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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

THE AERODYNAMIC CHARACTERISTICS IN PITCH OF A 1/15-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE AT MACH NUMBERS OF 1.41, 1.61, AND 2.01

TED NO. NACA ~~AD 3125~~

By Cornelius Driver

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

MAY 23 1956

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THE AERODYNAMIC CHARACTERISTICS IN PITCH OF A 1/15-SCALE MODEL OF THE GRUMMAN F11F-1 AIRPLANE AT MACH NUMBERS OF 1.41, 1.61, AND 2.01

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SUMMARY

Tests have been made in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.41, 1.61, and 2.01 to determine the static longitudinal stability and control characteristics of various arrangements of the Grumman F11F-1 airplane. Tests were made of the complete model and various combinations of its component parts and, in addition, the effects of various body modifications, a revised vertical tail, and wing fences on the longitudinal characteristics were determined.

The results indicate that for a horizontal-tail incidence of -10° the trim lift coefficient varied from 0.29 at a Mach number of 1.61 to 0.23 at a Mach number of 2.01 with a corresponding decrease in lift-drag trim from 3.72 to 3.15. Stick-position instability was indicated in the low-supersonic-speed range.

A photographic-type nose modification resulted in slightly higher values of minimum drag coefficient but did not significantly affect the static stability or lift-curve slope. The minimum drag coefficient for the complete model with the production nose remained essentially constant at 0.047 throughout the Mach number range investigated.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, the National Advisory Committee for Aeronautics has undertaken an investigation of the aerodynamic characteristics of the Grumman F11F-1 at subsonic, transonic, and supersonic speeds. The designation F11F-1 supersedes the previous model designated Grumman F9F-9.

The F11F-1 is a jet-propelled day-fighter design having a wing with 35° sweep at the quarter-chord line, an aspect ratio of 4, and NACA 65A-series sections having thickness ratios of 6 percent at the root and 4 percent at the tip. The wing is mounted in a semihigh position on the fuselage and the all-movable horizontal tail is located slightly below the extended chord line of the wing. The fuselage is indented in the vicinity of the wing to obtain a desirable area distribution for the purpose of reducing the transonic drag rise.

Tests have been conducted at subsonic speeds in the Langley low-turbulence pressure tunnel and through the transonic range in the Langley 8-foot transonic tunnel (ref. 1). Limited tests in the supersonic range made in the Langley 4- by 4-foot supersonic pressure tunnel were reported in reference 2. The present paper contains the static longitudinal stability and control results for an F11F-1 model having a longer nose length and a modified horizontal tail. Tests were conducted in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.41, 1.61, and 2.01.

COEFFICIENTS AND SYMBOLS

In the presentation of the experimental results, the force and moment coefficients are referred to the stability-axis system (fig. 1) with the reference center-of-gravity location (center of moments) at 25 percent of the mean aerodynamic chord.

C_L lift coefficient, L/qS

C_D' approximate drag coefficient, D'/qS

C_m pitching-moment coefficient, $M_Y/qS\bar{c}$

S wing area, (1.11), sq ft

q dynamic pressure, lb/sq ft

$\bar{c}$ wing mean aerodynamic chord (6.55), in.

M free-stream Mach number

L/D lift-drag ratio $\left(C_L/C_D{}'\right.$ for $\left.\beta = 0^\circ\right)$

R Reynolds number based on $\bar{c}$

b wing span (25.32), in.

α angle of attack of fuselage reference line, deg

i_t horizontal-tail incidence angle with respect to fuselage reference line (positive when trailing edge moves down), deg

ϵ effective downwash angle, deg

$C_{m_{i_t}}$ horizontal-tail effectiveness parameter $\left(\partial C_m/\partial i_t\right)$

Model designations:

W wing

B body - superscript 1 denotes fuselage with production nose; superscript 2 denotes fuselage with photographic nose; superscript 3 denotes fuselage with production nose but with afterburner ring installed.

V vertical tail - superscript 1 denotes original vertical tail; superscript 3 denotes vertical tail with extended chord.

H horizontal tail - superscript 1 denotes original horizontal tail used in reference 1; superscript 2 denotes modified horizontal tail used in present report; subscript denotes values of i_t.

MODEL AND APPARATUS

The tests were conducted in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.41, 1.61, and 2.01. A three-view drawing of the model is shown in figure 2. Drawings showing the different nose shapes tested, the modified vertical tail, and a composite view of the original and present model are shown in figure 3. Several photographs of the model are presented as figure 4. The geometric characteristics are presented in table I.

The basic configuration for this investigation had the production nose (B') and a wing with 35° sweepback at the quarter-chord line and an NACA 65A006 airfoil section at the root and an NACA 65A004 airfoil section at the tip. The air inlets were plugged and faired closed for all the present tests.

TEST CORRECTIONS AND ACCURACY

The test conditions are summarized in the following table:

Mach number	Stagnation temperature, °F	Stagnation pressure, lb/ft^2	Reynolds number (based on M.A.C.)	Dewpoint less than -
1.41	100	1,440	1.628×10^6	-25° F
1.61	100	1,440	1.558	-25° F
2.01	100	1,440	1.346	-25° F

The model was sting-mounted in the tunnel and forces and moments were measured through the use of a six-component internal strain-gage balance and indicating system. The angle-of-attack range varied from -4° to about 22°. The angles of attack have been corrected for deflection of the balance and sting caused by the aerodynamic loads. Base-pressure measurements were made and the drag coefficients were adjusted to correspond to a base pressure equal to free-stream static pressure.

The angles of attack and control deflection are estimated to be accurate to within ±0.1°. The maximum Mach number variation in the test section was approximately ±0.01.

The maximum estimated errors in the coefficients due to the balance system are as follows:

C_L . . . . ±0.007
C_D . . . . ±0.002
C_m . . . . ±0.0005

An index of the configurations and figures is presented in table II.

RESULTS AND DISCUSSION

Longitudinal Trim and Control Characteristics

The aerodynamic characteristics in pitch for the complete model with various angles of horizontal-tail incidence as well as with the horizontal tail off are presented in figure 5 for $M = 1.61$ and $M = 2.01$. The longitudinal trim characteristics are presented in figure 6. For the maximum horizontal-tail deflection tested at $M = 1.61$ (-16.4°), the maximum trim lift coefficient was about 0.5 with a trim drag coefficient of 0.143. For a horizontal-tail deflection of -10°, $C_{L_{trim}}$ varied from a value of 0.29 at $M = 1.61$ to 0.23 at $M = 2.01$ with a corresponding decrease in $(L/D)_{trim}$ from 3.72 to 3.15. The minimum trim drag coefficient was approximately 0.047 at Mach numbers of 1.61 and 2.01.

By the use of the stabilizer data (fig. 5) in conjunction with the lift coefficient required for level flight, the stabilizer deflection required for trim at each Mach number has been determined for several altitudes and a wing loading of 60 lb/sq ft (fig. 7). The longitudinal-control data shown in figures 7 and 8 include the data from reference 2 at $M = 1.41$ and the data from the present investigation at $M = 1.61$ and 2.01. A comparison between the original model (ref. 2) and the present model with the extended nose and modified horizontal tail (fig. 2) indicated that the parameters C_m/C_L, C_{L_α}, and C_{m_0} had essentially the same values for both models at $M = 1.41$.

The longitudinal-control results (fig. 7) indicated stick-position instability (rearward movement) when increasing the Mach number from 1.41 to 1.61 at altitudes below 50,000 feet with stable variations indicated at higher altitudes and between Mach numbers of 1.61 and 2.01. The normal accelerations (the ratio of maximum trim lift coefficient available to the lift coefficient required for level flight) for an i_t of -10° are also presented in figure 7 for an altitude of 50,000 feet. The increase noted in the maneuverability with increasing Mach number results from the fact that, in this Mach number range, the lift coefficient required for level flight decreases with Mach number at a more rapid rate than does the maximum trim lift coefficient available.

The horizontal-tail effectiveness parameter $\partial C_m/\partial i_t$ indicates a loss of effectiveness with increasing Mach number (fig. 8) and probably results from a decrease in C_{L_α} of the horizontal tail. Effective downwash values are also shown in figure 8 and indicate negative values (stabilizing) throughout the Mach number range investigated. However, since the wing-off data indicate a more negative value of $\partial\epsilon/\partial\alpha$, the existence of wing downwash as well as body upwash is indicated.

Effect of component parts.- The aerodynamic characteristics in pitch of the complete model and various combinations of its components are presented in figure 9 for $M = 1.61$ and $M = 2.01$. The addition of the wing or the horizontal tail to the body provides essentially the same pitching-moment increment. The addition of the wing and horizontal tail together, however, provides less pitching-moment increment than the summation of the wing and horizontal tail separately; this condition indicates an interference effect between the wing and the horizontal tail. As shown previously, the value of $\partial C_m/\partial i_t$ obtained from figure 9 for the wing off is greater than that obtained with the wing on; this result is a further indication of a wing wake or q loss at the horizontal tail. The addition of the vertical tail had little effect on the lift-curve slope or the static margin.

The longitudinal characteristics are summarized in figure 10. The lift-curve slope C_{L_α} for the complete model decreases from a value of 0.072 at $M = 1.41$ to 0.047 at $M = 2.01$. The corresponding values of minimum drag are 0.046 and 0.047, respectively. Both the complete model and the wing-body combination indicate a decrease in stability with increasing Mach number as evidenced by the forward movement of the neutral point (fig. 10).

Effect Of Body and Vertical-Tail Modifications

The data for the body with the production nose B^1, the photographic nose B^2, and the body with the afterburner ring installed B^3 indicated no significant differences in the static stability or lift-curve slope at $M = 1.41$. However, the results indicated that the body with the photographic nose B^2 had higher values of minimum drag coefficient at both $M = 1.41$ and $M = 1.61$.

The extended-chord vertical-tail modification V^3 (tested at $M = 1.41$ only) provided slightly lower values of minimum drag than the production vertical tail V^1. The tail modification produced no significant changes in the lift-curve slope or static margin (fig. 11).

Effect of Fences

The addition of the wing fences produced no significant changes in the aerodynamic characteristics in pitch at $M = 1.61$ (fig. 12).

SUMMARY OF RESULTS

Tests of various configurations of the Grumman F11F-1 at Mach numbers of 1.41, 1.61, and 2.01 have indicated the following results:

1. For a horizontal-tail incidence of -10° the trim lift coefficient varied from 0.29 at $M = 1.61$ to 0.23 at $M = 2.01$ with a corresponding decrease in trim lift-drag ratio from 3.72 to 3.15.

2. The minimum drag coefficient for the complete model (production nose) remained essentially constant at 0.047 throughout the Mach number range investigated.

3. Stick-position instability occurred at Mach numbers between 1.41 and 1.61 for altitudes below 50,000 feet.

4. The incorporation of a longer photographic-nose modification resulted in a slight increase in minimum drag coefficient without significantly affecting the static stability or lift-curve slope.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 8, 1956.

Cornelius Driver
Aeronautical Research Scientist

Approved:

John V. Becker
Chief of Compressibility Research Division

rmw

REFERENCES

1. Bielat, Ralph P.: A Transonic Wind-Tunnel Investigation of the Performance and of the Static Stability and Control Characteristics of a 1/15-Scale Model of the Grumman F9F-9 Airplane - TED No. NACA DE 390. NACA RM SL54J15, Bur. Aero., 1954.

