NASA TECHNICAL NOTE

NASA TN D-3025

NASA TN D-3025

GPO PRICE $ ____

CFSTI PRICE(S) $ ____

Hard copy (HC) $2.00

Microfiche (MF) .50 ¢

ff 653 July 65

FACILITY FORM 602

N65-34222	
(ACCESSION NUMBER)	(THRU)
28	1
(PAGES)	(CODE)
	01
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

EFFECT OF WING PLANFORM MODIFICATION ON LONGITUDINAL CHARACTERISTICS OF A VARIABLE-SWEEP M WING

by Edward J. Ray and William P. Henderson

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • OCTOBER 1965

NASA TN D-3025

EFFECT OF WING PLANFORM MODIFICATION ON LONGITUDINAL CHARACTERISTICS OF A VARIABLE-SWEEP M WING

By Edward J. Ray and William P. Henderson

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $2.00

EFFECT OF WING PLANFORM MODIFICATION ON LONGITUDINAL

CHARACTERISTICS OF A VARIABLE-SWEEP M WING

By Edward J. Ray and William P. Henderson
Langley Research Center

SUMMARY

34222

An investigation was conducted in the Langley high-speed 7- by 10-foot tunnel to determine the effects of wing planform modifications on the longitudinal aerodynamic characteristics of a variable-sweep wing having an M planform. The test planforms were investigated in combination with a basic-fuselage—vertical tail configuration, without engine packs or horizontal tail. The investigation was made at a Mach number of 0.40, corresponding to a dynamic pressure of about 213 lb/sq ft (101.98 N/m^2), and a Reynolds number of 2.52×10^6 per foot (per 30.5 cm), through an angle-of-attack range which extended from -3° to 22°.

The results indicated that increases in the aspect ratio and taper of the basic planform, accomplished by removing portions of the trailing edge of the outer wing panel, resulted in slight decreases in the variation of the longitudinal stability level with leading-edge sweep angle. The low-lift pitch-up tendencies of the basic planform, however, were aggravated by the modifications to the trailing edge of the outer wing panel. Modifications which were made to the basic planform by removing portions of the wing tip resulted in substantial reductions in the variation of longitudinal stability level with wing sweep. In addition, the wing-tip modifications considerably improved the variation of pitching-moment coefficient with lift coefficient at all leading-edge sweep angles.

INTRODUCTION

The National Aeronautics and Space Administration has investigated a number of configurations in the study of the longitudinal stability characteristics of variable-sweep wings. Examples of some of these various configurations are presented in references 1 to 4. The advantages of the variable-sweep M wing, from the standpoint of longitudinal stability characteristics, are discussed in reference 4. The investigation presented herein is related to the study described in reference 4 in that the basic wing series of the present investigation is identical to one of the wing series utilized in the investigation of reference 4. This wing consisted of a series of flat-plate airfoils representing a variable-sweep M wing at several different leading-edge sweep angles with an assumed wing pivot located at 45 percent of the sweptback wing semispan. The study presented in reference 4 was concerned with the determination of the effects of wing pivot location on the variations of the longitudinal stability level with wing sweep and the variation of pitching-moment coefficient with lift coefficient. The results of reference 4 revealed that the variable-sweep M wings exhibited pitch-up at all the test wing-sweep angles and wing pivot locations. The nonlinearities in the variation of pitching-moment coefficients with lift coefficients indicated in the investigation of reference 4 might have been alleviated by proper placement of a horizontal tail. However, to provide freedom in the positioning of the horizontal tail so as to avoid engine-efflux effect, the pitch-up must be minimized for the wing alone. The present investigation, therefore, was undertaken to study the effect of various wing planform modifications on the longitudinal characteristics of a variable-sweep M wing in an attempt to eliminate the undesirable variations of pitching-moment coefficient with lift coefficient.

The investigation included tests of five series of variable-sweep M wings, differing in outer wing panel planform, combined with a basic-fuselage—vertical-tail combination. Each wing series consisted of flat-plate airfoils with leading-edge outer panel sweeps of 15°, 30°, and 72°. The simulated pivot point for all the wing series was located at 45 percent of the sweptback wing semispan. The investigation was conducted in the Langley high-speed 7- by 10-foot wind tunnel at a Mach number of 0.40 which corresponds to a dynamic pressure of about 213 lb/sq ft (101.98 N/m^2), and a Reynolds number of 2.52×10^6 per foot (per 30.5 cm). Lift, drag, and pitching-moment data were determined for all the test configurations through an angle-of-attack range extending from -3° to 25°.

COEFFICIENTS AND SYMBOLS

The forces and moments measured on this configuration are presented about the wind-axis system. All coefficients are nondimensionalized with respect to the geometric characteristics associated with the maximum-sweep position of 72°. The reference dimensions for each wing series are given in table I. The planform area at the wing-fuselage juncture included in the reference areas of the test wing planform is indicated by the dashed lines shown in figure 1. The moment-reference points were chosen such that the 15° sweptback wing of each wing series had a longitudinal stability level of 5 percent of the mean aerodynamic chord. The moment-reference center for each wing series is shown in figures 1 to 3.

The units used for the physical quantities defined in this paper are given both in U.S. Customary Units and in the International System of Units (SI). Factors relating the two systems are given in reference 5.

A aspect ratio, $\frac{b^2}{S}$

b wing span, in. (m)

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

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

C_{L_α} lift-curve slope, per deg

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

$C_{m_{C_L}}$ longitudinal stability parameter, $\partial C_m/\partial C_L$, near $C_L = 0$

$\bar{c}$ mean aerodynamic chord, in. (m)

q dynamic pressure, lb/sq ft (N/m^2)

S wing reference area, sq ft (m^2)

α angle of attack, deg

Λ leading-edge sweep angle of the movable panel, deg

MODELS

The models of this investigation utilized flat-plate wings mounted beneath a fuselage with a vertical tail. Drawings of the configurations investigated are shown in figures 1 to 3. The basic wing of this investigation is designated wing series 1 and is shown in figure 1. This wing in the 72° sweptback position had an M planform with the leading-edge break located at 33 percent of the wing semispan. The wing pivot was located at 45 percent of the wing semispan and at 60 percent of the streamwise chord of the sweptback wing.

During the present investigation the movable panel of the basic wing series was modified to produce the wing series designated 2 to 5. Wing series 2 and 3 (fig. 2) were obtained by cutting away part of the trailing edge of the movable panel of the basic wing so that the trailing-edge sweep of the movable wing panel was changed in increments of 5°. The modifications made to the basic wing series to obtain wing series 2 and 3 result in a wing which not only has a higher aspect ratio but also has increased taper and less area.

Wing series 4 and 5 (fig. 3) were obtained by removing portions of the wing tip of the basic wing series. This type of modification results in a wing which has a span reduction for the wing in the 15° sweep position of 14 and 28 percent for wing series 4 and 5, respectively. Since only the outer panel of the basic wing was modified, this span reduction results in wings which have lower aspect ratios and less taper.

Wing sweep angles of 15°, 30°, and 72° were investigated for all the wing series. The wings were 3/16-inch (0.476-cm) flat plates with rounded leading edges and blunt trailing edges. No attempt was made to fair the wings into the fuselage and therefore the drag characteristics should be used with caution.

TESTS AND CORRECTIONS

The investigation was made in the Langley high-speed 7- by 10-foot tunnel at a Mach number of 0.40 which corresponds to a dynamic pressure of about 213 lb/sq ft (101.98 N/m^2), and a Reynolds number per foot (per 30.5 cm) of 2.52×10^6.

Lift, drag, and pitching moment were measured through an angle-of-attack range of -3° to 22°. The angle of attack was corrected for deflection of the sting support system under load. The drag data have not been corrected for the effects of base pressure acting on the base of the fuselage and the balance chamber. These tests were made without artificial transition strips on either the wings or the fuselage. Jet-boundary and blockage corrections (estimated from refs. 6 and 7) have been applied to the data.

PRESENTATION OF DATA

The data are presented in the following figures:

Figure

Effect of wing sweep on longitudinal aerodynamic characteristics of configuration with:

Wing series 1 4
Wing series 2 5
Wing series 3 6
Wing series 4 7
Wing series 5 8

Effect of wing planform modifications on variation of lift-curve slope and longitudinal stability parameters for:

Wing series 1, 2, and 3 9
Wing series 1, 4, and 5 10

Effect of wing planform modifications on variation of pitching moment with lift coefficient for:

Wing series 1, 2, and 3 11
Wing series 1, 4, and 5 12

RESULTS AND DISCUSSION

Since the main interest of this investigation was the effect of wing planform modifications on the stability characteristics of the basic wing series, the test wings were constructed of plate material to minimize fabrication time. No attempt was made to blend the wings with the basic fuselage or to correct the data for the pressure acting on the base of the fuselage. The reader is advised, therefore, to view the drag data with caution. The drag results have been presented herein without analysis simply to afford the reader an opportunity to observe the effects of the various wing modifications on the induced drag.

Effects of Wing Sweep on Longitudinal Characteristics of Wing Planforms

The effects of wing sweep on the longitudinal aerodynamic characteristics of the five M wing planforms are shown in figures 4 to 8. It should be noted that the moment-reference points for these test models have been adjusted so that the 15° sweptback wing of each wing series had a low-lift static margin of 5 percent of the mean aerodynamic chord. (See figs. 1, 2, and 3.) The data shown in figures 4 to 8 indicate that the effects of wing sweep on the longitudinal aerodynamic characteristics of the test models were similar for the five wing planforms investigated. In general, these data indicate that increases in the leading-edge sweep of the outer wing panels resulted in reductions of the lift-curve slope $C_{L_{\alpha}}$ and more favorable variations of pitching-moment coefficient with lift coefficient.

Effects of Wing Planform Modifications on Longitudinal Aerodynamic Characteristics of Basic Wing

The planform modifications which were made to the basic wing series, wing series 1, consisted of two types of modifications. Wing series 2 and 3 (fig. 2) represent modifications which were made to the basic planform by removing area from the trailing edge of the outer wing panel. The trailing-edge modifications resulted in wings having a higher aspect ratio and more taper than the basic wing. Wing series 4 and 5 (fig. 3) were obtained by removing portions of the wing tip of the basic planform. Wing series 4 and 5, therefore, had lower aspect ratios and less taper than the basic wing series 1 planforms.

