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RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION OF THE EFFECTS OF HORIZONTAL-TAIL POSITION ON THE LOW-SPEED LONGITUDINAL STABILITY CHARACTERISTICS OF AN AIRPLANE MODEL WITH A 35° SWEPTBACK WING EQUIPPED WITH CHORDWISE FENCES

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WIND-TUNNEL INVESTIGATION OF THE EFFECTS OF HORIZONTAL-TAIL POSITION ON THE LOW-SPEED LONGITUDINAL STABILITY CHARACTERISTICS OF AN AIRPLANE MODEL WITH A 35° SWEPTBACK WING EQUIPPED WITH CHORDWISE FENCES

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SUMMARY

An investigation has been made in the Langley stability tunnel to determine the effects of horizontal-tail position on the low-speed longitudinal stability characteristics of an airplane model with a 35° sweptback wing equipped with chordwise fences. The model with the horizontal tail located in the high position was longitudinally unstable at moderate angles of attack (10° to 14°) for several of the configurations investigated. Lowering the position of the horizontal tail to the fuselage center line improved the longitudinal stability characteristics of all the configurations investigated. The model with the horizontal tail on the fuselage center line was longitudinally stable for angles of attack from 0° to about 20° for all configurations investigated.

INTRODUCTION

A preliminary investigation made with an airplane model incorporating a 35° sweptback wing and a horizontal tail located well above the extended wing plane showed that the model was longitudinally unstable at moderate angles of attack for all the model configurations tested. An investigation has been made (reference 1) to determine whether the longitudinal stability characteristics of the model could be improved by use of chordwise fences attached to the upper surface of the wing. The results of the investigation showed that one set of fences located at a spanwise station of 36 percent of the wing semispan was required to improve the stability of the model with slats extended but that a different set of fences located at 73 percent of the wing semispan was required for configurations with slats retracted. In order to improve the longitudinal stability for all model configurations, it was found necessary to have both sets of fences on the model.

The position of the horizontal tail has been shown to have a large effect on some models with sweptback wings (see references 2, 3, and 4, for example); therefore, the present investigation was undertaken to determine what improvement in the longitudinal stability characteristics of the model equipped with chordwise fences could be obtained by lowering the position of the horizontal tail.

SYMBOLS

All forces and moments are given with respect to the stability axes with the origin at the projection on the plane of symmetry of the quarter chord of the wing mean aerodynamic chord. The positive directions of the forces and moments are shown in figure 1. The symbols and coefficients used herein are defined as follows:

b	wing span, feet
c	wing chord parallel to plane of symmetry, feet
$\bar{c}$	wing mean aerodynamic chord, feet $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$
q	dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$
S	wing area, square feet
V	free-stream velocity, feet per second
y	spanwise distance from plane of symmetry, feet
α	angle of attack of fuselage center line, degrees
ρ	mass density of air, slugs per cubic foot
D	drag, pounds
L	lift, pounds
M	pitching moment, foot-pounds

C_L lift coefficient $\left(\frac{L}{qS}\right)$

C_D drag coefficient $\left(\frac{D}{qS}\right)$

C_m pitching-moment coefficient $\left(\frac{M}{qS\bar{c}}\right)$

Subscripts and notations:

H high

M mid

L low

F fuselage

W wing

V vertical tail

H horizontal tail

APPARATUS, MODEL, AND TESTS

The tests of the present investigation were conducted in the 6- by 6-foot test section of the Langley stability tunnel. The model used in the tests (model 2 of reference 1) was constructed of laminated mahogany and incorporated removable slats, flaps, and landing gear. The dimensions of the model are given in figure 2 and in table I and the details of the slats and flaps are shown in figure 3.

Two sets of fences were used during the investigation. The fences (of the same plan form as those used in the tests of reference 1) were made from $\frac{1}{16}$-inch brass sheets and their shapes and dimensions are given in figure 4. The fences are designated as fence A alone and the combination of fences as A and N_2M_1, the designations being taken from reference 1. Fence N_2M_1 was made of two segments, N_2 and M_1. Segment N_2 was attached to the slat while segment M_1 was attached to the wing. The locations of the fences on the wing panels are shown in figure 5. The fences were mounted normal to the wing surface.

The model in its various configurations was tested with the horizontal tail in three positions (fig. 6). These positions are designated as the high or original position (6.60 in. above fuselage center line), the mid position (3.30 in. above the fuselage center line), and the low position (on fuselage center line). The horizontal tail was moved forward as it was lowered. The locations of the calculated aerodynamic center of the horizontal tail $\bar{c}_{tail}/4$ relative to the fuselage center line and to the calculated aerodynamic center of the wing $\bar{c}_{wing}/4$ are given in figure 6 for the three horizontal-tail positions.

The four complete-model configurations for which the effects of horizontal-tail position were investigated were:

(a) Slats, flaps, and landing gear retracted

(b) Slats retracted, flaps and landing gear extended

(c) Slats extended, flaps and landing gear retracted

(d) Slats, flaps, and landing gear extended

Some of the components of the models were also tested alone and in combination with each other. A photograph of the model is given as figure 7.

All tests of this investigation were made at a dynamic pressure of 39.7 pounds per square foot, which corresponds to a Mach number of 0.17 and a Reynolds number of 1.1×10^6 based on the wing mean aerodynamic chord of 0.94 foot.

CORRECTIONS

Approximate corrections for jet-boundary effects were applied to the angle of attack and drag coefficient by the methods of reference 5. Jet-boundary effects on the pitching moment contributed by the horizontal tail were accounted for by the methods of reference 6. Approximate blockage corrections were determined by use of reference 7 and were applied to all force and moment coefficients. No strut tare corrections have been applied to the data, as these corrections were found to be negligible.

RESULTS AND DISCUSSION

Presentation of Results

The results of the present investigation are given as a series of figures showing the variation of lift, drag, and pitching-moment coefficients with angle of attack of the fuselage for the various model configurations tested. The data are presented in the following groups:

	Figure
Configurations with wing off	8
Configurations with slats, flaps, and landing gear retracted	9
Configurations with slats retracted, flaps and landing gear extended	10
Configurations with slats extended, flaps and landing gear retracted	11
Configurations with slats, flaps, and landing gear extended	12

Preliminary Remarks

The position of the horizontal tail had no appreciable effects on the lift characteristics of the configurations investigated, and the effects of fences on the lift characteristics of the complete model were discussed in reference 1. Therefore the lift characteristics of complete-model configurations are presented herein primarily to relate the pitching-moment characteristics to the lift and are not discussed further. The drag data are given for the sake of completeness but are not discussed since they show no significant effects of horizontal-tail position. The drag data are presented for the various configurations with fence A but are not given for configurations with fences A and N_2M_1, since the addition of fences N_2M_1 caused no appreciable change in the drag of the models.

Configurations With Wing Off

The lift curves of the fuselage-horizontal-tail combinations were very nearly linear throughout the angle-of-attack range of the investigation (fig. 8). The fuselage alone produced no appreciable lift up to an angle of attack of about 12°; however, above 12° the lift-curve slope of the fuselage was at least 70 percent of that of any fuselage-horizontal-tail combination tested. This fact indicated that, above 12°, the increase in C_L with α for the fuselage-horizontal-tail combinations was due partly to the fuselage and, therefore, that the horizontal-tail lift effectiveness was less above 12° than it had been below 12° angle of attack. The pitching-moment data of figure 8 illustrate this. These data show a decrease in the stability of the fuselage-horizontal-tail configurations at angles of attack above about 12°. No tests were made with only the horizontal tail; however, the wing is of about the same plan form as the horizontal tail, and the wing lift characteristics indicated that the wing began to stall at a wing angle of attack of about 13° (fuselage angle of attack of 11°). It appeared, therefore, that at least part of the loss of effectiveness of the horizontal tail above $\alpha = 13^\circ$ was caused by stalling.

Lowering the position of the horizontal tail had no appreciable effects on the pitching-moment characteristics at low or moderate angles of attack but had a significant effect at angles of attack above 24°.

Configurations with Slats, Flaps, and Landing Gear Retracted

When the slats, flaps, and landing gear were retracted (fig. 9), the complete model with the horizontal tail in the high position was longitudinally unstable at angles of attack from about 10° to 14° with both fence combinations (A alone and A with N_2M_1). The instability was greater for the model with fence A than it was for the model with fences A and N_2M_1. Since the wing alone and the wing-fuselage combinations showed no rapid change in longitudinal stability at angles of attack from 10° to 14°, it appeared that the instability of the complete models in this angle-of-attack range was caused by a loss in horizontal-tail effectiveness. Some of the loss in effectiveness could be due to a greater rate of increase in downwash angle with angle of attack, a greater loss of dynamic pressure at the horizontal tail, or a combination of both factors (references 2 and 3).

Lowering the horizontal tail improved the longitudinal stability in the angle-of-attack range from 10° to 14°. With the horizontal tail in the low position the model with fences A and N_2M_1 was longitudinally stable throughout the angle-of-attack range. The model with fence A was neutrally stable near 12° angle of attack, but was stable at all other angles. The longitudinal stability of the models was about the same for both fence configurations at all angles of attack except in the range from 10° to 14° where the model with fences A and N_2M_1 showed more stability than it did with only fence A.

