NASA TECHNICAL MEMORANDUM

NASA TM X-2897

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CANARD-WING LIFT INTERFERENCE RELATED TO MANEUVERING AIRCRAFT AT SUBSONIC SPEEDS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • DECEMBER 1973

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM X-2897		

4. Title and Subtitle	5. Report Date
CANARD-WING LIFT INTERFERENCE RELATED TO MANEUVERING AIRCRAFT AT SUBSONIC SPEEDS	December 1973
	6. Performing Organization Code
7. Author(s) Blair B. Gloss and Linwood W. McKinney	8. Performing Organization Report No. L-9096
	10. Work Unit No. 760-67-01-01
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23665	11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	13. Type of Report and Period Covered Technical Memorandum
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

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The results indicated that although downwash from the canard reduced the wing lift at angles of attack up to approximately 16°, the total lift was substantially greater with the canard on than with the canard off. At angles of attack above 16°, the canard delayed the wing stall. Changing canard deflection had essentially no effect on the total lift, since the additional lift generated by the canard deflection was lost on the wing due to an increased downwash at the wing from the canard. There was a favorable wing-on-canard lift interference if the canard was located longitudinally near the wing leading edge and in the wing chord plane or above the wing plane. A favorable body-on-canard interference effect was found that delayed canard stall.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Canard-wing interference Canard location Lift interference Performance of maneuvering aircraft	Unclassified – Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	33	Domestic, $3.00 Foreign, $5.50

*For sale by the National Technical Information Service, Springfield, Virginia 22151

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SUMMARY

An investigation was conducted at Mach numbers of 0.7 and 0.9 to determine the lift interference effect of canard location on wing planforms typical of maneuvering fighter configurations. The canard had an exposed area of 16.0 percent of the wing reference area and was located in the plane of the wing or in a position 18.5 percent of the wing mean geometric chord above the wing plane. In addition, the canard could be located at two longitudinal stations. Two different wing planforms were tested: one with a leading-edge sweep angle of 60° and the other with a leading-edge sweep angle of 44°.

The results indicated that although downwash from the canard reduced the wing lift at angles of attack up to approximately 16°, the total lift was substantially greater with the canard on than with the canard off. At angles of attack above 16°, the canard delayed the wing stall. Changing canard deflection had essentially no effect on the total lift, since the additional lift generated by the canard deflection was lost on the wing due to an increased downwash at the wing from the canard. There was a favorable wing-on-canard lift interference if the canard was located longitudinally near the wing leading edge and in the wing chord plane or above the wing plane. A favorable body-on-canard interference effect was found that delayed canard stall.

INTRODUCTION

The use of canards on maneuvering aircraft offers several attractive features, such as increased trimmed lift capability (ref. 1) and the potential for reduced trimmed drag (ref. 2). In addition, the geometric characteristics of close-coupled canard configurations offer a potential for improved longitudinal progression of cross-sectional area which could result in reduced wave drag at low supersonic speeds.

In view of the potential benefits for maneuvering aircraft technology offered by canard configurations, the National Aeronautics and Space Administration is conducting a generalized study to determine the effect of configuration variables on canard-wing interference (refs. 2 and 3). This study is being conducted with a wind-tunnel model incorporating two balances to allow separation of the canard and wing contributions from the total forces and moments.

The present investigation consisted of tests to determine the effect of canard location on canard-wing interference. The tests were made at Mach numbers of 0.7 and 0.9 for Reynolds numbers based on the mean geometric chord of 2.58×10^6 and 2.91×10^6, respectively, and at angles of attack from approximately -4° to 24°.

SYMBOLS

The International System of Units, with U.S. Customary Units presented in parentheses, is used for the physical quantities of this paper. Measurements and calculations were made in U.S. Customary Units.

The longitudinal data are referred to the stability-axis system.

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

b wing span

$\bar{c}$ wing mean geometric chord

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

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

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

l longitudinal distance between quarter-chord points of mean geometric chords of canard and wing

M free-stream Mach number

q free-stream dynamic pressure

S_c area of canard (exposed)

S_w reference area of wing with leading and trailing edges extended to plane of symmetry

z	vertical coordinate with origin at wing chord plane (positive up)
α	angle of attack, deg
δ_c	canard deflection angle, positive when trailing edge down, deg
Λ	leading-edge sweep angle, deg

Subscripts:

C	load measured on canard balance
M	load measured on main balance

DESCRIPTION OF MODEL

A three-view drawing of the general research model showing the canard locations and wing planforms is presented in figure 1. Table I contains the pertinent geometric parameters associated with this model. A photograph of one of the model configurations mounted in the test section of the Langley high-speed 7- by 10-foot tunnel is presented as figure 2.

Two different untwisted wing planforms were used on this model; wing I had a leading-edge sweep angle Λ of 60° and wing II had a value of Λ of 44°. Both wings, however, had the same area, mean geometric chord, uncambered circular-arc airfoil sections, and thickness distribution which varied linearly from 6 percent of the chord at the root to 4 percent at the tip. The two wings were located longitudinally such that the quarter-chord points of both mean geometric chords were coincident.

The canard was untwisted and had a leading-edge sweep angle of 51.7° and an uncambered circular-arc airfoil section. The thickness varied linearly from 6 percent of the chord at the root to 4 percent at the tip. The exposed area of the canard was 16.0 percent of the wing reference area S_W. The canard was tested in the chord plane of the wing ($z/\bar{c} = 0.0$) and in a position 18.5 percent of the wing mean geometric chord above the wing chord plane ($z/\bar{c} = 0.185$). Associated with both of these values of $z/\bar{c}$ were two longitudinal locations 29.05 and 40.42 percent of the body length (canard pivot points measured from model nose); these locations correspond to $l/\bar{c} = 1.61$ and $l/\bar{c} = 1.14$, respectively.

The body fairings shown in figure 2 were installed to fair the canard mounting brackets into the fuselage. These fairings were removed when the canard was in the plane of the wing; this makes the fuselage symmetric about a longitudinal horizontal plane passing through the center of the model.

Table II gives the moment reference locations used in calculating the pitching moments for the various configurations. These moment reference locations were chosen to give a comparable stability level for all canard-wing configurations at a Mach number of 0.7.

APPARATUS, TESTS, AND CORRECTIONS

The present investigation was conducted in the Langley high-speed 7- by 10-foot tunnel. Forces and moments were measured by means of two internally mounted six-component strain-gage balances. One balance was housed within the forward segment of the fuselage and was rigidly attached to the rearward fuselage segment; a small unsealed gap was maintained between the fuselage segments to prevent fouling. This balance (hereinafter called canard balance) measured the loads on the canard and forward segment of the fuselage (shaded area in fig. 1). The second balance (hereinafter referred to as the main balance) was housed in the rearward segment of the fuselage and measured the total model loads.

Tests were made at Mach numbers of 0.7 and 0.9 for free-stream Reynolds numbers, based on the mean geometric chord, of 2.58×10^6 and 2.91×10^6, respectively, and at angles of attack from approximately -4° to 24° at a sideslip angle of 0°. All tests were made with boundary-layer transition fixed on the model by means of narrow strips of carborundum grit placed on the body, wings, and canards, as outlined in reference 4.

The data have been corrected for blockage and jet-boundary effects by the methods outlined in references 5 and 6, respectively. Angles of attack have been corrected for the effects of balance and sting deflection, occurring upstream of the model angle-of-attack measuring device, due to aerodynamic load. All drag measurements were corrected to a condition of free-stream static pressure acting on the base of the model.

PRESENTATION OF DATA

An outline of the contents of the data figures is as follows:

RESULTS AND DISCUSSION

The only results discussed are the effects on the lift of the interference of the canard on the wing, the wing on the canard, and the body on the canard.

Interference Effect of Canard on Wing

The data presented in figures 3 to 8 show that most of the increased lift on the canards obtained by canard deflection was lost by the wing due to the increased downwash on the wing; this adverse effect produced essentially no change in the total lift. (Note that the lift-coefficient scales are different for the canard and main balances.) This adverse interference effect was also noted in reference 2. However, unlike the result obtained in a previous study, this adverse interference at $M = 0.7$ and 0.9 persisted regardless of canard position. Increasing the Mach number from 0.7 to 0.9 had little effect on this interference (figs. 3 and 4).

The effects of the canard on the wing lift are summarized in figures 9 to 12. At low angles of attack (up to approximately 16°), the canard reduced the lift on both wings ($\Lambda = 60^{\circ}$ and $\Lambda = 44^{\circ}$) as would be expected due to the canard downwash; however, at angles of attack greater than about 16°, the canard has a favorable effect in that it delays stall of the main wing. This favorable effect is more pronounced for wing II, which had the lowest sweep angle ($\Lambda = 44^{\circ}$) with the canard in the close-coupled position ($l/\bar{c} = 1.14$). (See fig. 12.) This effect is believed to result from a delay in the breakdown of the main wing leading-edge vortex due to the presence of the canard. As the canard is moved forward, $l/\bar{c} = 1.61$, the unfavorable effects are not materially changed (fig. 11); however, the beneficial interference at high angles of attack is significantly reduced.

