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TECHNICAL MEMORANDUM

X-431

STATIC STABILITY AND CONTROL CHARACTERISTICS AT LOW-SUBSONIC SPEEDS OF A LENTICULAR REENTRY CONFIGURATION

By George M. Ware

Langley Research Center
Langley Field, Va.

[redacted]

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TECHNICAL MEMORANDUM X-431

STATIC STABILITY AND CONTROL CHARACTERISTICS AT LOW-SUBSONIC SPEEDS OF A LENTICULAR REENTRY CONFIGURATION*

By George M. Ware

SUMMARY

An investigation of the static stability and longitudinal control characteristics at low-subsonic speeds of a manned reentry configuration capable of high-drag reentry and glide landing has been made in the Langley free-flight tunnel. The model was lenticular in shape (double convex in cross section and circular in planform) and had several canopy designs and two horizontal-fin and end-plate combinations. The fin unit was designed to fold up during the high-drag reentry phase and to extend horizontally for the glide landing.

The body alone was longitudinally unstable about the 40-percent body-length point from an angle of attack of 0° to about 25° and stable from 25° to 90°. The addition of horizontal fins provided positive longitudinal stability throughout the angle-of-attack range but slightly reduced the untrimmed lift-drag ratio of the body. The addition of canopies to the upper surface of the body resulted in reductions in the lift-drag ratio. Deflecting the fin units was an effective means of obtaining pitch control. The investigation indicated that the model with three small bubble canopies and modified horizontal-fin and end-plate combination had satisfactory static lateral stability characteristics up to the stall.

INTRODUCTION

An investigation is being conducted by the National Aeronautics and Space Administration to provide information on the stability and control of configurations designed for controlled reentry into the earth's atmosphere. One type of configuration utilizes large drag values obtained at high angles of attack ($\alpha = 60^\circ$ to 90°) as a means of deceleration during reentry, and after completion of the reentry phase horizontal fins are extended in order to trim in the unstalled angle-of-attack range for controlled gliding flight to the desired point of landing. (See ref. 1.)

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*Title, Unclassified.

Such vehicles considered suitable as reentry configurations must possess adequate stability throughout the expected Mach number and angle-of-attack ranges. The characteristics of one of these vehicles, a lenticular configuration, has been reported in reference 2 at Mach numbers of 0.4 to 1.2 and in reference 3 at a Mach number of 1.99. The purpose of the present investigation is to provide additional information on a similar configuration at low subsonic speeds. These tests also furnished data for studies currently being made by NASA Space Task Group. The model was lenticular in shape (double convex in cross section and circular in planform) and had several canopy designs and two horizontal-fin and end-plate combinations. The fin units were designed to fold up in order to be shielded by the body during the reentry phase and then to fold out (extend) to provide static longitudinal stability and control during the glide landing.

This study consisted of static force tests at angles of attack from 0° to 90° to provide static longitudinal stability information on the body alone, body with fins extended, and body having a circular canopy on the upper surface with fins folded and extended. Tests were made at angles of attack up to 45° to determine the effect on the longitudinal characteristics of the glide configuration of several canopies and a modified horizontal fin.

Lateral tests were made at sideslip angles of 5° and -5° over an angle-of-attack range from 0° to 45° to determine the directional characteristics of one of the configurations.

SYMBOLS

The lateral data are referred to the body system of axes (fig. 1) and the longitudinal data are referred to the stability system of axes. The origin of the axes was located to correspond to a longitudinal center-of-gravity position of 40 percent of the body length and to a vertical position at the center line of the lenticular body. The coefficients were based on the dimensions of the body alone.

C_D	drag coefficient, D/qS
C_L	lift coefficient, L/qS
C_Y	side-force coefficient, F_Y/qS
C_l	rolling-moment coefficient, M_X/qSl

C_m	pitching-moment coefficient, M_Y/qSl
C_n	yawing-moment coefficient, M_Z/qSl

$C_{Y_\beta} = \frac{\partial C_Y}{\partial \beta}$, per deg

$C_{l_\beta} = \frac{\partial C_l}{\partial \beta}$, per deg

$C_{n_\beta} = \frac{\partial C_n}{\partial \beta}$, per deg

D	drag, lb
F_Y	side force, lb
L	lift, lb
l	body length, ft
M_X	rolling moment, ft-lb
M_Y	pitching moment, ft-lb
M_Z	yawing moment, ft-lb
q	dynamic pressure, $\frac{\rho V^2}{2}$, lb/sq ft
S	wing area, sq ft
V	airspeed, ft/sec
α	angle of attack (measured from the model center line), deg
β	angle of sideslip, deg
δ	fin deflection angle measured in a plane perpendicular to the hinge line (negative when trailing edge is up)
ρ	air density, slugs/cu ft

APPARATUS AND MODEL

The model was tested in the Langley free-flight tunnel, which is a low-speed tunnel with a 12-foot octagonal test section. A sting type of support system and internally mounted three-component strain-gage balances were used in the tests.

The investigation was made with a model similar to the one used in reference 2. Three-view drawings of the model and modifications are presented in figure 2 and some pertinent dimensions are given in table I. The model was circular in planform with a lenticular cross section and had flat-plate horizontal fins with end plates extending above the horizontal fins. The canopy configurations used in the investigation consisted of a large circular canopy, three small bubble canopies, and a single small bubble canopy. The horizontal fins were modified by removing a portion of the trailing edge and the end plates were modified by the addition of identical surfaces below the existing end plates.

TESTS

Force tests were made over an angle-of-attack range from 0° to 90° to determine the static longitudinal stability characteristics of the body alone, body with fins extended, and body with the circular canopy and fins folded and extended. Other static longitudinal tests were made at angles of attack up to 45° to determine the effect of canopies, fin modifications, and various fin settings on the longitudinal characteristics of the model in the glide configuration.

Lateral tests were made at angles of sideslip of 5° and -5° over an angle-of-attack range from 0° to 45° to determine the directional characteristics of the model with three canopies and modified horizontal-fin and end-plate combination. The tests were conducted at a dynamic pressure of 4.12 pounds per square foot which corresponds to an airspeed of 58.9 feet per second, and a Reynolds number of 0.83×10^6 based on the body diameter of 2.24 feet.

