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EFFECT OF EXTERNAL STORES ON THE STABILITY AND CONTROL CHARACTERISTICS OF A DELTA WING FIGHTER MODEL AT MACH NUMBERS FROM 0.60 TO 2.01

M. Leroy Spearman

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

SUMMARY

An investigation has been made to determine the effects of external stores on the stability and control characteristics of a delta wing fighter airplane model. Tests were made at Mach numbers from 0.60 to 2.01 for a Reynolds number of 3.0×10^6 per foot. The angle-of-attack range was from about -4 degrees to 20 degrees at a sideslip angle of 0 degrees for the transonic tests, and from about -4 degrees to 10 degrees at sideslip angles of 0 and 3 degrees for the supersonic tests.

In general, the results of the tests indicated no seriously detrimental effects of the stores on the stability and control characteristics of the model but did show an increase in the minimum drag level throughout the Mach number range. However, the drag-due-to-lift was such that for subsonic/transonic speeds, the drag at higher lifts was essentially unaffected and the indications are that the maneuvering capability may not be impaired by the stores.

INTRODUCTION

As part of a continuing program to study the aerodynamics of supersonic fighter aircraft, the National Aeronautics and Space Administration has conducted an investigation to determine the effects of external stores on the stability and control characteristics of a delta-wing fighter model configuration. The model incorporated a 57-degree delta wing and an all-moveable aft horizontal tail and is the same model as that used for the investigation reported in reference 1. Tests were conducted in the Langley 8-foot transonic pressure tunnel at Mach numbers from 0.60 to 1.20 and in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers from 1.41 to 2.01 at a Reynolds number of 3.0×10^6 per foot. The angle-of-attack range was from about -4 degrees to 20 degrees at a sideslip angle of 0 degrees for the transonic tests and from about -4 degrees to 10 degrees at sideslip angles of 0 degrees and 3 degrees for the supersonic tests. The program included tests of the basic model, the model with pylons and stores, and the model with pylons alone. Pitch control tests of the model with stores were included at supersonic speeds only.

COEFFICIENTS AND SYMBOLS

The moment reference point is located at a station corresponding to 57 percent of the body length or 35 percent of the wing mean geometric chord. The longitudinal characteristics are referred to the stability axis system and the lateral characteristics are referred to the body axis system.

The symbols are defined as follows:

b wing span

$\bar{c}$ wing mean geometric chord

c_r root chord

c_t tip chord

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

$C_{D,o}$ drag coefficient at zero lift

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

C_{l_β} effective-dihedral parameter (from tests at $\beta = 0°$ and $3°$), $\frac{\Delta C_l}{\Delta \beta}$ per degree

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

$\frac{\partial C_m}{\partial C_L}$ longitudinal stability parameter

$\frac{\partial C_m}{\partial \delta_h}$ pitch effectiveness of horizontal tail

C_{n_β} directional stability parameter (from tests at $\beta = 0°$ and $3°$), $\frac{\Delta C_n}{\Delta \beta}$ per degree

C_{Y_β} side-force parameter (from tests at $\beta = 0°$ and $3°$), $\frac{\Delta C_Y}{\Delta \beta}$ per degree

L/D lift-drag ratio

M freestream Mach number

q freestream dynamic pressure

R Reynolds number per foot

S wing area

α angle of attack, degree

β angle of sideslip, degree

δ_h horizontal tail deflection angle, positive when trailing-edge is down, degree

APPARATUS

Tunnel

The investigation was conducted in both the Langley 8-foot transonic pressure tunnel and the Langley 4- by 4-foot supersonic pressure tunnel, which are continuous flow facilities with variable pressure capability. Descriptions of these facilities may be found in reference 2.

Model

A three-view drawing of the model is shown in figure 1(a) and pertinent geometric characteristics are given in table I. The wing section was a NACA 65A004.5 in the stream direction, and the wing had 2 degrees of negative dihedral. The horizontal and vertical tails also had NACA 65A004.5 sections in the stream direction. The ventral fin was made from a 0.125 inch thick flat plate with a 16 degree edge angle. The model was equipped with a simulated canopy. No provisions were made for airflow through the model. The basic body cross sections were circular with upper and lower halves separated by a flat section aft of the region of the canopy. The model had two pylon mounted stores, one under each wing. Details of the pylons and stores are shown in figure 1(b). The stores are representative of a Sidewinder missile.

Tests

The tests were conducted at Mach numbers from 0.60 to 2.01 at a Reynolds number per foot of 3.0×10^6. The angle-of-attack range was approximately -4 degrees to 20 degrees for the transonic tests and about -4 degrees to 10 degrees for the supersonic tests. Sideslip derivatives were obtained from incremental values measured at angles of sideslip of about 0 degrees and 3 degrees.

The dewpoint, measured at stagnation pressure, was maintained low enough to assure negligible condensation effects. Boundary-layer transition strips, 1/16 inch wide of No. 60 carborundum grit, were placed 0.4 inch behind the leading edges of the wing and tail surfaces, and around the nose 1.2 inches aft of the apex.

Measurements

Aerodynamic forces and moments on the model were measured by means of a six-component electrical strain-gage balance which was housed within the model. The balance was attached to a sting, which, in turn, was rigidly fastened to the tunnel support system. Balance-chamber pressure, measured by means of a single static-pressure orifice located in the vicinity of the balance, was used to adjust the drag to correspond to freestream static pressure at the model base.

DISCUSSION

Longitudinal Characteristics

The effects of the pylons and stores on the longitudinal characteristics are presented in figure 2. The addition of the pylons and stores cause an increase in minimum drag through the Mach number range as would be expected. However, the drag-due-to-lift is less with the pylon and stores installed and at the higher lifts that might be encountered in maneuvering flight, the drag increment due to the stores tends to disappear. The stores reduce the pitching-moments at the higher lifts which, in turn, would reduce the control deflections required for maneuvering. There is no measurable effect of the stores on the total lift so the change in pitching-moment is apparently due to a change in lift distribution. This characteristic is an indication that the spanwise location of the pylon, and the attendant flow interference region, is an important geometric consideration. In addition, the configuration shows negative values of pitching-moment at zero lift at subsonic speeds either with or without stores. At supersonic speeds, these values become positive and the stores, in fact, add a small positive increment. The positive values of pitching-moment at zero lift tend to reduce the control deflections required for trimming or maneuvering at positive lifts.

Longitudinal control tests were made for $M = 1.41$, 1.61, and 2.01 (fig. 3) for the model with missiles. These results, when compared with the clean configuration results of reference 1, indicate essentially no effect of the external store installation on the longitudinal control characteristics. This fact, coupled with the favorable drag-due-to-lift and positive pitching-moment increments associated with the stores, should tend to minimize the effects of stores on the maneuvering characteristics.

A summary of some longitudinal parameters as a function of Mach number is presented in figure 4. The primary detriment associated with the stores installation is the increased minimum drag which would adversely affect the power requirements and the acceleration characteristics at low lifts. However, the reduction in stability level, the unchanged control effectiveness, the positive increments of pitching-moment, the improved drag-due-to-lift, and the unaffected lift, all tend to negate any adverse effects of the stores at higher lifts and particularly at lifts required for high maneuverability.

Lateral Characteristics

The effects of the pylons and stores on the lateral characteristics are presented in figure 5. Even though the positive increment in side force ($-C_{Y_\beta}$) is below the roll axis, the pylon and stores generally caused an increase in effective dihedral ($-C_{l_\beta}$) at subsonic/transonic speeds probably due to a loss in lift on the downwind wing outboard of the pylon. In this speed range, there is also a decrease in C_{n_β}, probably due to direct sideforce on the store installation acting ahead of the moment reference point. However, positive directional stability is still maintained to relatively high angles of attack for maneuvering (about 16 degs) due to the inherently high values of C_{n_β} for the basic configuration. Of course, for more forward locations of the center of gravity (moment reference) which may be realistic, the permissible maneuvering angle of attack limit would be even higher.

At supersonic speeds, the effects of the stores on C_{l_β} disappears. In this speed range, any roll from direct sideforce effects of the stores acting below the roll axis may be offset by interference flow fields from the pylon which, in sideslip, would tend to decrease the lift of the windward wing inboard of the pylon and to increase the lift of the downwind wing inboard of the pylon.

The directional stability, for the limited angle range of the supersonic tests, indicated a small beneficial effect of the stores. This may be due to a more confined effect of the pylon/store flow field to regions aft of the moment reference. In addition, any effects of the stores on the vertical tail contribution to C_{n_β} (or C_{l_β}) cannot be detected since vertical-tail-off data is not available.

CONCLUDING REMARKS

The investigation of the effects of external stores on a delta wing fighter model indicated no seriously detrimental effects on the stability and control characteristics. An increase in the minimum drag due to the stores would adversely affect the power requirements and acceleration characteristics at low lifts. However, with increasing lift, other factors affecting the drag, pitching-moments, and control effectiveness were such that the indications are that the maneuvering capability would not be impaired by the stores. All things considered, it appears that the geometric location of the pylon and store for this configuration is an important factor in determining the effects of store carriage on the stability and control characteristics and that these effects may be quite small or even favorable, particularly for maneuvering flight.

REFERENCES

1. Spearman, M. Leroy; and Corlett, William A.: Stability and Control Characteristics at Mach Numbers From 0.60 to 2.50 of a Delta Wing Fighter Airplane Model Having an Aft Horizontal Tail. NASA TM-1752, 1969.

2. Schaefer, William T., Jr.: Characteristics of Major Active Wind Tunnels at the Langley Research Center. NASA TM X-1130, 1965.

TABLE I.- GEOMETRIC CHARACTERISTICS

Wing

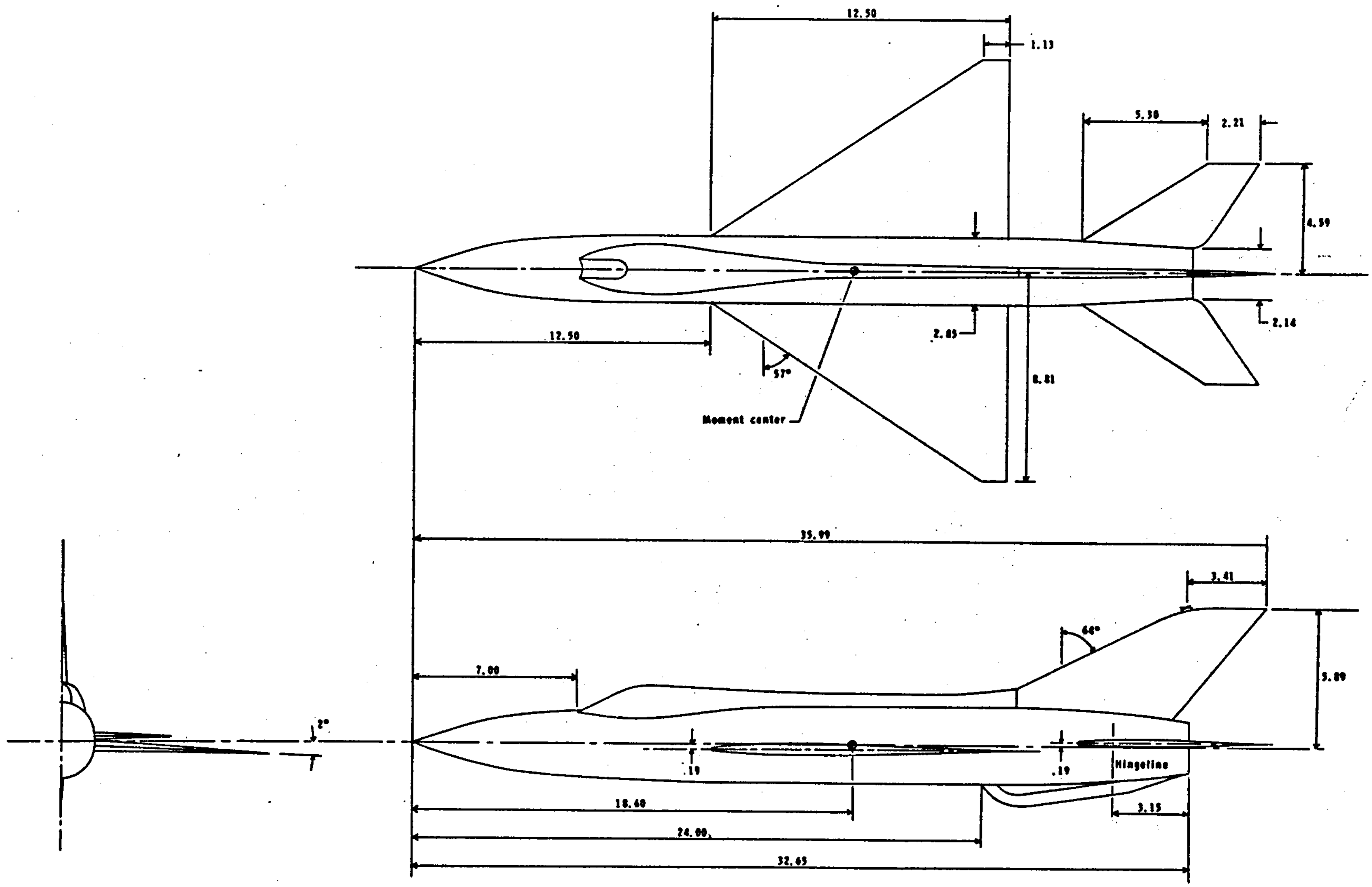
b, in	17.62
Λ, leading edge, deg	57.0
Λ, trailing edge, deg	0
$\bar{c}$, mean aerodynamic chord, in	9.85
c_r, at body intersection, in	12.5
c_t, in	1.125
Γ, deg	-2
Section	NACA 65A004.5
S, including fuselage intercept, sq in	139.5
A	2.22
Body station for trailing edge intersection, in	25

Horizontal tail

Span, total, in	9.19
c_r at body center line	6.60
c_t	2.21
Hinge line, percent exposed root chord	30.0
Section	NACA 65A004.5
Λ, leading edge, deg	58.5
Body station for intersection of extended leading edge with body centerline, in	25.825

