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RESEARCH MEMORANDUM

STATIC LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF A MODEL OF A 45° SWEPT-WING FIGHTER AIRPLANE AT MACH NUMBERS OF 1.41, 1.61, AND 2.01

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel to determine the static longitudinal stability and control characteristics of a model of a 45° swept-wing fighter airplane at Mach numbers of 1.41, 1.61, and 2.01.

The results indicate that the static margin, which was fairly constant through the lift range, decreased from 32 to 27 percent mean aerodynamic chord with increase in Mach number from 1.41 to 2.01. With the horizontal tail at an incidence of -10°, a trim lift coefficient of 0.30 was obtained at a Mach number of 1.41 which decreased to 0.17 with increase in Mach number to 2.01. Corresponding values of trim lift-drag ratio varied from 3.0 to 1.7.

The control characteristics indicate that as the Mach number is increased from 1.41 to 1.61 a conventional forward movement of the stick (stick position stability) is required to maintain level flight. When the Mach number is further increased from 1.61 to 2.01, a rearward movement of the stick (stick position instability) is required to maintain level flight.

INTRODUCTION

The National Advisory Committee for Aeronautics has undertaken an investigation of the aerodynamic characteristics of a model of a 45° swept-wing fighter airplane in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.41, 1.61, and 2.01. The model is of conventional design having a low-wing—fuselage arrangement with the horizontal tail located slightly below the extended wing-chord plane.

Tests of a similar model have been made at Mach numbers from 0.6 to 1.03 and have been reported in references 1 and 2.

This paper presents the results of a wind-tunnel investigation of the model to determine the static longitudinal stability and control characteristics at Mach numbers of 1.41, 1.61, and 2.01.

SYMBOLS

The results of the tests, presented as nondimensional coefficients, are referred to the stability axes (fig. 1) with the reference center of gravity at 37.5 percent of the mean aerodynamic chord. The symbols used herein are defined as follows:

C_L	lift coefficient, L/qS
$C_{L_{trim}}$	trim lift coefficient (at $C_m = 0$)
C_X	longitudinal-force coefficient, X/qS
C_m	pitching-moment coefficient, $M_Y/qS\bar{c}$
L	lift
X	force along X-axis
M_Y	pitching moment about Y-axis
$\bar{c}$	wing mean aerodynamic chord
$\bar{c}_t$	horizontal-tail mean aerodynamic chord
$\bar{c}_v$	vertical-tail mean aerodynamic chord
λ	taper ratio
Λ_{LE}	leading-edge sweepback of vertical tail
A	aspect ratio
q	free-stream dynamic pressure, lb/sq ft
M	Mach number

g	acceleration due to gravity, ft/sec^2
α	angle of attack of wing-chord plane, deg
i_t	tail-incidence angle measured with respect to fuselage reference line, negative when trailing edge is up, deg
L/D	lift-drag ratio, $C_L/-C_X$
W/S	wing loading, lb/sq ft
$\partial C_m/\partial i_t$	tail effectiveness parameter
$\partial C_m/\partial C_L$	static stability parameter
C_{L_α}	rate of change of lift coefficient with angle of attack
$\Delta C_X/C_L^2$	drag-rise factor
ϵ_e	effective downwash angle, deg
$\partial\epsilon/\partial\alpha$	rate of change of downwash angle with angle of attack

Model Component Designations

W	wing
B	body
H	horizontal tail
V	vertical tail

MODEL

The principal geometric characteristics and dimensions of the model are presented in figure 2 and table I.

The wing had 45° of sweepback at the quarter-chord line, an aspect ratio of 3.86, taper ratio of 0.262, and NACA $64_{(06)}$A007 airfoil sections in a streamwise direction. The wing and fuselage were joined so as to form a low-wing—fuselage arrangement with the wing-chord plane approximately 10 percent wing semispan below the fuselage reference line.

The model was tested with two vertical-tail configurations composed of a basic vertical tail and a modified vertical tail (fig. 2) that had 27 percent more area than the basic vertical tail. Both of the vertical tails and the horizontal tail had NACA 65A003.5 airfoil sections. The horizontal tail was located 2.58 percent wing semispan below the extended wing-chord plane. The horizontal tail was manually adjustable through a range of incidence angles from 0° to -10°.

The model was sting-supported and forces and moments were obtained through the use of a six-component internal strain-gage balance.

TESTS

The tests were made through an angle-of-attack range from 0° to about 20°. The stagnation dewpoint was maintained at -25° or less so that no condensation effects were encountered in the test section. Test conditions are shown in the following table:

Mach number	Stagnation pressure, lb/sq in. abs	Stagnation temperature, $^{\circ}F$	Reynolds number based on $\bar{c}$
1.41	6	100	1.40×10^{6}
1.61	6	100	1.34
2.01	6	100	1.16

CORRECTIONS AND ACCURACY

The values of angle of attack have been corrected for deflections of the balance and sting due to load. On the basis of pressure measurements made at the base of the fuselage, the longitudinal-force coefficients were adjsted to correspond to free-stream static pressure at the base. The estimated errors in the various measured quantities are as follows:

	M = 1.41 and 1.61	M = 2.01
C_L	±0.0044	±0.0051
C_X	±0.0005	±0.0007
C_m	±0.0017	±0.0021
α, deg		±0.1
i_t, deg		±0.1
Mach number		±0.01

PRESENTATION OF RESULTS

The results are presented in the following figures:

	Figure
Characteristics in pitch of the complete model and various combinations of its components -	
For M = 1.61	3(a)
For M = 2.01	3(b)
Longitudinal control characteristics of the complete model -	
For M = 1.41	4(a)
For M = 1.61	4(b)
For M = 2.01	4(c)
Variation of various aerodynamic parameters with Mach number	5
Variation of tail effectiveness and effective downwash characteristics	6
Longitudinal control characteristics	7

DISCUSSION

The characteristics in pitch for the complete model and various combinations of its components are presented in figures 3(a) and 3(b) for Mach numbers of 1.61 and 2.01, respectively. In general, the stability characteristics of the wing-fuselage configuration without the horizontal tail are unaffected by the vertical tail at $M = 1.61$ or $M = 2.01$. It may be noted, however, that the addition of the vertical tail to the wing-fuselage configuration in combination with the horizontal tail resulted in an increase in the lift-curve slope at $M = 2.01$, whereas at $M = 1.61$ the lift-curve slope was unaffected by the vertical tail.