Configurations with Slats Retracted, Flaps and Landing Gear Extended

When the slats were retracted and the flaps and landing gear were extended (fig. 10), the complete model with the horizontal tail in the high position was longitudinally unstable at angles of attack from 10° to 14° with fence A but was neutrally stable in the same angle-of-attack range with fences A and N_2M_1. The poor stability characteristics in the angle-of-attack range from 10° to 14° appear to be caused by loss in tail effectiveness, since the wing-fuselage combination showed no rapid stability loss in this angle-of-attack range. Lowering the position of the horizontal tail caused a large improvement in the longitudinal stability of the model in the angle-of-attack range from 10° to 14°. The model was longitudinally stable at all angles of attack and for both fence configurations when the horizontal tail was located on the fuselage center line.

Configurations with Slats Extended, Flaps and Landing Gear Retracted

The longitudinal stability characteristics of the model with slats extended and flaps and landing gear retracted (fig. 11) were about the same with fence A on the wing as with the combination of fences A and N_2M_1. The model with the horizontal tail in the high position was approximately neutrally stable at angles of attack from 11° to 14°, but this region of neutral stability was made stable by lowering the horizontal tail to the fuselage center line. The incremental changes in pitching-moment characteristics obtained by lowering the horizontal tail were greater for configurations with slats retracted than for configurations with slats extended (compare figs. 9 and 11, for example). At high angles of attack (above 20°) the pitching-moment curve of the models with fence A varied quite erratically with change in angle of attack and showed some regions of instability. These regions of instability were eliminated by the addition of fences N_2M_1.

Configurations with Slats, Flaps, and Landing Gear Extended

The complete model was neutrally or only slightly stable at angles of attack near 12° when the slats, flaps, and landing gear were extended (fig. 12). Lowering the horizontal tail caused some improvement in the longitudinal stability of the model. The characteristics of the model were about the same with fence A on the wing as with fences A and

N_2M_1, except that, at high angles of attack (above 20°), the addition of fences N_2M_1 eliminated some unstable breaks which occurred in the pitching-moment curves of the model with fence A.

CONCLUSIONS

An investigation was made in the Langley stability tunnel to determine the effects of horizontal-tail position on the low-speed longitudinal stability characteristics of an airplane model with a 35° sweptback wing equipped with chordwise fences. The results of the investigation have led to the following conclusions:

1. Lowering the horizontal tail from the high position to the fuselage center line improved the longitudinal stability of all complete-model configurations tested.

2. All complete-model configurations were longitudinally stable in the angle-of-attack range from 0° to about 20° when the horizontal tail was on the fuselage center line. At angles of attack above about 20° the pitching moments varied erratically with angle of attack for some model configurations.

3. The model with the horizontal tail in the high position and equipped with fences at a spanwise station of 36 percent of the wing semispan was longitudinally unstable at angles of attack from 10° to 14° for model configurations with slats retracted, and was approximately neutrally stable in the same range of angles for configurations with slats extended.

4. The model with the horizontal tail in the high position and equipped with fences at spanwise stations of 36 and 73 percent of the wing semispan was slightly unstable at angles of attack from 11° to 14° when the slats, flaps, and landing gear were extended and was neutrally stable in the same angle-of-attack-range with the slats extended, flaps and landing gear retracted, but was longitudinally stable up to about 20° for all other complete-model configurations investigated.

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4. Salmi, Reino J.: Horizontal-Tail Effectiveness and Downwash Surveys for Two 47.7° Sweptback Wing-Fuselage Combinations with Aspect Ratios of 5.1 and 6.0 at a Reynolds Number of 6.0×10^6. NACA RM L50K06, 1951.

5. Silverstein, Abe, and White, James A.: Wind-Tunnel Interference with Particular Reference to Off-Center Positions of the Wing and to the Downwash at the Tail. NACA Rep. 547, 1936.

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7. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, with Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Formerly NACA RM A7B28.)

TABLE I.- DIMENSIONS AND CHARACTERISTICS OF MODEL

Wing:	
Root airfoil section (normal to 0.33 chord line)	NACA 63-010
Tip airfoil section (normal to 0.33 chord line)	NACA 63-012
Total area, square inches	428
Span, inches	38.84
Mean aerodynamic chord, inches	11.30
Root chord (parallel to plane of symmetry), inches	14.10
Tip chord (parallel to plane of symmetry), inches	7.95
Taper ratio	0.565
Aspect ratio	3.57
Sweep at 0.33 chord, degrees	35.0
Incidence, degrees	3.0
Dihedral, degrees	-3.0
Total flap area, square inches	31.50
Horizontal Tail:	
Airfoil section (normal to 0.35 chord line)	NACA 63-010
Total area, square inches	97.50
Span, inches	18.66
Mean aerodynamic chord, inches	5.42
Root chord (parallel to plane of symmetry), inches	6.97
Tip chord (parallel to plane of symmetry), inches	3.48
Taper ratio	0.50
Aspect ratio	3.59
Sweep at 0.35 chord line, degrees	40.0
Incidence (from fuselage center line), degrees	0
Tail length (from $\bar{c}/4$ of wing to $\bar{c}/4$ of tail), inches -	
High tail	30.58
Mid tail	29.05
Low tail	27.50
Tail height (from fuselage center line), inches -	
High tail	6.60
Mid tail	3.30
Low tail	0.0

TABLE I.- DIMENSIONS AND CHARACTERISTICS OF MODEL - Concluded

Vertical Tail:	
Airfoil section (normal to 0.45 chord)	NACA 63-010
Root chord (parallel to fuselage center line), inches	18.90
Height, from fuselage center line, inches	12.68
Sweep at 0.45 chord, degrees	41.0
Fuselage:	
Length, inches	65.52
Maximum diameter	7.80
Fineness ratio	8.40

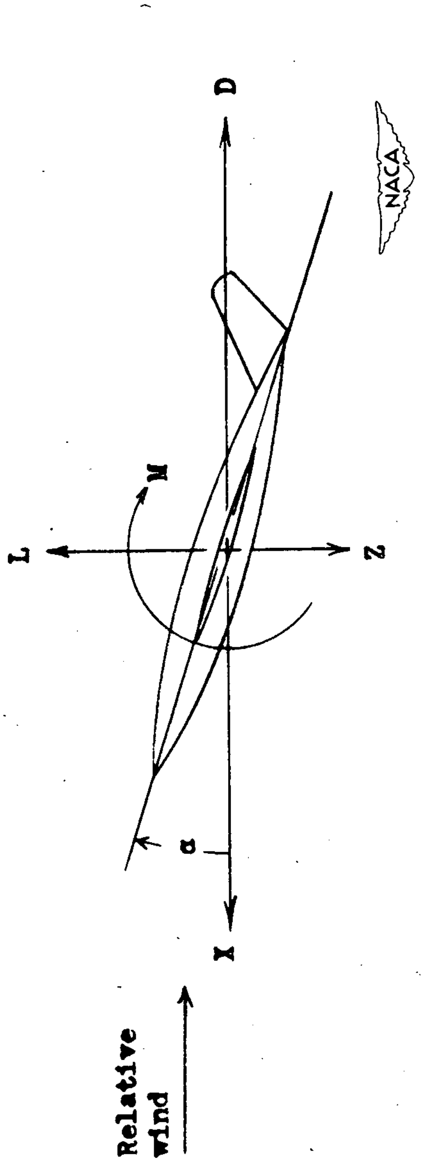


Figure 1.- System of axes used. Arrows indicate positive direction of angles, forces, and moment.