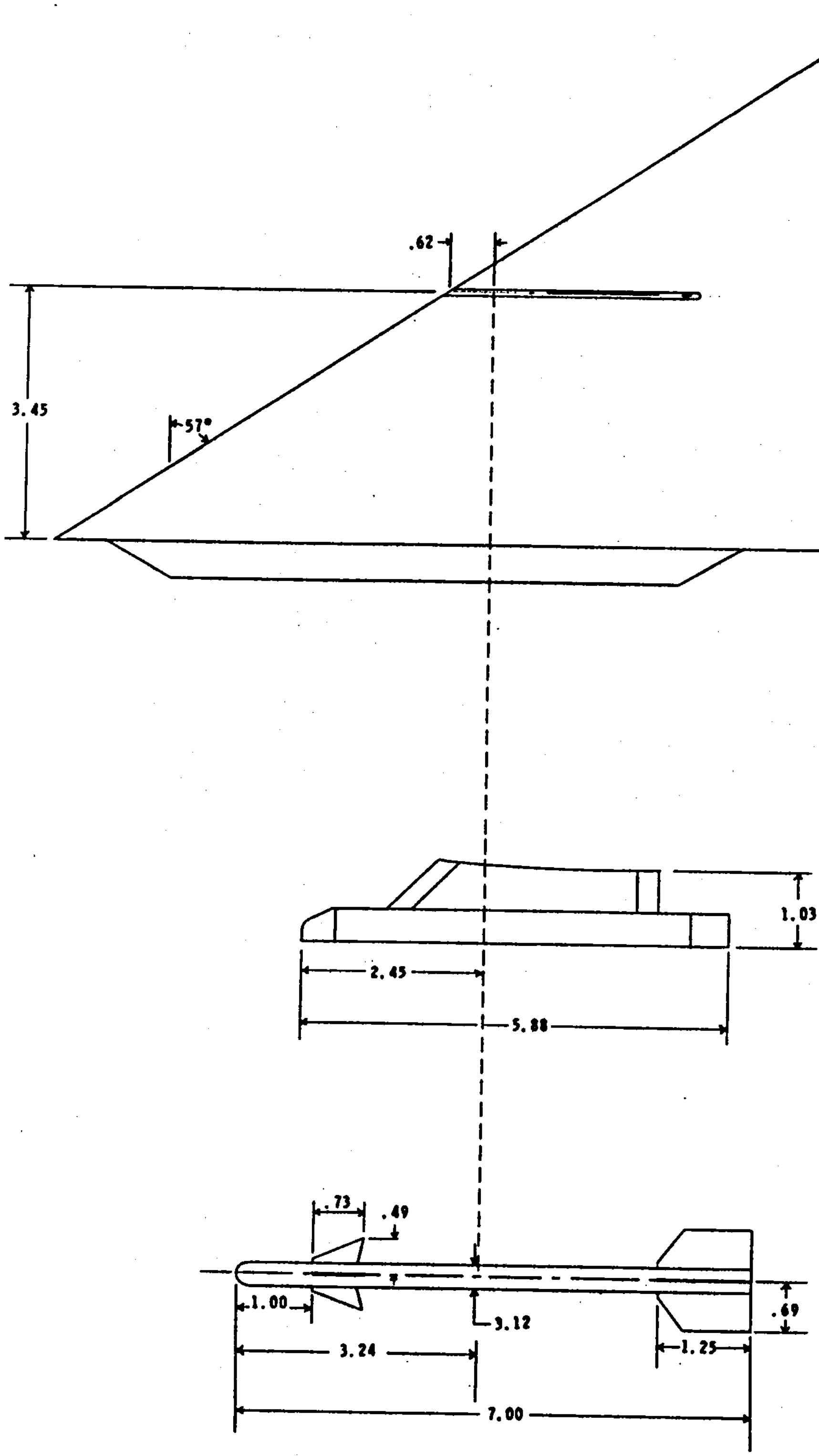
Vertical tail

Span, exposed, in	4.51
c_r, exposed, in	9.09
c_t, in	3.41
Section	NACA 65A004.5
Λ, leading edge, deg	64
Body station for intersection of extended leading edge with wing chord plane, in	20.125
c_r at intersection with wing chord plane, in	10.65



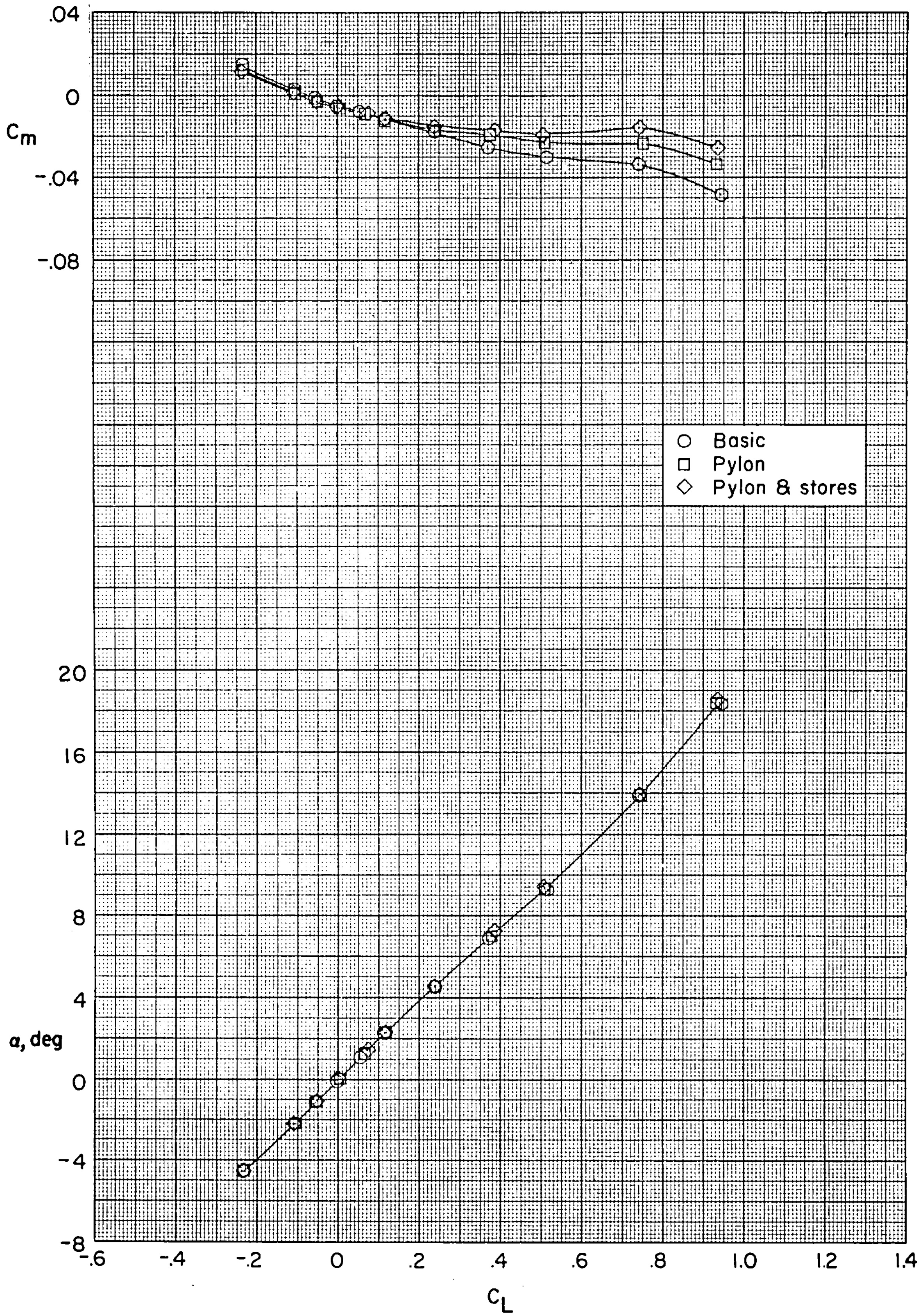
(a) Complete model.

Figure 1.- Model details. (All dimensions are in inches unless otherwise noted.)



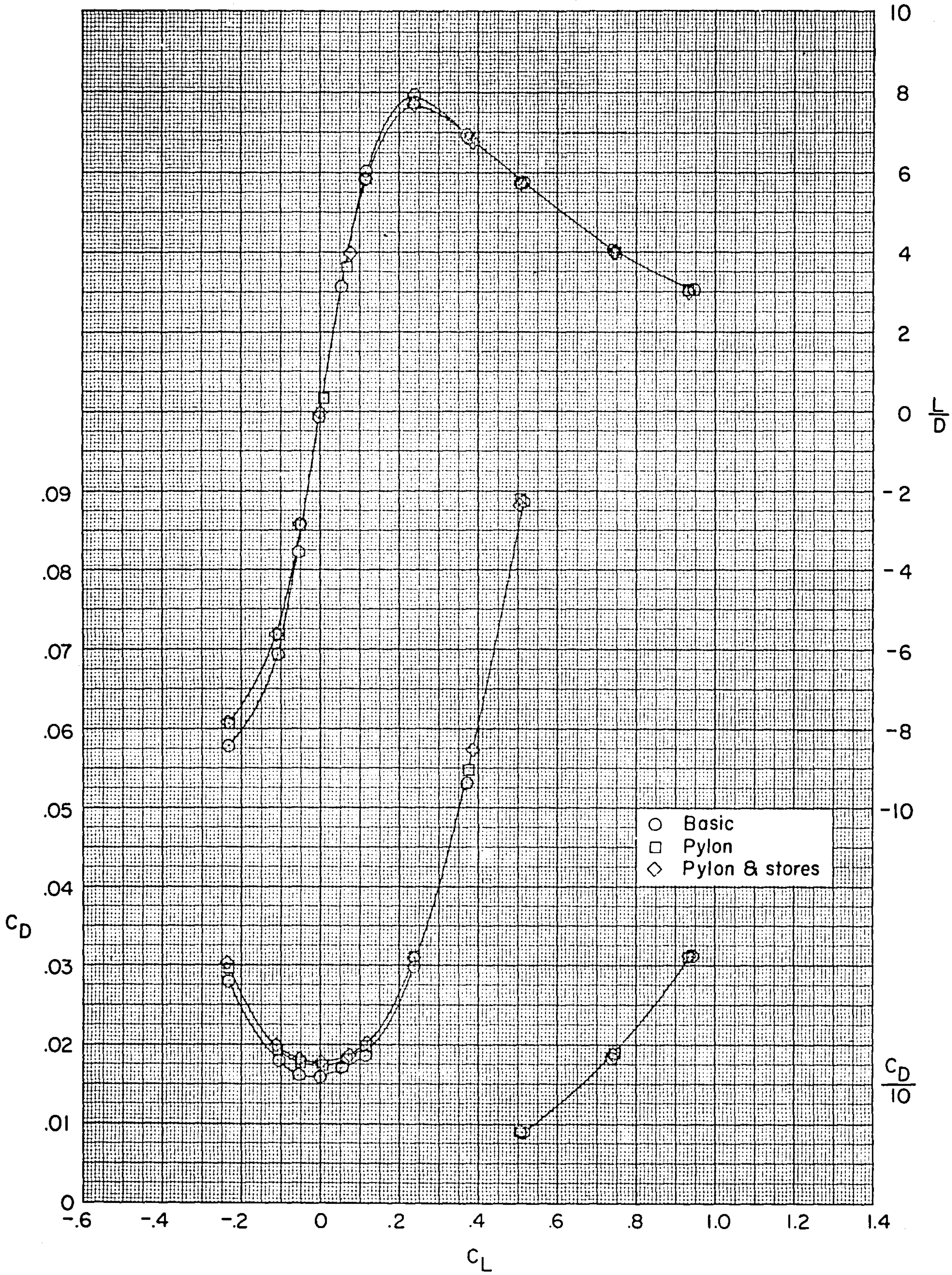
(b) Pylon and store details.

Figure 1.- Concluded.



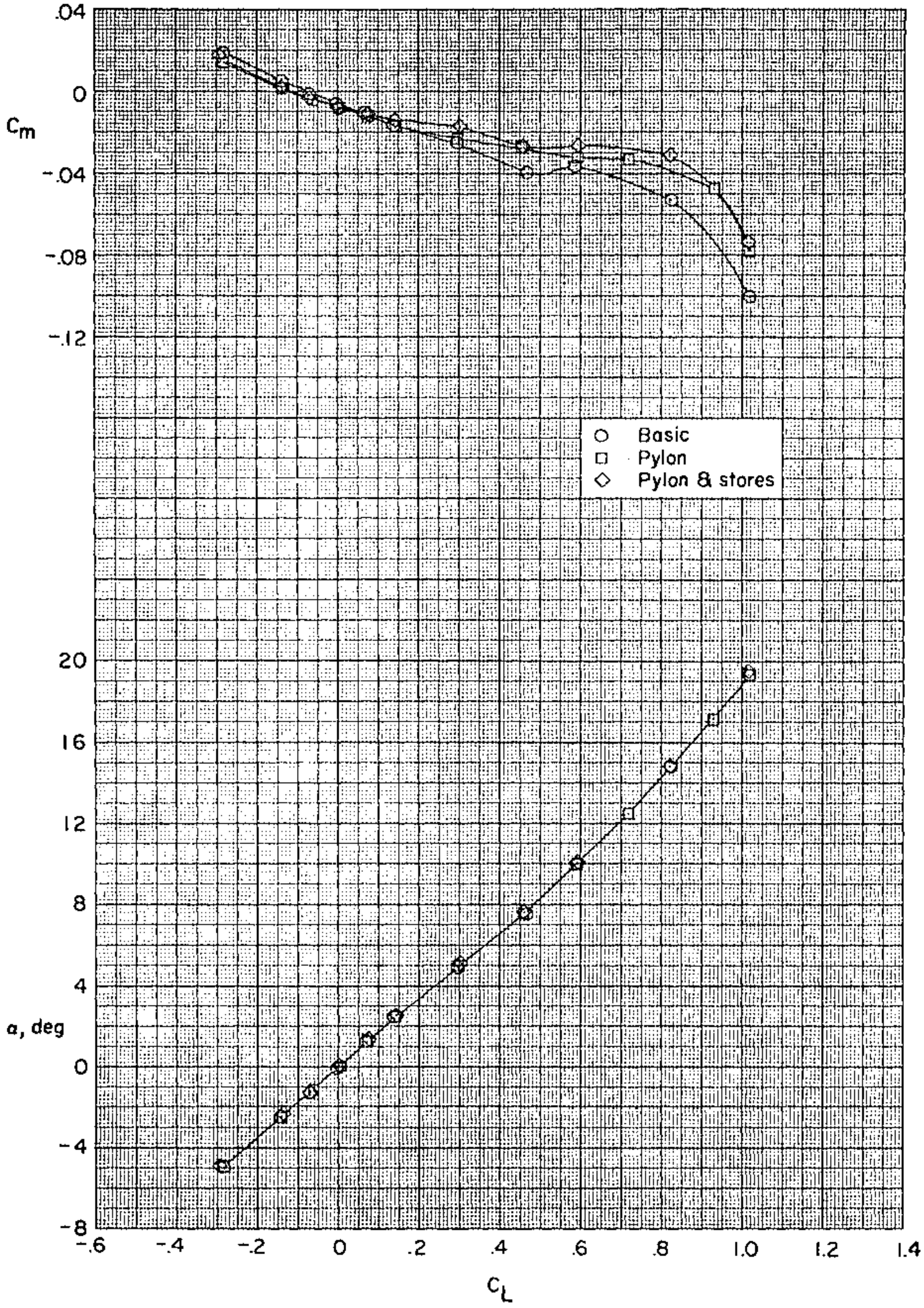
(a) M = .60.

Figure 2.- Effect of pylons and stores on longitudinal characteristics.