The longitudinal control characteristics of the model (fig. 4) were obtained at $M = 1.41$ with the modified vertical tail and at $M = 1.61$ and $M = 2.01$ with the basic vertical tail. On the basis of the results showing the effect of the vertical tail (fig. 3), it is apparent that, except for a change in drag, the attendant change in size of the vertical tail would have little effect on the longitudinal characteristics. The results (fig. 4) indicate that the static margin for a given Mach number within the limits of the investigation is fairly constant throughout the lift-coefficient range. Increase in Mach number, however, resulted in a small decrease in the static margin (fig. 5). For example, the static margin obtained at Mach numbers of 1.41, 1.61, and 2.01 was $0.32\bar{c}$, $0.31\bar{c}$, and $0.27\bar{c}$, respectively. This decrease in static margin is associated in part with the effect of Mach number on the wing-body characteristics, and in part with the effect of Mach number on the lift-curve slope of the horizontal tail (fig. 5). With the horizontal tail at an incidence angle of -10°, a trim lift coefficient of 0.30 was obtained at $M = 1.41$ which decreased to 0.17 with an increase in Mach number to 2.01 (figs. 4 and 7). Corresponding values of trim $(L/D)_{max}$ varied from 3.0 to 1.7 (fig. 5). Figure 6 indicates that the effectiveness of the horizontal tail as described by $\partial C_m/\partial i_t$ decreased from a value of -0.0131 at $M = 1.41$ to -0.0082 for $M = 2.01$.

The variation of effective downwash angle with angle of attack (fig. 6) as determined from tail-on and tail-off pitching-moment data indicates a positive value of $\partial \epsilon/\partial \alpha$ at low angles of attack which decreased with angle of attack, becoming negative above angles of attack near 8°. This decrease in $\partial \epsilon/\partial \alpha$ is probably associated with the upwash field of the body (ref. 3).

By the use of the longitudinal-control data of figure 4 in conjunction with the lift coefficient required for trimmed level flight, the stabilizer deflection required for trimmed level flight at $M = 1.41$, 1.61, and 2.01 was determined. The results (fig. 7) indicate that a forward movement of the stick (stick position stability) is required to maintain trimmed level flight when increasing Mach number from 1.41 to 1.61. However, from $M = 1.61$ to $M = 2.01$, stick position instability occurs in that a rearward movement of the stick would be required to maintain trimmed level flight. The data of figure 7 also indicate the maximum maneuverability limits available for $i_t = -10^{\circ}$ at altitudes of 30,000 feet and 50,000 feet for a wing loading of 60 pounds per square foot.

SUMMARY OF RESULTS

A wind-tunnel investigation of the longitudinal stability and control characteristics of a model of a 45° swept-wing fighter airplane at Mach numbers of 1.41, 1.61, and 2.01 indicated the following results:

1. The static margin which was fairly constant through the lift range decreased from 32 to 27 percent mean aerodynamic chord with increase of Mach number from 1.41 to 2.01.

2. With the horizontal tail at an incidence angle of -10°, a trim lift coefficient of 0.30 was obtained at a Mach number of 1.41 which decreased to 0.17 with an increase in Mach number to 2.01. Corresponding values of trim lift-drag ratio varied from 3.0 to 1.7.

3. Control characteristics indicate that to maintain level flight while increasing Mach number from 1.41 to 1.61 a conventional forward movement of the control is required, whereas when Mach number is increased from 1.61 to 2.01 a rearward movement of the control is required.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 27, 1956.

REFERENCES

1. Runckel, Jack F., and Schmeer, James W.: The Aerodynamic Characteristics at Transonic Speeds of a Model With a 45° Sweptback Wing, Including the Effect of Leading-Edge Slats and a Low Horizontal Tail. NACA RM L53J08, 1954.

2. Whitcomb, Charles F., and Norton, Harry T., Jr.: Transonic Investigation of Aerodynamic Characteristics of a Swept-Wing Fighter-Airplane Model With Leading-Edge Droop in Combination With Outboard Chord-Extensions and Notches. NACA RM L55H30, 1956.

3. Palazzo, Edward B., and Spearman, M. Leroy: Static Longitudinal and Lateral Stability and Control Characteristics of a Model of a 35° Swept-Wing Airplane at a Mach Number of 1.41. NACA RM L54G08, 1955.

TABLE I

GEOMETRIC CHARACTERISTICS OF THE MODEL

Wing:		
Area, sq ft		1.89
Span, in.		32.41
Aspect ratio		3.86
Taper ratio		0.262
Mean geometric chord, in.		9.38
Sweep of 0.25c line, deg		45
Incidence, deg		0
Dihedral, deg		0
Twist, deg		0
Airfoil section		NACA $64_{(06)}$A007
Fuselage:		
Length, in.		40.45
Frontal area, sq ft		0.13
Horizontal tail:		
Area, sq ft		0.48
Span, in.		15.73
Aspect ratio		3.54
Taper ratio		0.302
Mean geometric chord, in.		4.88
Sweep of 0.25c line, deg		45
Airfoil section		NACA 65A003.5
Tail length, 0.25c of wing to 0.25c of horizontal tail, in.		12.07

	Basic	Modified
Vertical tail:		
Area, sq ft	0.167	0.213
Span (exposed), in.	5.16	6.66
Aspect ratio	1.10	1.45
Taper ratio	0.428	0.301
Sweep of 0.25c line, deg	45	45
Airfoil section	NACA 65A003.5	

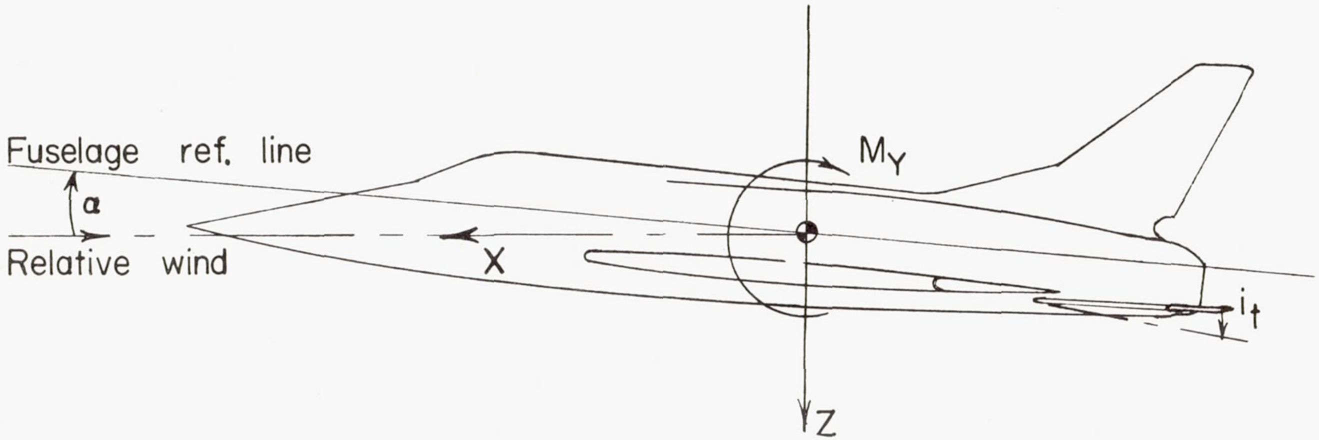

Figure 1.- Stability axis systems. Arrows indicate positive directions.