The effects of the modifications to the trailing edge of the outer wing panel on the longitudinal characteristics of the basic planform may be determined by comparing the results for wing series 1 (fig. 4) with the results for wing series 2 and 3 (figs. 5 and 6), respectively. A comparison of the variations of the longitudinal aerodynamic characteristics with wing sweep for these three wing planforms is shown in figure 9. It should be noted here that the results contained in reference 4 were utilized to aid in the fairing of the data shown herein in figures 9 and 10. These data indicate that the removal of area from the trailing edge of the basic planform, with consequent increases in aspect ratio, resulted in higher lift-curve slopes at all sweep angles. Wing series 3, having the highest aspect ratio, exhibited an increase in lift-curve slope of about 0.003 throughout the wing-sweep angle above the lift-curve slope values indicated for the basic planform. The variation of the longitudinal stability parameter $C_{m_{C_L}}$ with the leading-edge sweep angle was reduced slightly for wing series 2 and 3, due to the removal of area from the trailing edge of the outer wing panels. The largest reduction in the variation of the longitudinal stability parameters $C_{m_{C_L}}$ with sweep angle was a reduction of about 0.015 as indicated for wing series 3.

A comparison of the results for wing series 1 (fig. 4) with the longitudinal characteristics of wing series 4 and 5 (figs. 7 and 8) indicates the effects of removing portions of the wing tip from the basic wing planform. These effects have been summarized in figure 10. The lift-curve slopes indicated for wing series 4 and 5 were lower than the lift-curve slopes of the basic planform throughout the sweep range due to the reductions in aspect ratio. In addition, the removal of area from the outer wing panel substantially improved the variation of the longitudinal stability parameter $C_{m_{C_L}}$ with leading-edge sweep angle, and in fact produced less longitudinal stability at 72° sweep than at 15° sweep.

Figures 11 and 12 were prepared to illustrate the effect of the various planform modifications on the variation of pitching-moment coefficient with lift coefficient. The pitching-moment data shown in figures 11 and 12 have been adjusted so that the static margins of the wing planforms at all sweep angles were equal to 5 percent of the mean aerodynamic chord $\bar{c}$ of each planform. The effects of the trailing-edge modifications to the outer wing panel on the longitudinal stability characteristics of the model are shown in figure 11. The trailing-edge modifications to the basic wing planform are seen to have an adverse effect on the longitudinal stability characteristics. The increased nonlinearities in the variation of pitching-moment coefficient with lift coefficient indicated for wing series 2 and 3 resulted from the increases in the taper of the basic wing panel which is believed to cause the flow over the outer wing panel to separate more readily.

Although the removal of area from the basic outer wing panel trailing edge aggravated the pitch-up tendency of the basic planforms, figure 12 shows that the longitudinal stability characteristics for the basic planform can be improved by removing area from the tip of the outer wing panel. The wing modifications of wing series 4 and 5, which in effect reduced the aspect ratio and taper of the basic planform, considerably reduced the effect of outer wing panel separation on the pitching moment. Although the linearity of the variation of pitching-moment coefficients with lift coefficients was substantially improved by the removal of wing-tip area and subsequent reductions in aspect ratio, it should be remembered that these modifications would naturally result in reductions of the subsonic lift-to-drag ratios.

The planform modifications which were considered in the present investigation did not improve the longitudinal stability characteristics of the basic planform to the extent that the variation of pitching-moment coefficient with lift coefficient was linear at all sweep angles. Wing series 5, however, having reduced taper and outer wing panel area exhibited a nearly linear variation of pitching-moment coefficient with lift coefficient at leading-edge sweep angles of 30° and 72°. It is believed that the addition of leading-edge devices to several of the test planforms would be one method to minimize the pitching-moment nonlinearities and result in acceptable longitudinal stability characteristics which, in turn, might possibly allow some freedom in the choice of wing planform and tail location. In addition, the longitudinal stability characteristics indicated in the present investigation for the flat-plate wings might be significantly changed by incorporating wing twist and camber.

CONCLUSIONS

The results of a low-speed investigation to determine the effects of wing planform modifications on the longitudinal aerodynamic characteristics of a variable-sweep wing having an M planform indicated the following conclusions:

1. Increases in the aspect ratio and outer panel taper of the basic planform, accomplished by removing portions of the trailing edge of the outer wing panel, resulted in slight decreases in the variation of the longitudinal stability level with leading-edge sweep angle. The trailing-edge modifications, however, aggravated the low-lift pitch-up tendencies of the basic planform.

2. Modifications which were made to the basic planform by removing portions of the wing tip resulted in substantial reductions in the variation of longitudinal stability level with wing sweep. The wing-tip modifications considerably improved the variation of pitching-moment coefficient with lift coefficient at all leading-edge sweep angles.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., June 25, 1965.

REFERENCES

1. Henderson, William P.: Low-Speed Longitudinal Stability Characteristics of a Supersonic Transport Configuration With Variable-Sweep Wings Employing a Double Inboard Pivot. NASA TM X-744, 1962.

2. Alford, William J., Jr.; Hammond, Alexander D.; and Henderson, William P.: Low-Speed Stability Characteristics of a Supersonic Transport Model With a Blended Wing-Body, Variable-Sweep Auxiliary Wing Panels, Outboard Tail Surfaces, and Simplified High-Lift Devices. NASA TM X-802, 1963.

3. Lockwood, Vernard E.; McKinney, Linwood W.; and Lamar, John E.: Low-Speed Aerodynamic Characteristics of a Supersonic Transport Model With a High-Aspect-Ratio Variable-Sweep Warped Wing. NASA TM X-979, 1964.

4. Henderson, William P.; and Ray, Edward J.: Effect of Wing Pivot Location on Longitudinal Aerodynamic Characteristics of a Variable-Sweep Wing Having an M Planform. NASA TM X-1022, 1964.

5. Mechtly, E. A.: The International System of Units - Physical Constants and Conversion Factors. NASA SP-7012, 1964.

6. Gillis, Clarence L.; Polhamus, Edward C.; and Gray, Joseph L., Jr.: Charts for Determining Jet-Boundary Corrections for Complete Models in 7- by 10-Foot Closed Rectangular Wind Tunnels. NACA WR L-123, 1945. (Supersedes NACA ARR L5G31.)

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

TABLE I.- WING SERIES REFERENCE DIMENSIONS

Wing series	S		b		$\bar{c}$		A
	ft^2	m^2	in.	cm	in.	cm	
1	1.727	0.1604	21.240	53.95	13.591	34.52	1.814
2	1.659	.1541	21.240	53.95	12.904	32.78	1.888
3	1.568	.1457	21.240	53.95	12.795	32.50	1.998
4	1.623	.1508	19.500	49.53	13.638	34.64	1.627
5	1.514	.1407	17.860	45.36	13.708	34.82	1.463

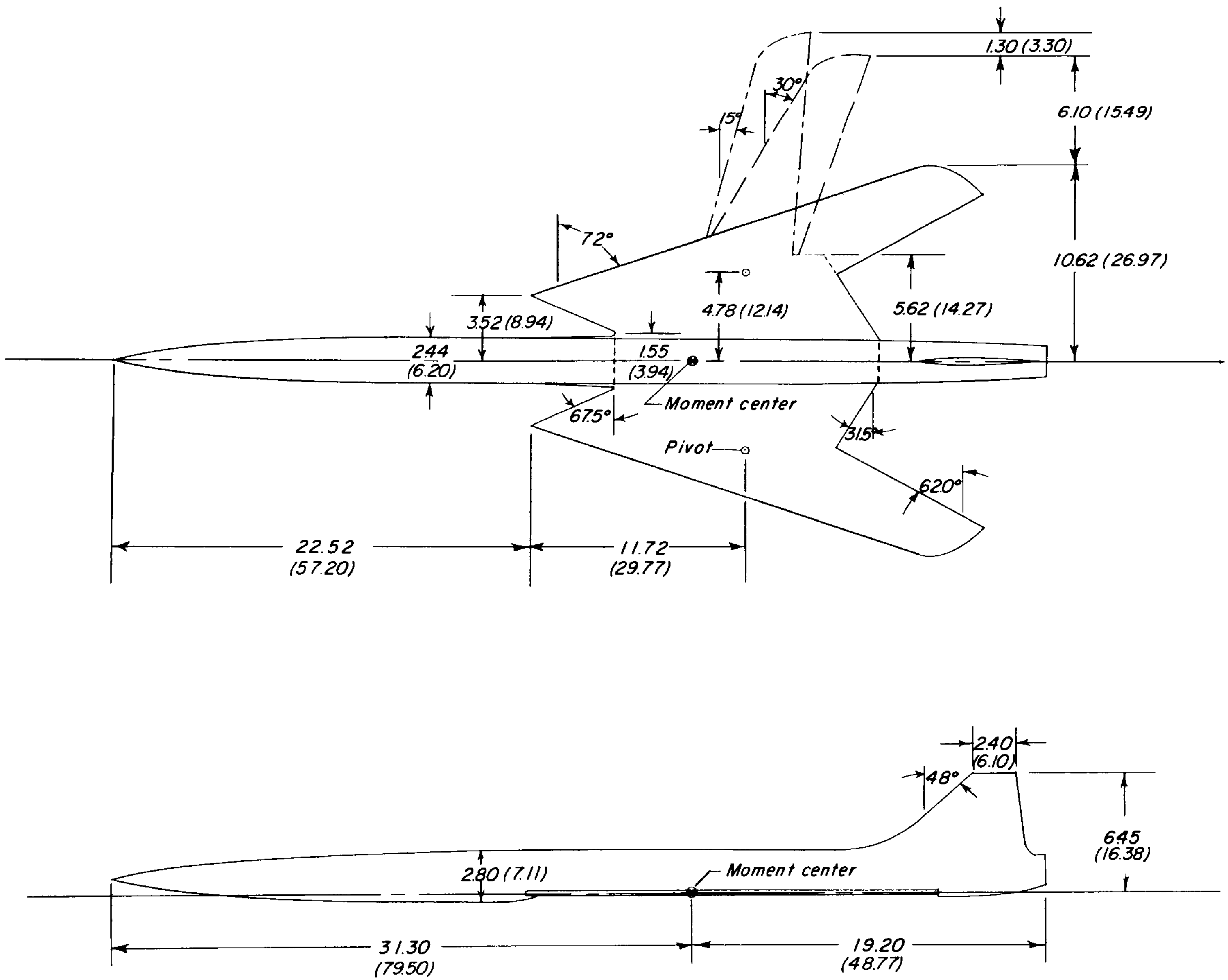
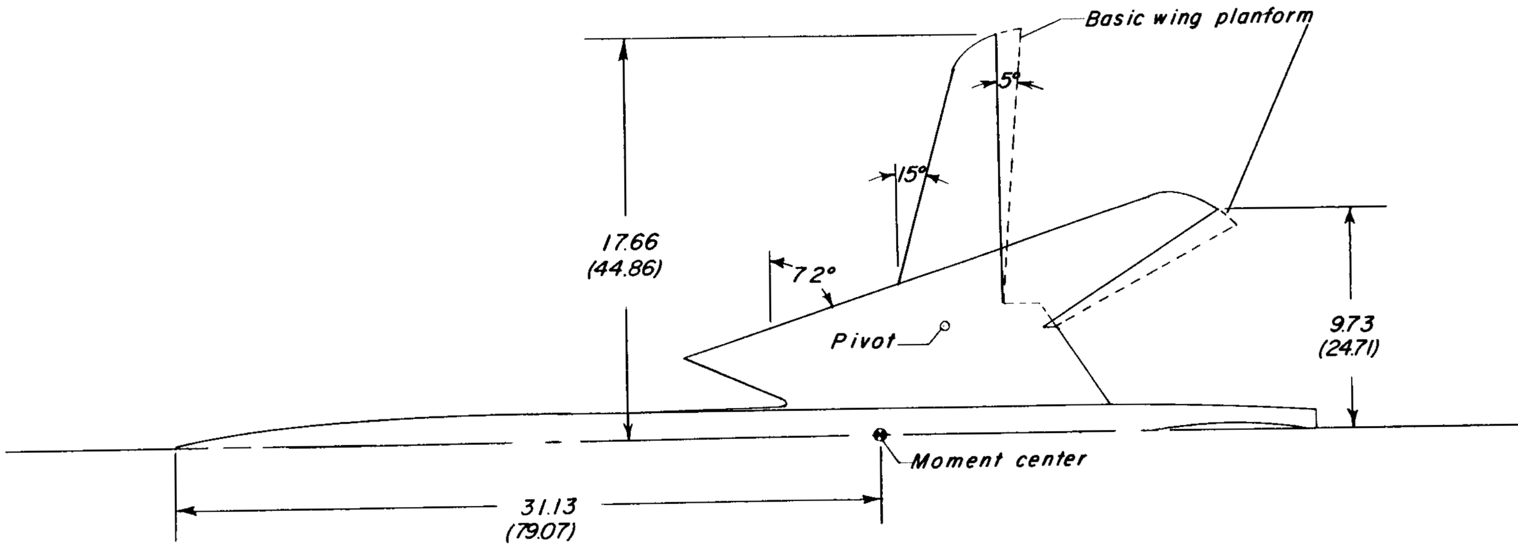
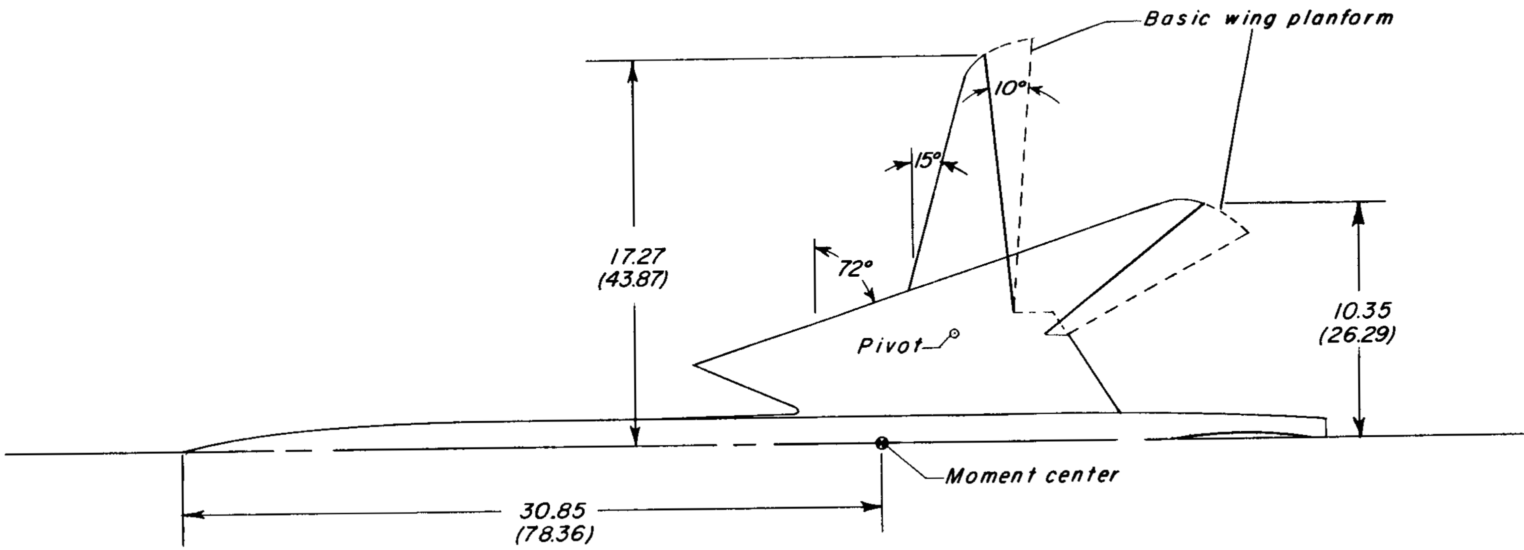


