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TECHNICAL MEMORANDUM

X-568

SUPERSONIC AERODYNAMIC CHARACTERISTICS OF TRIANGULAR PLAN-FORM MODELS AT ANGLES OF ATTACK TO 90°

By Lyle E. Wiggins and George E. Kaattari

Ames Research Center
Moffett Field, Calif.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON July 1961

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-568

SUPERSONIC AERODYNAMIC CHARACTERISTICS OF TRIANGULAR PLAN-FORM MODELS AT ANGLES OF ATTACK TO 90°*

By Lyle E. Wiggins and George E. Kaattari

SUMMARY

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Results are presented of an investigation of a family of triangular plan-form models with 75° swept leading edges tested through the angle-of-attack range -5° to +90° at Mach numbers of 2.94, 3.87, and 4.78 at Reynolds number 1.06×10^6. The results are in the form of aerodynamic lift, drag, and pitching-moment coefficients, and lift-drag ratios. Effects of apex bluntness and cross-sectional shape on the models are considered. Aerodynamic coefficients for a slab model with tip controls and trailing-edge flaps and for a modified elliptic cone model with tip controls are also presented.

Author

INTRODUCTION

It has been shown in references 1 and 2 that the use of lift during entry of a planetary atmosphere can reduce guidance requirements, extend range, and provide a maneuvering capability. Configurations of triangular plan-form which provide lift during atmosphere entry have been proposed and investigated in references 3 to 8. Additional experimental data are required for such vehicles, however, to determine the effects of cross-sectional shape, apex bluntness, control size, and control location on the aerodynamic performance, stability, and control characteristics over a wide range of angles of attack. It is the purpose of this report to provide some of the needed data. Longitudinal force and moment data are presented for the angle-of-attack range -5° to +90°, for Mach numbers of 2.94, 3.87, and 4.78, and a Reynolds number of 1.06×10^6 based on vehicle length. Estimated aerodynamic coefficients of the vehicles are compared with experimental values.

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*Title, Unclassified

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SYMBOLS

$\frac{a}{b}$ ratio of major to minor semiaxes of elliptic cone

C_L lift coefficient, $\frac{\text{lift}}{qS}$

C_D drag coefficient, $\frac{\text{drag}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{pitching moment}}{qS\bar{c}}$

$\bar{c}$ mean geometric chord, in.

M free-stream Mach number

q dynamic pressure, lb/sq in.

R Reynolds number based on model length

S plan-form area, sq in.

α angle of attack, deg

δ control deflection angle, deg

ϵ semiapex angle, deg

EXPERIMENTAL CONSIDERATIONS

Wind Tunnel

The investigation was conducted in the Ames 1- by 3-Foot Supersonic Wind Tunnel No. 1 which is a single-return, continuous-operation, variable-pressure wind tunnel having a Mach number range of 1.2 to 6. The Mach number is changed by varying the wall contour by use of flexible plates which comprise the top and bottom walls of the wind tunnel.

Models and Balance

The models were a circular cone, an elliptic cone, a modified elliptic cone, and a triangular slab wing with a centerbody. Dimensional drawings are shown in figure 1. All models had a leading-edge sweepback of 75° (semiapex angle of 15°). The elliptic cone had a major to minor

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axis ratio of 3 to 1. Two variations of the elliptic cone were made by blunting the apex. The shape of the blunted apex was parabolic in both plan and side projections. The modified elliptic cone was formed by scooping out the top portion of the cone to form a centerbody similar to that of the slab wing model. This modification left the model with a base area of 41 percent of that of the unmodified model.

Controls were provided for both the slab wing model and the modified elliptic cone. The latter was provided with tip controls having 10 percent of the plan-form area. Two types of controls were provided the slab wing: tip controls having 10 percent and 20 percent of the plan-form area, and trailing-edge flaps having 10 percent of the model plan-form area.

To achieve the large range of angles of attack desired, it was necessary to support the models with a shrouded straight sting for angles of -5° to $+45^{\circ}$ and a sting with an offset adapter for the angles of 45° to 90°. Photographs of typical model installations in the tunnel test section are shown in figure 2.

The balance used to measure the aerodynamic forces was a six-component, side-support, strain-gage-type balance whose details are described in reference 9. Only three components, normal force, axial force, and pitching moment, were used in the present tests.

Tests, Procedures, and Data Reduction

Measurements of normal force, axial force, and pitching moment were made at Mach numbers of 2.94, 3.87, and 4.78 at a Reynolds number of 1.06×10^{6} based on model length. At Mach number 2.94, additional data were taken at a Reynolds number of 2.12×10^{6} to ascertain any Reynolds number effects. Pressures at the model base were recorded simultaneously with the aerodynamic forces when the shrouded straight sting was used. The correction for support interference was believed to be small and the coefficients herein presented are for total axial force.

Measured forces are reduced to coefficient form in the wind axes system. The actual plan-form area and mean geometric chord of the models were used for reference. Pitching-moment coefficients refer to a point 60 percent of the actual model length from the nose except for models with controls. Pitching-moment reference points are indicated in figure 1 for all models.

Data Uncertainties

The uncertainties in the data were estimated by considering the repeatability of the measured quantities. Repeatability of the data was checked by making several runs with a given model and was found to be consistent with the values given below:

C_L	±0.01
C_D	±.01
C_m	±.005
α	±.1°
M	±.01

RESULTS

The results for the models without control surfaces are presented in figures 3 and 4 in the form of lift-drag ratio, C_L, C_D, and C_m as functions of angle of attack. Figure 3 was prepared to show the effect of cross-sectional shape on the aerodynamic characteristics; results of impact theory (refs. 4 and 10) are also shown. It can be seen that there are large changes in coefficients for the range of cross-sectional shapes considered; impact theory is only of limited value in predicting the coefficients. The theory works best for C_L and L/D and for angles of attack above about 20°.

Figure 4, prepared to show the effects of apex bluntness, indicates a slight decrease in the maximum value of L/D and less negative values of C_m as the bluntness is increased. If the centroid of plan area of each model had been chosen as the moment reference, instead of 60 percent of the actual model length from the nose, there would have been very little change in C_m with changes in bluntness, since the center of pressure of these models was close to the centroid of plan area.

Figures 5 through 8 show the aerodynamic characteristics for the models with controls. It can be seen that none of the controls are effective in providing trim at large angles of attack.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., April 20, 1961

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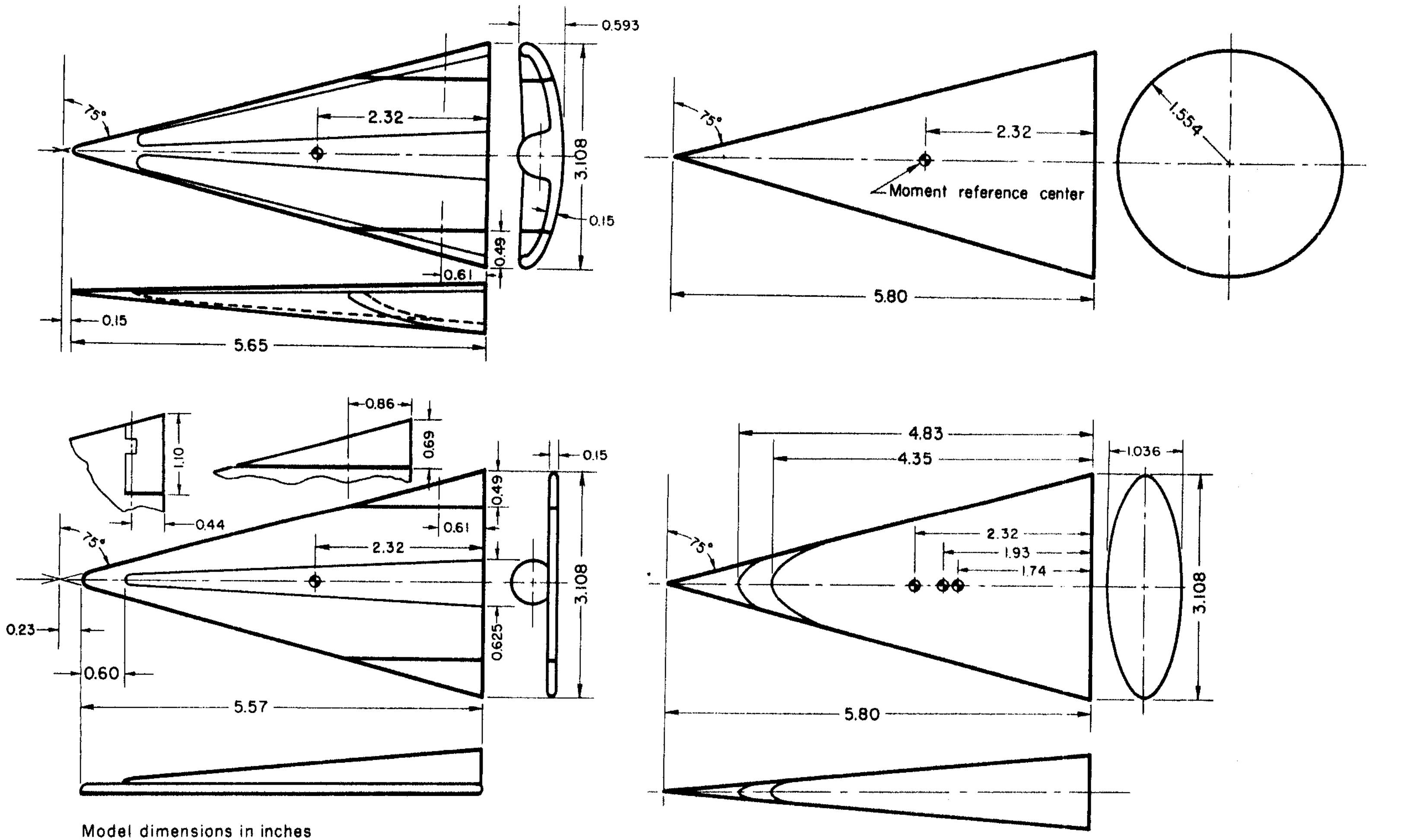

Figure 1.- Models.

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Figure 2.- Typical model installations in tunnel.

A
4
2
4

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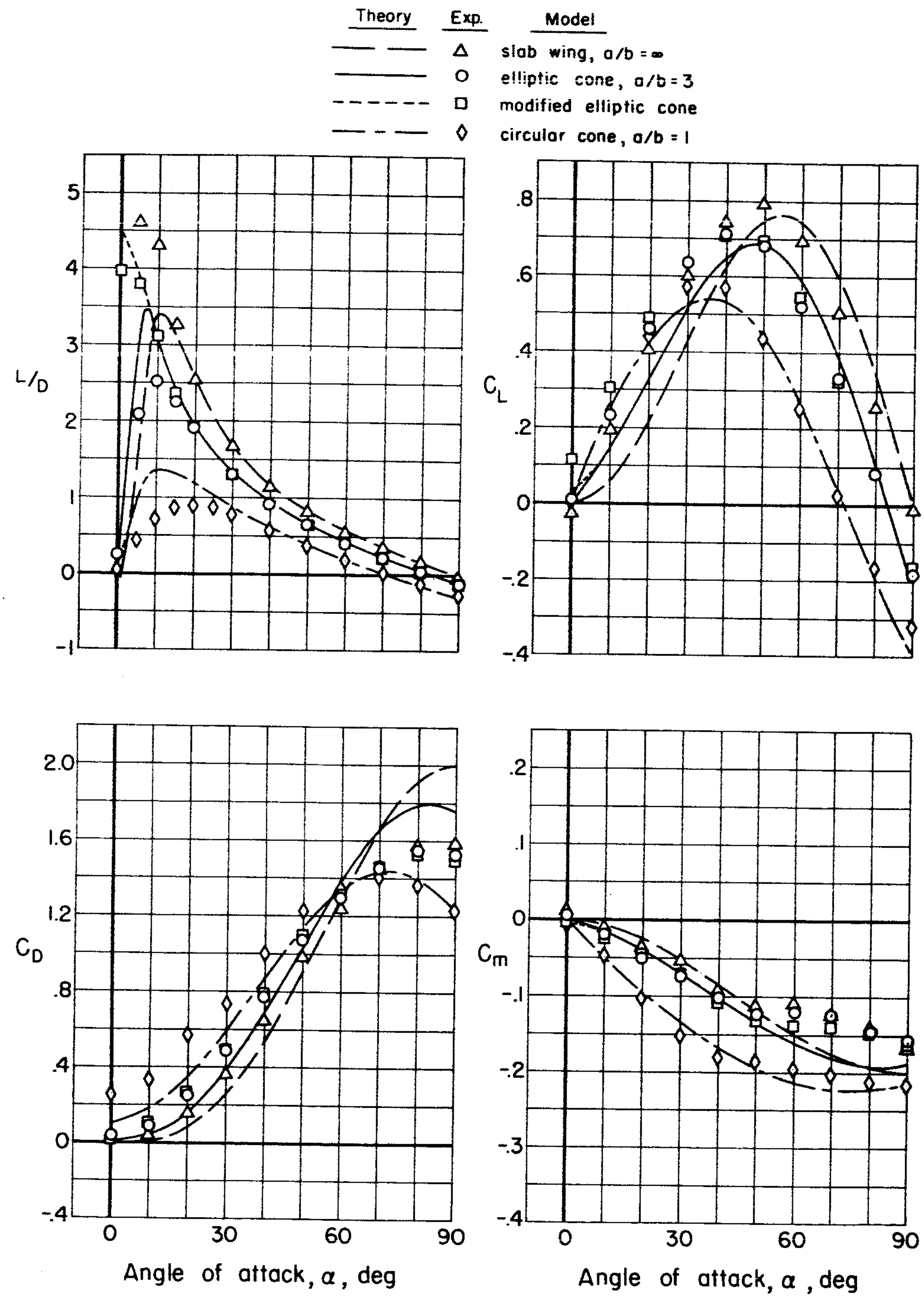

(a) M = 2.94

Figure 3.- Effect of cross-sectional shape on the aerodynamic characteristics of triangular plan-form models; $\epsilon = 15^{\circ}$.

