IN-08
394 387

NASA

MEMORANDUM

AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF A

CANARD CONTROL ON THE LIFT, DRAG, AND PITCHING

MOMENT OF AN ASPECT-RATIO-2.0 TRIANGULAR WING

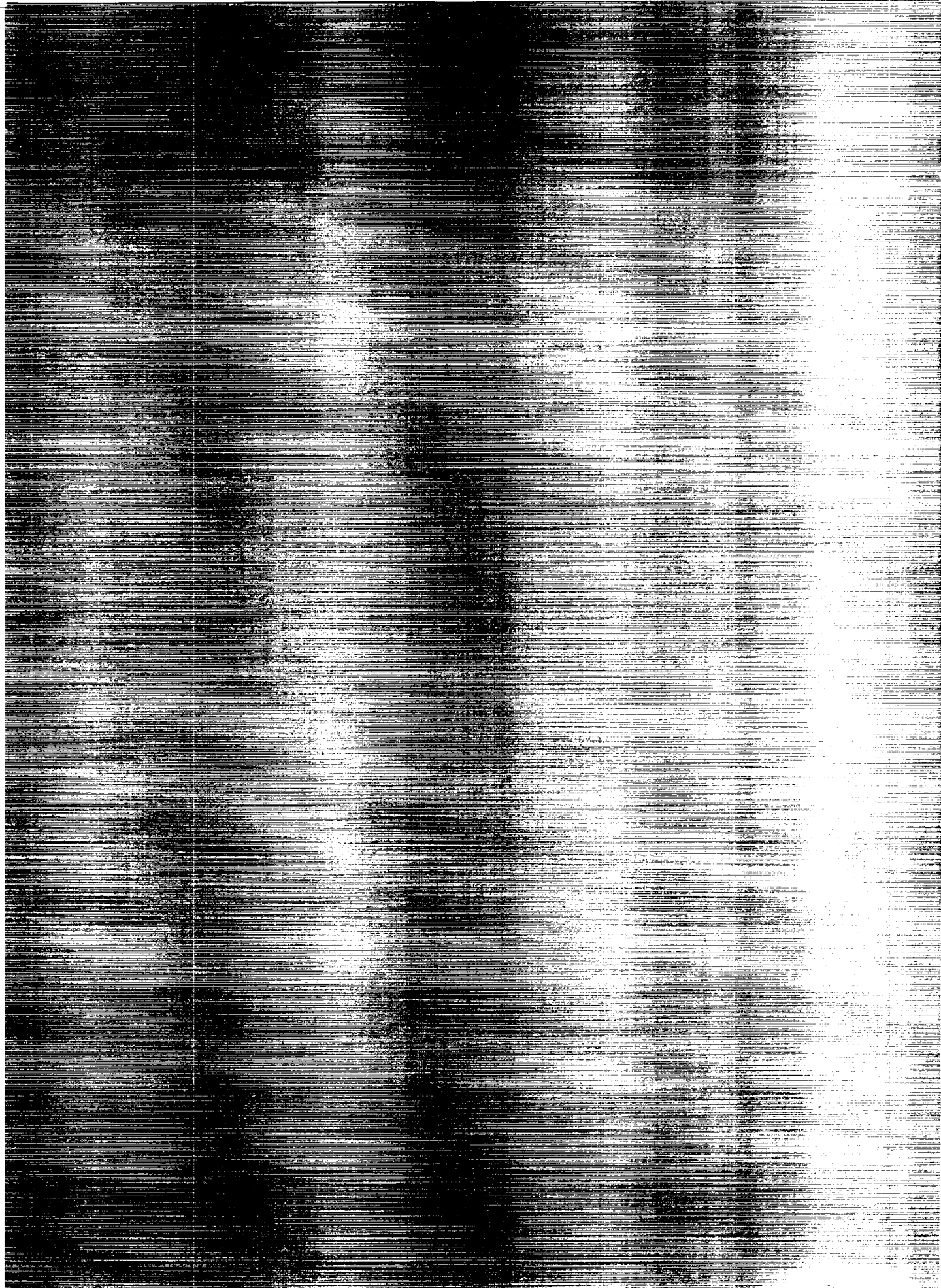## INCORPORATING A FORM OF CONICAL CAMBER

By Gene P. Menees and John W. Boyd

Ames Research Center
Moffett Field, Calif.

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
WASHINGTON

May 1959
Declassified July 11, 1961

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MEMORANDUM 5-20-59A

AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF A

CANARD CONTROL ON THE LIFT, DRAG, AND PITCHING

MOMENT OF AN ASPECT-RATIO-2.0 TRIANGULAR WING

INCORPORATING A FORM OF CONICAL CAMBER

By Gene P. Menees and John W. Boyd

SUMMARY

The results of an experimental investigation to determine the effect of a canard control on the lift, drag, and pitching-moment characteristics of an aspect-ratio-2.0 triangular wing incorporating a form of conical camber are presented. The canard had a triangular plan form of aspect ratio 2.0 and was mounted in the extended chord plane of the wing. The ratio of the area of the exposed canard panels to the total wing area was 6.9 percent, and the ratio of the total areas was 12.9 percent. Data were obtained at Mach numbers from 0.70 to 2.22 through an angle-of-attack range from -6° to +18° with the canard on, and with the canard off. To provide a basis for comparison, the canard was also tested with a symmetrical wing having the same plan form, aspect ratio, and thickness distribution as the cambered wing.

The results of the investigation showed that at the high subsonic speeds the gain in maximum lift-drag ratio achieved by camber was considerably reduced by the addition of a canard. At the supersonic speeds, the addition of the canard did not change the effect of camber on the maximum lift-drag ratios.

INTRODUCTION

The possible gains to be realized at supersonic speeds in the form of reduced trim drag and increased maneuverability by the use of canards have resulted in numerous investigations of these arrangements (see refs. 1 through 9). The requirement still exists in some instances that these

configurations designed to fly at supersonic speeds must be capable of efficient flight at high subsonic speeds in order to fulfill their required mission. For triangular and other swept plan forms this requirement can be satisfied by the use of conical camber which has been shown to be effective in reducing the drag due to lift of these configurations at high subsonic speeds.

The question arises, therefore, as to how the known benefits of conical camber in reducing the drag due to lift at high subsonic speeds would be affected by the presence of a canard surface. The present investigation was undertaken, therefore, to show the effects of a canard on the longitudinal characteristics of an aspect-ratio-2.0 triangular wing incorporating a form of conical camber.

NOTATION

b wing span, ft

$\bar{c}$ mean aerodynamic chord of wing, ft

$\bar{c}_c$ mean aerodynamic chord of canard, ft

C_D drag coefficient, $\dfrac{drag}{qS}$

ΔC_D drag-coefficient increment due to camber, drag coefficient of cambered wing minus drag coefficient of symmetrical wing

C_L lift coefficient, $\dfrac{lift}{qS}$

C_m pitching-moment coefficient, referred to the projection of the point at $0.21\bar{c}$ onto the body reference center line, $\dfrac{pitching\ moment}{qS\bar{c}}$

$\left(\dfrac{L}{D}\right)_{max}$ maximum lift-drag ratio

M free-stream Mach number

q free-stream dynamic pressure, lb/sq ft

S wing area formed by extending the leading and trailing edges to the vertical plane of symmetry, sq ft

x,y,z   Cartesian coordinates in streamwise, spanwise, and vertical directions, respectively
(The origin is at the wing apex.)

α angle of attack of wing root chord, deg

δ angle of deflection of the canard with respect to the root chord plane of the wing (positive for trailing edge down), deg

APPARATUS AND MODELS

Test Facility

The experimental data were obtained in the Ames 6- by 6-foot supersonic wind tunnel which is a closed-circuit variable-pressure type with a Mach number range continuous from 0.70 to 2.24. The test-section floor and ceiling are perforated to enable uniform flow to be maintained at transonic and low supersonic speeds. A somewhat more detailed description of the facility is presented in reference 1.

Description of Models

The models tested during the investigation consisted of either a symmetrical or cambered triangular wing of aspect ratio 2.0, a low-aspect-ratio vertical tail, and an aspect-ratio-2.0 all-movable triangular canard mounted on a 12.5 fineness ratio Sears-Haack body. The cambered wing tested in the present investigation was identical to the wing of reference 10 having flap No. 1 in the undeflected position. A photograph and dimensional sketch of the cambered wing configuration are shown in figures 1(a) and 1(b), respectively, and the coordinates of the mean camber line are plotted in figure 1(c). It should be noted that the wing had camber only over the outboard 5 percent of the semispan. The wings and vertical tail had standard NACA 0003-63 thickness distributions streamwise, and the constant thickness canard, detailed in figure 1(d), had beveled leading and trailing edges. The canard was pivoted about a hinge line through the 0.35 point of the canard mean aerodynamic chord and was mounted in the extended chord plane of the wing, 1.21 wing mean aerodynamic chords ahead of the reference center of moments ($0.21\bar{c}$). The ratio of the area of the exposed canard panels to the total wing area was 6.9 percent, and the ratio of the total area of the canard to the total area of the wing was 12.9 percent. The wings, canard, and vertical tail were of solid steel construction to minimize aeroelastic effects. The surfaces were polished smooth and further treated to prevent corrosion.

The afterportion of the body was removed, as shown in figure l(b), to accommodate the sting and the internally mounted six-component, electrical, strain-gage-type balance which measured forces and moments on the entire configuration.

TESTS AND PROCEDURES

Range of Test Variables

Experimental data were taken at Mach numbers of 0.70, 0.90, 1.30, 1.70, and 2.22 through an angle-of-attack range from -6° to $+18^\circ$ at a constant Reynolds number of 3.68 million based on the wing mean aerodynamic chord. Data were obtained for the cambered and symmetrical wings with the canard off and with the canard on, set at nominal angles of 0°, 5°, and 10°. (The exact canard deflection angles were 0°, 4.7°, and 9.7°.) Wires were placed on the component parts of the test models at the locations shown in figure l(b) to induce transition.

Reduction of Data

The data presented herein have been reduced to standard coefficient form. The pitching-moment coefficients have been referred to the projection of the 0.21 point of the wing mean aerodynamic chord onto the body reference center line. This location was chosen to give a minimum static margin of $0.03\bar{c}$ in the range of trim lift coefficients between 0 and 0.60 throughout the Mach number range investigated. The experimental results have been adjusted to account for the following effects:

Base drag.- The base pressure was measured and the data were adjusted to correspond to a base pressure equal to the free-stream static pressure.

Stream inclination.- The experimental data were corrected for a stream-angle inclination of less than $\pm0.30^\circ$ which existed through the Mach number range of the tests.

RESULTS AND DISCUSSION

The results of the investigation are presented in figures 2 through 6. Comparisons of the drag, lift, and pitching-moment characteristics, respectively, of the cambered wing with those of the symmetrical wing are

shown in figures 2, 5, and 6 with the canard off and with the canard on deflected at nominal angles of 0°, 5°, and 10°. Selected data summarizing the effects of the canard on the drag characteristics of the symmetrical and cambered wings are shown in figures 3 and 4.

The results of figure 2 which compare the drag characteristics of the symmetrical and cambered wings with and without the canard show that at the high subsonic speeds the reductions in drag due to camber were substantially less with the canard on than with the canard off. These data also show that the drag reductions due to camber were, generally, further decreased in the range of lift coefficients near those for maximum lift-drag ratio as the canard was deflected. At the supersonic speeds, the small increase in drag coefficient resulting from camber was essentially the same with the canard on or off. Cross plots of the results of figure 2 showing the drag increment above or below that of the symmetrical wing achieved by the cambered wing with the canard off and with the canard on are shown in figure 3. These data reveal that the adverse effect of the canard on the drag reductions resulting from camber at the high subsonic speeds persisted throughout the lift-coefficient range of the tests.

To illustrate further the influence of the canard on the drag characteristics, figure 4 presents the maximum lift-drag ratios of the symmetrical and cambered wings with the canard on and off. These data show that at the high subsonic speeds the increment in maximum lift-drag ratio due to camber is reduced considerably with the addition of the canard. At a Mach number of 0.90, for example, the gain in maximum lift-drag ratio due to camber with the canard on was only about half that obtained with the canard off. An inspection of the data shows that this results primarily from the fact that the canard has a large adverse effect on the drag characteristics of the cambered wing. This suggests that the canard interference effects may be influencing those pressures in the vicinity of the wing leading edge from which the cambered wing develops its effective thrust force and hence high lift-drag ratio. At supersonic speeds the addition of the canard did not change the effect of camber on the maximum lift-drag ratio. The results of figures 5 and 6 show that the addition of the canard to either the symmetrical or cambered wing had the same effect on the lift and pitching-moment characteristics.