2. 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 MODEL

Wing:		
Area, sq ft		1.11
Aspect ratio		4.00
Sweepback of quarter-chord line, deg		35
Taper ratio		0.500
Mean geometric chord, ft		0.5453
Airfoil section, root		modified NACA 65A006
Airfoil section, tip		modified NACA 65A004
Twist, deg		0
Dihedral, deg		-2.5
Span, ft		2.109
Incidence, deg		0
Horizontal tail:		
Area, sq ft		0.291
Aspect ratio		3.50
Sweepback of quarter-chord line, deg		35
Taper ratio		0.400
Airfoil section, root		NACA 65A006
Airfoil section, tip		NACA 65A004
Span, ft		1.01
Vertical tail:	V^1	V^3
Area (exposed), sq ft	0.178	0.222
Aspect ratio (based on exposed area and span)	1.51	1.20
Sweepback of quarter-chord line, deg	44.4	44.0
Taper ratio	0.177	0.25
Airfoil section, root	NACA 65A006	NACA 65A006
Airfoil section, tip	NACA 65A004	NACA 65A004
Fuselage:		
Length for B^1, in.		32.31
Length for B^2, in.		33.66
Length for B^3, in.		33.10
Base area, B^2, sq in.		4.68
Miscellaneous:		
Tail length from $\bar{c}/4$ wing to $\bar{c}/4$ of the horizontal tail, in.		12.438

TABLE II.- INDEX OF FIGURES AND CONFIGURATIONS

Figure	M	Body	Horizontal tail	Vertical tail	Wing	i_t, deg	Fence	Type
5(a)	1.61	B^1	H^2	V^1	On	0	Off	Basic data
	1.61	B^1	Off	V^1	On	-----	Off	Basic data
	1.61	B^1	H^2	V^1	On	-5	Off	Basic data
	1.61	B^1	H^2	V^1	On	-10	Off	Basic data
	1.61	B^1	H^2	V^1	On	-16.4	Off	Basic data
5(b)	2.01	B^1	H^2	V^1	On	0	Off	Basic data
	2.01	B^1	Off	V^1	On	-----	Off	Basic data
	2.01	B^1	H^2	V^1	On	-10	Off	Basic data
6	Longitudinal trim characteristics							
7	Longitudinal control characteristics							
8	Tail effectiveness and downwash characteristics							
9(a)	1.61	B^1	H^2	V^1	On	0	Off	Basic data
	1.61	B^1	H^2	V^1	Off	0	Off	Basic data
	1.61	B^1	H^2	V^1	Off	-10	Off	Basic data
	1.61	B^1	Off	V^1	On	-----	Off	Basic data
	1.61	B^1	Off	V^1	Off	-----	Off	Basic data
	1.61	B^1	H^2	Off	On	0	Off	Basic data
	1.61	B^1	H^2	Off	Off	0	Off	Basic data
	1.61	B^1	Off	Off	On	0	Off	Basic data
	1.61	B^1	Off	Off	Off	-----	Off	Basic data
9(b)	2.01	B^1	H^2	V^1	On	0	Off	Basic data
	2.01	B^1	H^2	Off	On	0	Off	Basic data
	2.01	B^1	Off	V^1	On	-----	Off	Basic data
	2.01	B^1	Off	Off	On	-----	Off	Basic data
10	Summary of longitudinal characteristics							
11(a)	1.41	B^1	H^2	V^1	On	0	Off	Basic data
	1.41	B^1	Off	Off	On	-----	Off	Basic data
	1.41	B^2	H^2	V^3	On	0	Off	Basic data
	1.41	B^2	Off	Off	On	-----	Off	Basic data
	1.41	B^3	H^2	V^3	On	0	Off	Basic data
11(b)	1.61	B^1	H^2	V^1	On	0	Off	Basic data
	1.61	B^1	Off	Off	On	-----	Off	Basic data
	1.61	B^2	H^2	V^1	On	0	Off	Basic data
	1.61	B^2	Off	Off	On	-----	Off	Basic data
12	1.61	B^1	H^2	V^1	On	0	On	Basic data

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[redacted]

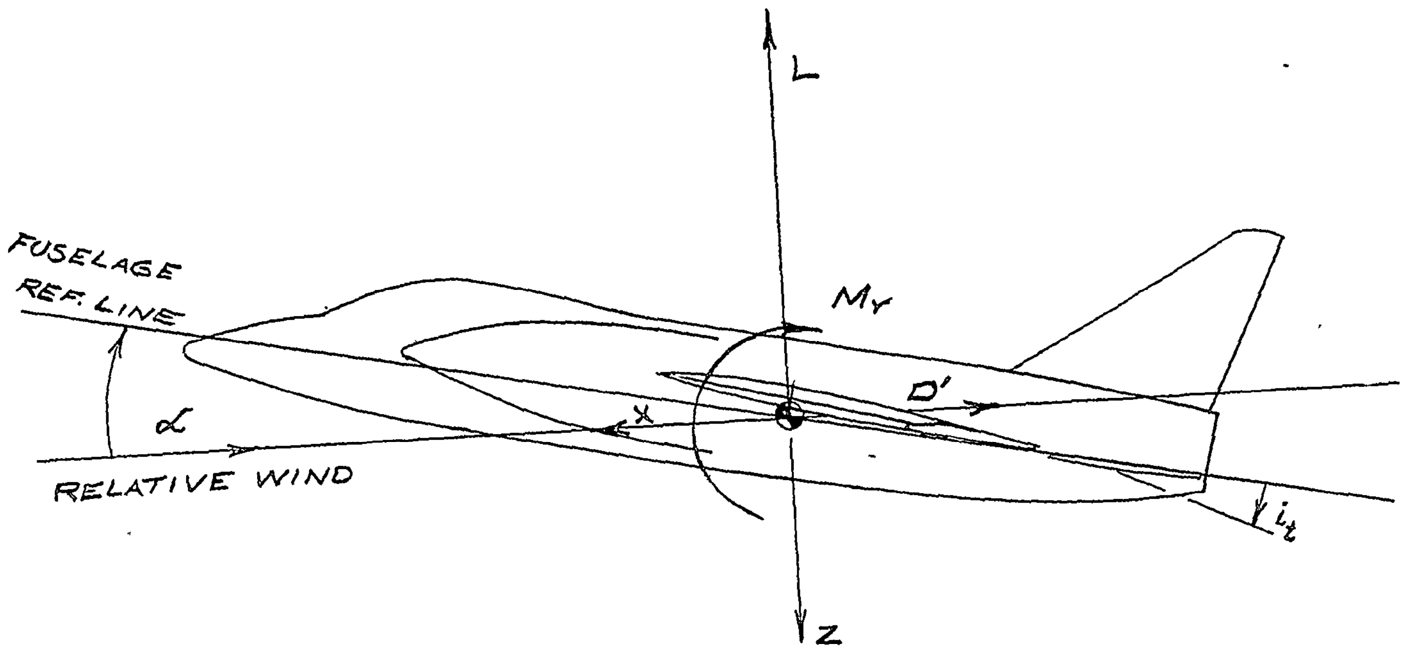

Figure 1.- The stability-axes system. Arrows indicate positive directions.

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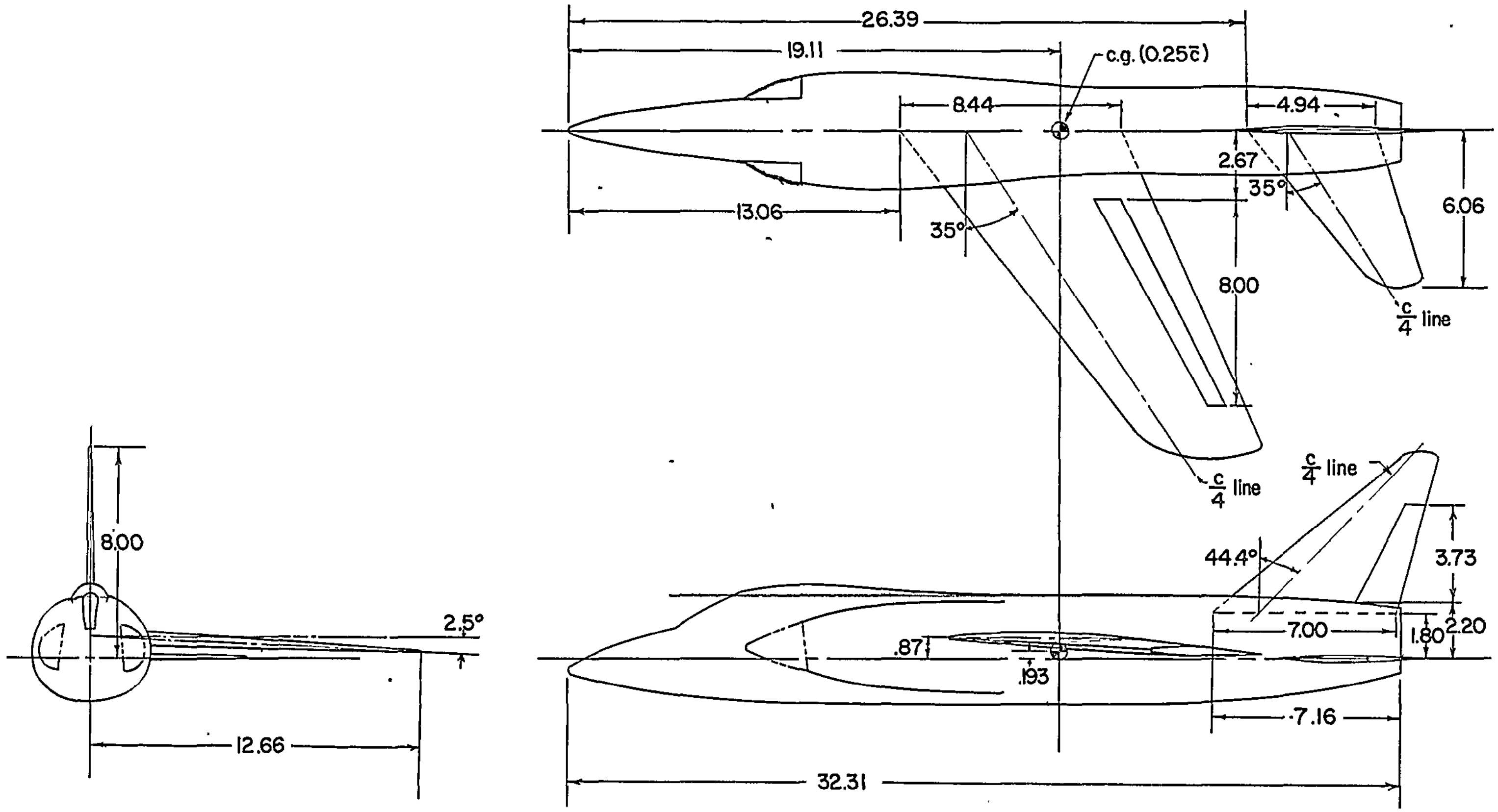

Figure 2.- Three-view drawing of model.