RESULTS

The longitudinal stability data for the body alone and the body with basic fins extended are presented in figure 3. These data show that the body alone was unstable at $\alpha = 0^\circ$ to about 25°, stable at $\alpha = 25^\circ$ to 90°, and trimmed at $\alpha = 50^\circ$. By adding the basic horizontal fins to the body, the model was made stable over the entire angle-of-attack range. The addition of the fins caused a reduction in the untrimmed L/D over the angle-of-attack range.

The longitudinal stability characteristics of the model with the circular canopy and with the fins folded and extended are presented in figure 4. These data, when compared with those of the model with canopy off (fig. 3), show that the lift and lift-drag ratio were reduced substantially by the large circular canopy. The maximum untrimmed L/D of this configuration with fins extended may be seen to be only 2.2.

The effect of fin deflection on the longitudinal stability characteristics of the model with basic fins, canopy off, single bubble canopy, three bubble canopies, and three bubble canopies with modified horizontal-fin and end-plate combination is presented in figure 5. These data show that the configurations were stable over the test angle-of-attack range. The addition of the three bubble canopies resulted in the variation of pitching-moment coefficient with lift coefficient becoming more nonlinear and the model with modified horizontal fins produced even more nonlinearity in the curves. The data also show that either the basic or modified fins provided trim over the angle-of-attack range required for gliding flight. The maximum trimmed L/D for the model with canopy off and a single bubble canopy (figs. 5(a) and 5(b)) may be seen to be about 5.9 while the maximum trimmed L/D for the model with three bubble canopies with basic and modified horizontal fins (figs. 5(c) and 5(d)) dropped to 4.1 and 3.8, respectively. This reduction in L/D resulted from increased drag and reduced lift caused by the disturbed flow around the three canopies and loss in lift incurred by use of the smaller (modified) horizontal fins.

The static lateral stability characteristics in the form of the stability derivatives C_{Y_β}, C_{n_β}, and C_{l_β} plotted against angle of attack are presented in figure 6 for the model with the three canopies and modified horizontal-fin and end-plate combination. The data show that the model had an almost constant value of positive directional stability up to the stall (30° angle of attack) but became unstable above the stall. The effective dihedral $-C_{l_\beta}$ remained positive throughout the angle-of-attack range.

CONCLUDING REMARKS

The results of the investigation at low-subsonic speeds showed that the body alone was longitudinally unstable about the 40-percent body-length point up to about an angle of attack of 25° and stable from

25° to 90° while the model with horizontal fins was stable over the entire angle-of-attack range. The addition of canopies to the upper surface of the body resulted in reductions in the lift-drag ratio. Deflecting the fin units was an effective means of obtaining pitch control. The model with three bubble canopies and modified horizontal-fin and end-plate combination had satisfactory static lateral stability characteristics.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., August 31, 1960.

REFERENCES

1. Staff of Langley Flight Research Division (Compiled by Donald C. Cheatham): A Concept of a Manned Satellite Reentry Which Is Completed With a Glide Landing. NASA TM X-226, 1959.

2. Mugler, John P., Jr., and Olstad, Walter B.: Static Longitudinal Aerodynamic Characteristics at Transonic Speeds of a Lenticular-Shaped Reentry Vehicle. NASA TM X-423, 1960.

3. Jackson, Charlie M., Jr., and Harris, Roy V., Jr.: Static Longitudinal Stability and Control Characteristics at a Mach Number of 1.99 of a Lenticular-Shaped Reentry Vehicle. NASA TN D-514, 1960.

TABLE I

MODEL GEOMETRIC CHARACTERISTICS

Body:	
Length, in.	26.82
Planform area, sq in.	565
Thickness ratio	0.290

Fins:	Basic	Modified
Horizontal-fin area (each), sq in.	108.86	78.62
End-plate area (each), sq in.	21.6	43.2
Leading-edge sweep, deg	9.82	9.82