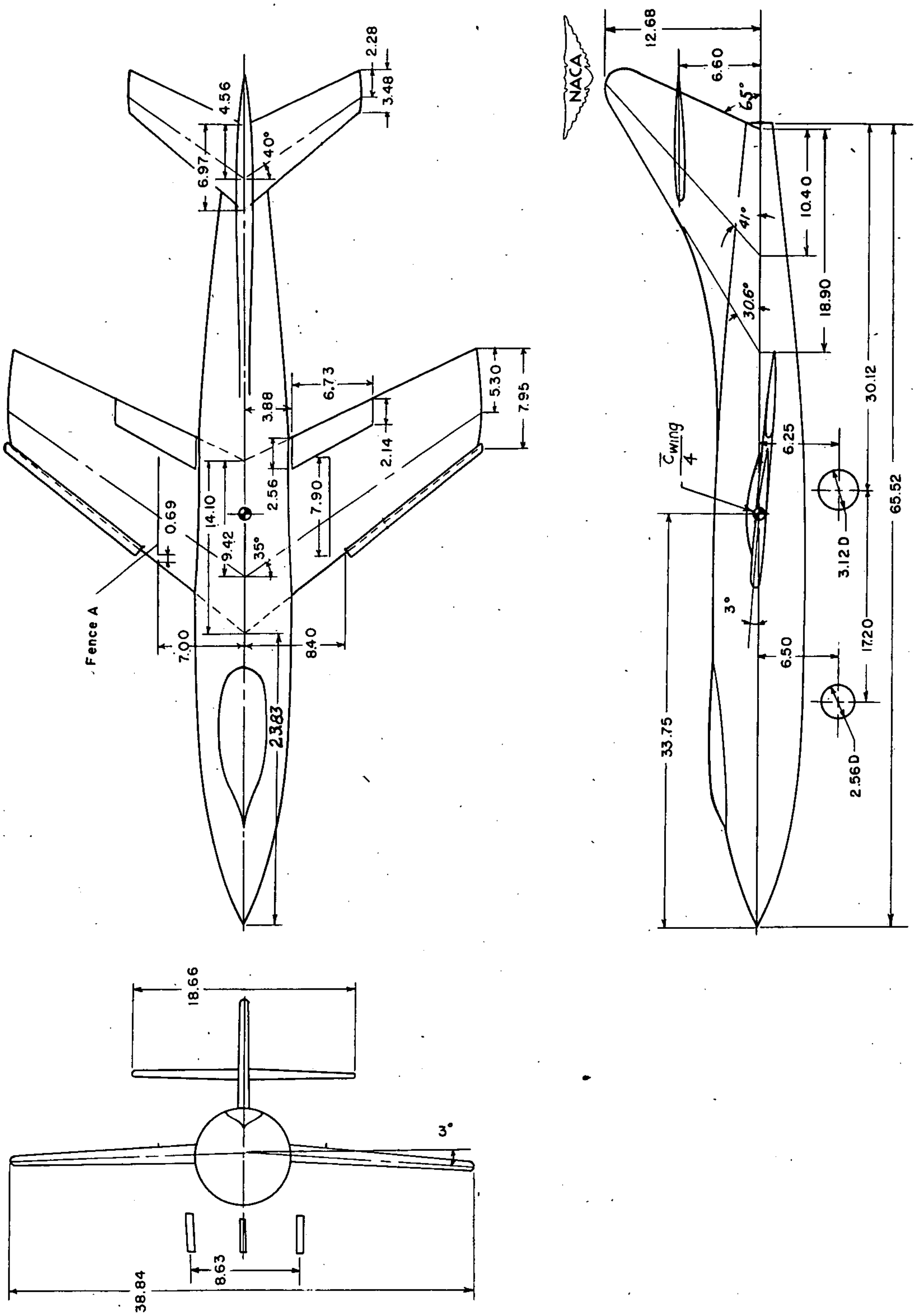


Figure 2.- Drawing of model used in the investigation. All dimensions given in inches.

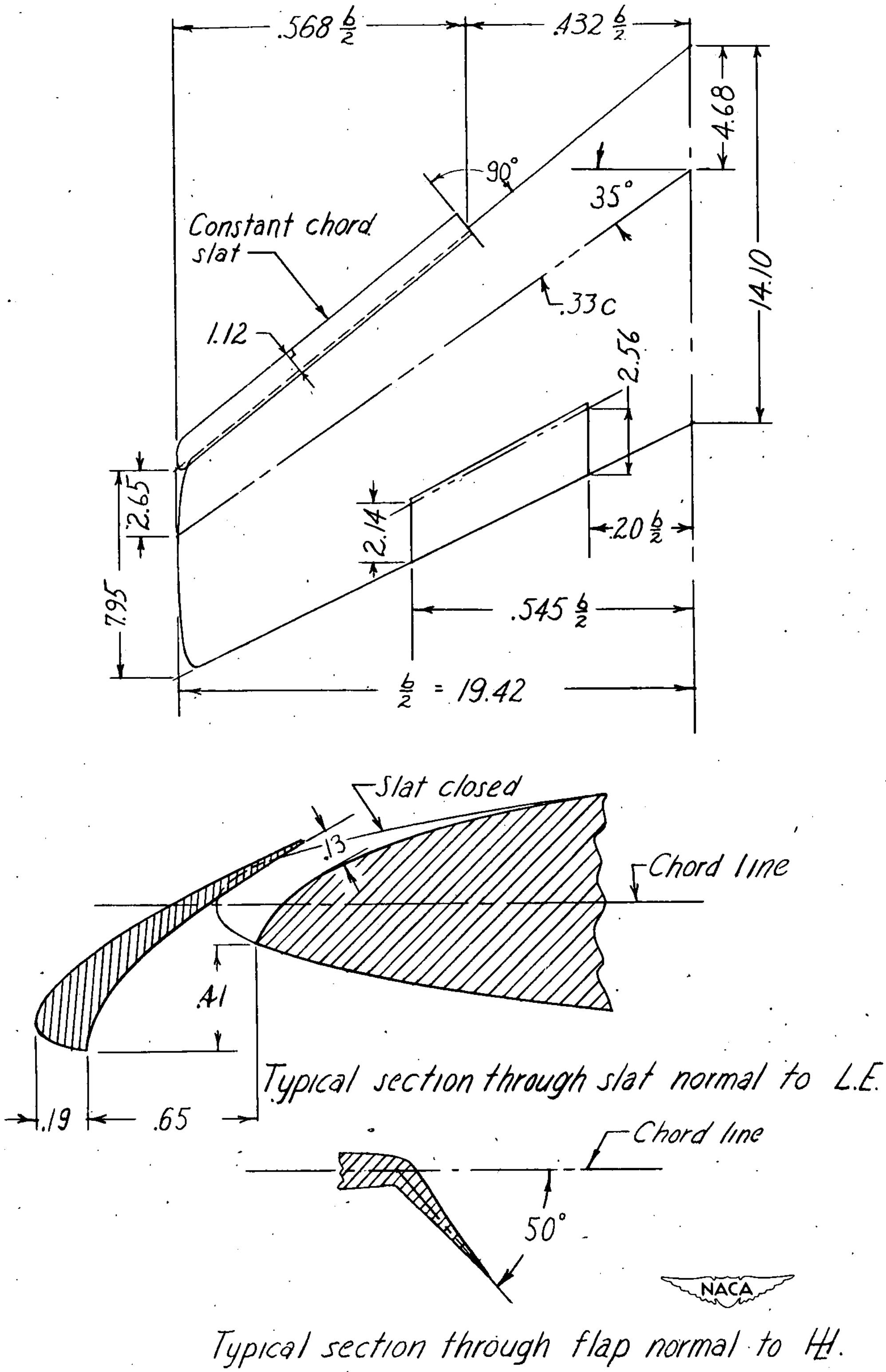


Figure 3.- Details of slats and plain flaps. All dimensions given in inches.

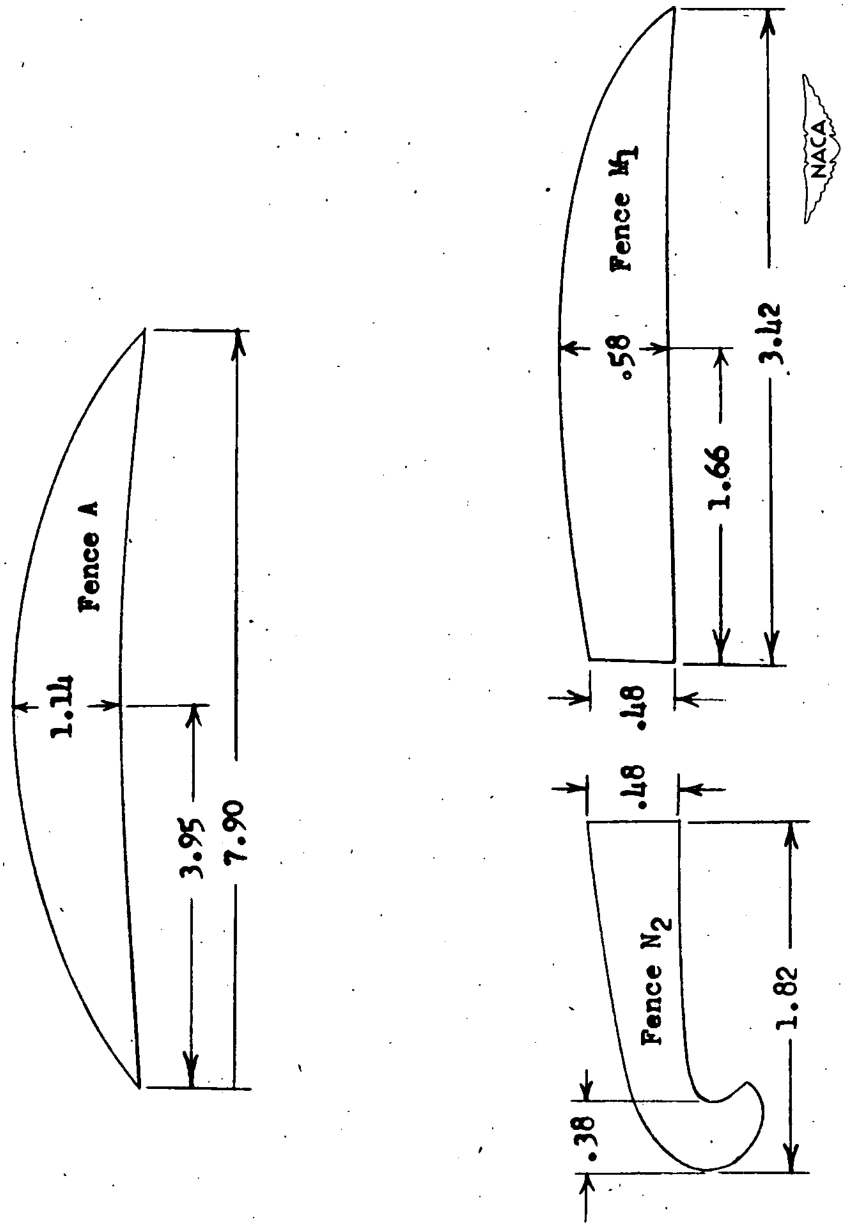
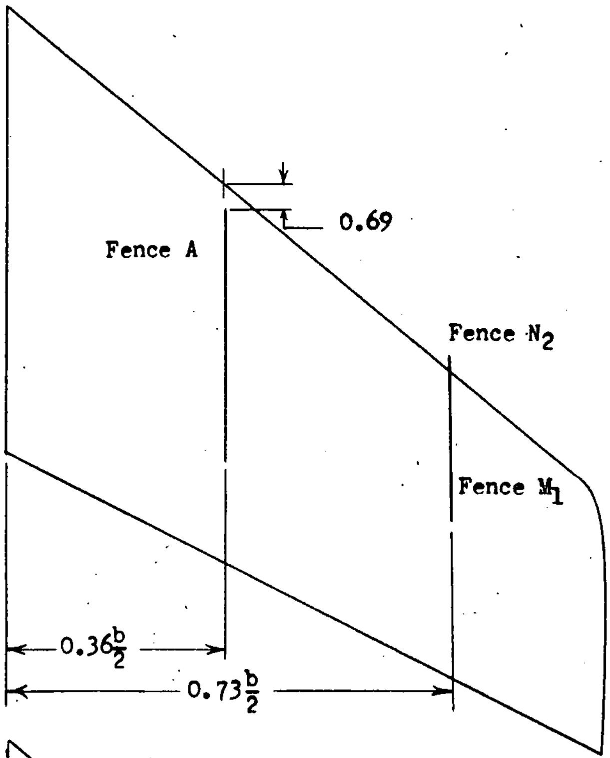
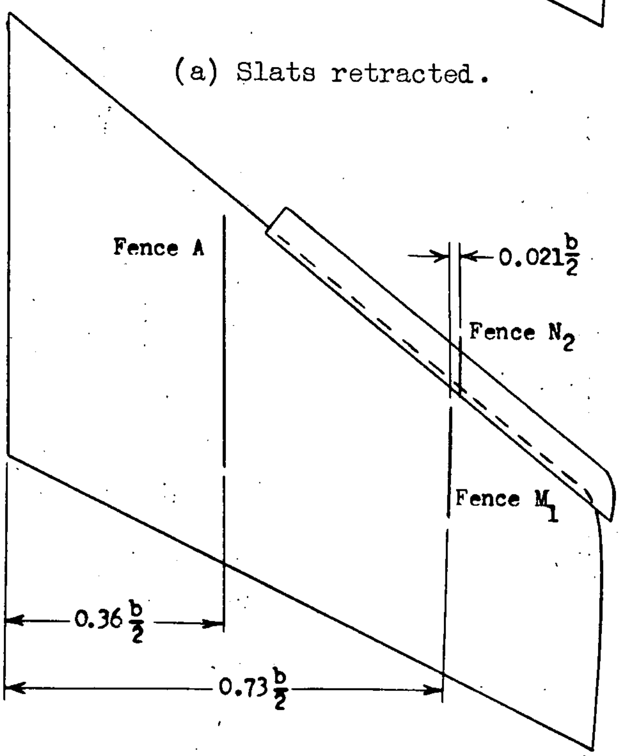