It should be pointed out that although the canard has an unfavorable effect on the wing at moderate angles of attack, the lift for the canard-wing configuration is significantly higher than that for the wing alone. This effect is due in part to the favorable interference of the wing on the canard.

Interference Effect of Wing on Canard

When the lift on the canard with the wing off is compared with the lift on the canard with the wing on (figs. 9 to 12), it is found that when the canard is in the aft position ($l/\bar{c} = 1.14$), there is a sizable favorable interference effect on the canard lift from the wing for angles of attack greater than approximately 8° (figs. 10 and 12). For angles of attack less than 8°, there was no interference effect. Even when the canard is in the forward position, there is a small favorable interference effect on the canard from the wing (figs. 9 and 11). This favorable interference effect is attributed to the upwash of the wing, which increases the effective angle of attack of the canard.

Interference Effect of Body on Canard

The interference effect of the body on the canard is also shown in figures 9 to 12. From the canard lift data presented in these figures, it is noted that the canard with the wing off does not appear to stall throughout the test angle-of-attack range when mounted at $z/\bar{c} = 0.185$ and $l/\bar{c} = 1.14$ as it does when at any other position. The lift curve for the case with the high canard in the aft position and with the wing off is the same as the lift curve for the case with the low canard in the aft position and with the wing off up to an angle of attack of about 12°. (See figs. 10 and 12.) The differences between the lift curves at angles of attack above 12° are probably due to the favorable interference effect on the high canard in the aft location as a result of the body vortices shed from the fuselage nose. This effect is discussed in reference 7.

SUMMARY OF RESULTS

The results of the investigation to determine the effect of canard location on canard-wing interference for a general research model are summarized as follows:

1. The downwash from the canard reduced the wing lift at angles of attack up to approximately 16°. However, the total lift was substantially greater with the canard on than with the canard off.

2. At angles of attack above 16°, the canard delayed the wing stall.

3. Increasing the canard deflection produced essentially no change in the total lift due to the increased downwash on the wing.

4. There was a favorable interference of the wing on the canard lift when the canard was near the wing leading edge in the wing chord plane or above it.

5. A favorable interference effect of the body on the canard which delayed canard stall was obtained for the configuration with the canard above the wing chord plane in the aft position.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., October 14, 1973.

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TABLE I.- GEOMETRIC CHARACTERISTICS OF MODEL

Body length, cm (in.)	96.52 (38.00)
Wings I and II:	
A	2.5
b/2, cm (in.)	25.4 (10.00)
Λ of wing I, deg	60
Λ of wing II, deg	44
$\bar{c}$, cm (in.)	23.32 (9.18)
Airfoil section	Circular arc
S_w, cm^2 (in^2)	1032.3 (160.00)
Root chord, cm (in.)	29.79 (11.73)
Tip chord, cm (in.)	6.78 (2.67)
Maximum thickness, percent chord, at –	
Root	6
Tip	4
Canard:	
Λ, deg	51.7
Airfoil section	Circular arc
S_c, cm^2 (in^2)	165.16 (25.60)
b/2, cm (in.)	13.97 (5.50)
Root chord, cm (in.)	13.54 (5.33)
Tip chord, cm (in.)	2.72 (1.07)
Maximum thickness, percent chord, at –	
Root	6
Tip	4

TABLE II.- MOMENT REFERENCE LOCATIONS FOR CANARD-WING CONFIGURATIONS

[Body length measured from nose of model]

Wing	$l/\bar{c}$	Moment reference location, % of body length
I ($\Lambda = 60^{\circ}$)	1.61	62.23
	1.14	61.27
II ($\Lambda = 44^{\circ}$)	1.61	56.80
	1.14	59.22

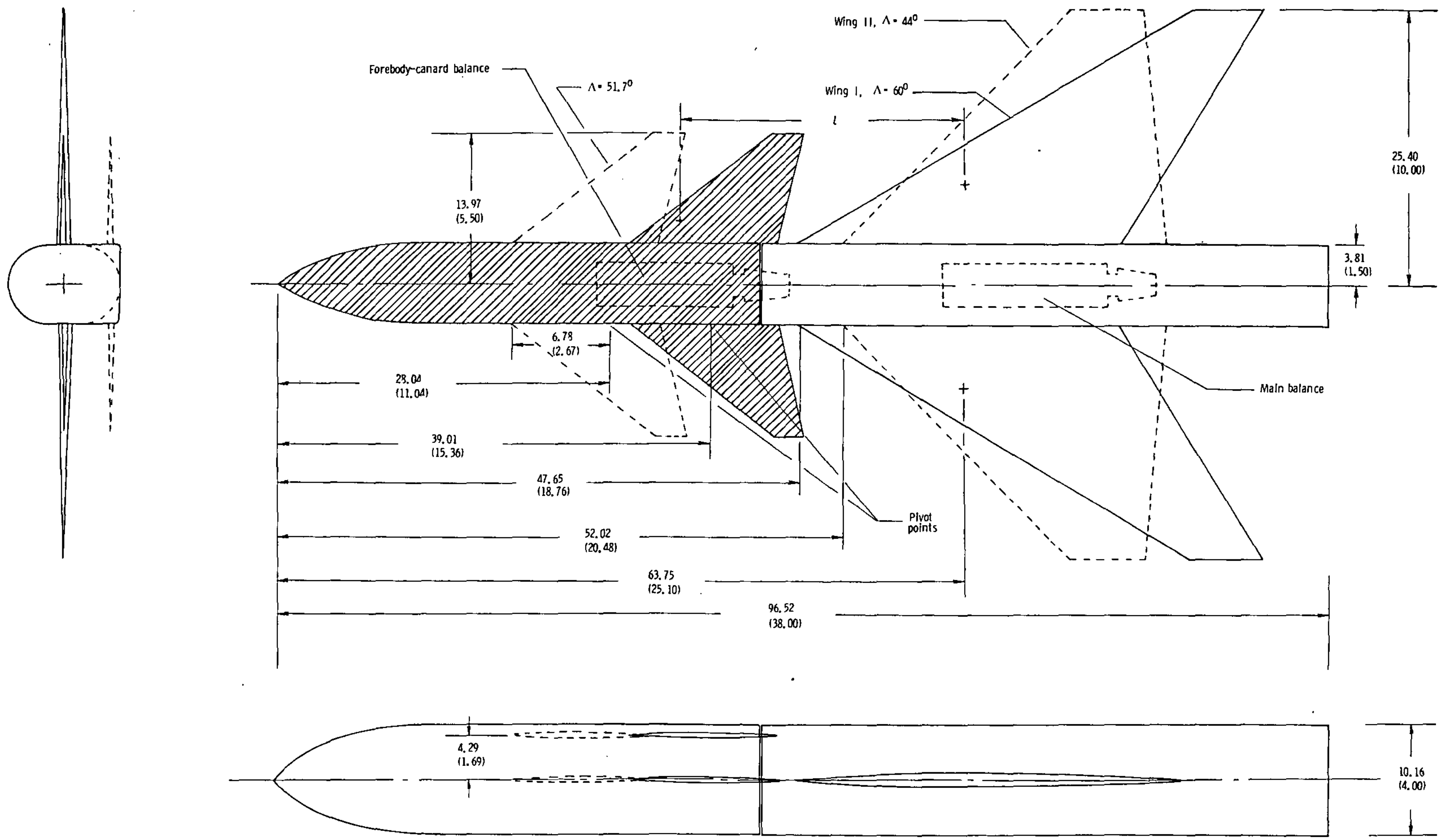

Figure 1.- Three-view drawing of general research model. All dimensions are in centimeters (inches) unless otherwise indicated.