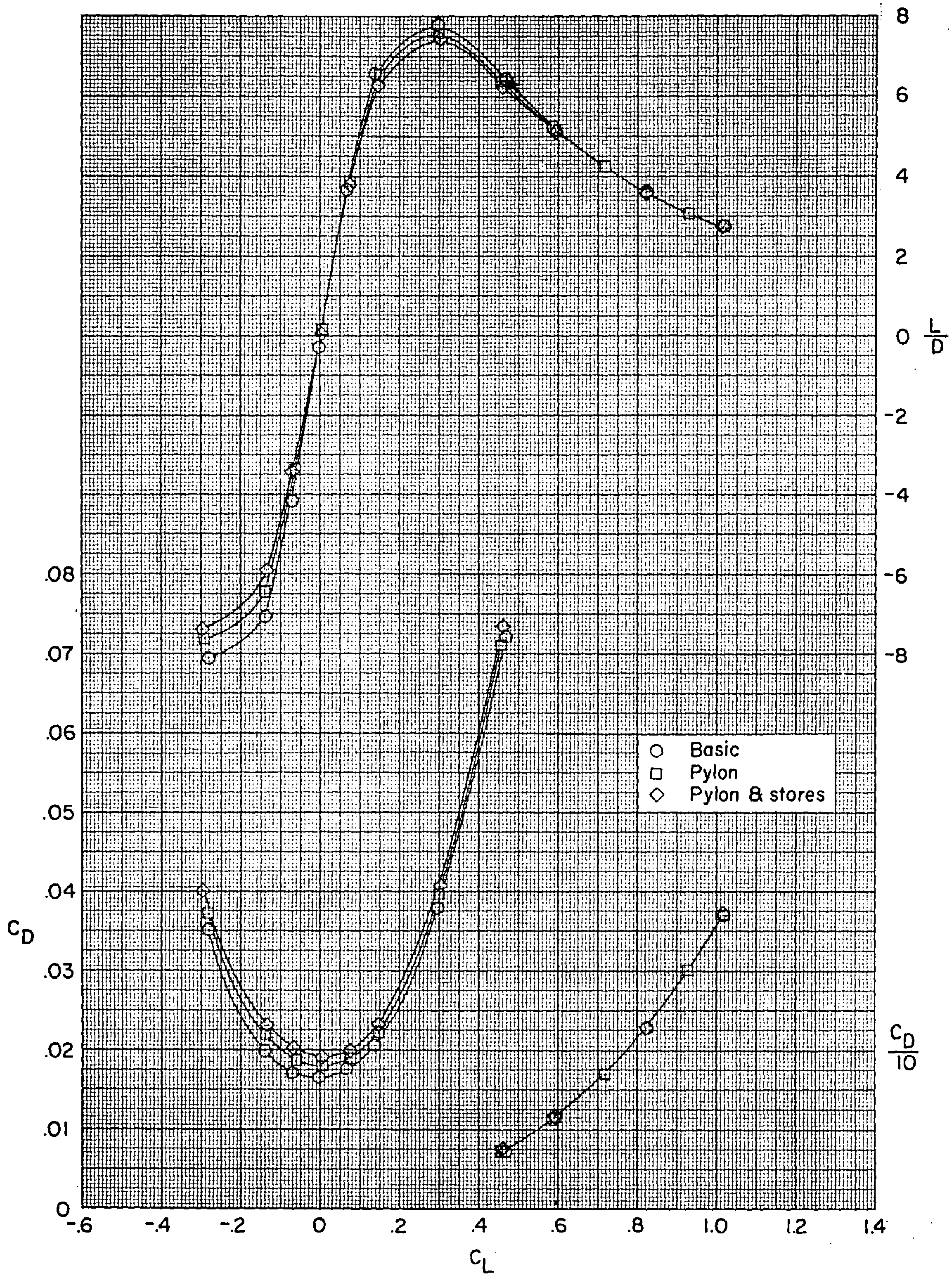
(a) Concluded.

Figure 2.- Continued.



(b) M = .90.

Figure 2.- Continued.



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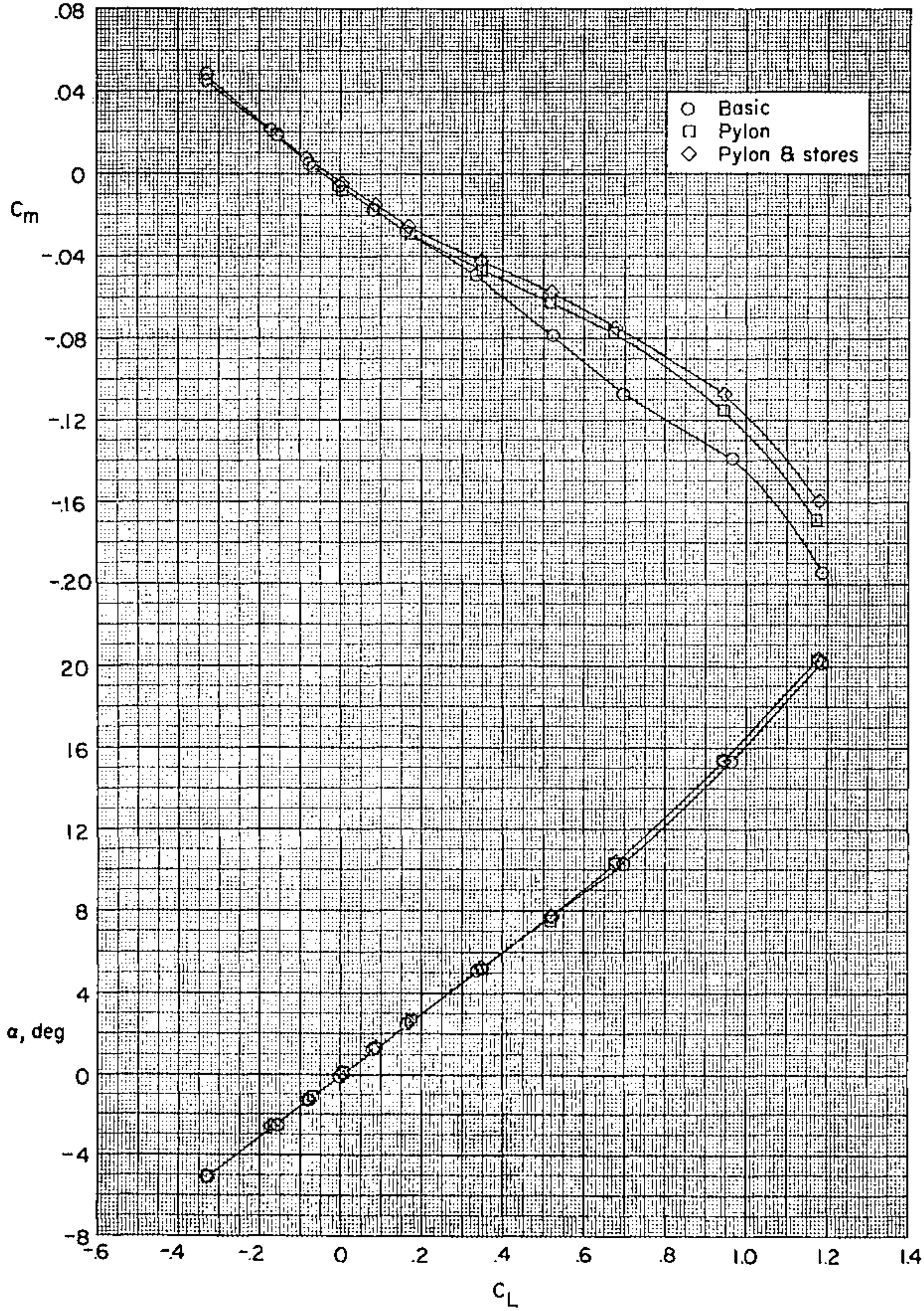
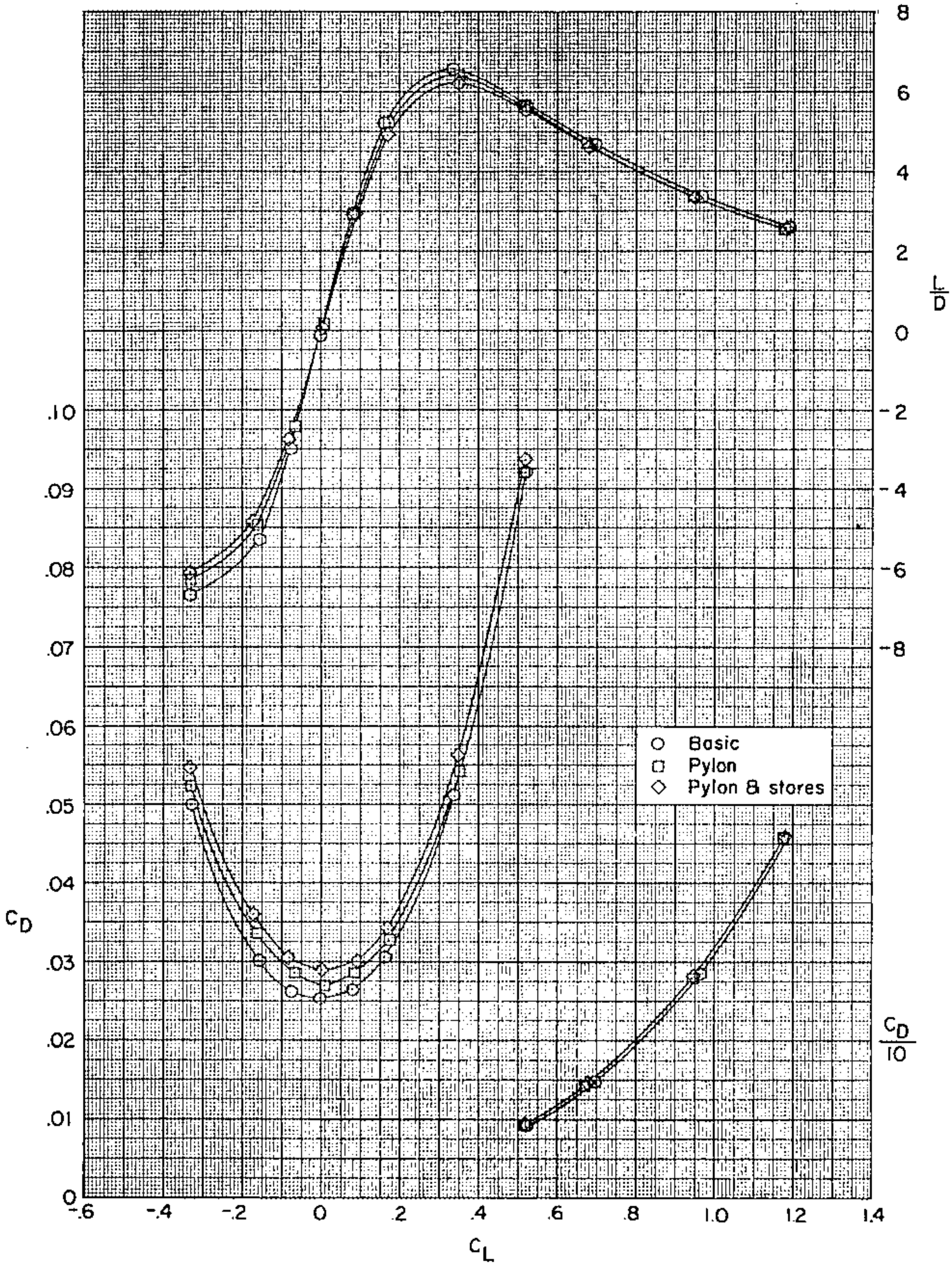


(c) M = 1.00.

Figure 2.- Continued.



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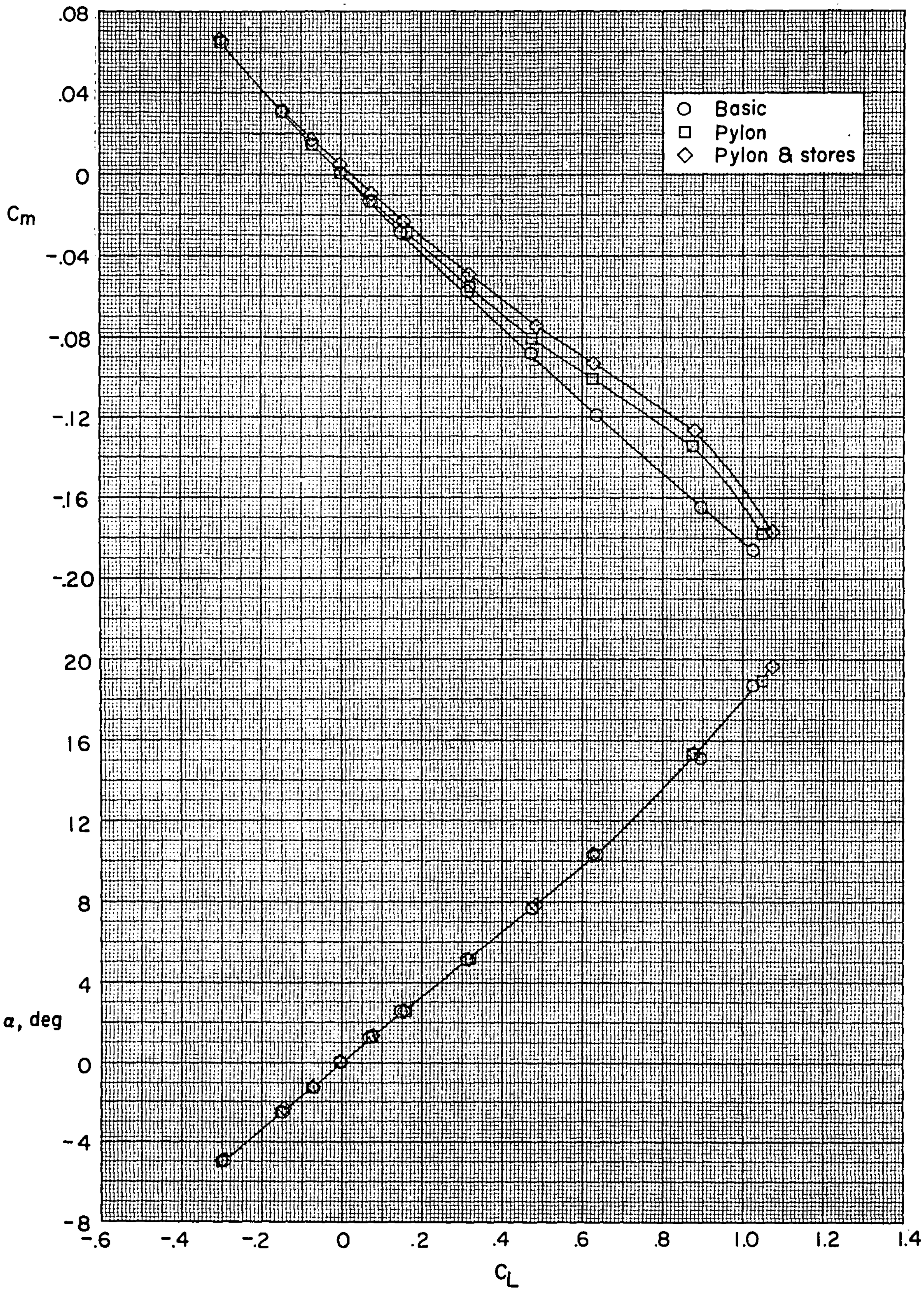
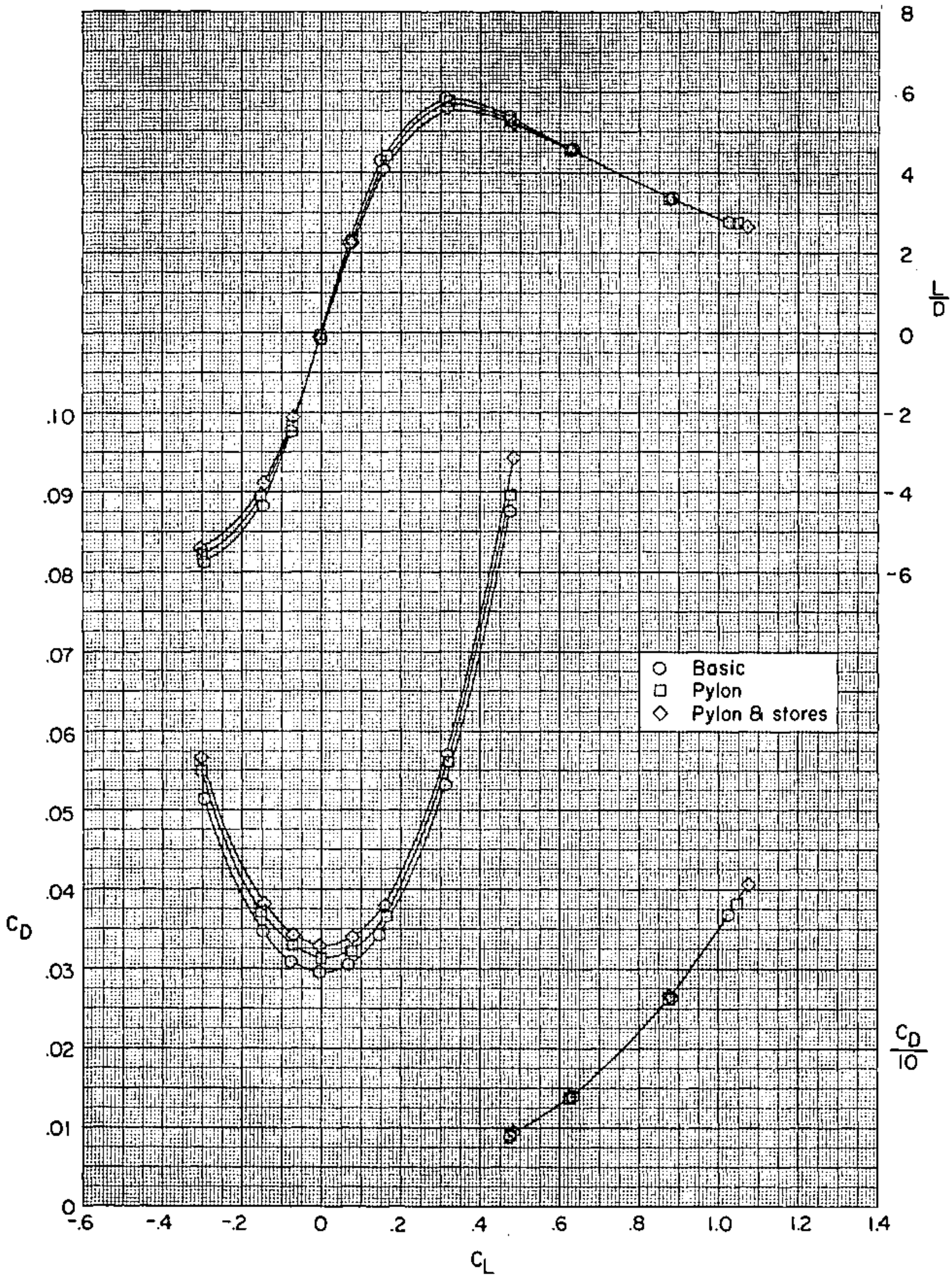