Figure 4.- Profiles of fences used with models. All dimensions given in inches.



(a) Slats retracted.



(b) Slats extended.

Figure 5.- Location of fences on wing.

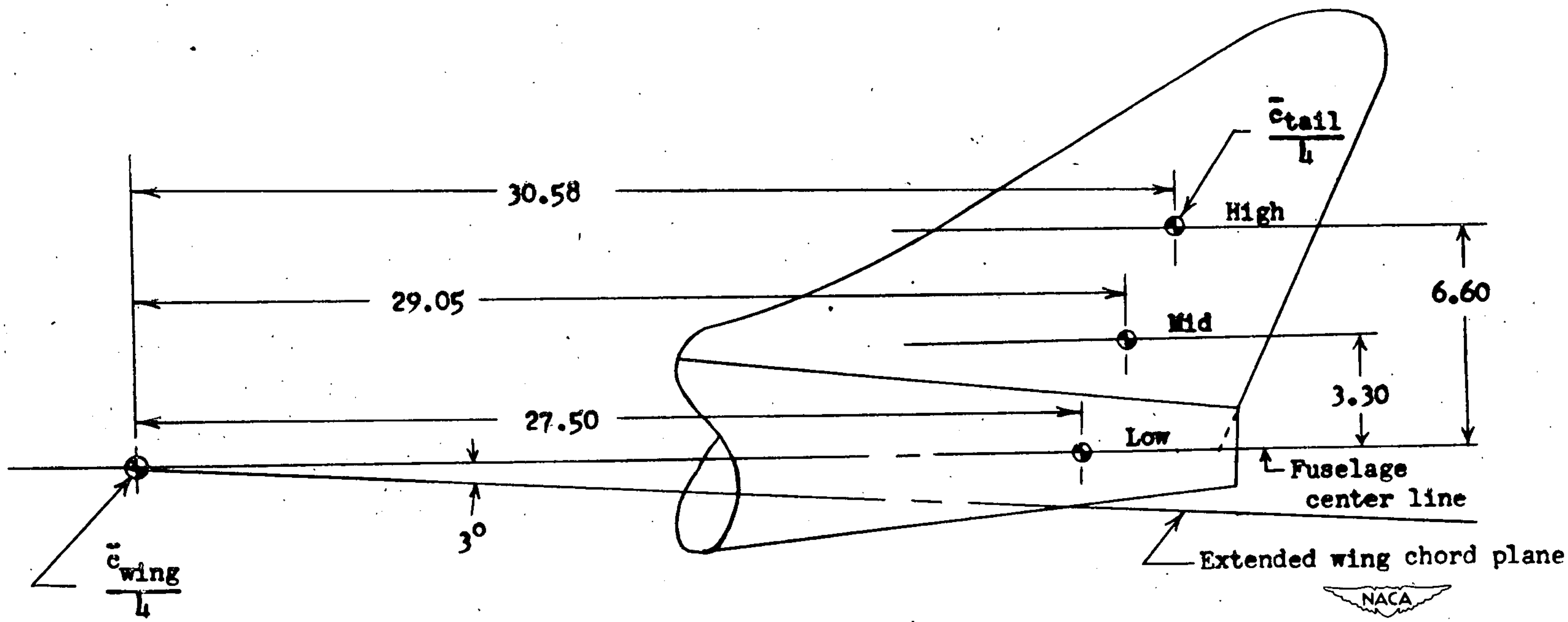


Figure 6.- Position of horizontal tail used during the investigation. All dimensions are in inches.

