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NASA TECHNICAL MEMORANDUM

NASA TM X-959

~~X64 13389~~

Code 2

NASA TM X-959

(NASA-TM-X-959) AERODYNAMIC CHARACTERISTICS AT MACH NUMBERS FROM 2.50 TO 4.63 OF A VARIABLESWEEP MODEL AT SWEEP ANGLES FROM 55 DEG TO 75 DEG L.S. Jernell (NASA) Apr. 1964 38 p

N72-73509

Unclas

00/99 32309

CLASSIFICATION CHANGED

TO UNCLASSIFIED

By Authority of TD-12-235 Date 6-2-72

AERODYNAMIC CHARACTERISTICS AT MACH NUMBERS FROM 2.50 TO 4.63 OF A VARIABLE-SWEEP MODEL AT SWEEP ANGLES FROM 55° TO 75° (U)

by Lloyd S. Jernell

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, ~~D. C.~~ NASA • APRIL 1964

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AERODYNAMIC CHARACTERISTICS AT MACH NUMBERS FROM 2.50 TO 4.63 OF A VARIABLE-SWEEP MODEL AT SWEEP ANGLES FROM 55° TO 75°

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AERODYNAMIC CHARACTERISTICS AT MACH NUMBERS FROM 2.50

TO 4.63 OF A VARIABLE-SWEEP MODEL AT

SWEEP ANGLES FROM 55° TO 75°*

By Lloyd S. Jernell
Langley Research Center

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SUMMARY

An investigation has been conducted in the Langley Unitary Plan wind tunnel to determine the longitudinal and lateral aerodynamic characteristics of a variable-sweep fighter model for sweep angles from 55° to 75° at Mach numbers from 2.50 to 4.63. The untrimmed maximum lift-drag ratio varies from 6.0 for a sweep angle of 65° at $M = 2.50$ to a value of 4.6 for a sweep angle of 75° at $M = 4.63$. For each test Mach number a change in sweep angle from 55° to 75° results in a static margin change of only about 2 percent of the mean geometric chord. For each test sweep angle the static margin decreases about 12 percent of the mean geometric chord because of an increase in Mach number from 2.50 to 4.63.

A variation in sweep angle from 55° to 75° has a relatively small effect on the sideslip derivatives for angles of attack to 6°. There is a general decrease in the tail contribution to the directional stability as angle of attack and Mach number are increased. However, for the range $3.95 \leqq M \leqq 4.63$, the change in tail effectiveness due to Mach number is relatively small for angles of attack to about 21°. Conf.

AUTHOR

INTRODUCTION

The National Aeronautics and Space Administration is currently investigating configurations incorporating the variable-sweep wing concept as a means of improving the off-design performance of supersonic aircraft. One particular type of aircraft being considered is the multimission fighter. A number of configurations of this type have been examined, and the results are summarized in reference 1. To investigate this type of aircraft further, a variable-sweep fighter model was constructed and the results of the investigations at Mach numbers from 0.60 to 2.20 for wing sweep angles from 25° to 75° are presented in references 2 and 3.

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*Title, Unclassified.

The U.S. Air Force and Navy have recently specified the desired flight characteristics for this type of aircraft, which includes a maximum speed in excess of Mach number 2.2. Hence, an investigation was initiated to determine the aerodynamic characteristics of the model of references 2 and 3 at Mach numbers from 2.50 to 4.63 for sweep angles from 55° to 75°.

SYMBOLS

The longitudinal and lateral stability data are presented about the stability- and body-axes systems, respectively. All coefficients are based on the geometry of the 75° wing. The moment center is on the fuselage reference line at a longitudinal location corresponding to the wing pivot point (fig. 1).

A	aspect ratio
b	reference wing span, 1.515 ft
$\bar{c}$	reference mean geometric chord, 0.9 ft
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
$C_{D,0}$	drag coefficient at zero lift
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_{L_α}	lift-curve slope, $\frac{\partial C_L}{\partial \alpha}$, per deg
C_l	rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$
C_{l_β}	effective dihedral parameter, $\frac{\partial C_l}{\partial \beta}$, $\beta \approx 0$
ΔC_{l_β}	tail contribution to effective dihedral parameter
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS\bar{c}}$
$C_{m,0}$	pitching-moment coefficient at zero lift
$\frac{\partial C_m}{\partial C_L}$	longitudinal stability parameter, $C_L \approx 0$

$\frac{\Delta C_m}{\Delta \delta_h}$ horizontal-tail effectiveness parameter

C_n yawing-moment coefficient, $\frac{\text{Yawing moment}}{qSb}$

C_{n_β} directional stability parameter, $\frac{\partial C_n}{\partial \beta}$, $\beta \approx 0$

ΔC_{n_β} tail contribution to directional stability parameter

C_Y side-force coefficient, $\frac{\text{Side force}}{qS}$

C_{Y_β} side-force parameter, $\frac{\partial C_Y}{\partial \beta}$, $\beta \approx 0$

ΔC_{Y_β} tail contribution to side-force parameter

L/D lift-drag ratio

M free-stream Mach number

q free-stream dynamic pressure, lb/sq ft

S reference wing area, 1.212 sq ft

α angle of attack, referred to fuselage reference line, deg

β angle of sideslip (positive when nose is left), deg

δ_h horizontal-tail deflection angle (positive when trailing edge is down), deg

Λ leading-edge sweep angle of outboard wing panel, deg

Subscript:

max maximum value

MODEL AND APPARATUS

Details of the model are presented in figure 1. The movable outboard wing panels could be positioned at leading-edge sweep angles from 25° to 75° in 10° increments. Geometric characteristics corresponding to the various sweep angles

are tabulated in figure 1(b). The horizontal tail could be positioned at deflection angles of 0°, -5°, and -10°.

Boundary-layer transition strips approximately 1/16 inch wide were placed at the 5-percent local chord of the wing (75° sweep) and tail surfaces, and 1 inch aft of the nose apex. These strips were composed of No. 80 carborundum grains embedded in a plastic adhesive.

Forces and moments acting on the model were measured by means of a sting-supported, six-component, strain-gage balance mounted within the fuselage. The base drag was measured by means of static-pressure orifices located at the fuselage base and within the balance cavity.

The tests were conducted in the high Mach number test section of the Langley Unitary Plan wind tunnel, which is a variable-pressure return-flow tunnel having a Mach number range from approximately 2.3 to 4.7. The test section is 4 feet square by 7 feet in length and employs an asymmetric sliding-block nozzle which permits a continuous variation in Mach number without tunnel shutdown.

TESTS, CORRECTIONS, AND ACCURACY

The test conditions were as follows:

Mach number	Stagnation pressure, lb/sq ft abs	Dynamic pressure, lb/sq ft	Stagnation temperature, $^{\circ}F$
2.50	2536	649	150
2.96	3243	575	150
3.95	5744	441	175
4.63	7883	348	175

The dewpoint was maintained low enough to assure negligible condensation effects. The Reynolds number was held constant at 3.0×10^{6} per foot. The angle of attack generally varied from approximately -5° to 11° and the angle of sideslip range was about -4° to 6°.

The data have been corrected for the internal duct drag by measuring the loss in momentum from the free-stream condition to that at the duct exits. In addition, the drag coefficients have been adjusted to a condition of free-stream static pressure at the base of the model. The angles of attack and sideslip have been corrected for wind-tunnel-flow misalinement and model-support-system deflection under aerodynamic load.

The estimated accuracies, based on instrument calibration and data repeatability, are as follows:

C_L	±0.0035
C_D	±0.0005
C_m	±0.001
C_l	±0.0002
C_n	±0.0003
C_Y	±0.0025
M (2.50 and 2.96)	±0.015
M (3.95 and 4.63)	±0.050
α, deg	±0.1
β, deg	±0.1

PRESENTATION OF RESULTS

The results of this investigation are presented in the following figures:

	Figure
Aerodynamic characteristics in pitch. $\delta_h = 0$	2
Summary of the aerodynamic characteristics in pitch	3
Effect of horizontal-tail deflection on the aerodynamic characteristics in pitch. $\Lambda = 75^\circ$	4
Variation of horizontal-tail effectiveness with Mach number. $\Lambda = 75^\circ$, $\alpha = 0^\circ$	5
Aerodynamic characteristics in sideslip. $\Lambda = 75^\circ$, M = 3.95	6
Variation of sideslip derivatives with sweep angle	7
Variation of sideslip derivatives with angle of attack. $\Lambda = 75^\circ$	8
Variation of tail contribution to sideslip derivatives with angle of attack. $\Lambda = 75^\circ$	9

DISCUSSION

Longitudinal Characteristics

The aerodynamic characteristics in pitch for the complete model $\delta_h = 0^\circ$ are presented in figure 2 and summarized in figure 3. The pitching-moment curves exhibit a linear variation with lift coefficient at the lower Mach numbers, but at Mach numbers of 3.95 and 4.63 the curves are nonlinear, the nonlinearity being more pronounced for the model with the lower sweep angles. The lift curves are essentially linear throughout the angle-of-attack range for all test Mach numbers and sweep angles. The lift-curve slopes (fig. 3) show the familiar decrease with Mach number for all wing sweep positions. Increasing the sweep angle causes a decrease in the lift-curve slope, the effect becoming less pronounced as Mach number is increased. The tail-on maximum lift-drag ratio varies from a value of about 6.0 for a sweep angle of 65° and M = 2.50 to a value of 4.6 for a sweep angle of 75° and M = 4.63.

For a given sweep angle, the static margin decreases about $0.12\bar{c}$ as Mach number is increased from 2.50 to 4.63. In addition, throughout the test Mach number range the change in static margin due to a change in sweep angle from 55° to 75° is only about $0.02\bar{c}$.

The tail-on data indicate that the zero-lift pitching-moment coefficient $C_{m,0}$ is invariant with sweep angle; however, its value varies from about 0.01 at $M = 2.50$ to a slightly negative value at the highest Mach number. The tail-off configuration exhibits a near-zero value of $C_{m,0}$ throughout the test Mach number range.

The effects of horizontal-tail deflection for a sweep angle of 75° is shown in figure 4 and summarized in figure 5. The summary data represent the change in the pitching-moment coefficient at $\alpha = 0^{\circ}$ due to a horizontal-tail deflection of -10°. The tail effectiveness decreases about 50 percent as Mach number is increased from 2.50 to 4.63. The tail effectiveness is essentially linear throughout the lift range at Mach numbers of 2.50 and 2.96. However, at Mach numbers of 3.95 and 4.63, there is a definite increase in the tail effectiveness with increasing lift that probably results from an increase in dynamic pressure at the tail caused by the flow field from the underside of the wing.

Sideslip Characteristics

For all configurations and test conditions the aerodynamic characteristics in sideslip were essentially linear throughout the range of β; hence, only a portion of the basic data typifying the linearity is presented in figure 6.

The variation of the sideslip derivatives with wing sweep angle for $\alpha = 0^{\circ}$, 3°, and 6° (fig. 7) indicates little effect of sweep angle on the sideslip derivatives.

Sideslip data were obtained at angles of attack to about 20° for the model with a wing sweep angle of 75°, vertical and horizontal tail on and off (fig. 8). At each Mach number the complete configuration exhibits positive effective dihedral $\left(-C_{l_\beta}\right)$ that increases as the angle of attack is increased. In general, the directional stability of the complete configuration decreases with increasing angle of attack. For $M = 2.50$, C_{n_β} becomes zero at $\alpha = 13.5^{\circ}$. At $M = 2.96$, the directional stability becomes neutral at an angle of attack of near 12°, and a further increase in α to 19° results in a partial recovery of C_{n_β}. For Mach numbers of 3.95 and 4.63, directional instability occurs at angles of attack of about 3° and 2°, respectively. The instability of the wing-body combination increases slightly with increasing angle of attack at $M = 2.50$. However, as the Mach number is increased, the wing-body instability begins to decrease with increasing angle of attack. This effect probably results from an increase in dynamic pressure over the afterbody caused by the high wing.

The contribution of the vertical and horizontal tails to the lateral and directional stability characteristics is presented in figure 9. The parameter

ΔC_{l_β} reflects, in general, a relatively small tail contribution to the effective dihedral. In general, there is a reduction in ΔC_{n_β} with increase in angle of attack, although at $M = 2.96$ there is an unexplained increase in tail effectiveness at angles of attack greater than about 12°.

The results of this investigation, as well as data from other tests, exemplify the directional stability problem encountered at high supersonic speeds. These data show that as Mach number is increased beyond about 4, there is little change in tail effectiveness, and thus the lift capabilities of the surfaces become relatively invariant with Mach number as hypersonic speeds are approached.

CONCLUSIONS

An investigation to determine the longitudinal and lateral aerodynamic characteristics of a variable-sweep fighter model at sweep angles from 55° to 75° and Mach numbers from 2.50 to 4.63 indicates the following conclusions:

1. The untrimmed maximum lift-drag ratio varies from 6.0 for a sweep angle of 65° at $M = 2.50$ to a value of 4.6 for a sweep angle of 75° at $M = 4.63$.

2. For each test Mach number a change in sweep angle from 55° to 75° results in a static margin change of only about 2 percent of the mean geometric chord. For each test sweep angle the static margin decreases about 12 percent of the mean geometric chord because of an increase in Mach number from 2.50 to 4.63.

3. A variation in sweep angle from 55° to 75° has a relatively small effect on the sideslip derivatives for angles of attack to 6°.

4. There is generally a decrease in the tail contribution to the directional stability as angle of attack and Mach number are increased. However, for the range $3.95 \leqq M \leqq 4.63$, the change in tail effectiveness due to Mach number is relatively small for angles of attack to about 21°.