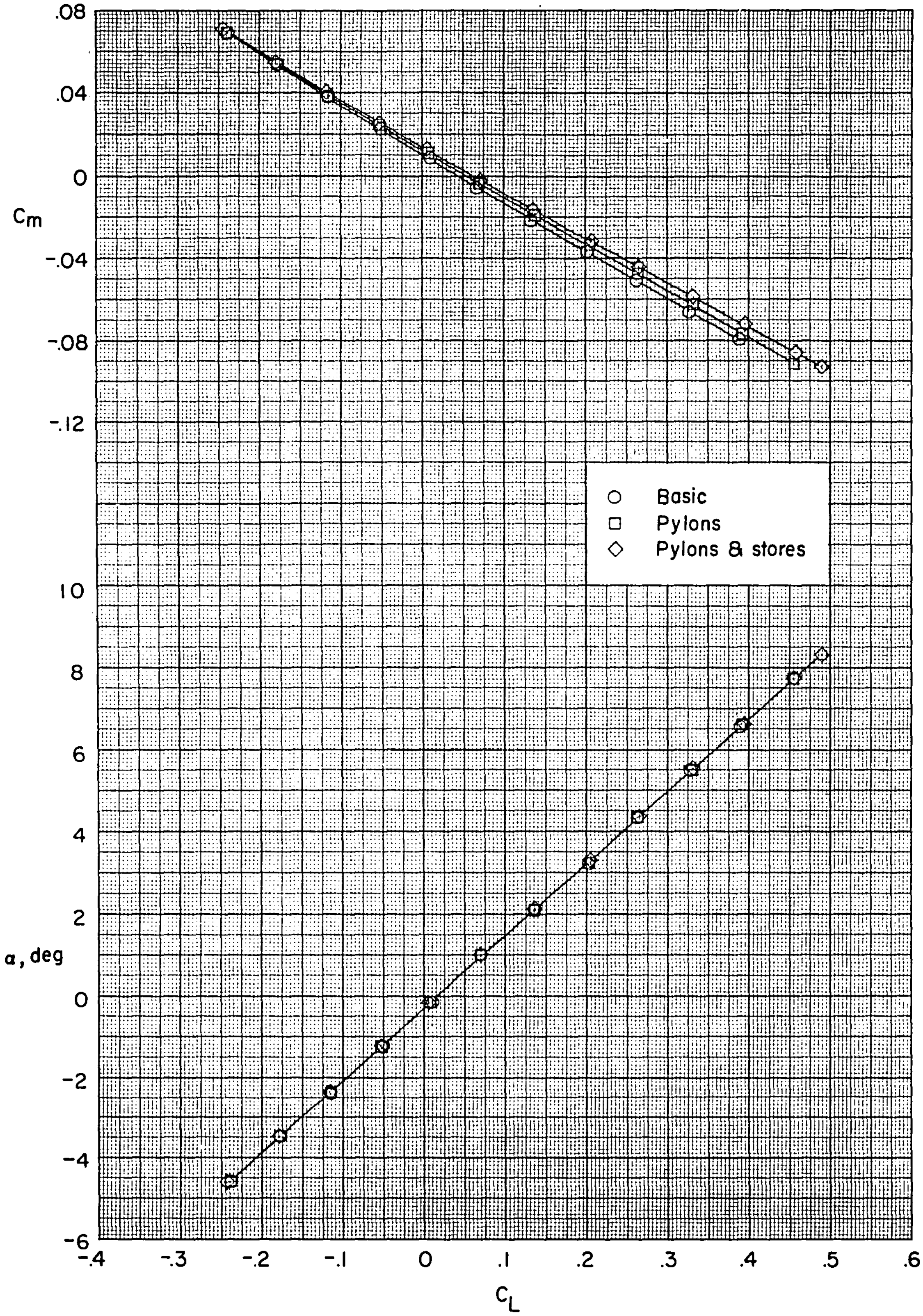
(d) M = 1.20.

Figure 2.- Continued.



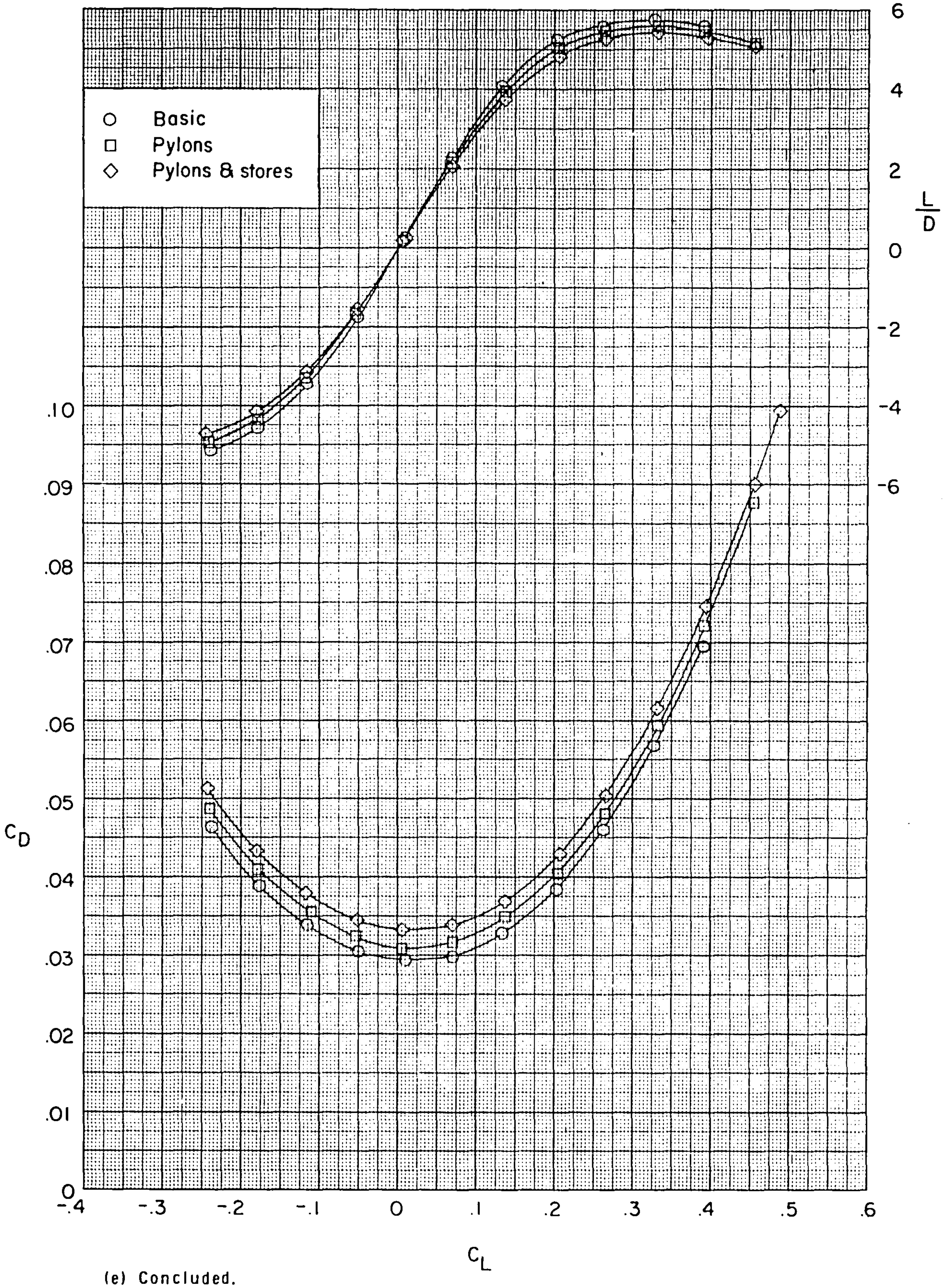
(d) Concluded.

Figure 2.- Continued.



(e) M = 1.41.

Figure 2.- Continued.



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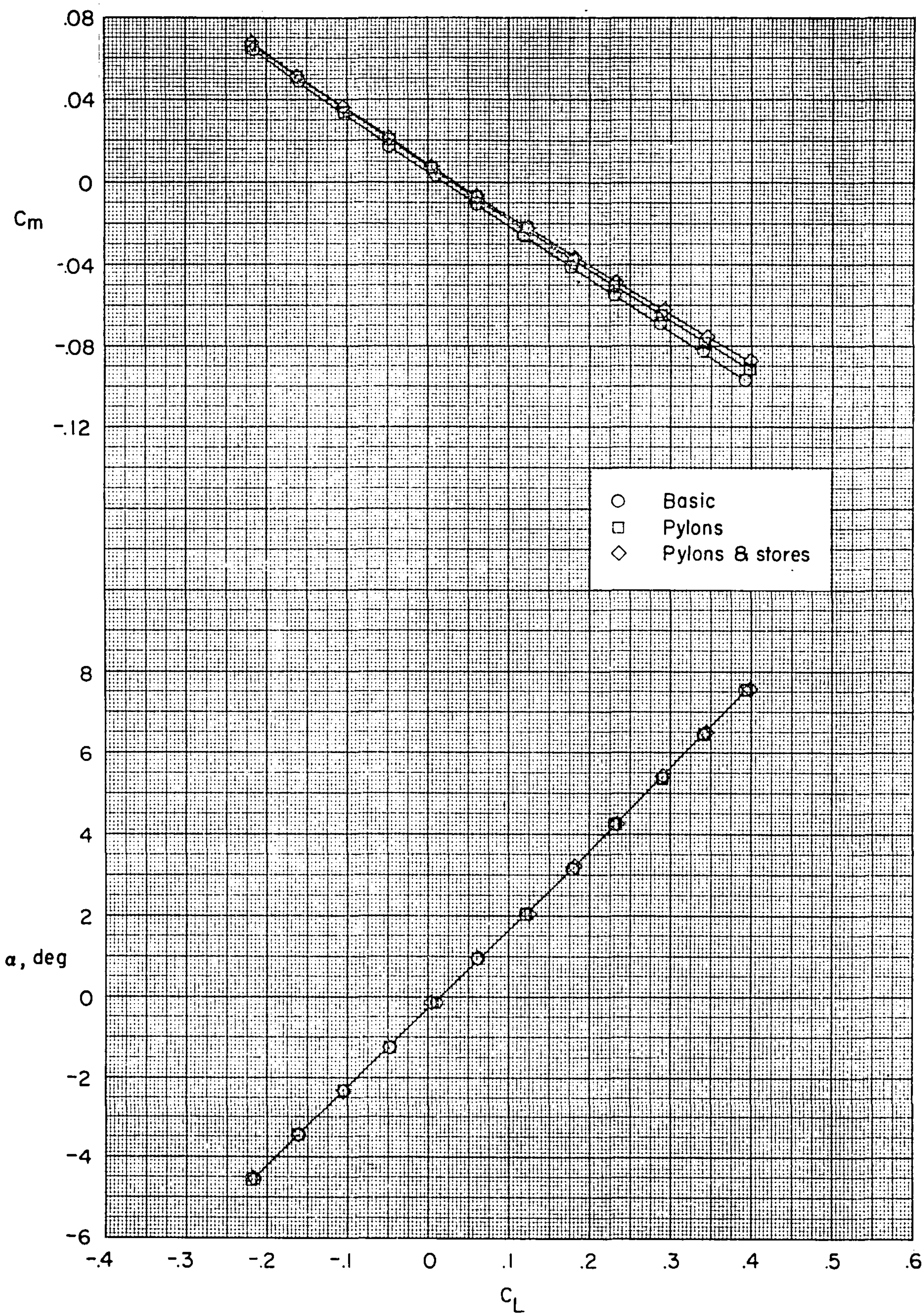
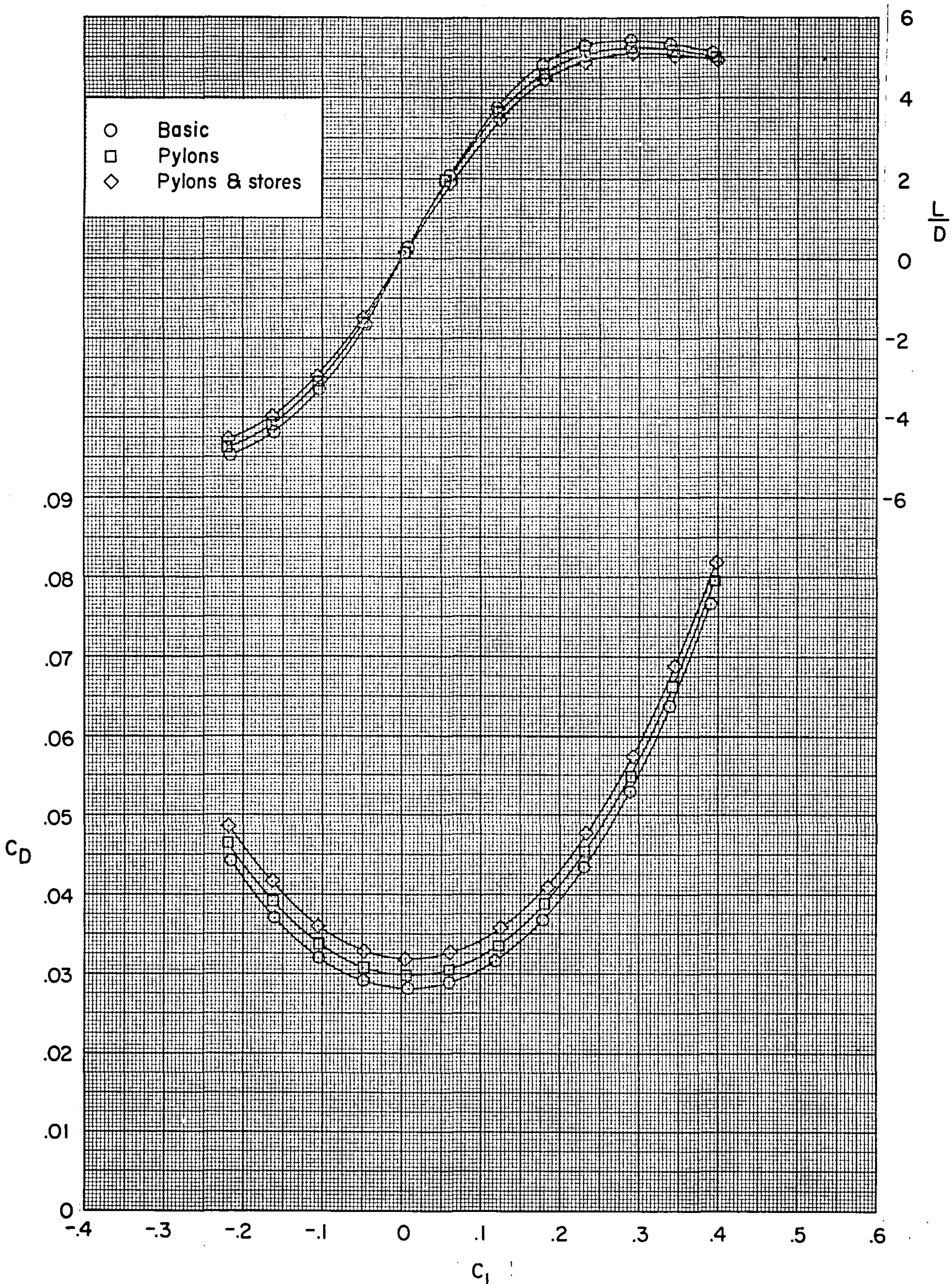


(f) M = 1.61.

