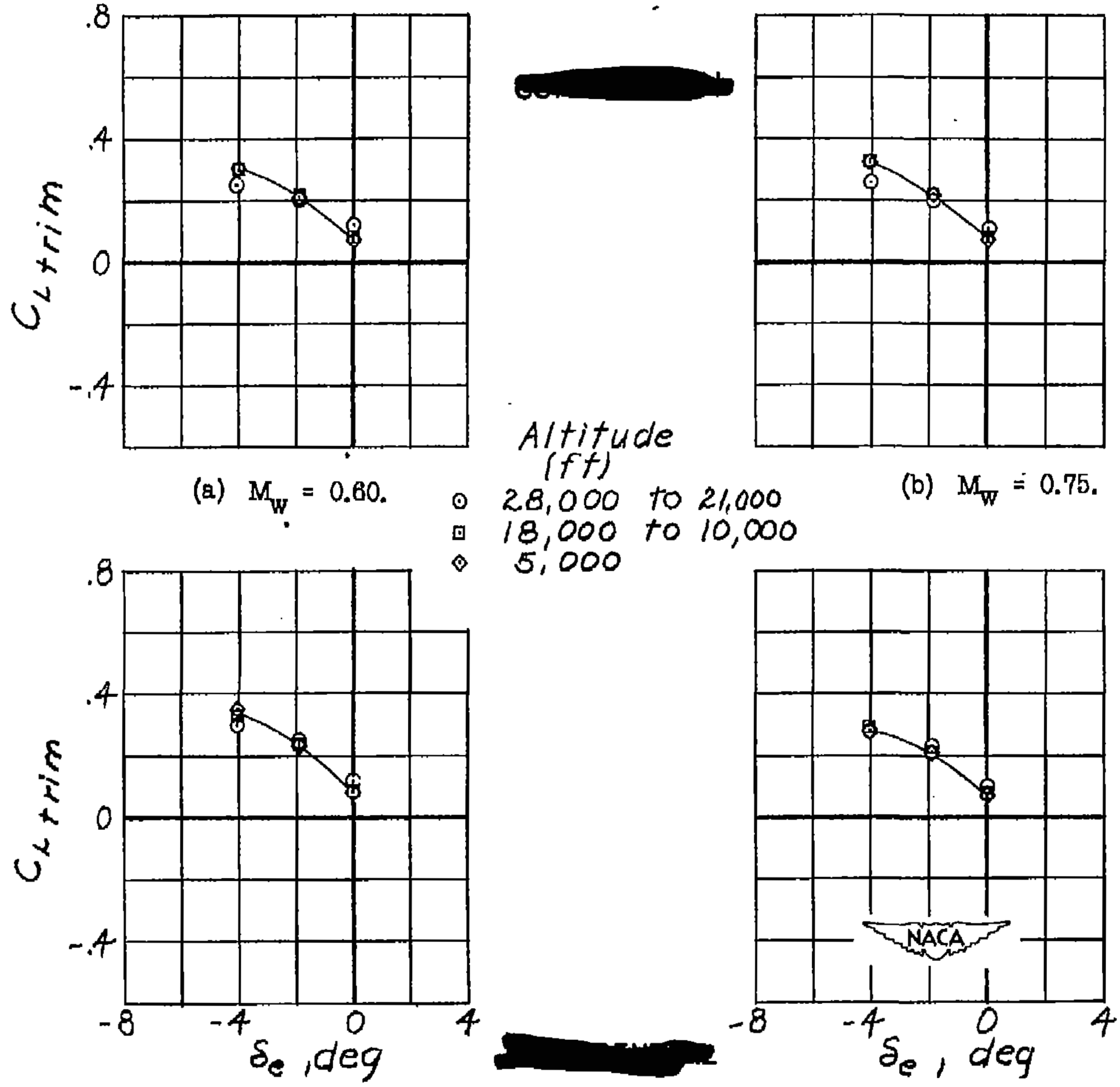
(g) M_W = 1.00.

(h) M_W = 1.05.

[redacted]

Figure 16.- Concluded.

[redacted]



(a) M_W = 0.60.

(b) M_W = 0.75.