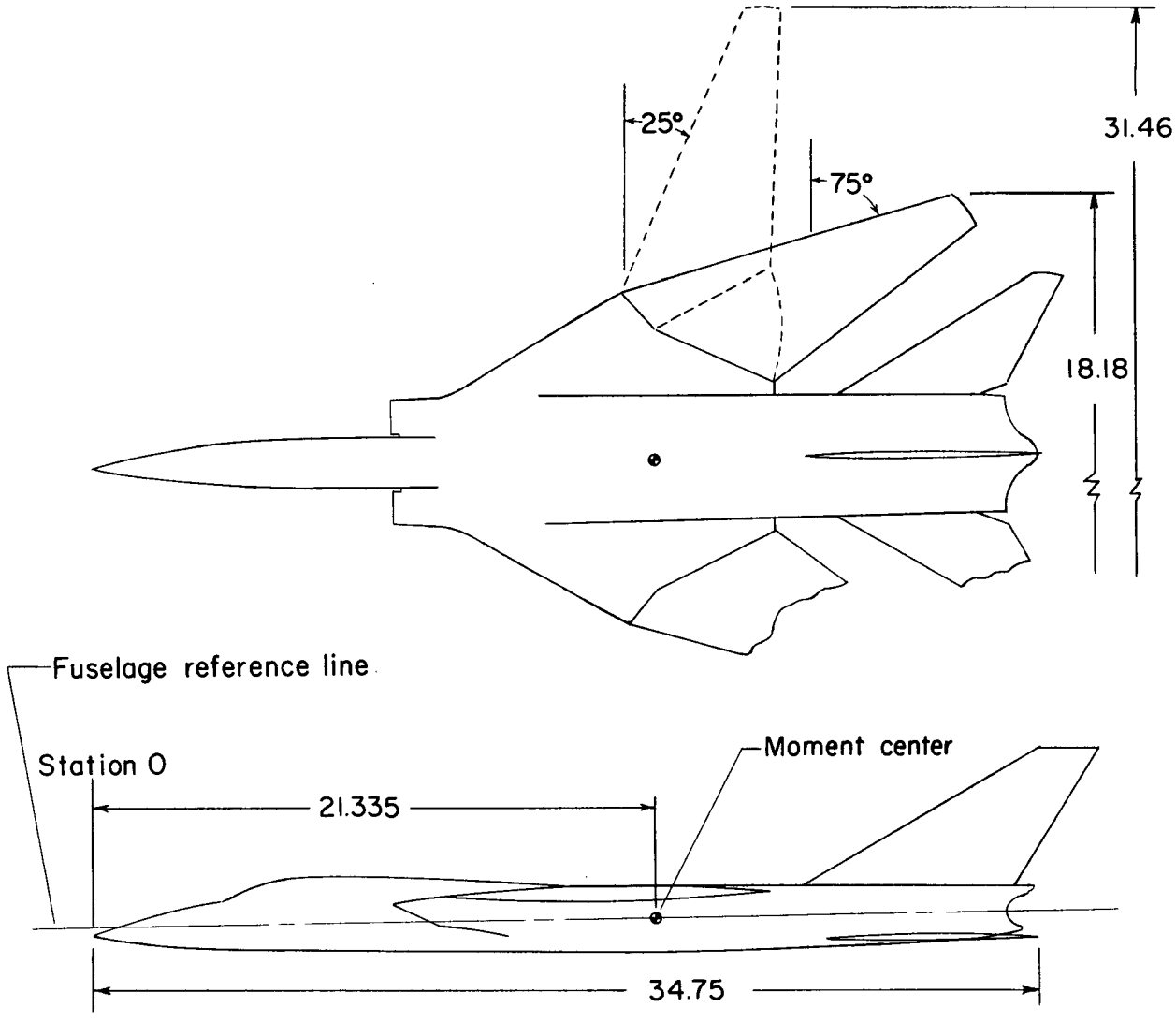
Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., February 5, 1964.

REFERENCES

1. Polhamus, Edward C., and Hammond, Alexander D.: Aerodynamic Research Relative to Variable-Sweep Multimission Aircraft. Ch. II of Compilation of Papers Summarizing Some Recent NASA Research on Manned Military Aircraft. NASA TM X-420, 1960, pp. 13-38.

2. Spearman, M. Leroy: Longitudinal and Lateral Aerodynamic Characteristics at Mach Numbers From 0.60 to 2.20 of a Variable-Sweep Fighter Model With Wing Sweep Angles From 25° to 75°. NASA TM X-710, 1962.

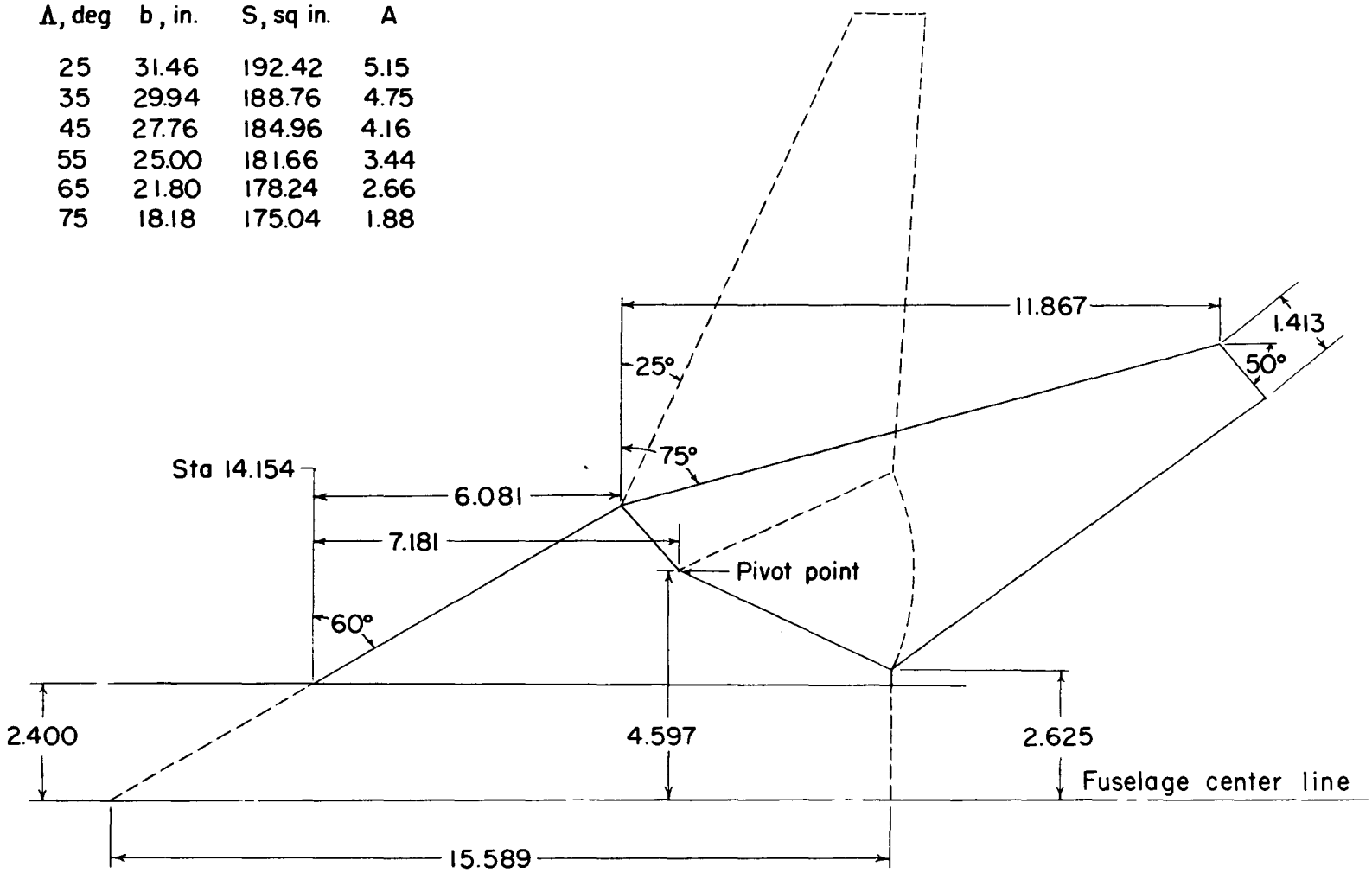
3. Spearman, M. Leroy, and Harris, Roy V., Jr.: The Longitudinal and Lateral Aerodynamic Characteristics at Mach Numbers of 1.41 and 2.20 of a Variable-Sweep Fighter Model With Wing Sweeps Varying From 25° to 75°. NASA TM X-759, 1963.



(a) General arrangement.

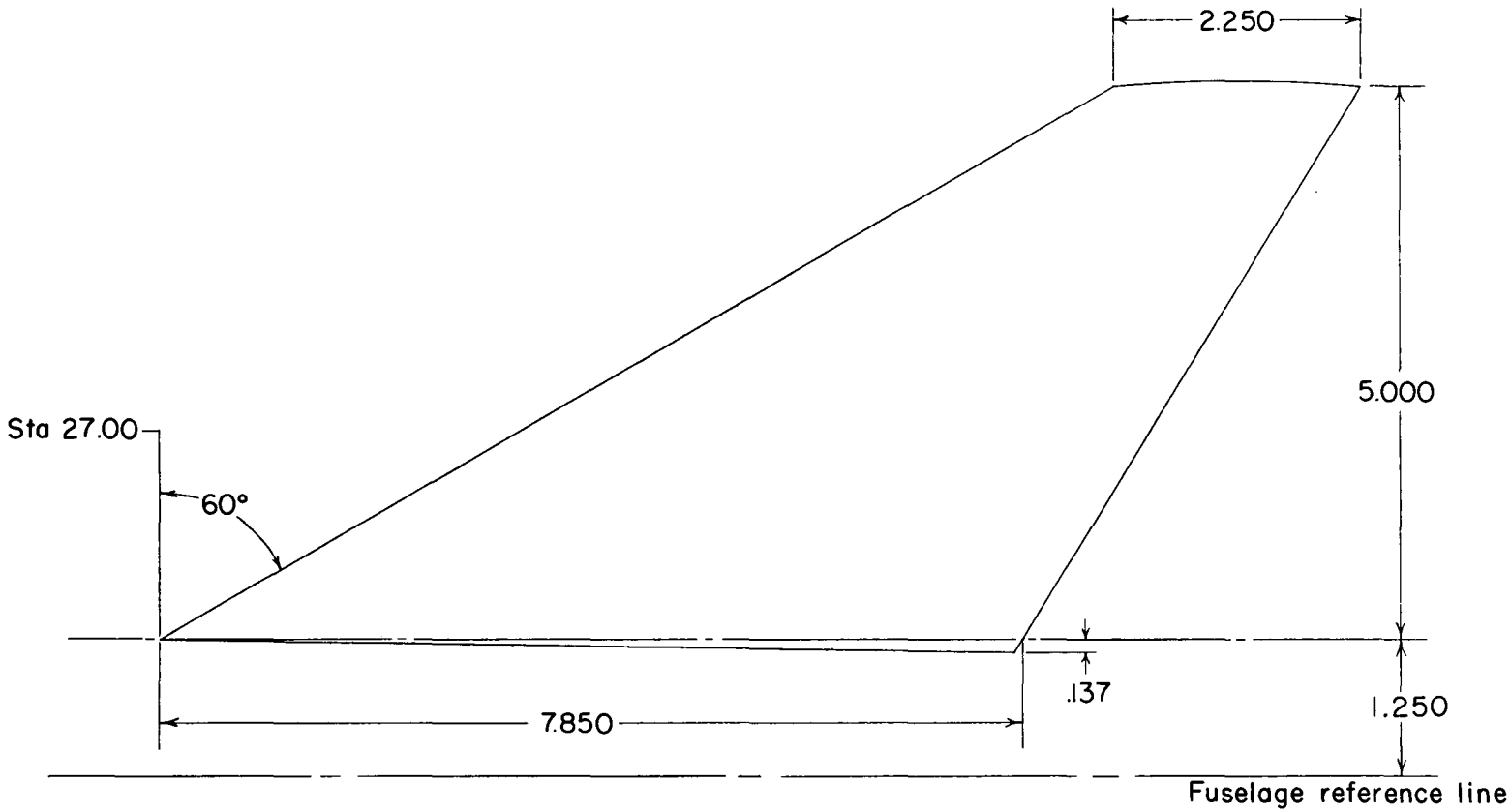
Figure 1.- Details of model. Dimensions are in inches unless otherwise noted.

Λ, deg	b, in.	S, sq in.	A
25	31.46	192.42	5.15
35	29.94	188.76	4.75
45	27.76	184.96	4.16
55	25.00	181.66	3.44
65	21.80	178.24	2.66
75	18.18	175.04	1.88



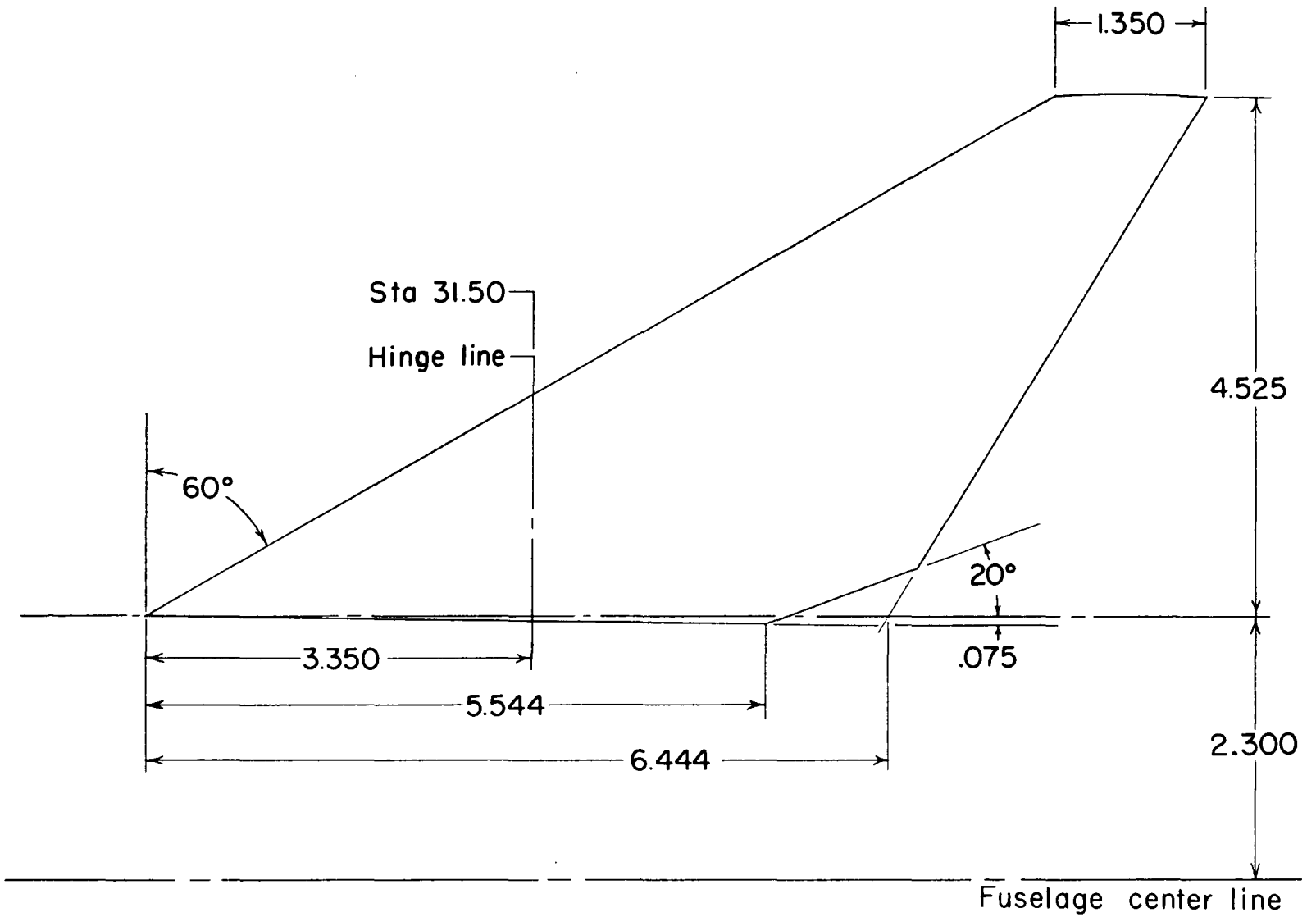
(b) Wing details.

Figure 1.- Continued.