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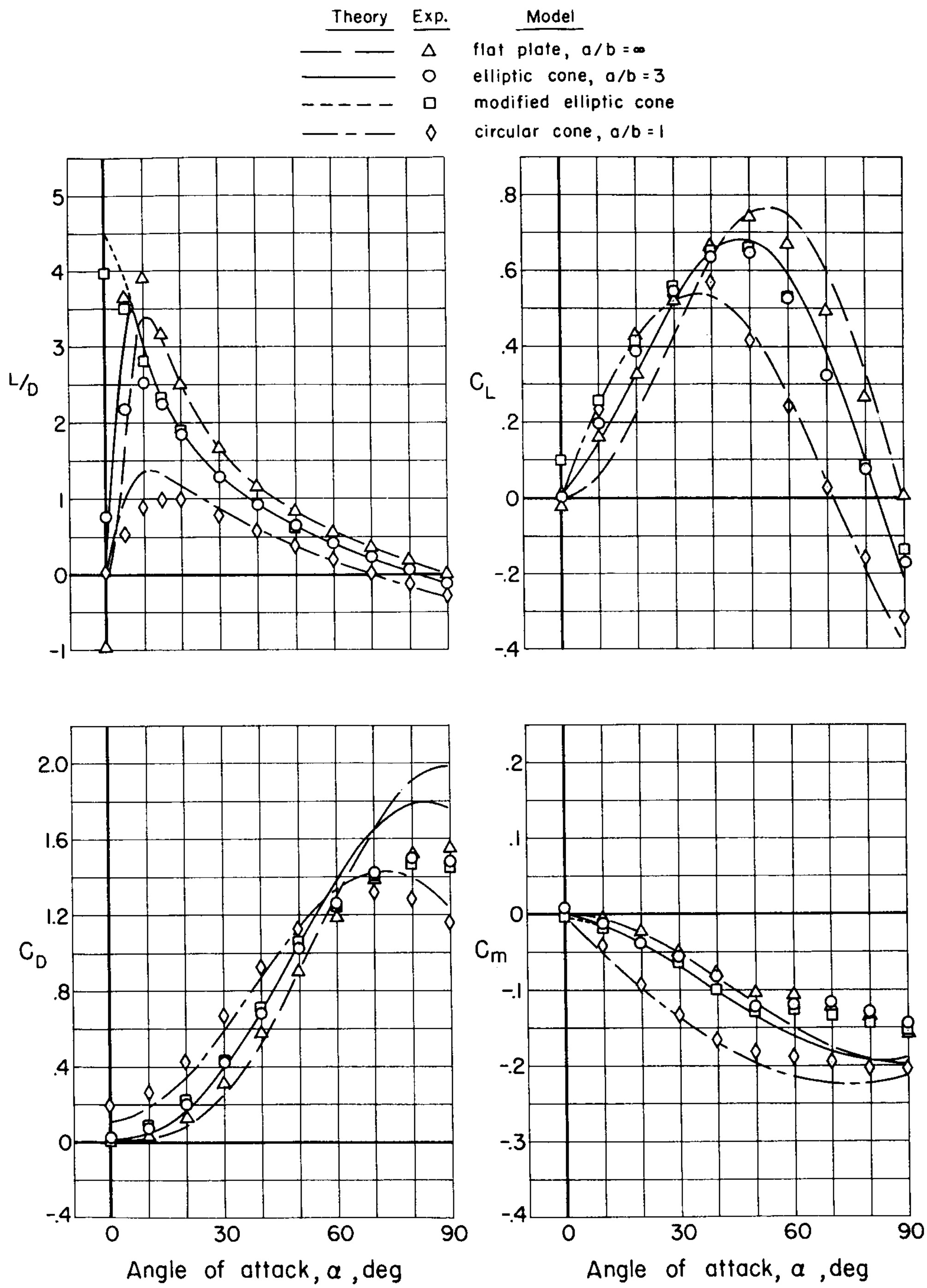
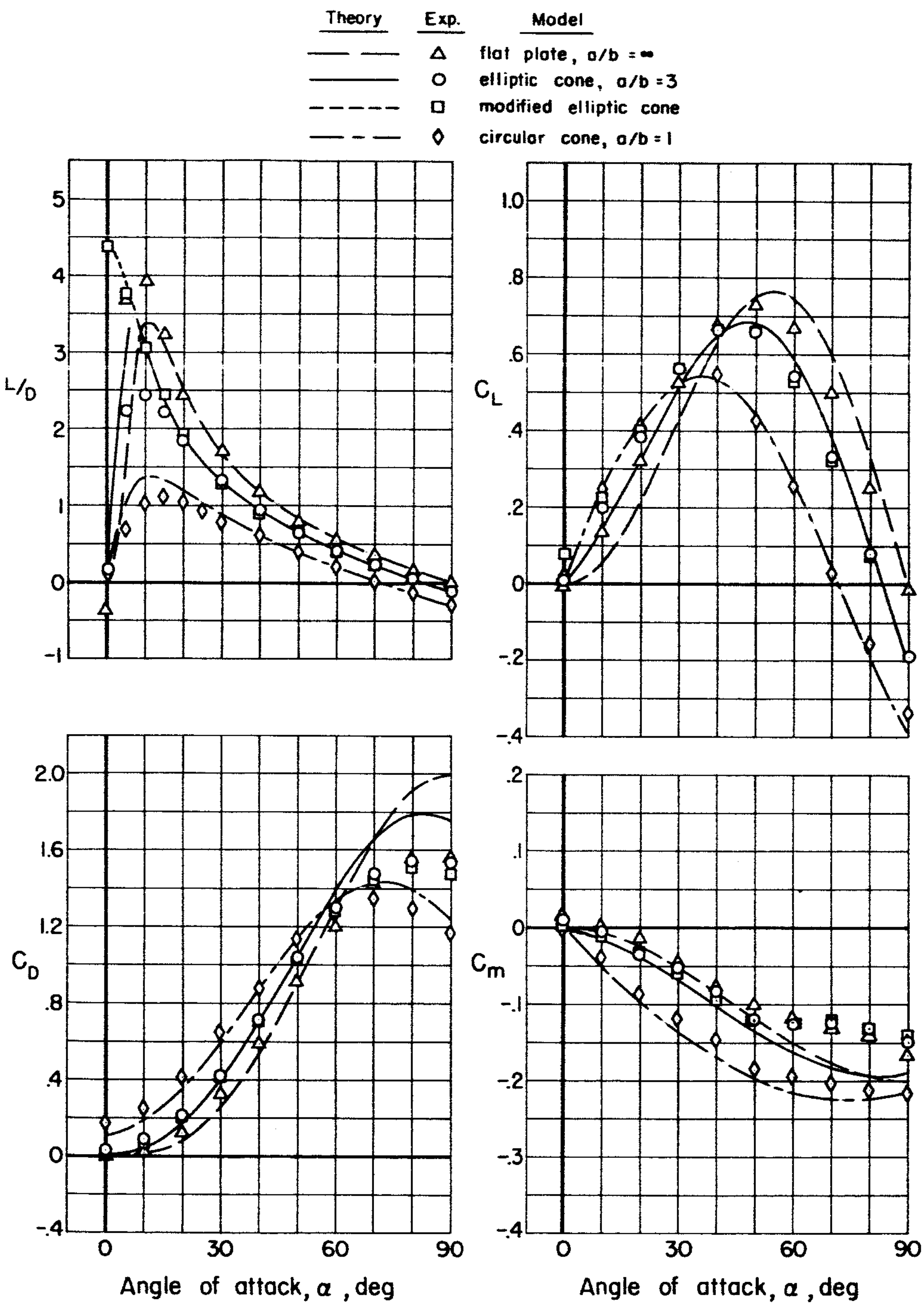


(b) M = 3.87

Figure 3.- Continued.

A
4
2
4

[redacted]

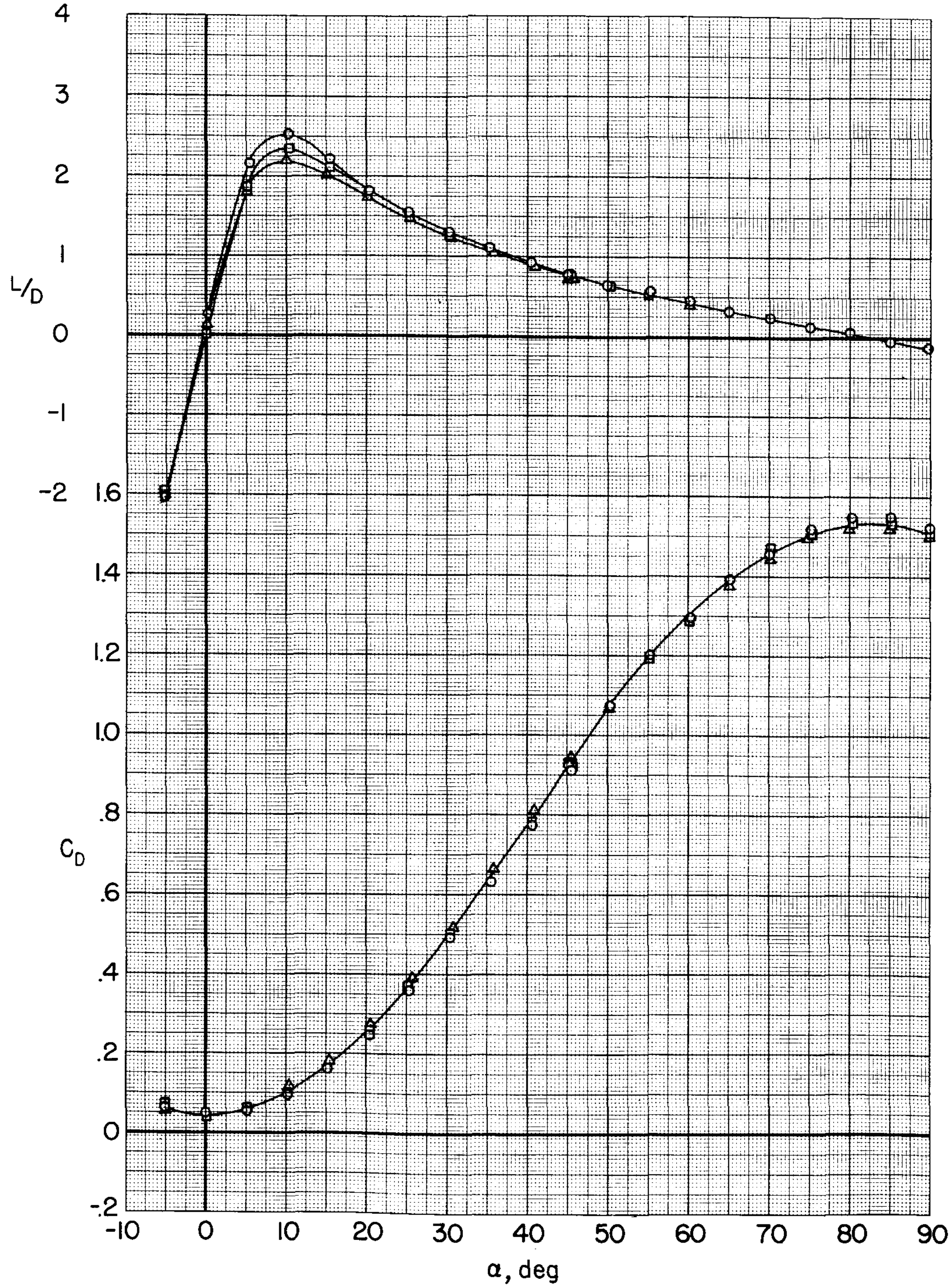


(c) M = 4.78

Figure 3.- Concluded.

[redacted]

[redacted]



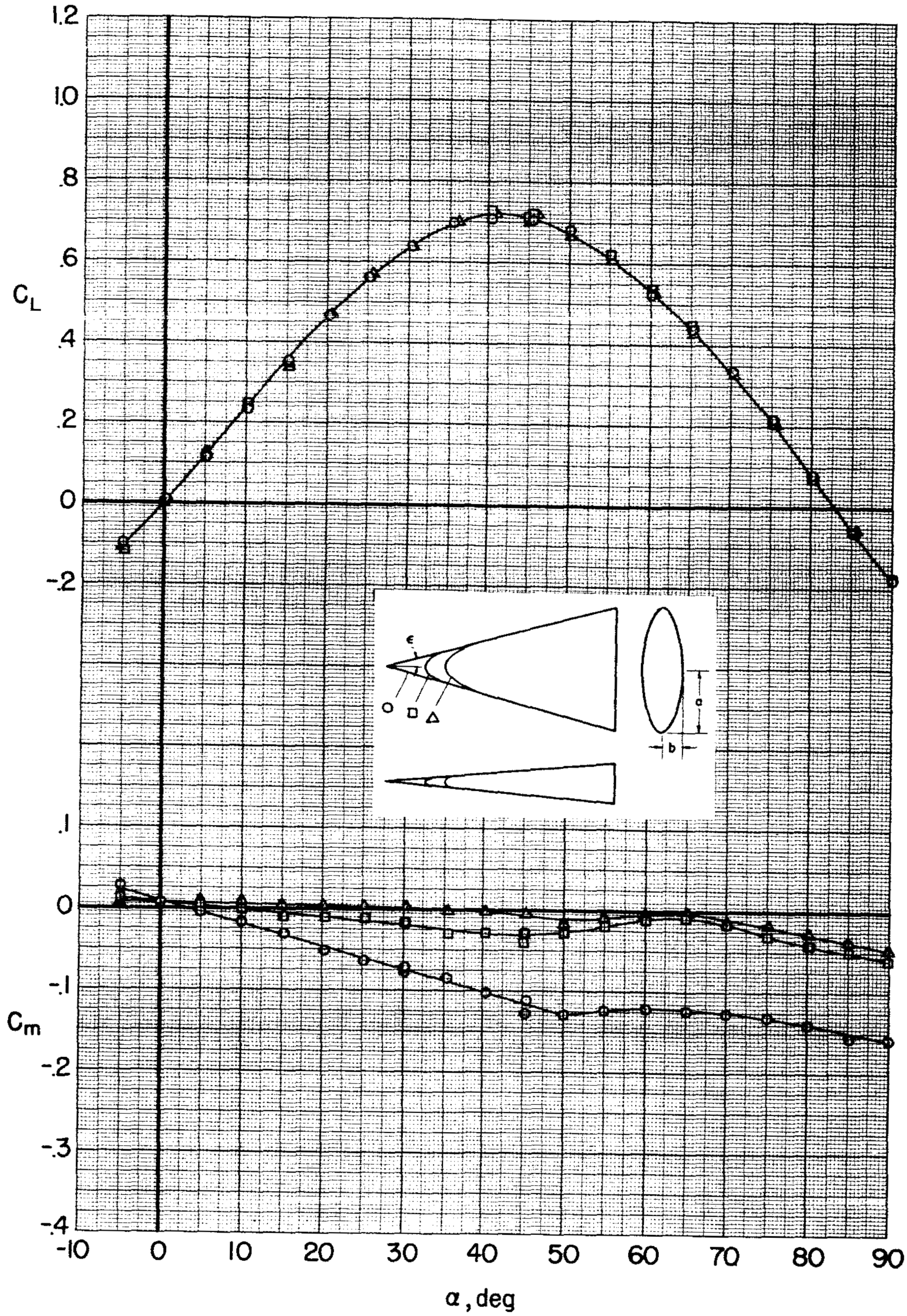
(a) M = 2.94

Figure 4.- Effect of apex blunting on the aerodynamic characteristics of an elliptic cone; $a/b = 3$, $\epsilon = 15^\circ$.

A
4
2
4

[redacted]

A
4
2
4

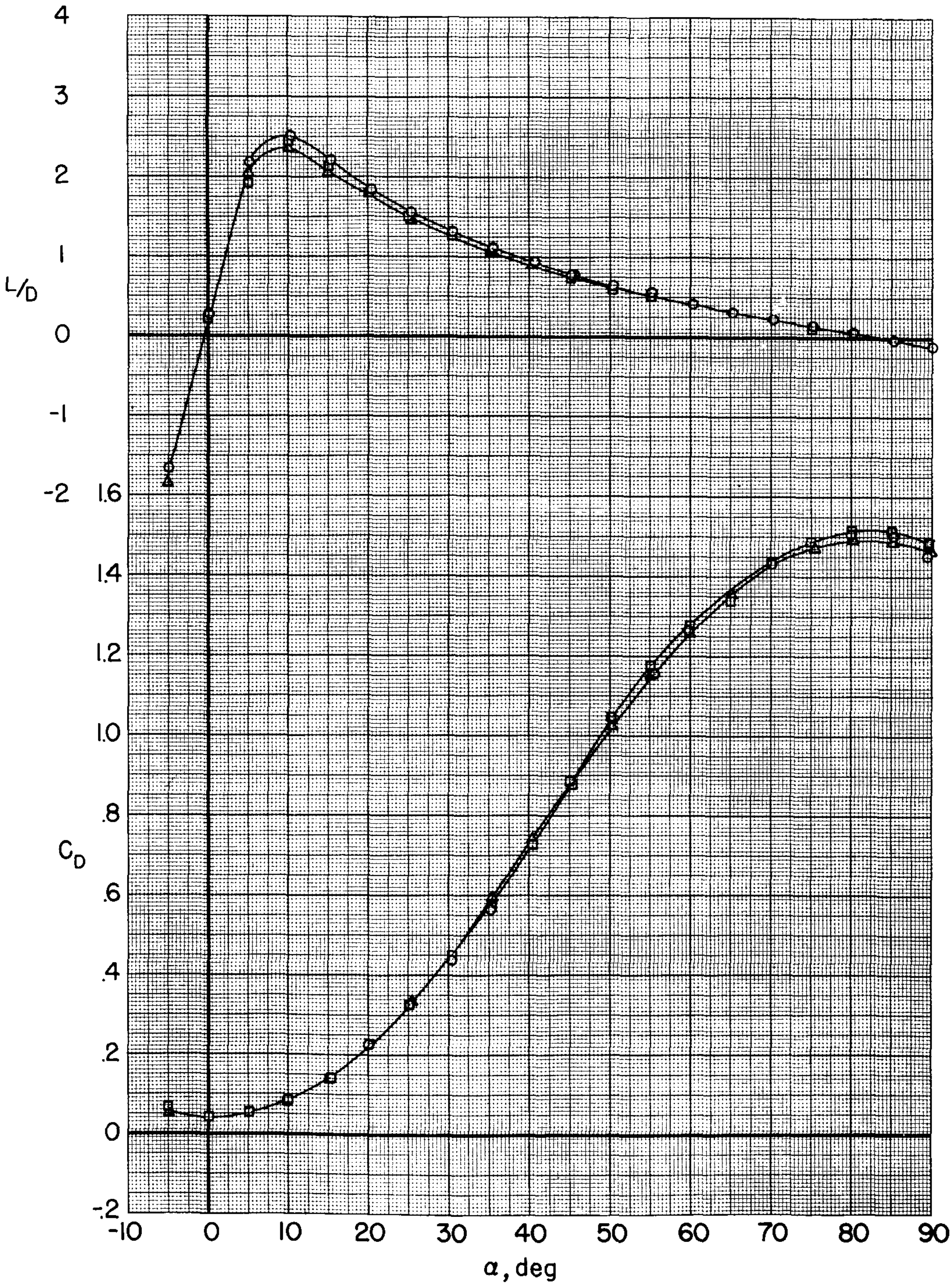


(a) M = 2.94 - Concluded.

Figure 4.- Continued.