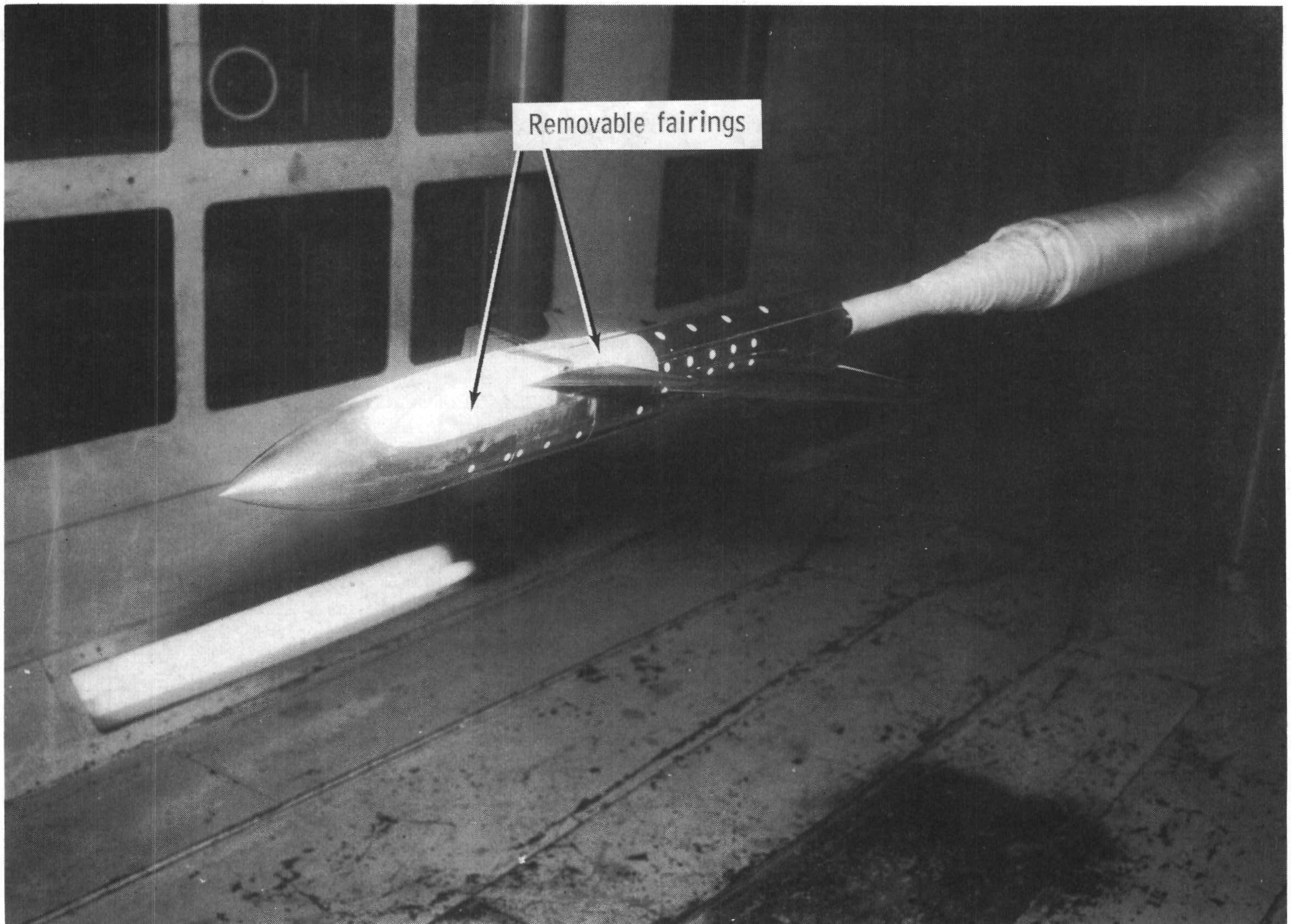

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Figure 2.- General research model with wing II ($\Lambda = 44^{\circ}$). $z/\bar{c} = 0.185$; $l/\bar{c} = 1.14$.

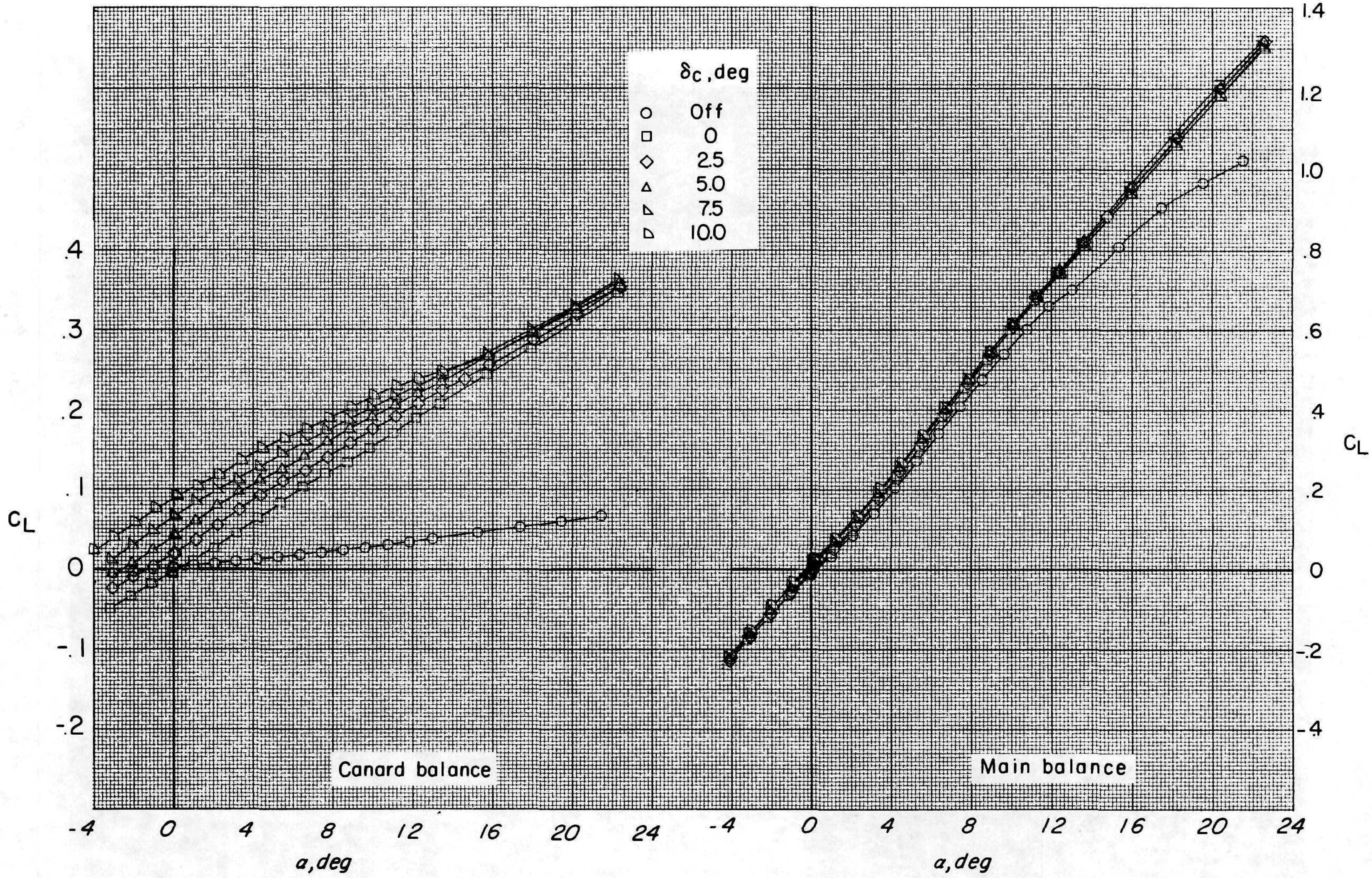
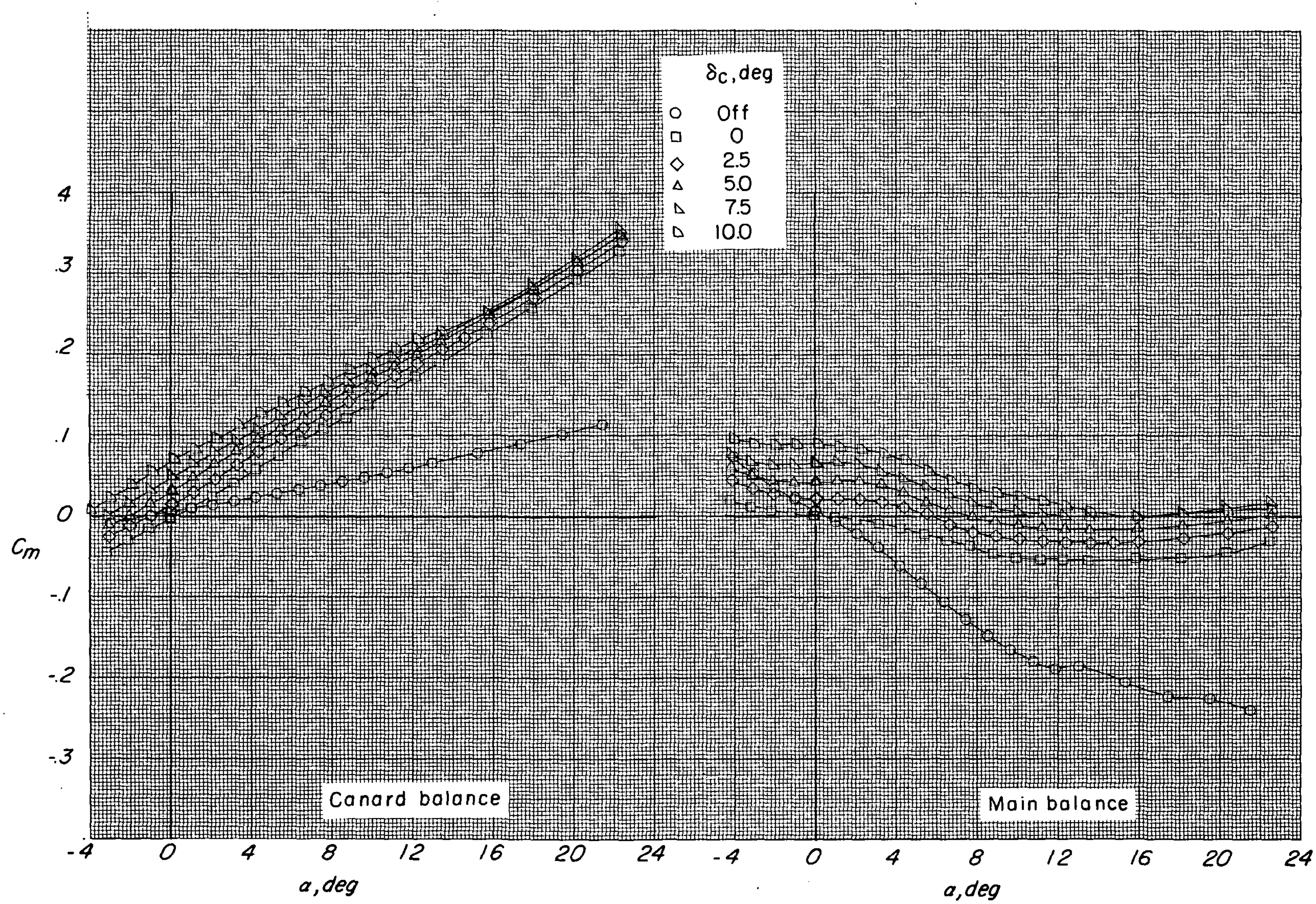