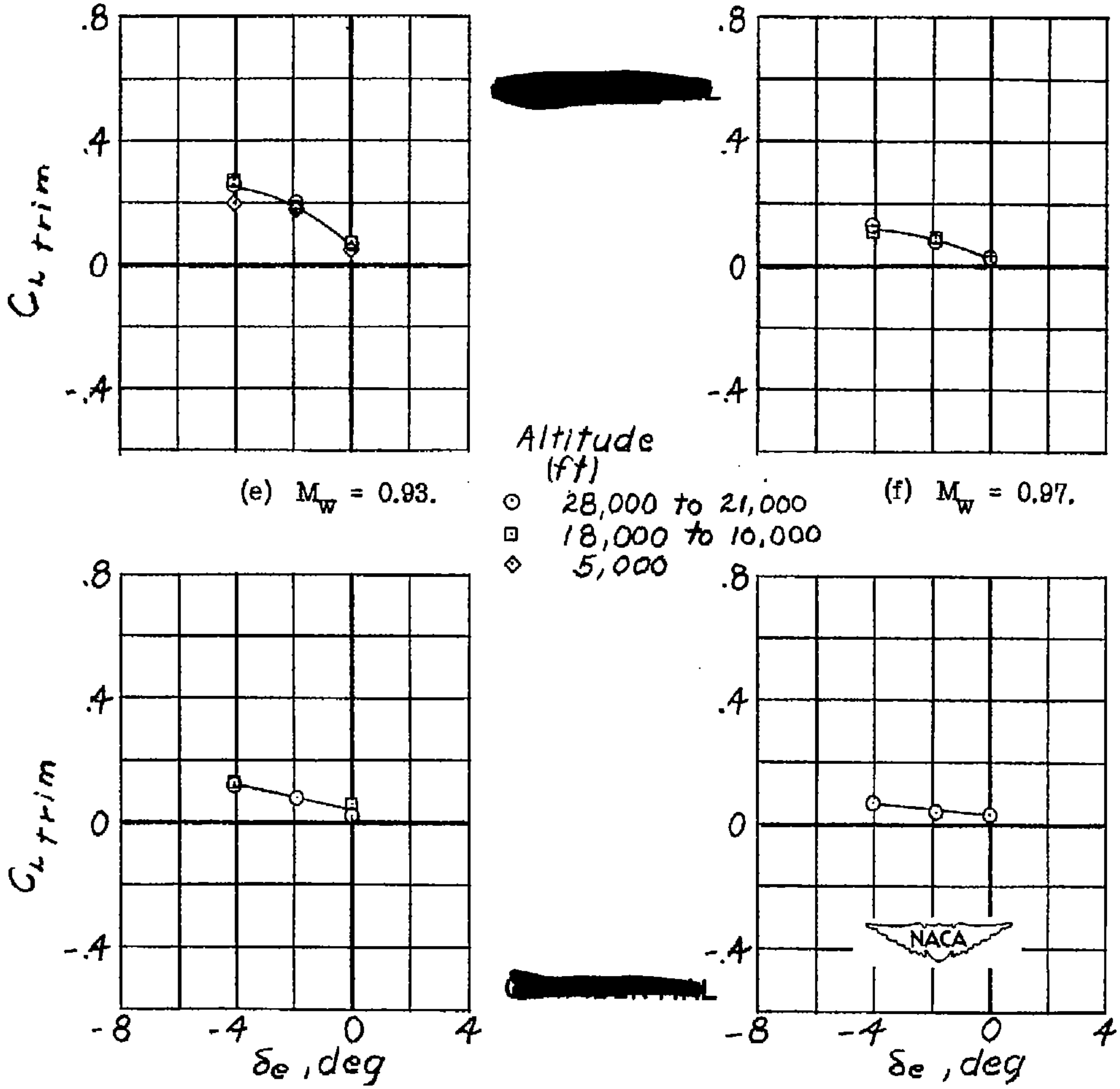
(c) M_W = 0.85.

(d) M_W = 0.90.

[redacted]

Figure 17.- Variation of lift coefficient for trim with elevator deflection for various Mach numbers. Transition wires on model wing and tail. $i_t = 2.8^{\circ}$.

[redacted]



(e) M_W = 0.93.

(f) M_W = 0.97.

(g) M_W = 1.00.

(h) M_W = 1.05.