[redacted]

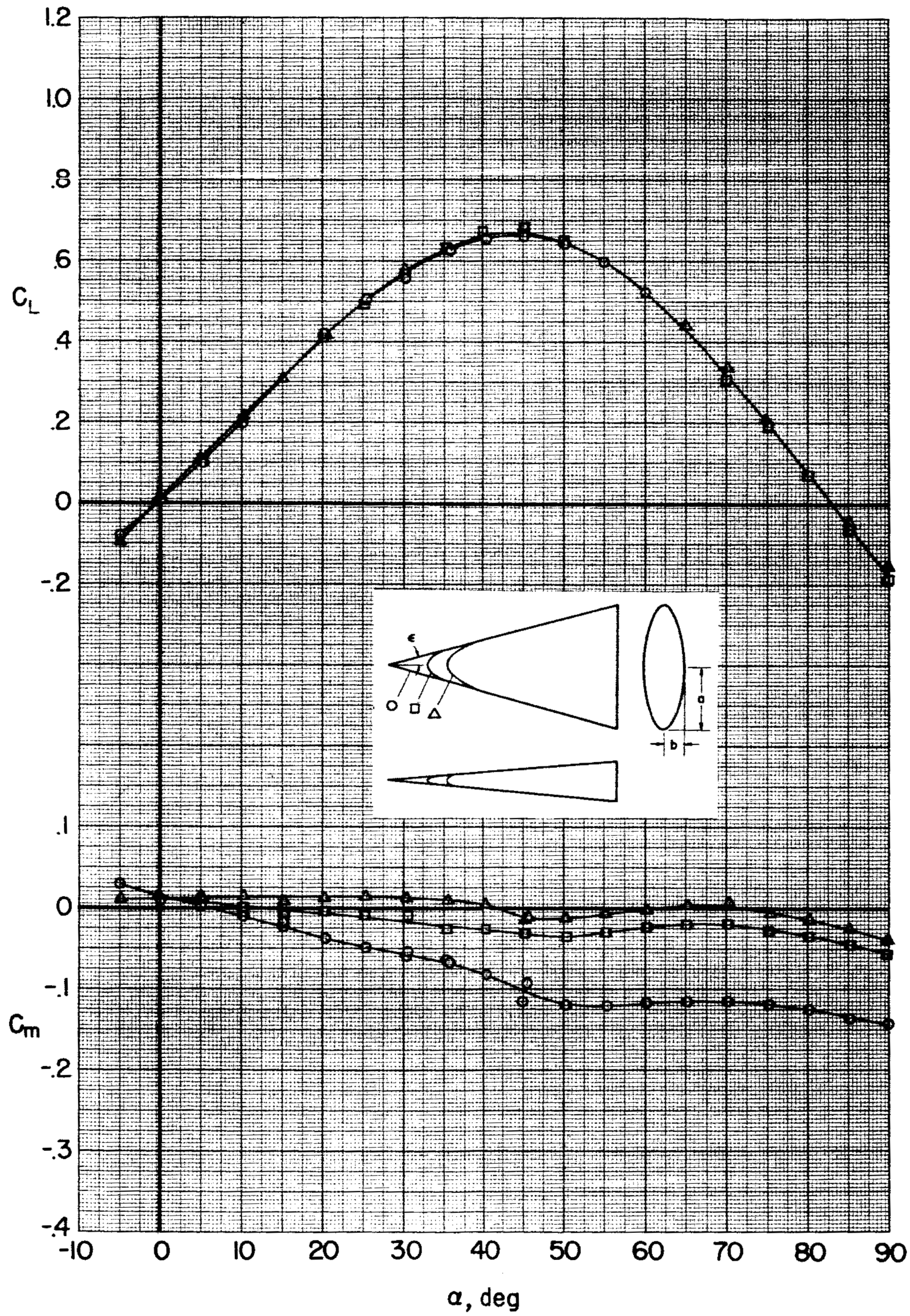
[redacted]



(b) M = 3.87

Figure 4.- Continued.

[redacted]



(b) M = 3.87 - Concluded.

Figure 4.- Continued.

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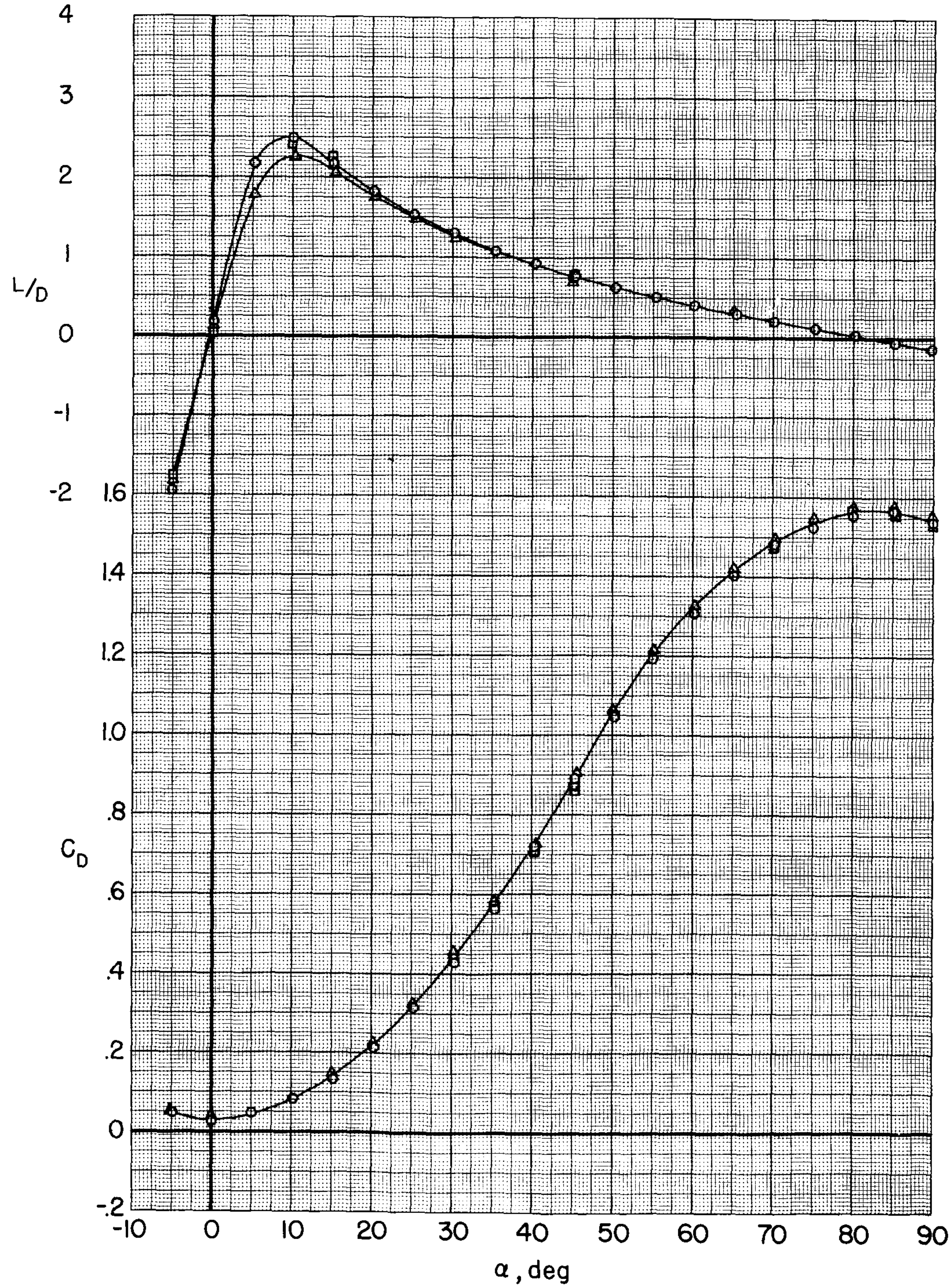
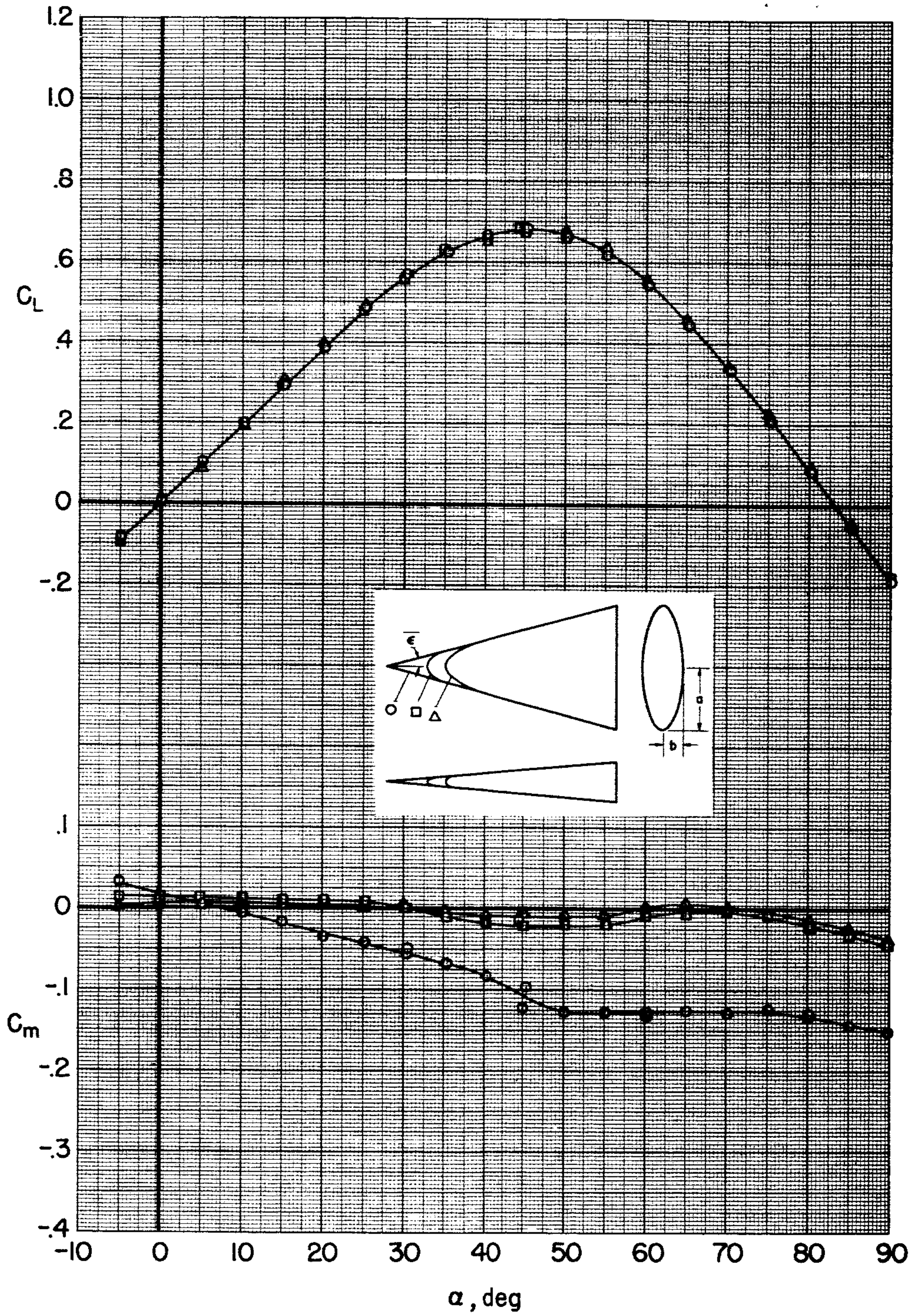


(c) M = 4.78

Figure 4.- Continued.

[redacted]



A
4
2
4

(c) M = 4.78 - Concluded.

Figure 4.- Concluded.

[redacted]

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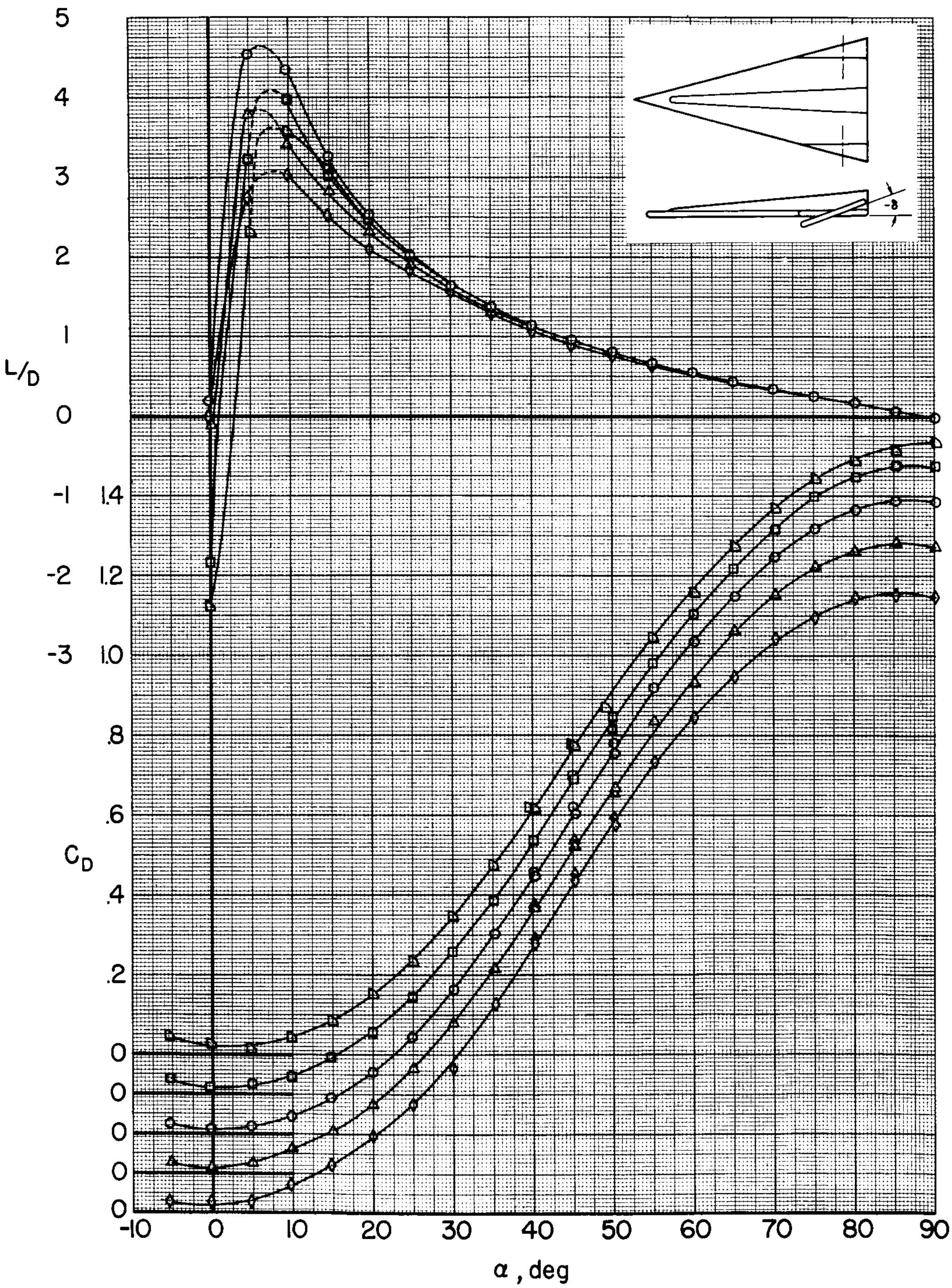
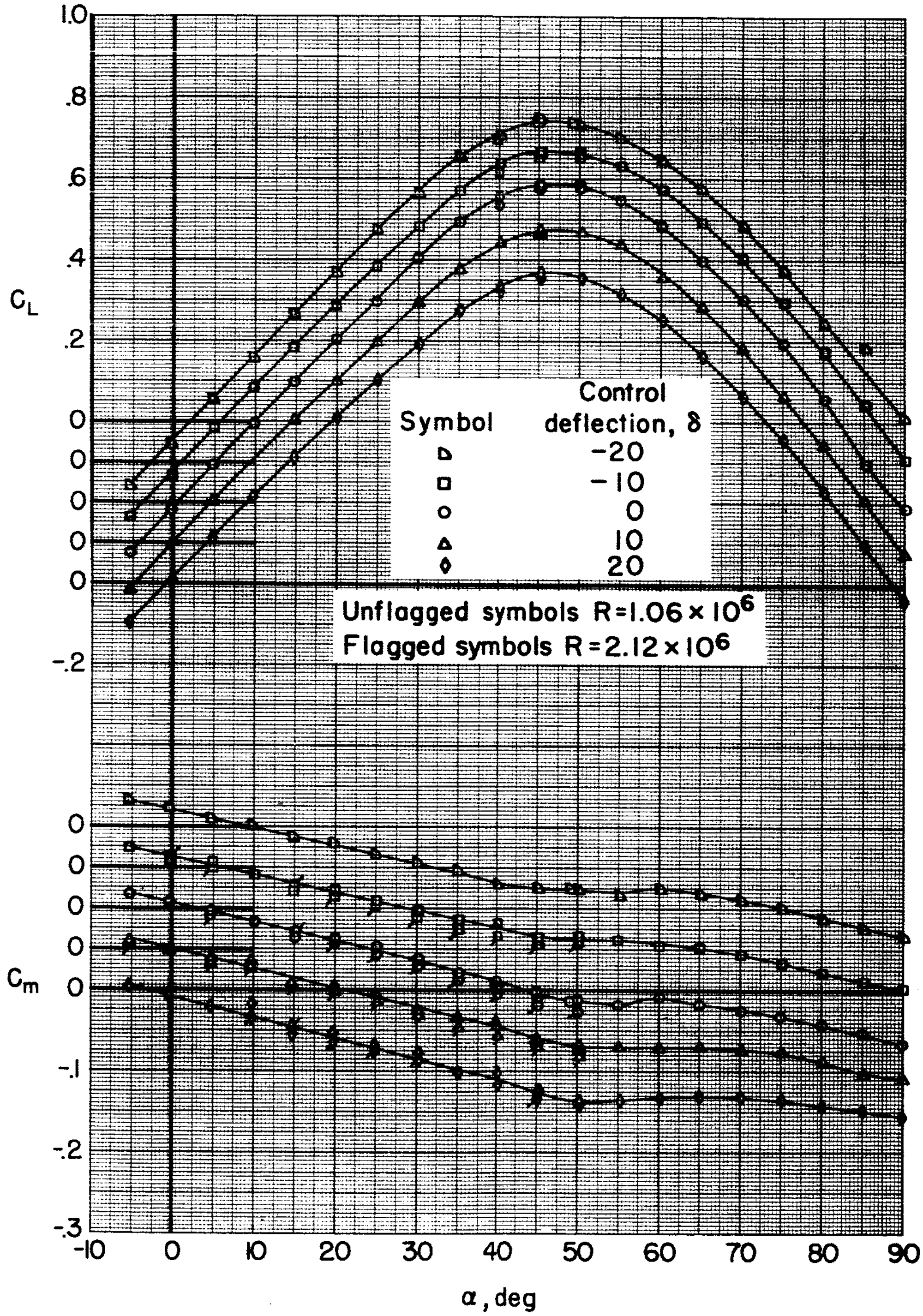


(a) $M = 2.94$

Figure 5.- Effect of controls on the aerodynamic characteristics of a triangular slab; tip control area = 10 percent S, $\epsilon = 15^{\circ}$.