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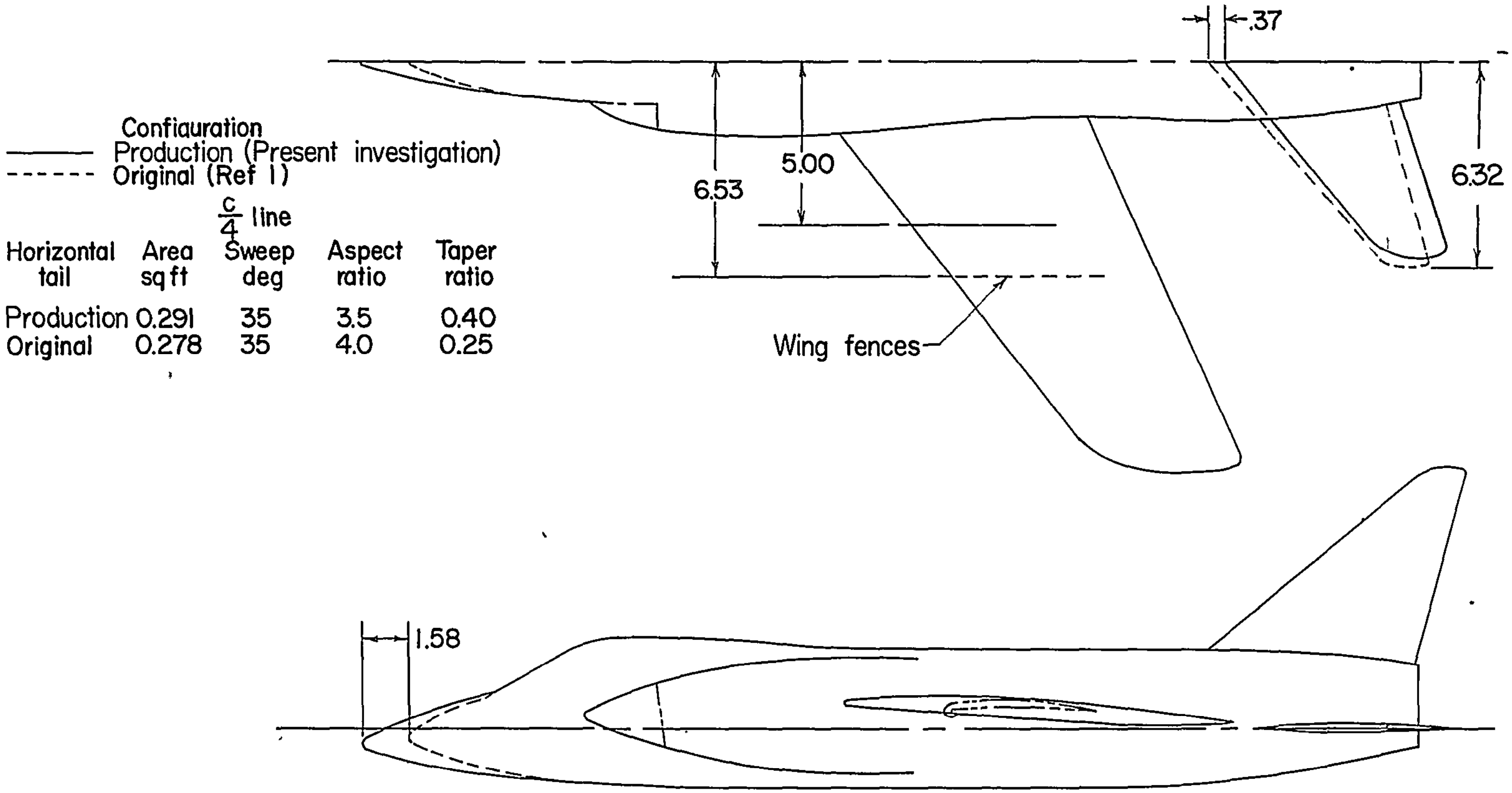

a) Original and production models

Figure 3.- Details of modifications to the basic configuration. All dimensions are in inches except as noted.

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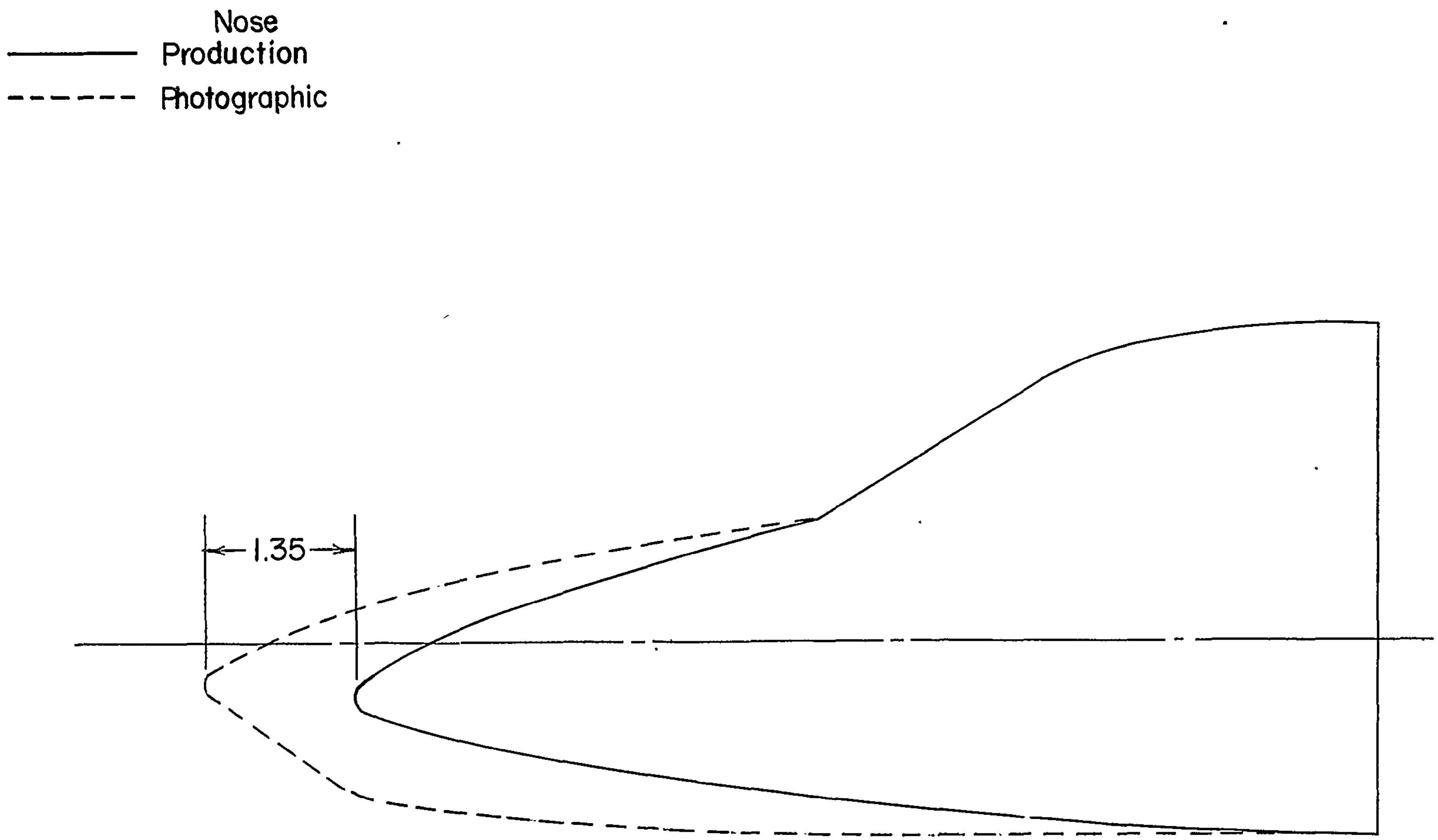

b) Production and photographic nose

Figure 3.- Continued.

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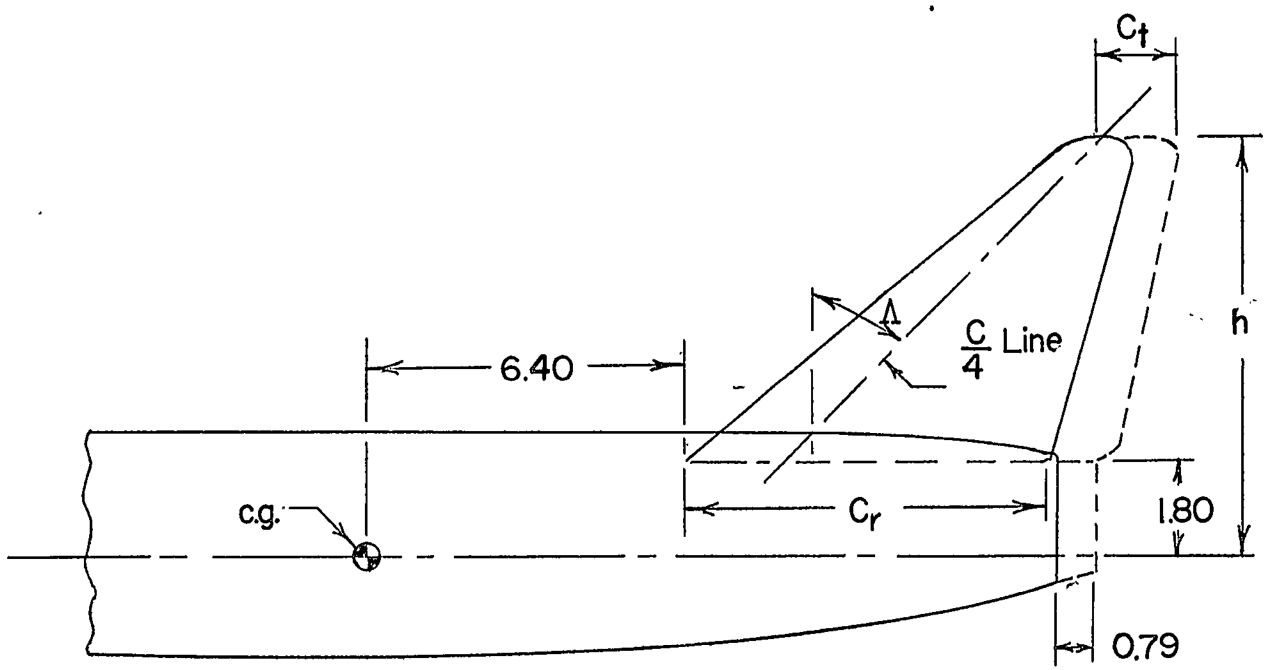
		h in.	C_r in.	C_t in.	Λ deg	Area sq ft	Aspect ratio	Taper ratio
———	V^1	8.00	7.00	1.24	44.5	.1778	1.51	0.177
– – –	V^3	8.00	8.23	2.07	44.0	.222	1.20	0.250



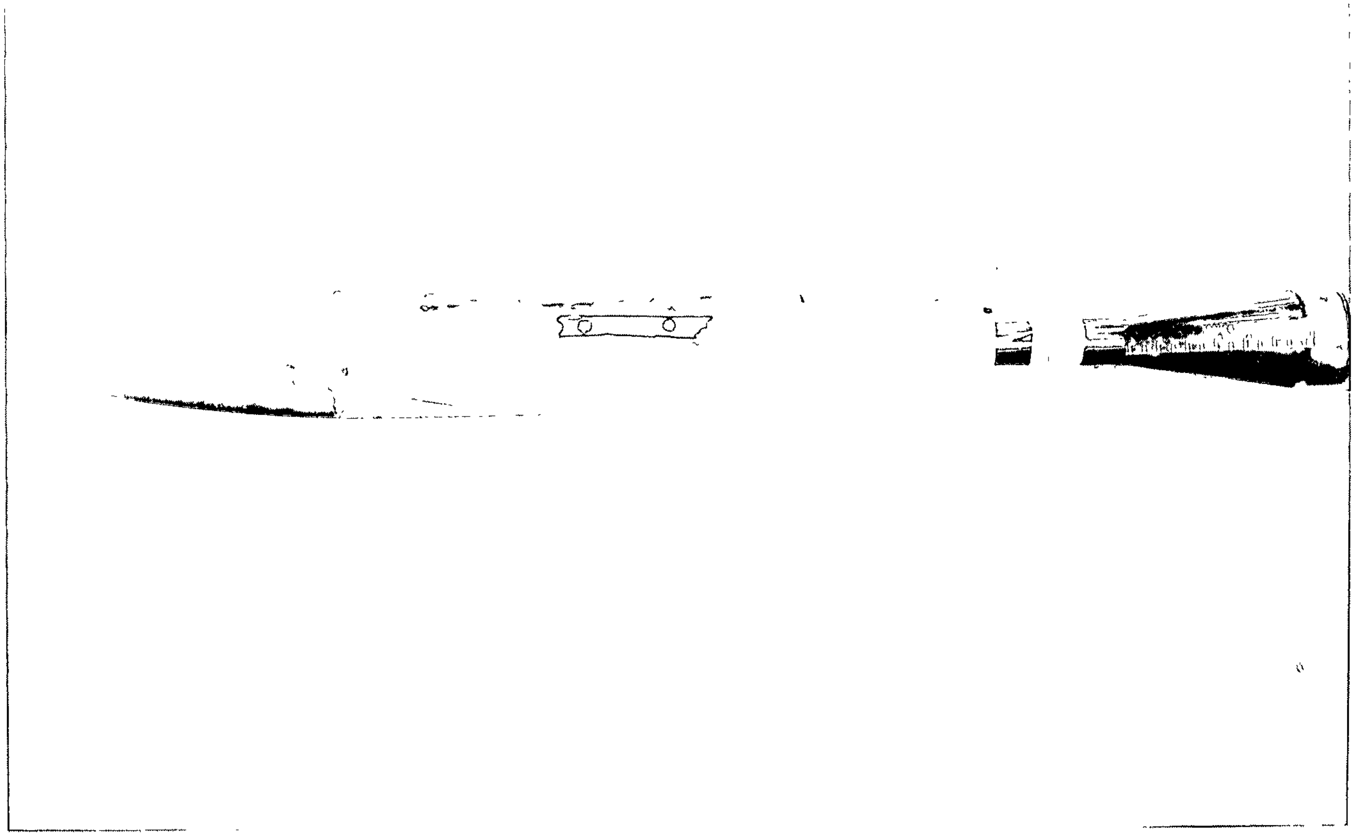
(c) Tail modifications.