Figure 1.- Drawing of basic configuration. (Wing series 1.) All linear dimensions are in inches. (Parenthetical dimensions are in cm.)

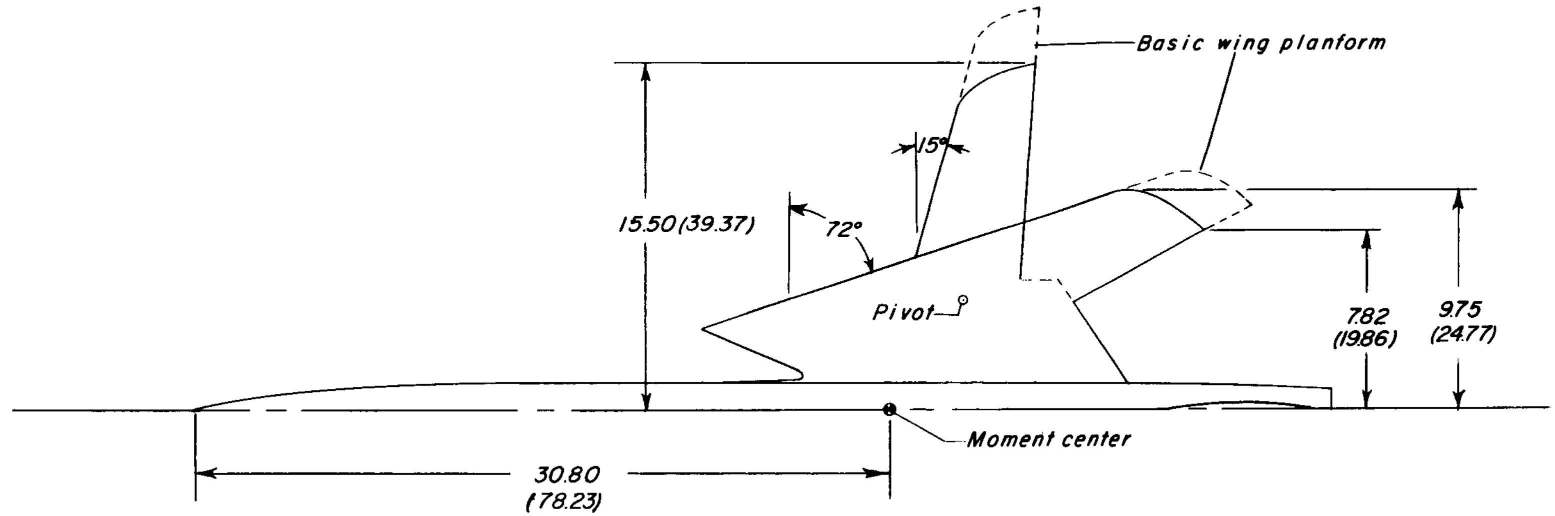


(a) Wing series 2.

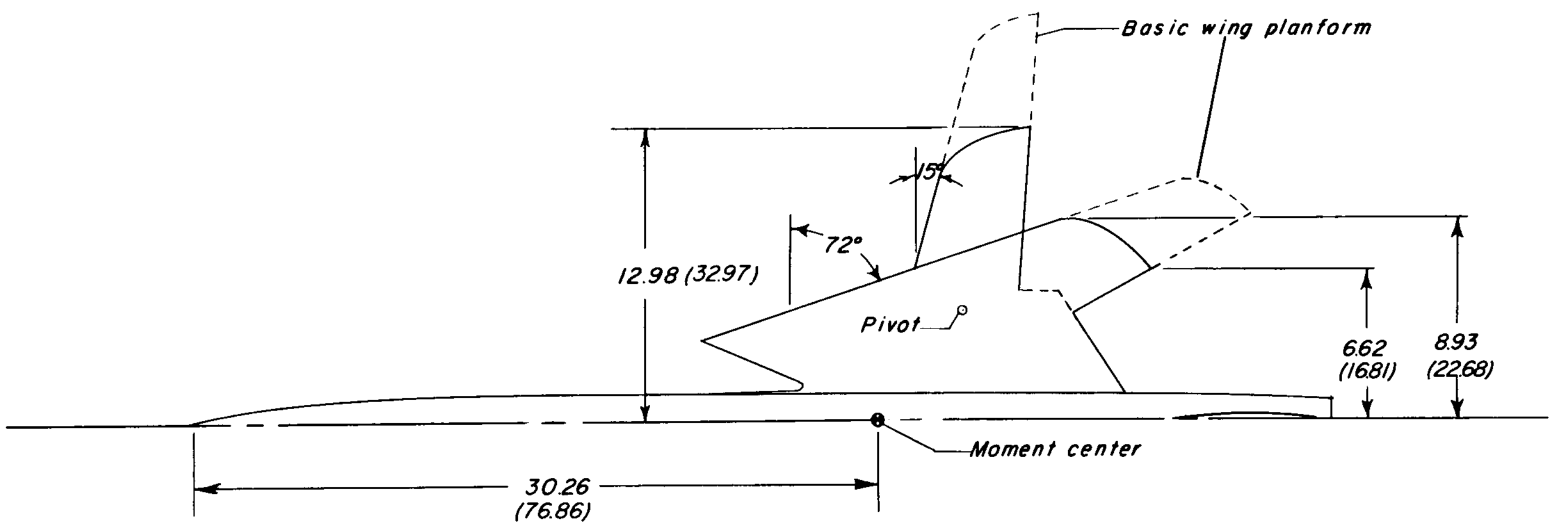


(b) Wing series 3.

Figure 2.- Drawing of wing series 2 and 3. All linear dimensions are in inches. (Parenthetical dimensions are in cm.)



(a) Wing series 4.



(b) Wing series 5.

Figure 3.- Drawing of wing series 4 and 5. All linear dimensions are in inches. (Parenthetical dimensions are in cm.)