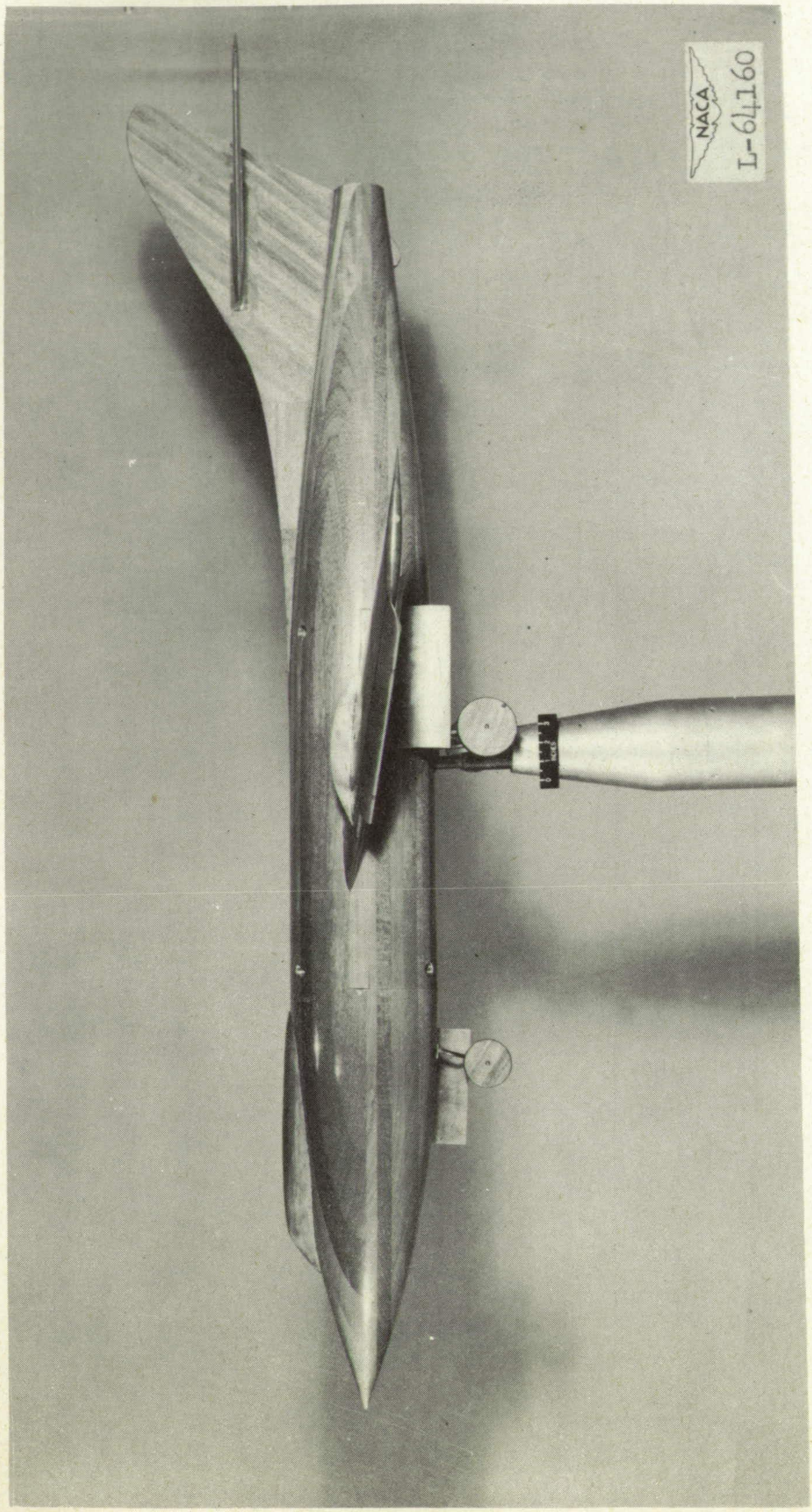
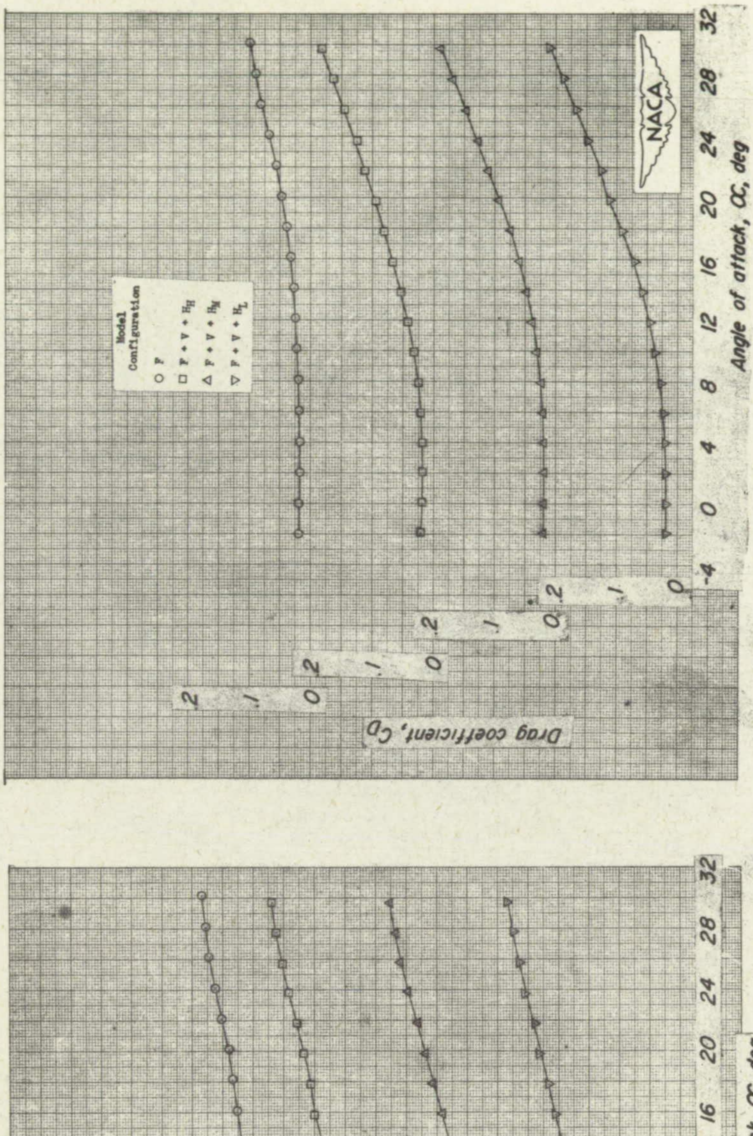
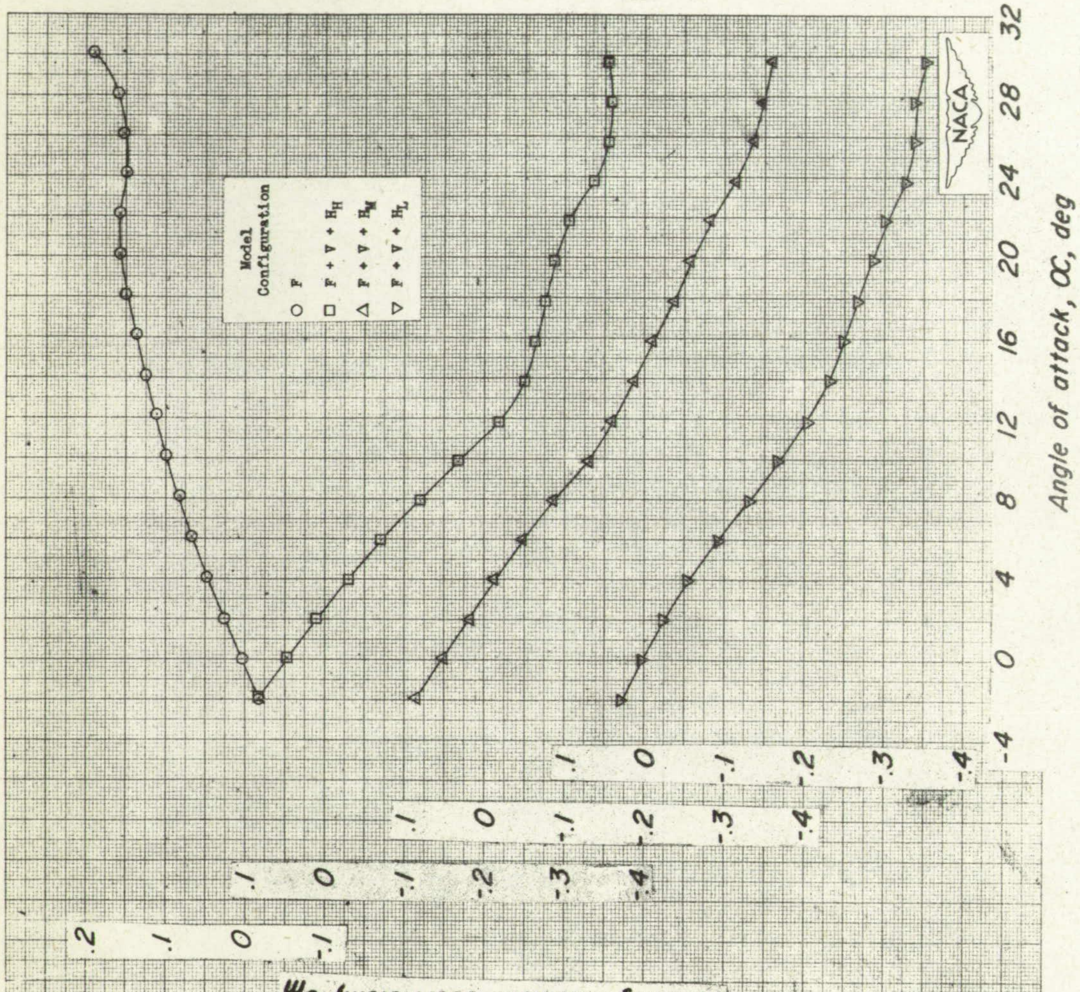


Figure 7.- Photograph of model used in tests.



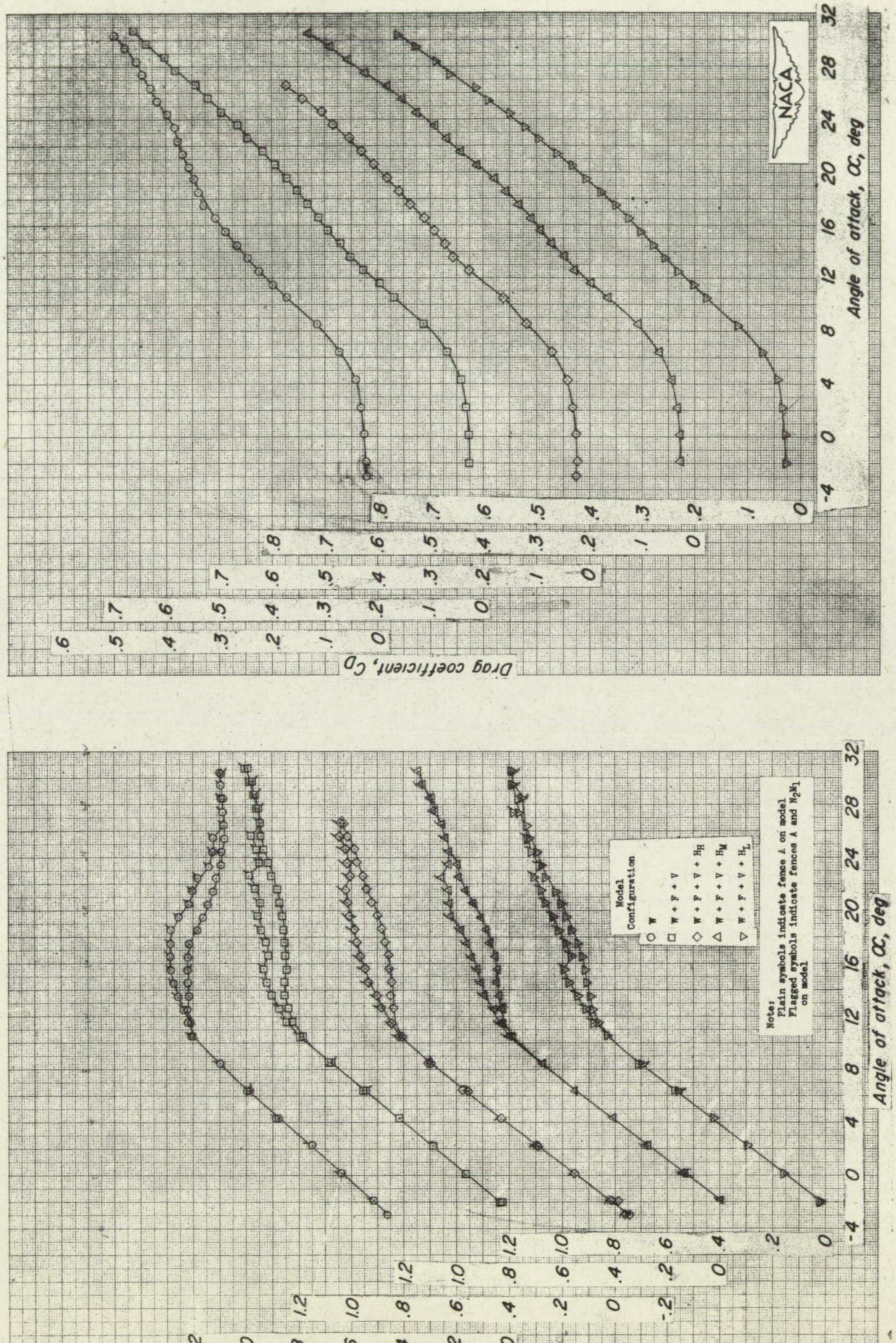
(a) Lift and drag characteristics.