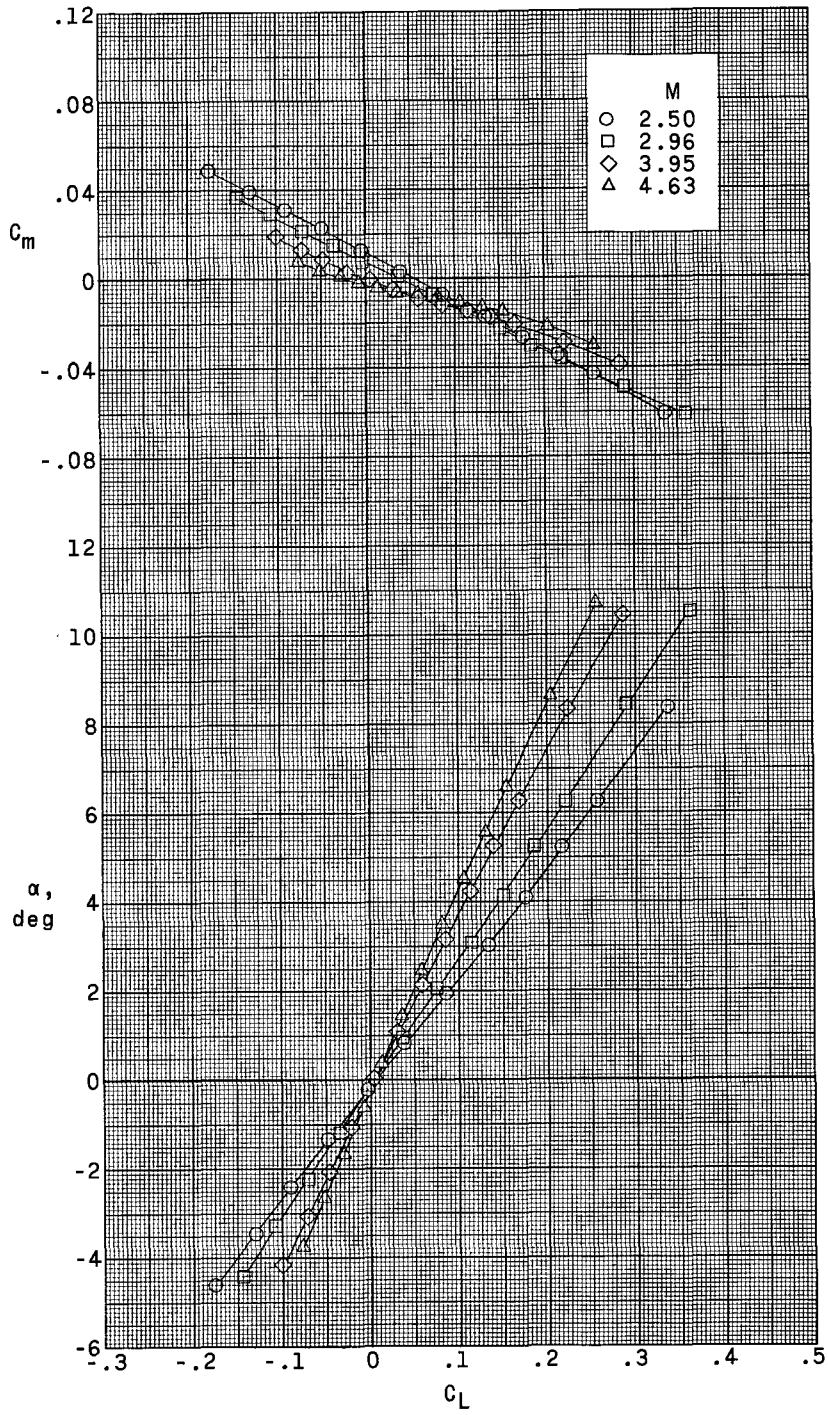
(c) Vertical-tail details.

Figure 1.- Continued.



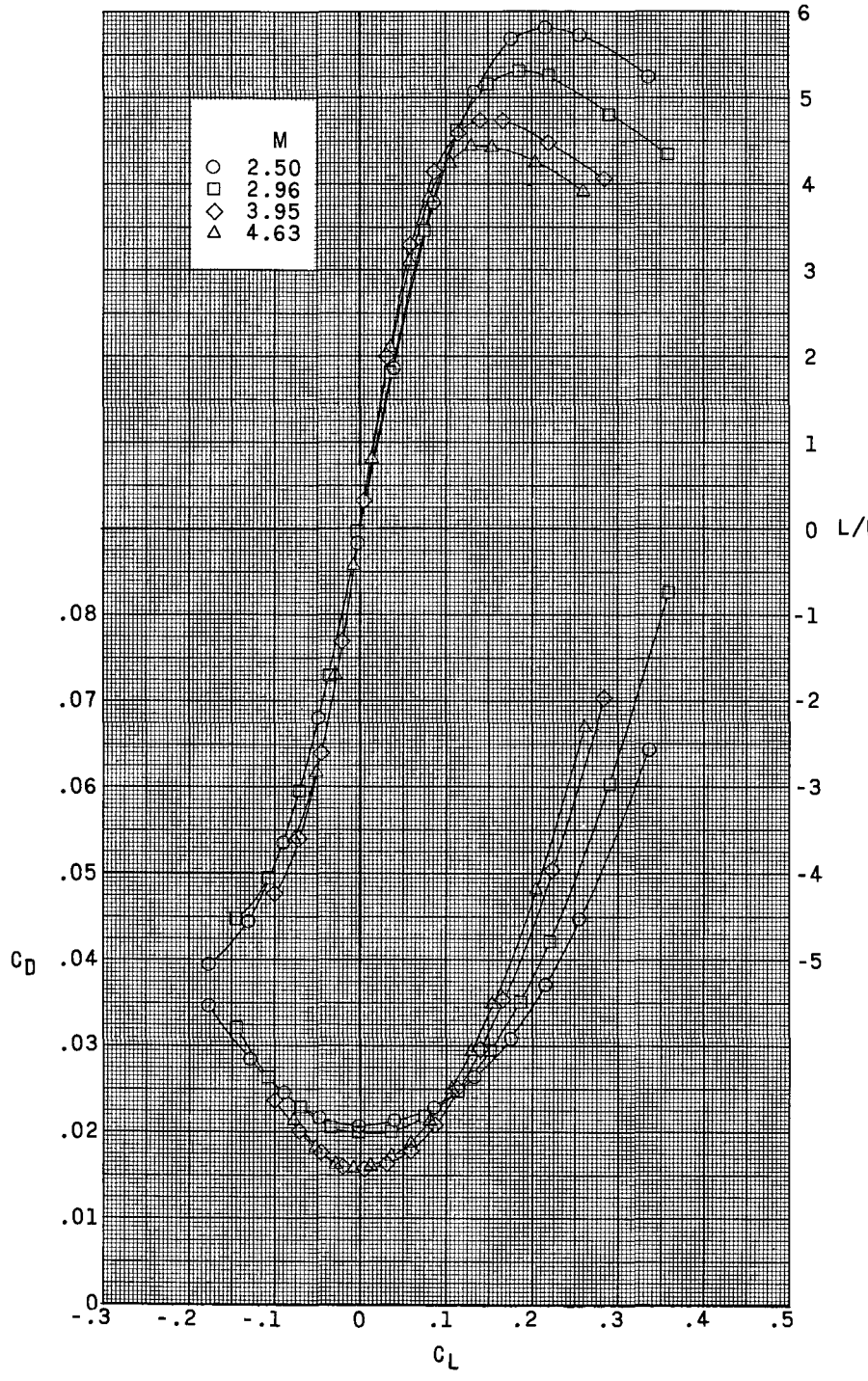
(d) Horizontal-tail details.

Figure 1.- Concluded.



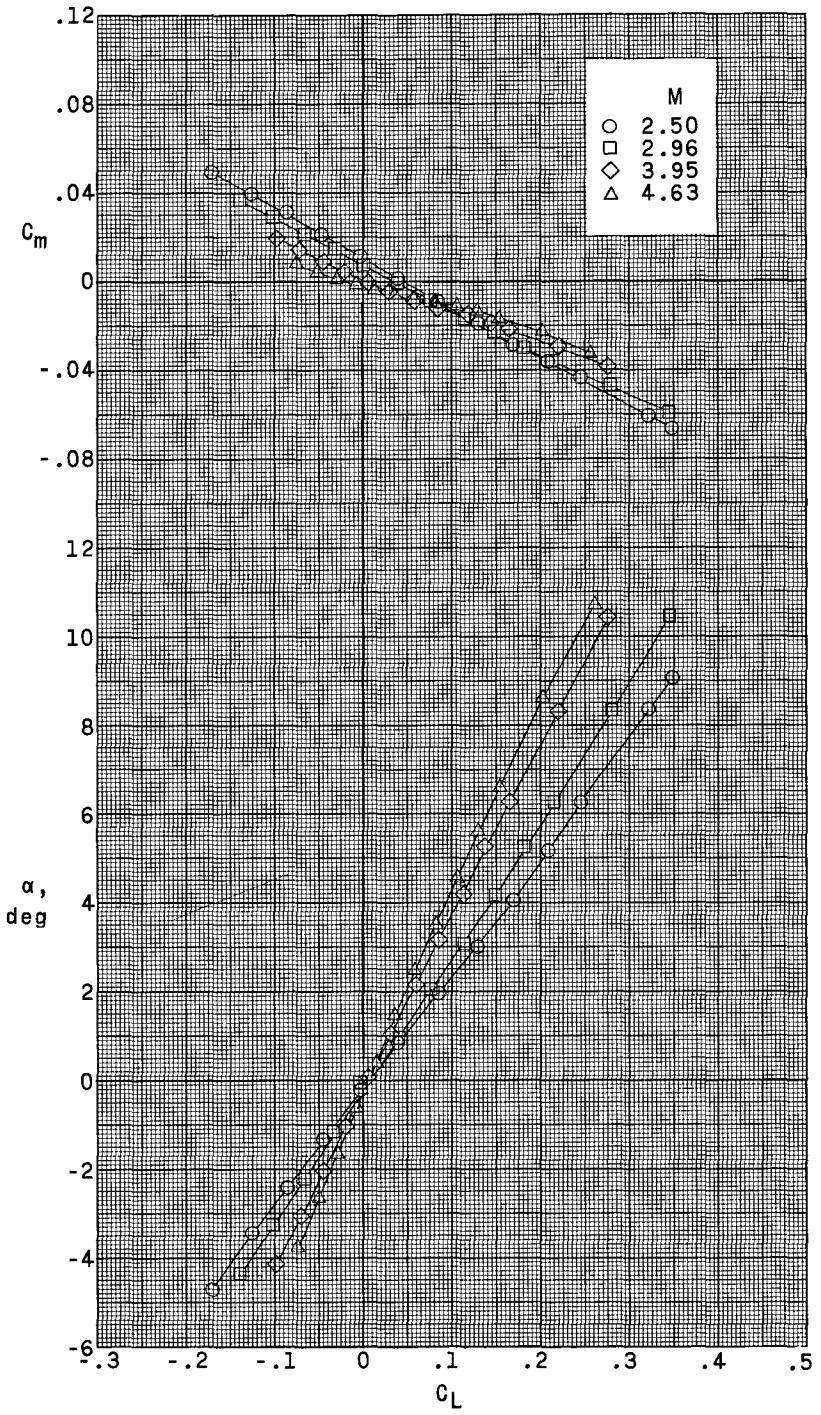
(a) $\Lambda = 55^{\circ}$.

Figure 2.- Aerodynamic characteristics in pitch for complete model. $\delta_h = 0^{\circ}$.



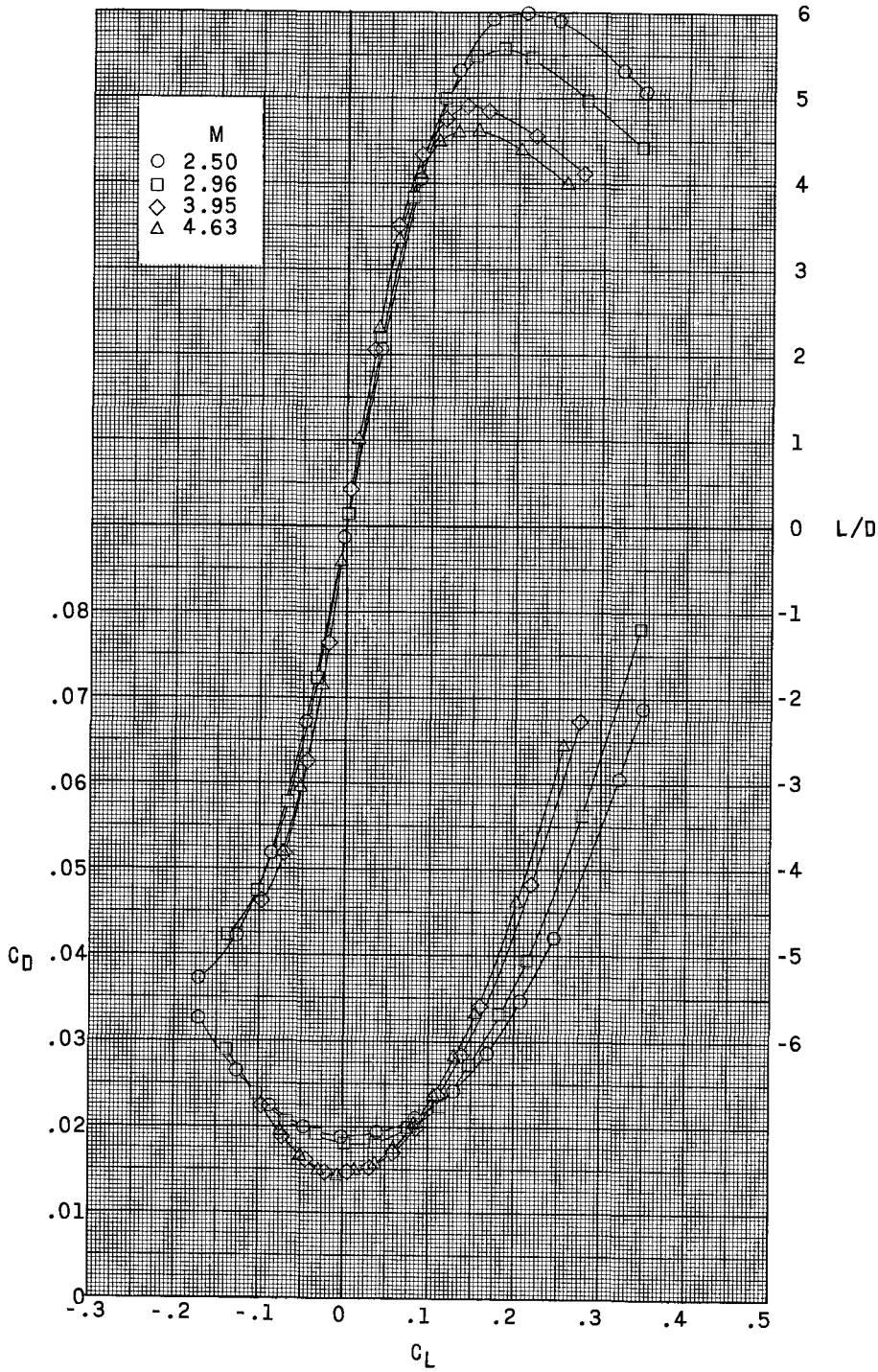
(a) $\Lambda = 55^{\circ}$ - concluded.

Figure 2.- Continued.