Figure 2.- Continued.



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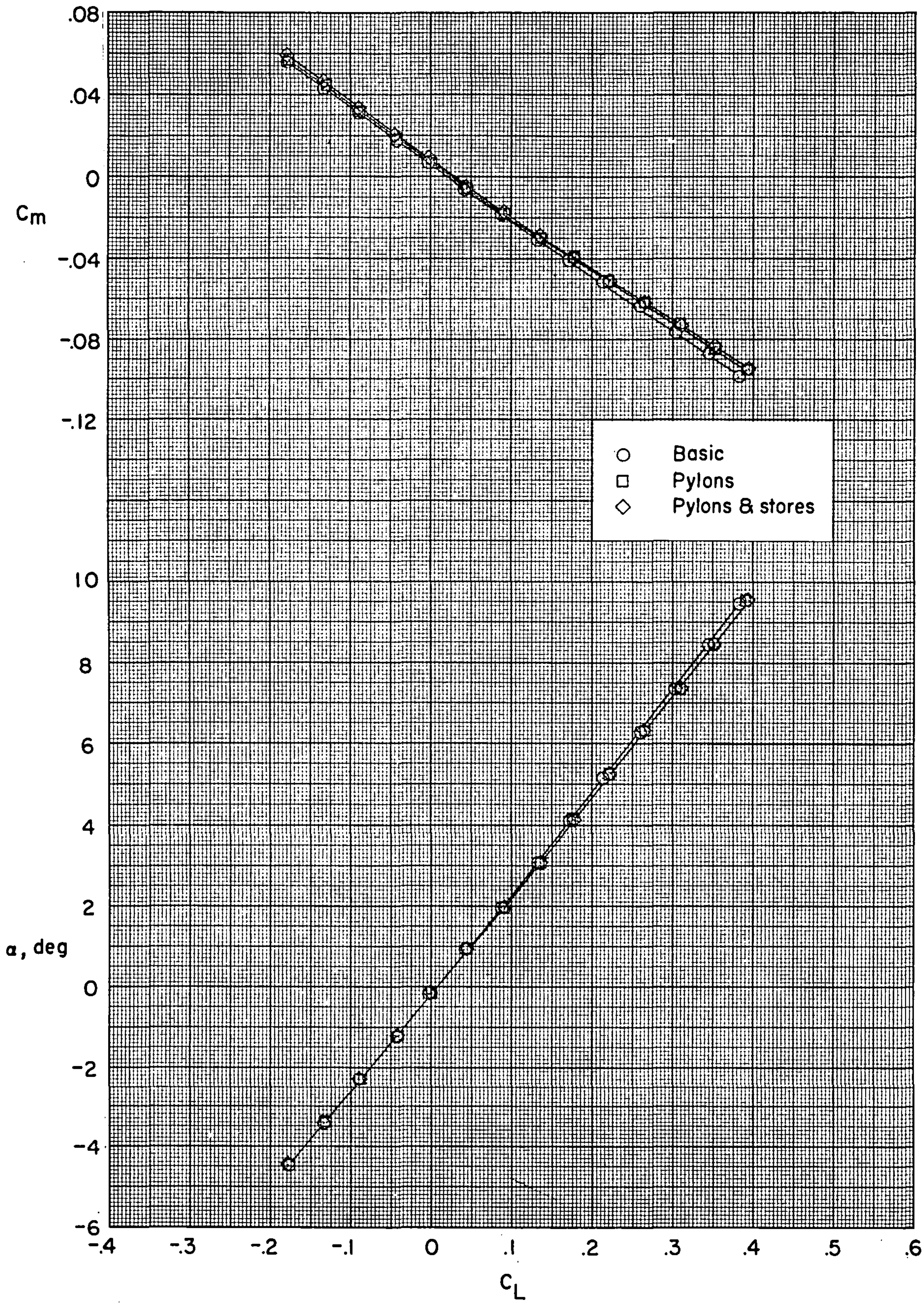
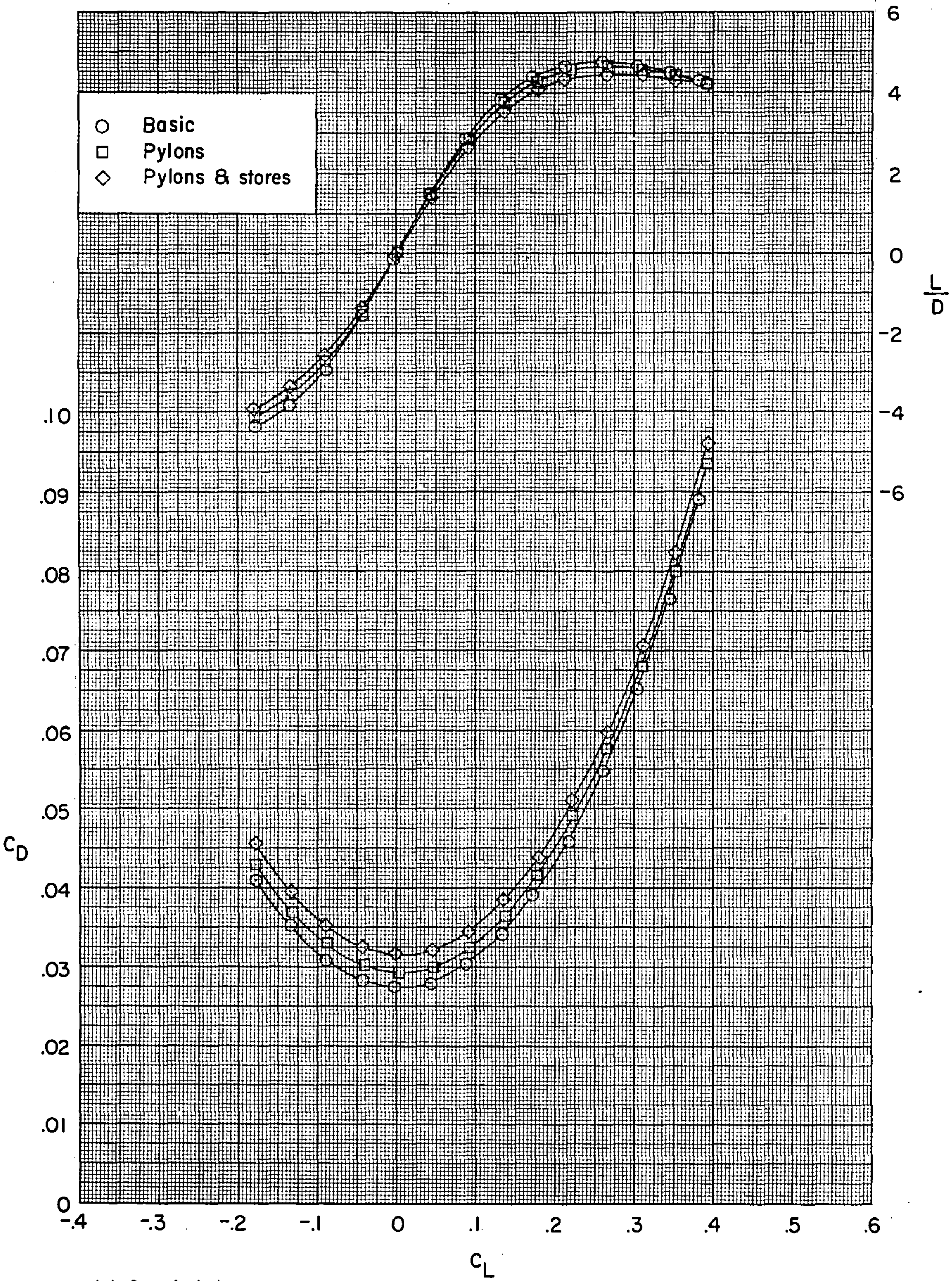


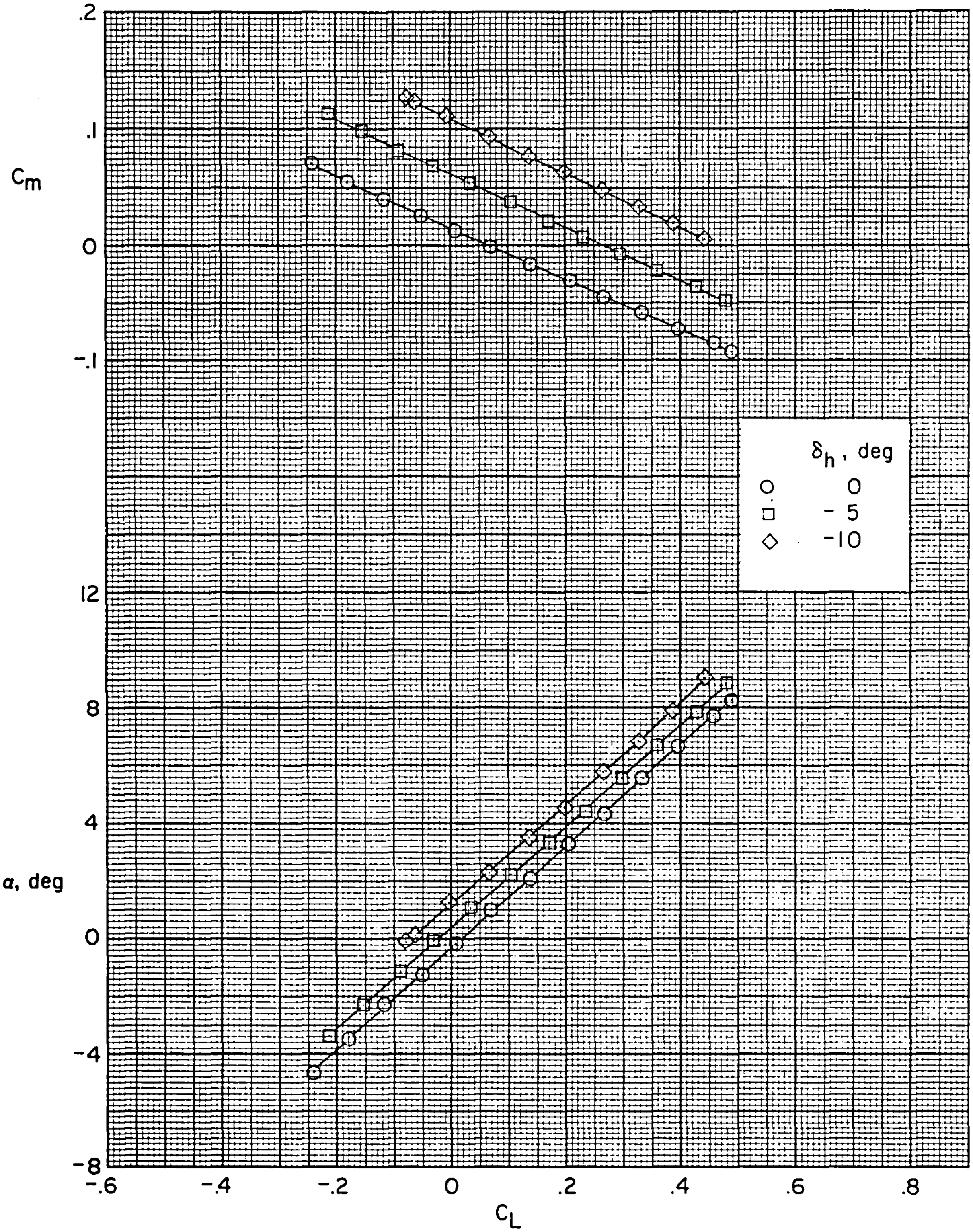
(g) M = 2.01.

Figure 2.- Continued.



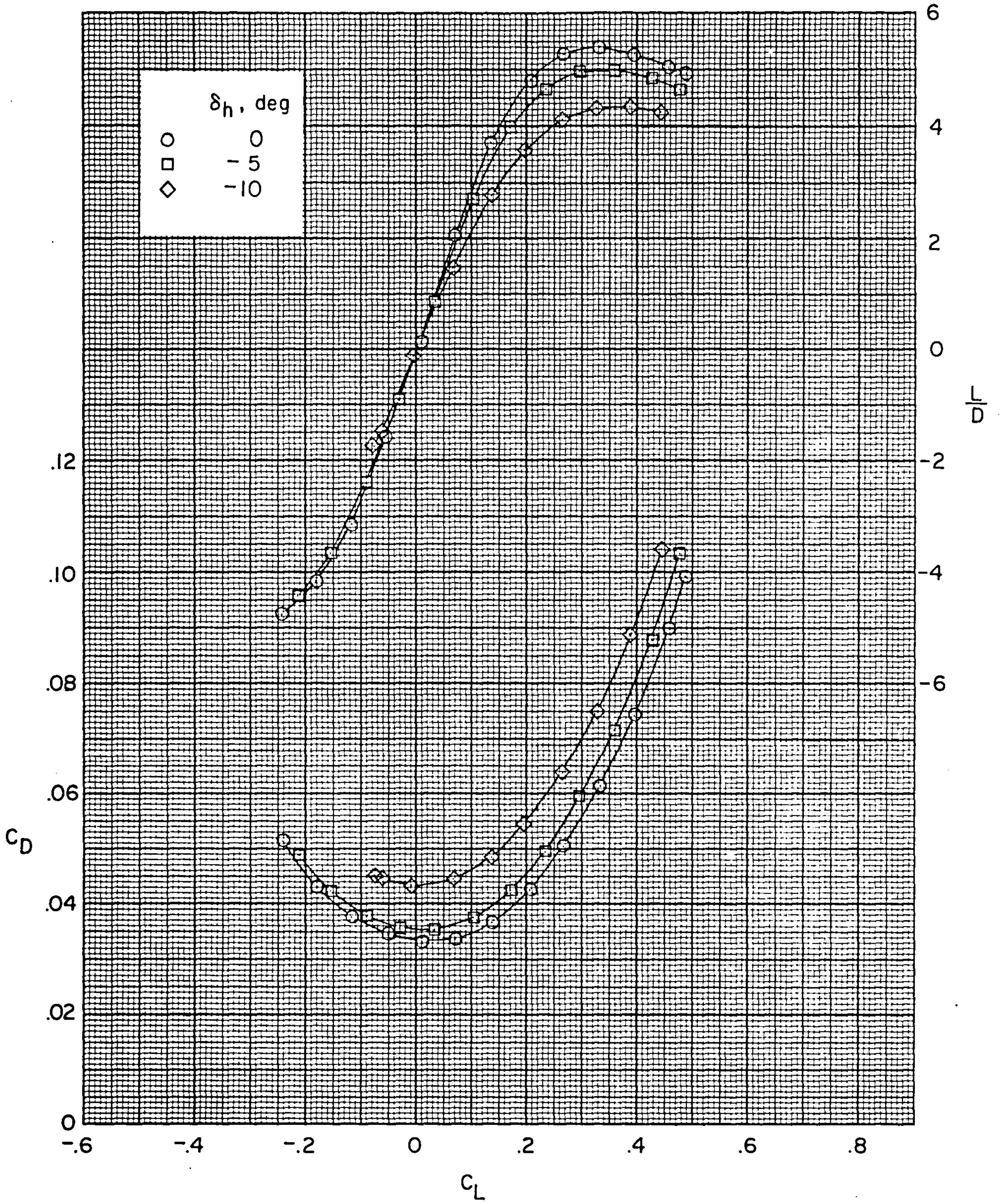
(g) Concluded.