[redacted]



(a) M = 2.94 - Concluded.

Figure 5.- Continued.

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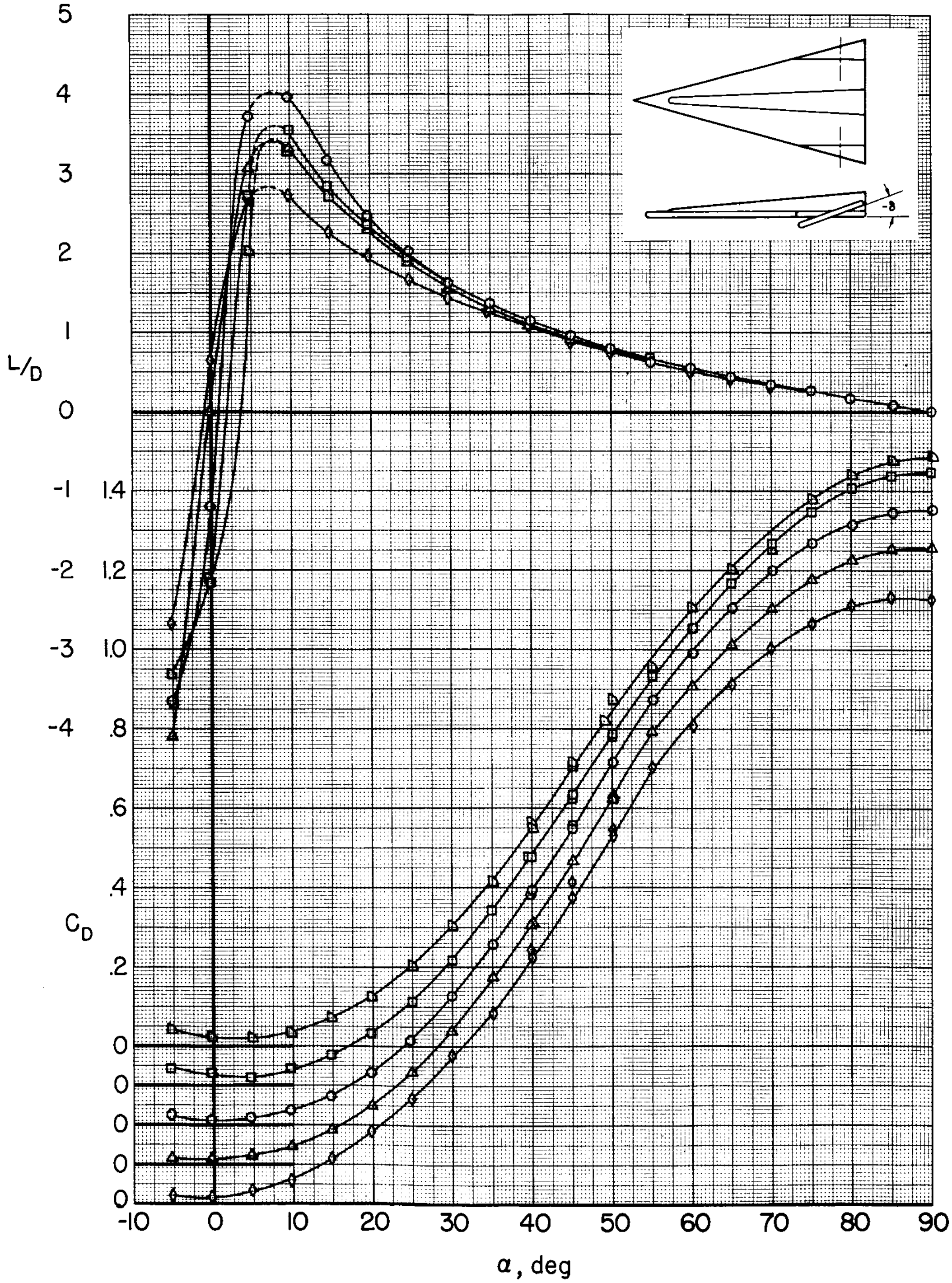
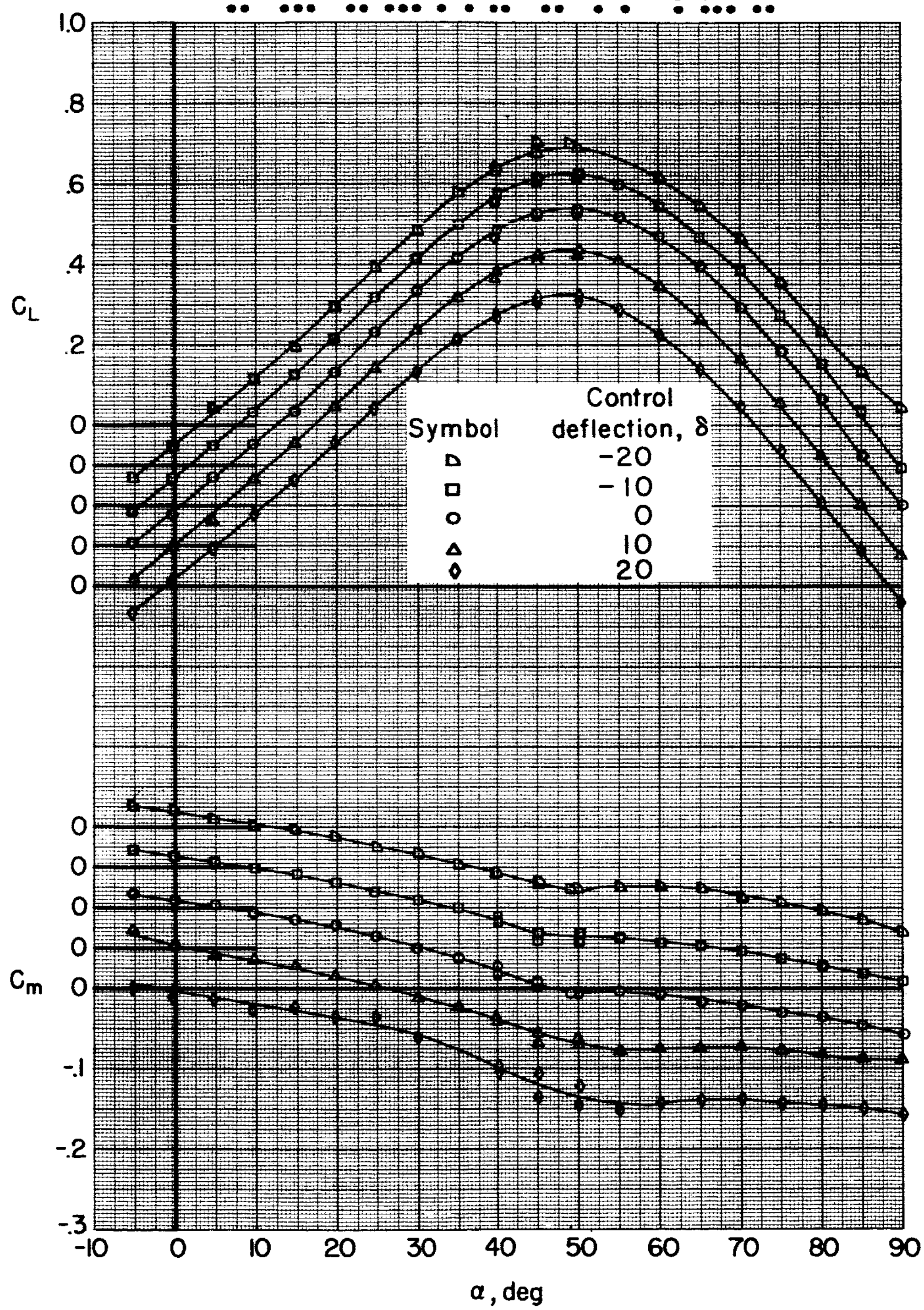
[redacted]



(b) M = 3.87

Figure 5.- Continued.

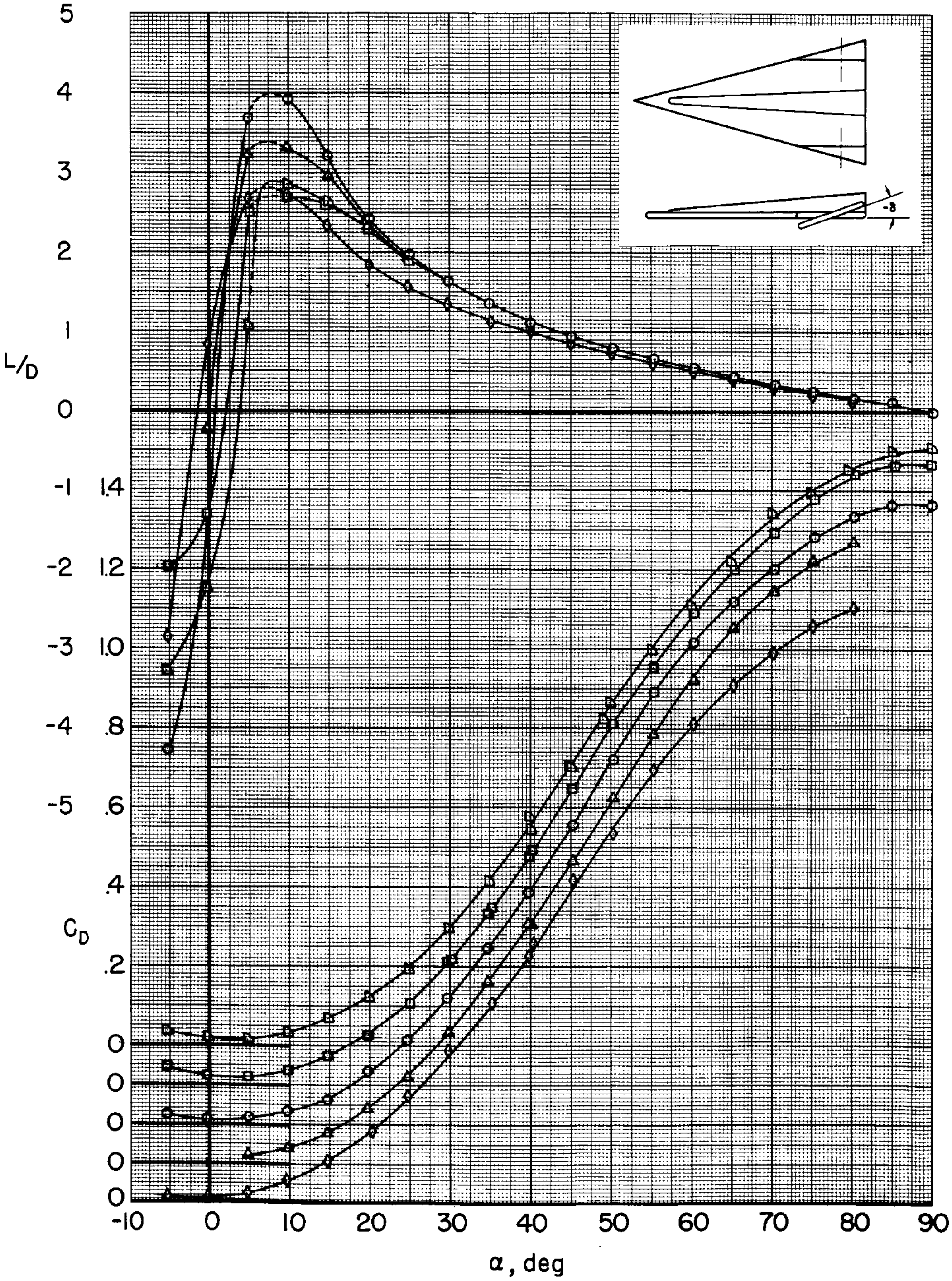
[redacted]



(b) M = 3.87 - Concluded.

Figure 5.- Continued.

[redacted]

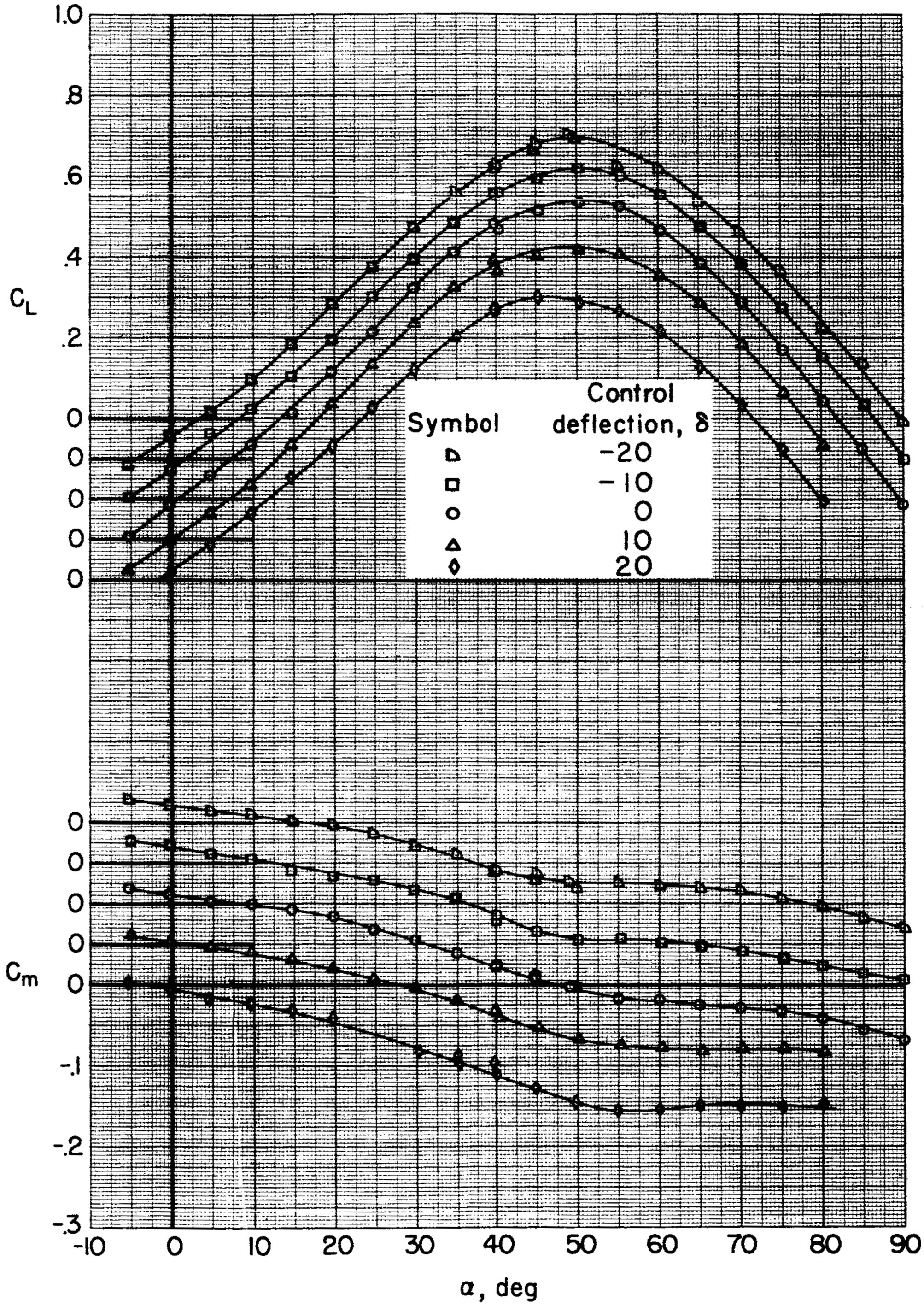


(c) M = 4.78

Figure 5.- Continued.