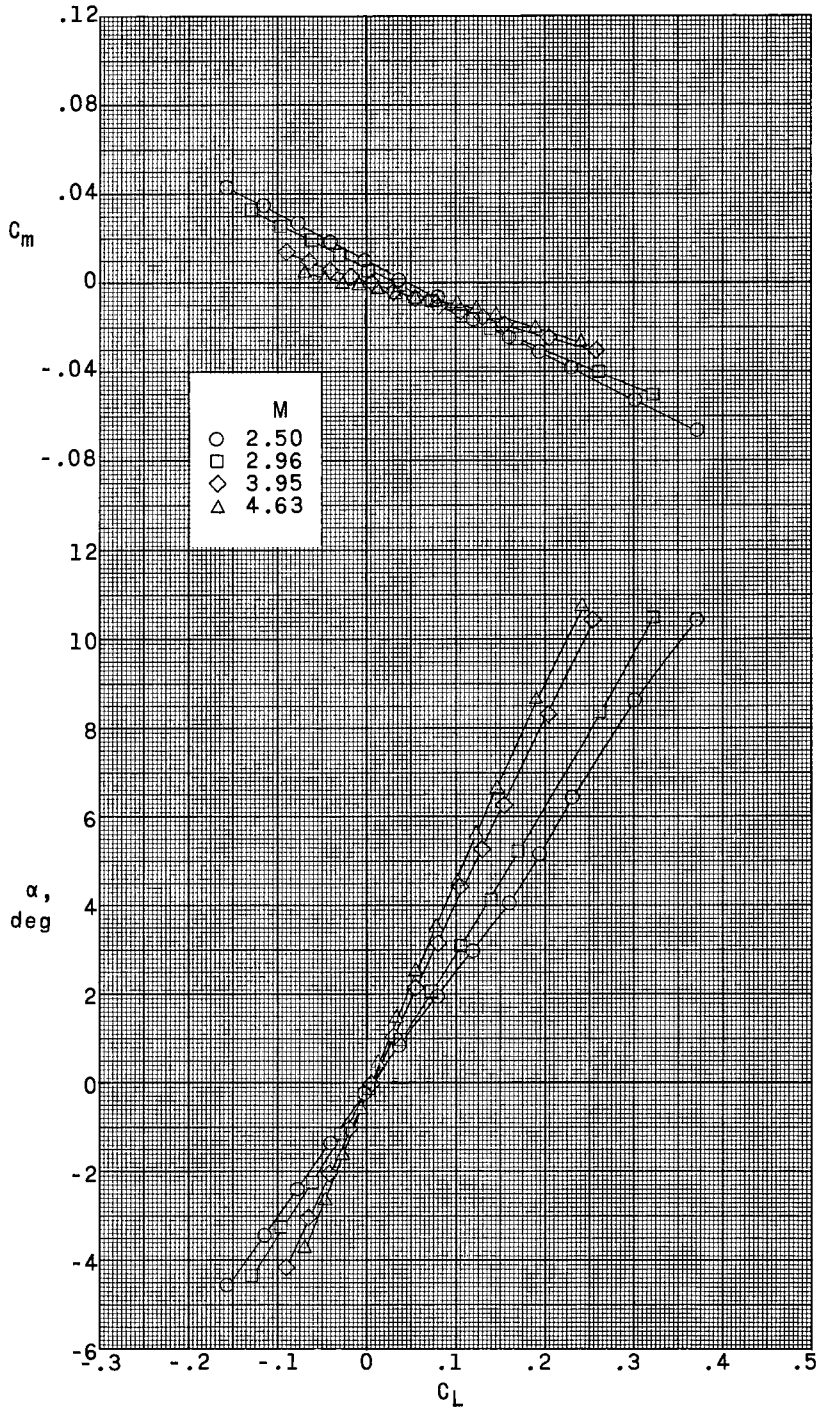
(b) $\Lambda = 65^{\circ}$.

Figure 2.- Continued.



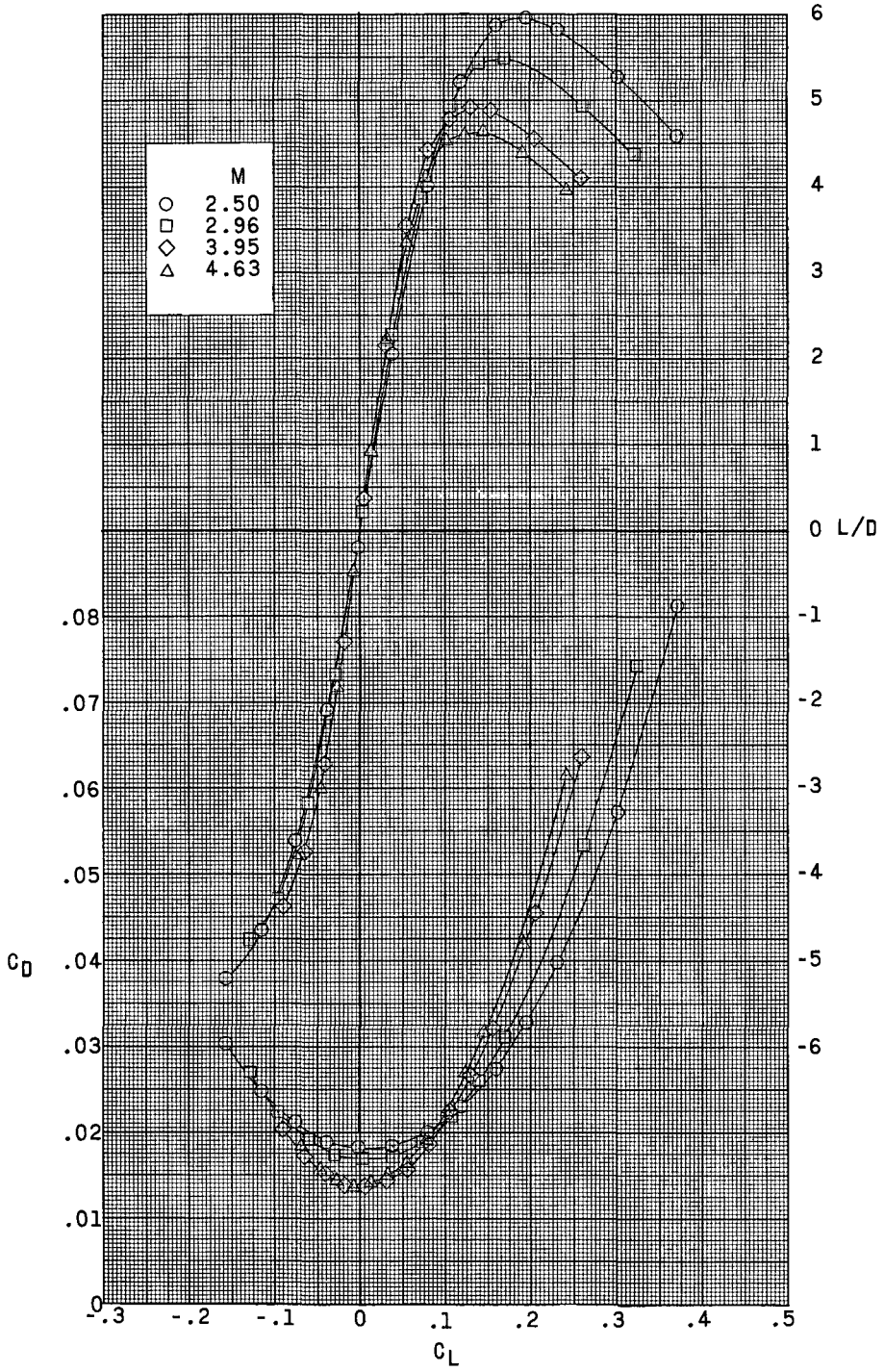
(b) $\Lambda = 65^{\circ}$ - concluded.

Figure 2.- Continued.



(c) $\Lambda = 75^{\circ}$.

Figure 2.- Continued.



(c) $\Lambda = 75^{\circ}$ - concluded.

Figure 2.- Concluded.

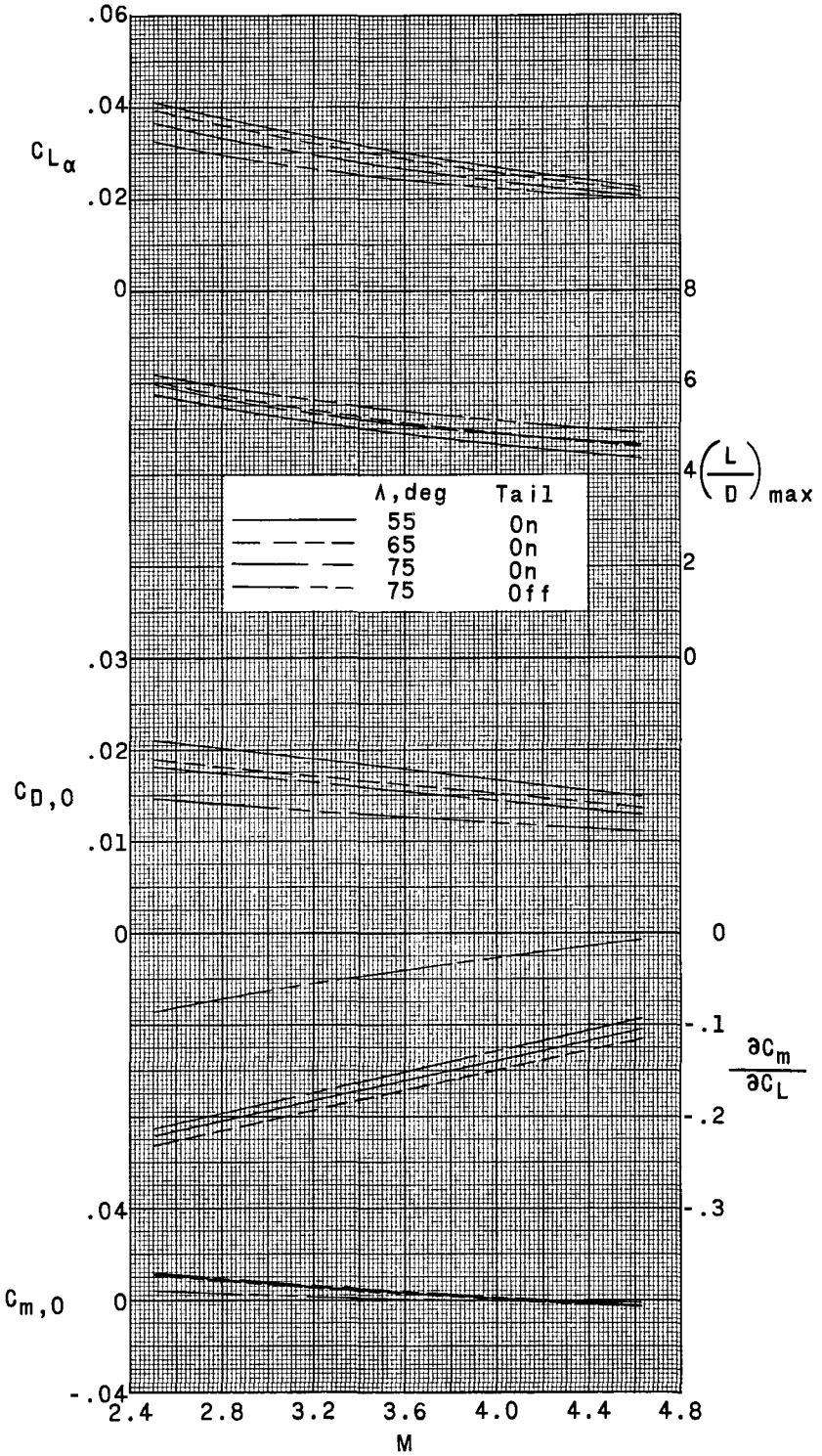
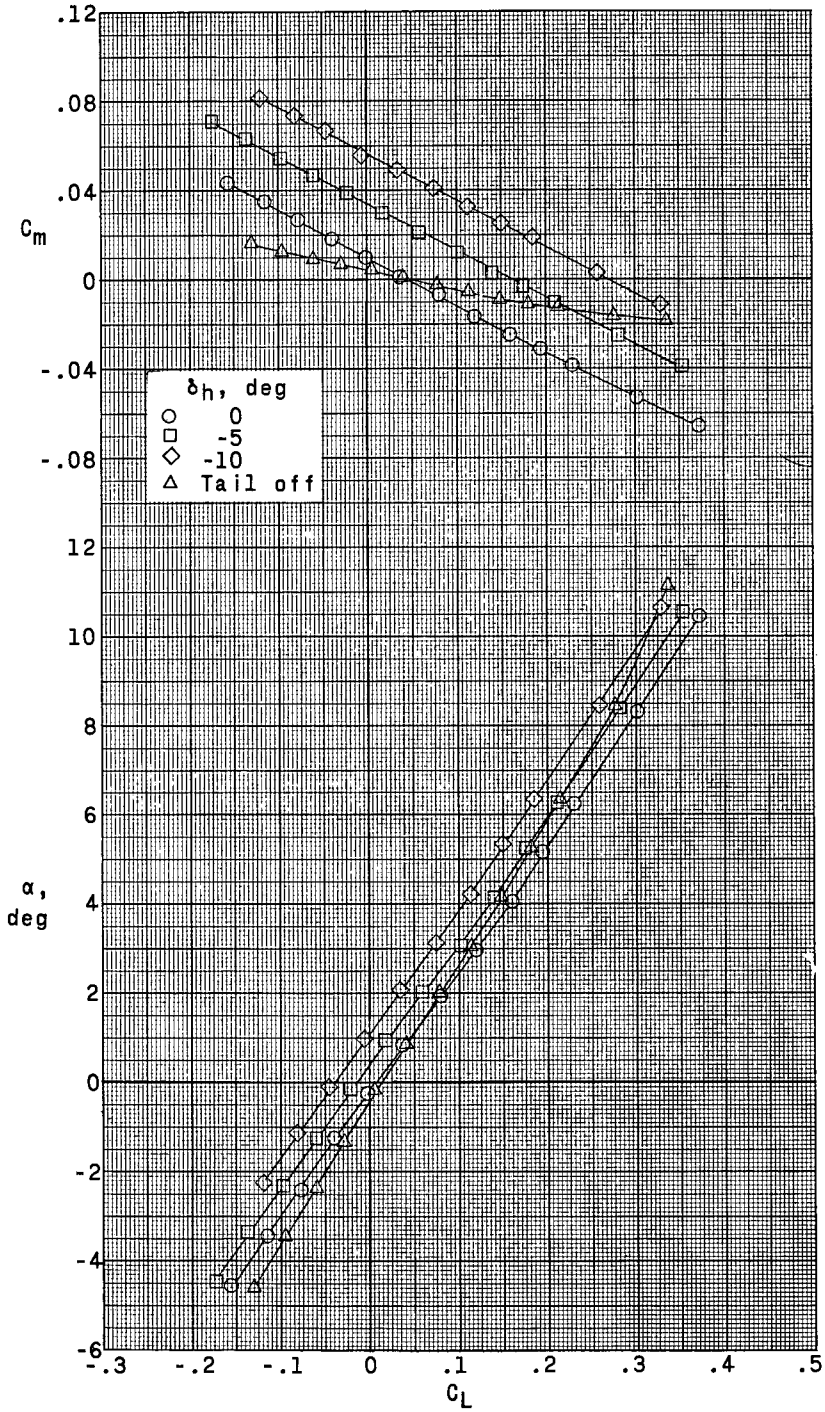
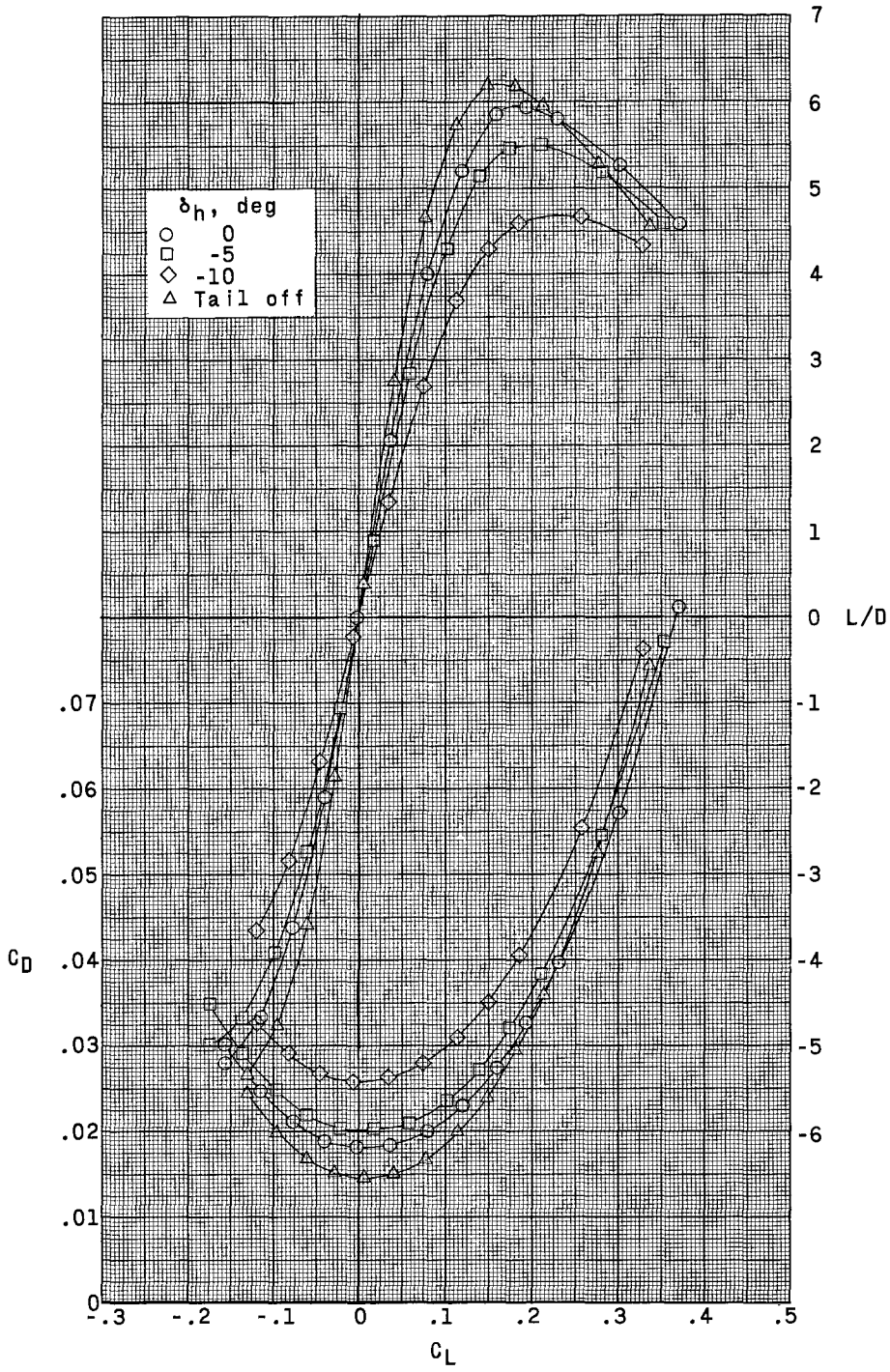