Figure 3.- Effect of canard deflection on the longitudinal aerodynamic characteristics of wing I ($\Lambda = 60^{o}$) for $z/\bar{c} = 0.185$, $l/\bar{c} = 1.14$, and $M = 0.7$.



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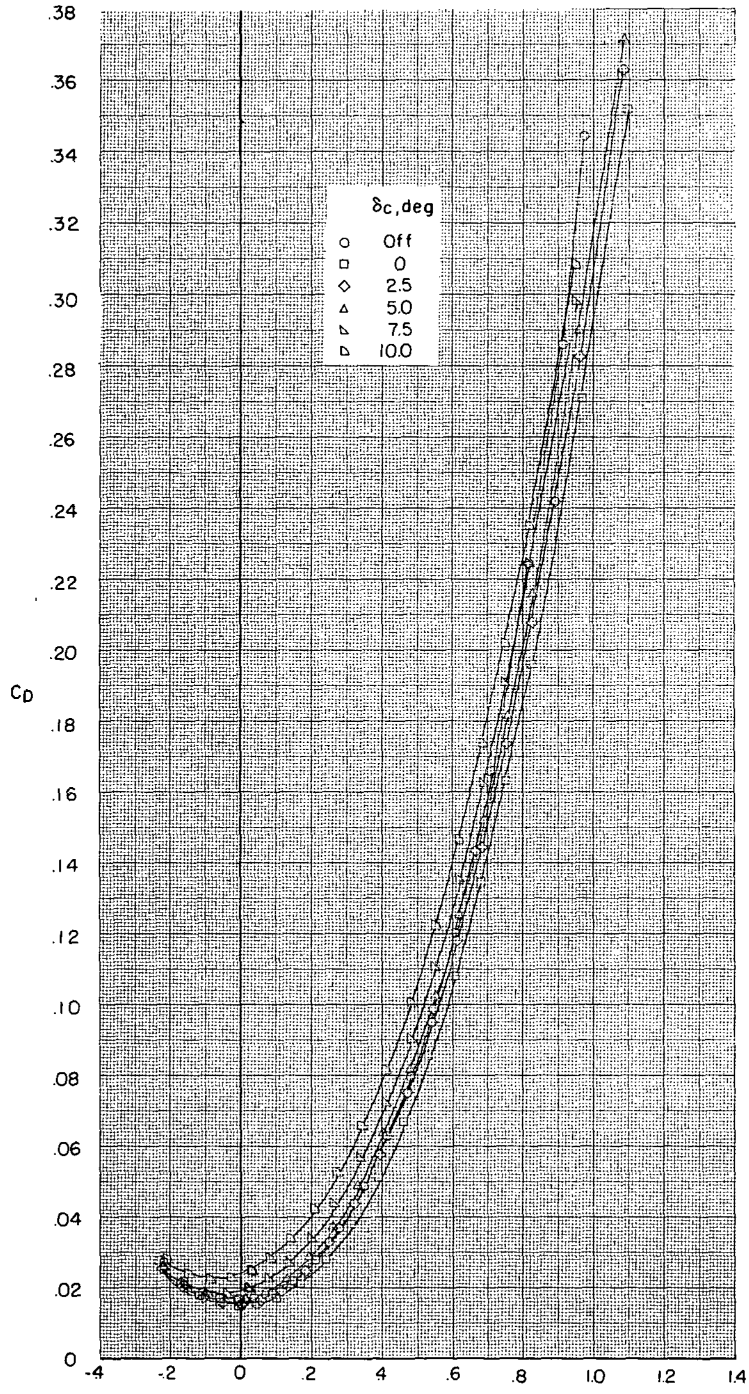