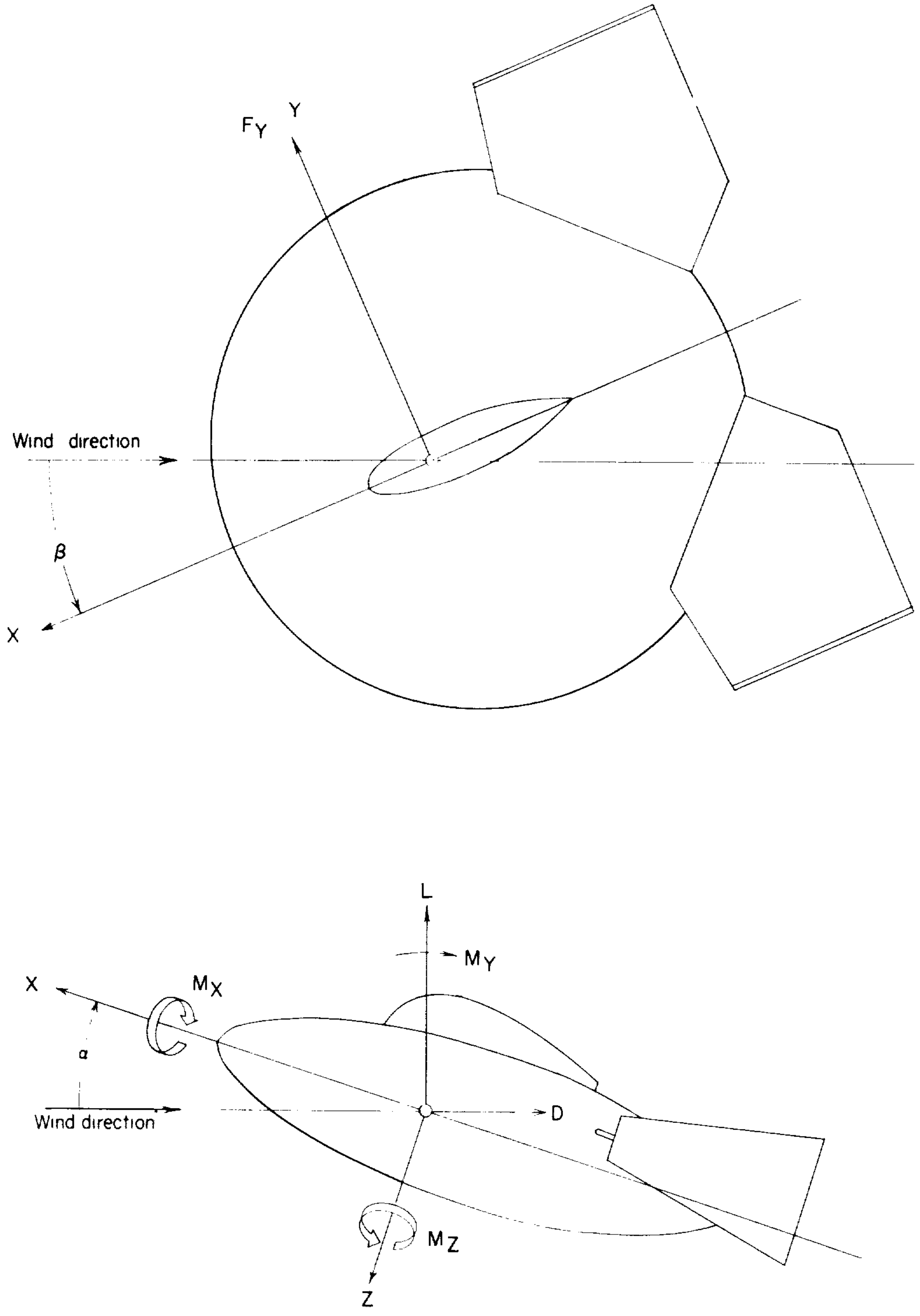
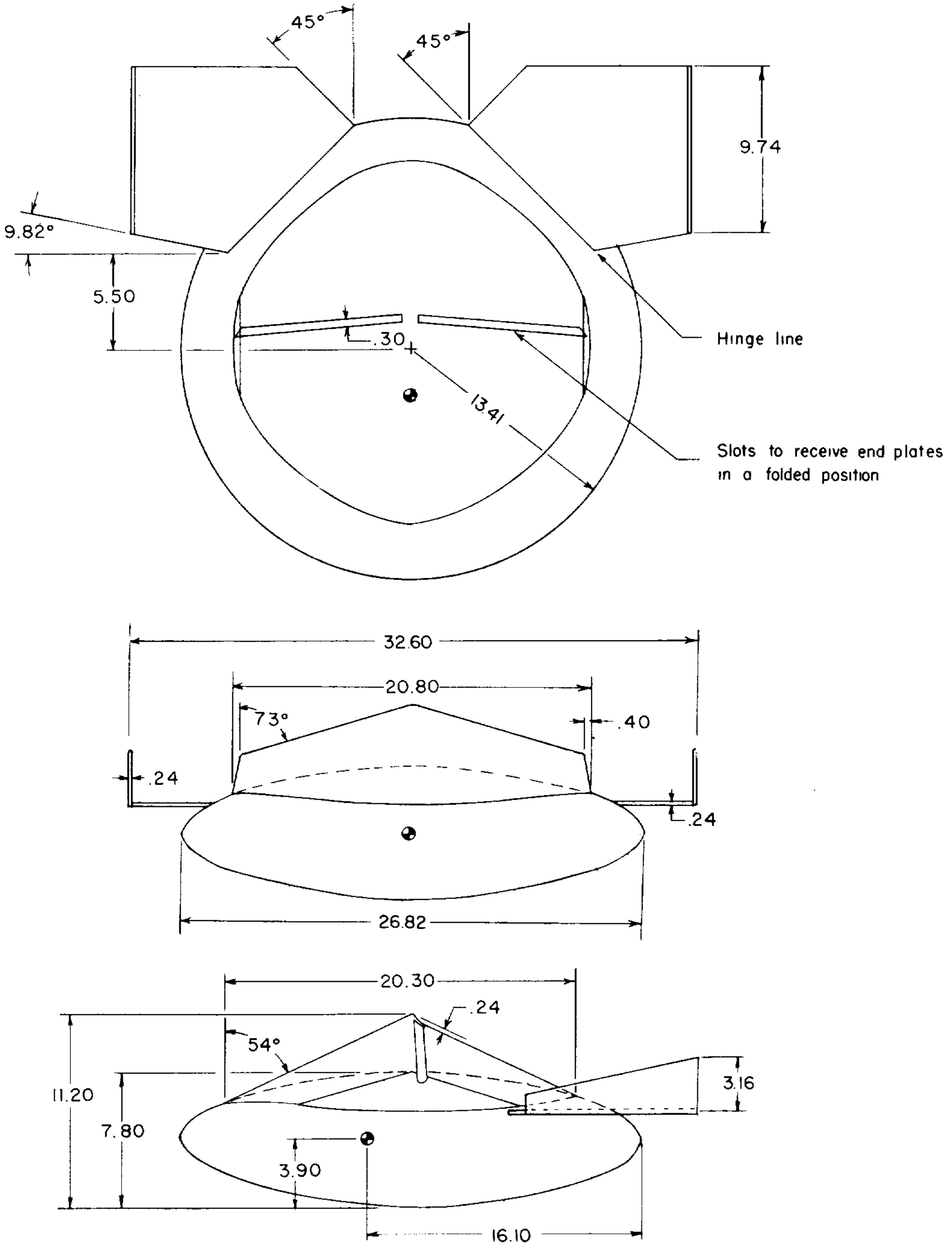
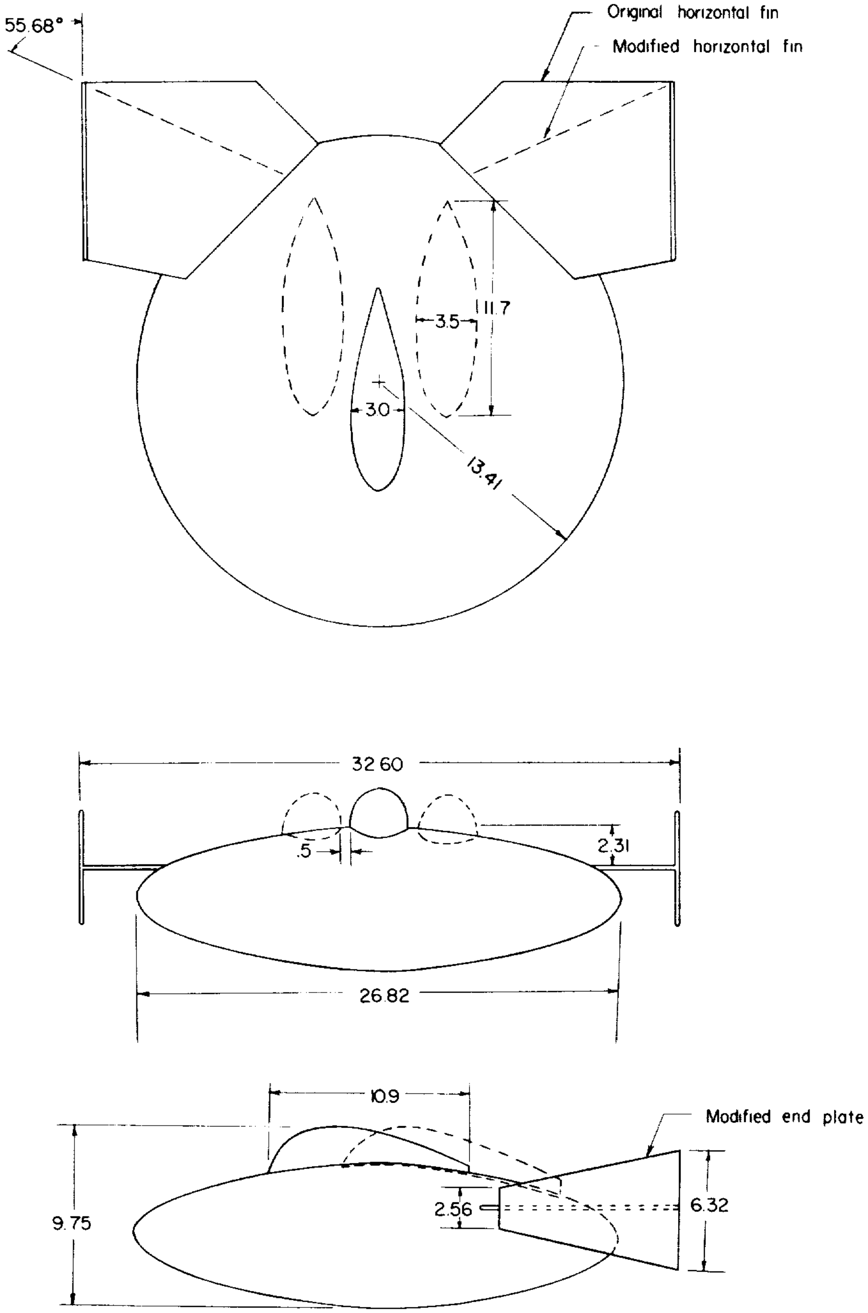