Figure 2.- Concluded.



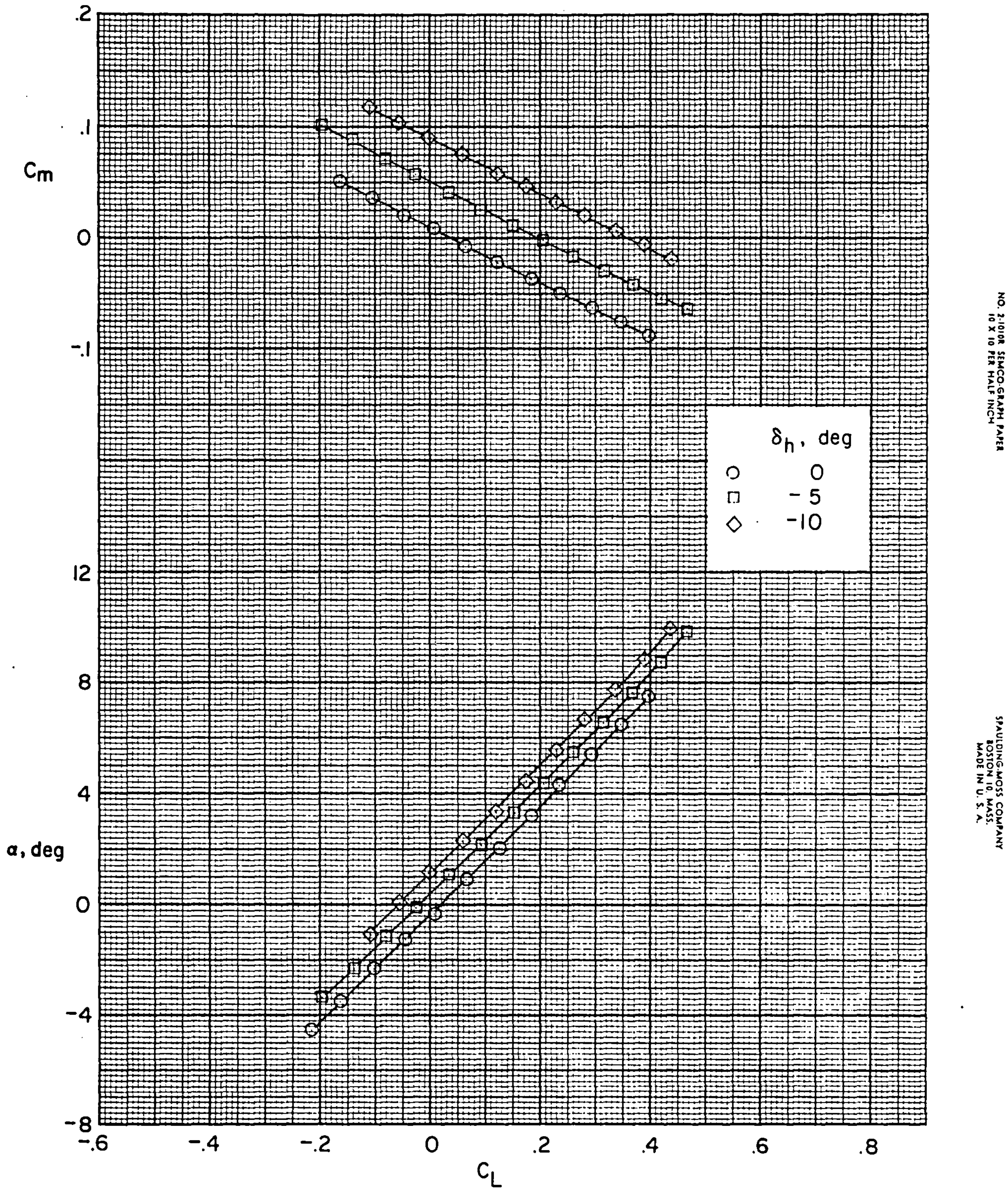
(a) M = 1.41.

Figure 3.- Longitudinal control characteristics with pylons and stores.



(a) Concluded.

Figure 3.- Continued.



(b) M = 1.61.

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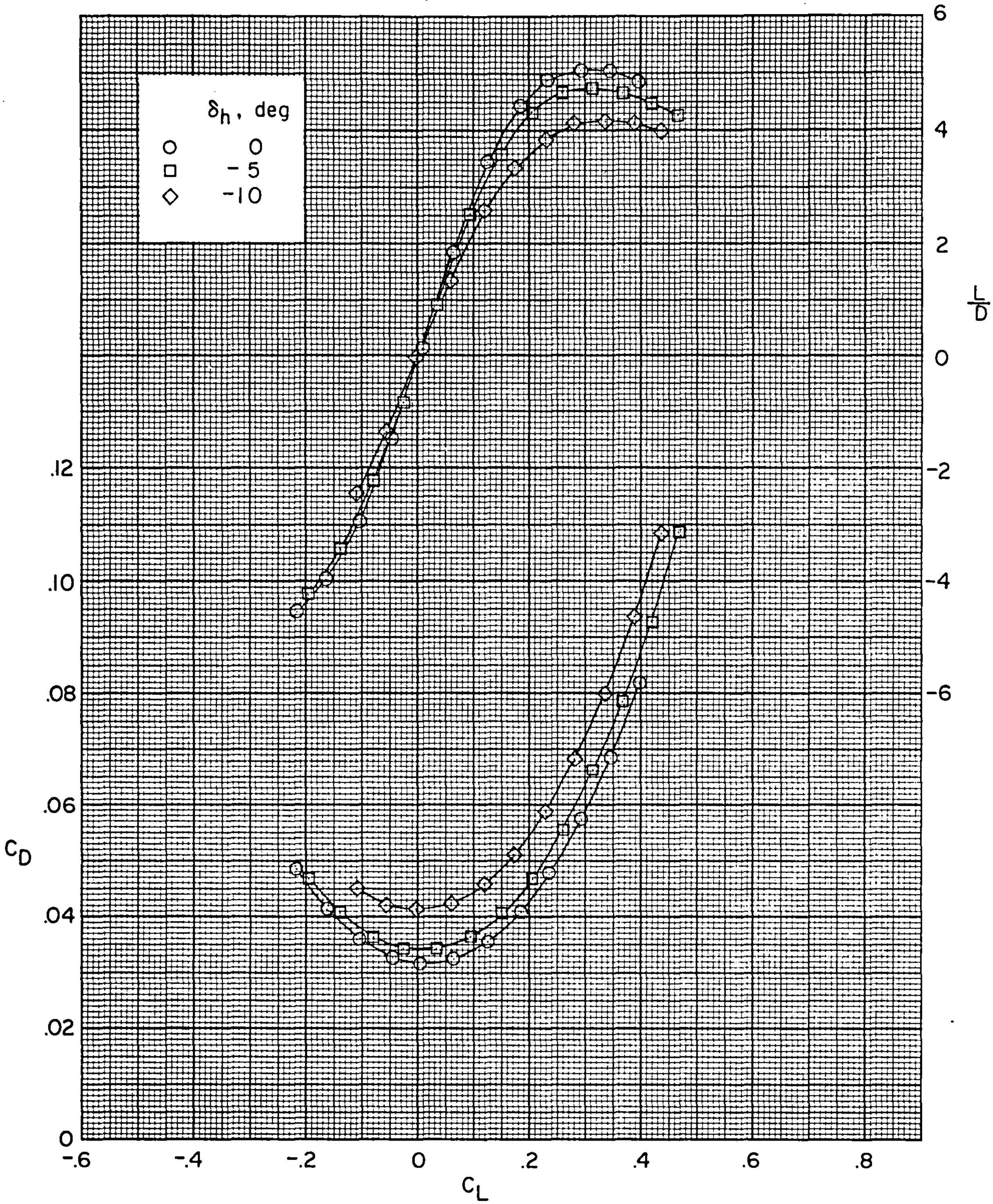

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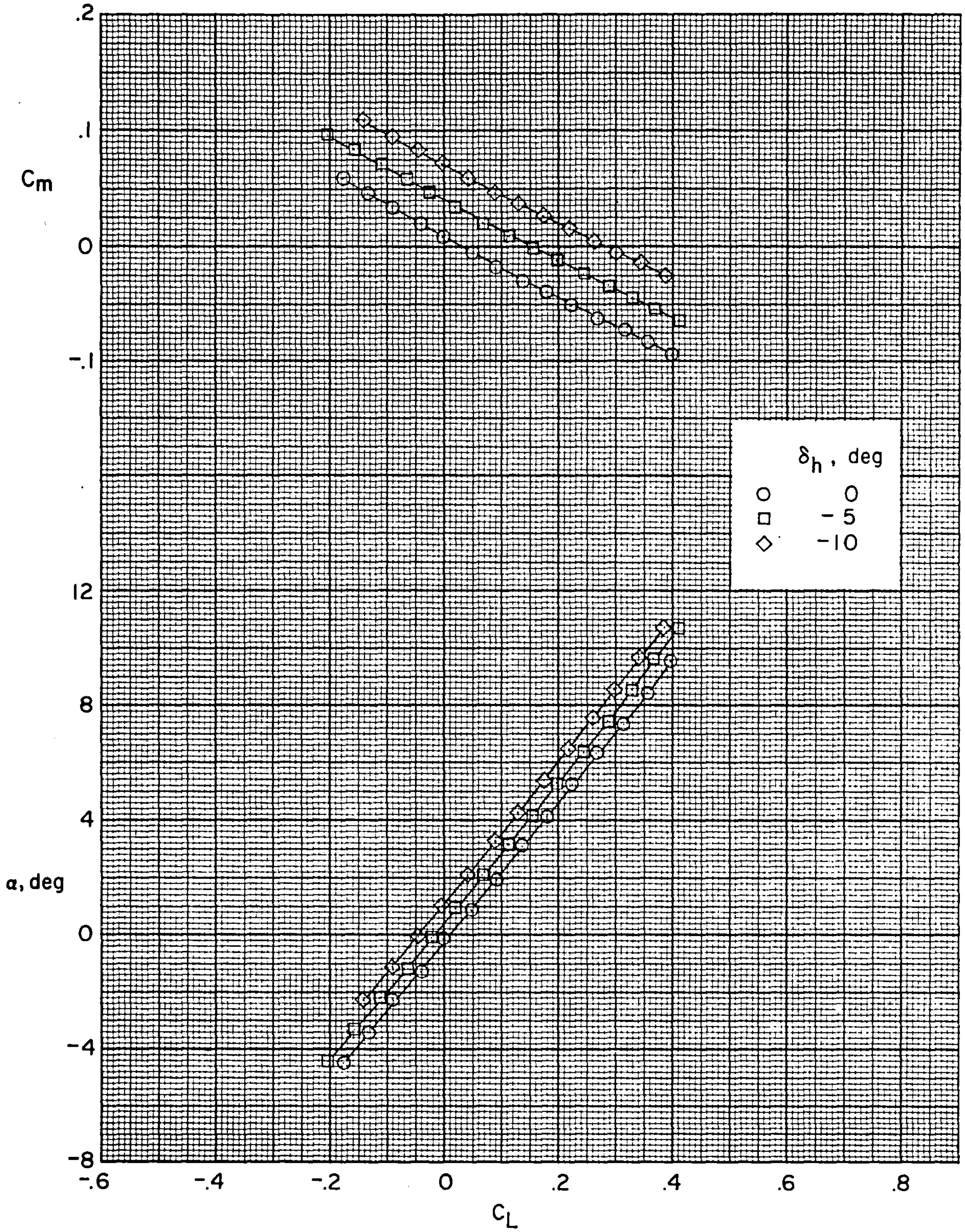

(c) M = 2.01.

Figure 3.- Continued.

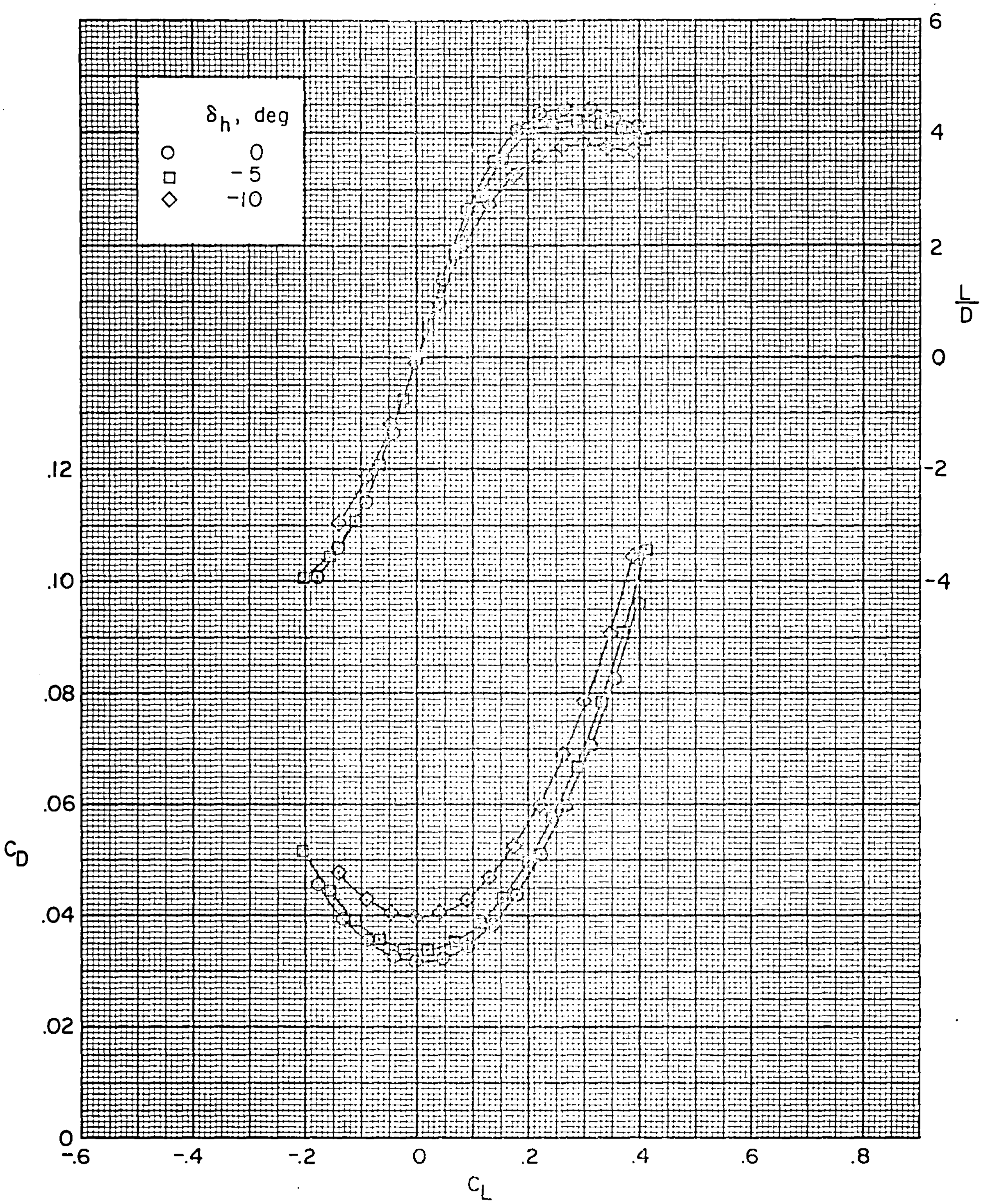

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Figure 3.- Concluded.