[redacted]

Figure 17.- Concluded.

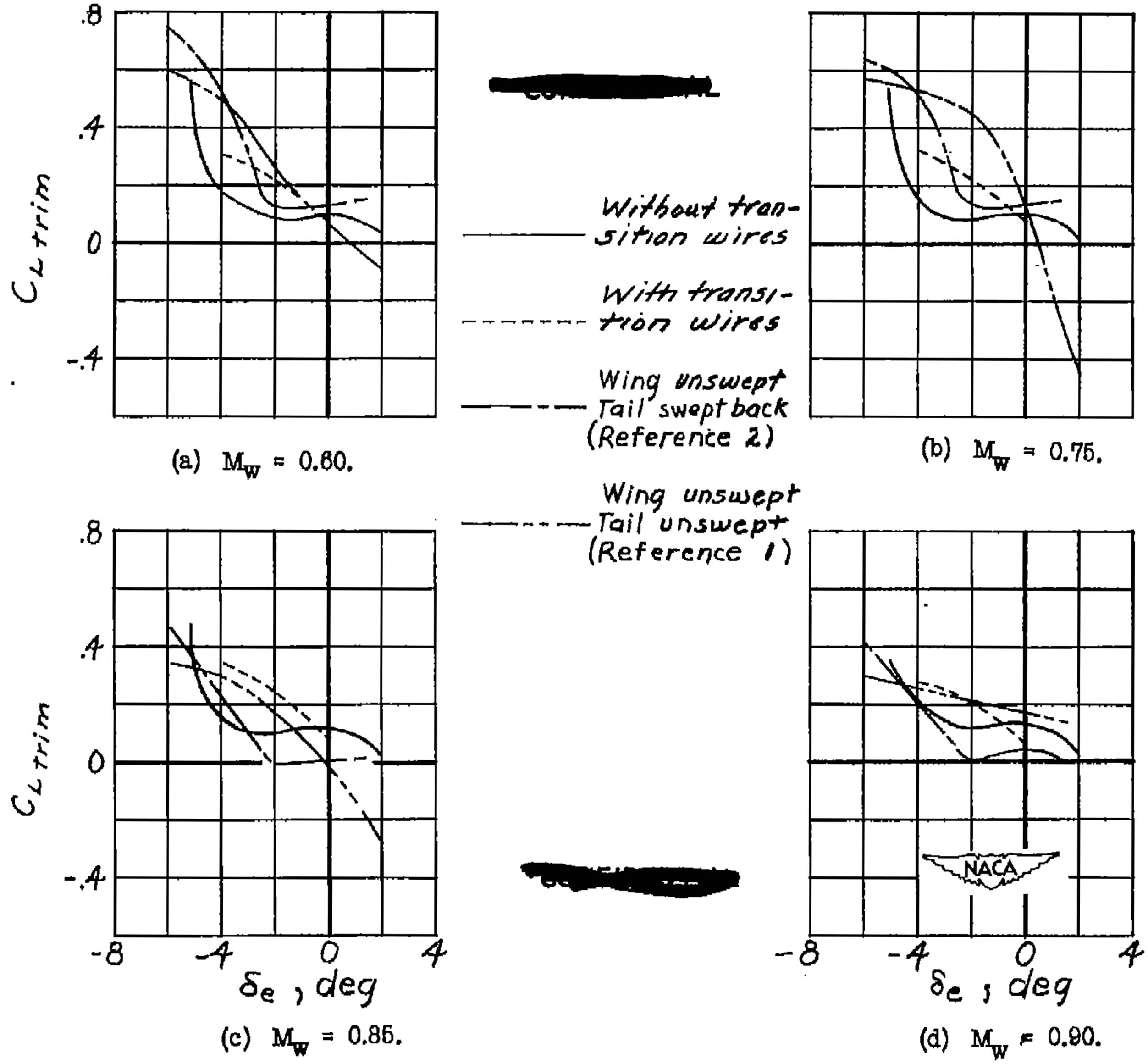


Figure 18.- Variation of lift coefficient for trim with elevator deflection for various Mach numbers. Comparison of data from present tests without transition wires (i_t = 2.3°) and with transition wires on model wing and tail (i_t = 2.8°) with data for sweptback tail from reference 2 (i_t = 3.7°) and for unswept tail reference 1 (i_t = 4.0°).