Figure 3.- Summary of aerodynamic characteristics in pitch.



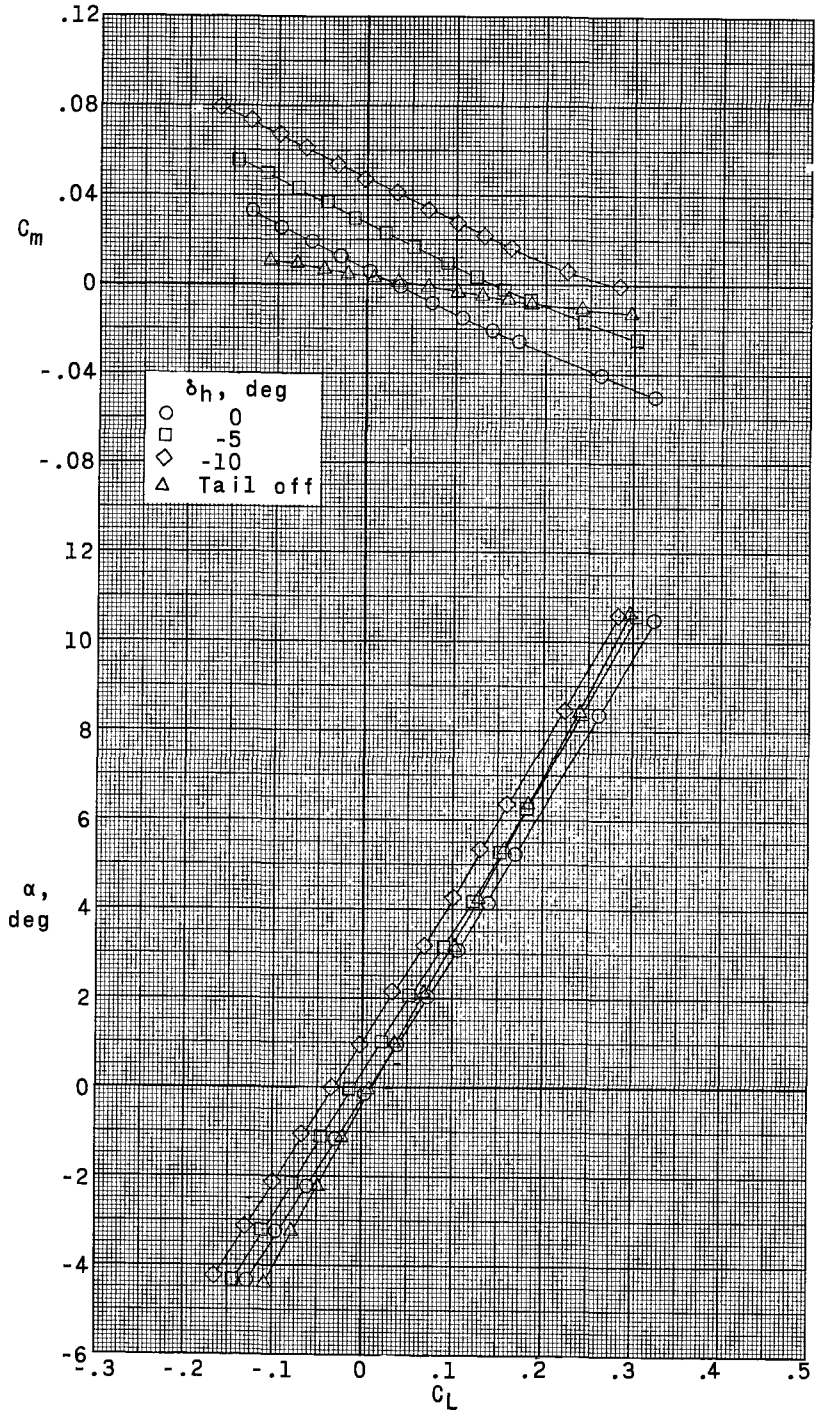
(a) M = 2.50.

Figure 4.- Effect of horizontal-tail deflection on aerodynamic characteristics in pitch. $\Lambda = 75^{\circ}$.



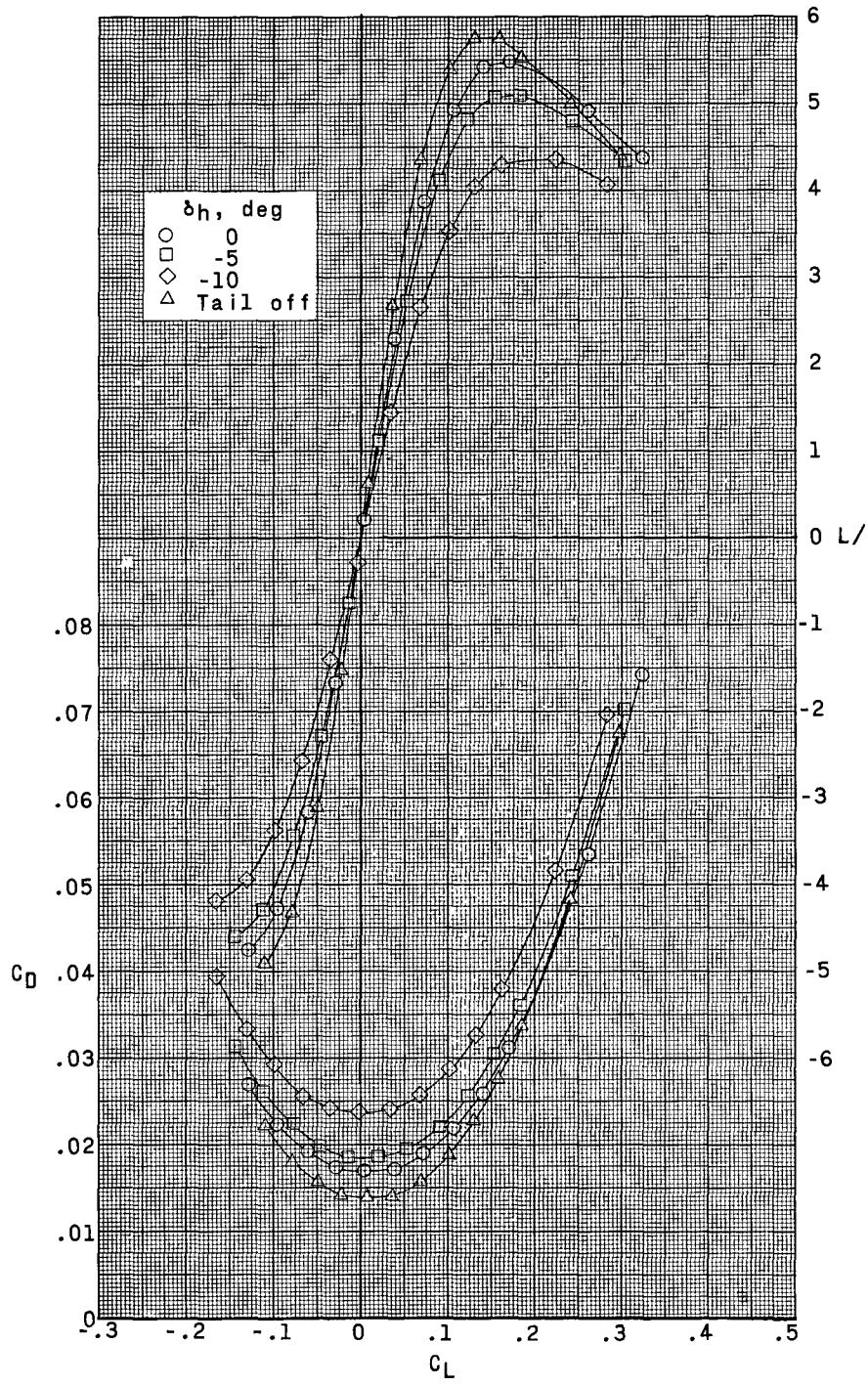
(a) M = 2.50 - concluded.

Figure 4.- Continued.



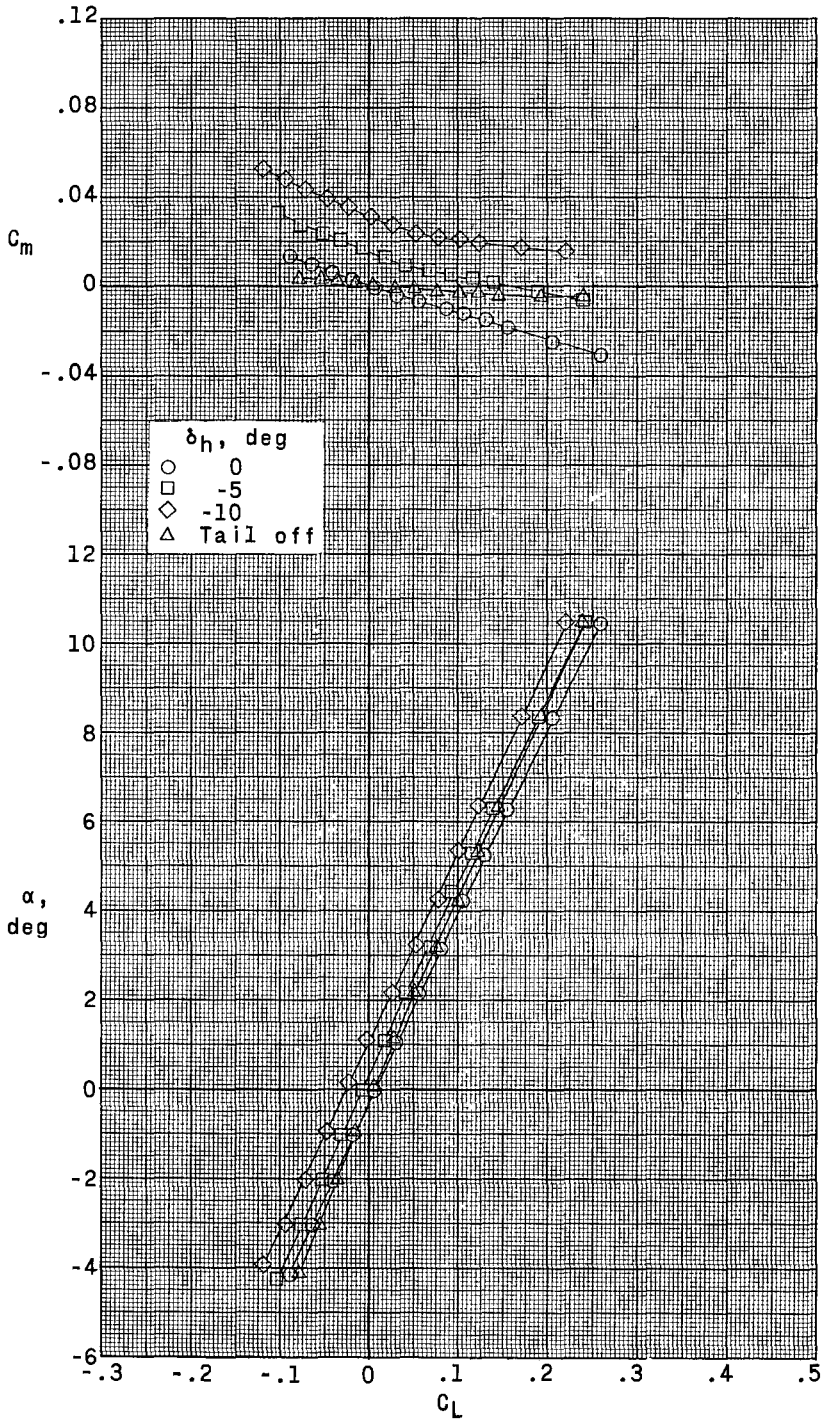
(b) M = 2.96.

Figure 4.- Continued.