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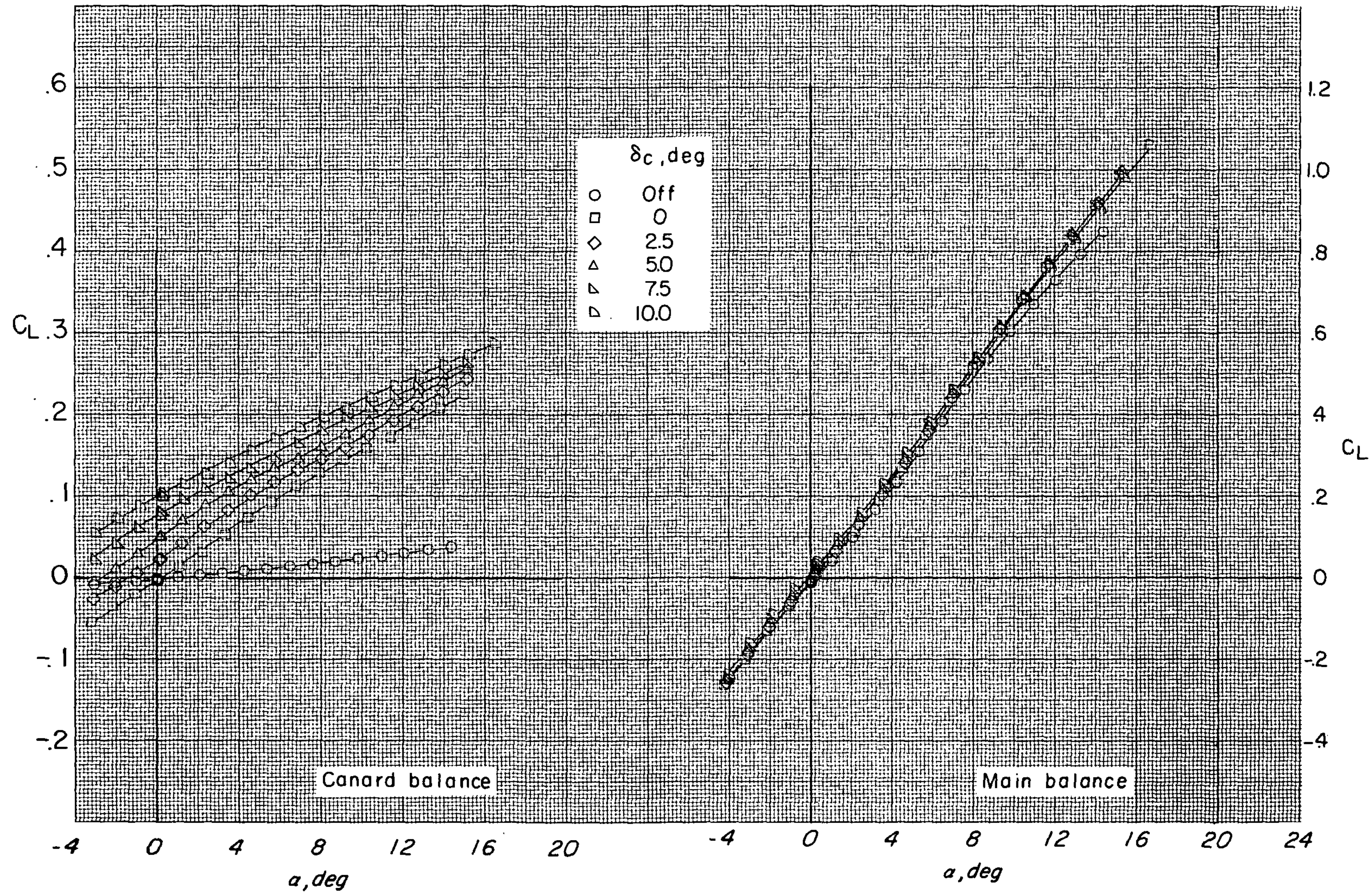
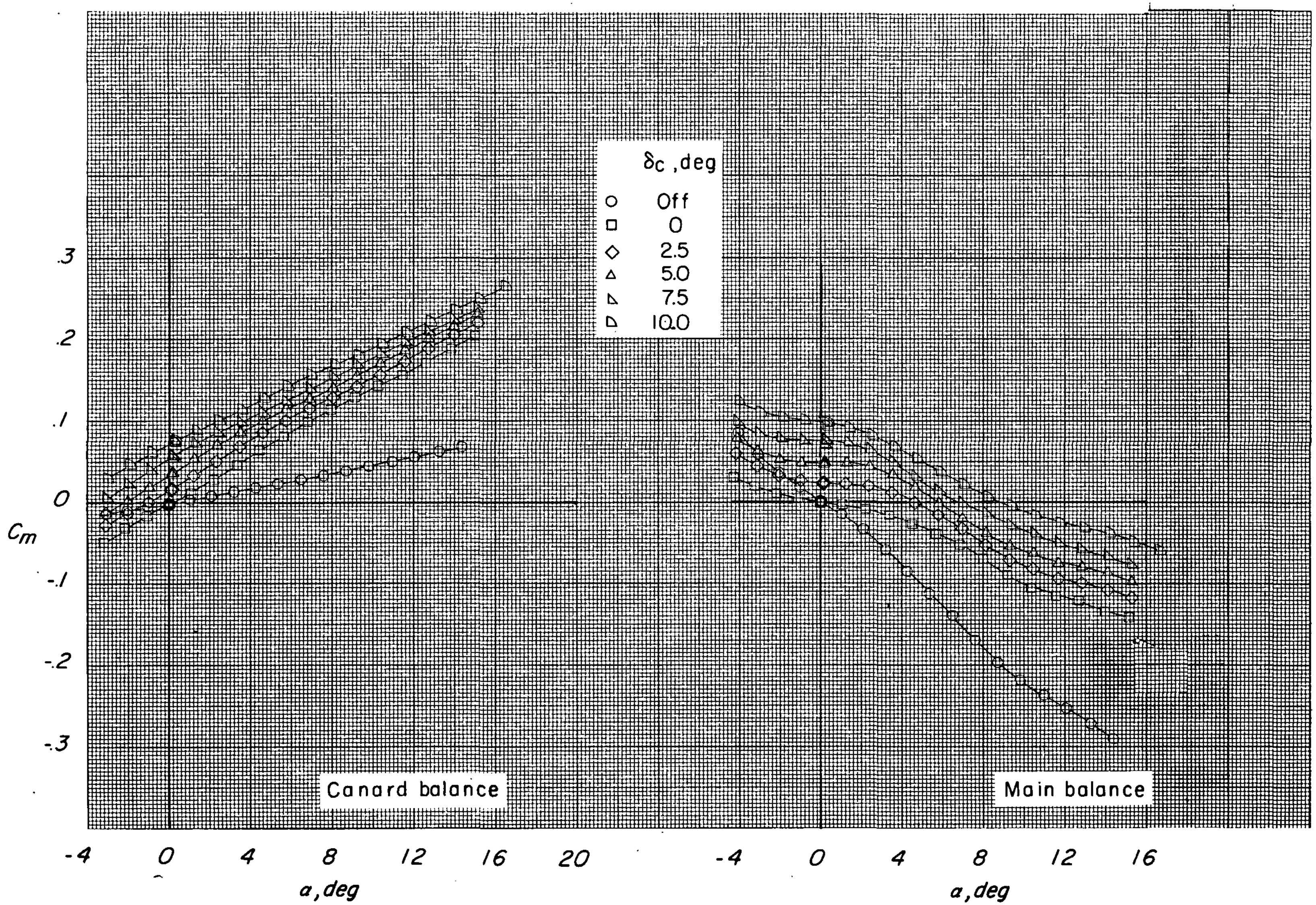


Figure 4.- Effect of canard deflection on the longitudinal aerodynamic characteristics of wing I ($\Lambda = 60^{o}$) for $z/\bar{c} = 0.185$, $l/\bar{c} = 1.14$, and $M = 0.9$.



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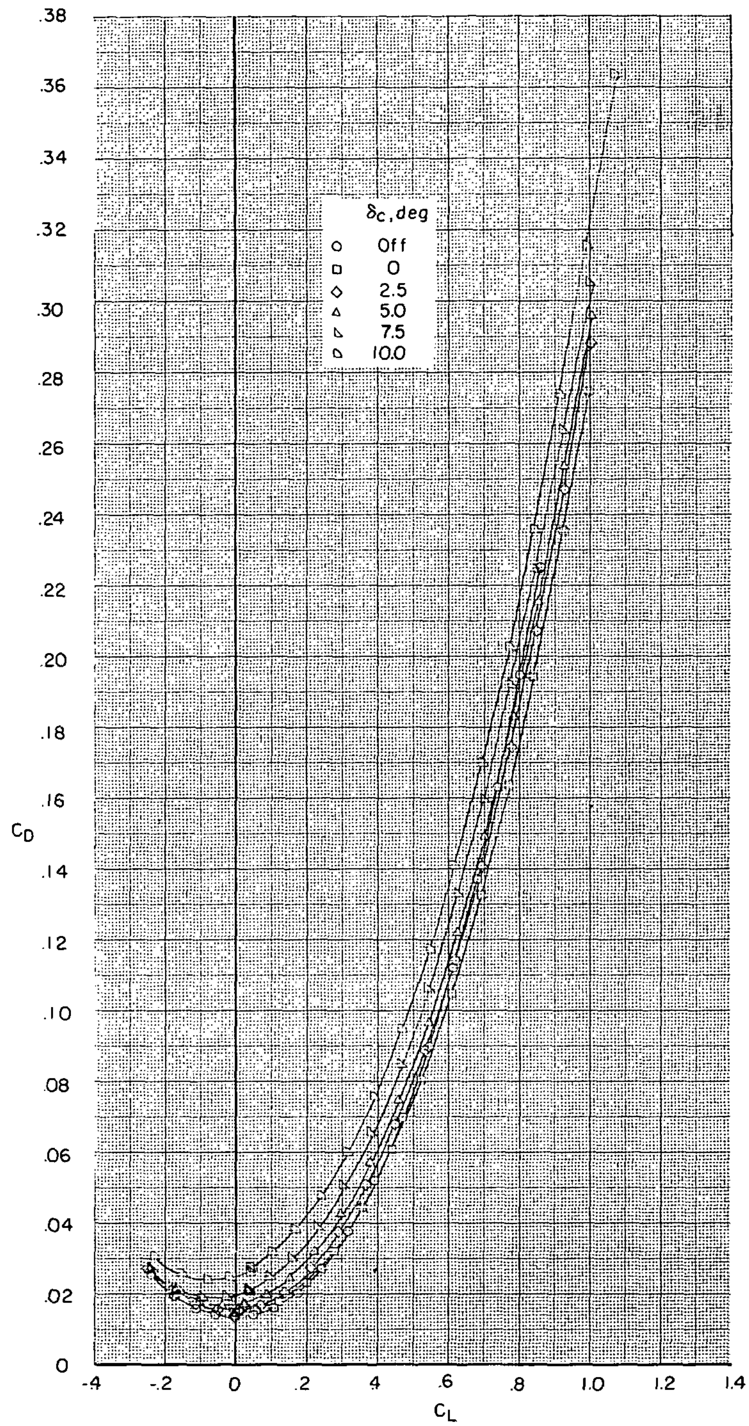