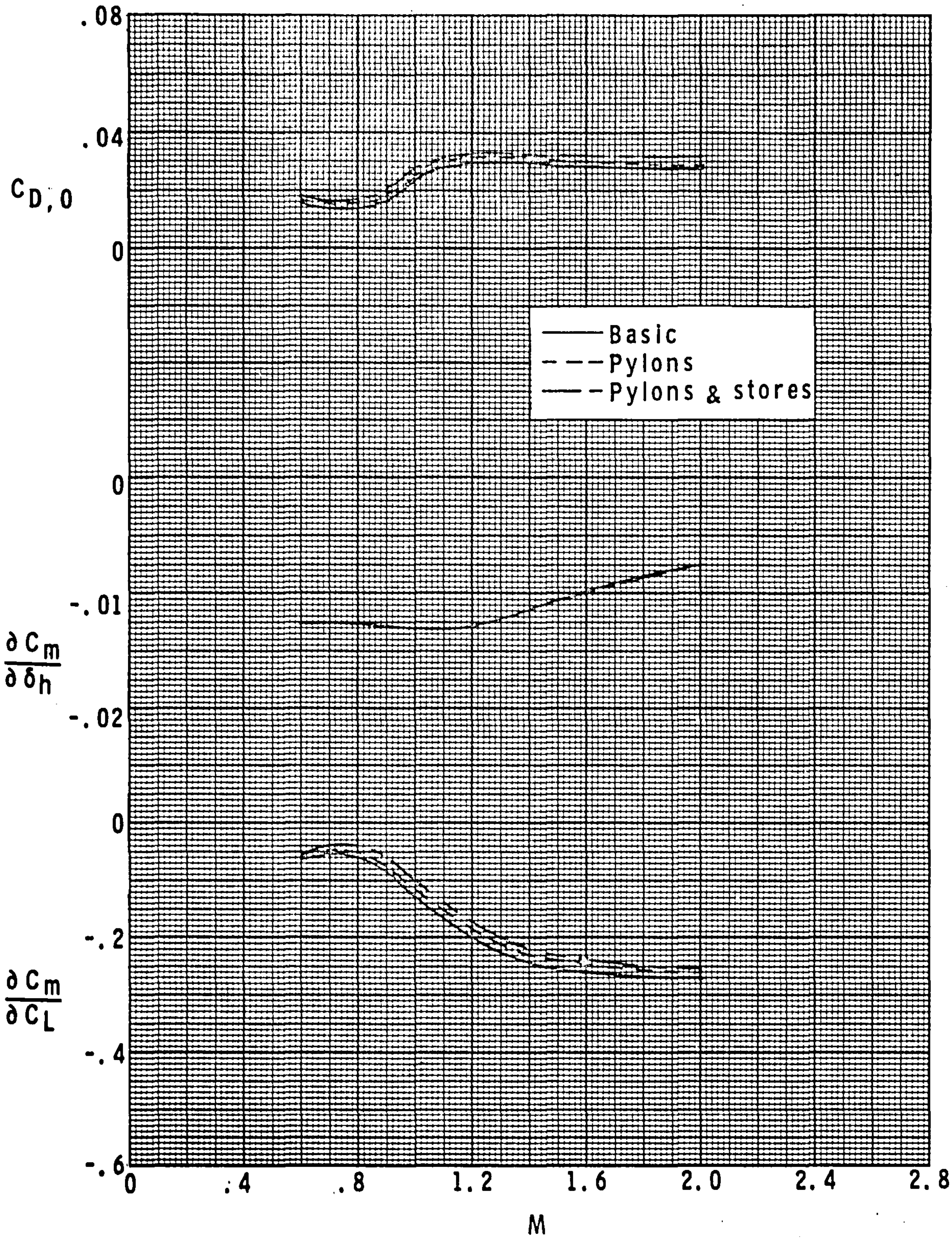
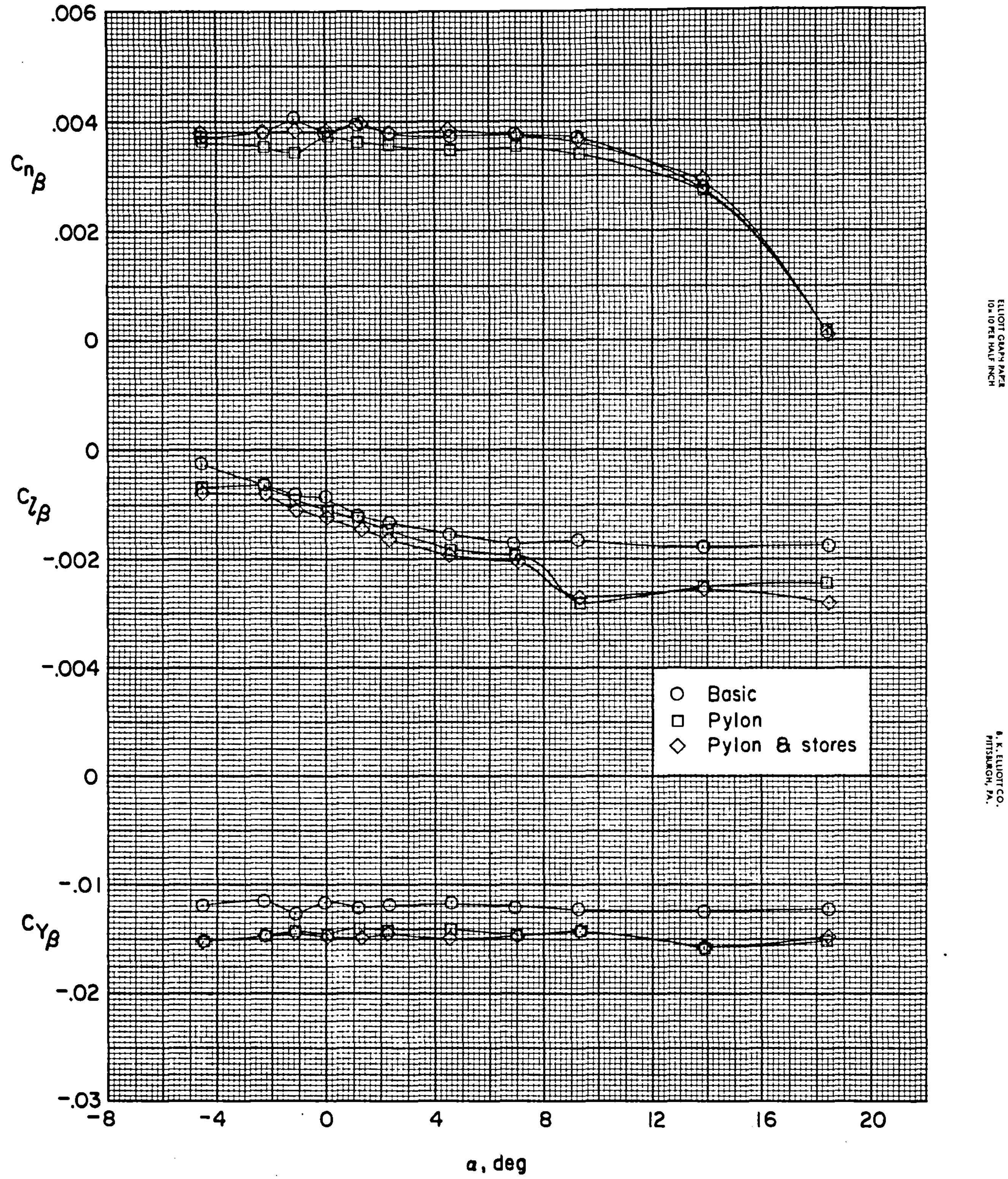
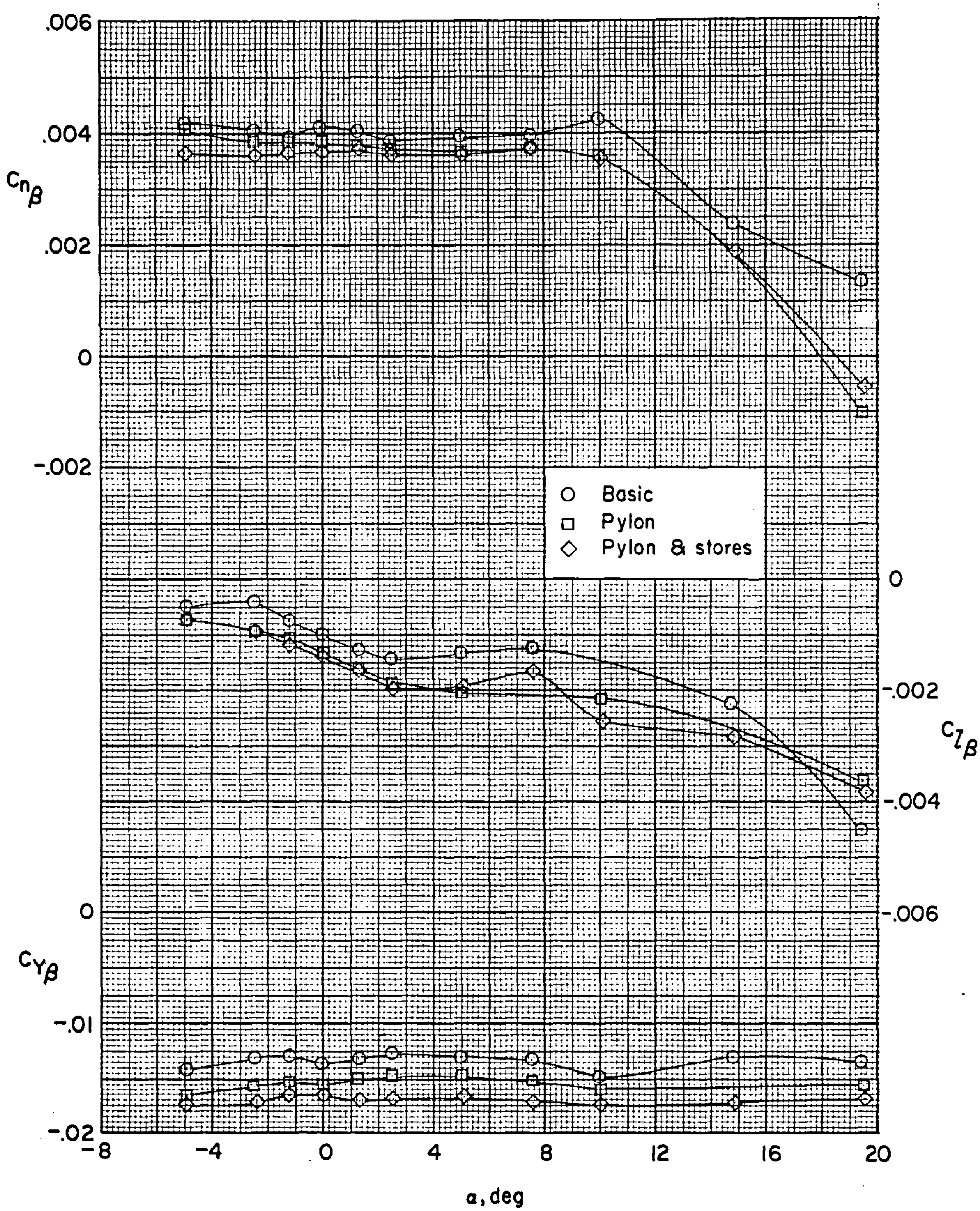


Figure 4.- Summary of longitudinal parameters.



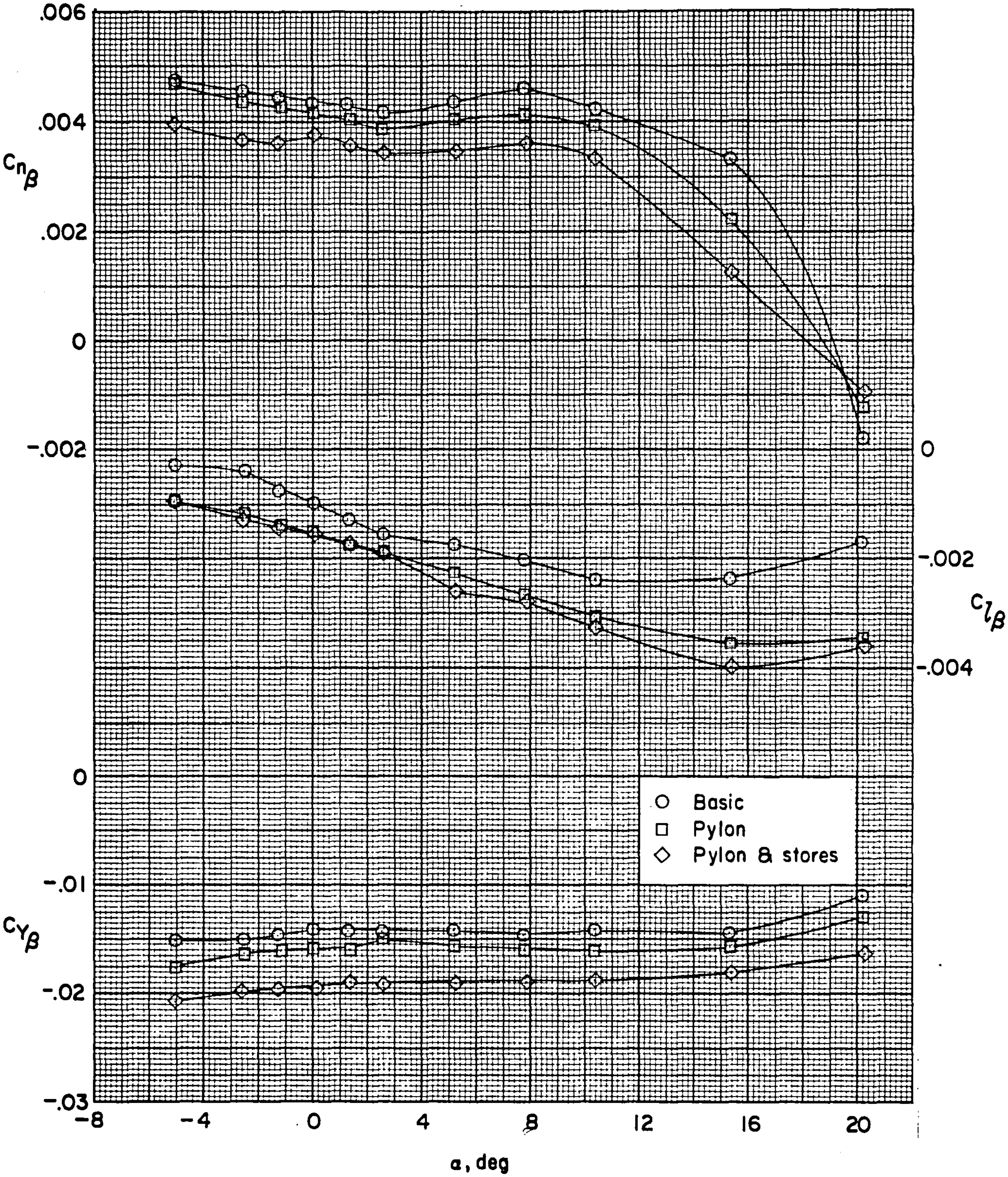
(a) M = .60.