Figure 8.-Longitudinal aerodynamic characteristics of various model configurations with wing off.



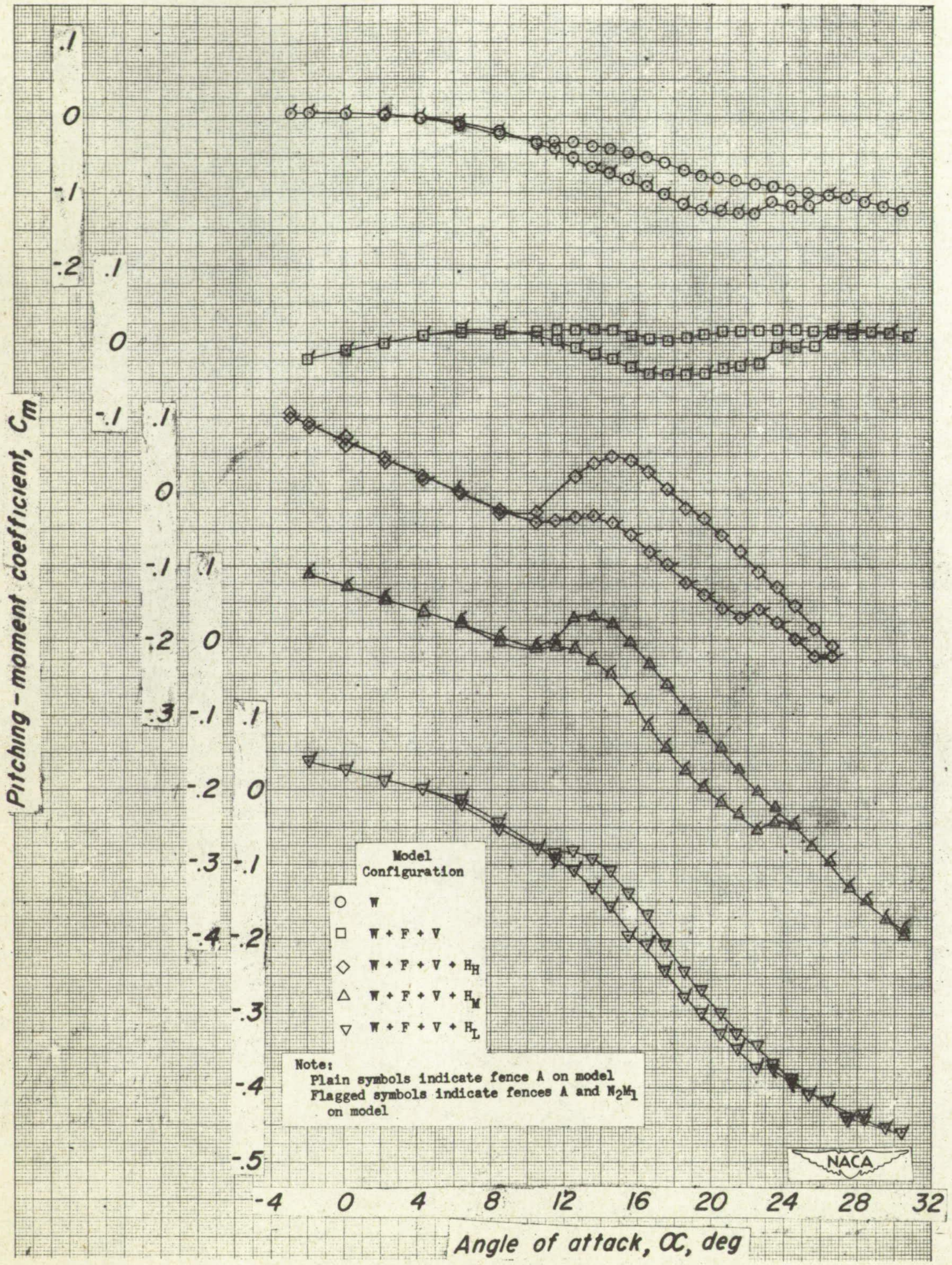
(b) Pitching-moment characteristics.

Figure 8.- Concluded.



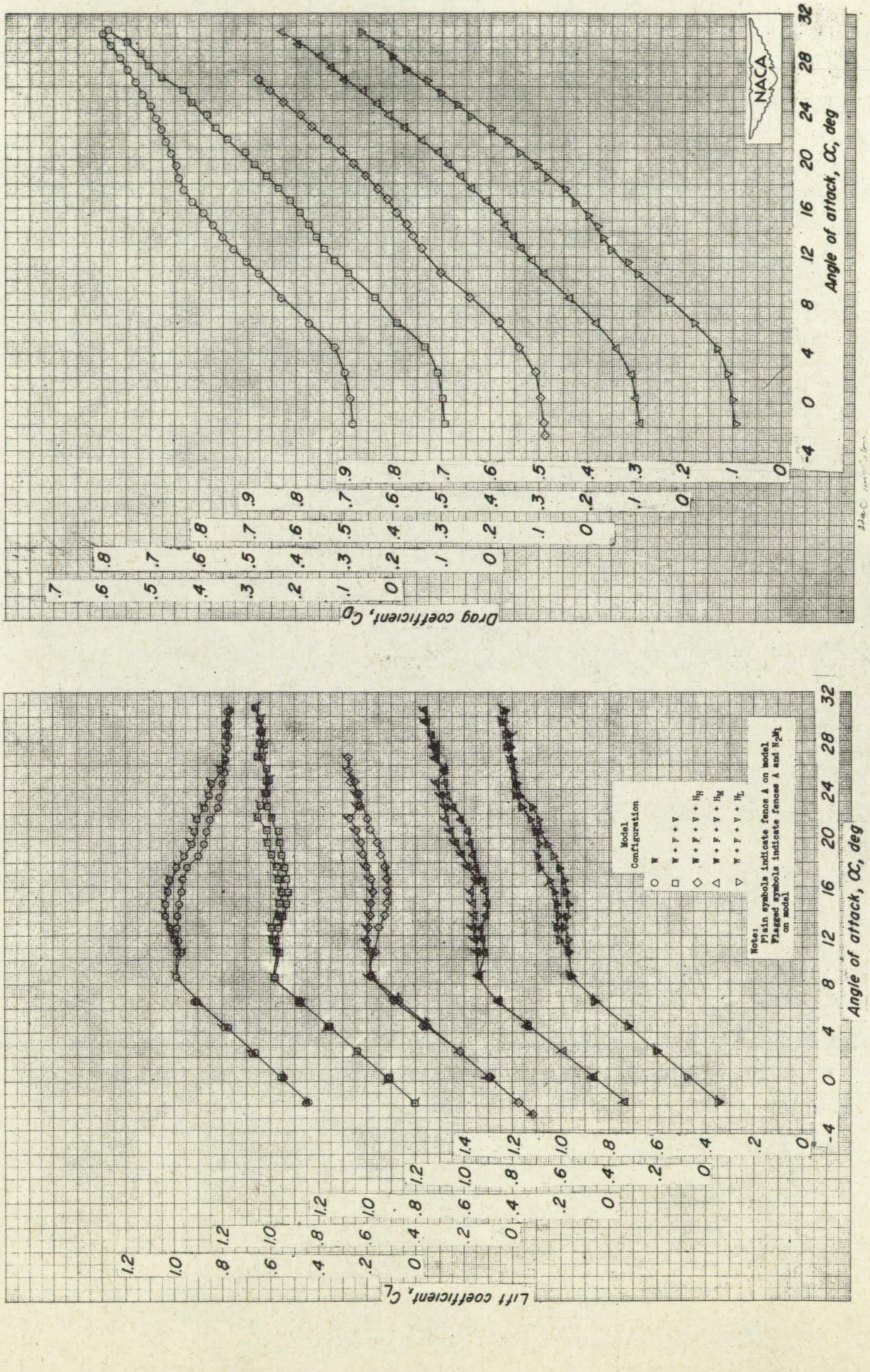
(a) Lift and drag characteristics.

Figure 9.- Longitudinal aerodynamic characteristics of various model configurations with slats, flaps, and landing gear retracted.