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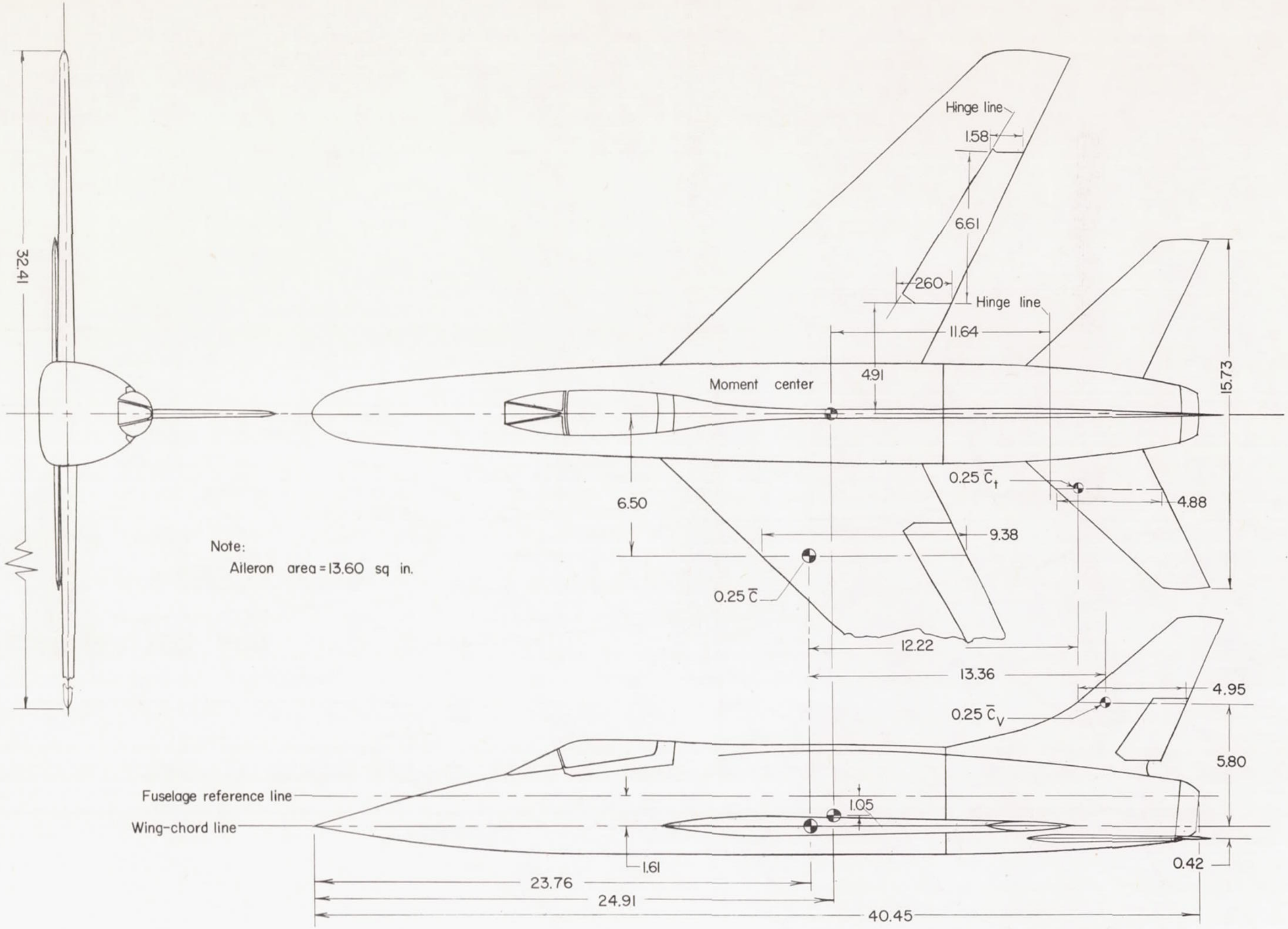
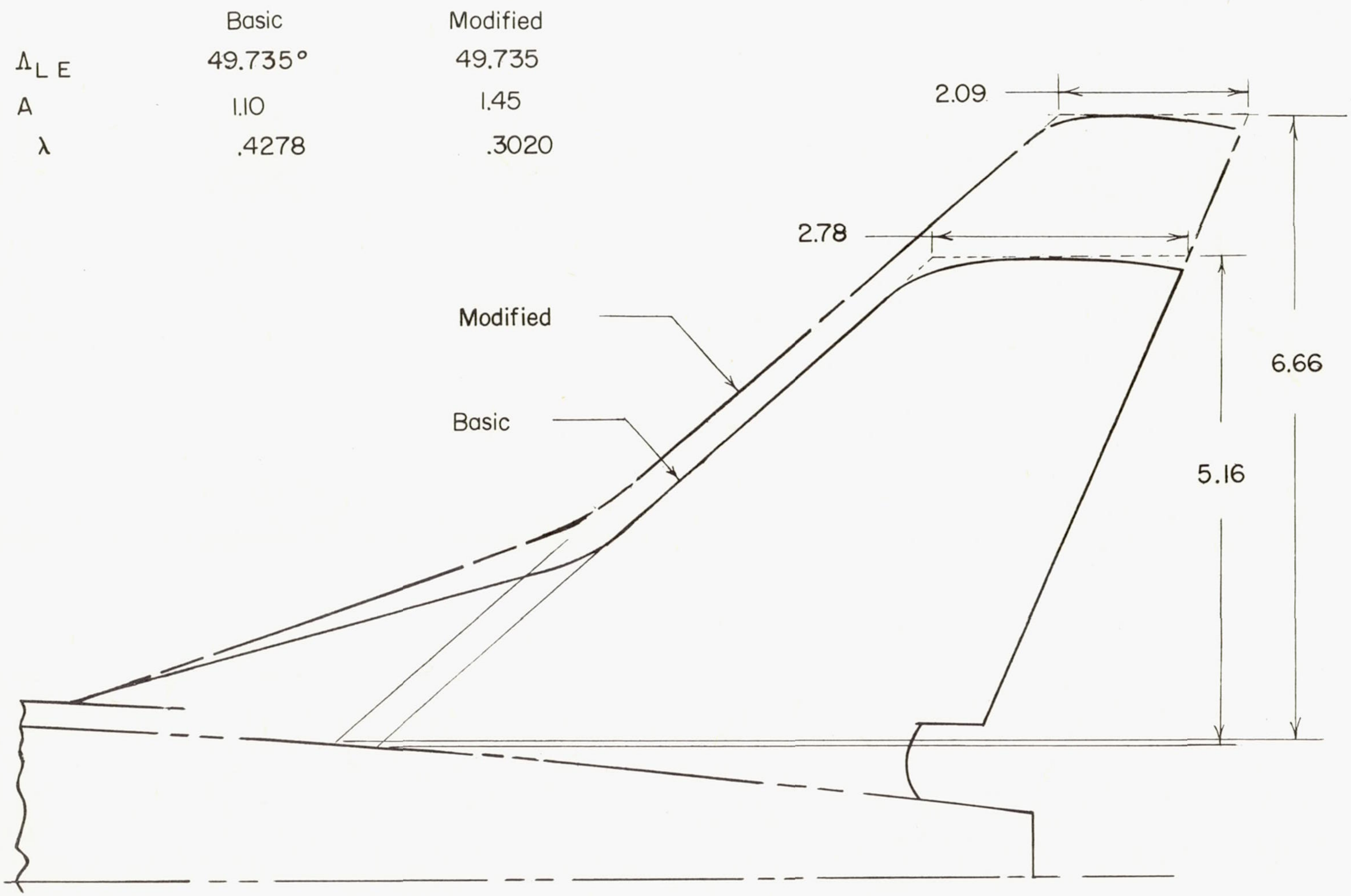