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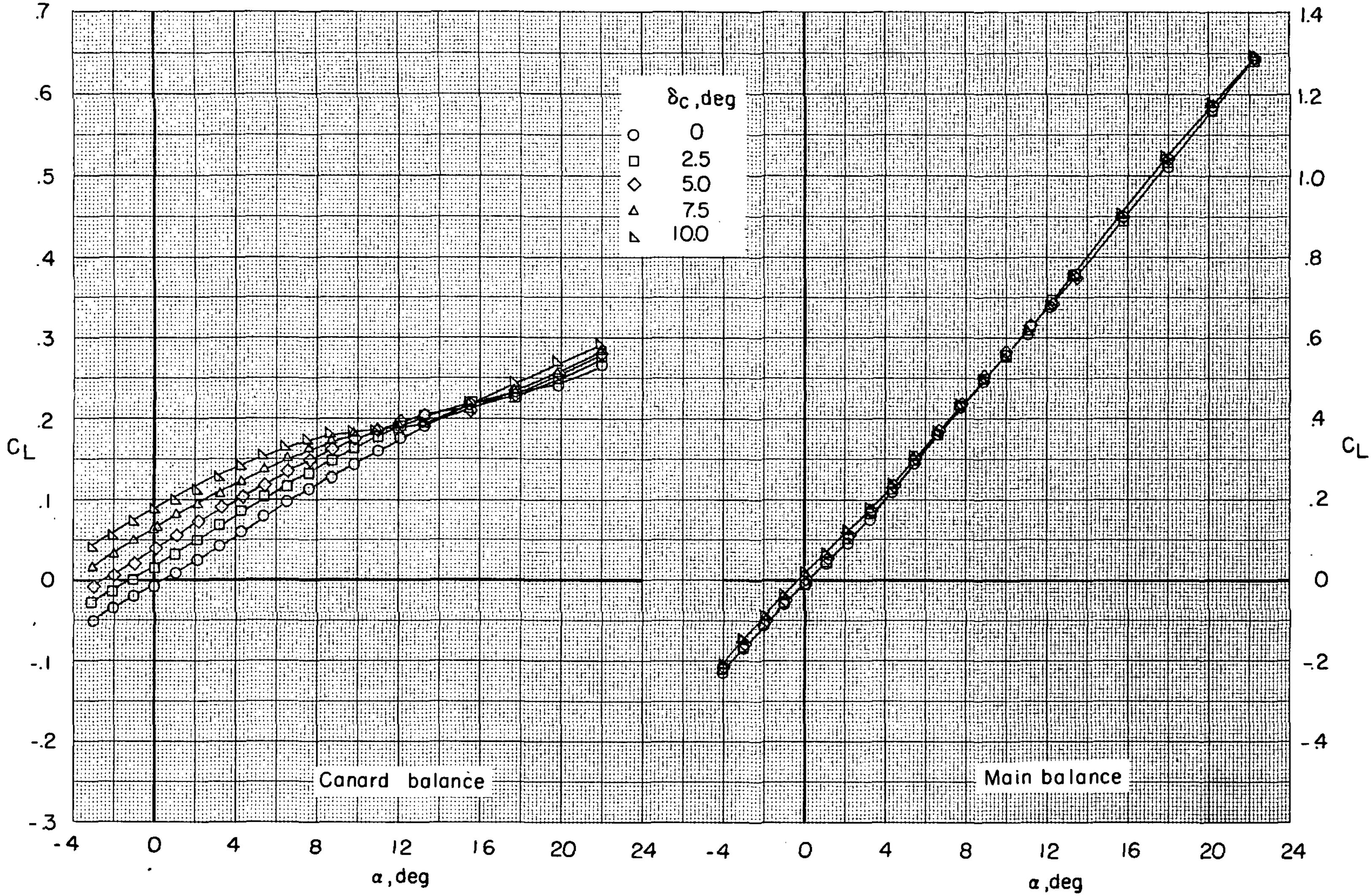
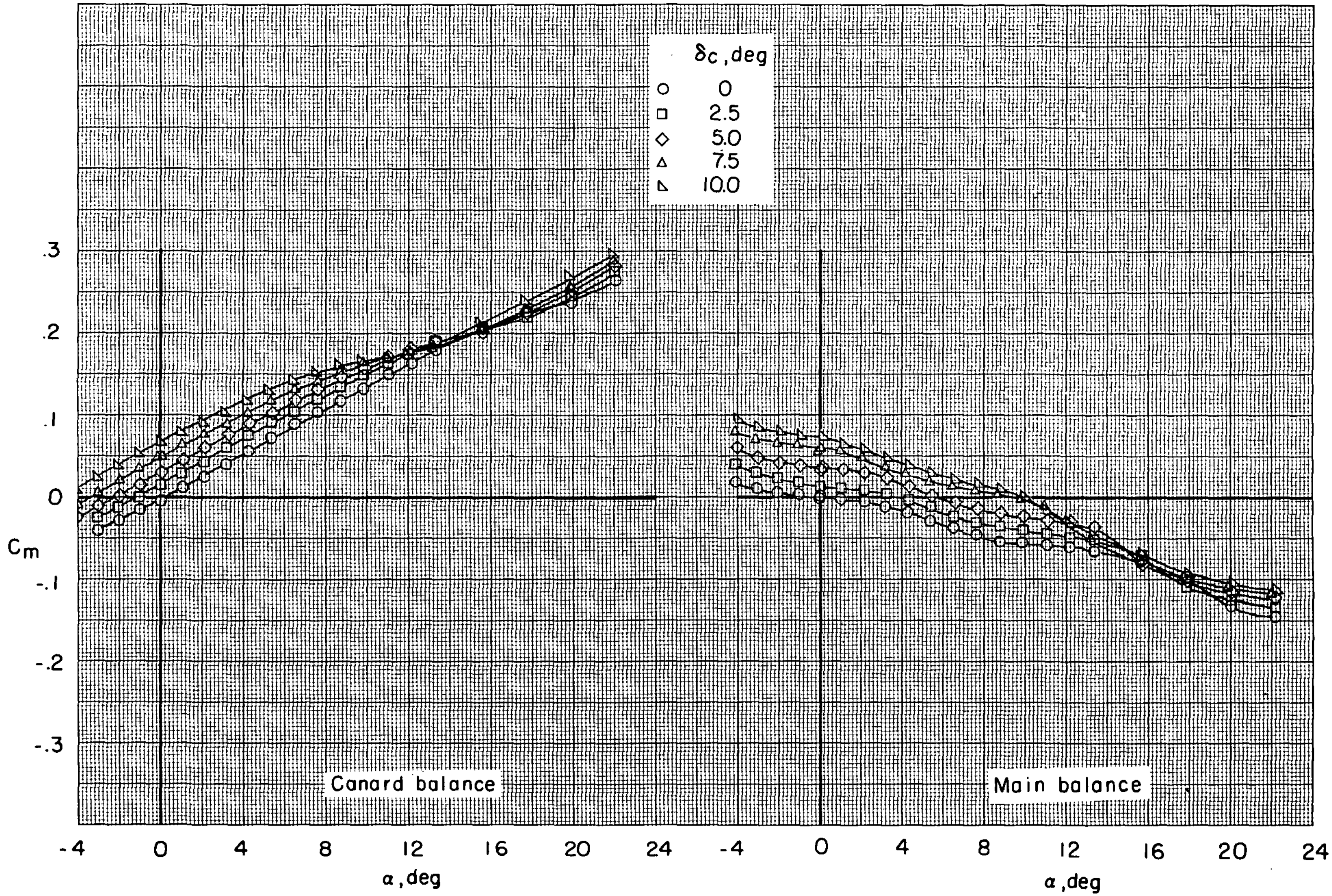


Figure 5.- Effect of canard deflection on the longitudinal aerodynamic characteristics of wing I ($\Lambda = 60^{\circ}$) for $z/\bar{c} = 0.0$, $l/\bar{c} = 1.14$, and $M = 0.7$.