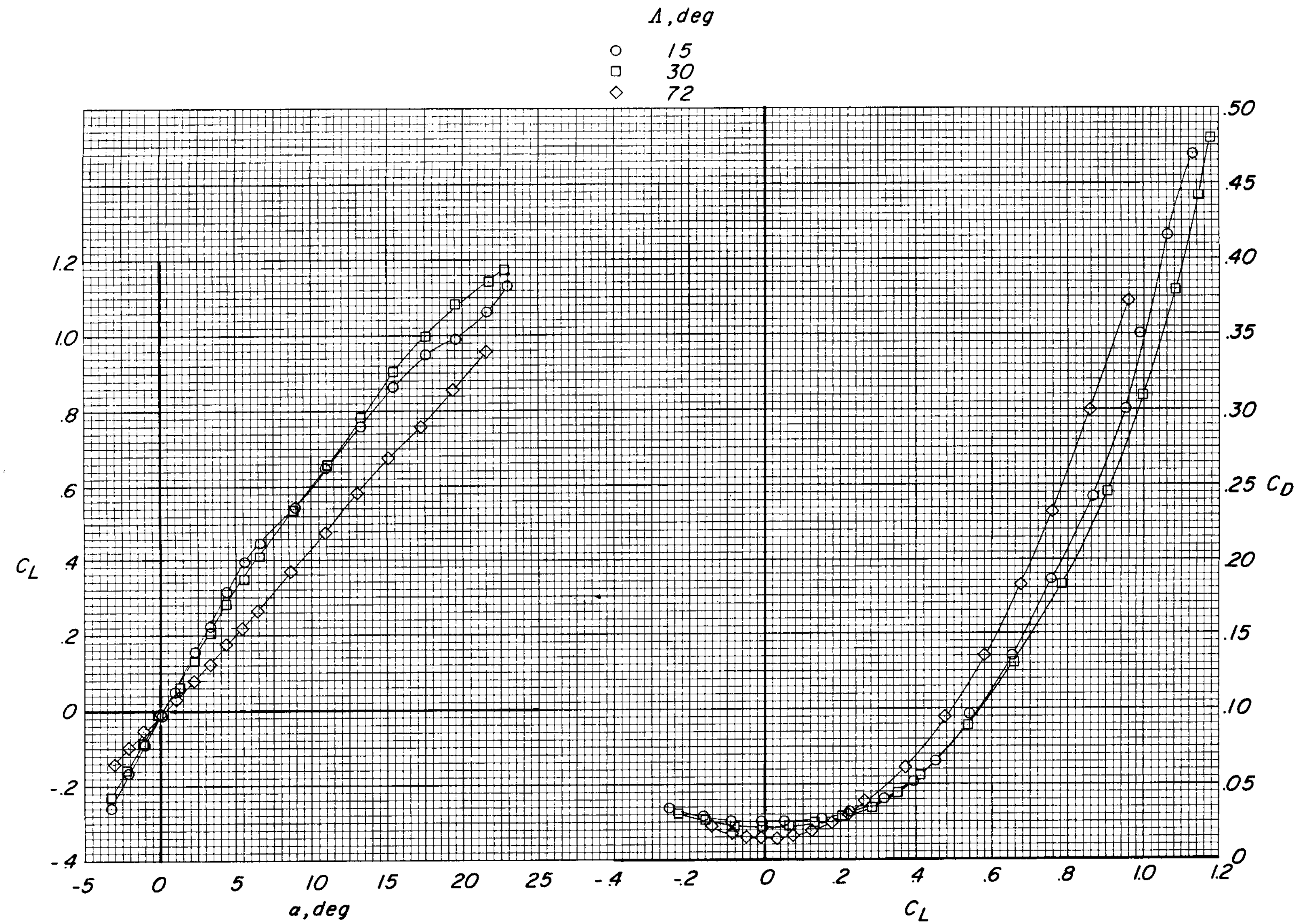


Figure 4.- Effect of wing sweep on longitudinal aerodynamic characteristics of configuration with wing series 1.

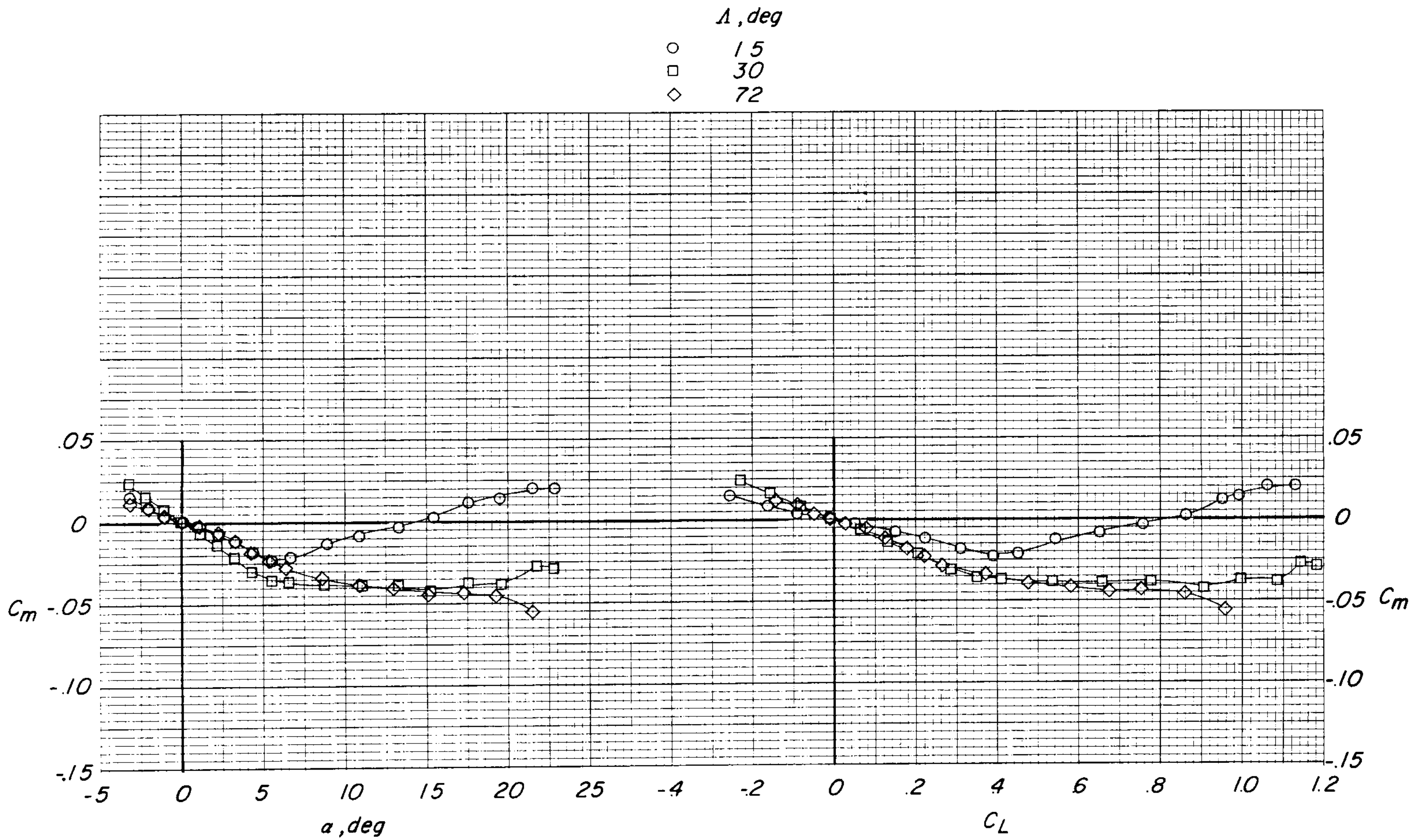


Figure 4.- Concluded.

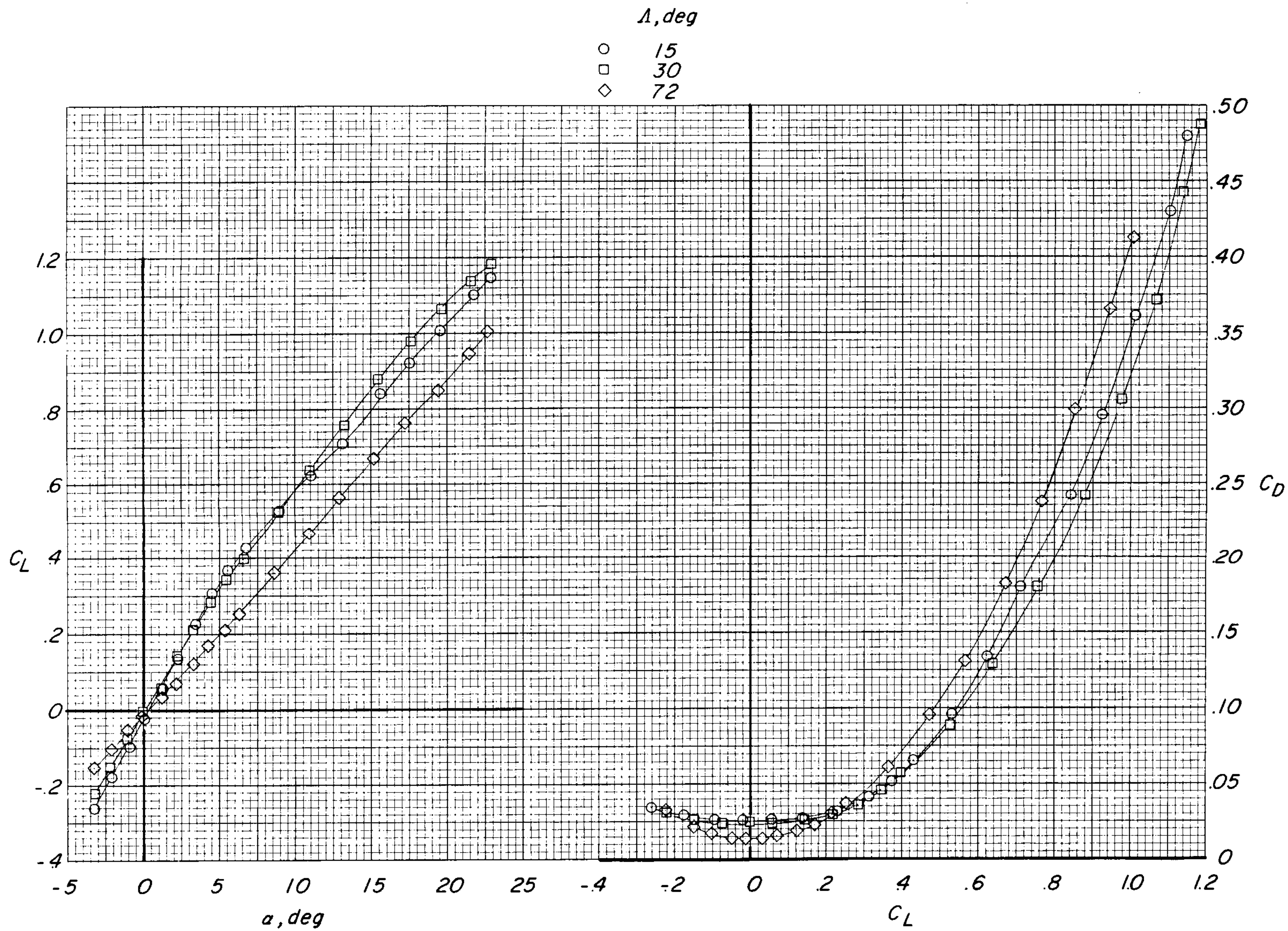


Figure 5.- Effect of wing sweep on longitudinal aerodynamic characteristics of configuration with wing series 2.