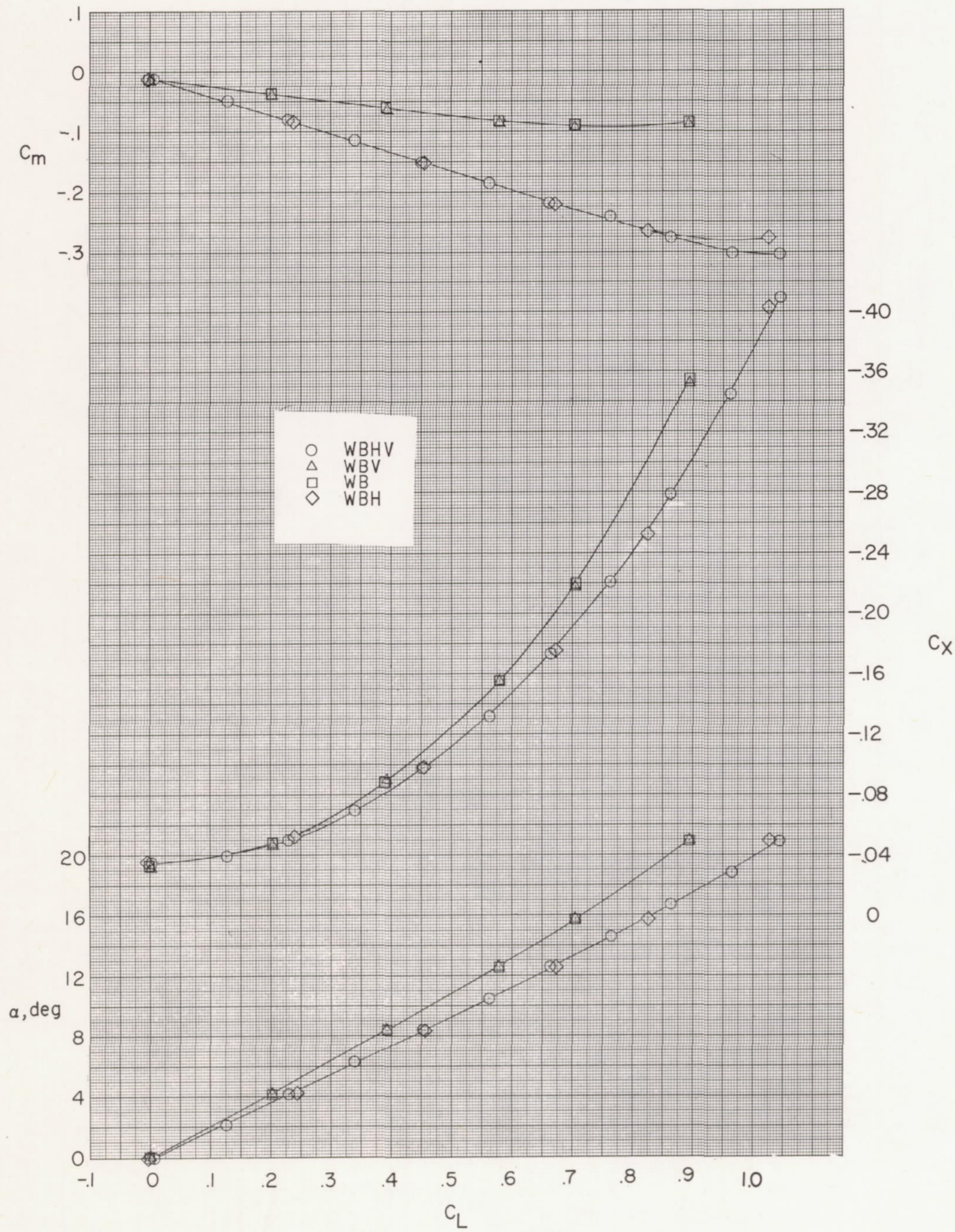
(a) Arrangement of model.

Figure 2.- Details of model. All dimensions in inches.