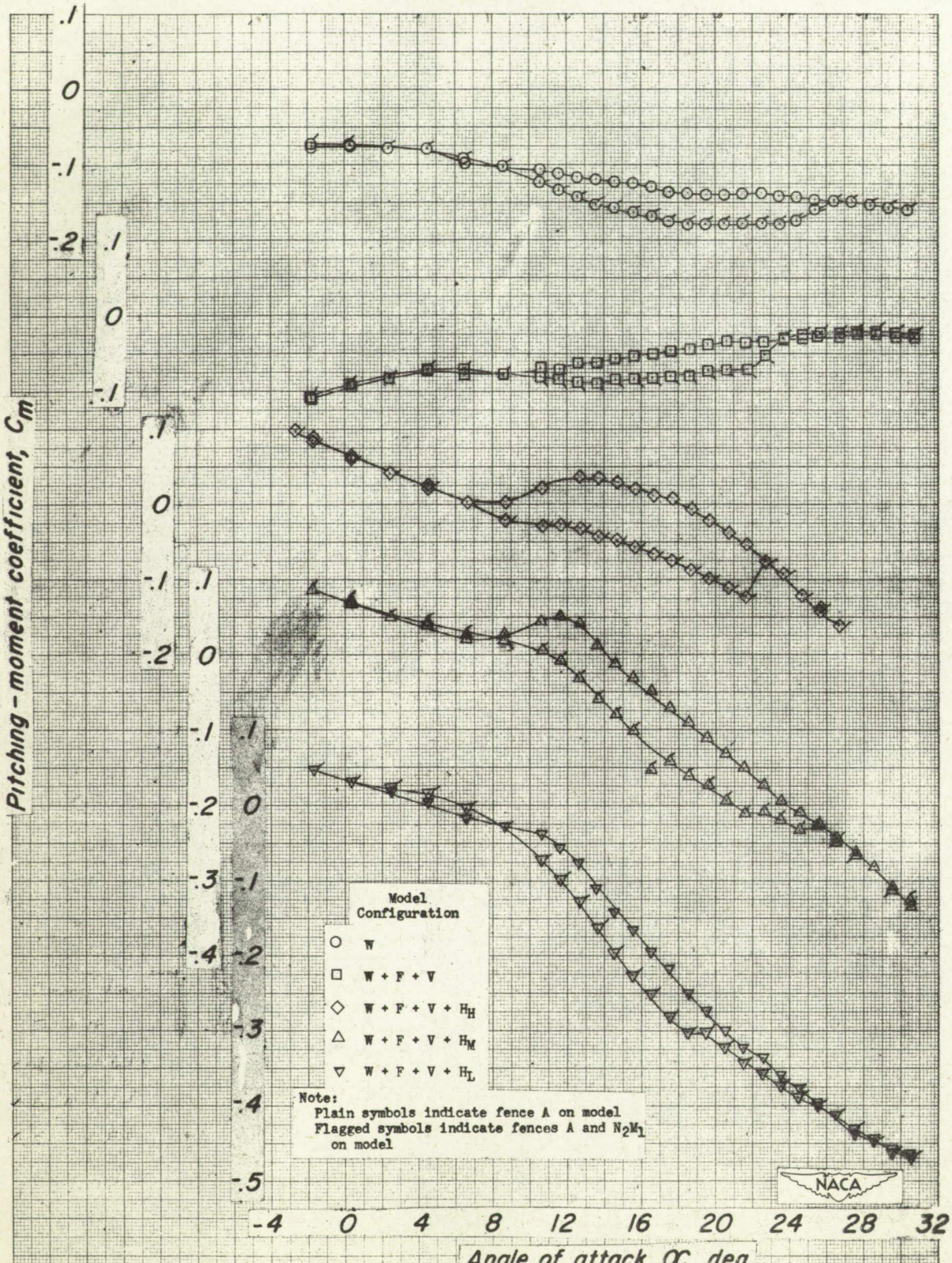
(b) Pitching-moment characteristics.

Figure 9.- Concluded.



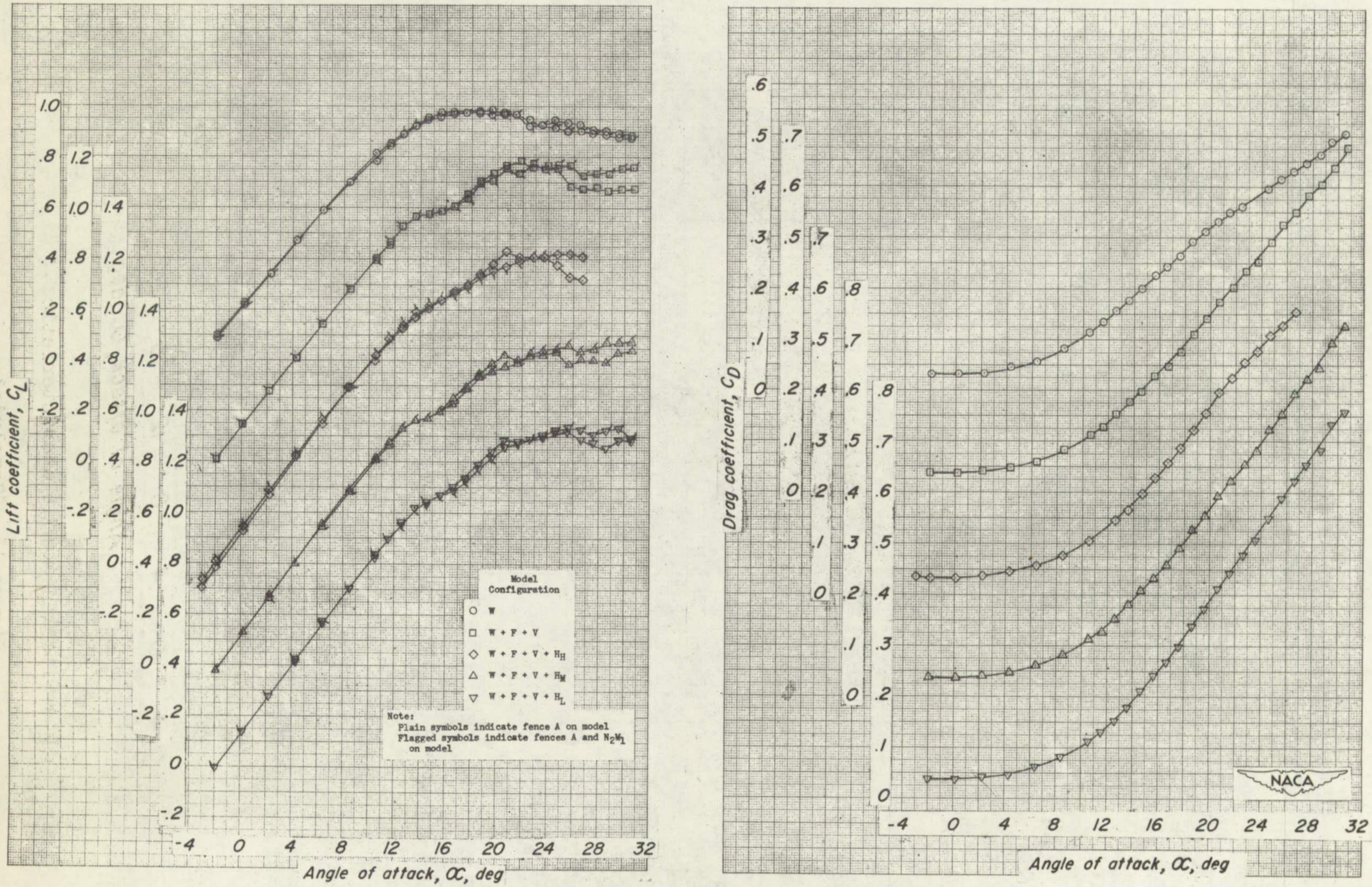
(a) Lift and drag characteristics.

Figure 10.- Longitudinal aerodynamic characteristics of various model configurations with slats retracted, flaps and landing gear extended.



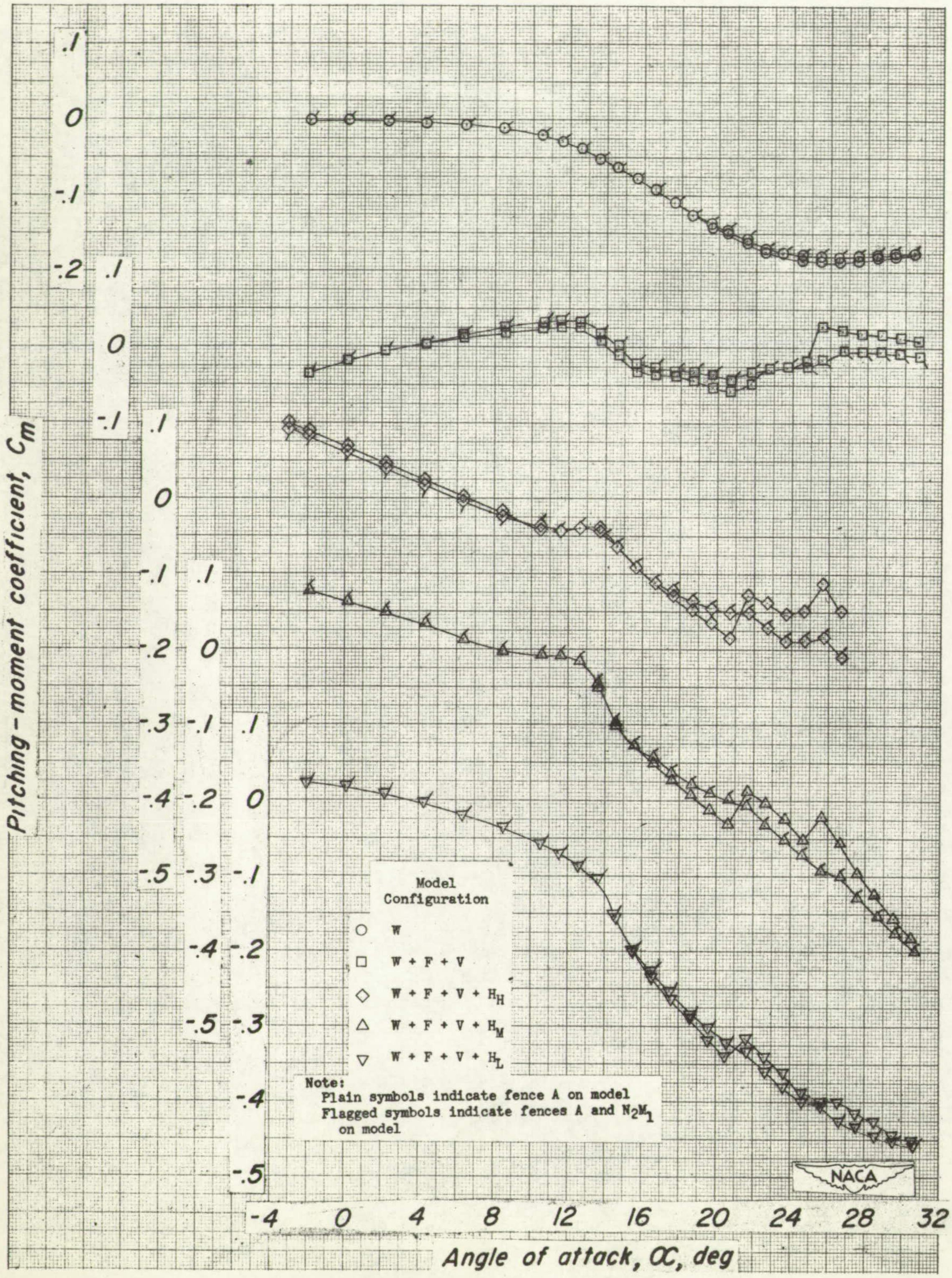
(b) Pitching-moment characteristics.