Figure 3.- Concluded.

(a) Three-quarter front view. L-88318

Figure 4.- Photograph of model.

[redacted]



(b) Side view. L-88321

Figure 4.- Continued.

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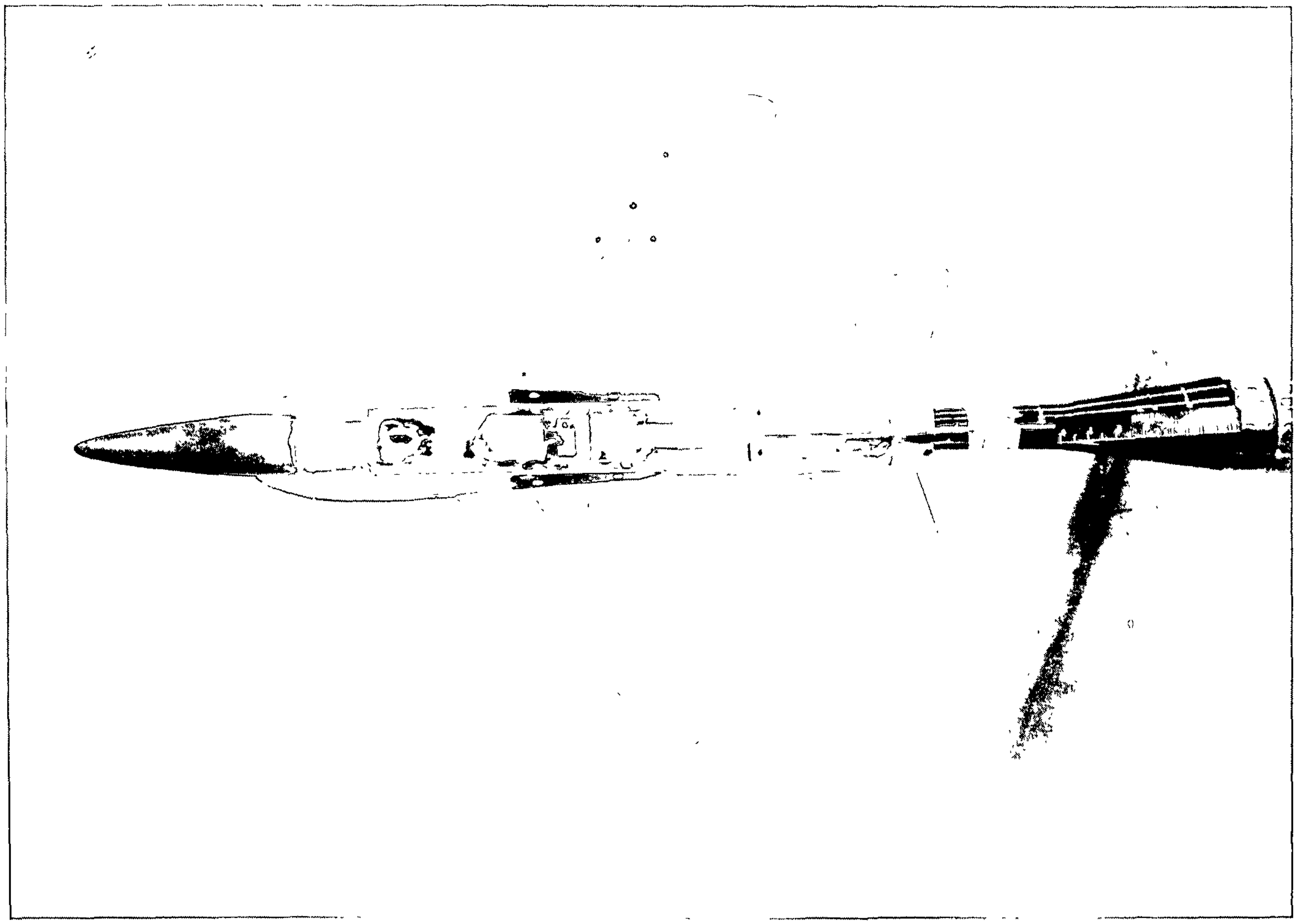
[redacted]



(c) Top view. L-88322

Figure 4.- Continued.

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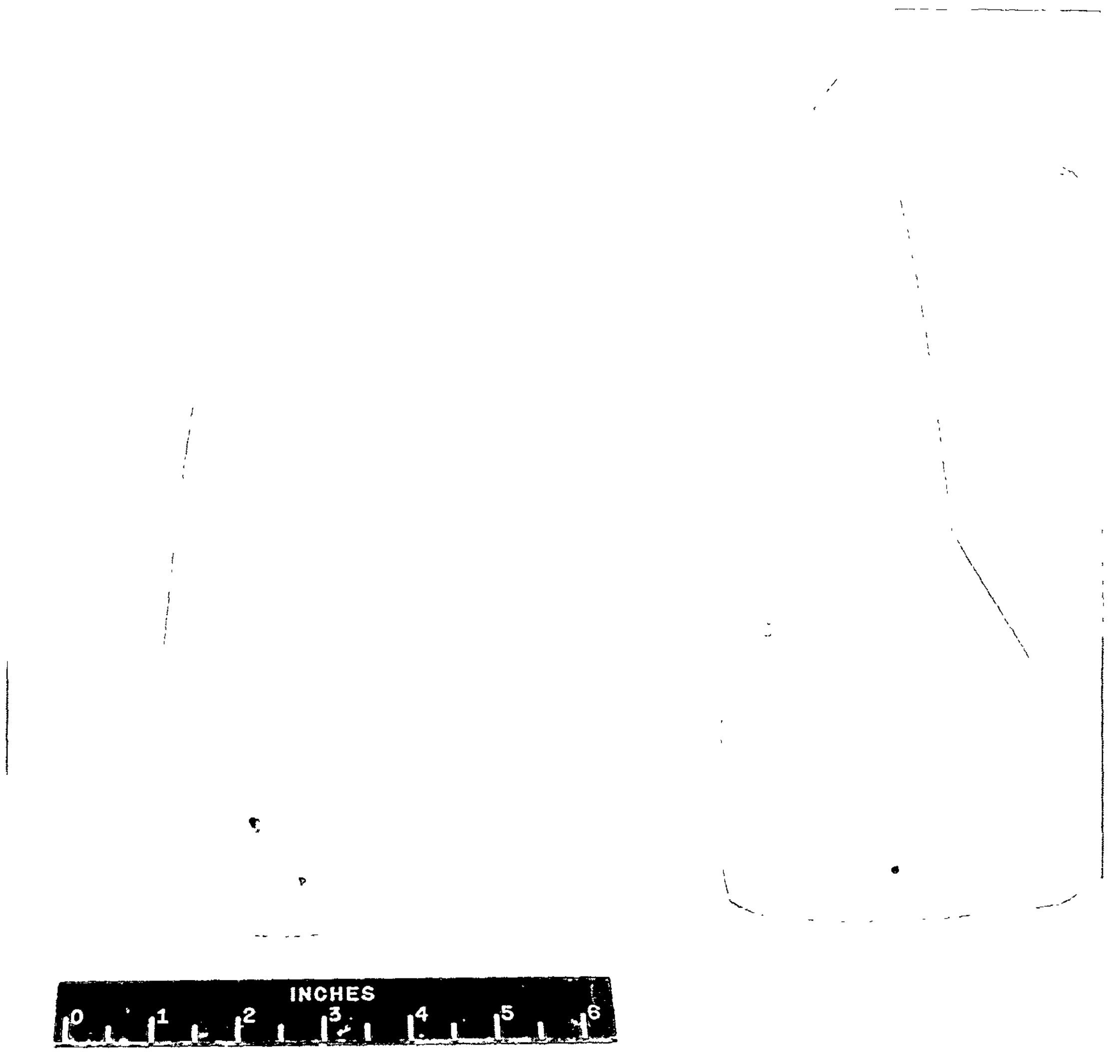
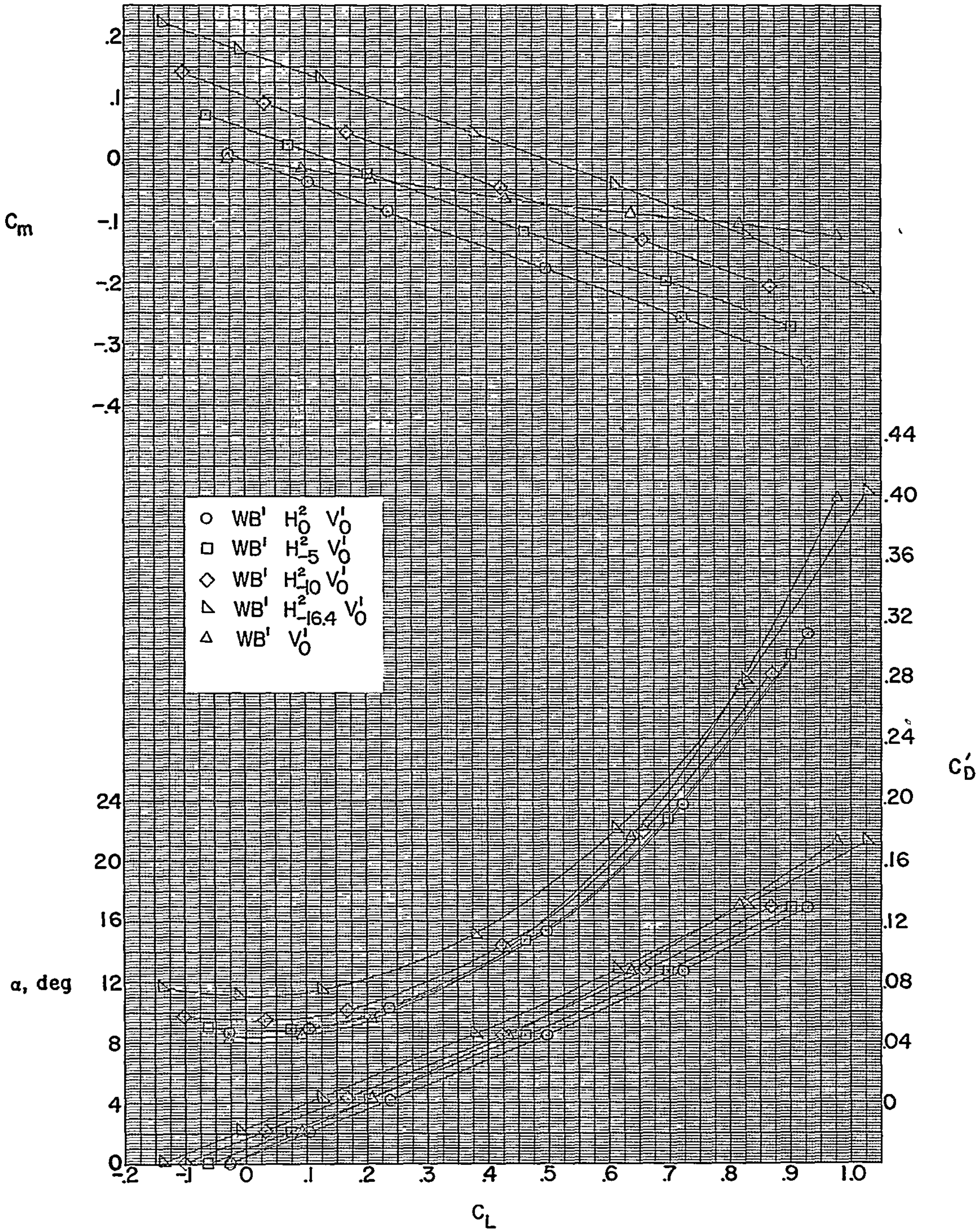