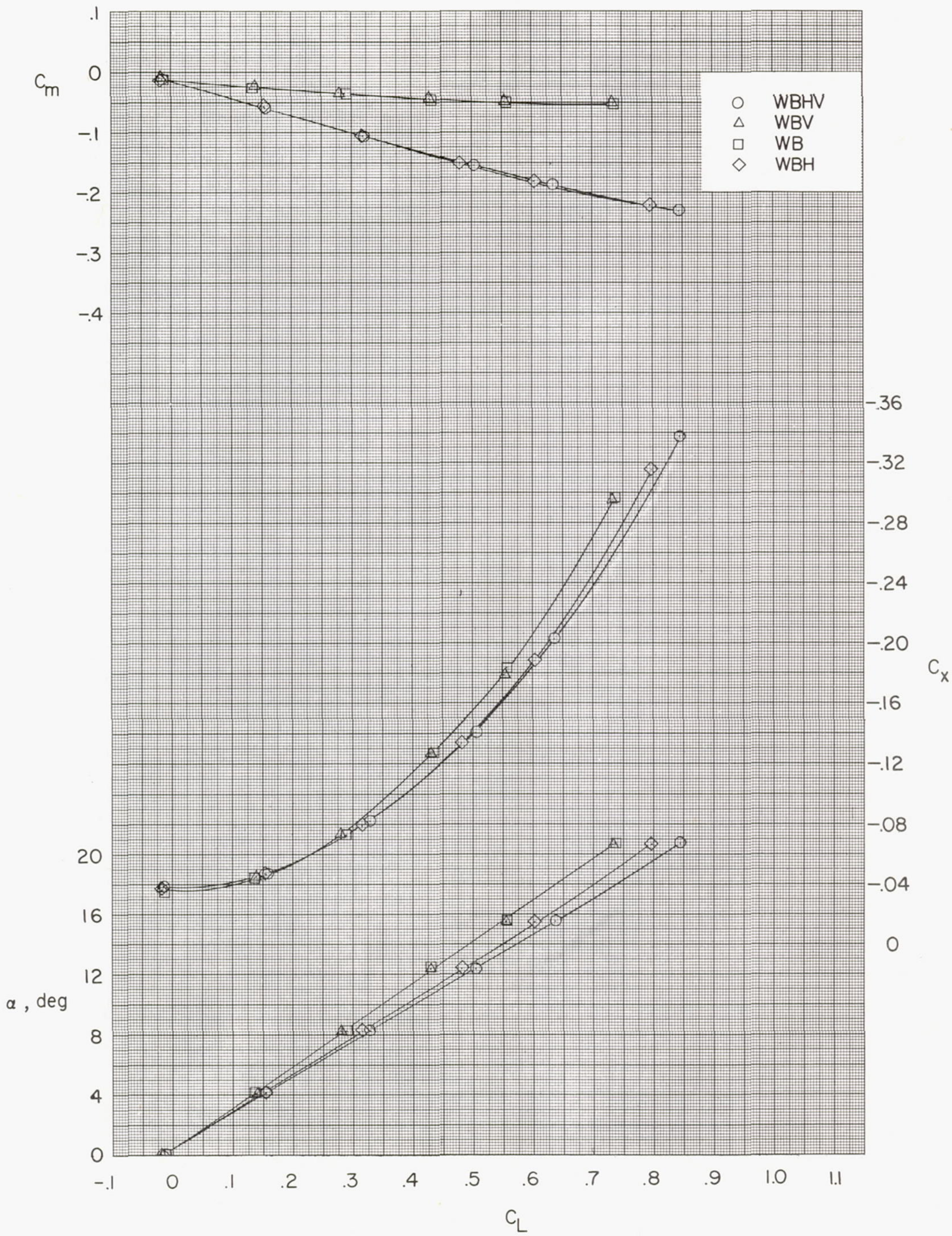
(b) Plan view of basic and modified vertical tail.

Figure 2.- Concluded.



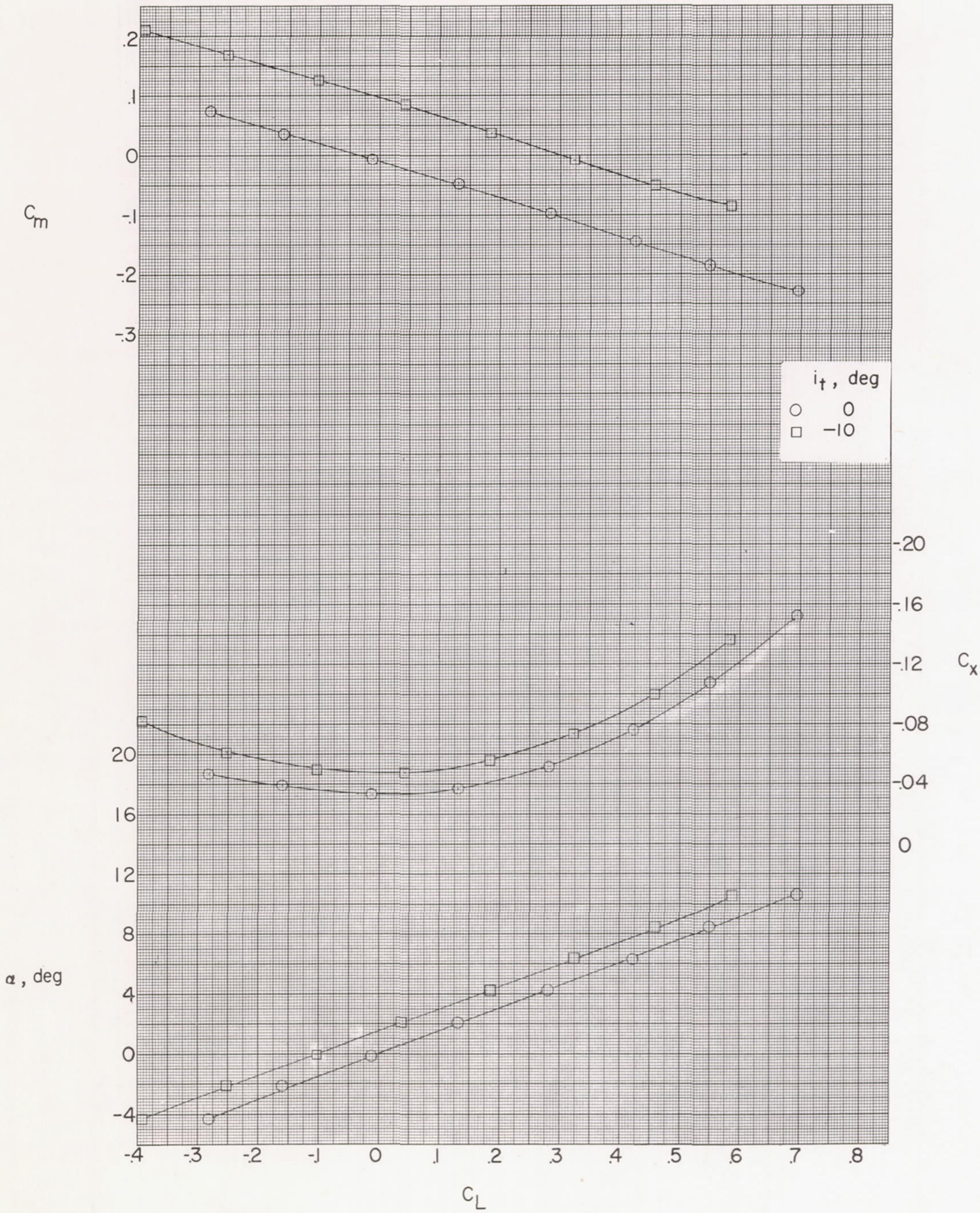
(a) M = 1.61.