[redacted]

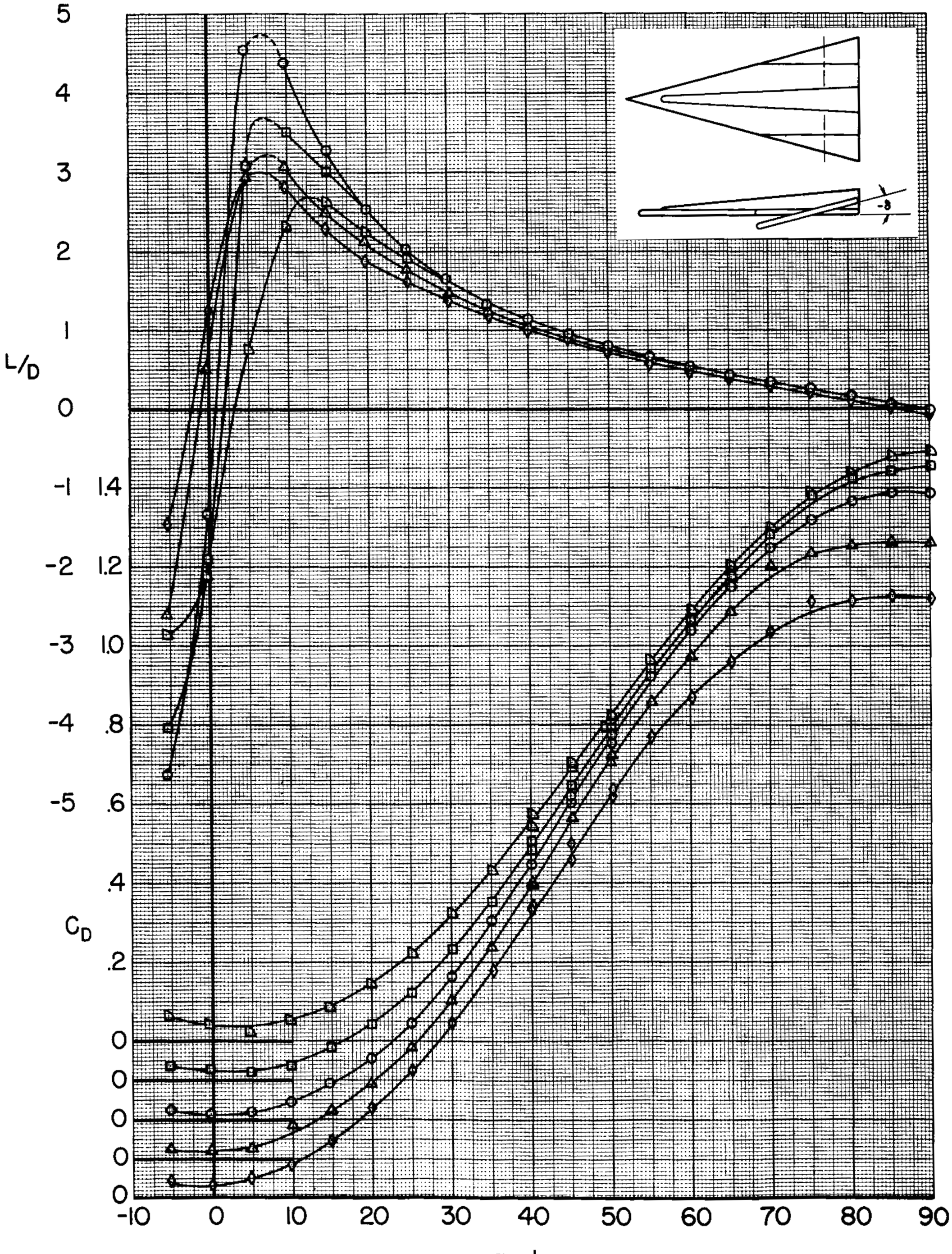
A
4
2
4



(c) M = 4.78 - Concluded.

Figure 5.- Concluded.

[redacted]

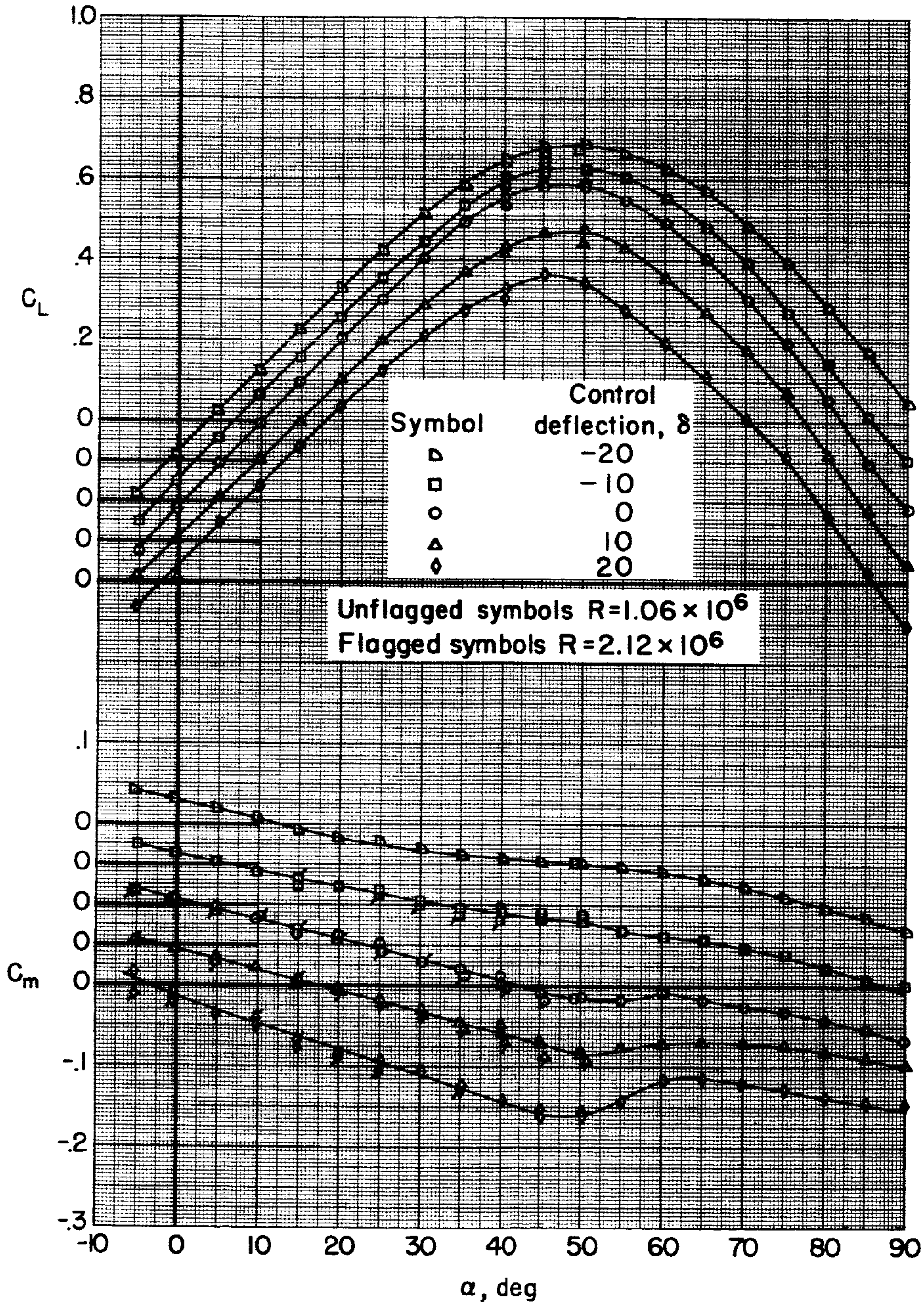


(a) M = 2.94

Figure 6.- Effect of controls on the aerodynamic characteristics of a triangular slab; tip control area = 20 percent S, $\epsilon = 15^{\circ}$.

A
4
2
4

[redacted]



(a) M = 2.94 - Concluded.

Figure 6.- Continued.

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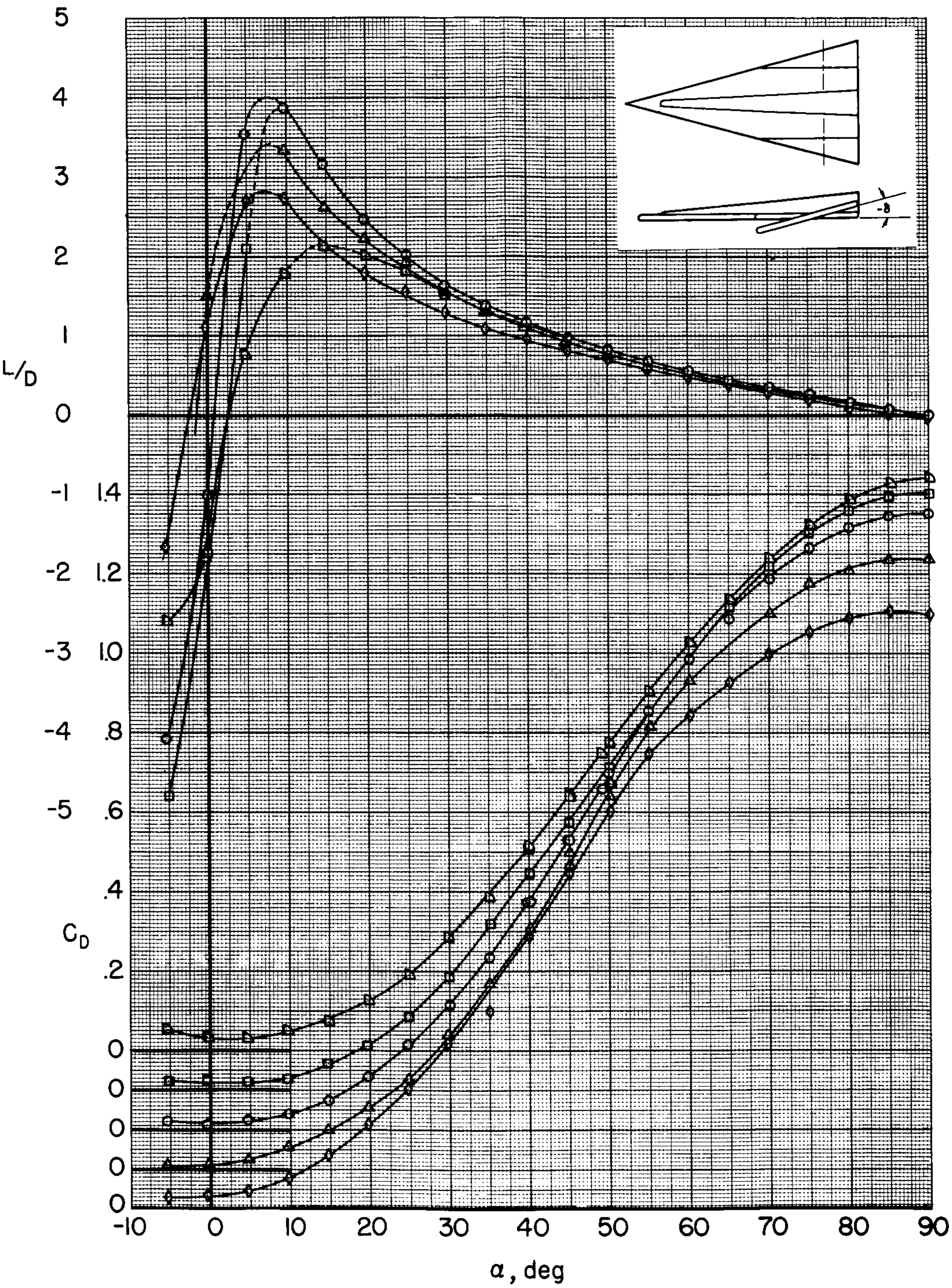
[redacted]

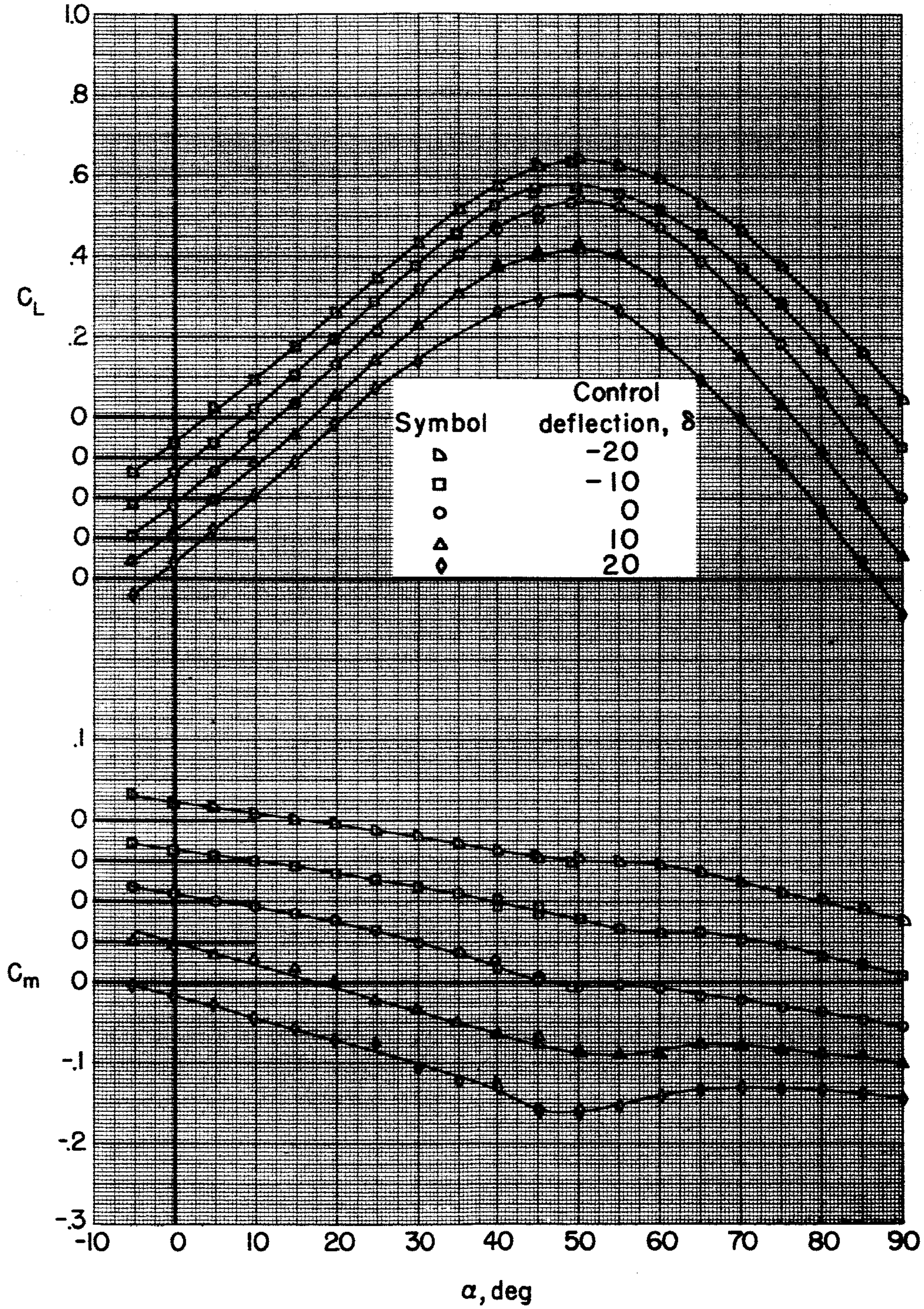


(b) M = 3.87

Figure 6.- Continued.

[redacted]

A
4
2
4



(b) M = 3.87 - Concluded.

Figure 6.- Continued.

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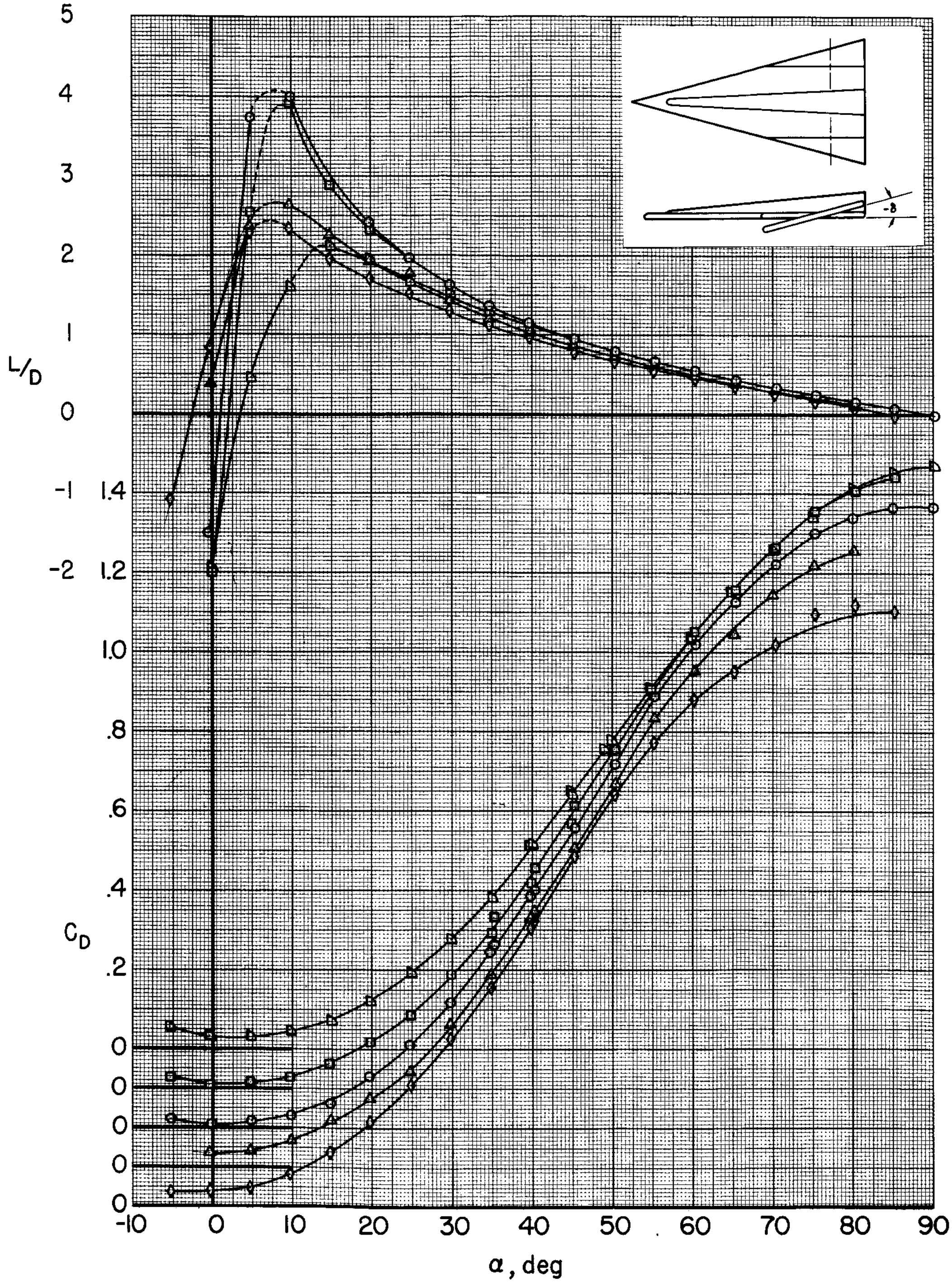

(c) M = 4.78

Figure 6.- Continued.