Figure 1.- Sketch of system of axes used in the investigation, showing positive direction of forces, moments, velocities, and angles.



(a) Model with circular canopy.

Figure 2.- Three-view drawings showing model used in the investigation. All dimensions are in inches.



(b) Model with single and three bubble canopies and modified horizontal-fin and end-plate combination.

Figure 2.- Concluded.

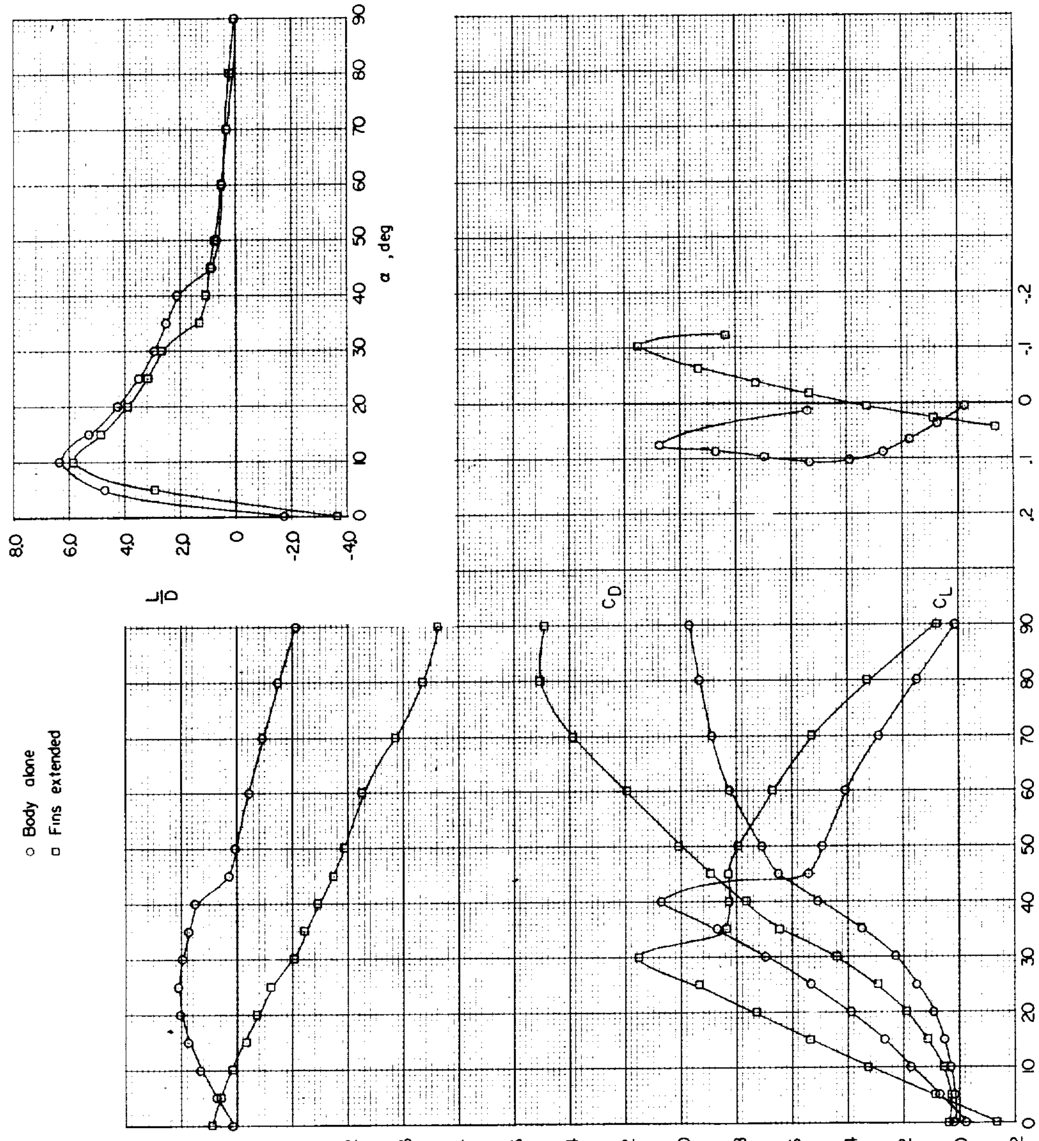


Figure 3.- Longitudinal stability characteristics of model with canopy off. β = 0°.