Figure 3.- Characteristics in pitch of the complete model and various combinations of its components. Basic vertical tail is used.



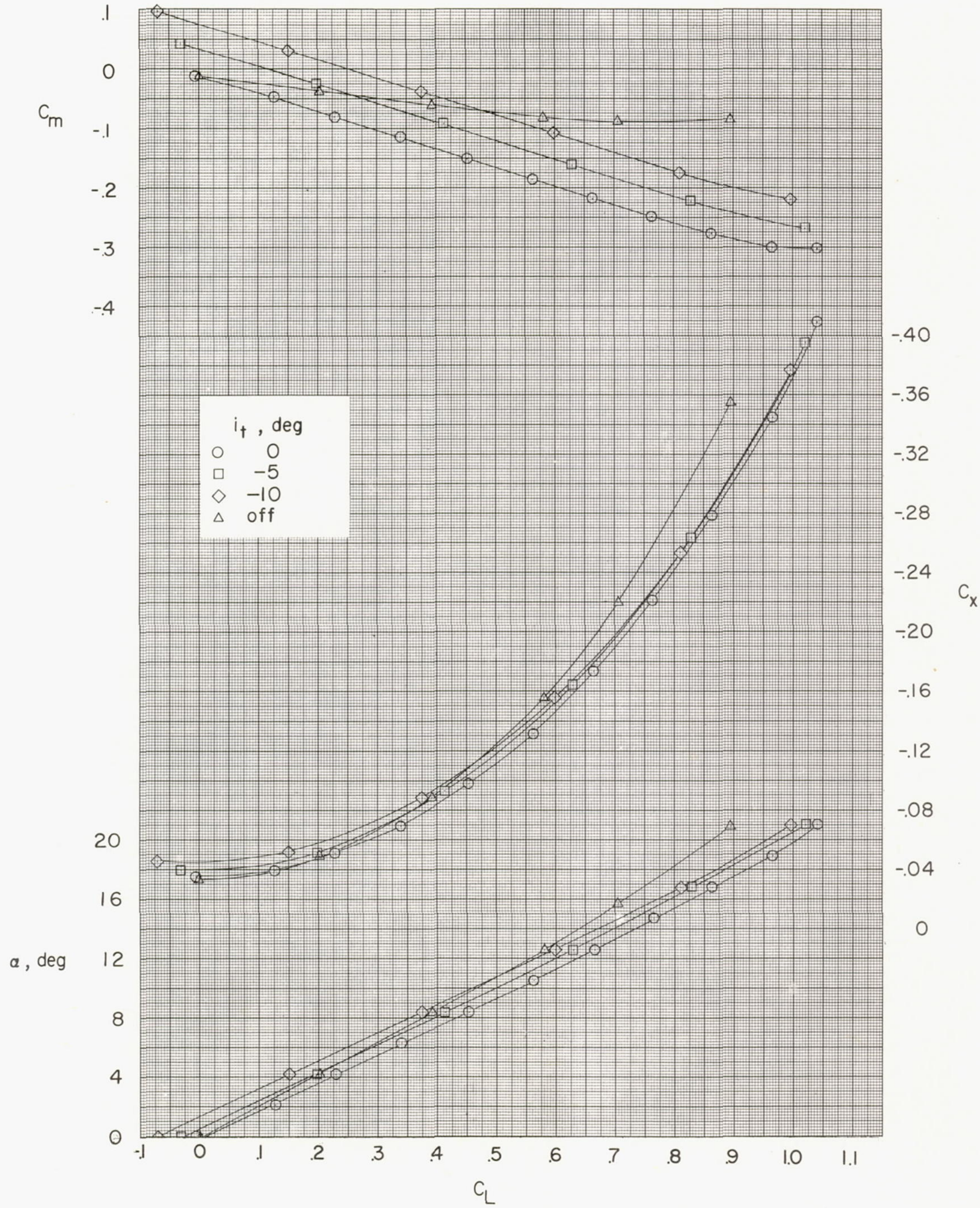
(b) M = 2.01.

Figure 3.- Concluded.



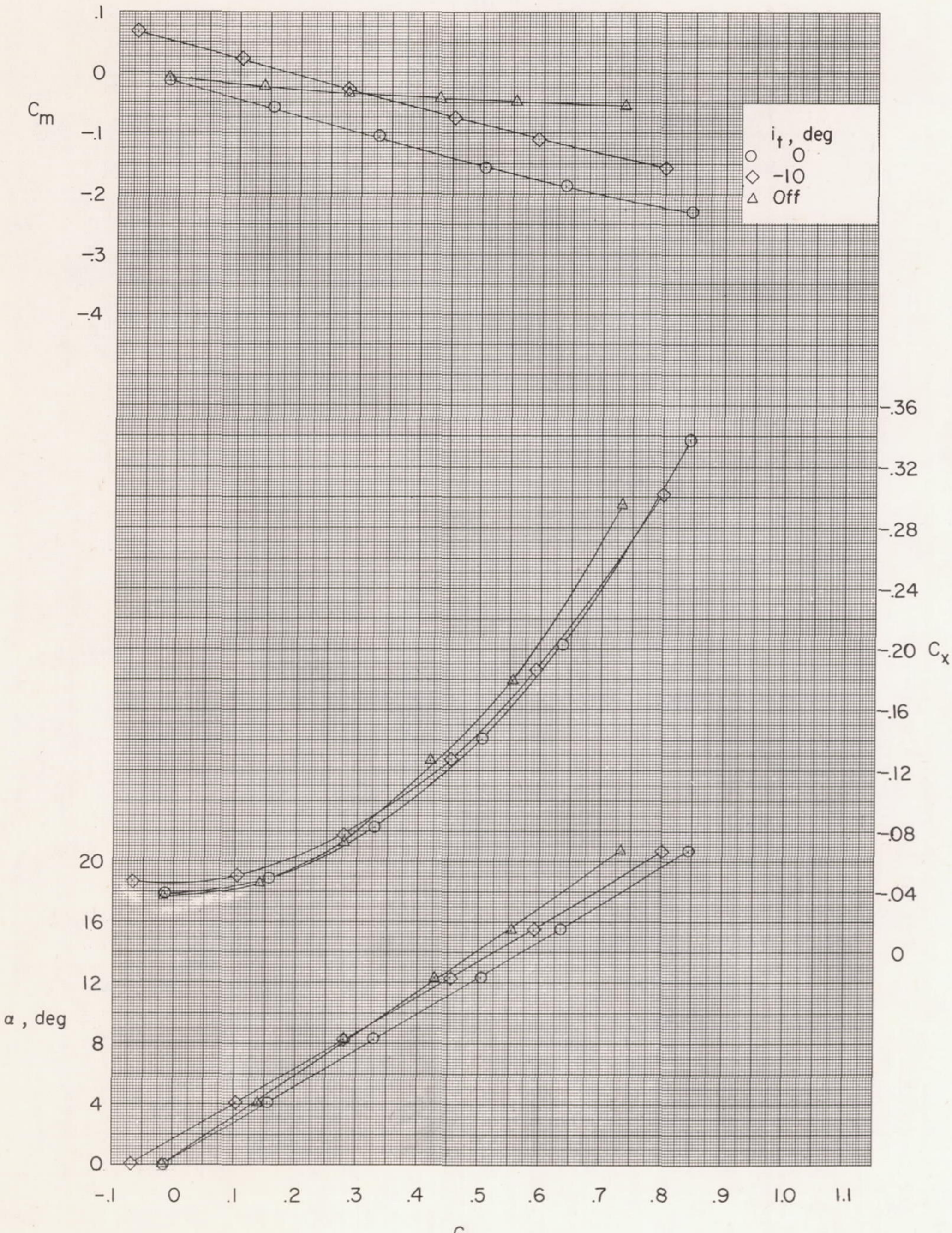
(a) M = 1.41; modified vertical tail on.