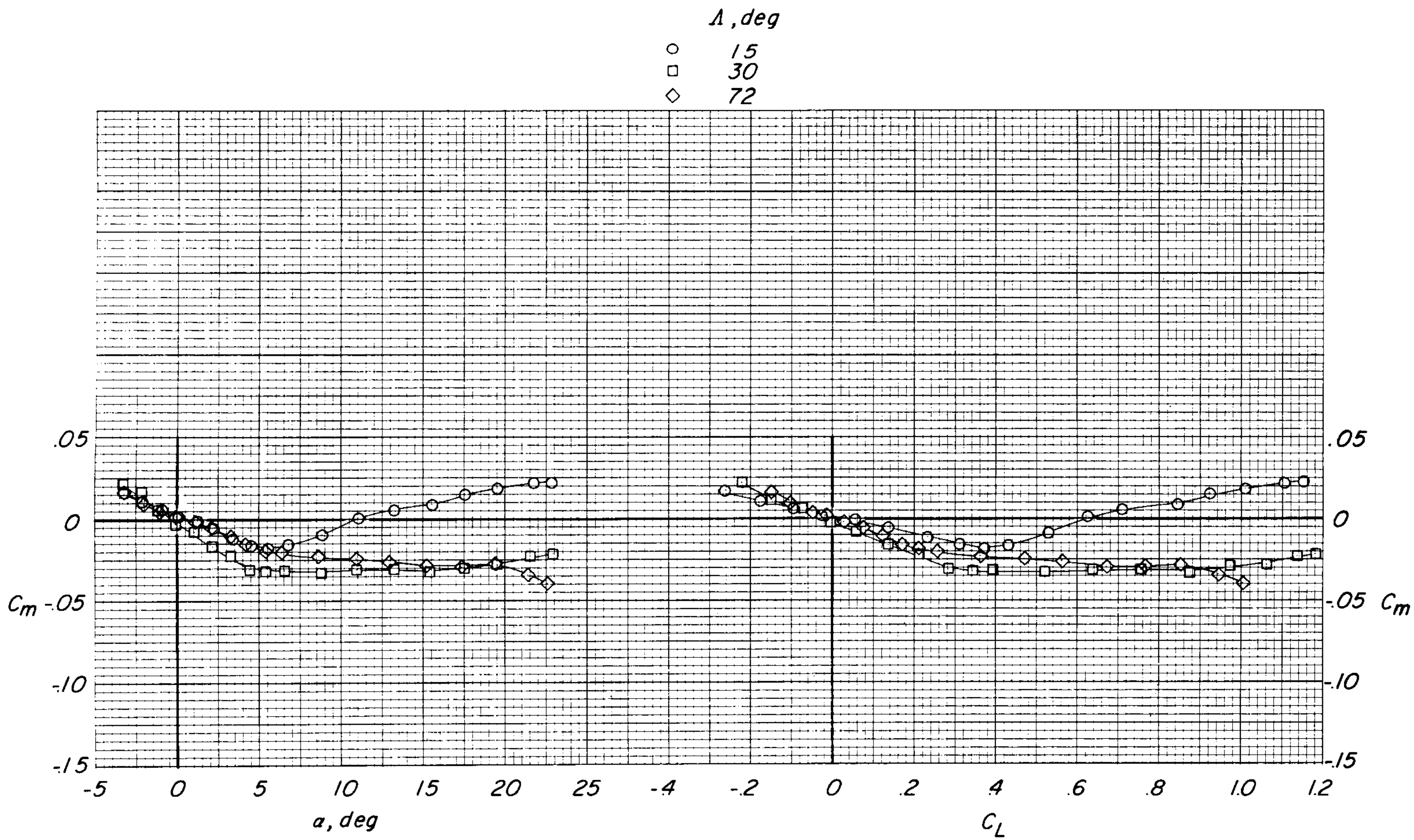


Figure 5.- Concluded.

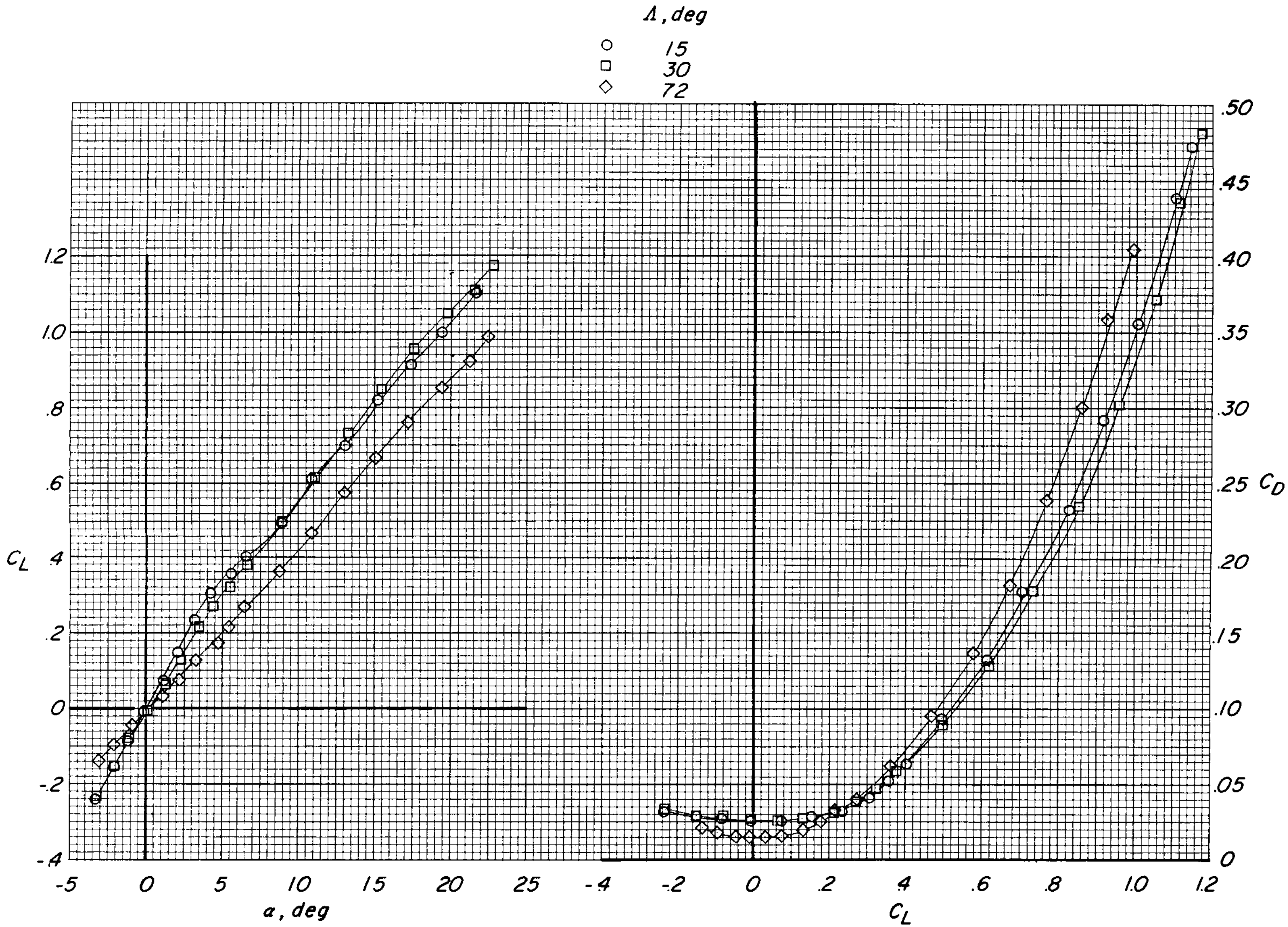


Figure 6.- Effect of wing sweep on longitudinal aerodynamic characteristics of configuration with wing series 3.

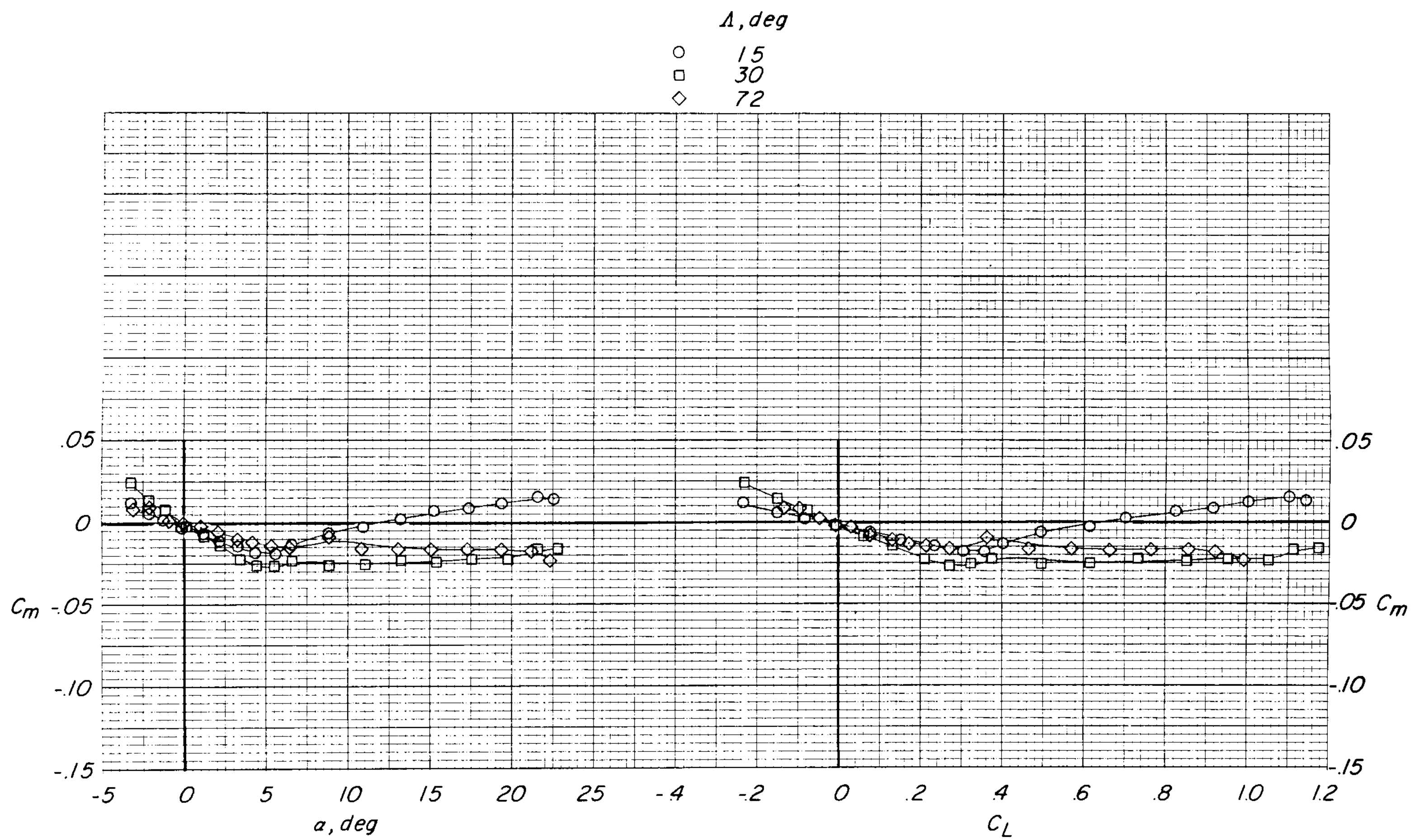


Figure 6.- Concluded.