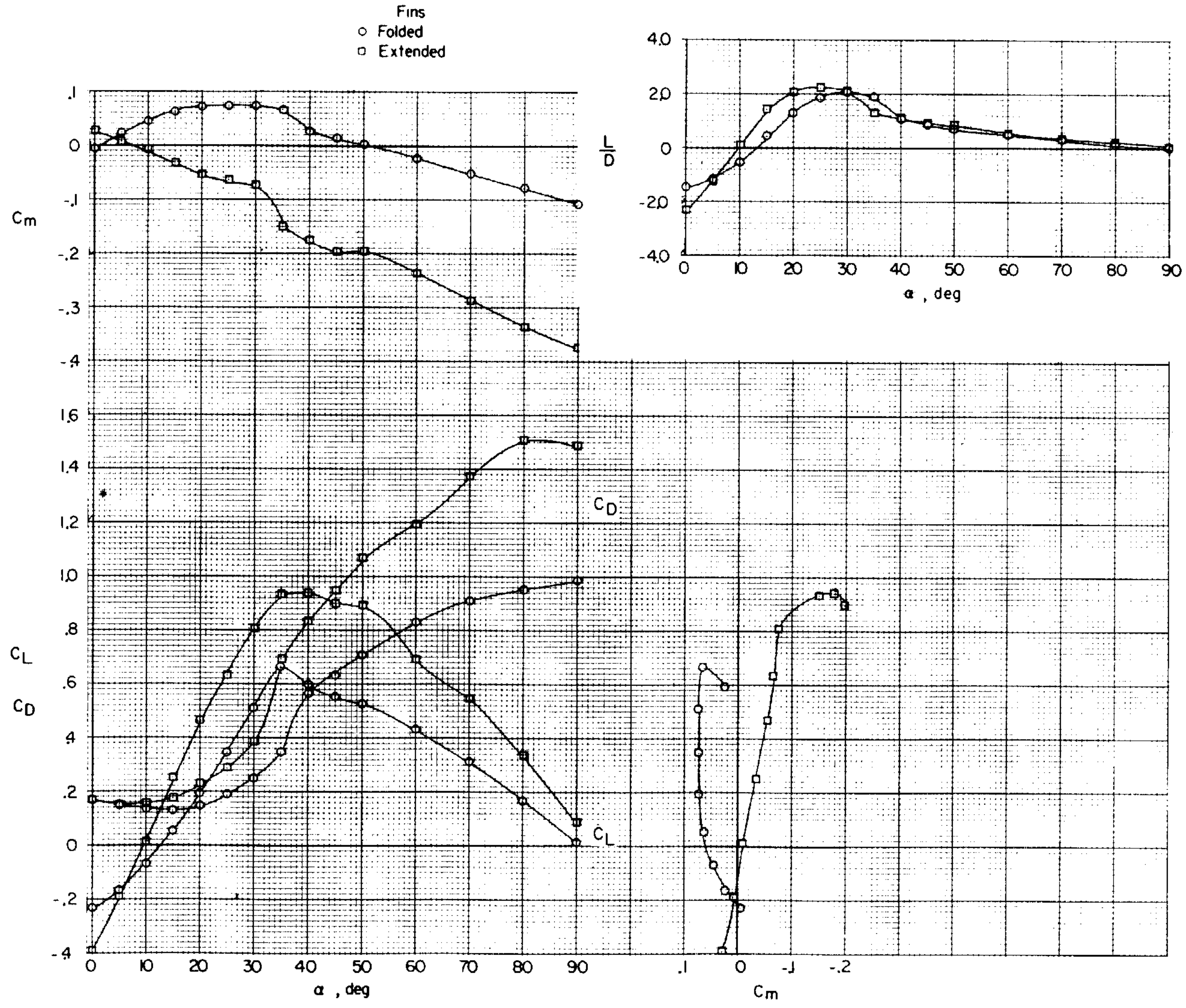
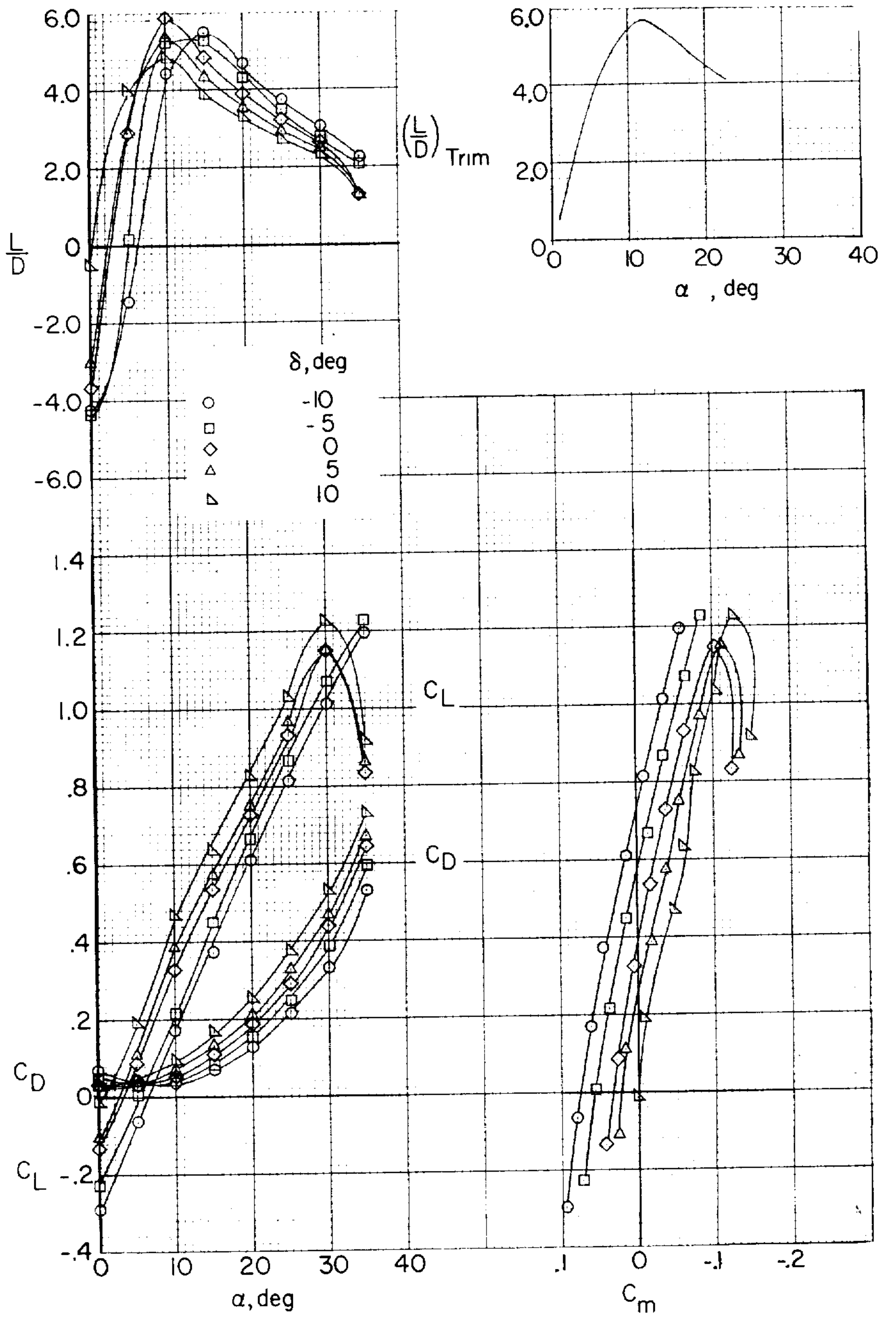
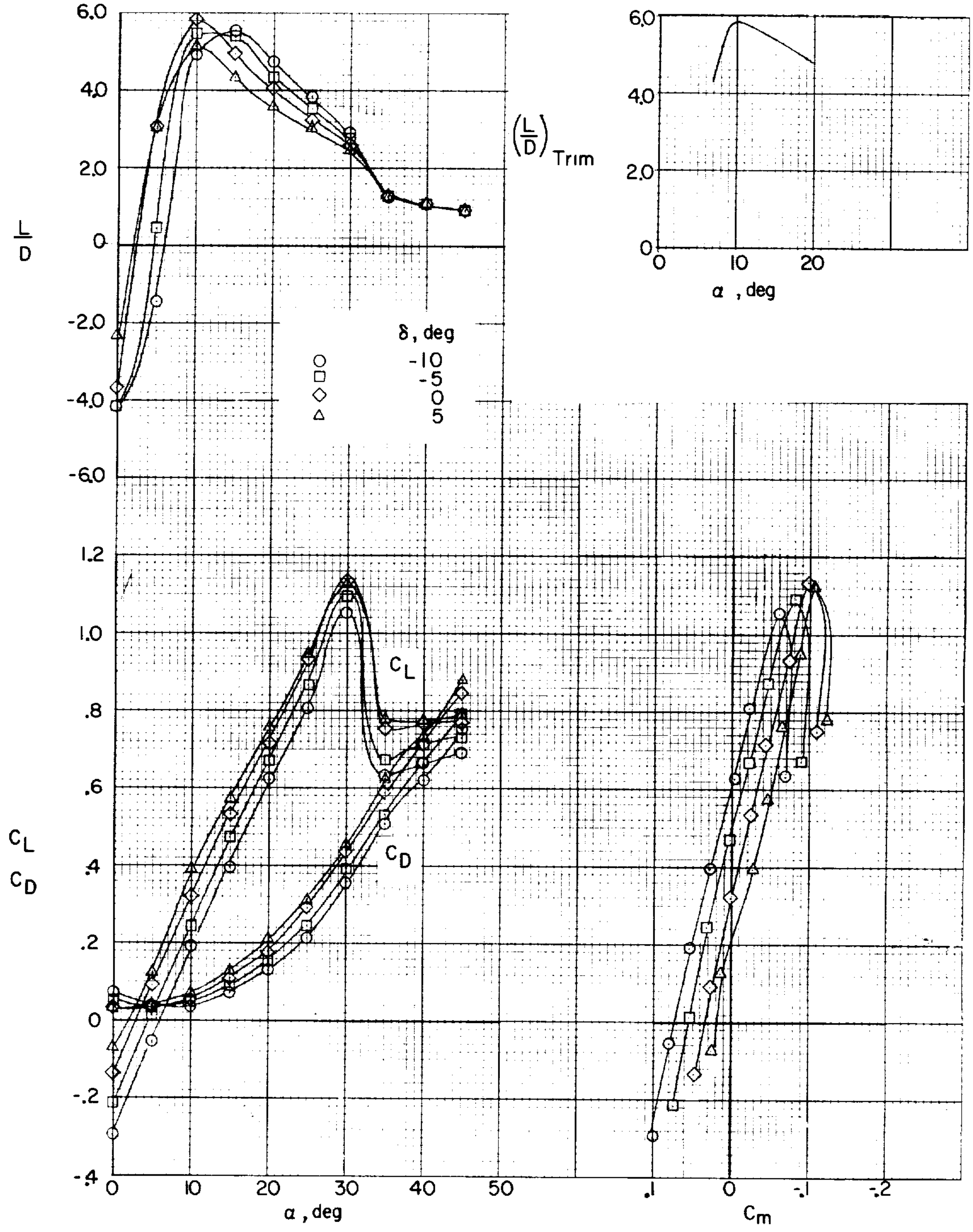


Figure 4.- Longitudinal stability characteristics of model with circular canopy. β = 0°.