Figure 4.- Longitudinal control characteristics of complete model.



(b) M = 1.61; basic vertical tail on.

Figure 4.- Continued.



(c) M = 2.01; basic vertical tail on.

Figure 4.- Concluded.

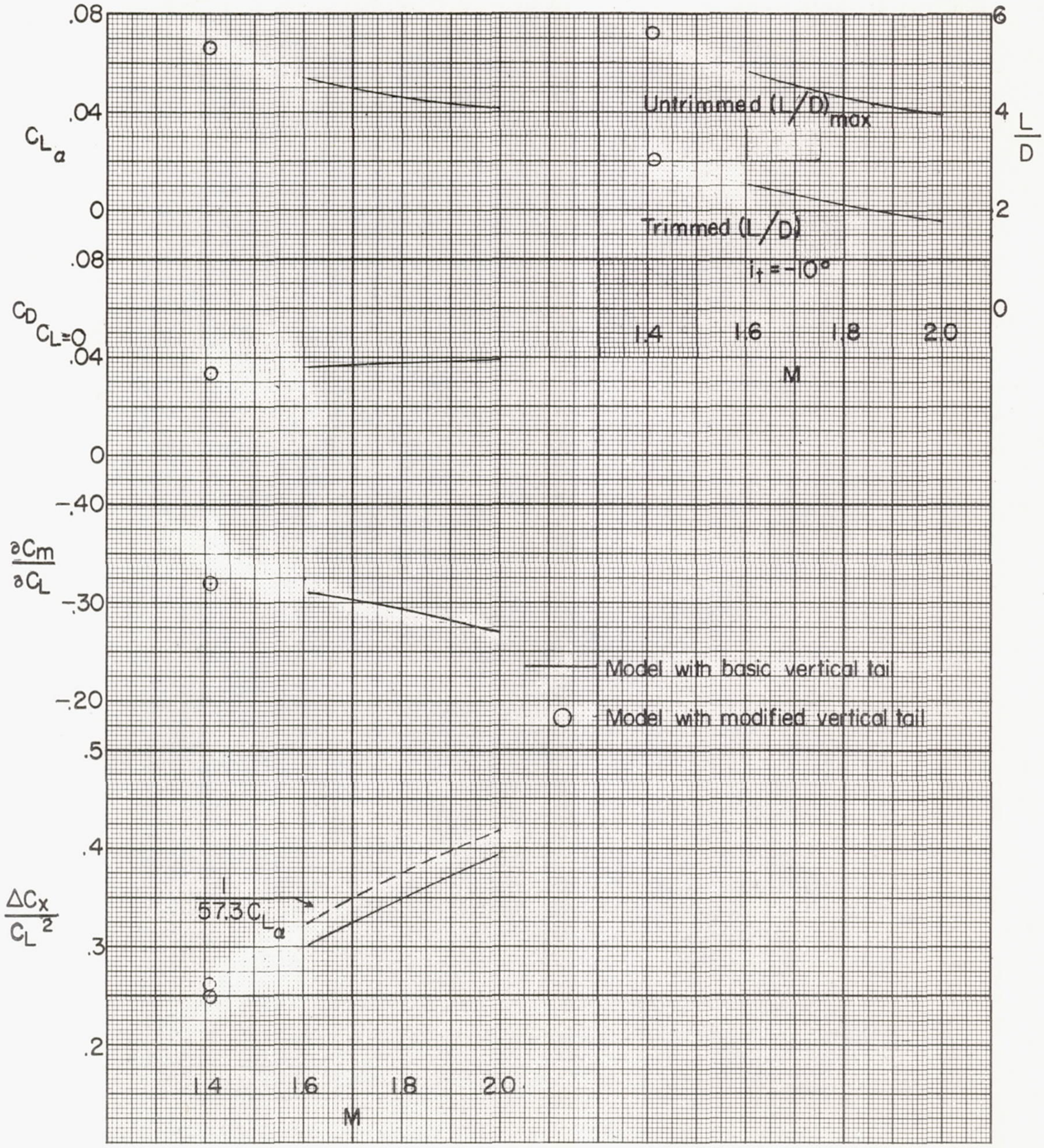


Figure 5.- Variation of various aerodynamic parameters with Mach number.