CONCLUSIONS

An experimental investigation was conducted to determine the effect of a canard control on the lift, drag, and pitching-moment characteristics of an aspect-ratio-2.0 triangular wing incorporating a form of conical camber. The results of this study show that at the high subsonic speeds

6

the gain in maximum lift-drag ratio achieved by camber is considerably
reduced by the addition of a canard. At the supersonic speeds, the
addition of the canard does not change the effect of camber on the
maximum lift-drag ratios.

Ames Research Center
        National Aeronautics and Space Administration
                Moffett Field, Calif., Feb. 18, 1959

REFERENCES

1. Boyd, John W., and Peterson, Victor L.: Static Stability and Con-
        trol of Canard Configurations at Mach Numbers From 0.70 to 2.22 -
        Longitudinal Characteristics of a Triangular Wing and Canard.
        NACA RM A57J15, 1958.

2. Peterson, Victor L., and Menees, Gene P.: Static Stability and Con-
        trol of Canard Configurations at Mach Numbers From 0.70 to 2.22 -
        Lateral-Directional Characteristics of a Triangular Wing and Canard.
        NACA RM A57L18, 1958.

3. Boyd, John W., and Peterson, Victor L.: Static Stability and Control
        of Canard Configurations at Mach Numbers From 0.70 to 2.22 -
        Triangular Wing and Canard on an Extended Body. NACA RM A57K14,
        1958.

4. Peterson, Victor L., and Menees, Gene P.: Static Stability and
        Control of Canard Configurations at Mach Numbers From 0.70 to 2.22 -
        Longitudinal Characteristics of a Triangular Wing and Unswept Canard.
        NACA RM A57K26, 1958.

5. Peterson, Victor L., and Boyd, John W.: Static Stability and Control
        of Canard Configurations at Mach Numbers From 0.70 to 2.22 - Longi-
        tudinal Characteristics of an Unswept Wing and Canard. NACA
        RM A57K27, 1958.

6. Hedstrom, C. Ernest, Blackaby, James R., and Peterson, Victor L.:
        Static Stability and Control Characteristics of a Triangular Wing
        and Canard Configuration at Mach Numbers From 2.58 to 3.53. NACA
        RM A58C05, 1958.

7. Peterson, Victor L.: Static Stability and Control of Canard Configu-
        rations at Mach Numbers From 0.70 to 2.22 - Lateral-Directional
        Characteristics of an Unswept Wing and Canard. NASA MEMO 4-20-59A,
        1959.

8. Boyd, John W., and Menees, Gene P.: Longitudinal Stability and
    Control Characteristics at Mach Numbers From 0.70 to 2.22 of a
    Triangular Wing Configuration Equipped With a Canard Control, a
    Trailing-Edge-Flap Control, and a Cambered Forebody. NASA
    MEMO 4-21-59A, 1959.

9. Hall, Charles F., and Boyd, John W.: Effects of Canards on Airplane
    Performance and Stability. NACA RM A58D24, 1958.

10. Menees, Gene P.: Lift, Drag, and Pitching Moment of an Aspect-Ratio-2
    Triangular Wing With Leading-Edge Flaps Designed to Simulate Conical
    Camber. NASA MEMO 10-5-58A, 1958.
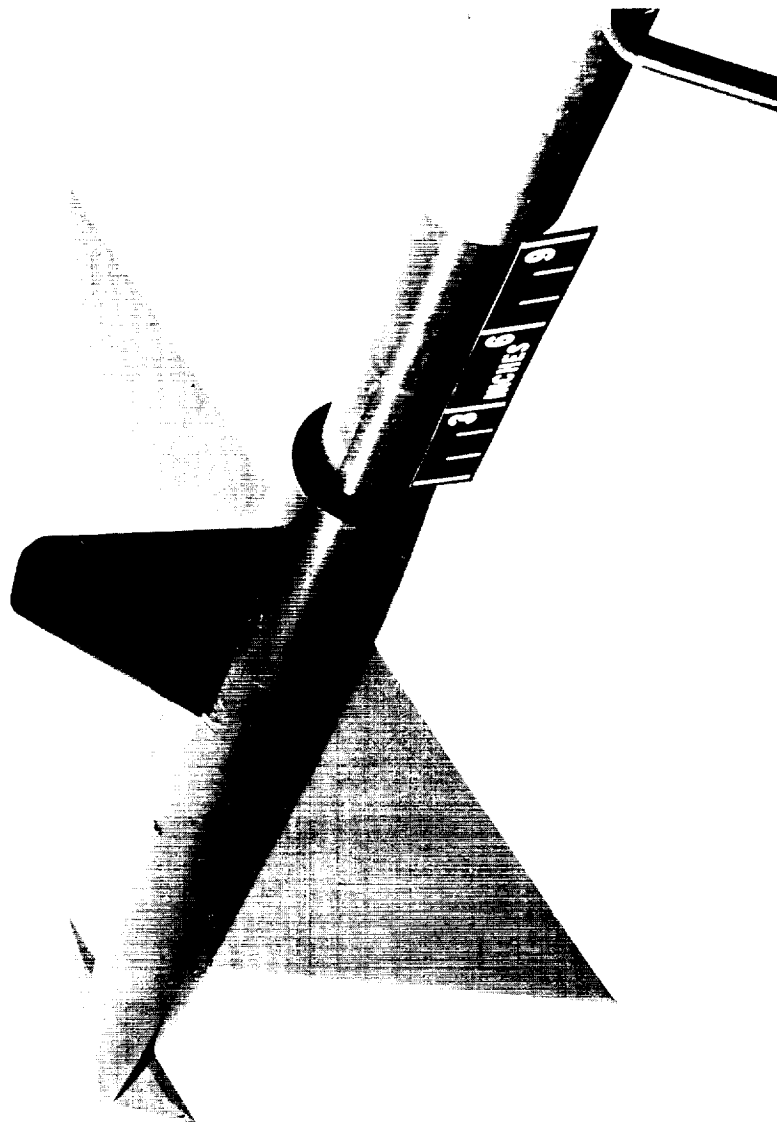
(a) Photograph of the model with the cambered wing.

Figure 1.- Model details and dimensions.

A-24537

10

Equation of fuselage ordinates

$$r = r_0 \left[1 - \left(1 - \frac{2x}{l} \right)^2 \right]^{\frac{3}{4}}$$

2646

1.33

0.010 diameter transition wire

$\bar{c} = 17.68$

$r_0 = 2.38$

Center of moments

26.46

63°26'

28.39

0.50

Hinge line

7.00

0.005 diameter transition wire

15.85

9.90

3.14

0.005 diameter transition wire

56°30'

9.50

36.25

46.90

$l = 59.50$

x

r

All dimensions in inches
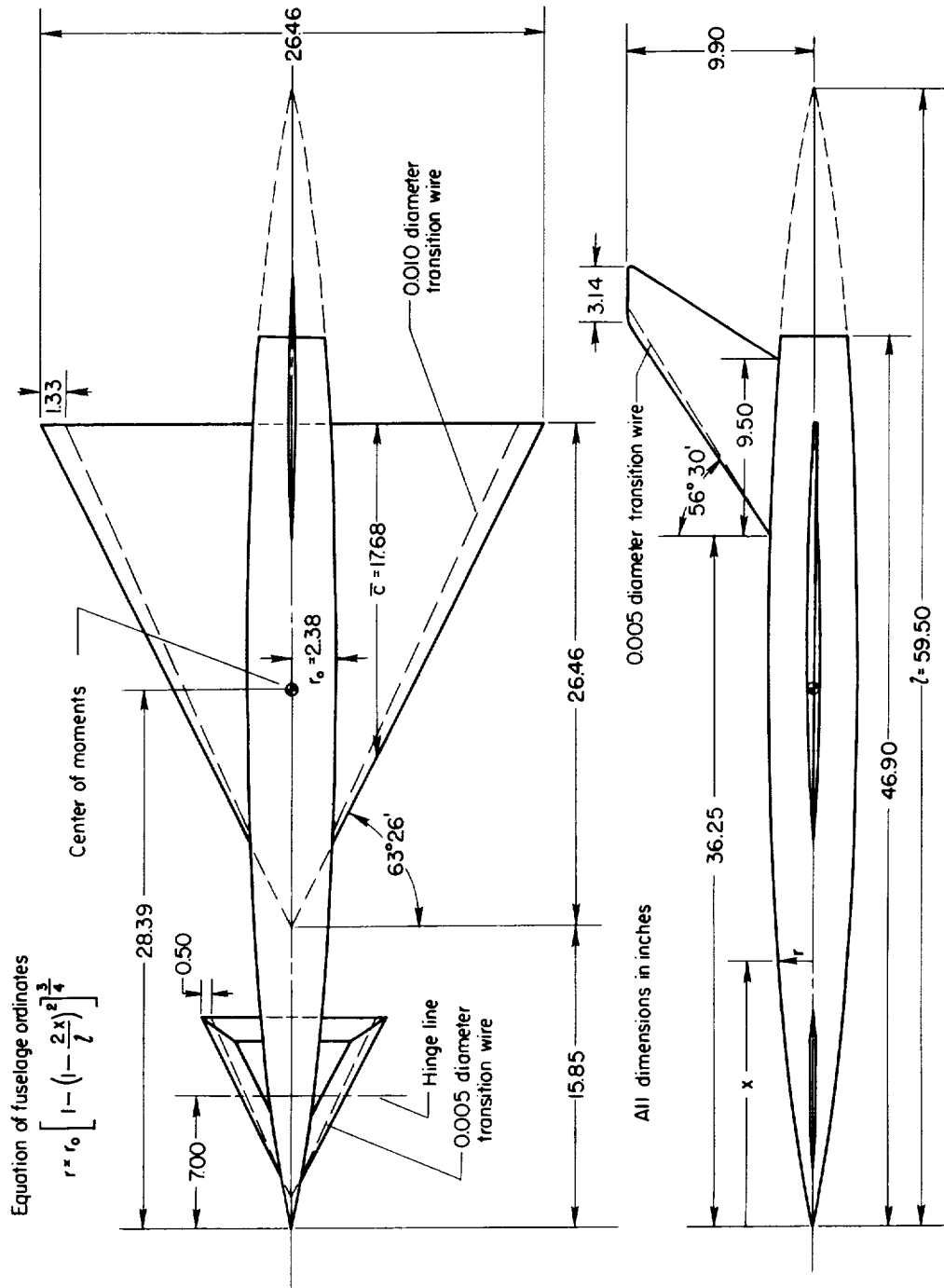
(b) Dimensional sketch of model with the cambered wing.