Figure 5.- Effects of pylons and stores on sideslip derivatives.



(b) M = .90.

Figure 5.- Continued.



(c) M = 1.00.

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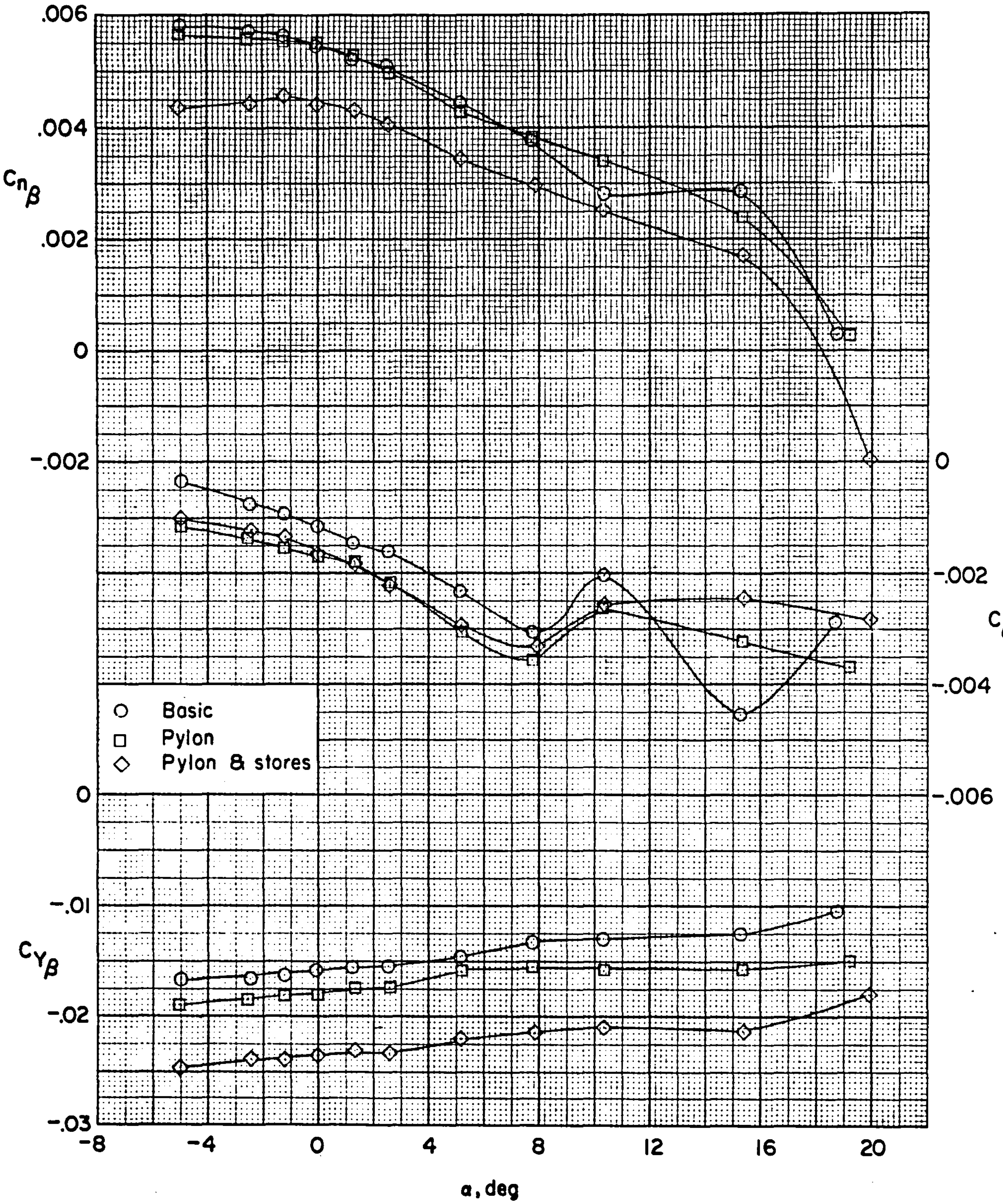
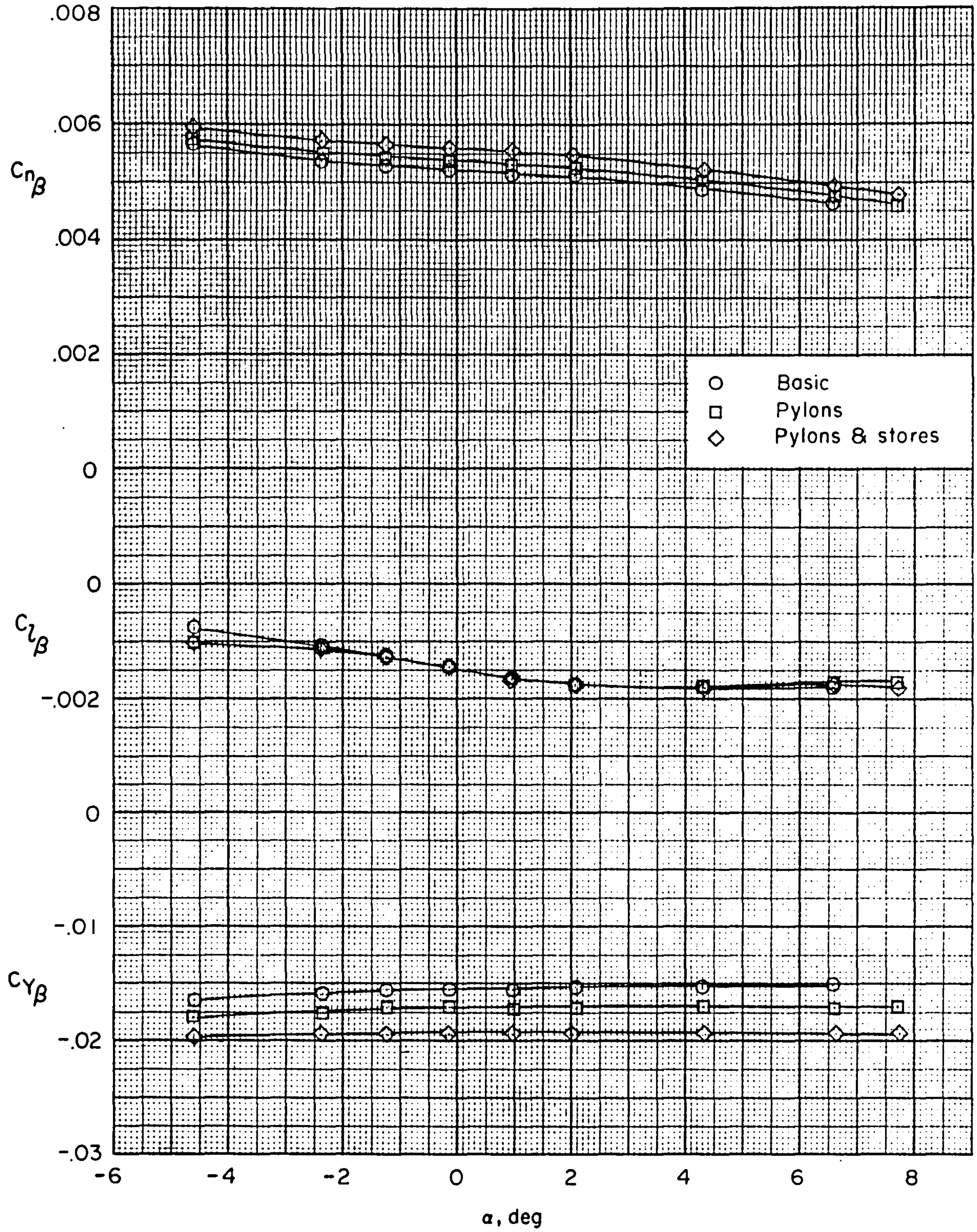


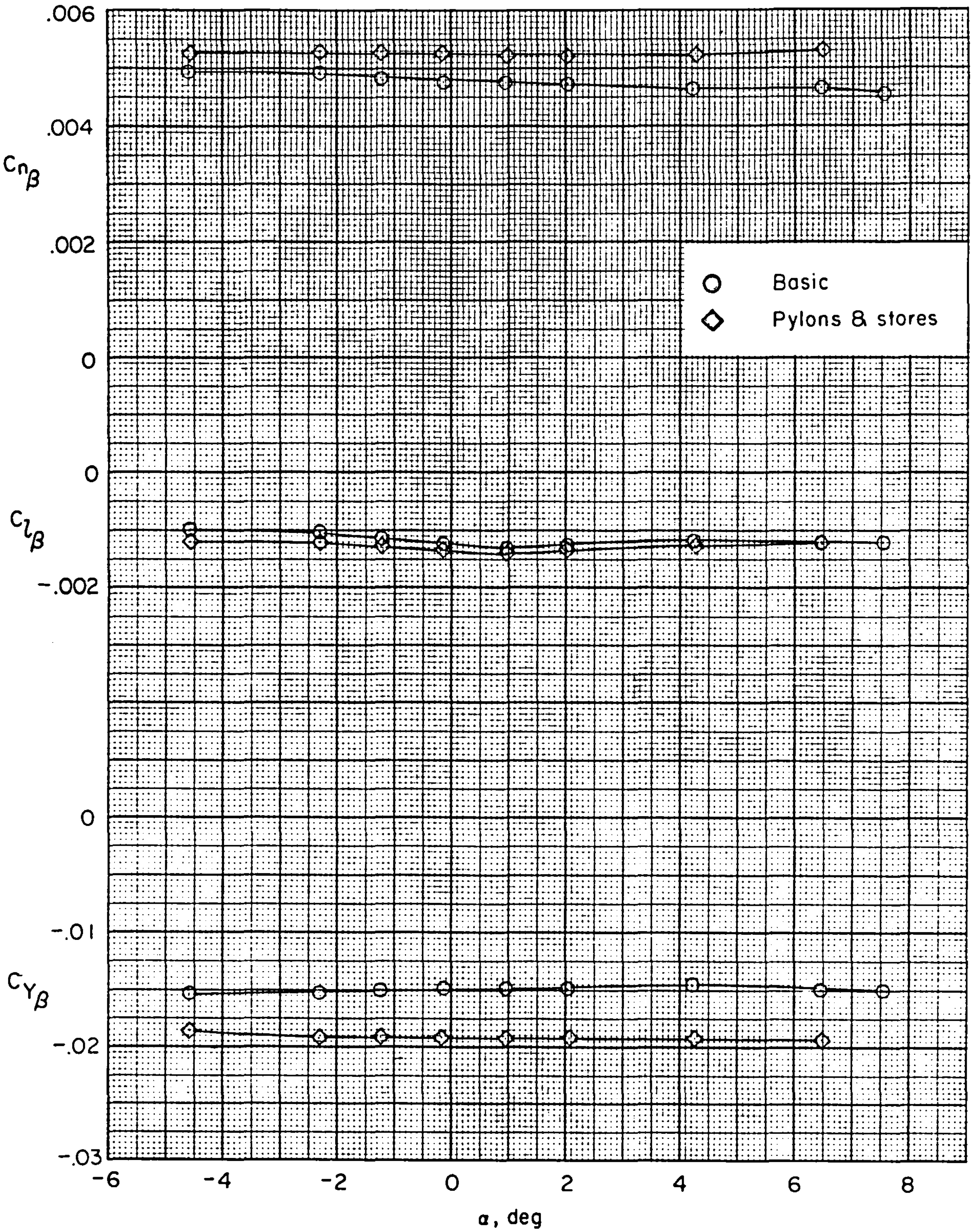
(d) M = 1.20.

Figure 5.- Continued.



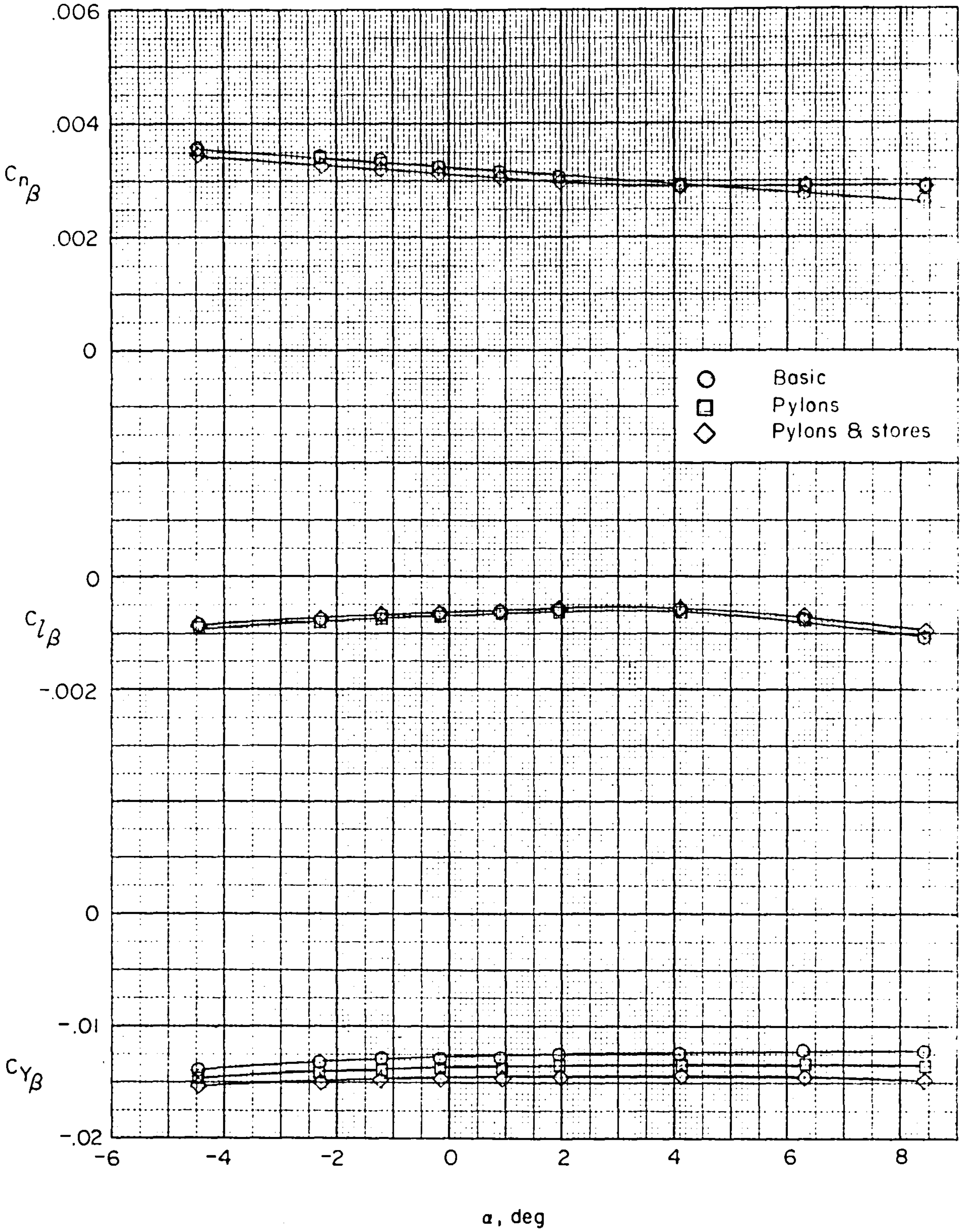
(e) M = 1.41.

Figure 5.- Continued.



(f) M = 1.61.

Figure 5.- Continued.



(g) M = 2.01.

Figure 5. Concluded.

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16. Abstract

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