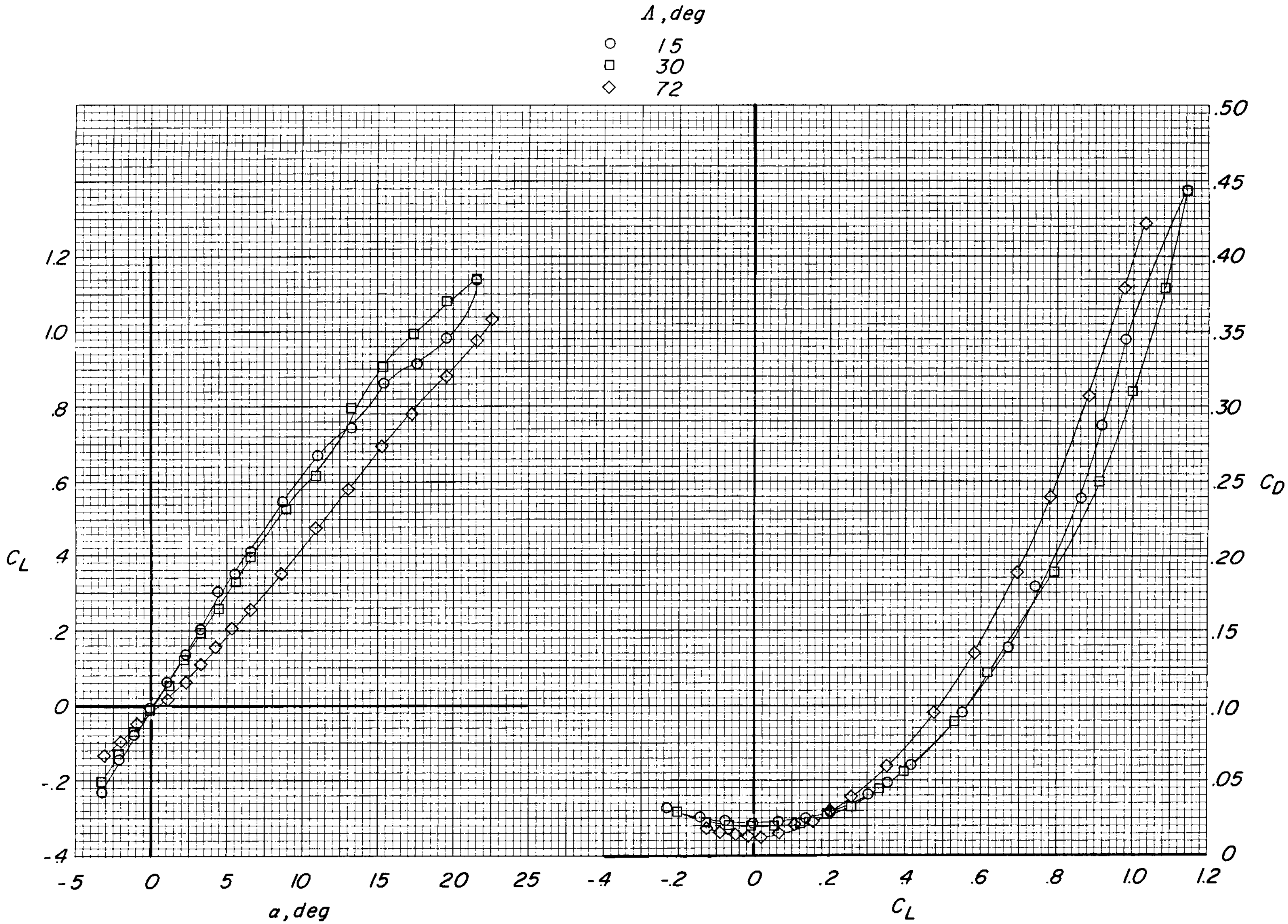


Figure 7.- Effect of wing sweep on longitudinal aerodynamic characteristics of configuration with wing series 4.

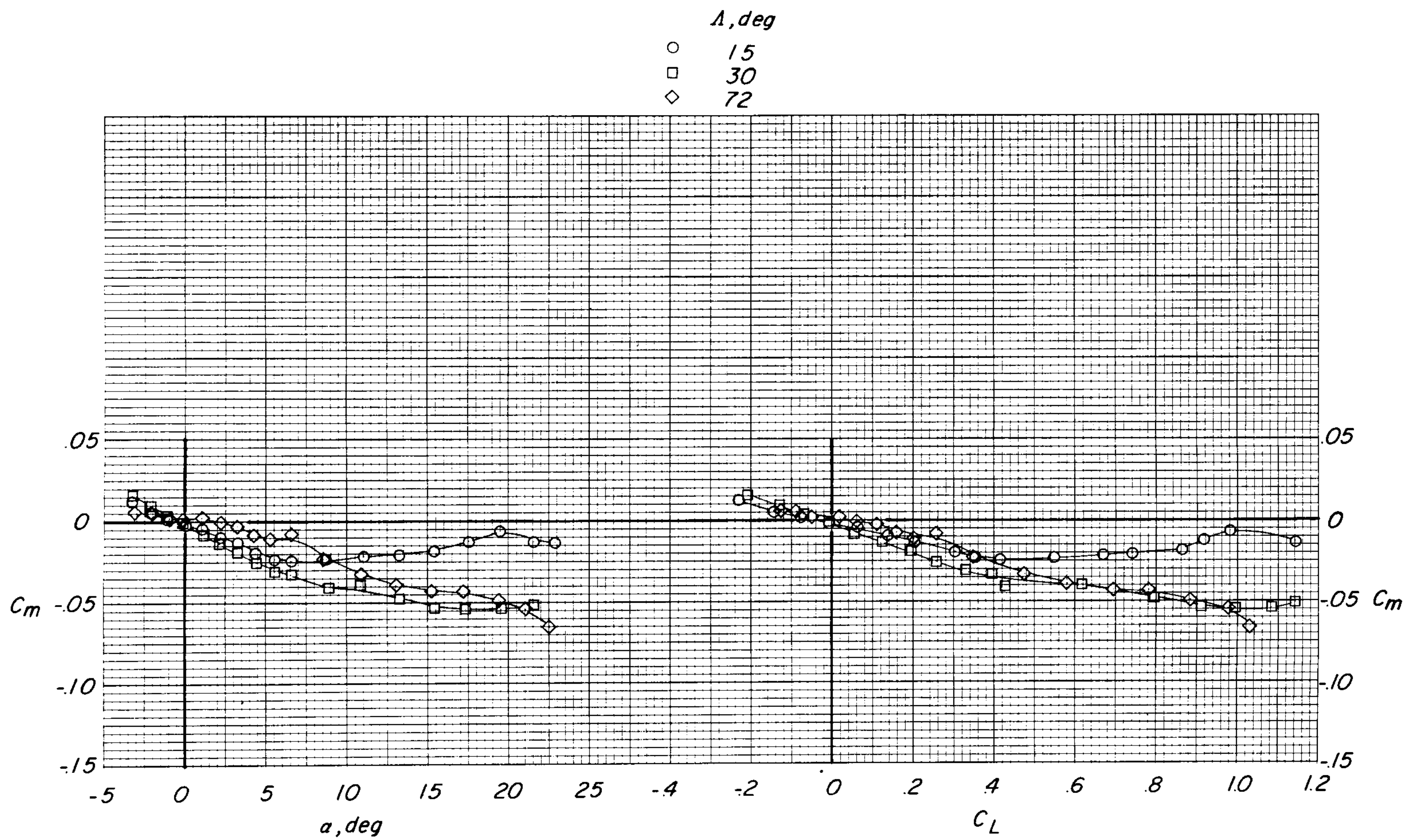


Figure 7.- Concluded.