Figure 1.- Continued.
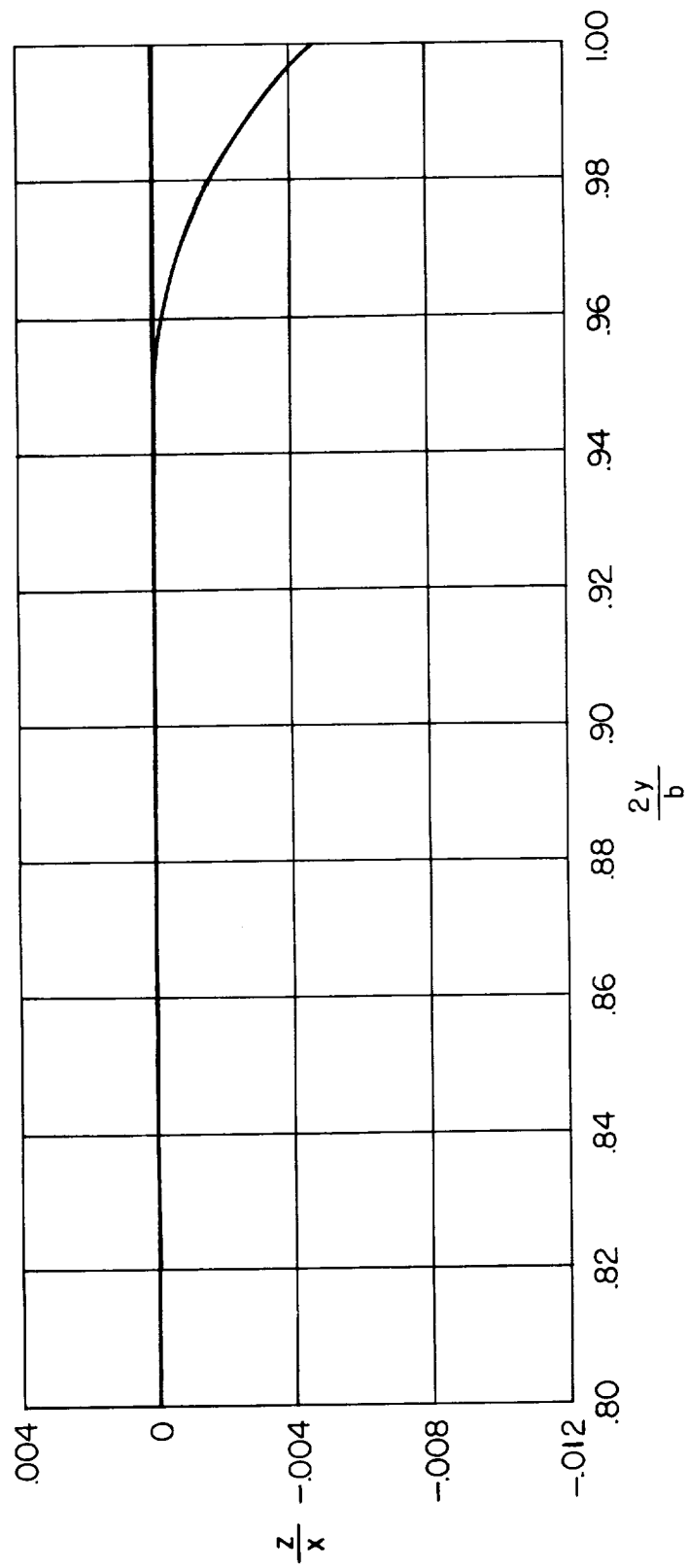
(c) Coordinates of mean camber line.

Figure 1.- Continued.
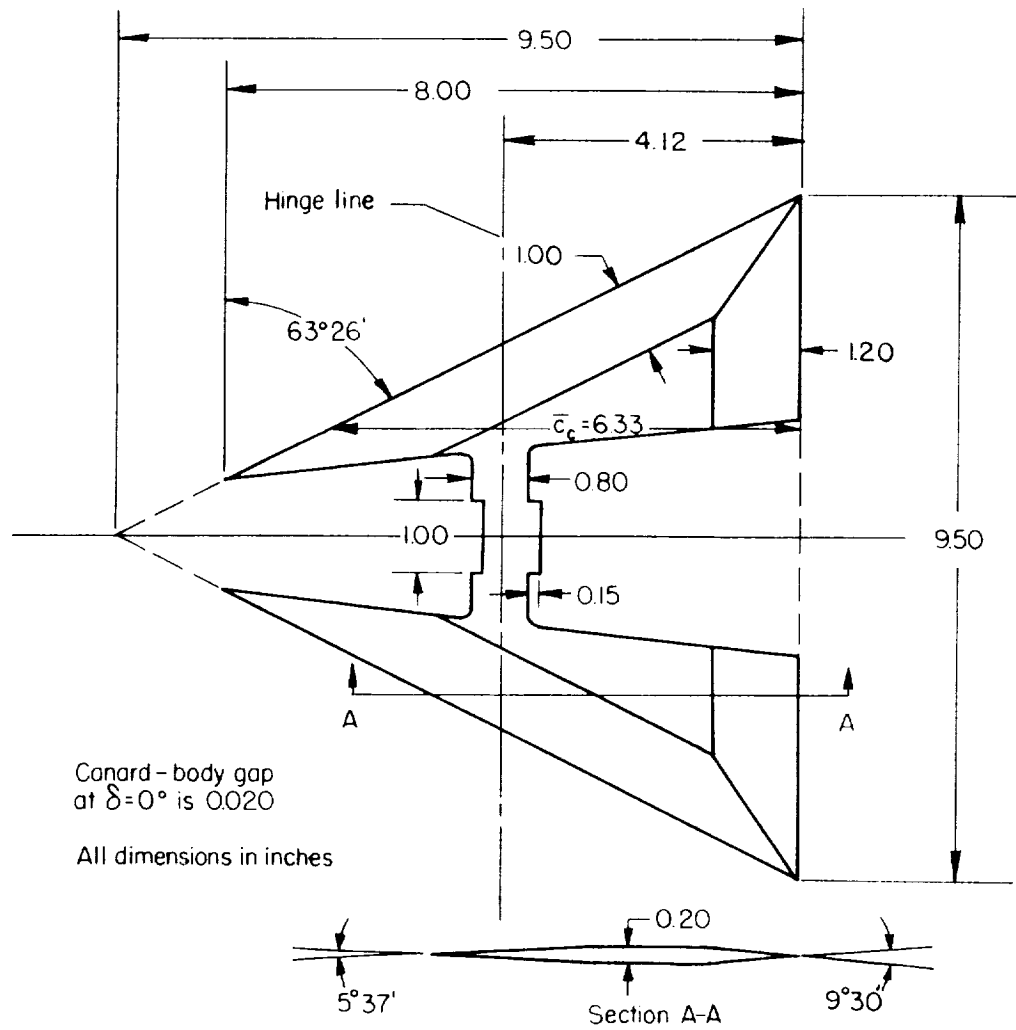
(d) Details of the canard.

Figure 1.- Concluded.
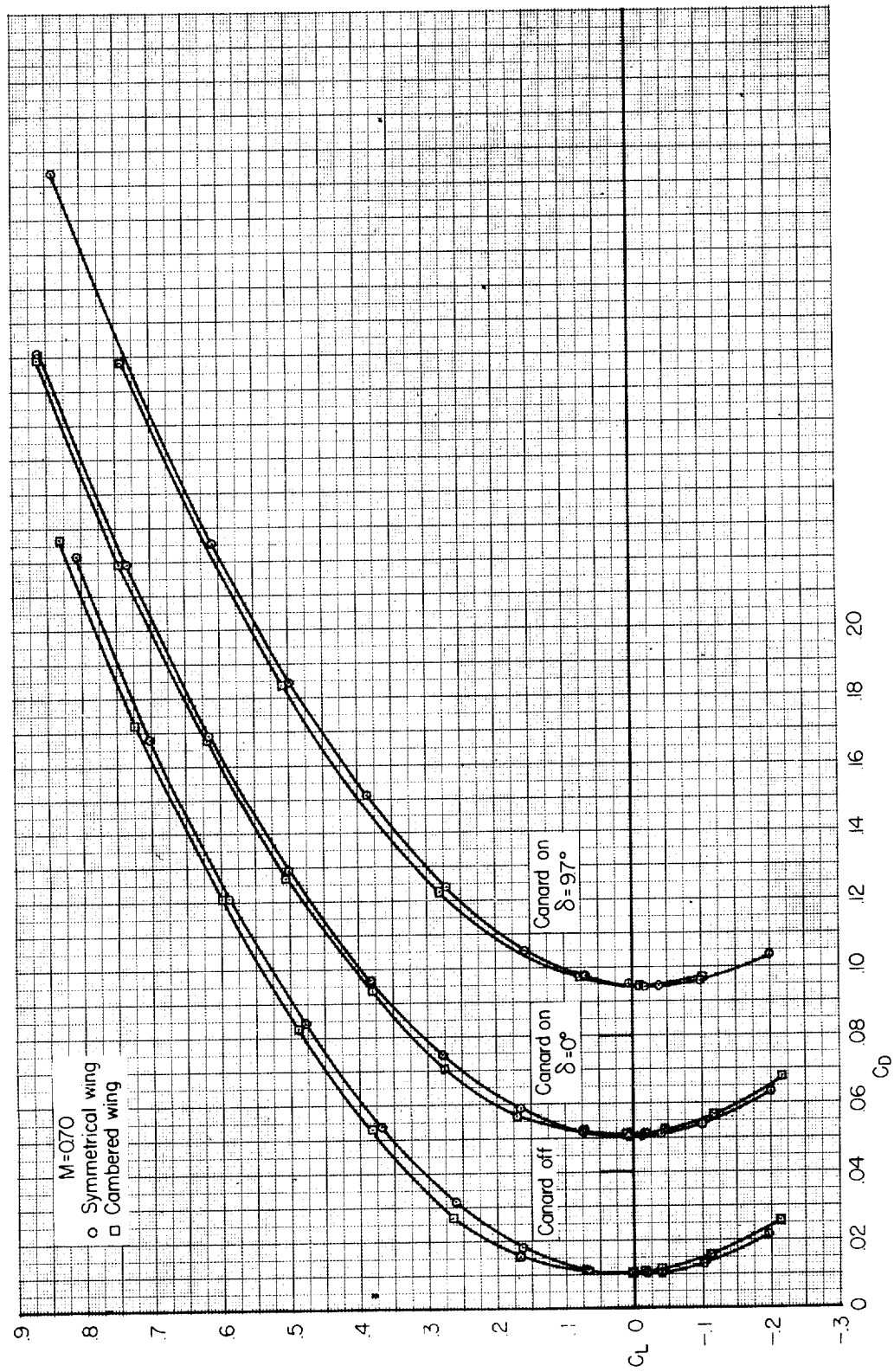
(a) M = 0.70

Figure 2.- Variation of drag coefficient with lift coefficient.
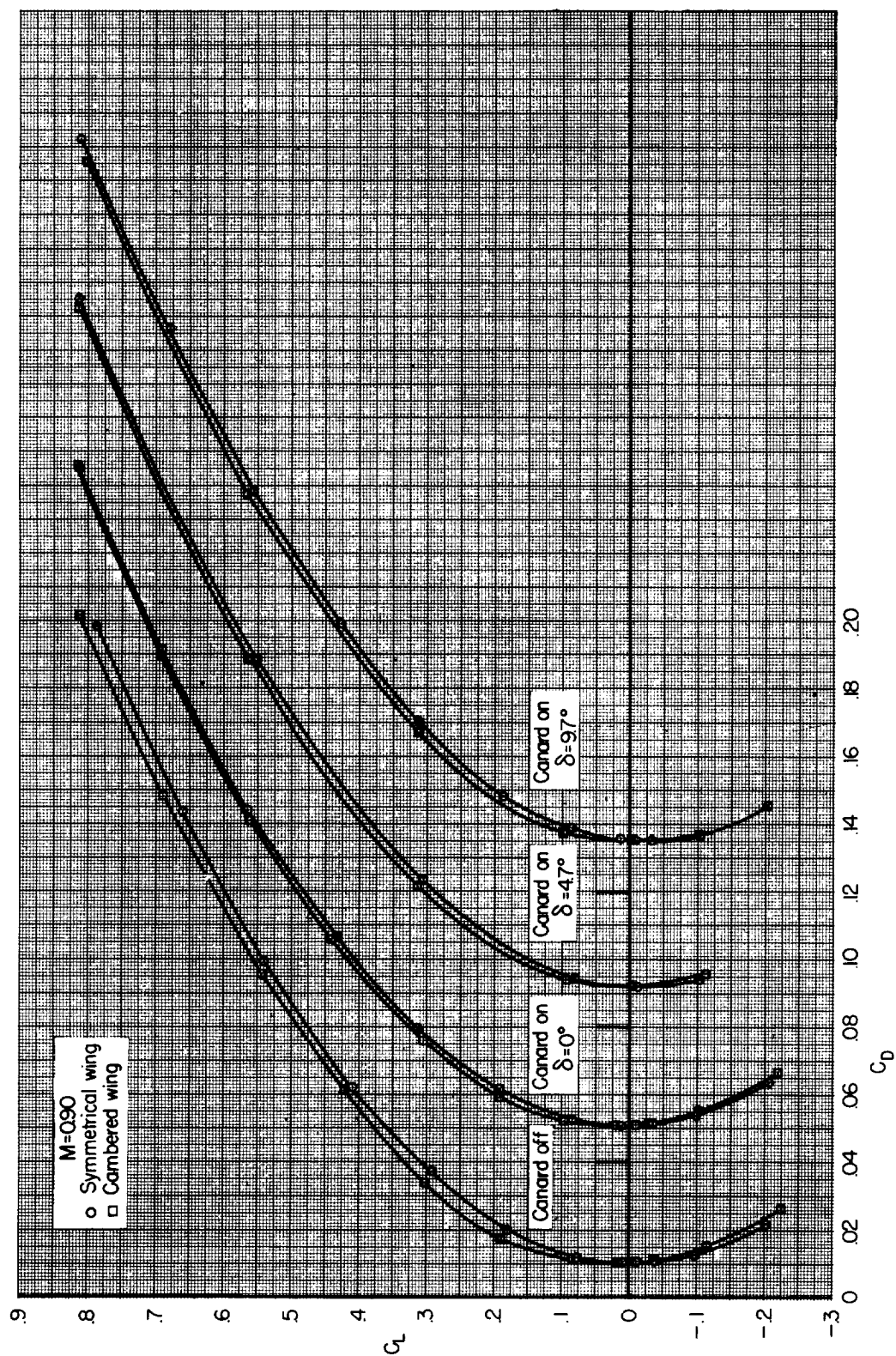
(b) M = 0.90