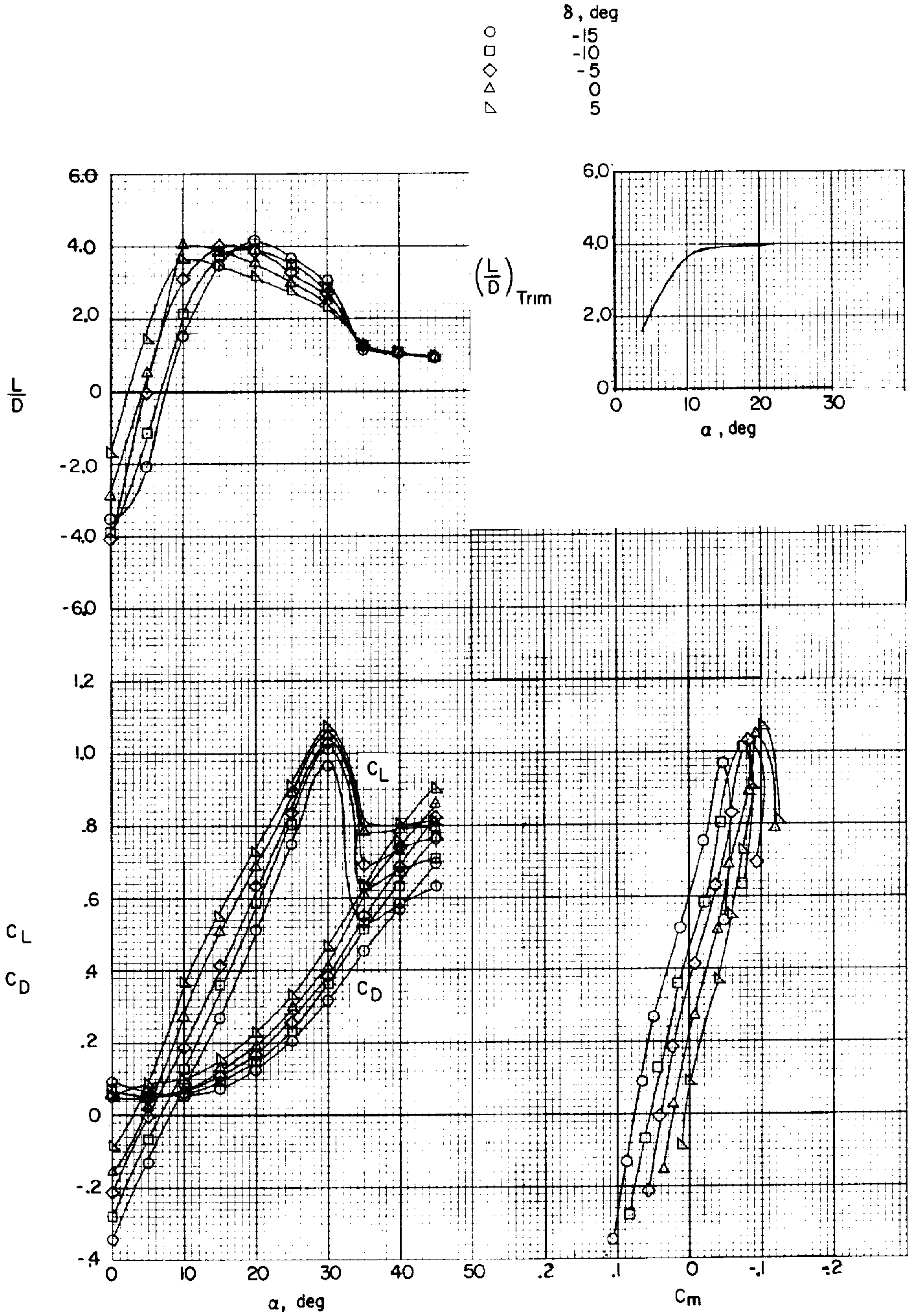
(a) Canopy off.

Figure 5.- Effect of fin deflection on longitudinal stability characteristics of model. $\beta = 0^{\circ}$.