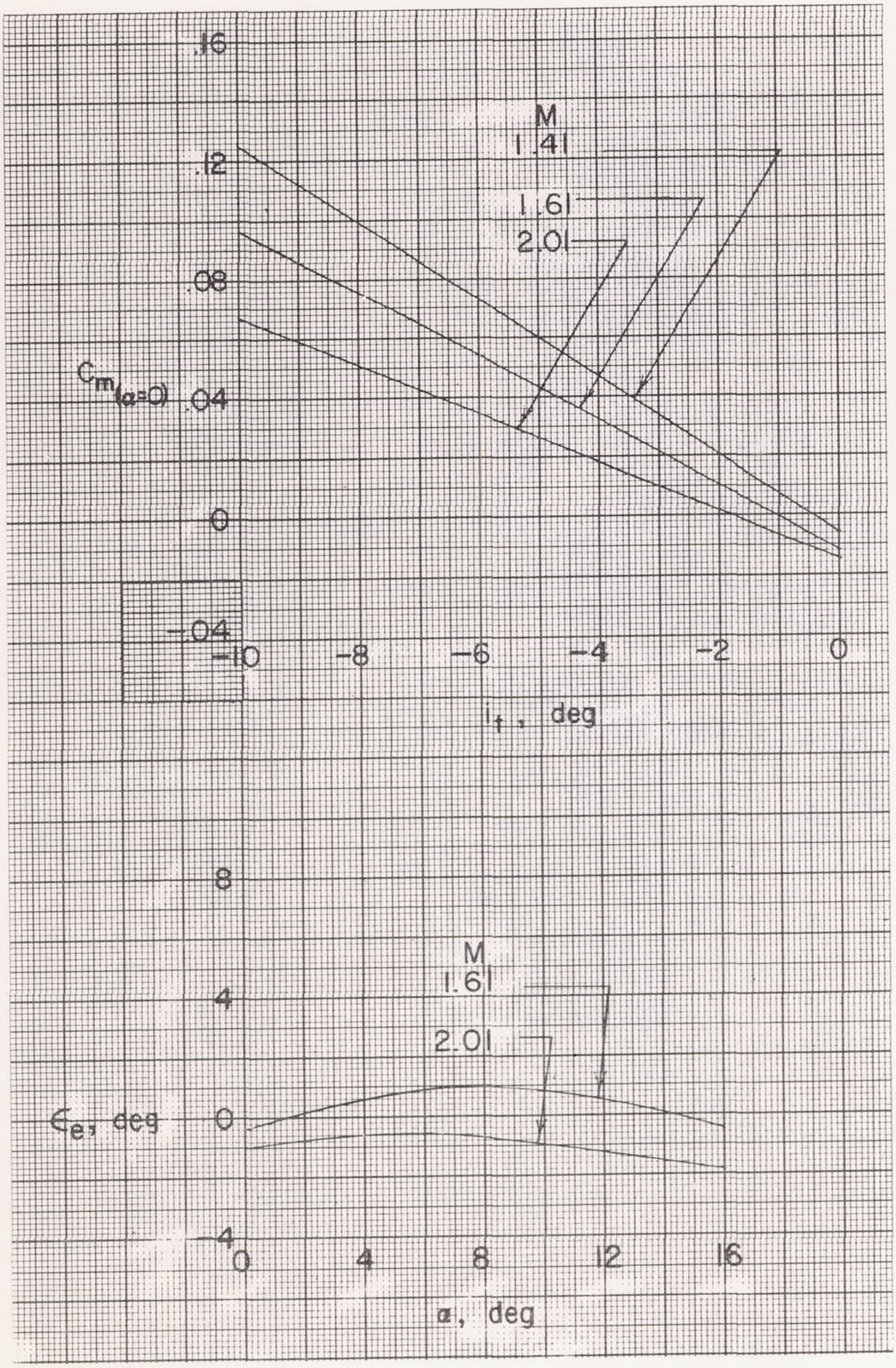


Figure 6.- Variation of tail effectiveness and effective downwash characteristics.

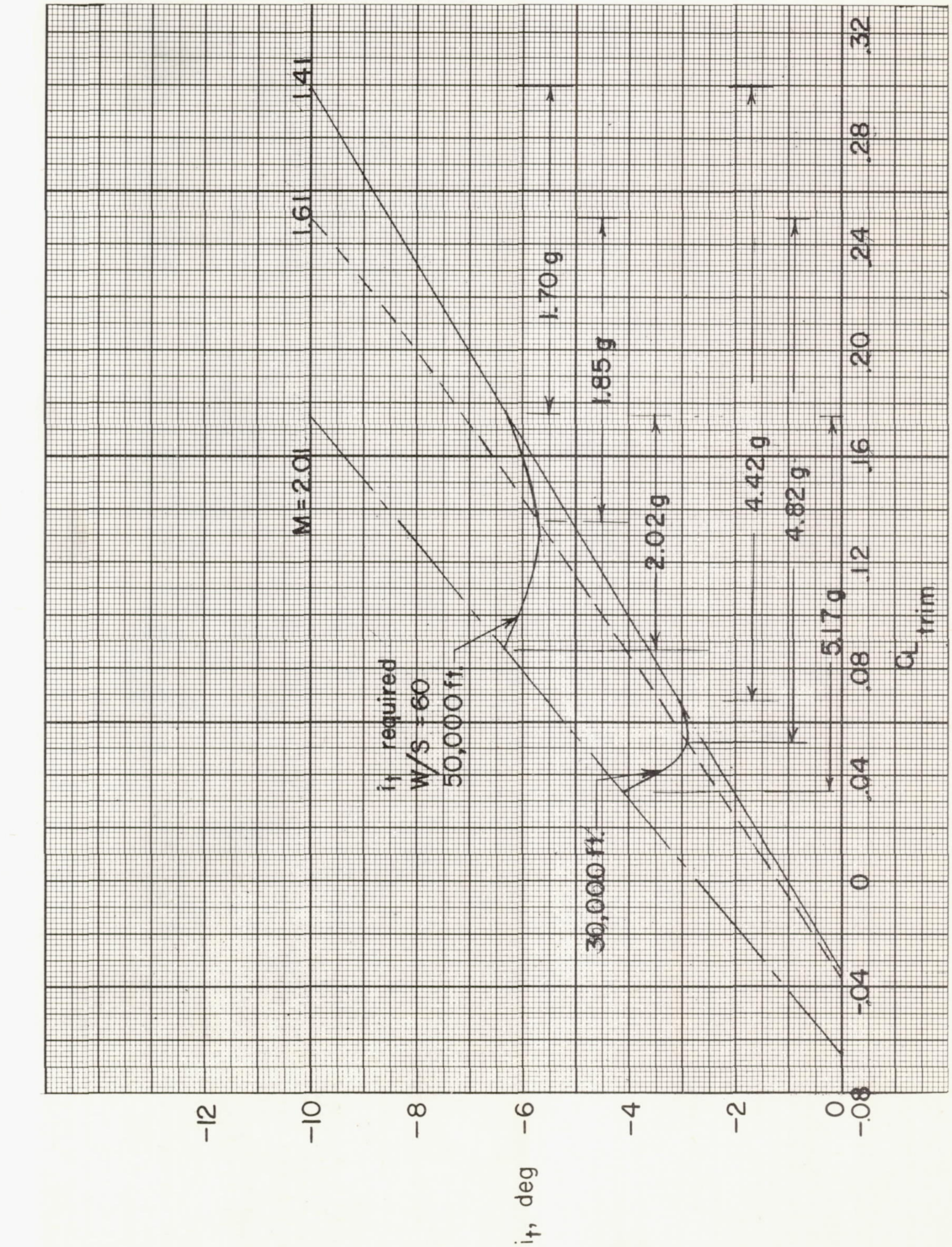


Figure 7.- Longitudinal control characteristics for various Mach numbers.

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