Figure 2.- Continued.
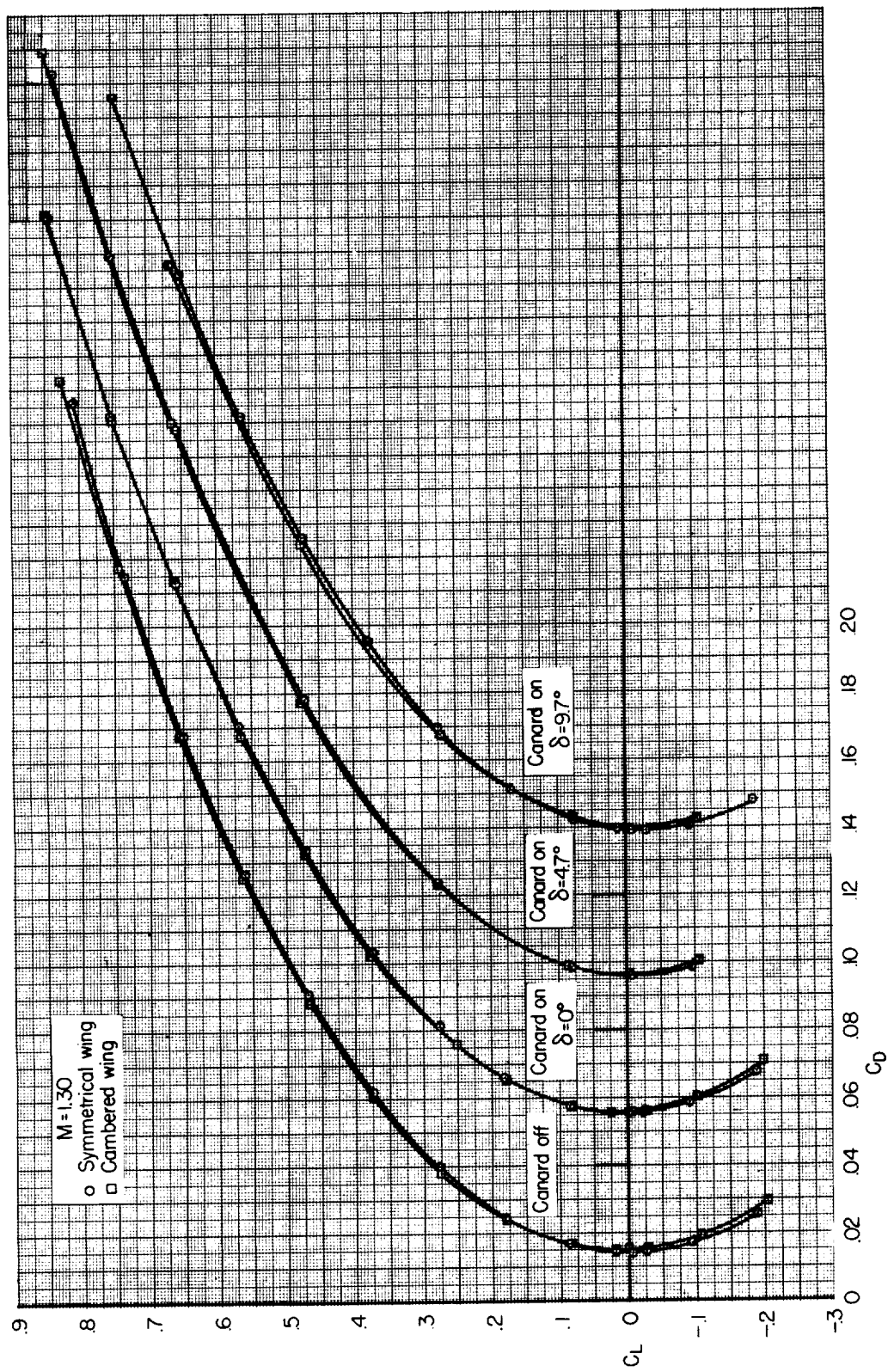
(c) M = 1.30

Figure 2.- Continued.
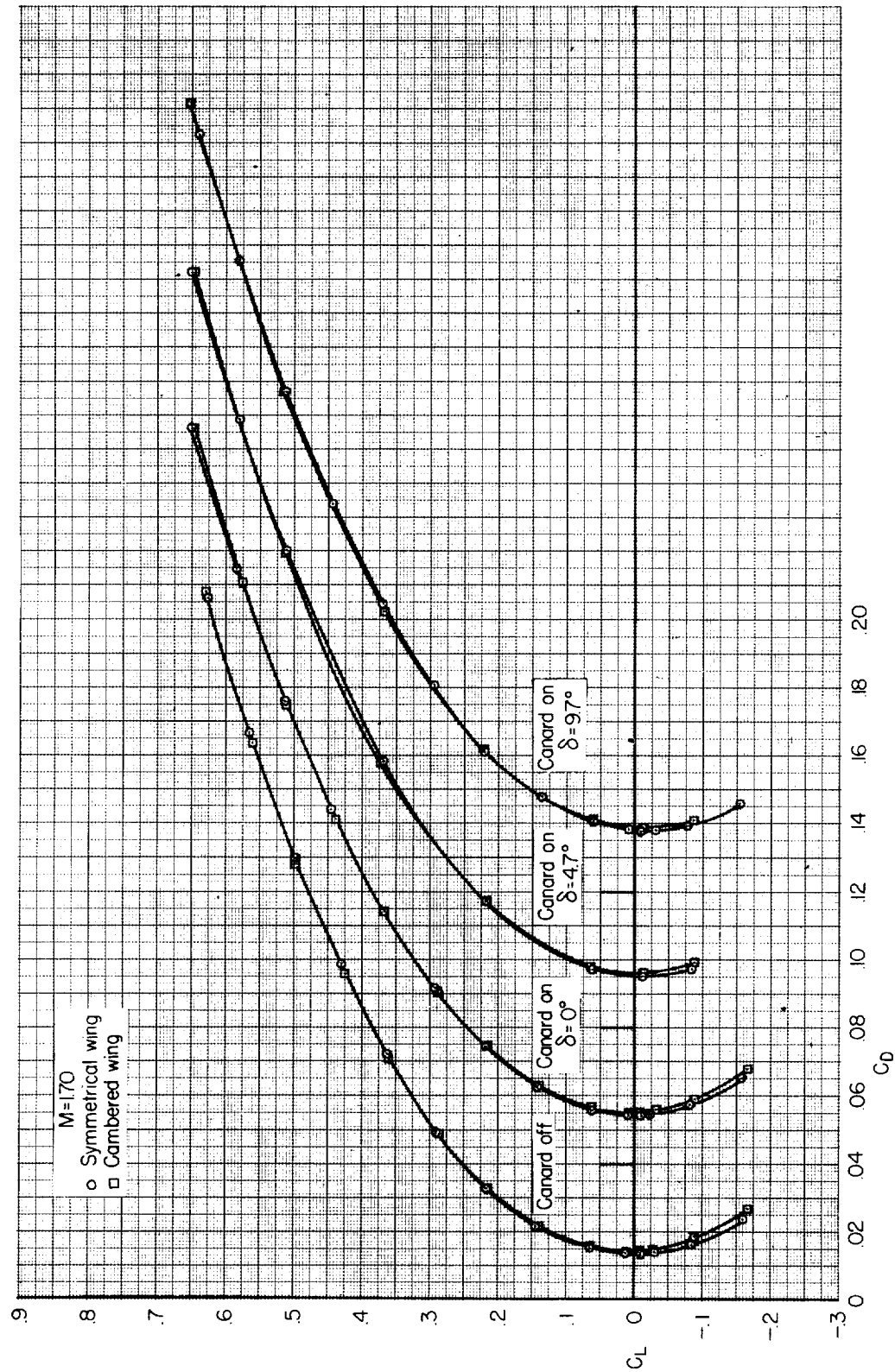
(d) M = 1.70

Figure 2.- Continued.
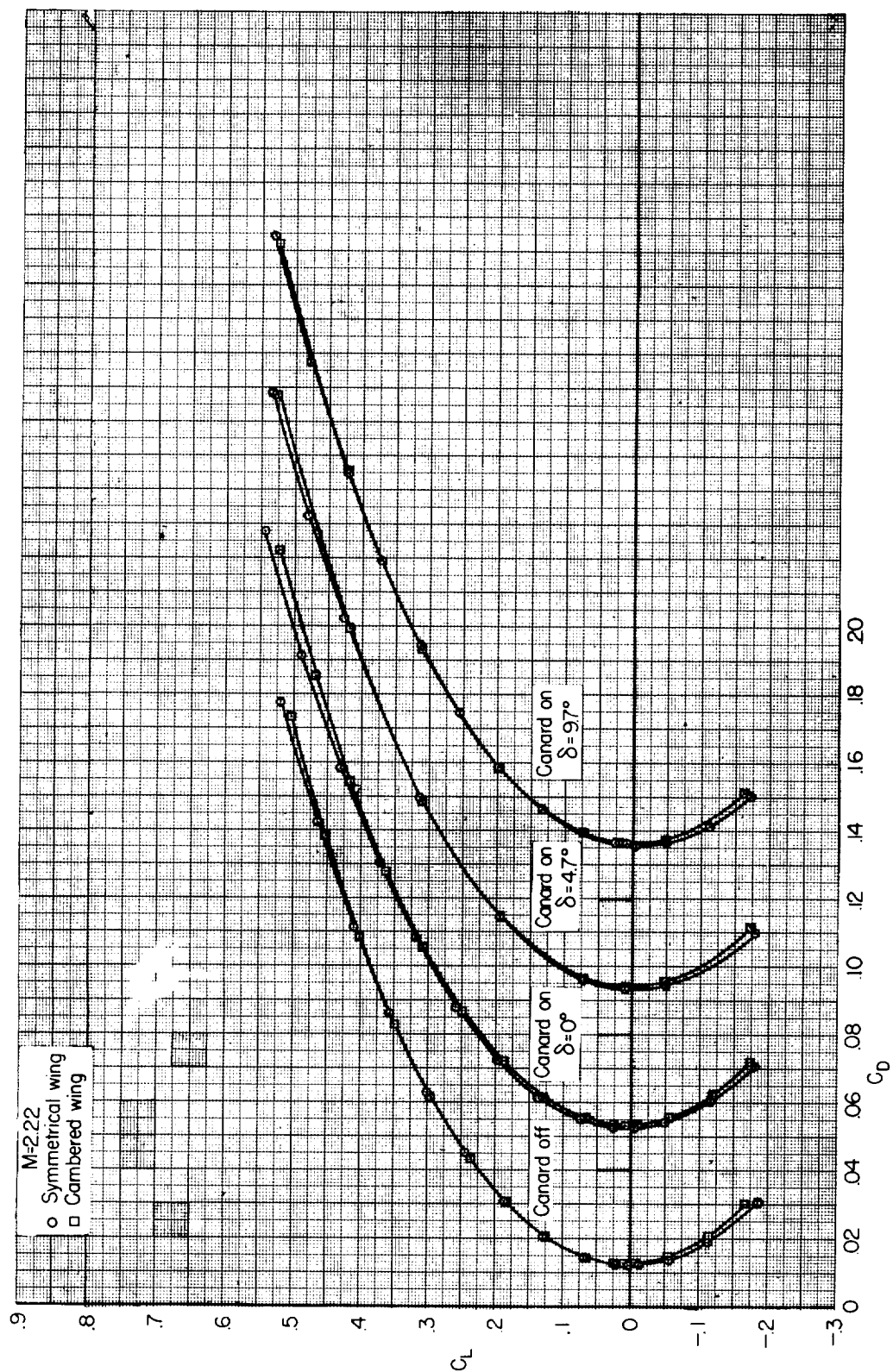
(e) M = 2.22

Figure 2.- Concluded.
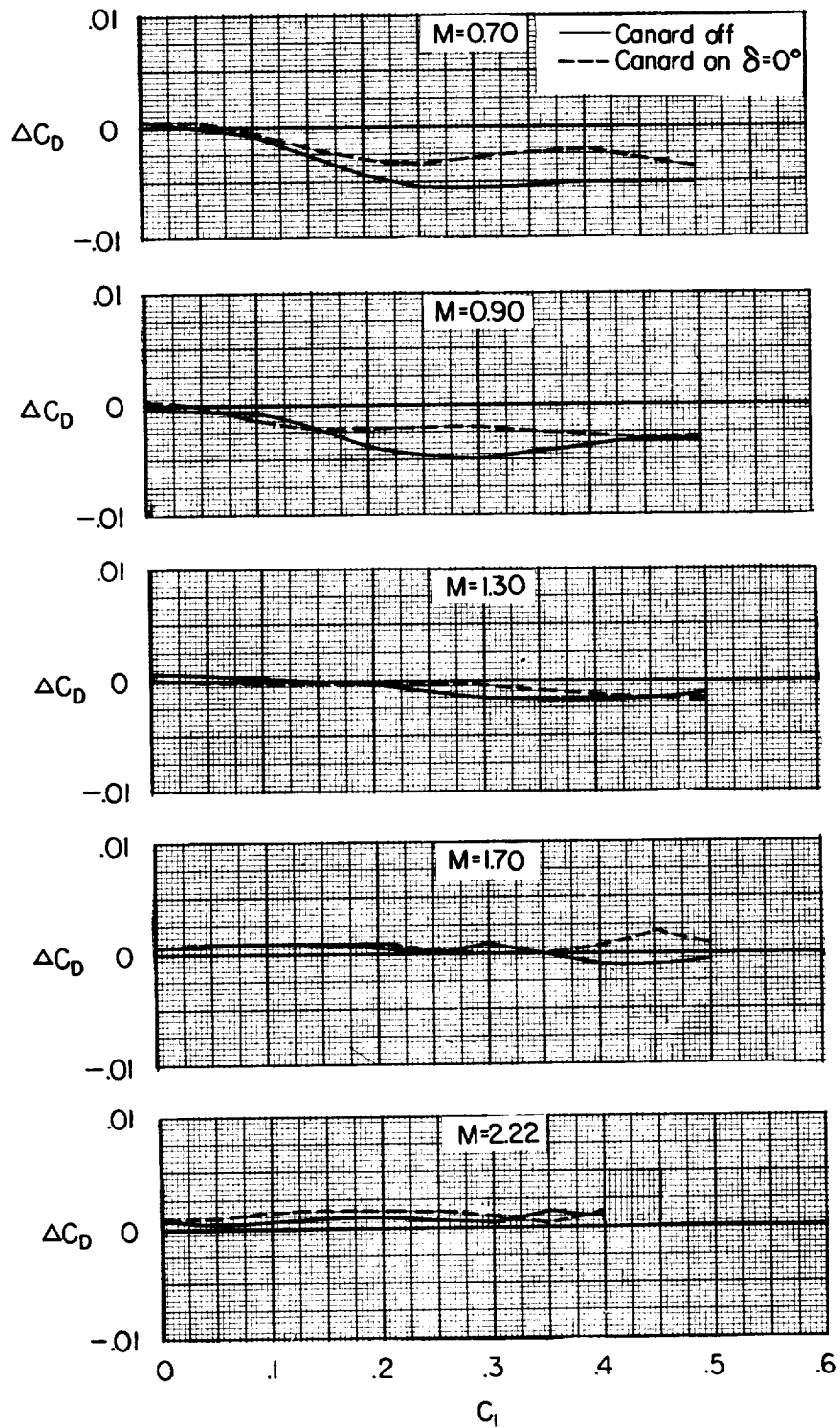
Figure 3.- Variation of drag-coefficient increment due to camber with lift coefficient.