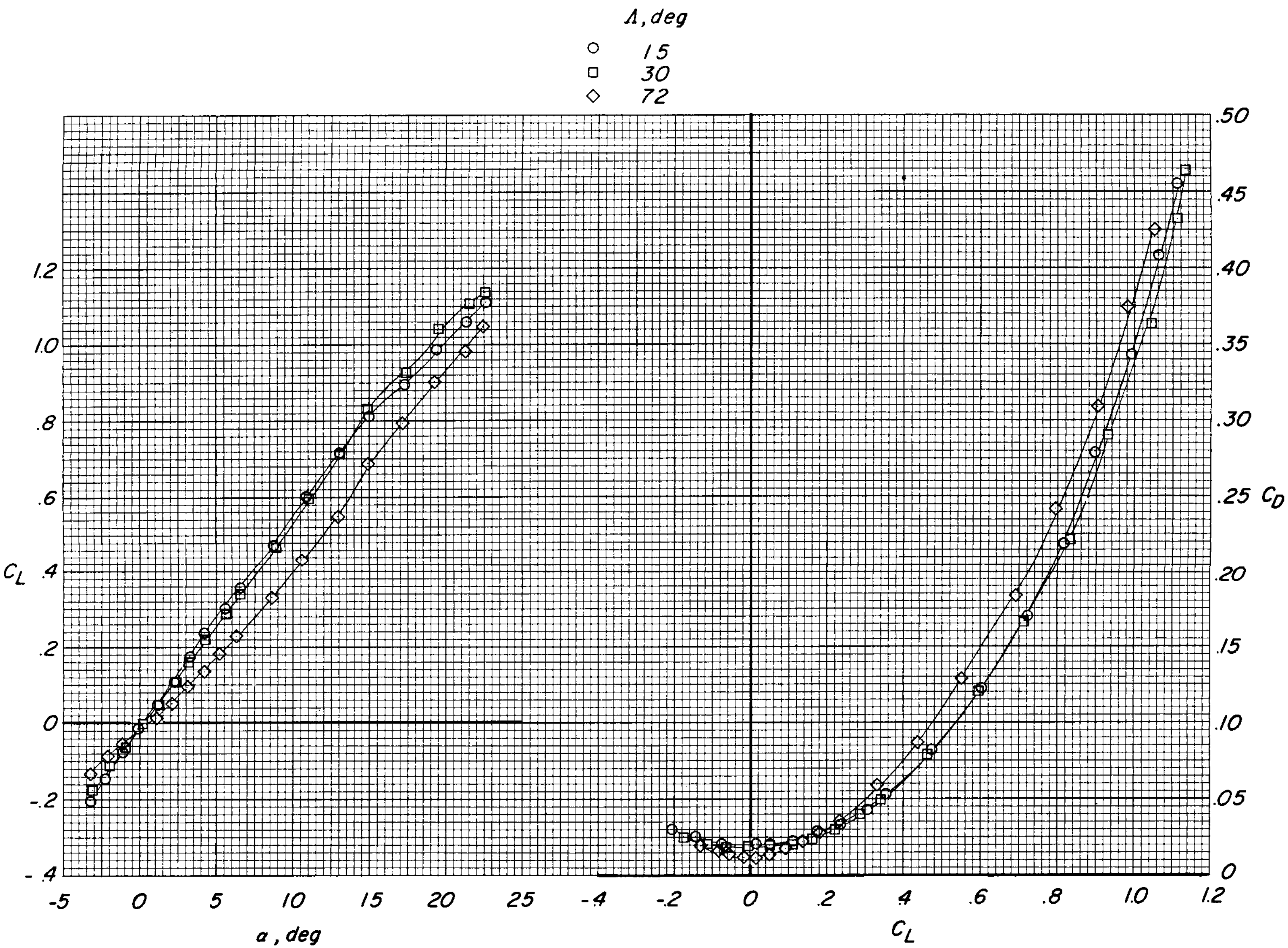


Figure 8.- Effect of wing sweep on longitudinal aerodynamic characteristics of configuration with wing series 5.

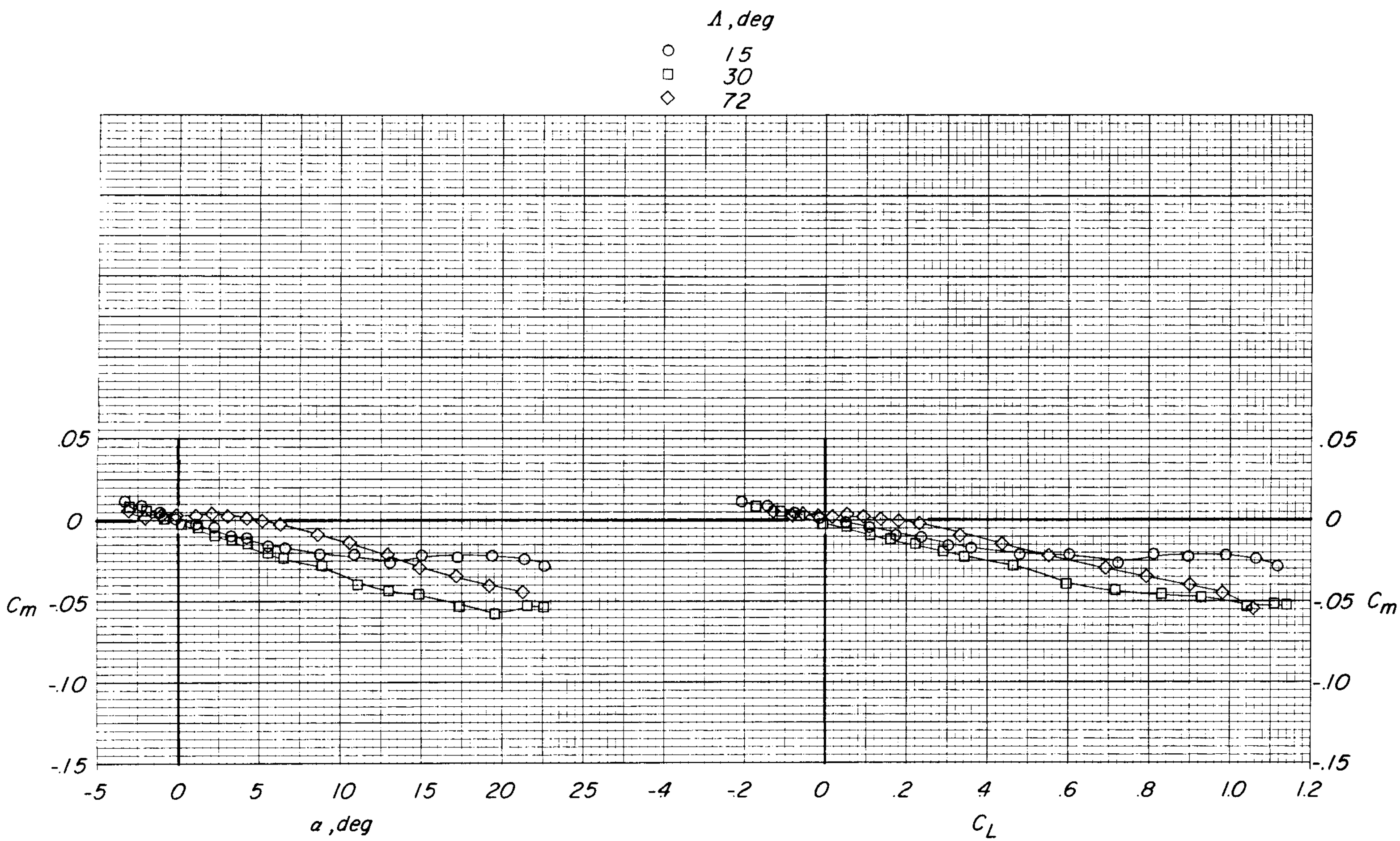


Figure 8.- Concluded.

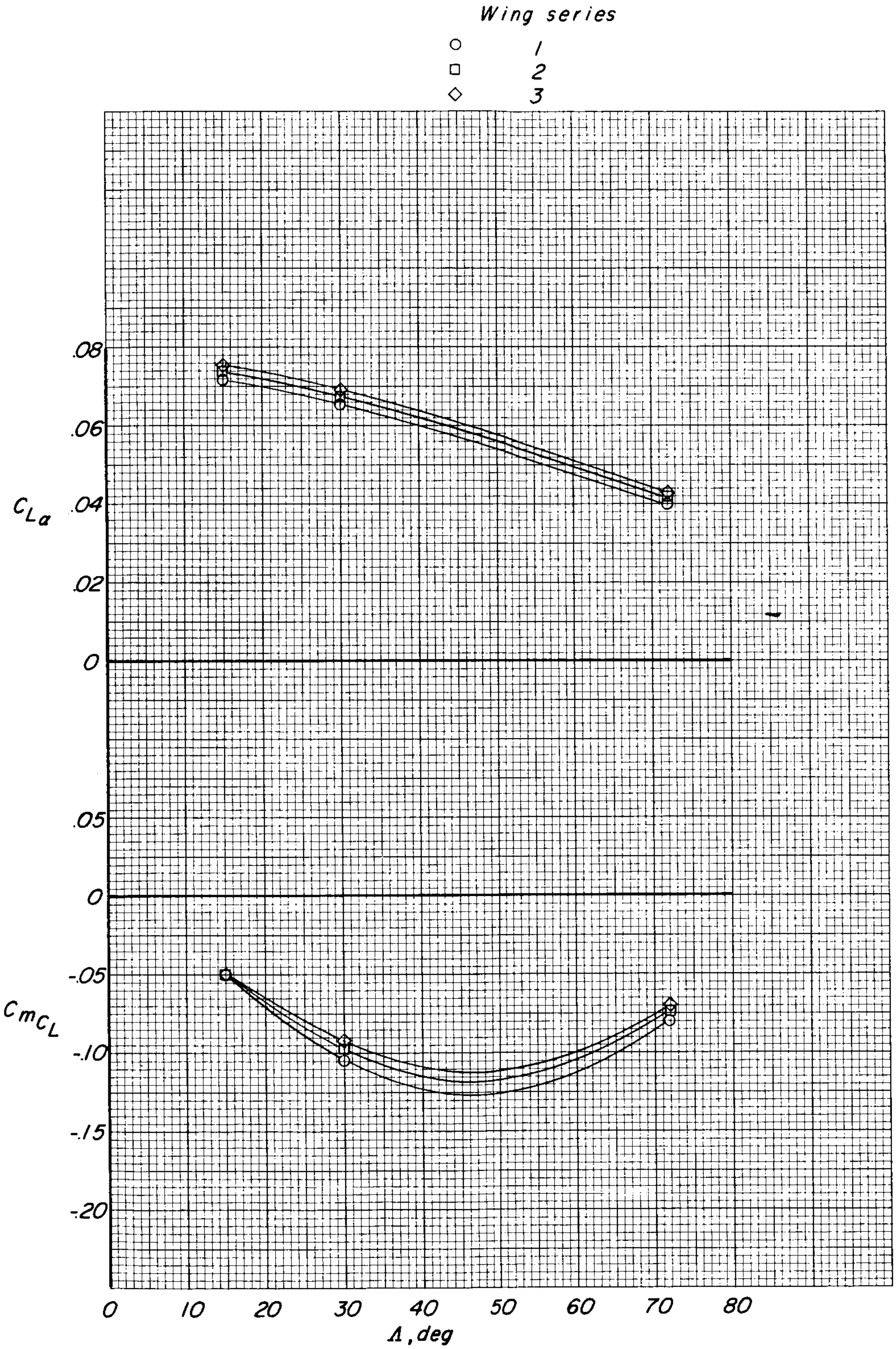


Figure 9.- Effect of wing planform modifications on variation of lift-curve slope and longitudinal stability parameter with wing sweep.