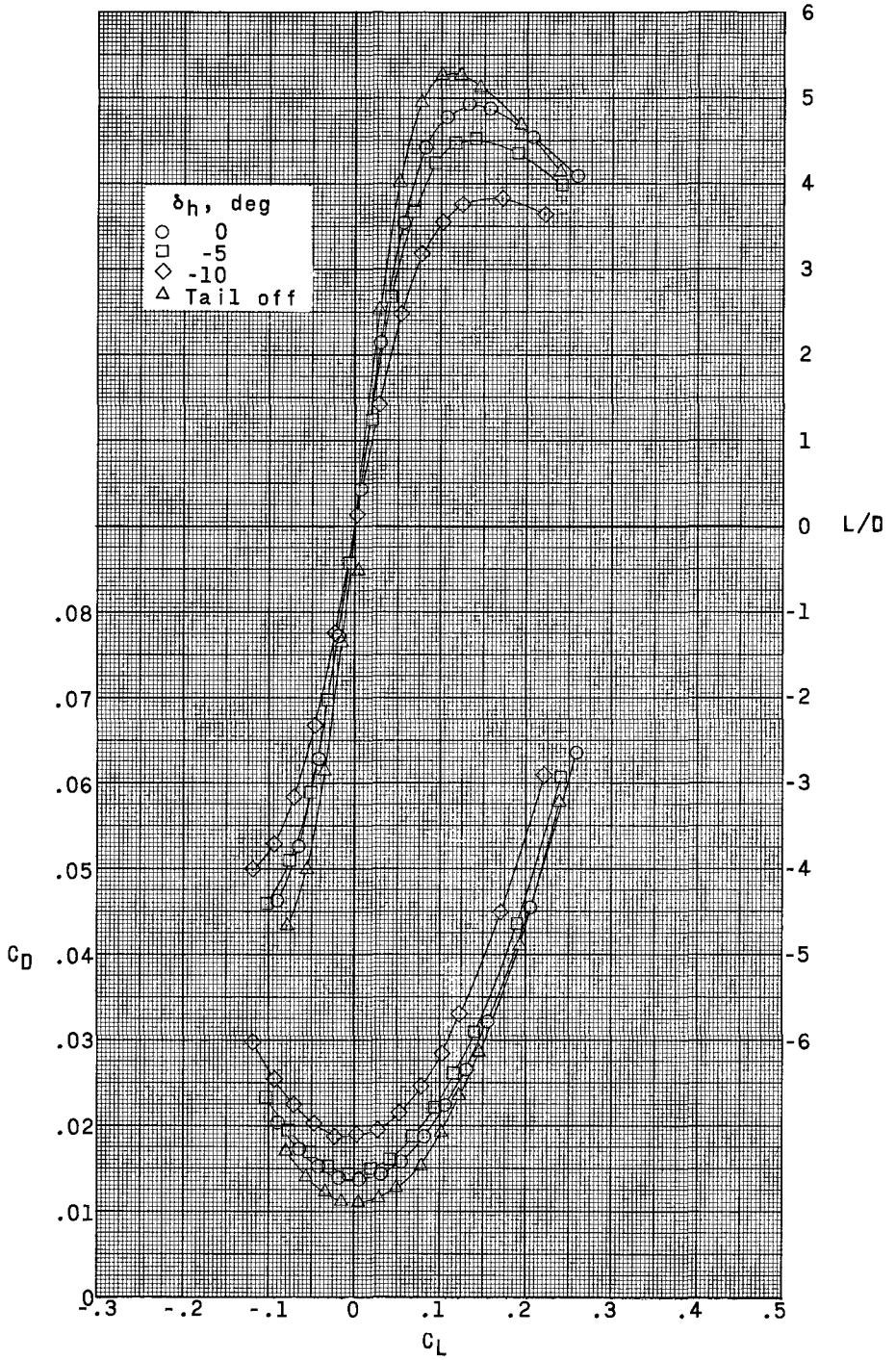
(b) M = 2.96 - concluded.

Figure 4.- Continued.



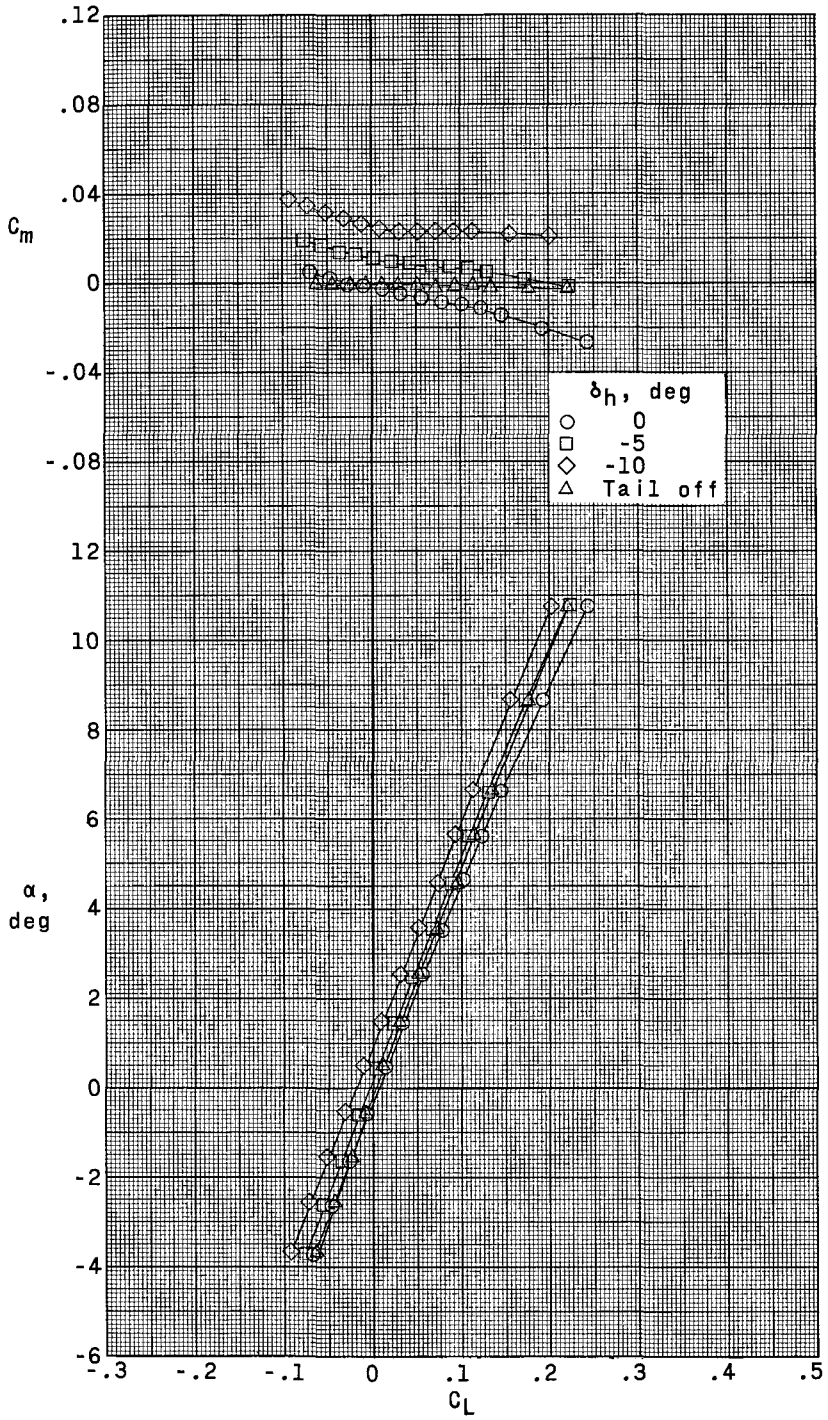
(c) M = 3.95.

Figure 4.- Continued.



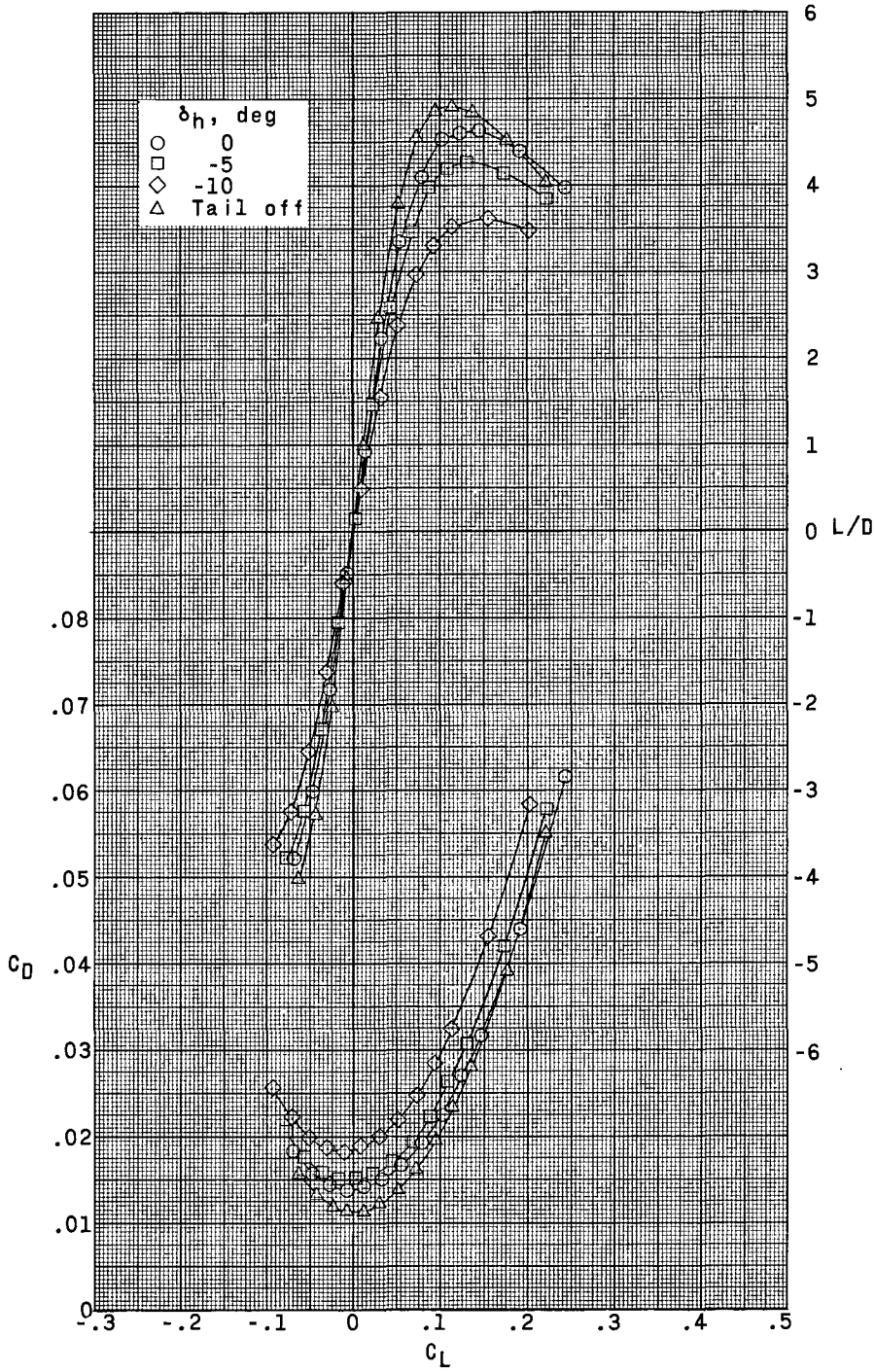
(c) M = 3.95 - concluded.

Figure 4.- Continued.



(d) M = 4.63.

Figure 4.- Continued.



(d) M = 4.63 - concluded.

Figure 4.- Concluded.