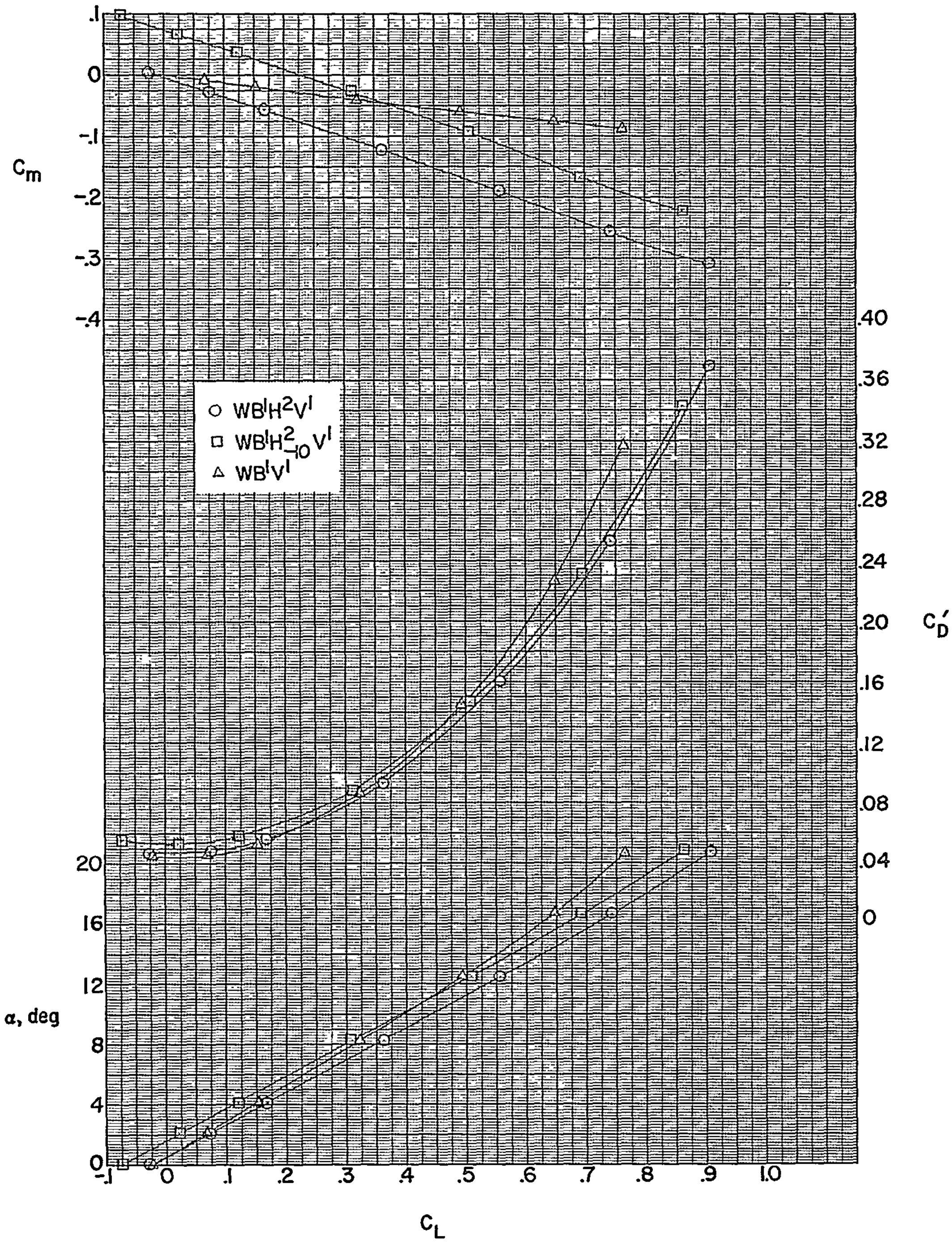
(d) Details of noses tested. L-88319.1

Figure 4.- Concluded.



(a) M = 1.61.

Figure 5.- Longitudinal-control characteristics.



(b) M = 2.01.

Figure 5.- Concluded.

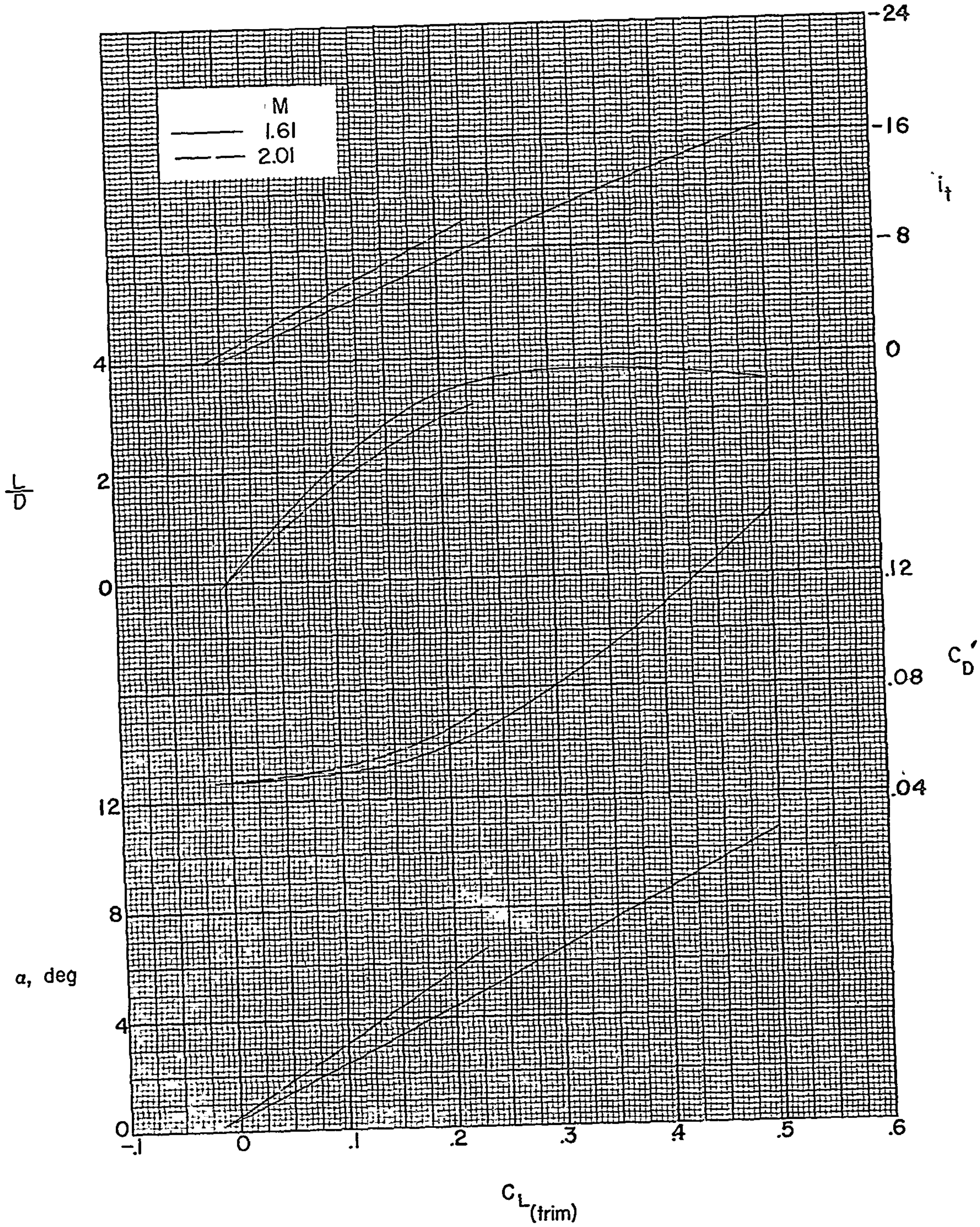


Figure 6.- Variation of the longitudinal-trim characteristics. $C_m = 0$.

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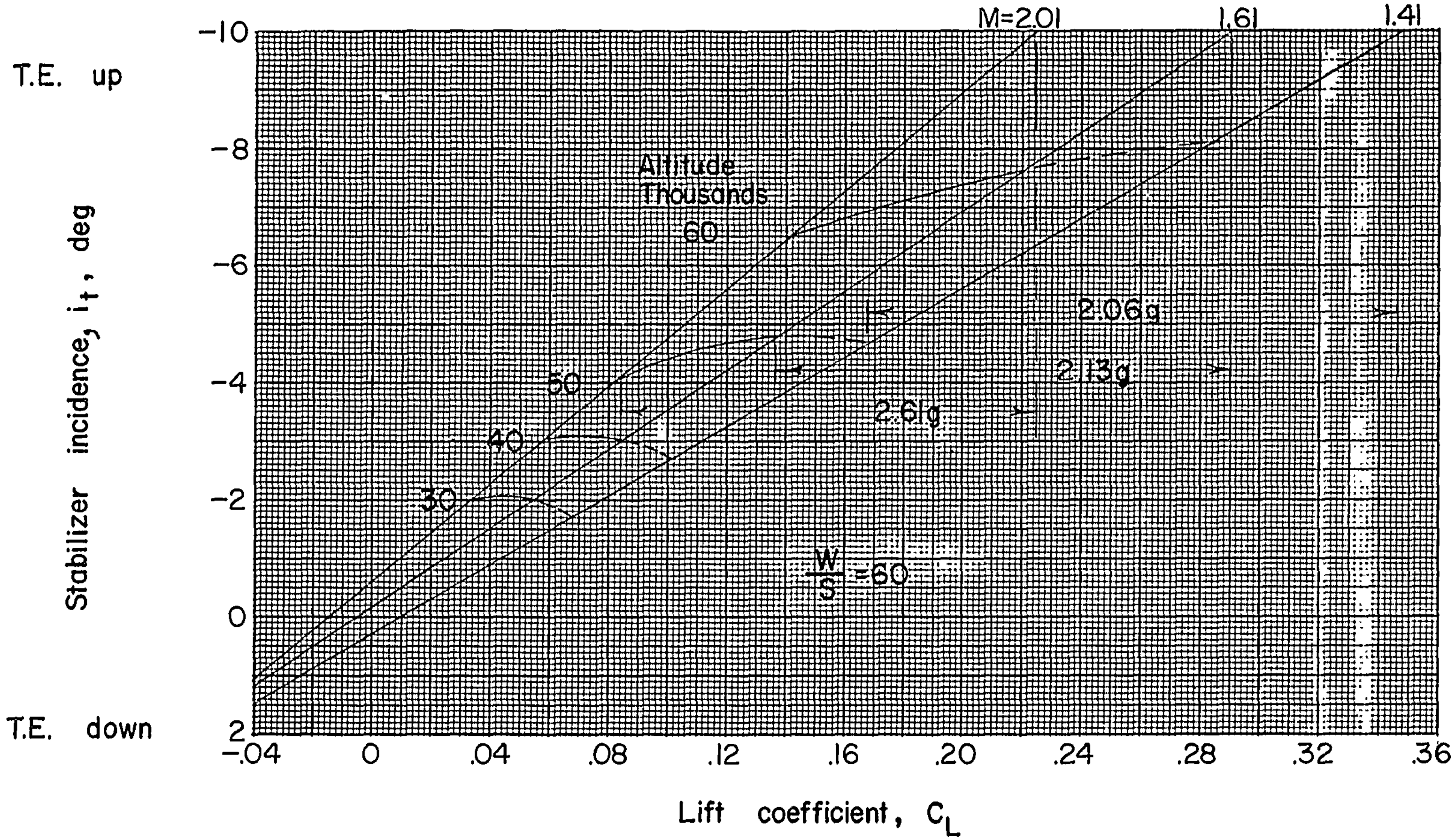

Figure 7.- Longitudinal-control characteristics. M = 1.41, 1.61, and 2.01. Dashed line indicates original horizontal tail.