Figure 10.- Concluded.



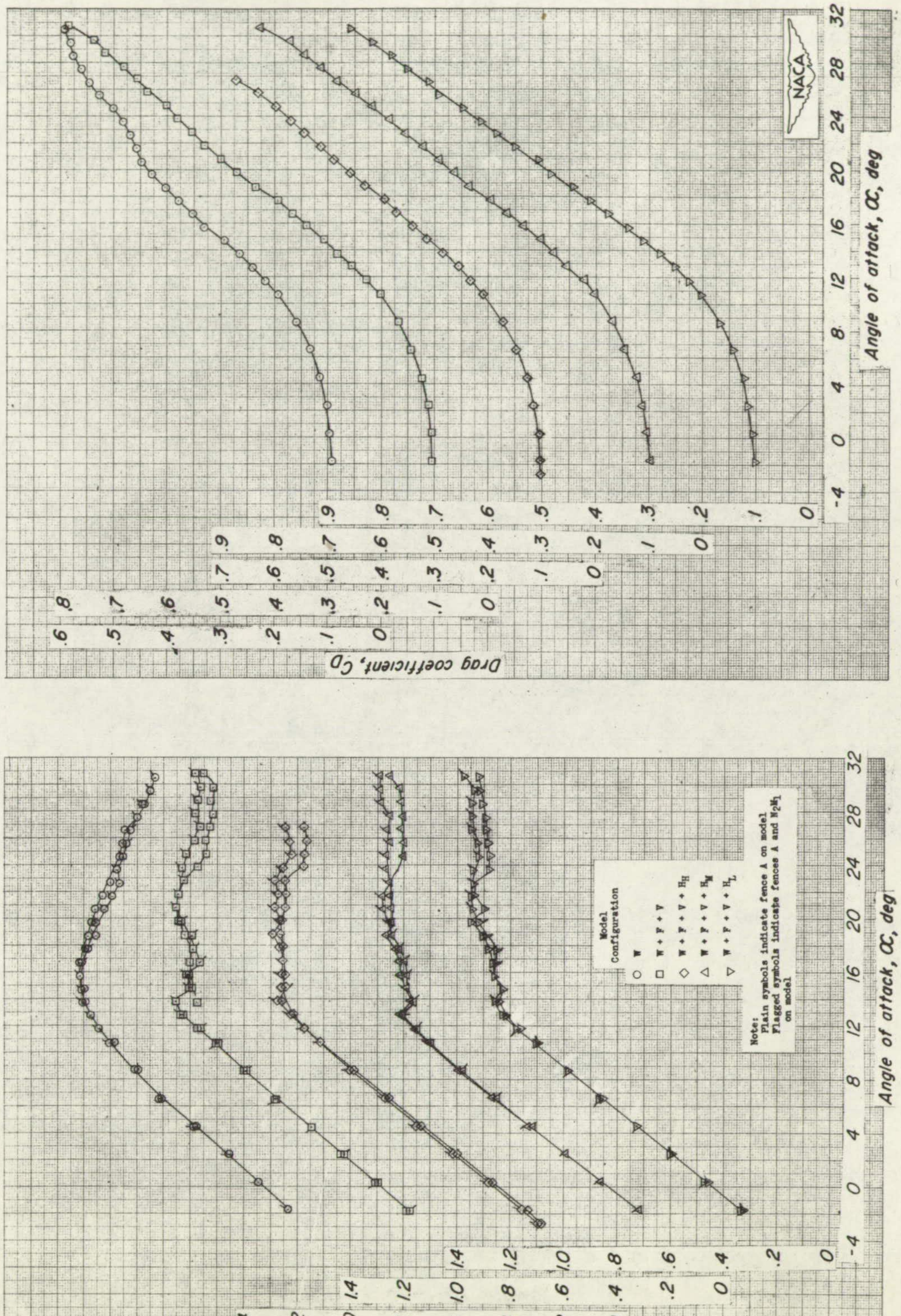
(a) Lift and drag characteristics.

Figure 11.- Longitudinal aerodynamic characteristics of various model configurations with slats extended, flaps and landing gear retracted.



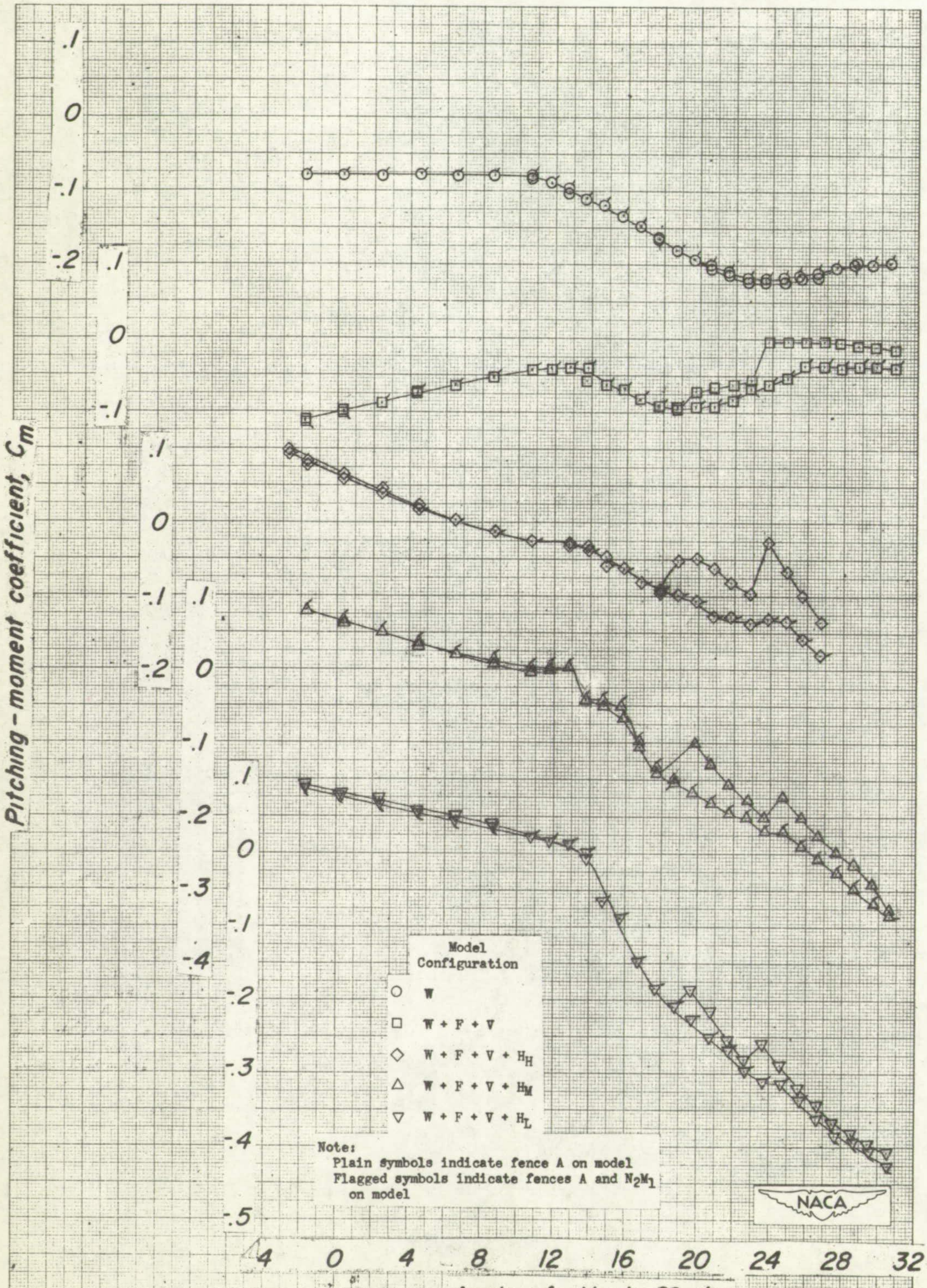
(b) Pitching-moment characteristics.

Figure 11.- Concluded.



(a) Lift and drag characteristics.

Figure 12.- Longitudinal aerodynamic characteristics of various model configurations with slats, flaps, and landing gear extended.



(b) Pitching-moment characteristics.

Figure 12.- Concluded.