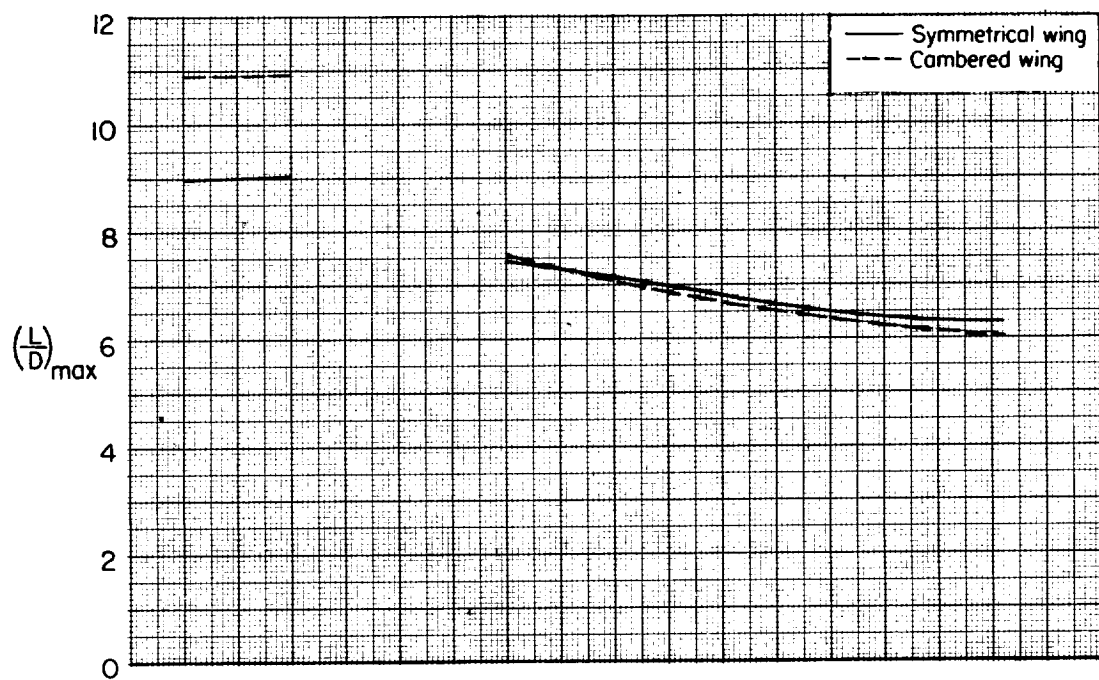
(a) Canard off.
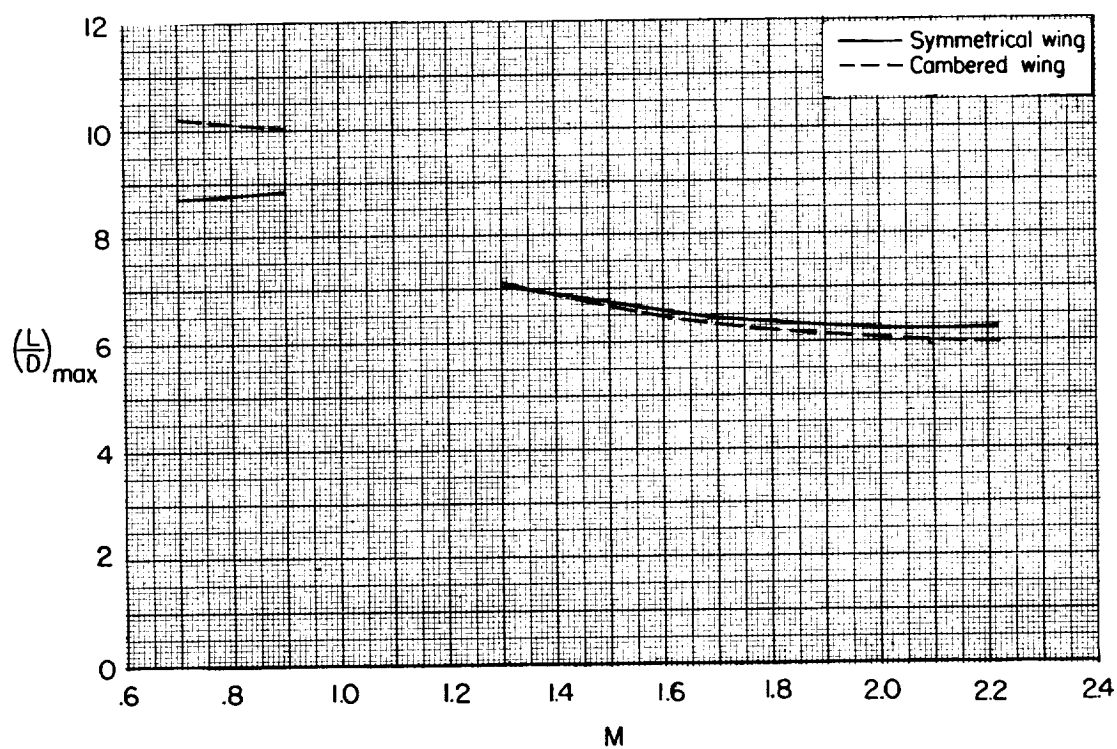
(b) Canard on; $\delta = 0^{\circ}$.

Figure 4.- Variation of maximum lift-drag ratio with Mach number.
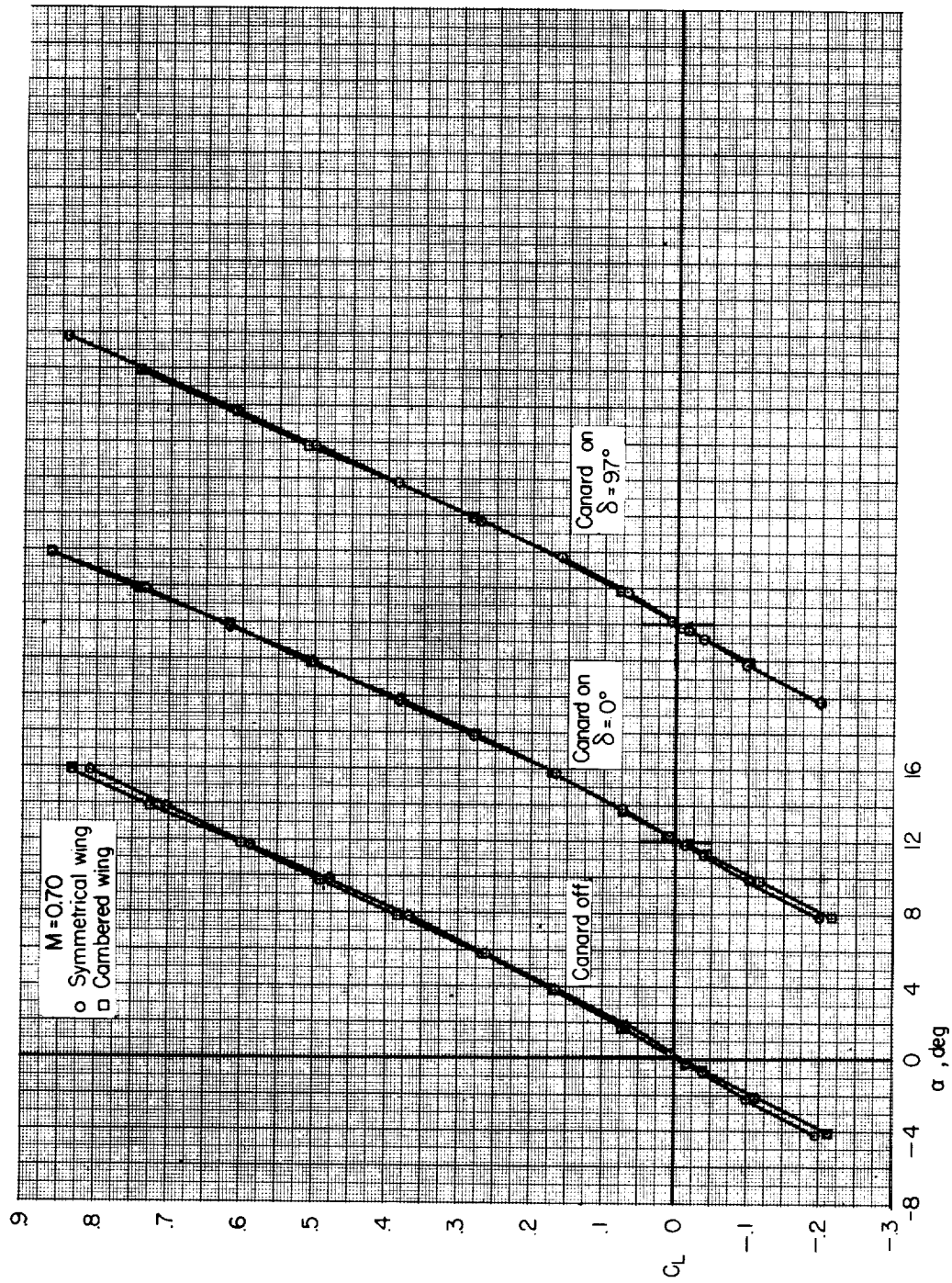
(a) M = 0.70

Figure 5.- Variation of lift coefficient with angle of attack.