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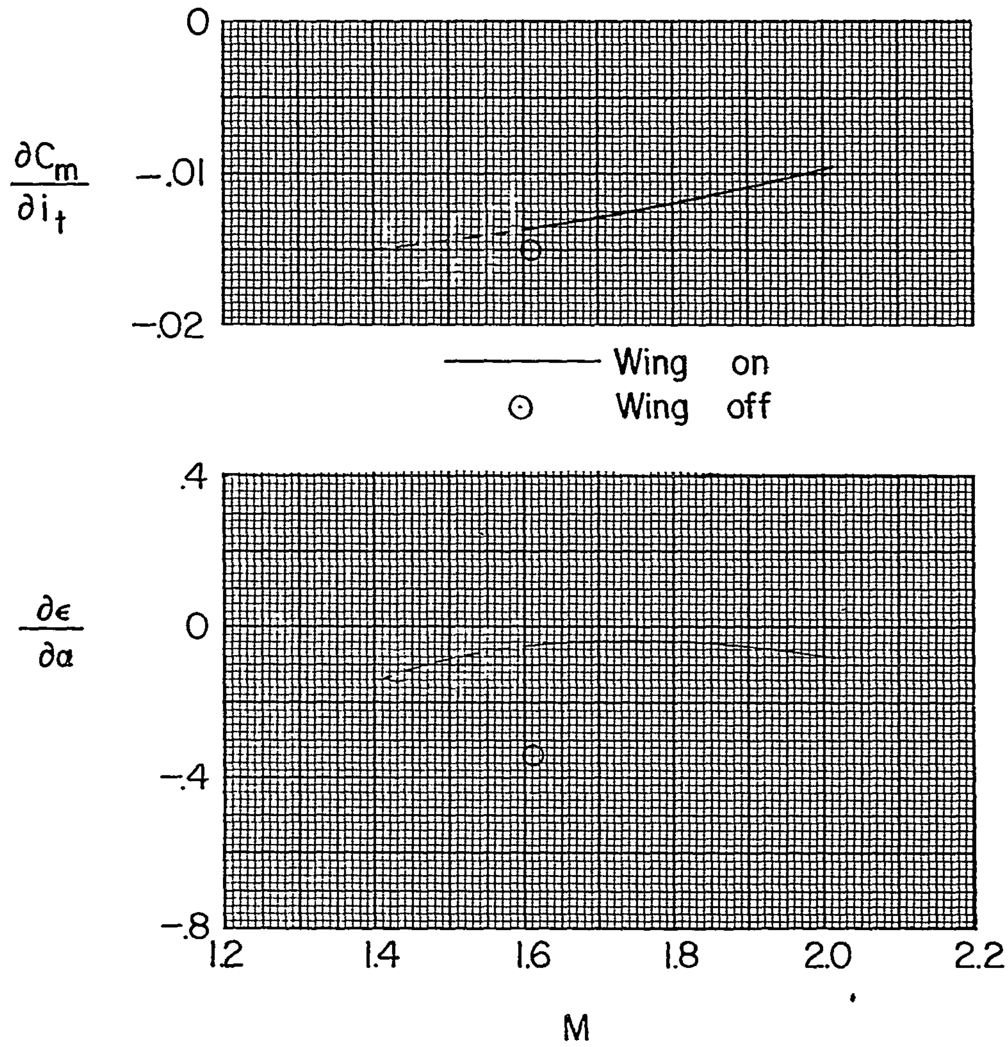
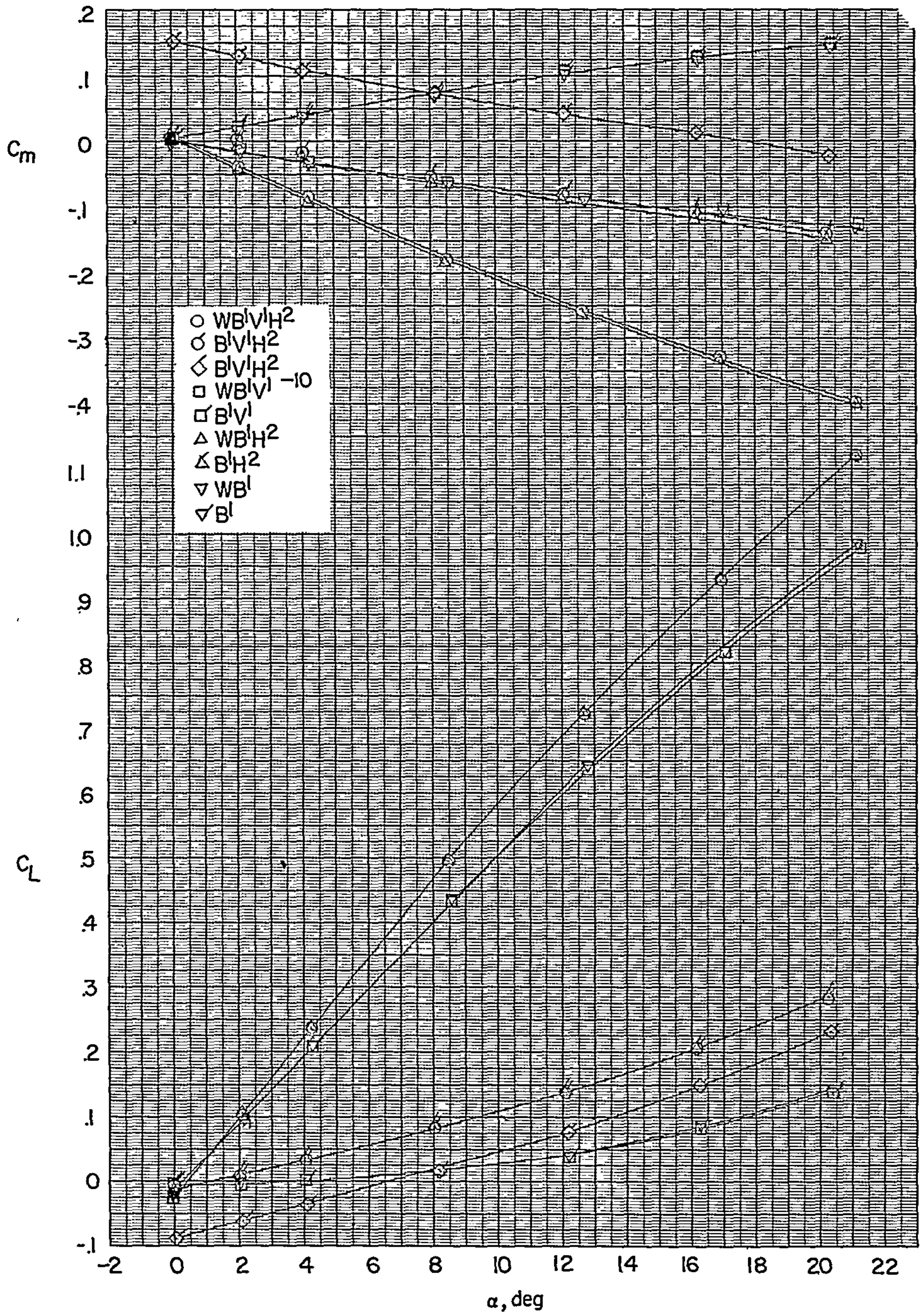
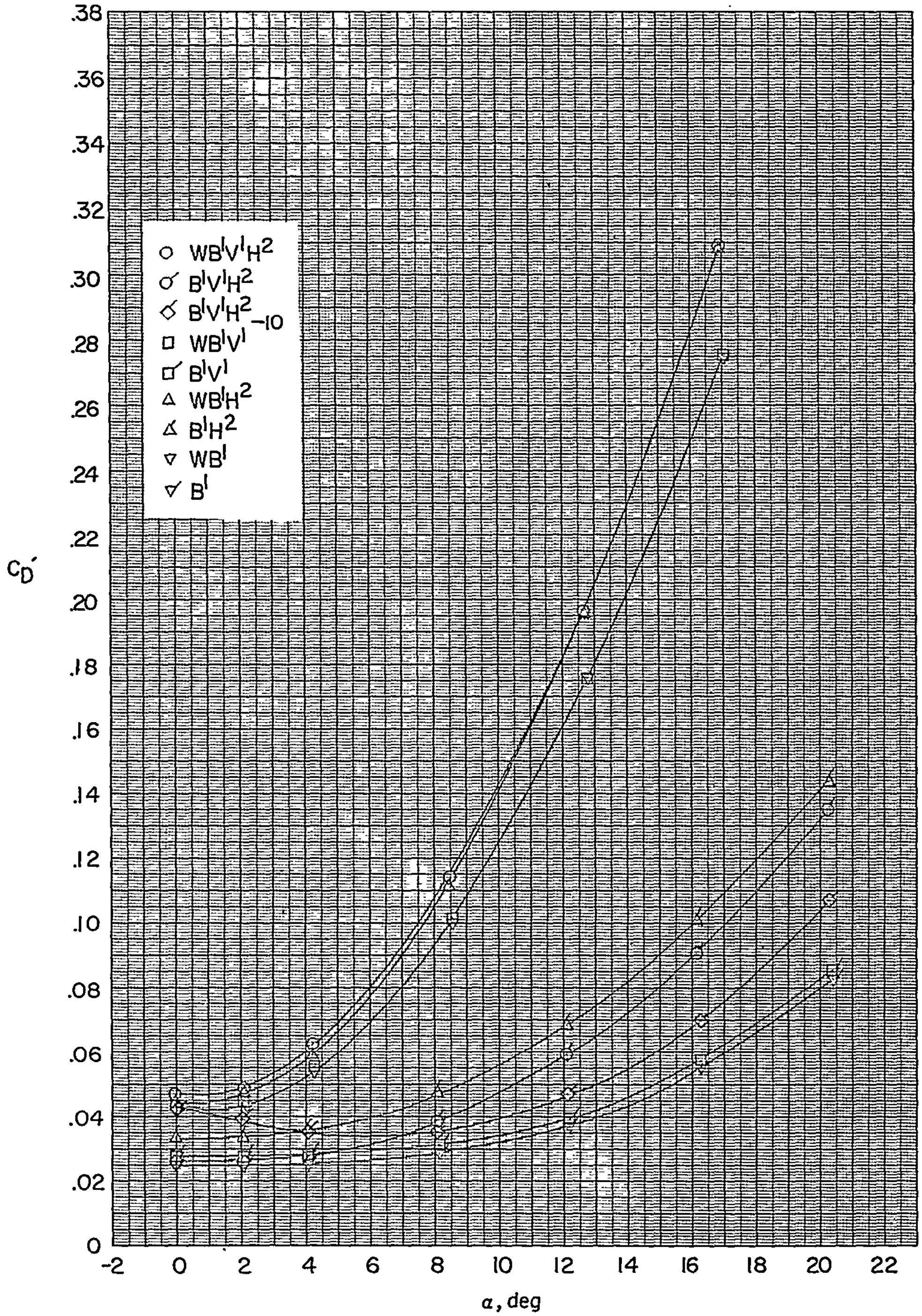


Figure 8.- Horizontal-tail effectiveness. Dashed line indicates original horizontal tail.