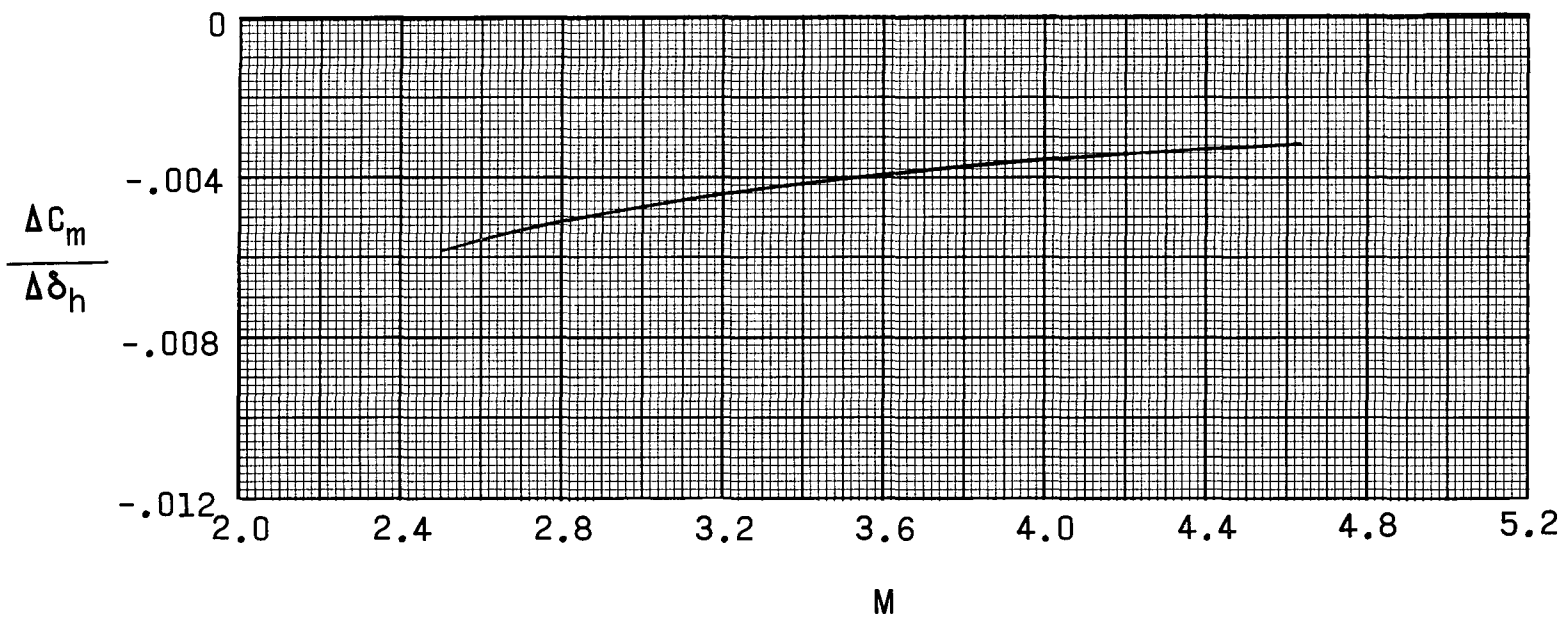
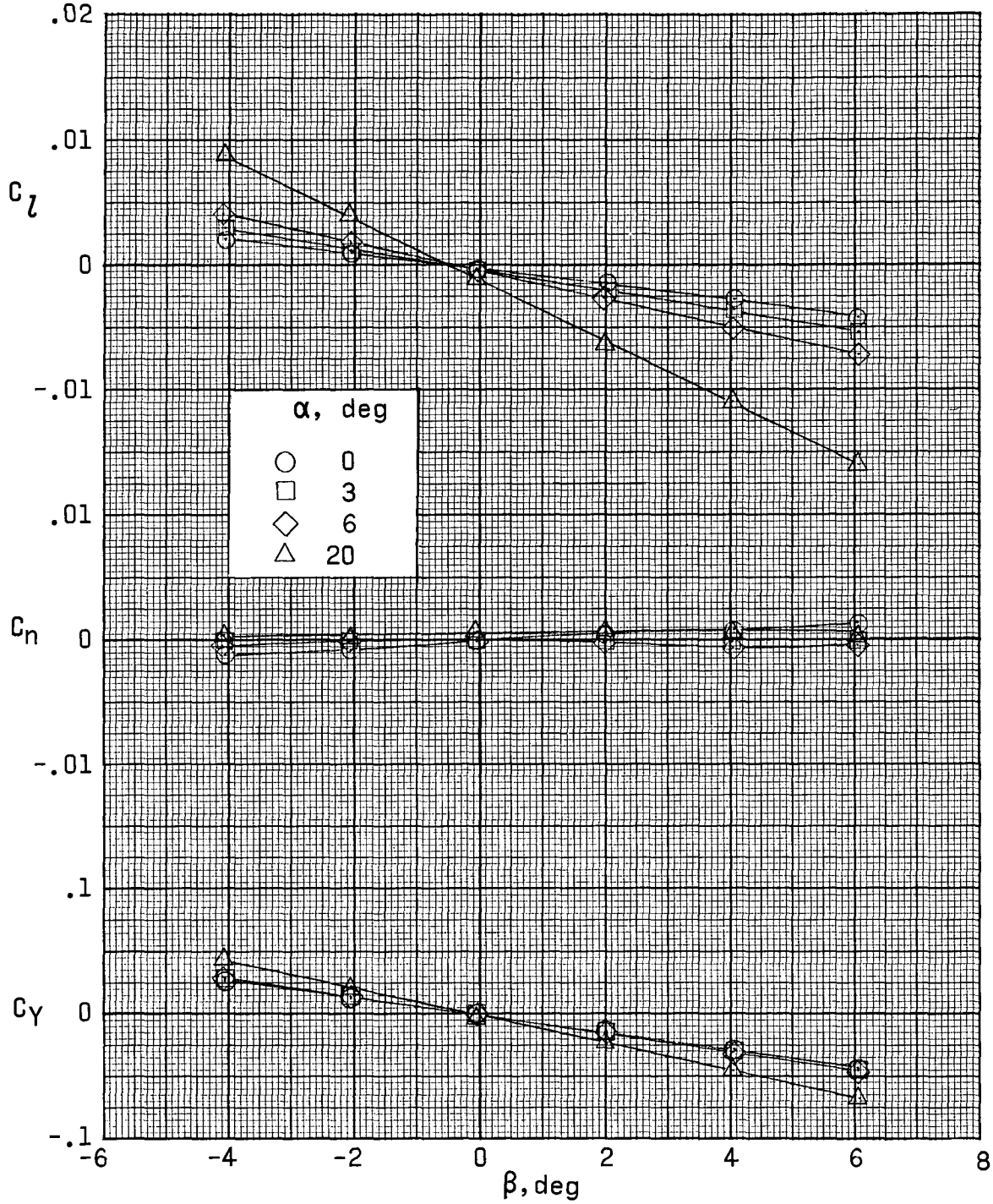
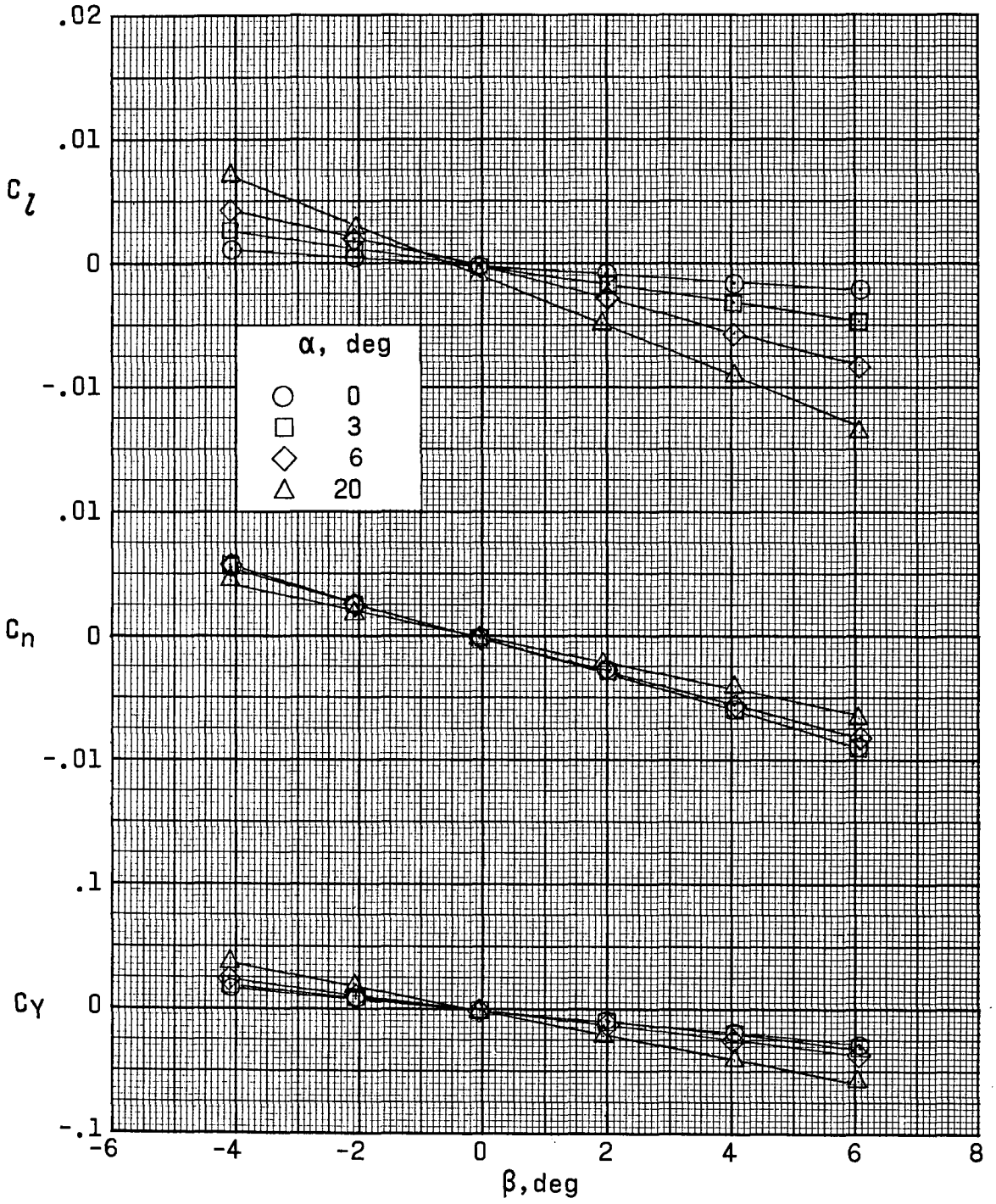


Figure 5.- Variation of horizontal-tail effectiveness with Mach number. $\Lambda = 75^{\circ}$; $\alpha = 0^{\circ}$.



(a) Complete model.

Figure 6.- Aerodynamic characteristics in sideslip. $\Lambda = 75^{\circ}$; $M = 3.95$.



(b) Vertical and horizontal tails off.

Figure 6.- Concluded.

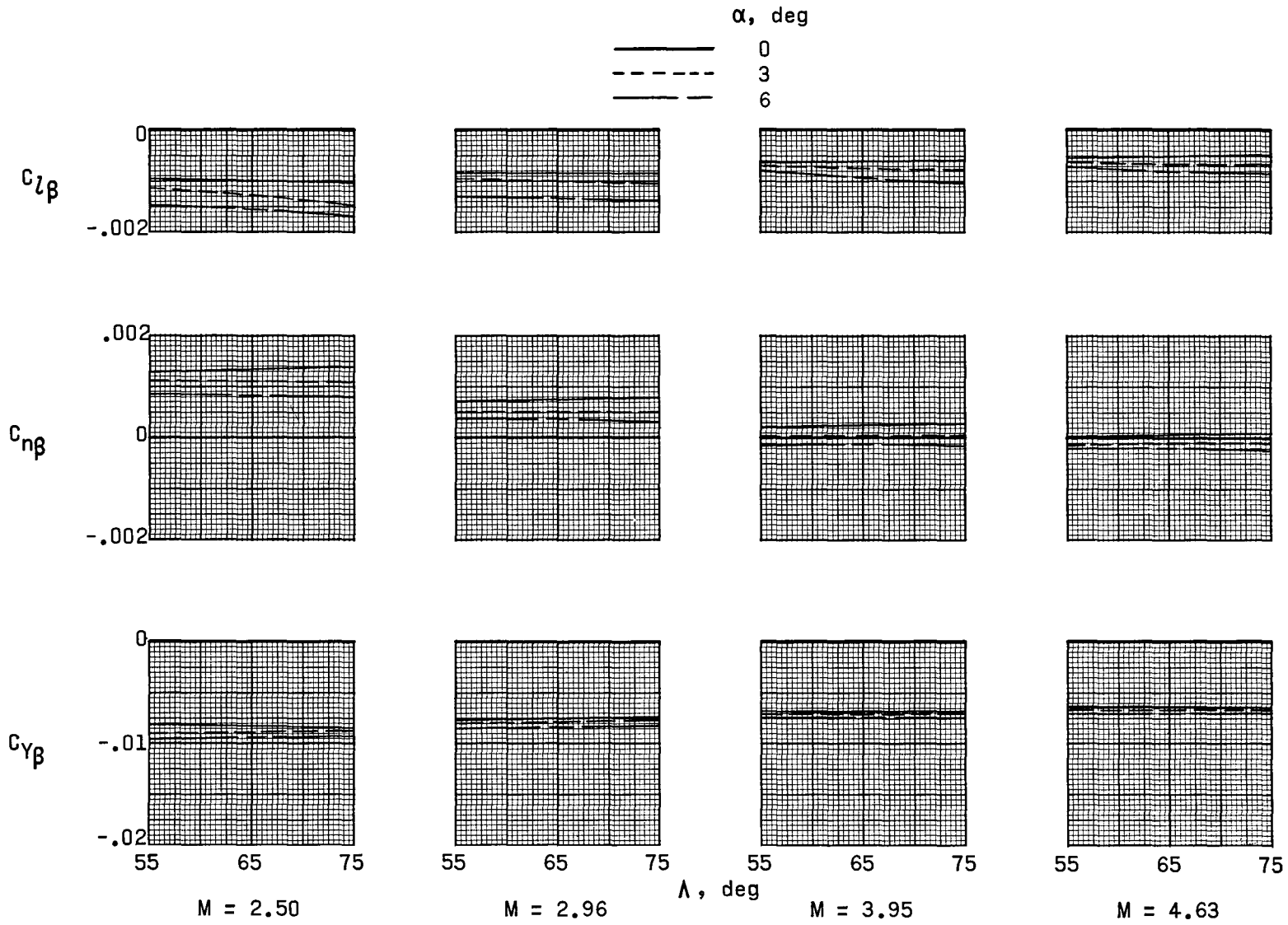
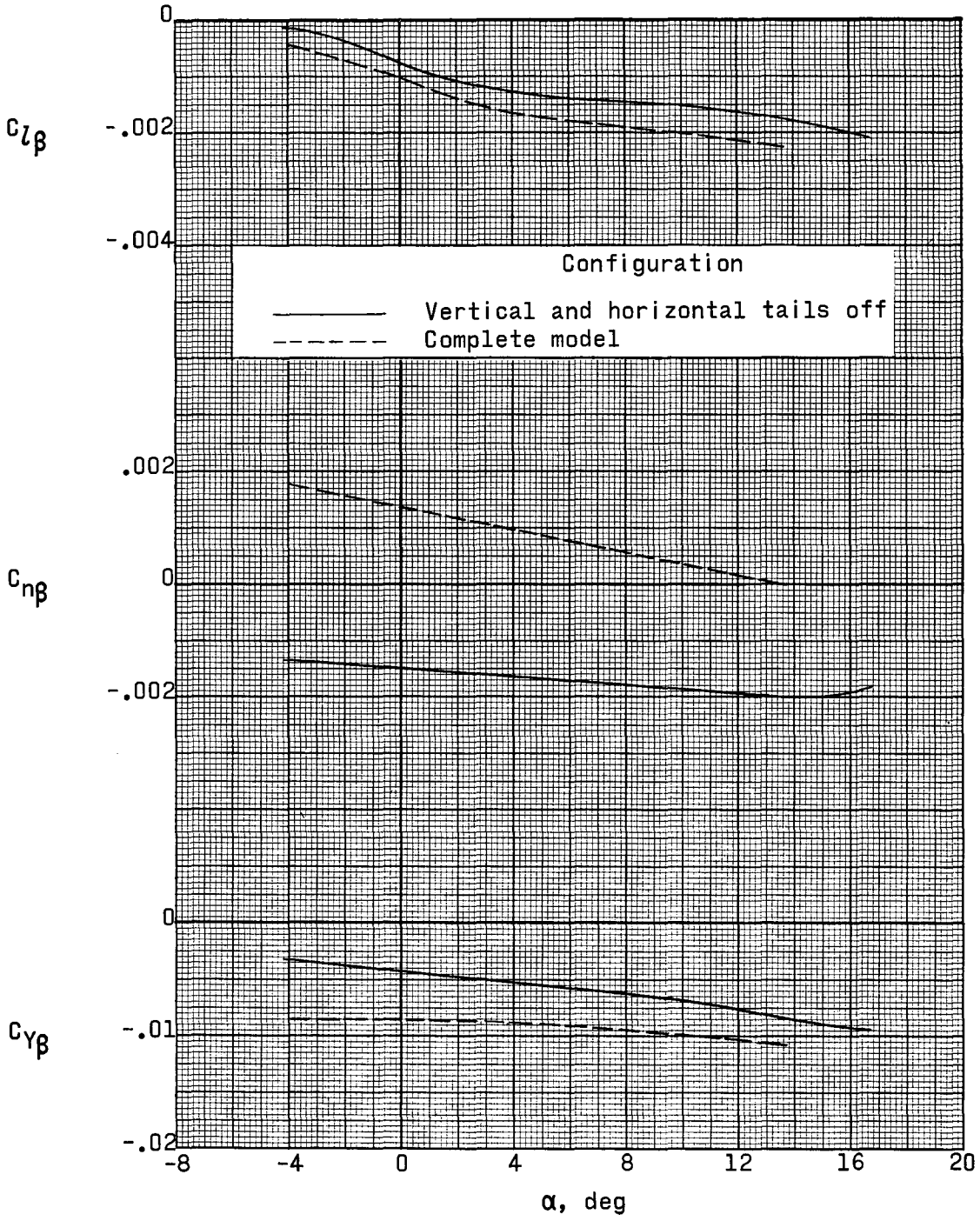
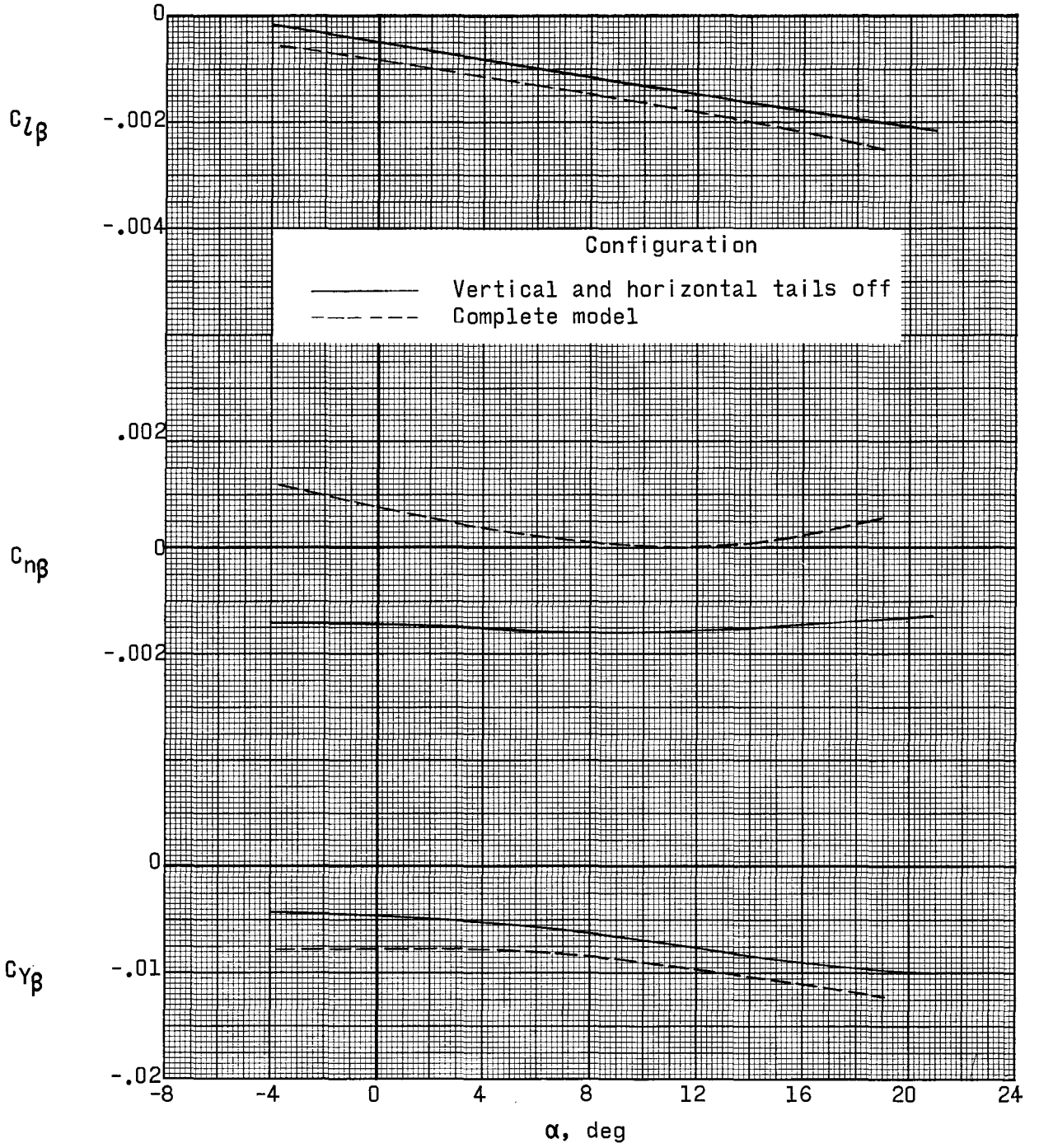