A
4
2
4

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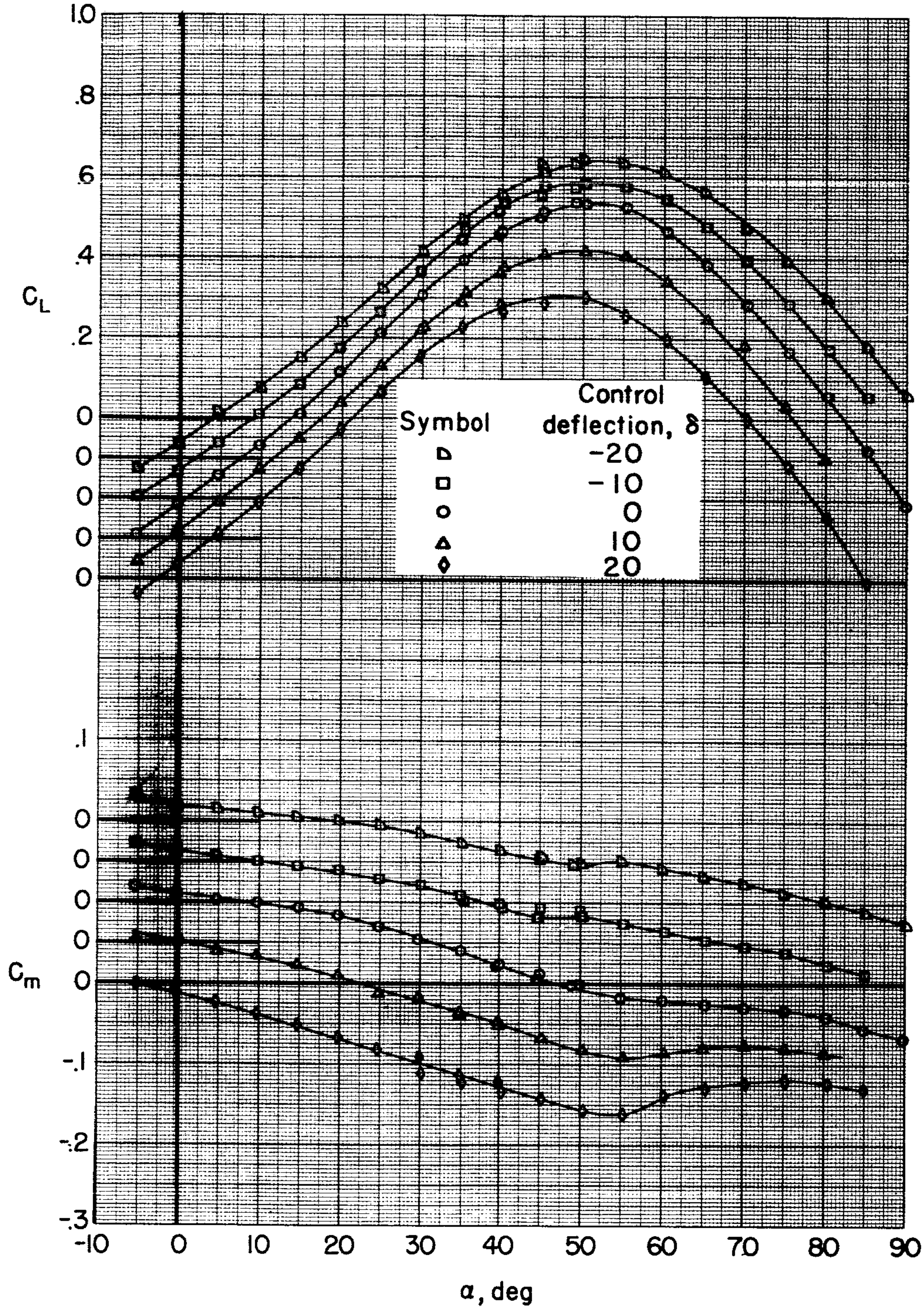

(c) M = 4.78 - Concluded.

Figure 6.- Concluded.

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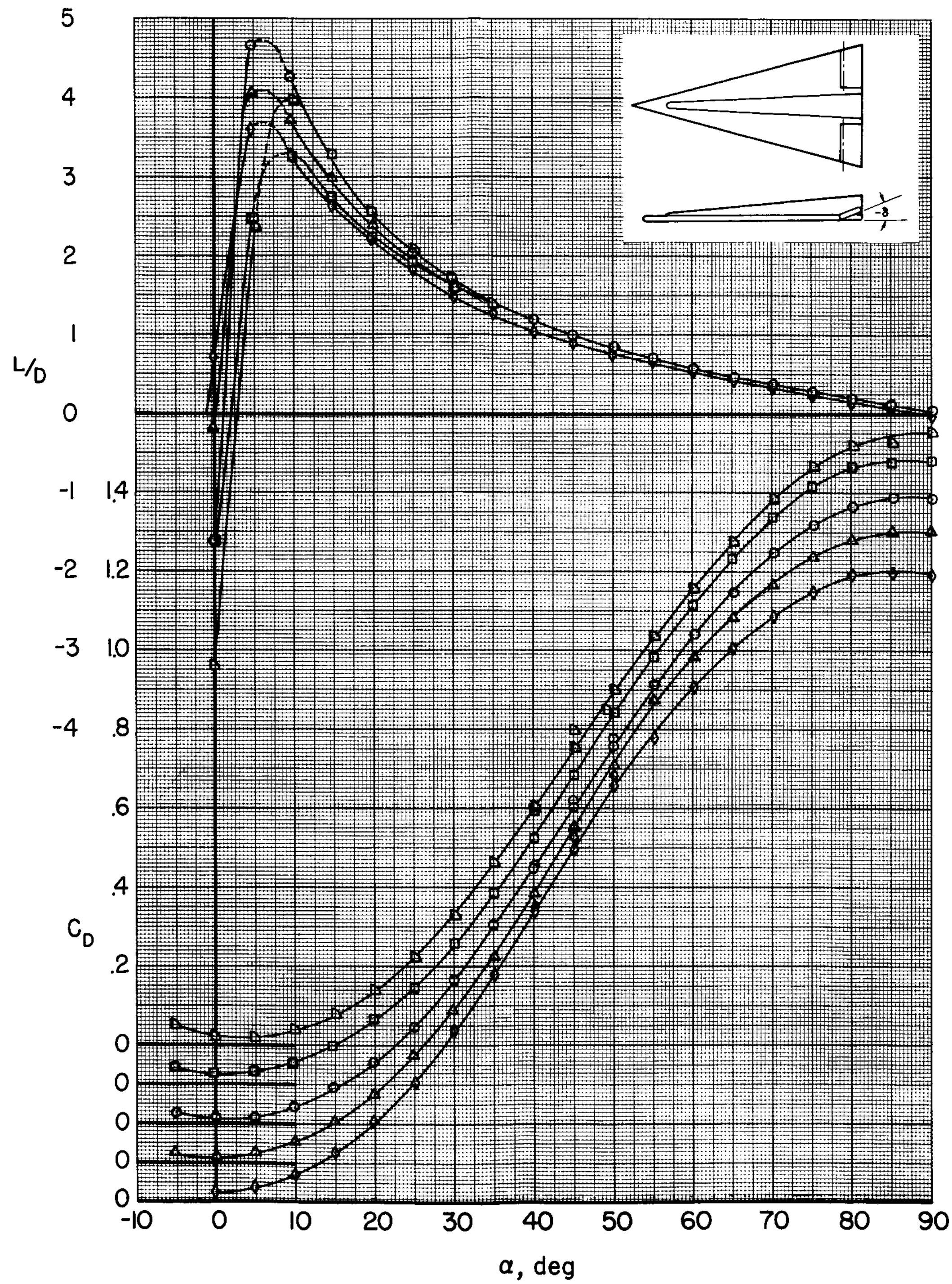
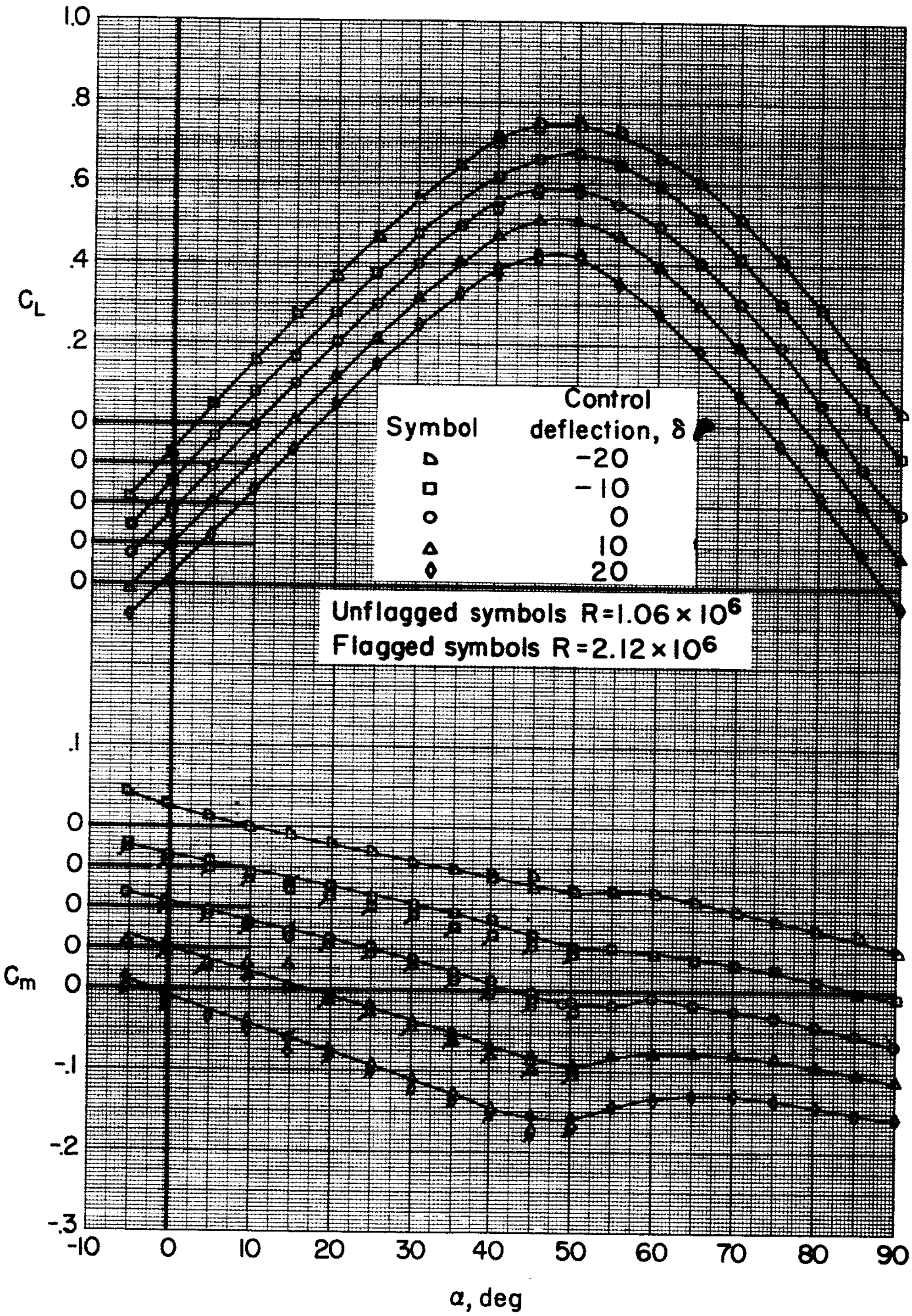


(a) M = 2.94

Figure 7.- Effect of controls on the aerodynamic characteristics of a triangular slab; flap control area = 10 percent S, $\epsilon = 15^{\circ}$.

A
4
2
4

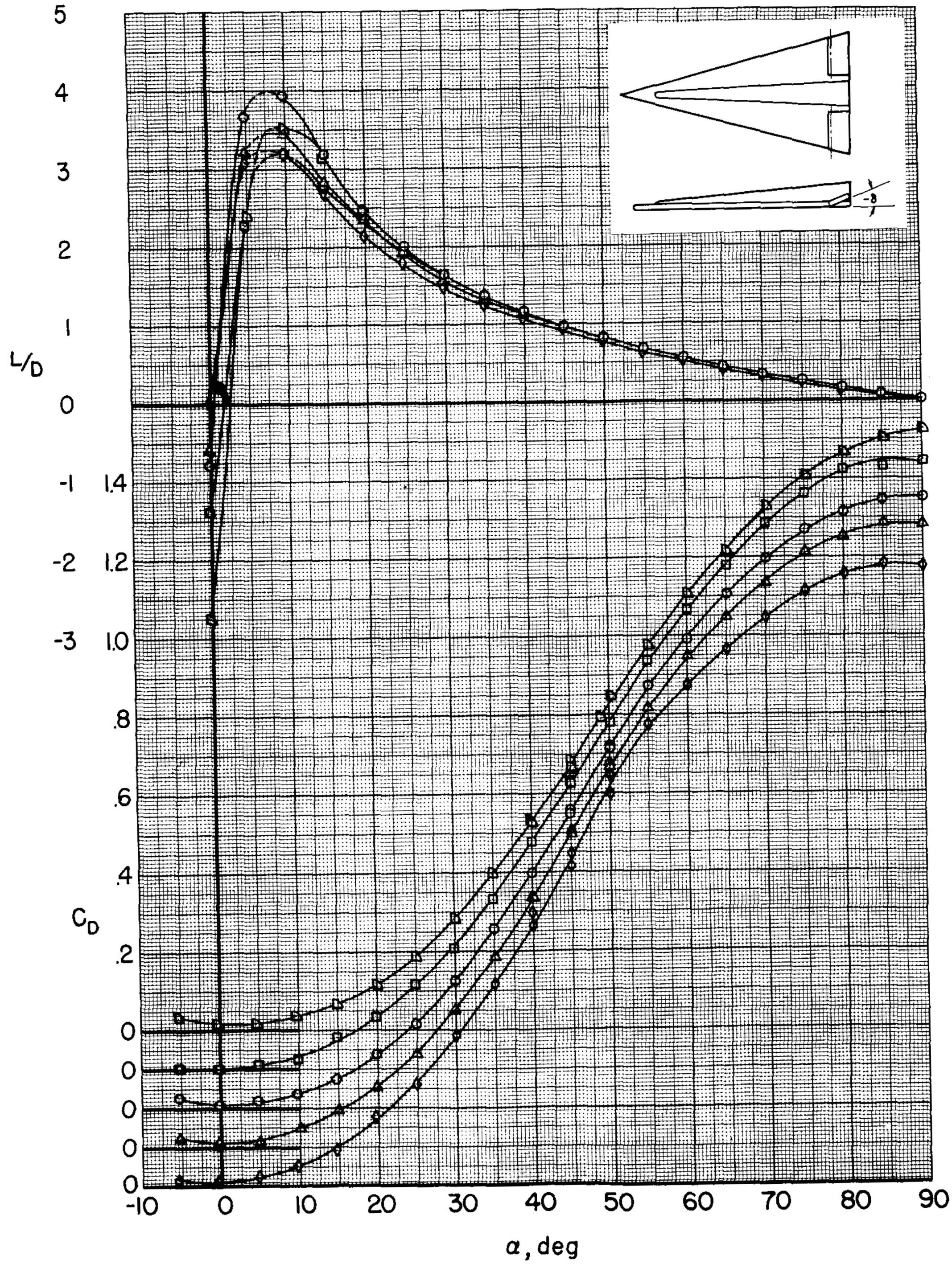
[redacted]



(a) M = 2.94 - Concluded.

Figure 7.- Continued.