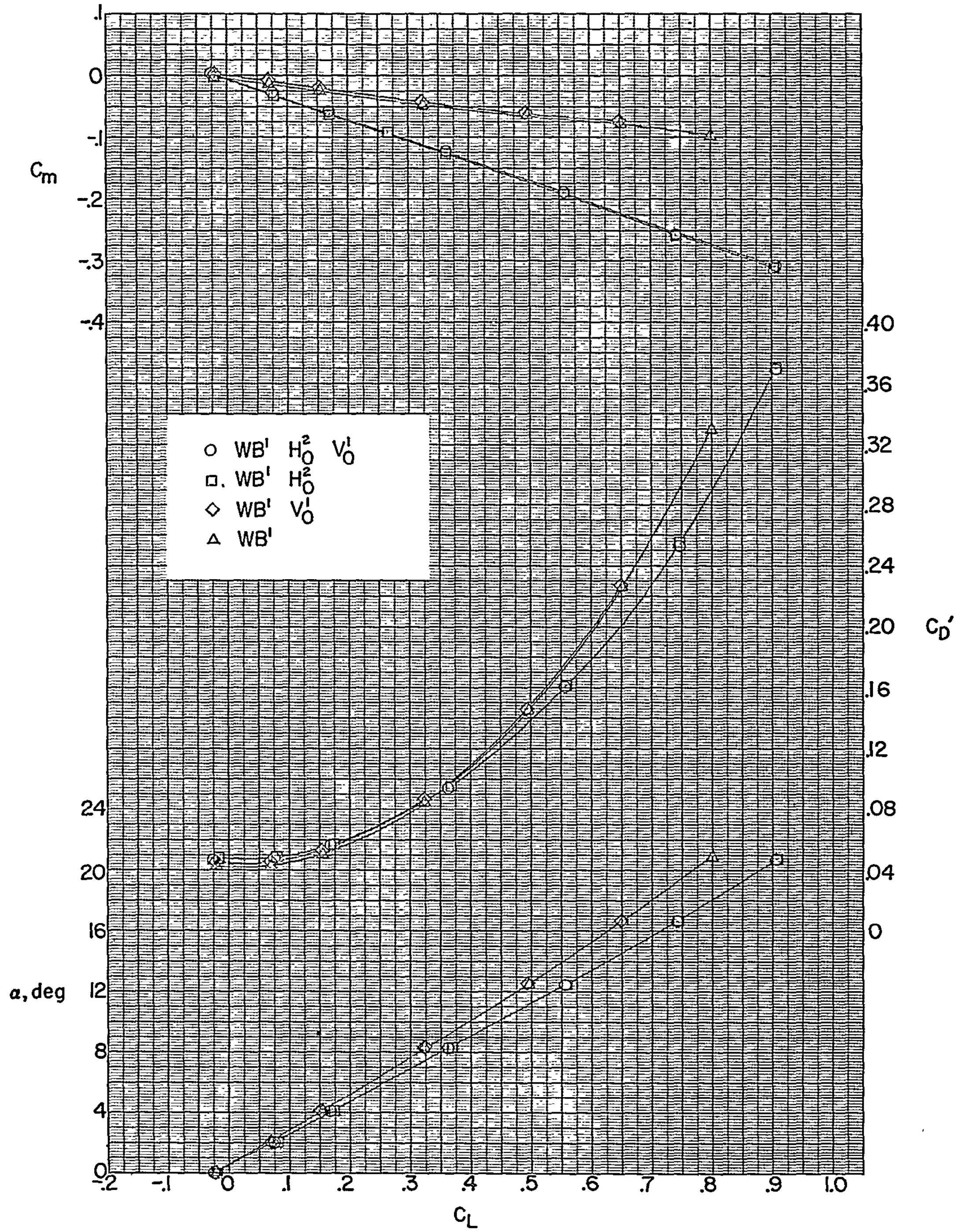
(a) M = 1.61.

Figure 9.- Effect of various component parts on the aerodynamic characteristics in pitch.



(a) Concluded.

Figure 9.- Continued.



(b) M = 2.01.

Figure 9.- Concluded.

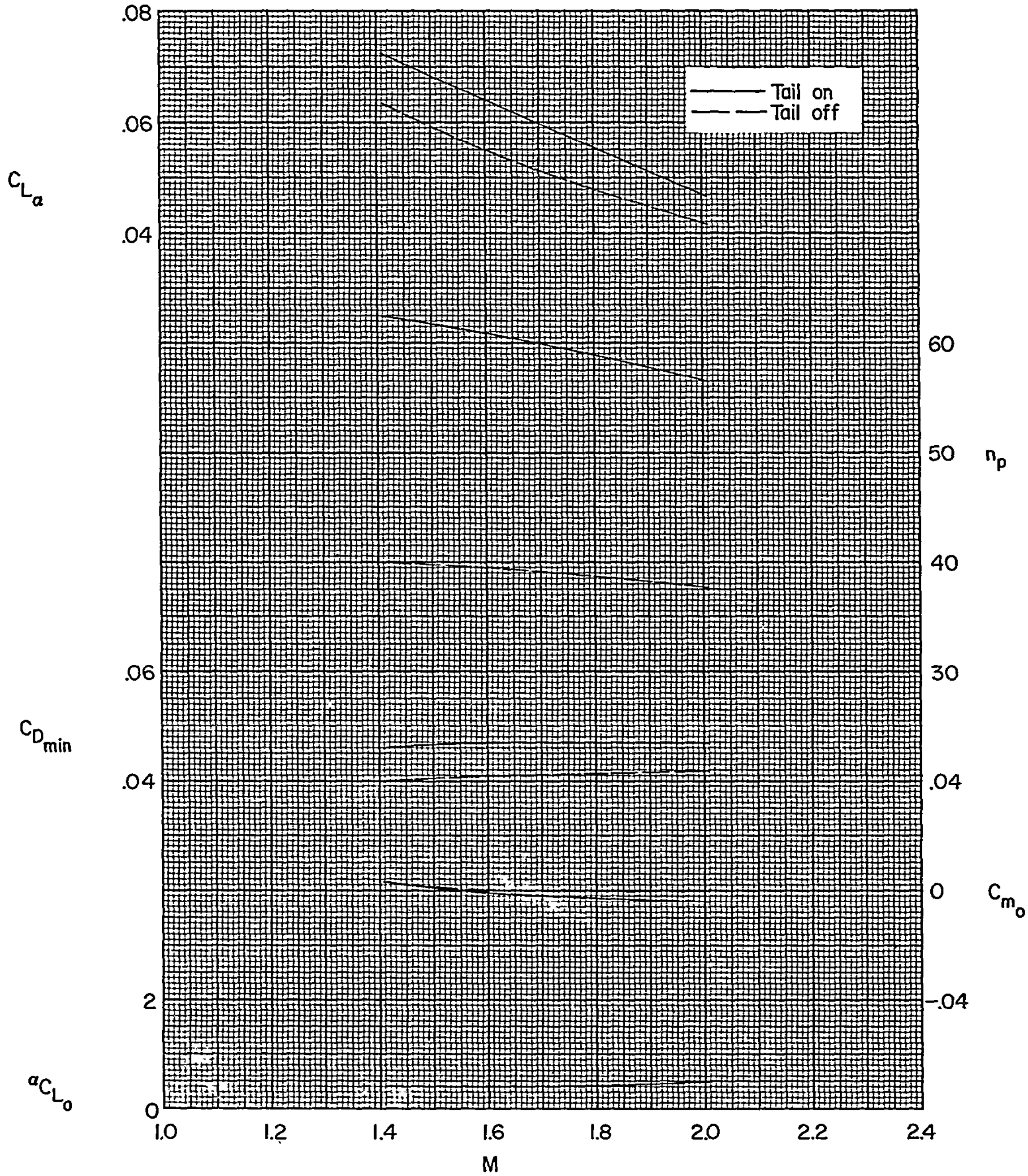
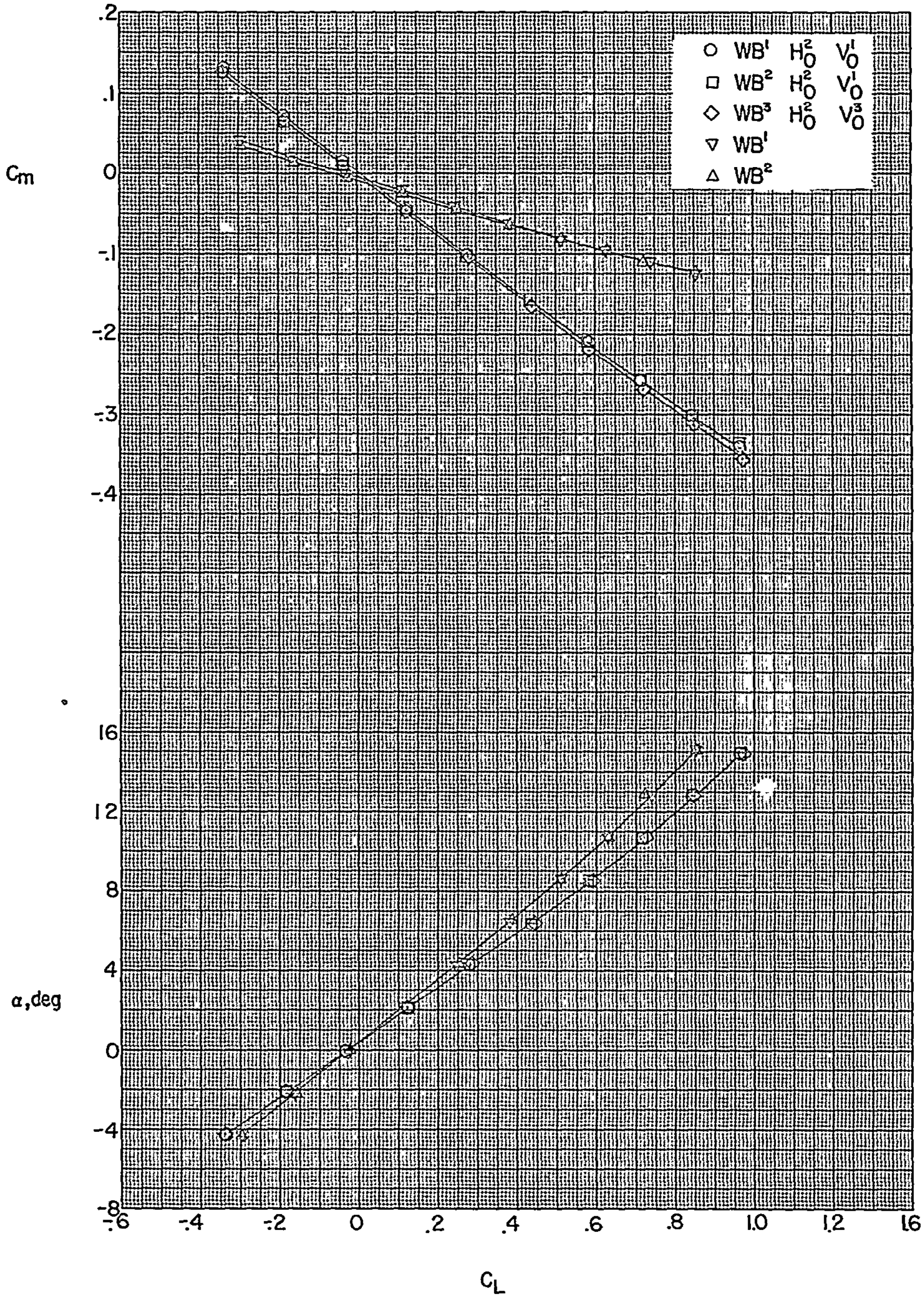


Figure 10.- Longitudinal characteristics.



(a) M = 1.41.

Figure 11.- Effect of body modifications on the aerodynamic characteristics in pitch. $i_t = 0^{\circ}$.