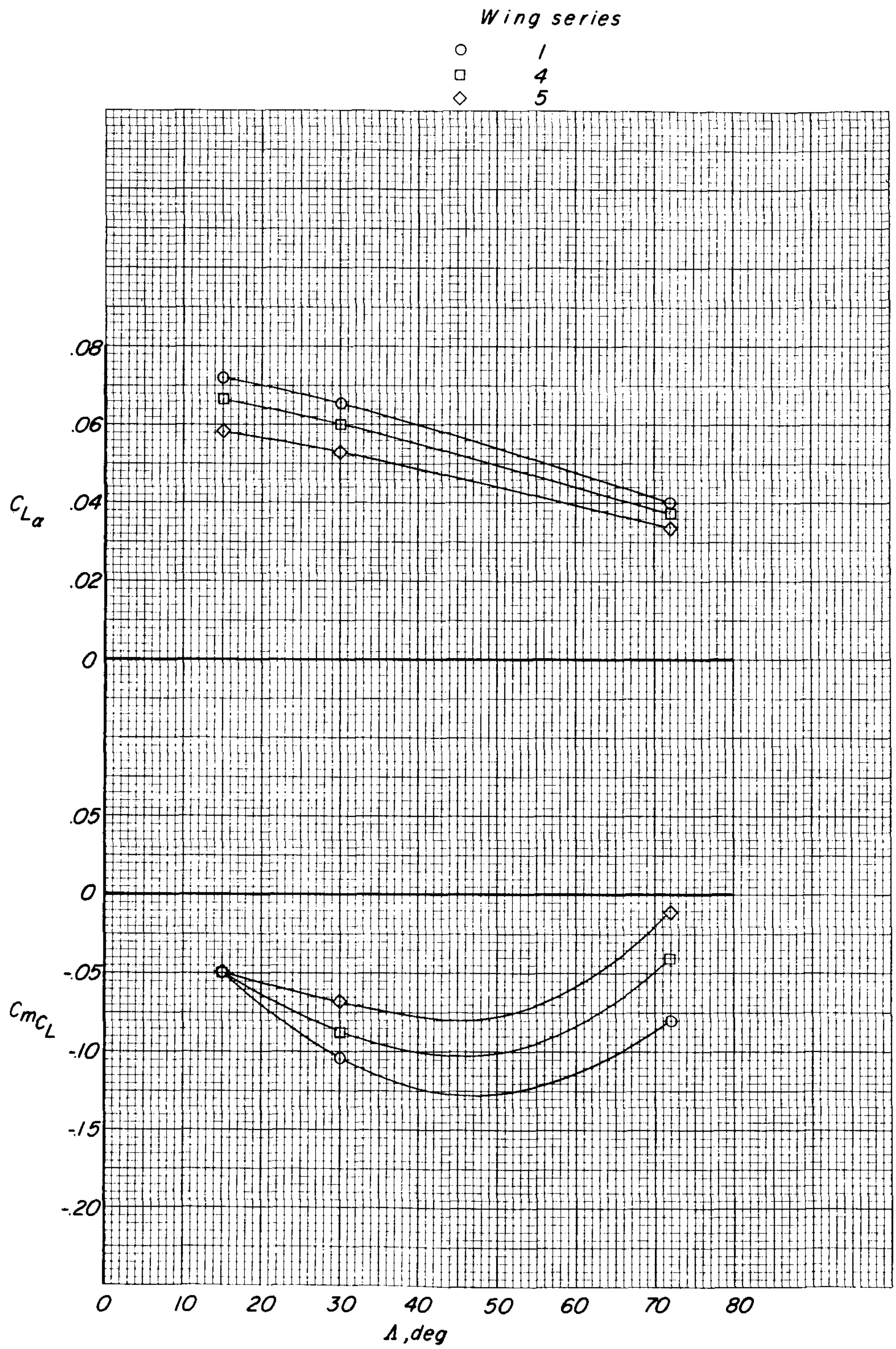


Figure 10.- Effect of wing planform modifications on variation of lift-curve slope and longitudinal stability parameter with wing sweep.

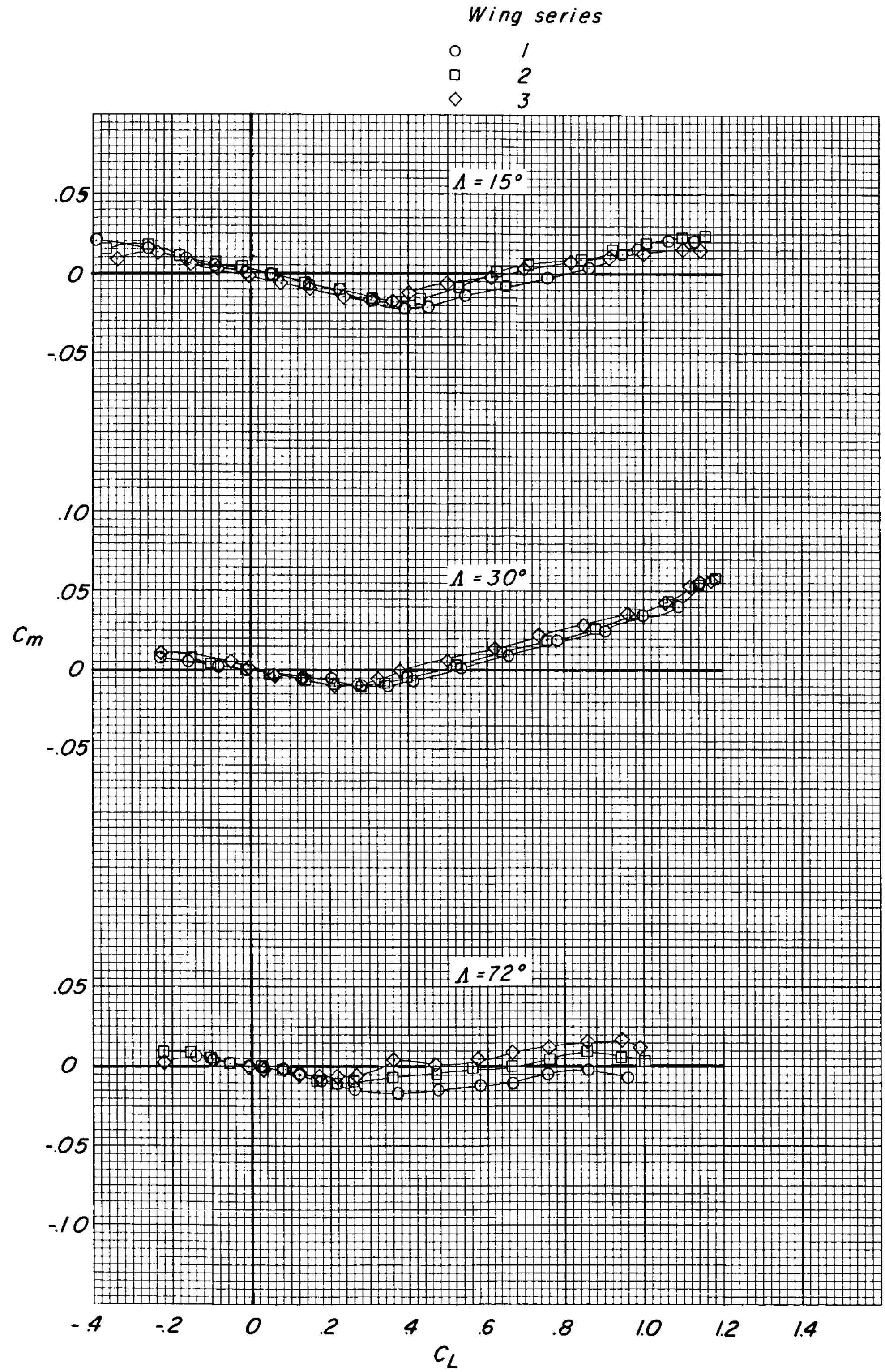


Figure 11.- Effect of wing planform modifications on variation of pitching-moment coefficient C_m with lift coefficient C_L. (Data transferred to common stability level near $C_L = 0$.)

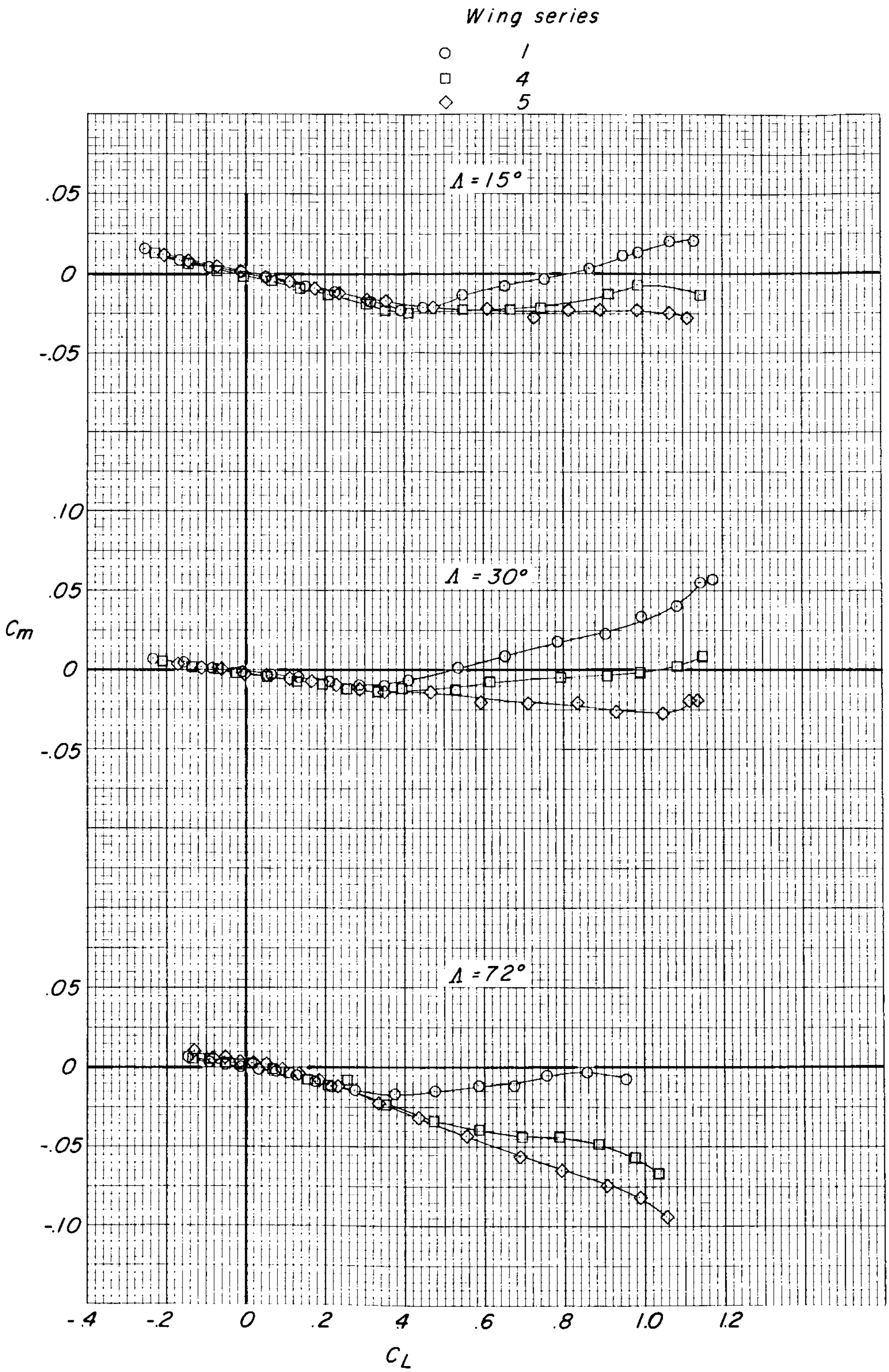


Figure 12.- Effect of wing planform modifications on variation of pitching-moment coefficient C_m with lift coefficient C_L. (Data transferred to common stability level near $C_L = 0$.)

NASA-Langley, 1965 L-4559