21
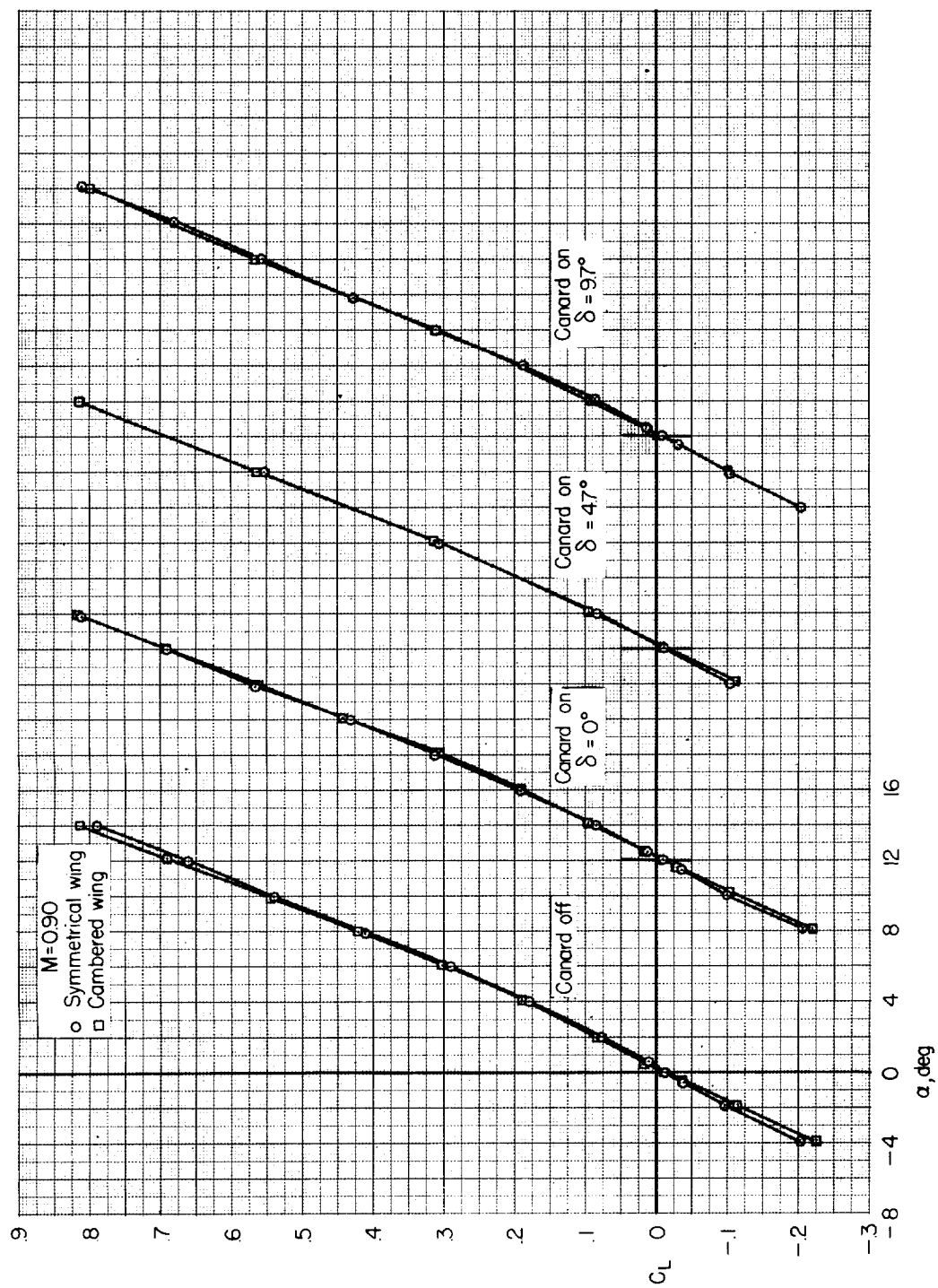
(b) M = 0.90

Figure 5.- Continued.
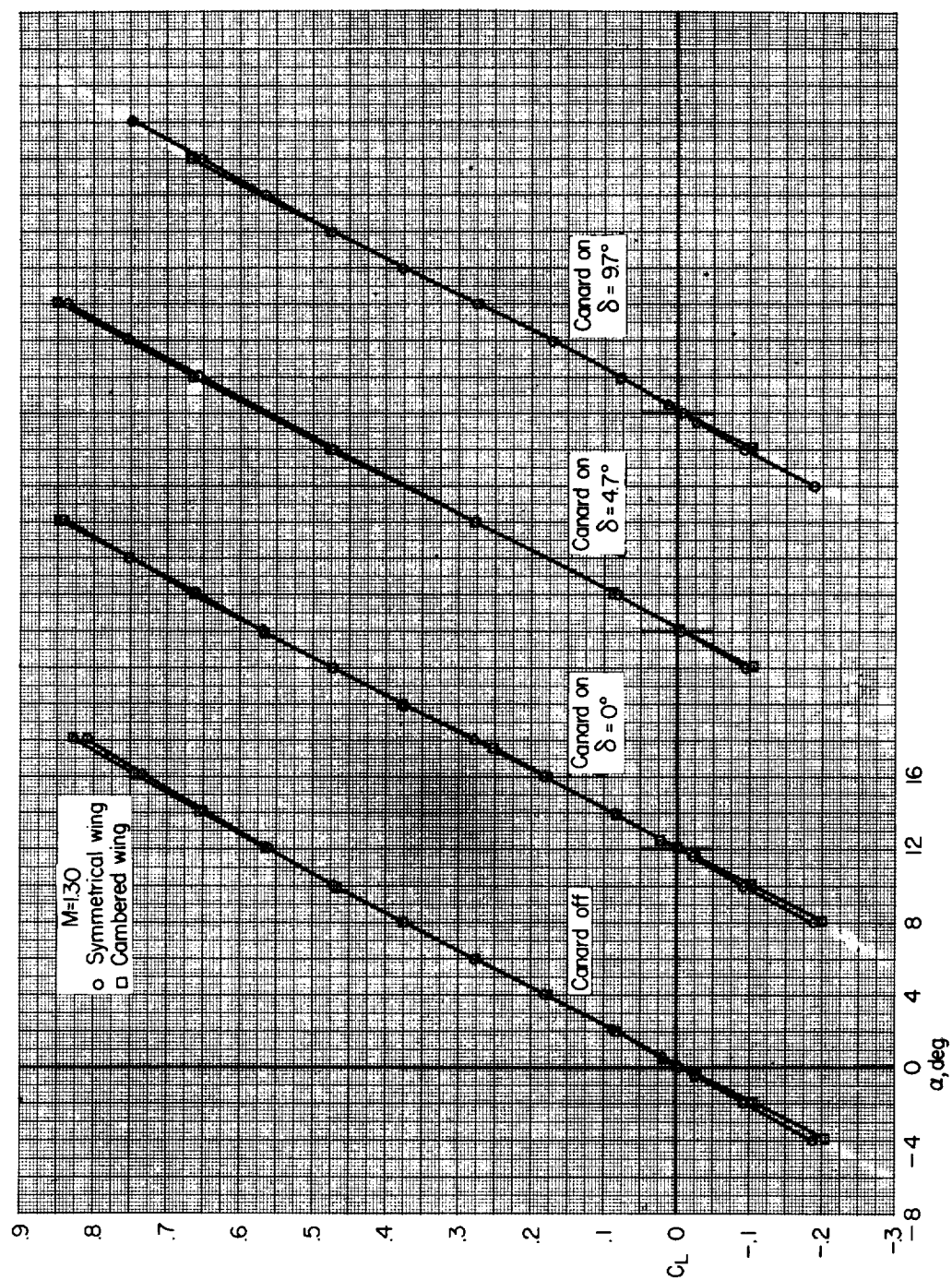
(c) M = 1.30

Figure 5.- Continued.