[redacted]

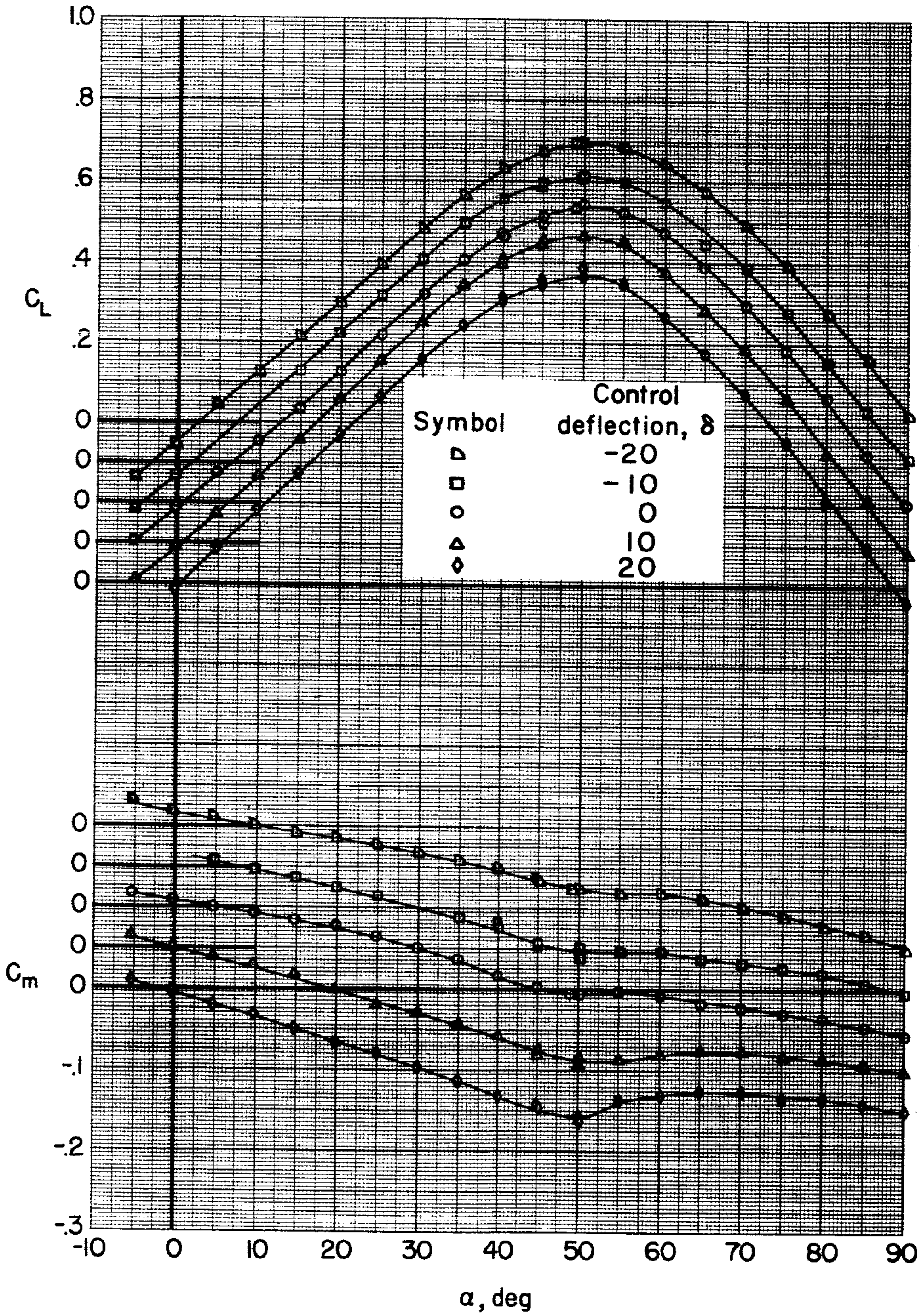


(b) M = 3.87

Figure 7.- Continued.

A
4
2
4

[redacted]



(b) M = 3.87 - Concluded.

Figure 7.- Continued.

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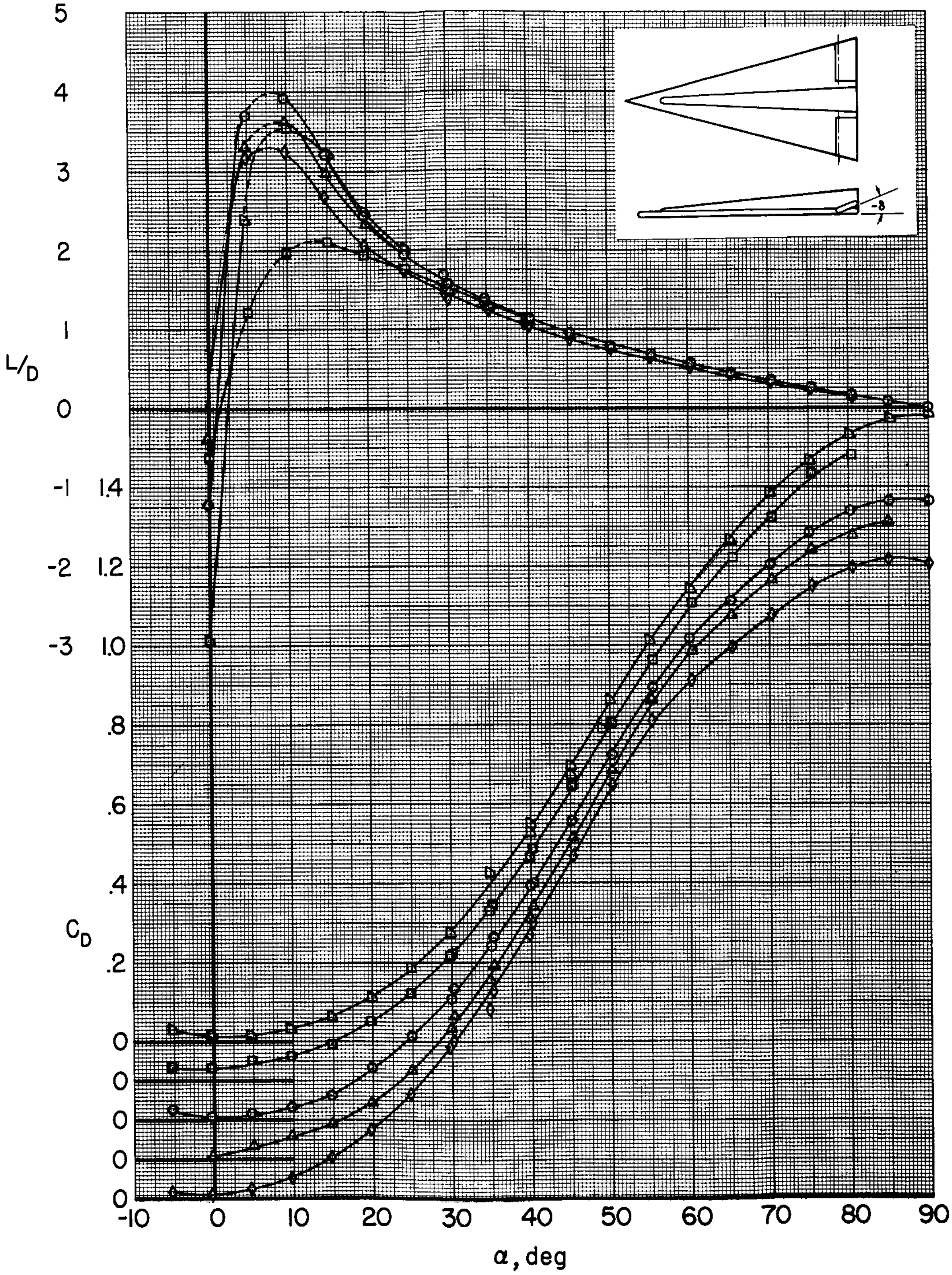

(c) M = 4.78

Figure 7.- Continued.

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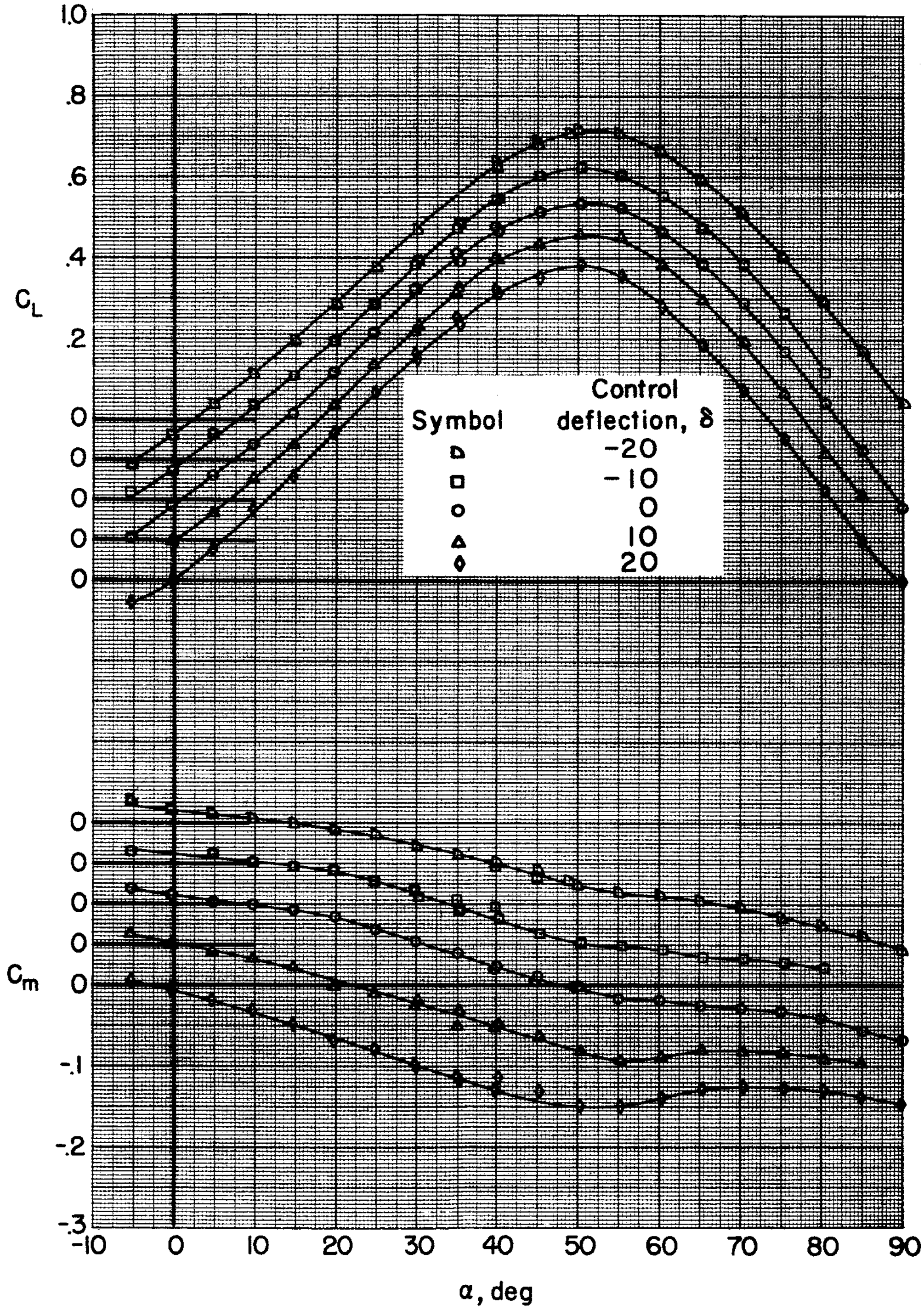

(c) M = 4.78 - Concluded.

Figure 7.- Concluded.

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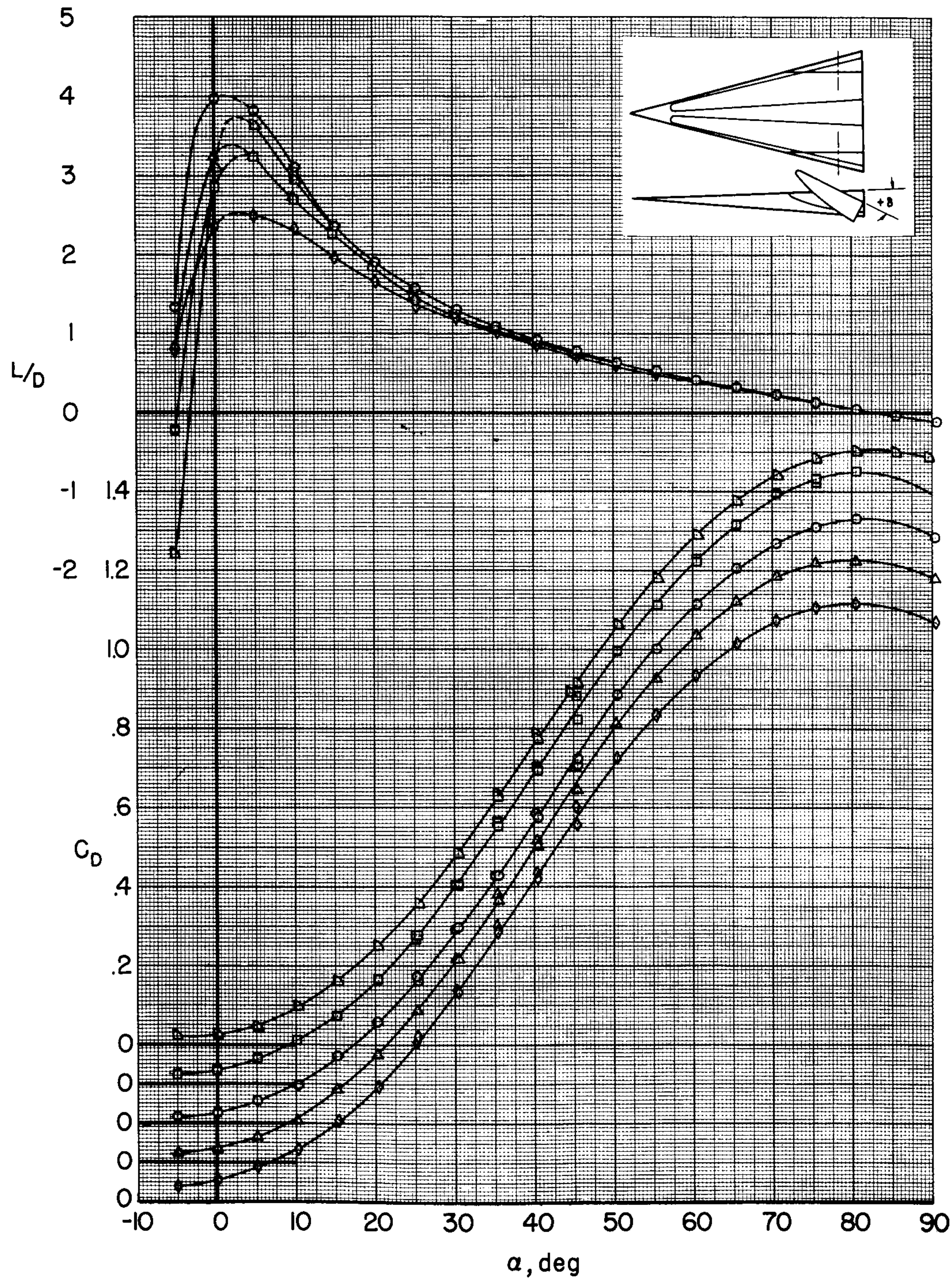

(a) $M = 2.94$

Figure 8.- Effect of controls on the aerodynamic characteristics of the modified elliptic cone; tip control area = 10 percent S, $\epsilon = 15^{\circ}$, $a/b = 3$.

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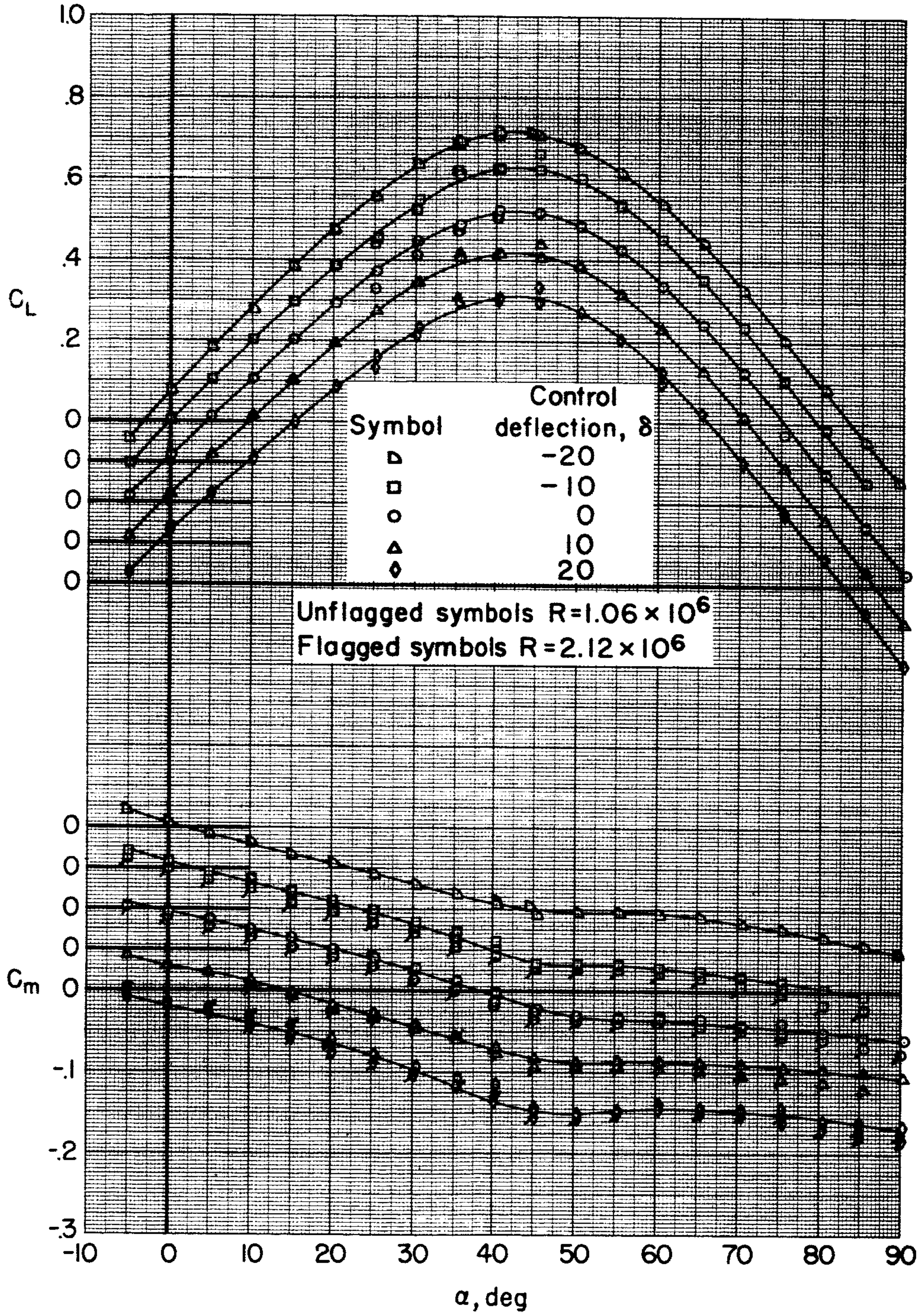

(a) M = 2.94 - Concluded.