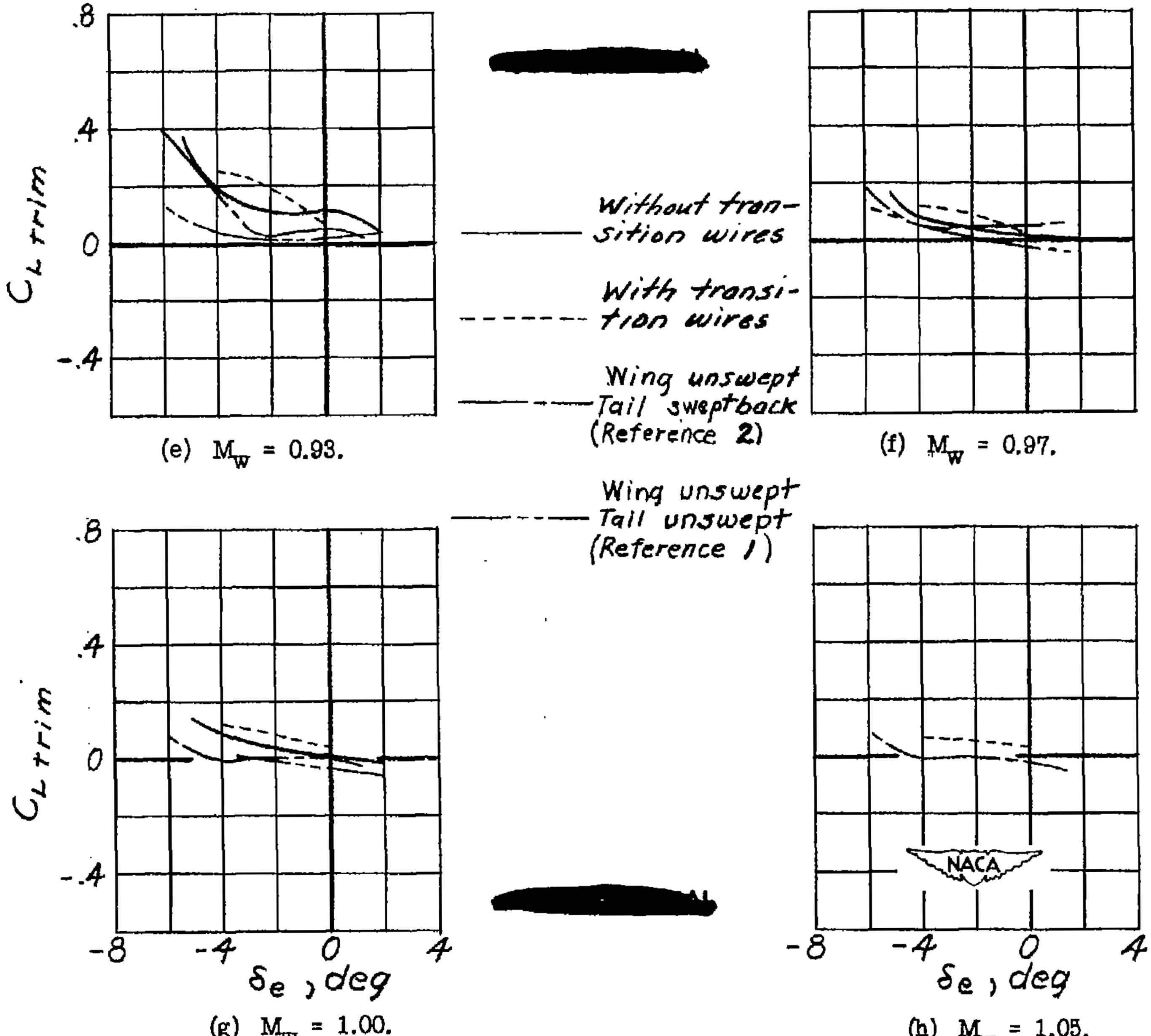
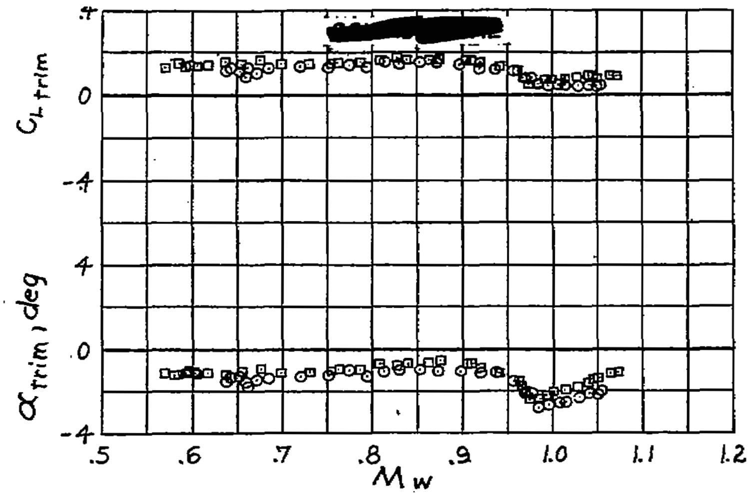
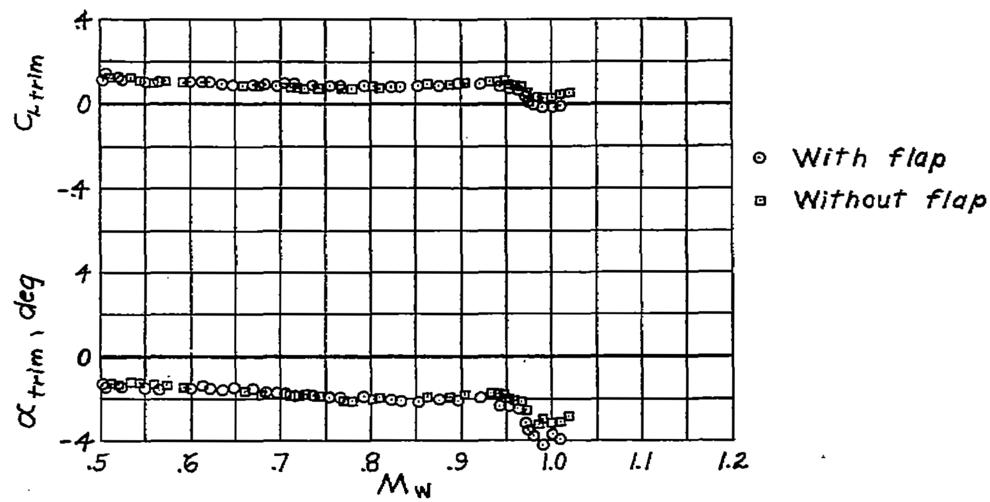