23
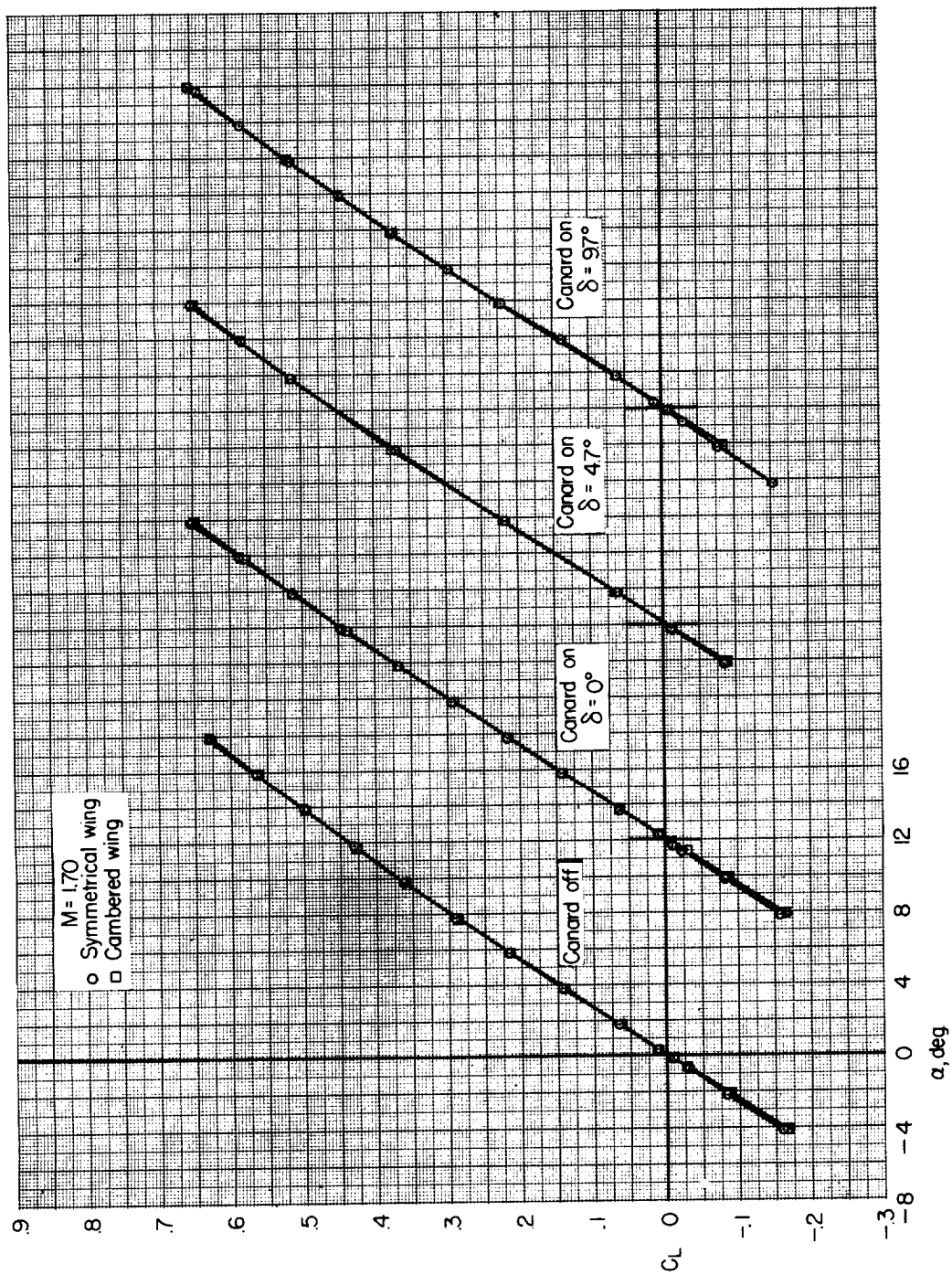
(d) M = 1.70

Figure 5.- Continued.
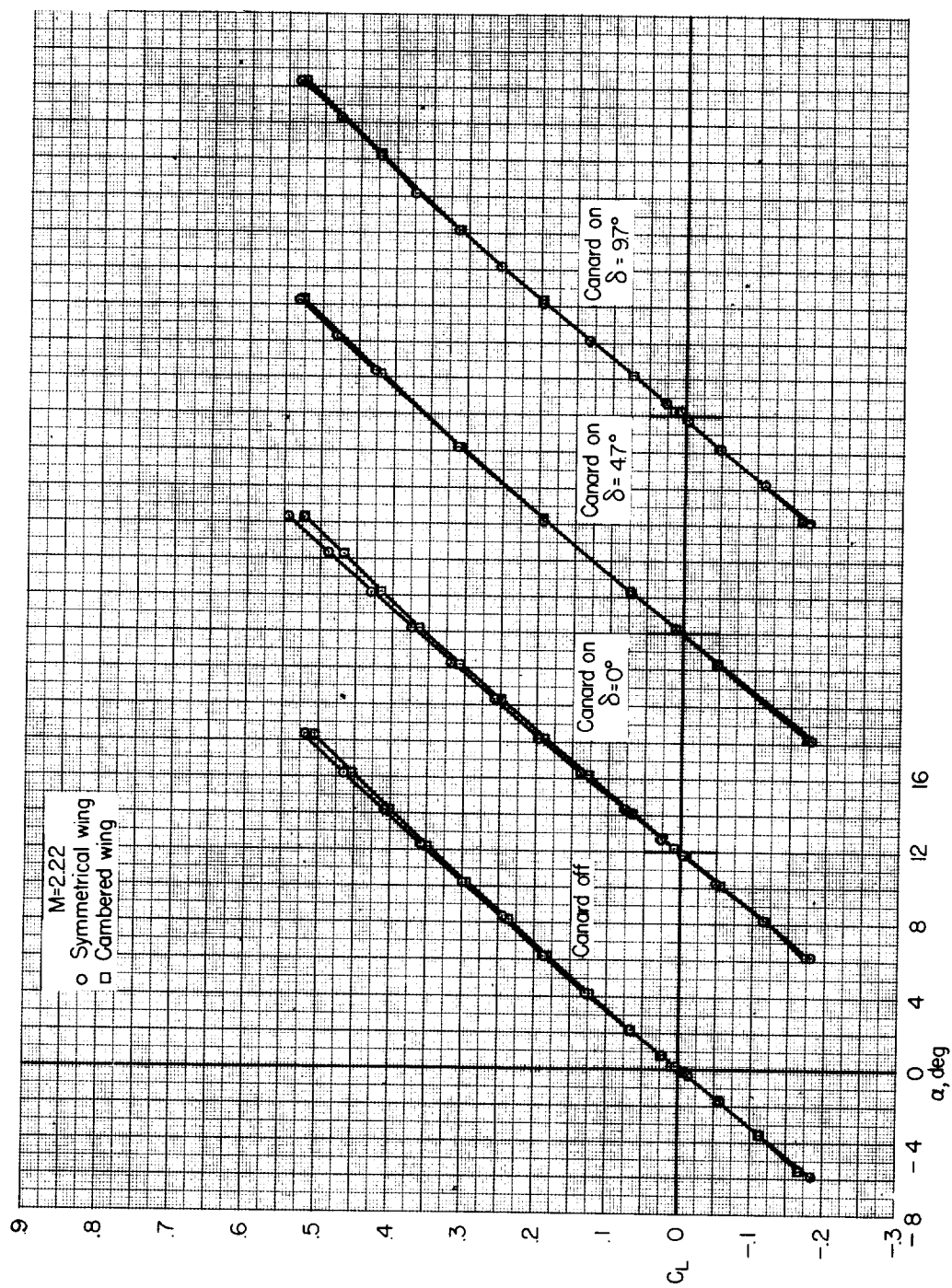
(e) M = 2.22

Figure 5.- Concluded.
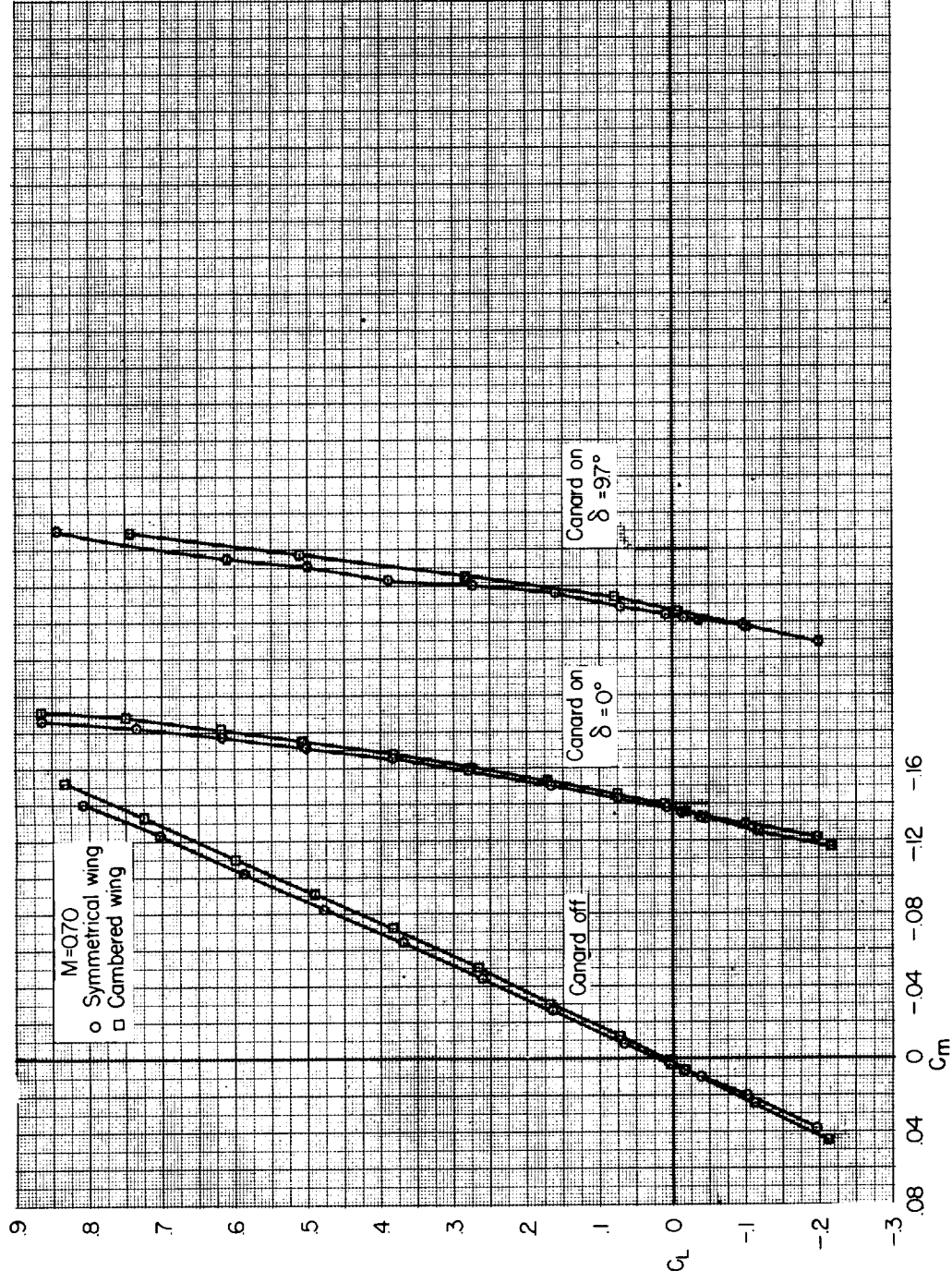
(a) M = 0.70

Figure 6.- Variation of pitching-moment coefficient with lift coefficient.
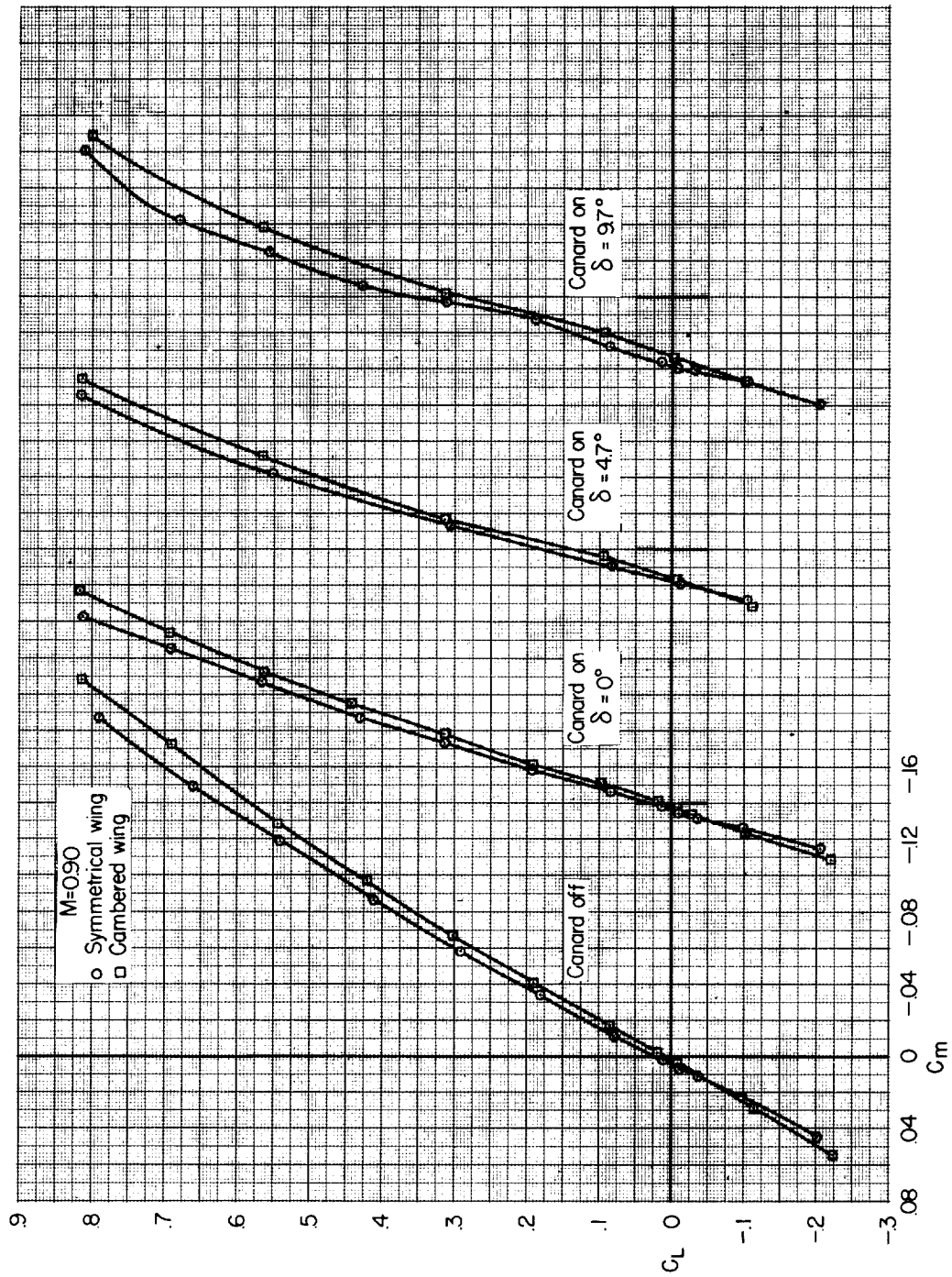
(b) M = 0.90