Figure 8.- Continued.

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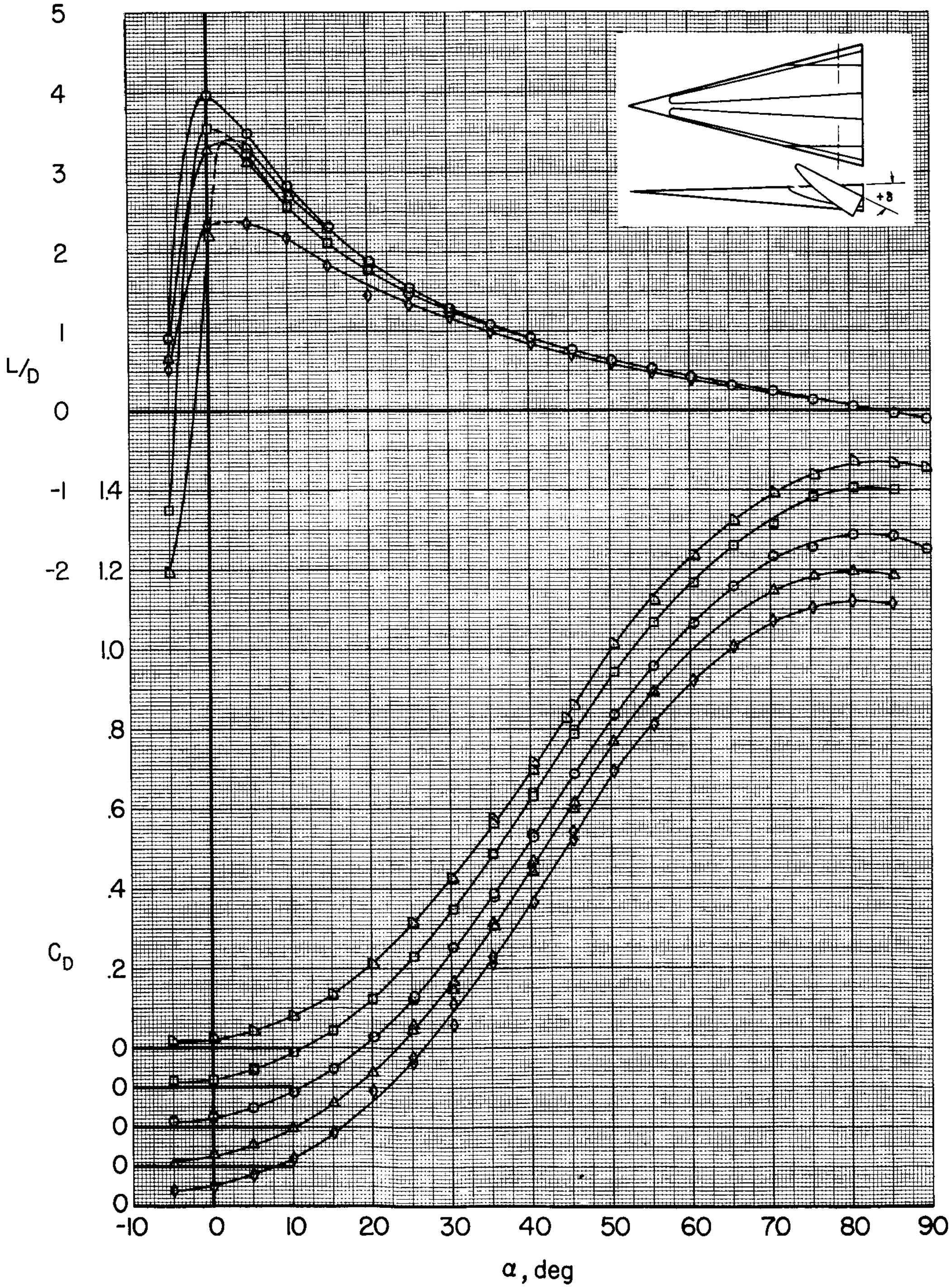
[redacted]



(b) M = 3.87

Figure 8.- Continued.

[redacted]

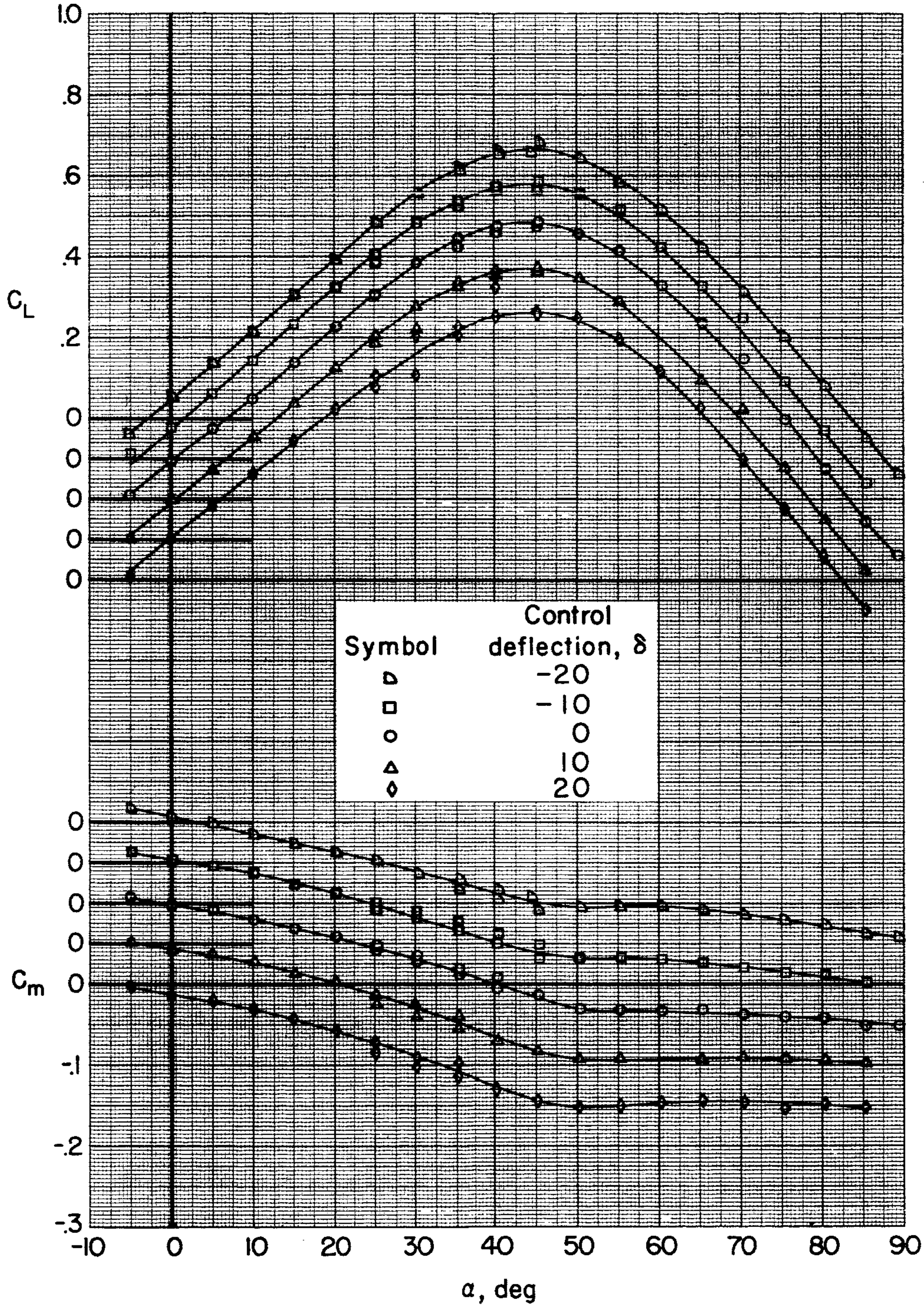


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Figure 8.- Continued.

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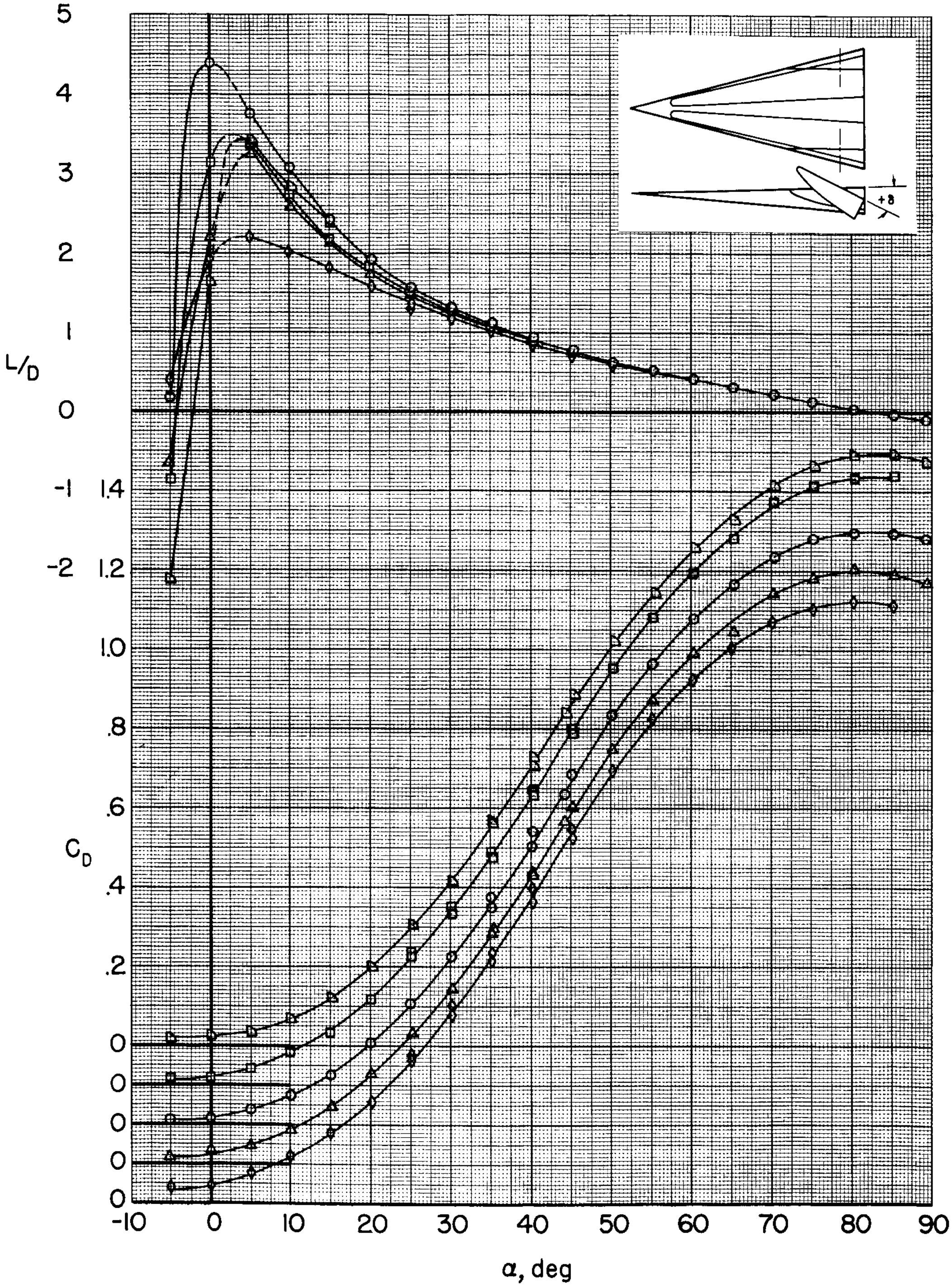

(c) M = 4.78

Figure 8.- Continued.

A
4
2
4

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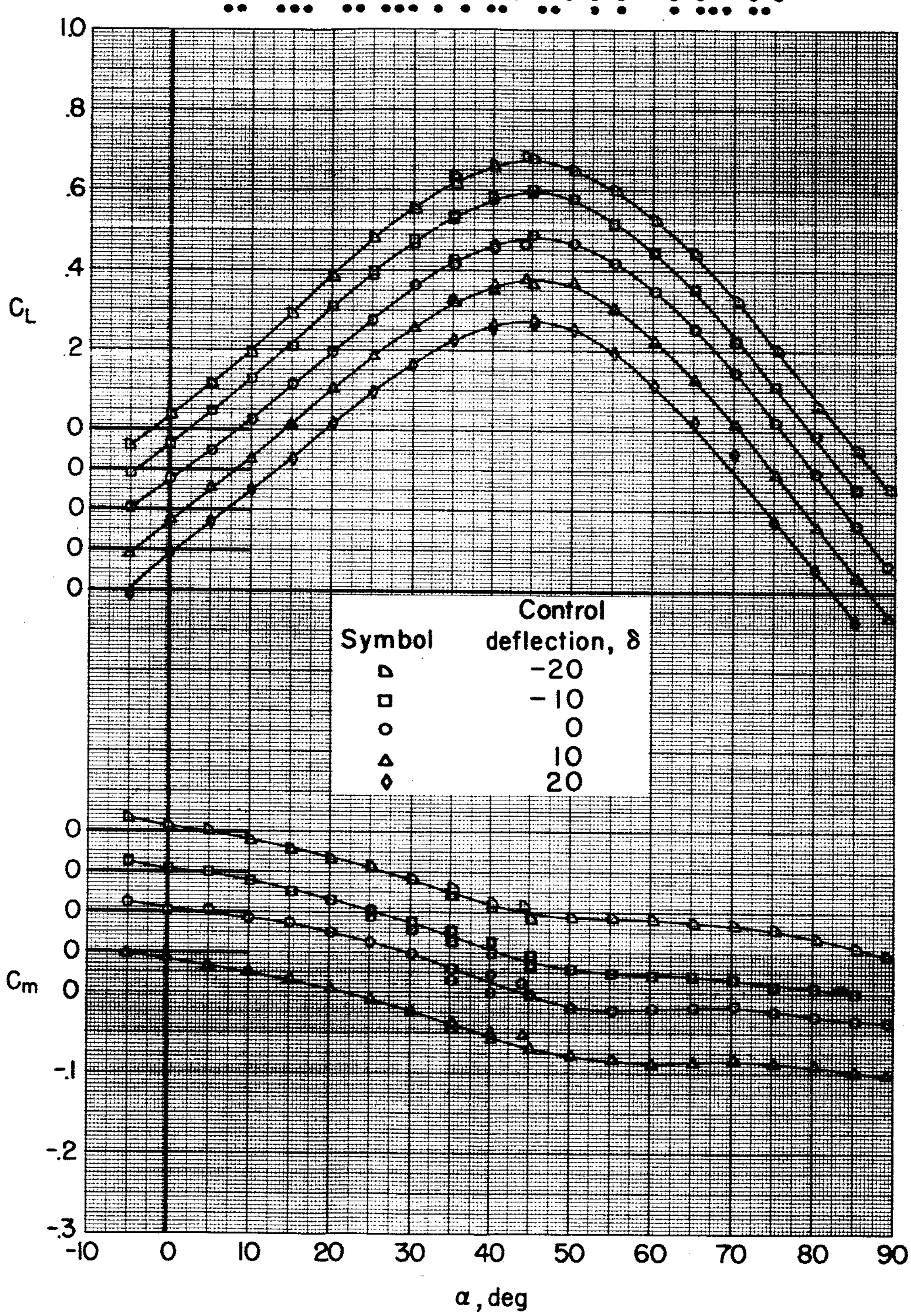

(c) M = 4.78 - Concluded.

Figure 8.- Concluded.