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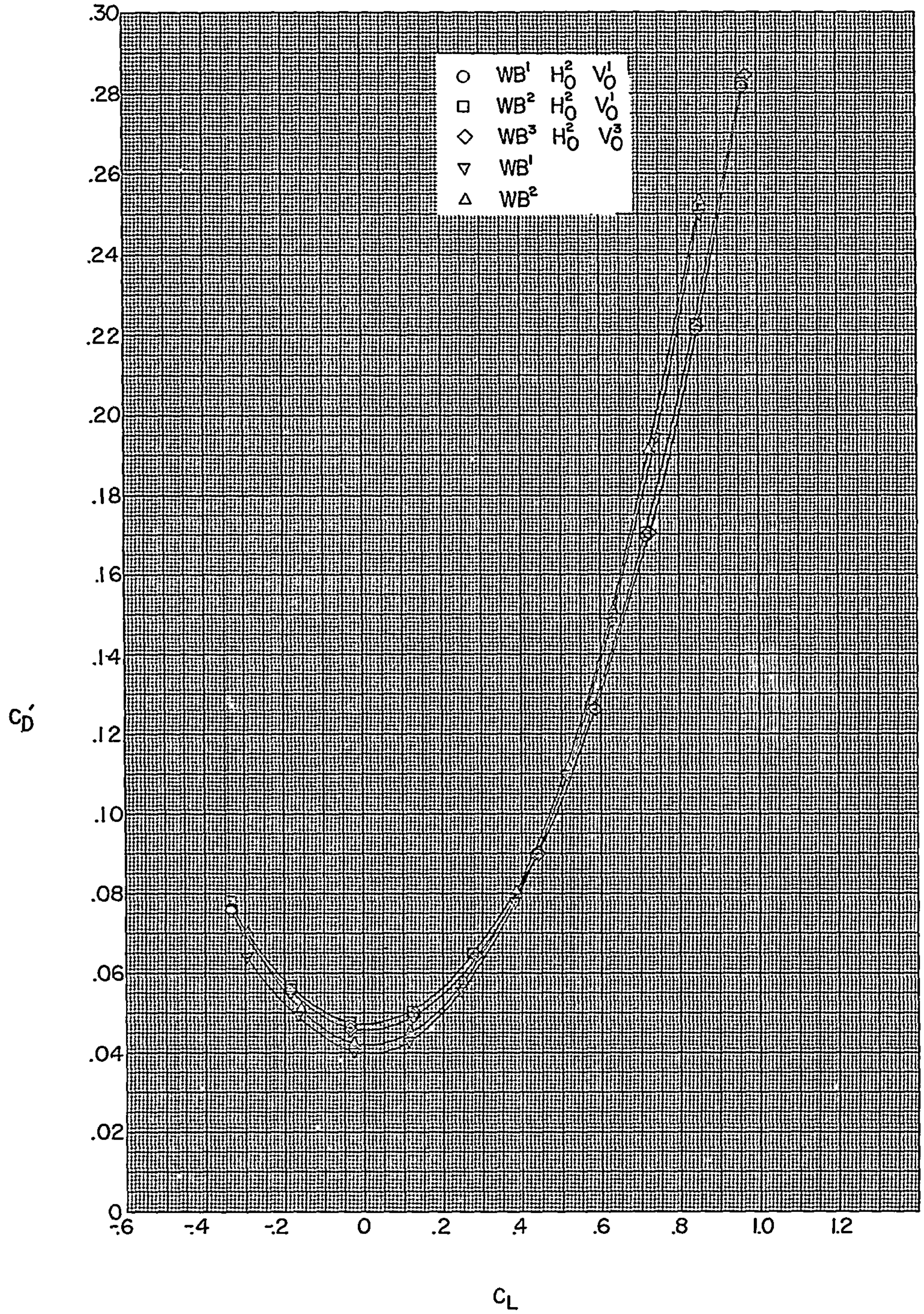

(a) M = 1.41. Continued.

Figure 11.- Continued.

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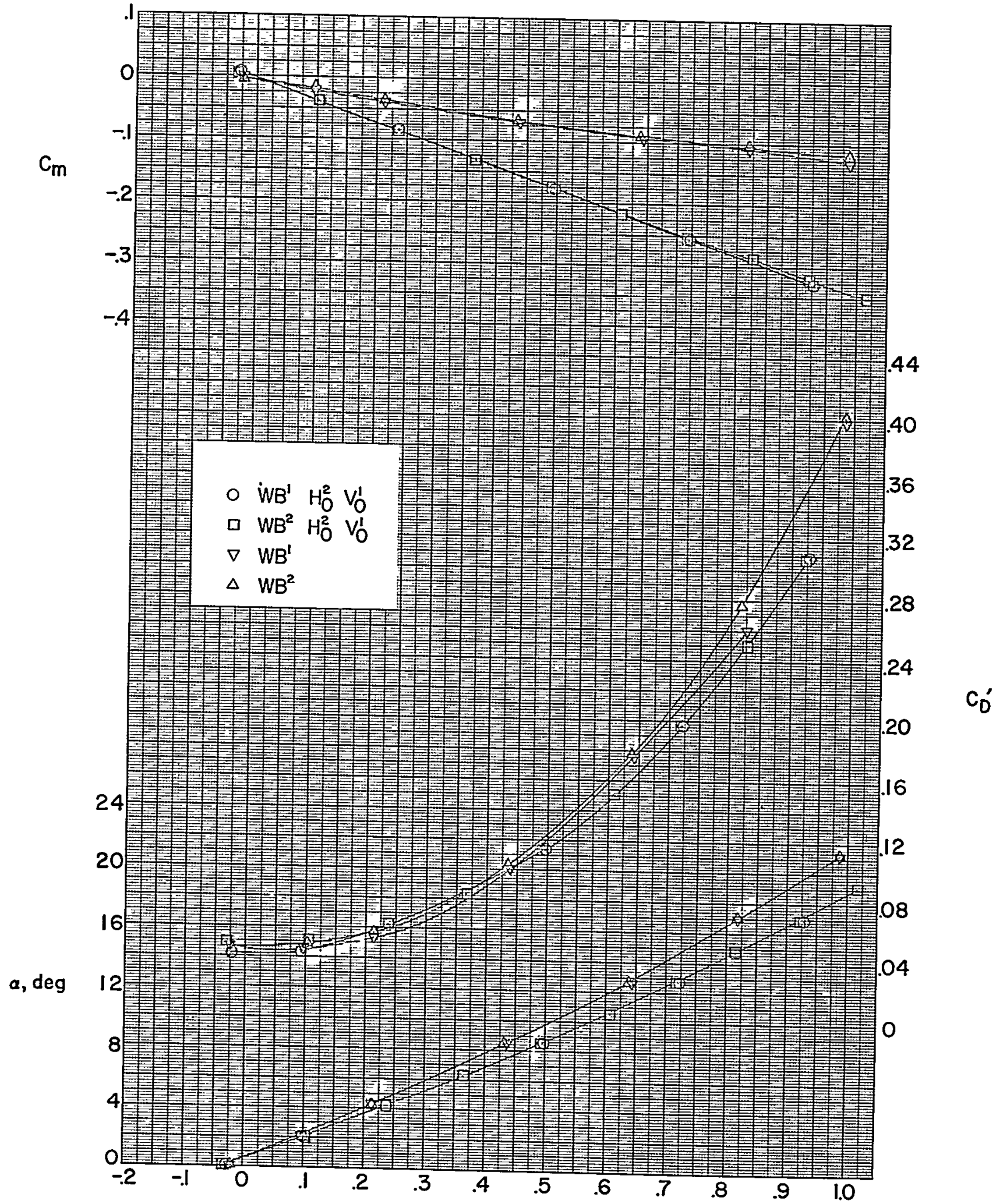

(b) M = 1.61.

Figure 11.- Concluded.

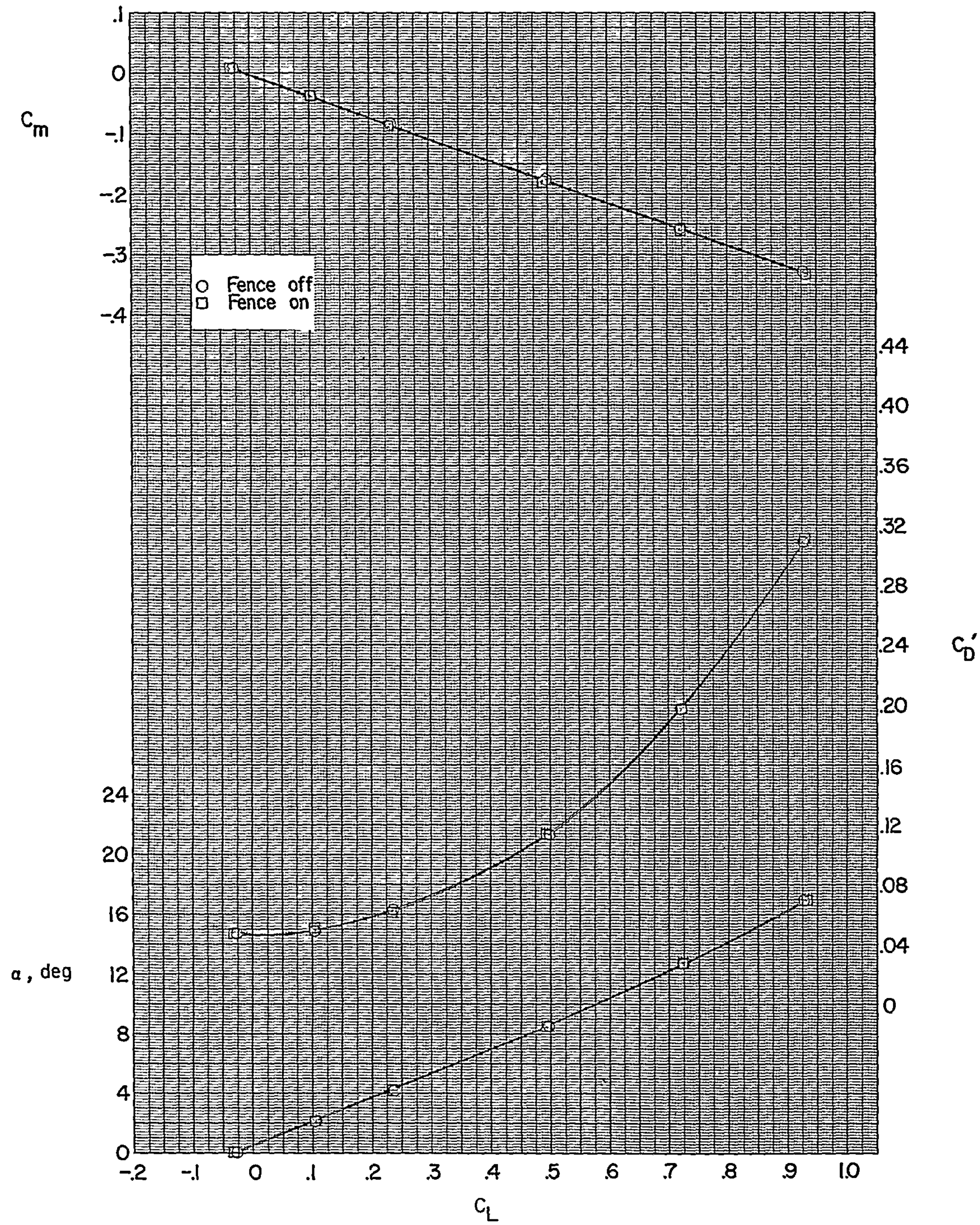

Figure 12.- Effect of wing fences on the aerodynamic characteristics in pitch. $M = 1.61$; $i_t = 0^\circ$.

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ABSTRACT

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel to determine the static longitudinal stability characteristics of a 1/15-scale model of the Grumman F11F-1 airplane at Mach numbers of 1.41, 1.61, and 2.01. The effects of a photographic-type nose modification, wing fences, and a revised vertical tail were also investigated.