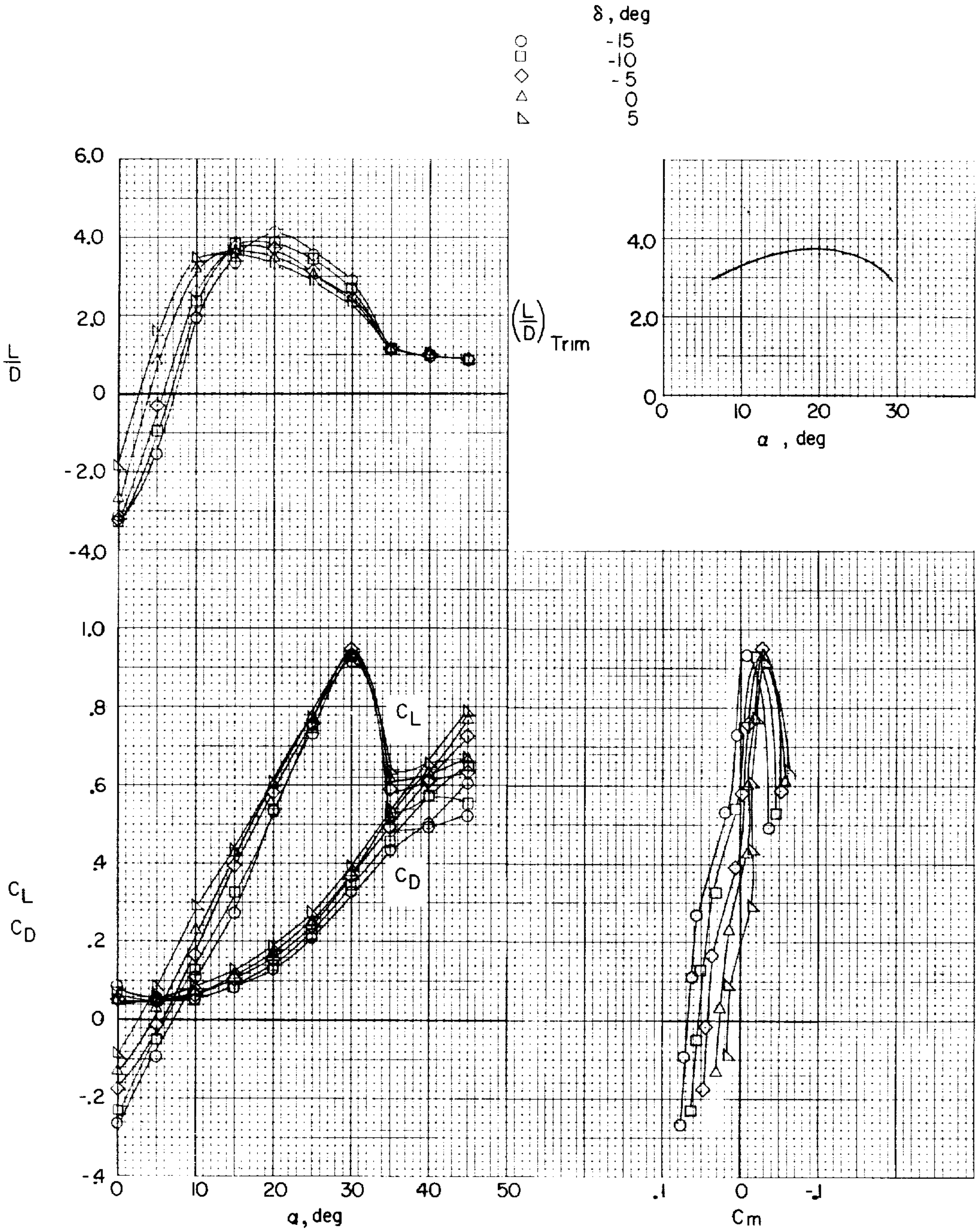
(b) Single bubble canopy.

Figure 5.- Continued.



(c) Three bubble canopies.

Figure 5.- Continued.



(d) Three bubble canopies and modified horizontal-fin and end-plate combination.

Figure 5.- Concluded.

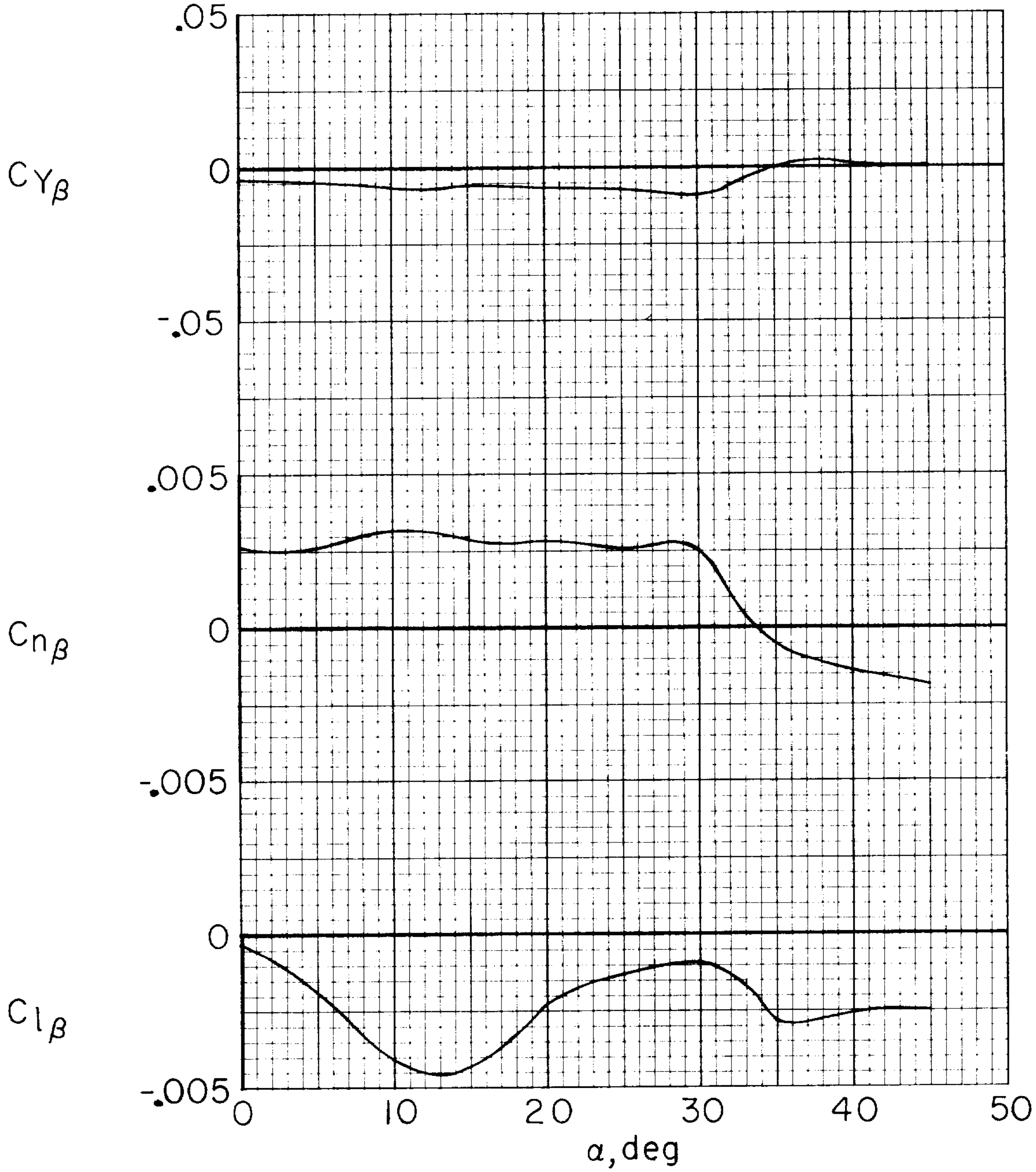


Figure 6.- Lateral stability characteristics of model with three bubble canopies and modified horizontal-fin and end-plate combination.