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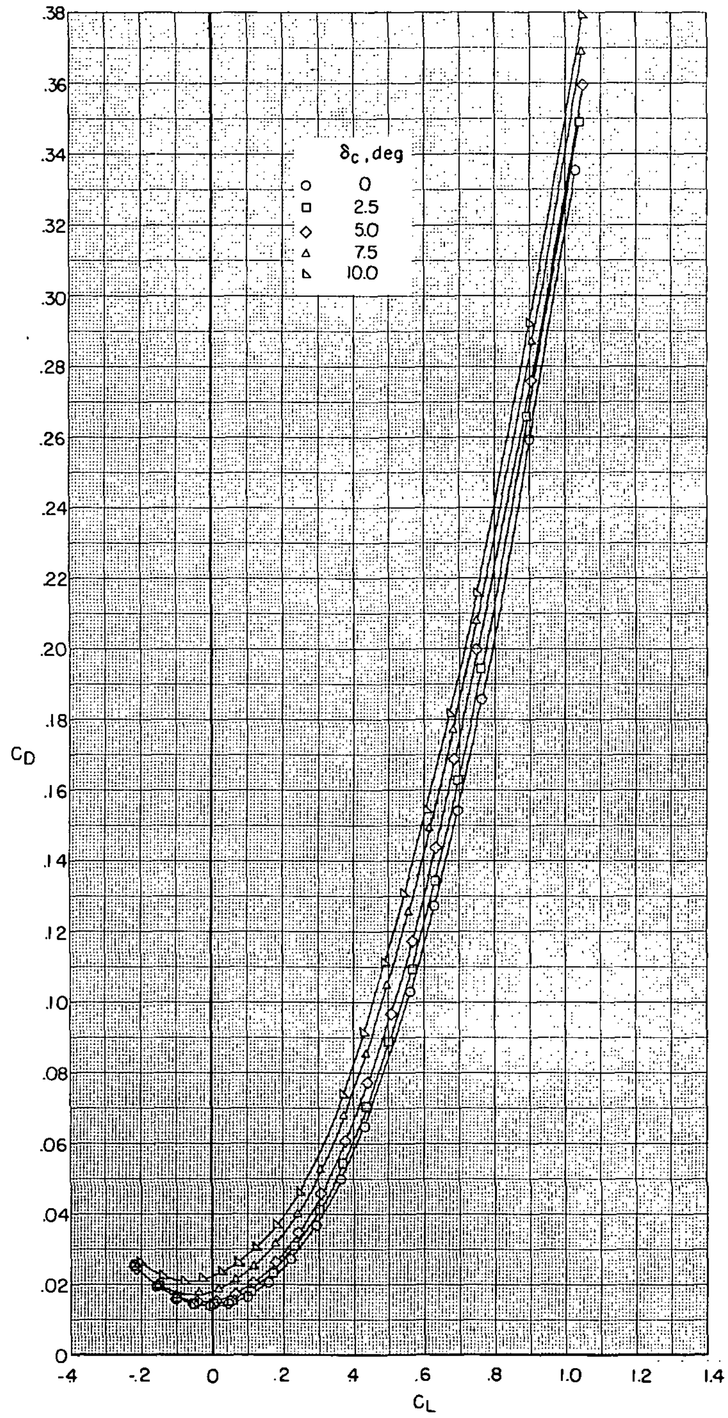

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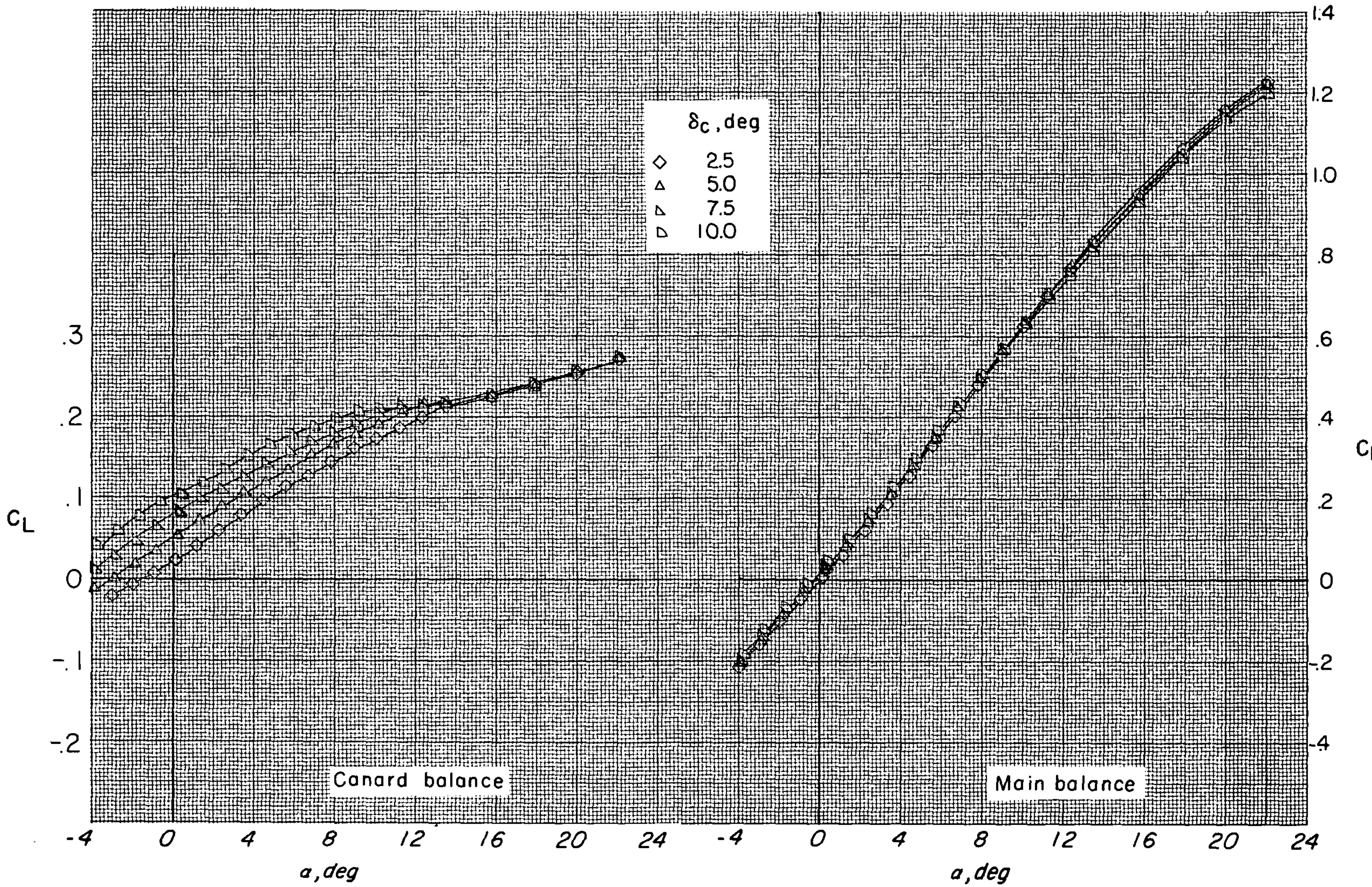
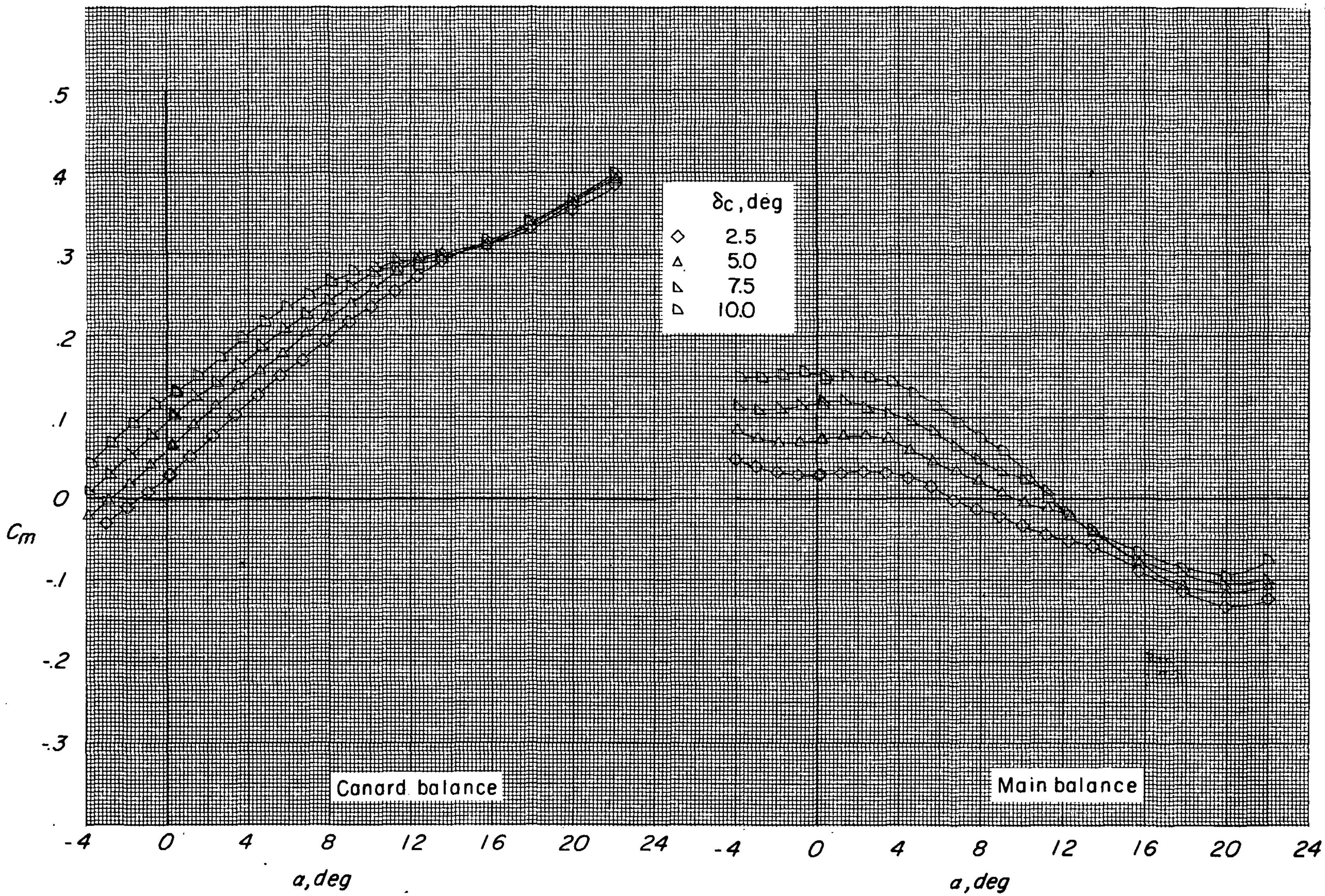