Figure 7.- Variation of sideslip derivatives with wing sweep angle. Complete model.



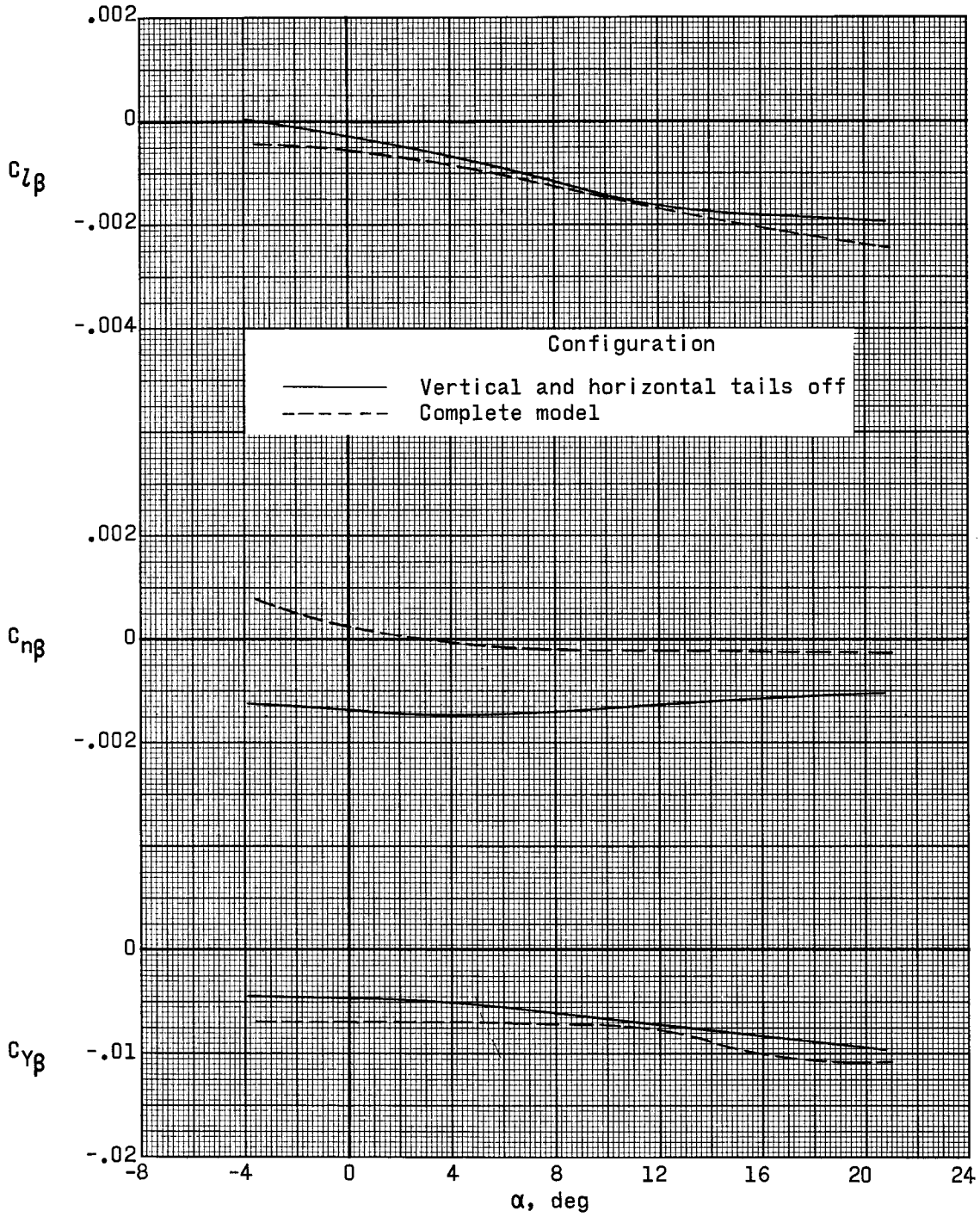
(a) M = 2.50.

Figure 8.- Variation of sideslip derivatives with angle of attack. $\Lambda = 75^{\circ}$.



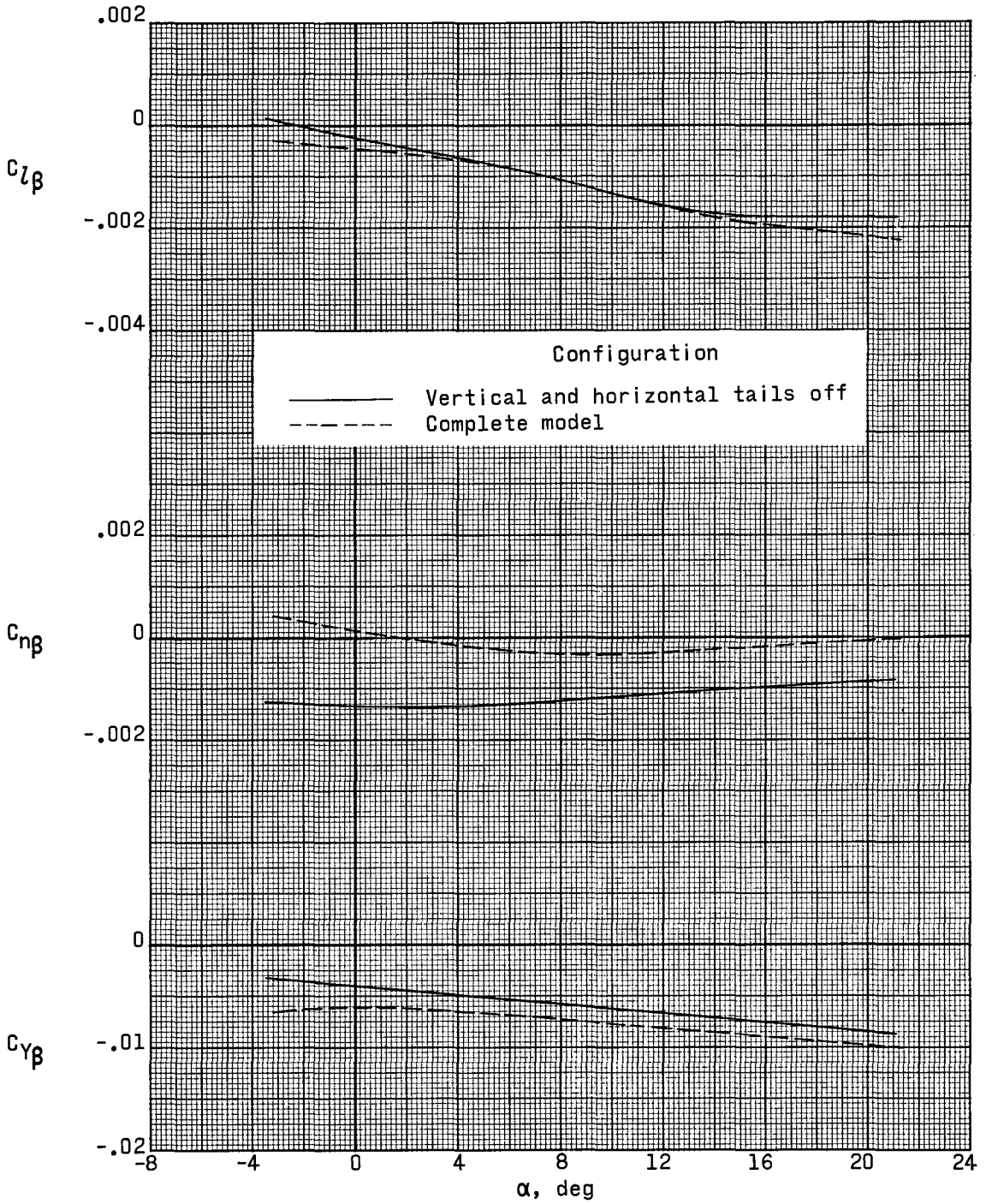
(b) M = 2.96.

Figure 8.- Continued.



(c) M = 3.95.

Figure 8.- Continued.



(d) M = 4.63.

Figure 8.- Concluded.

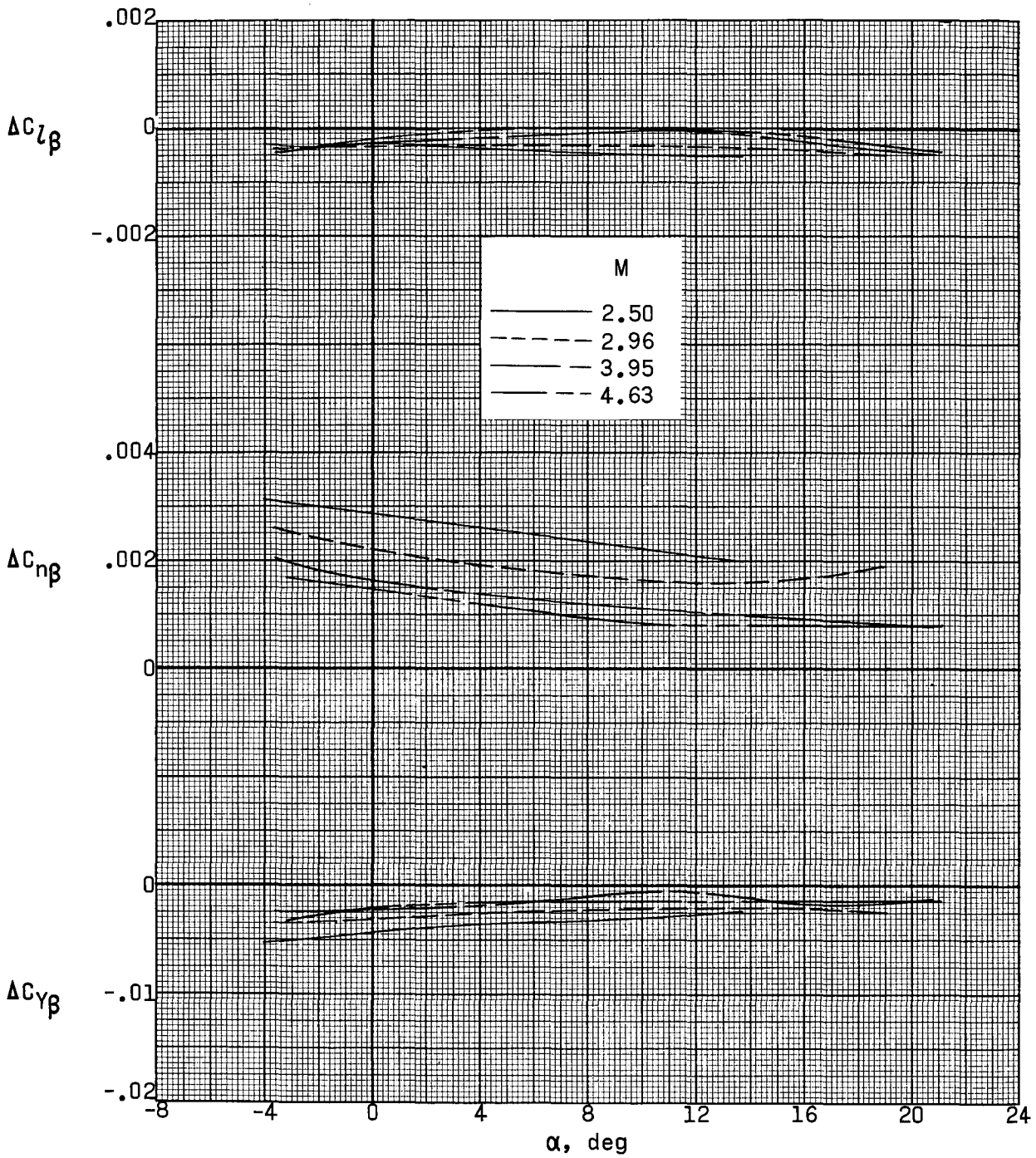


Figure 9.- Variation of tail contribution to sideslip derivatives with angle of attack. $\Lambda = 75^{\circ}$.

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