Figure 6.- Continued.
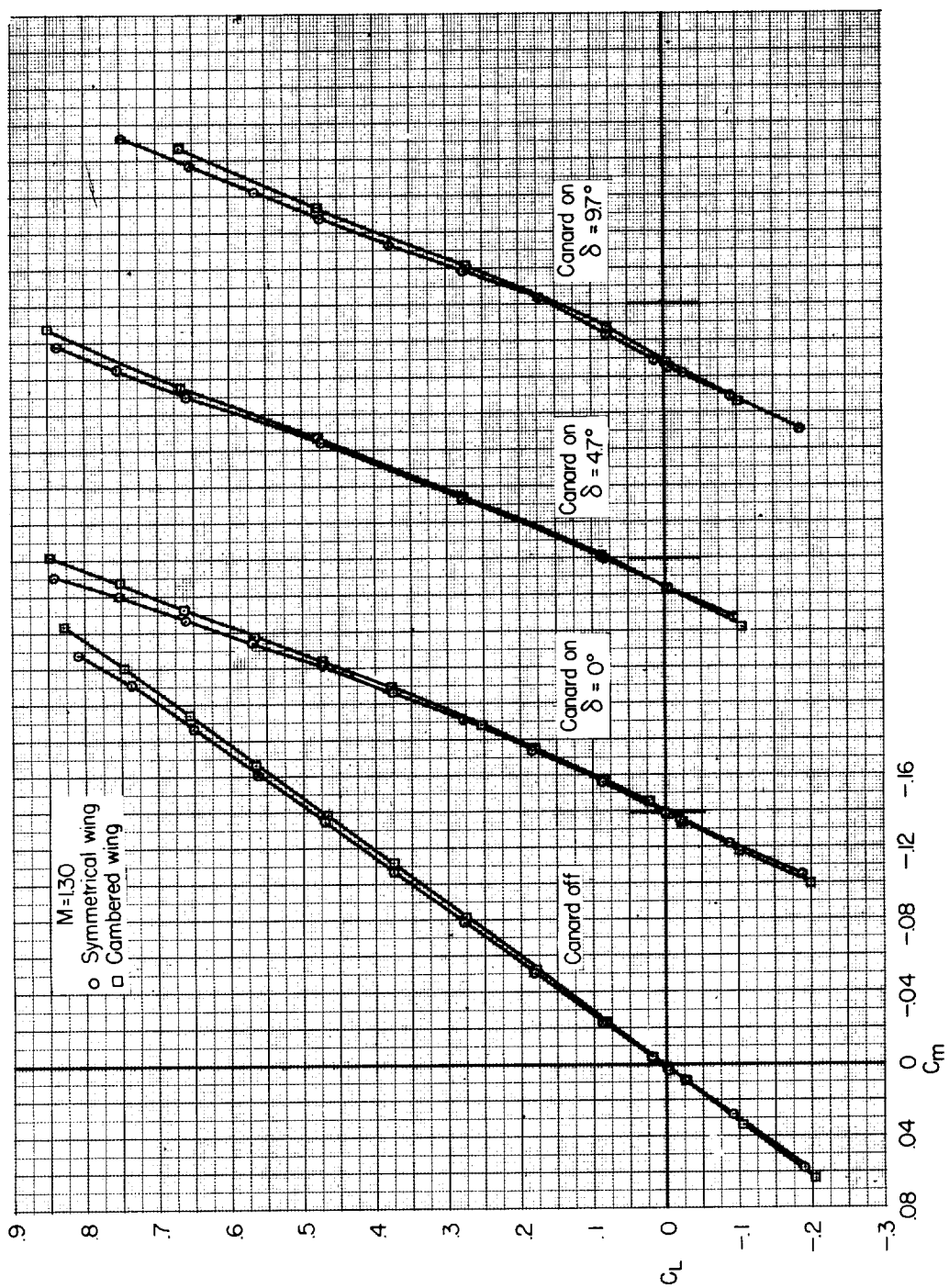
(c) M = 1.30

Figure 6.- Continued.

28
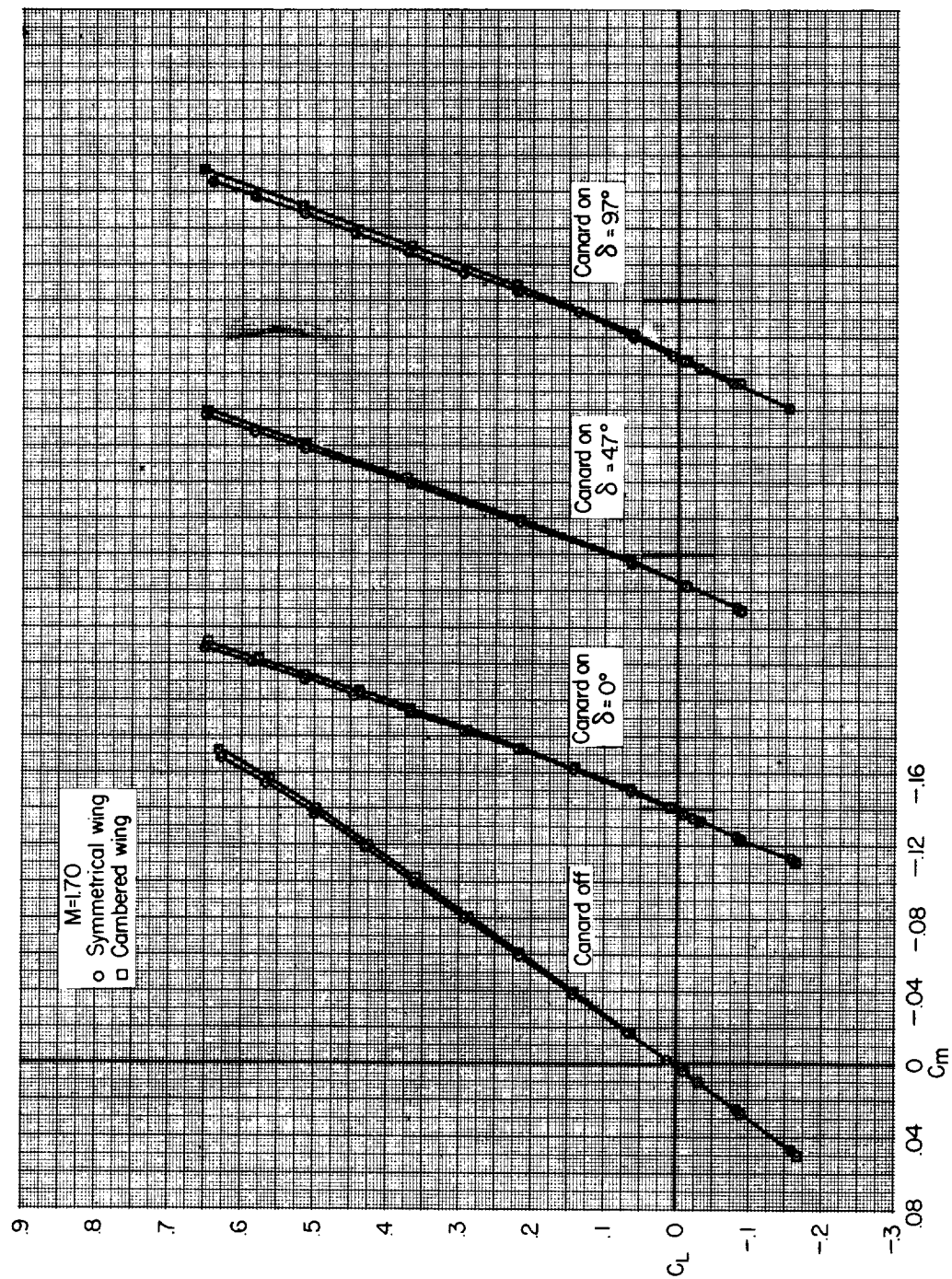
(d) M = 1.70

Figure 6.- Continued.
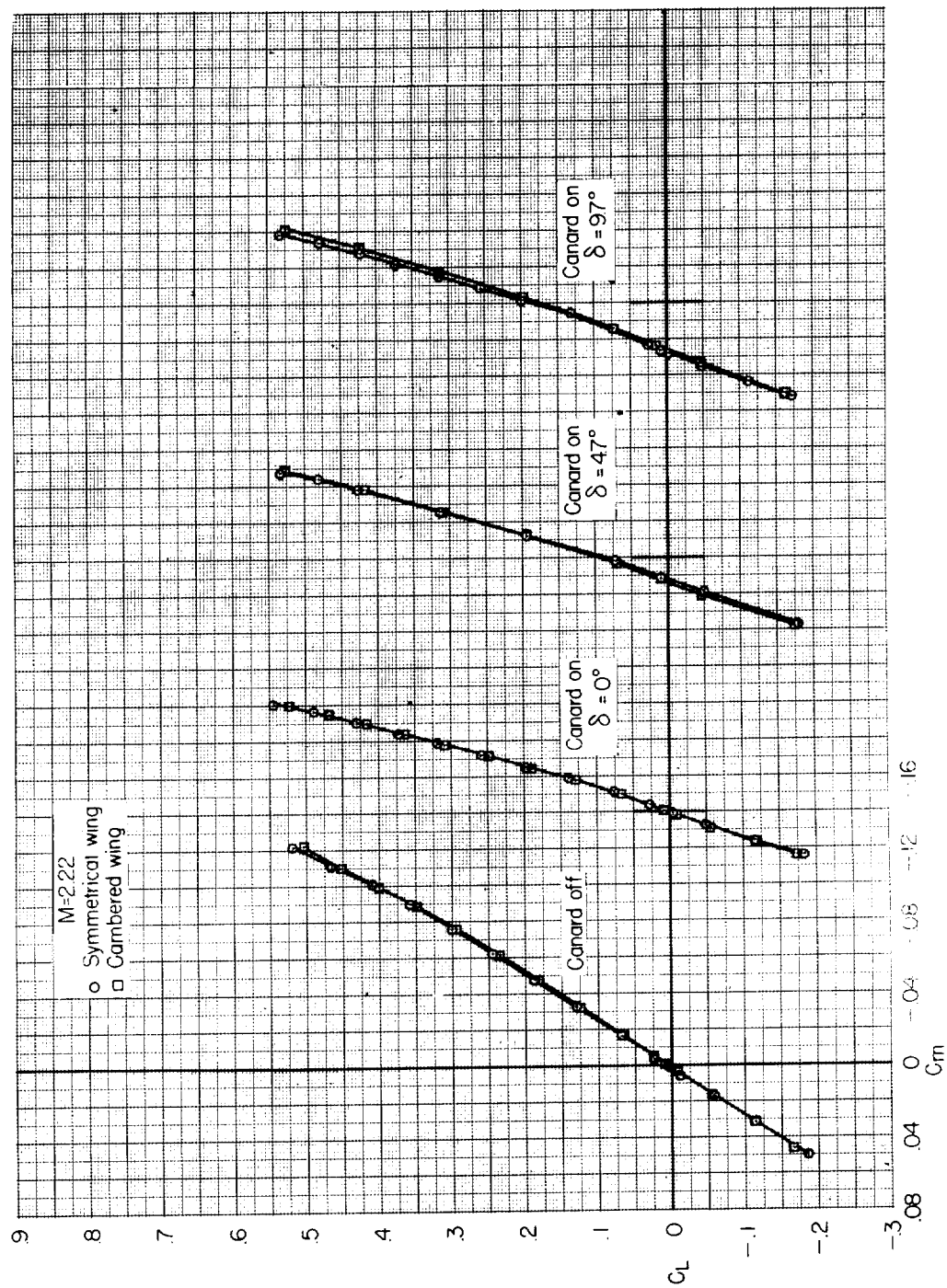
(e) M = 2.22

Figure 6.- Concluded.

NASA MEMO 5-20-59A

National Aeronautics and Space Administration.
AN EXPERIMENTAL INVESTIGATION OF THE
EFFECT OF A CANARD CONTROL ON THE LIFT,
DRAG, AND PITCHING MOMENT OF AN ASPECT-
RATIO-2.0 TRIANGULAR WING INCORPORATING A
FORM OF CONICAL CAMBER. Gene P. Menees
and John W. Boyd. May 1959. 29p. diagrs., photo.
(NASA MEMORANDUM 5-20-59A)
                    (Title, Unclassified)

The hinge line of the aspect-ratio-2.0 triangular
canard was in the extended chord plane of the wing,
and the ratio of the area of the exposed canard panels
to the total wing area was 6.9 percent. Data were
taken at Mach numbers of 0.70 to 2.22 through an
angle-of-attack range from -6° to +18° with the
canard set at nominal angles of 0°, 5°, and 10° and
with the canard off. The canard was also tested
with a symmetrical wing to provide a basis for
comparison.

Copies obtainable from NASA, Washington

1. Wing Sections -
     Camber   (1.2.1.2.1)
2. Mach Number Effects -
     Complete Wings
                    (1.2.2.6)
3. Airplanes - Components
     in Combination (1.7.1.1)
4. Control, Longitudinal
                    (1.8.2.1)
I.   Menees, Gene P.
II. Boyd, John W.
III. NASA MEMO 5-20-59A

                    NASA