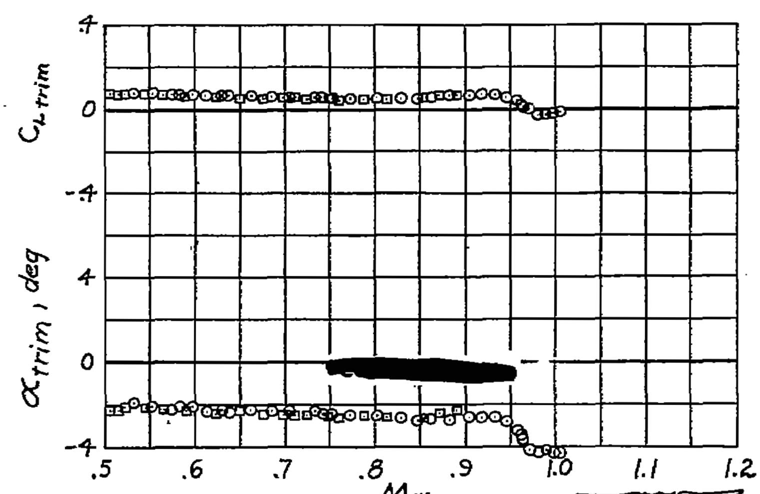
Figure 18.- Concluded.



(a) Altitude, 28,000 to 21,000 feet.

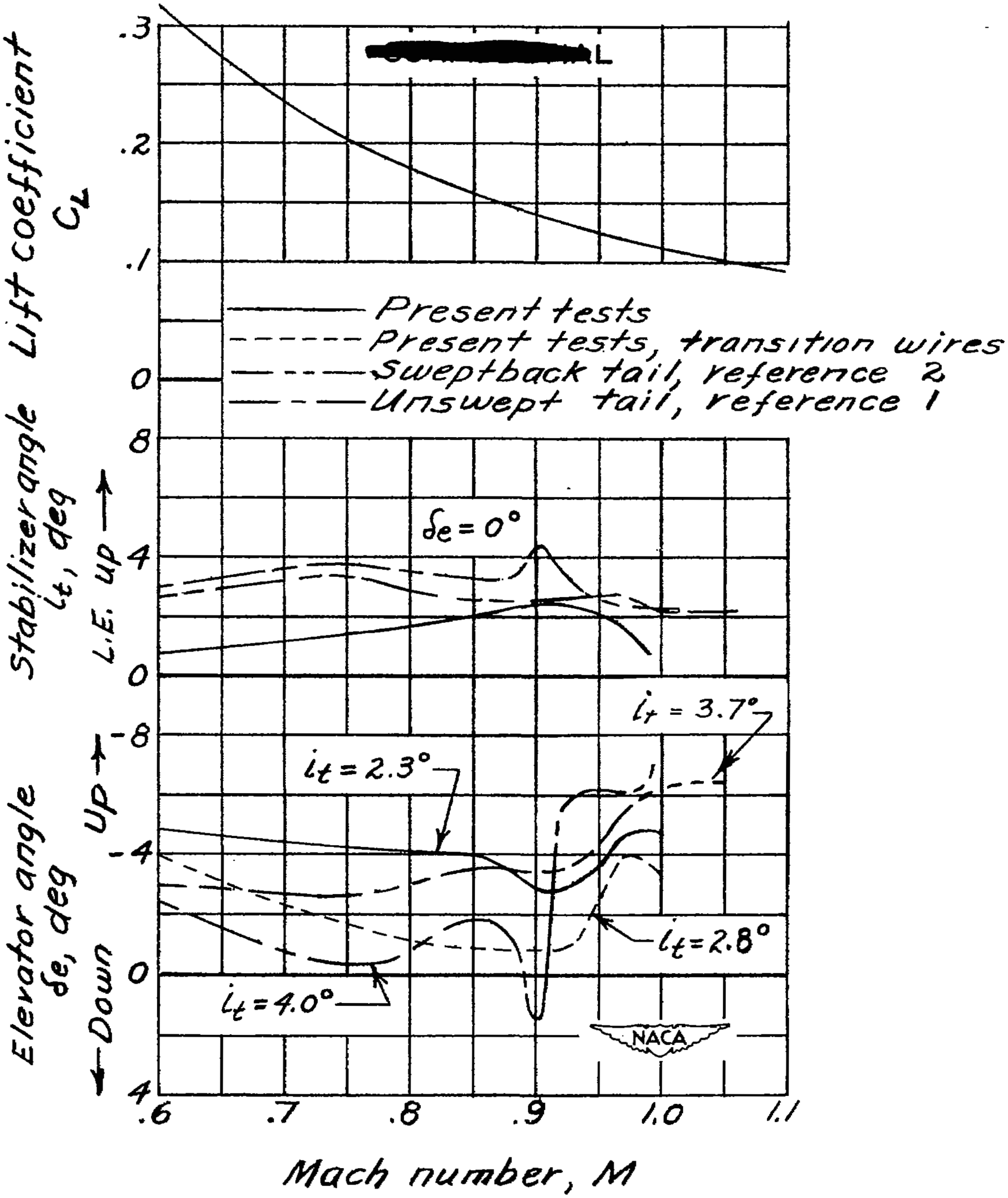


(b) Altitude, 18,000 to 10,000 feet.



(c) Altitude, 5,000 feet.

Figure 19.- Variation with Mach number of lift coefficient and angle of attack for trim with and without dive-recovery flap; $i_t = 2.8^{\circ}$,



[redacted]

Figure 20.- Variation with Mach number of stabilizer angle and elevator deflection required for trim in level flight at altitude of 30,000 feet and wing loading of 50. Lift coefficient for level flight also shown. Results for model with unswept wing and sweptback tail from reference 2 and for model with unswept wing and unswept tail from reference 1 shown for comparison.