Figure 6.- Effect of canard deflection on the longitudinal aerodynamic characteristics of wing I ($\Lambda = 60^o$) for $z/\bar{c} = 0.185$, $l/\bar{c} = 1.61$, and $M = 0.7$.



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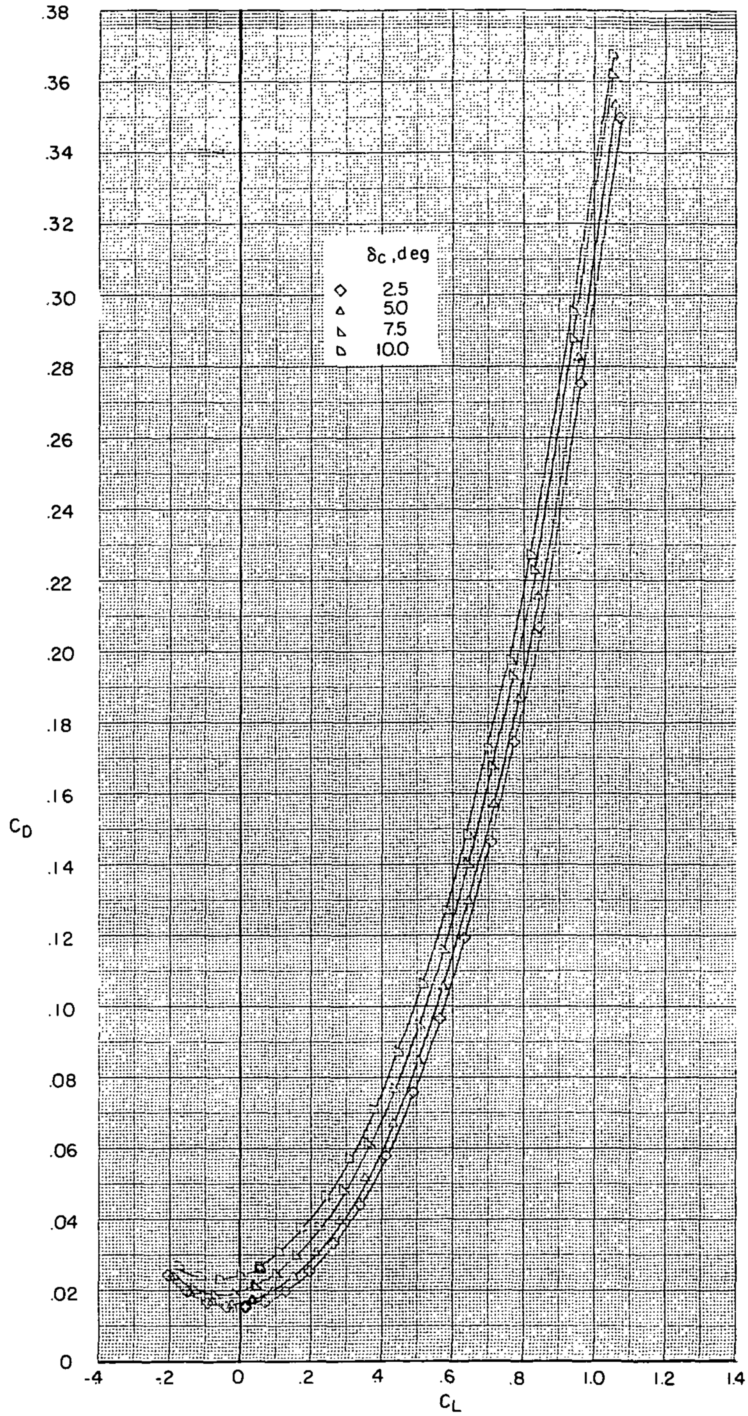

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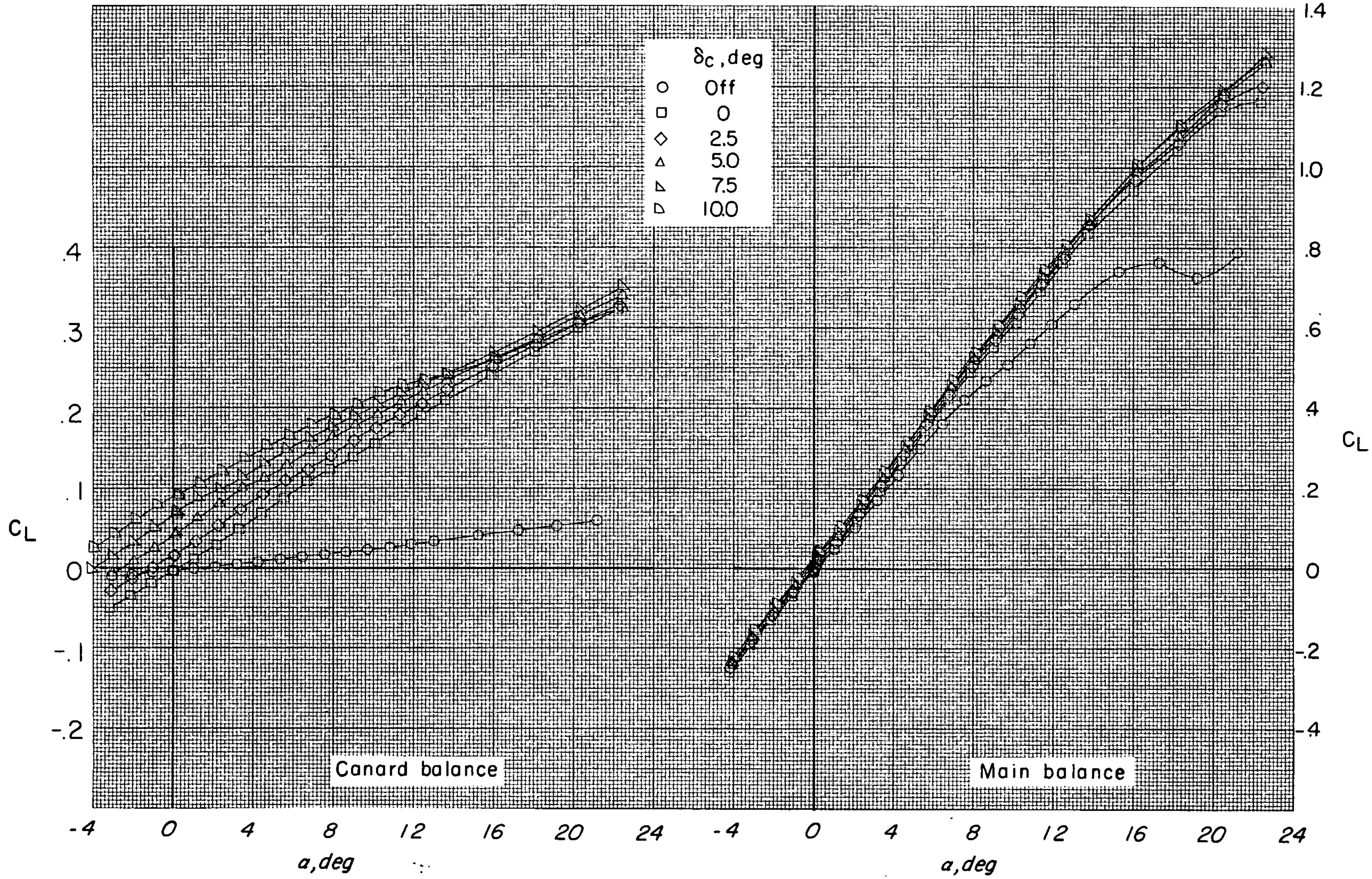
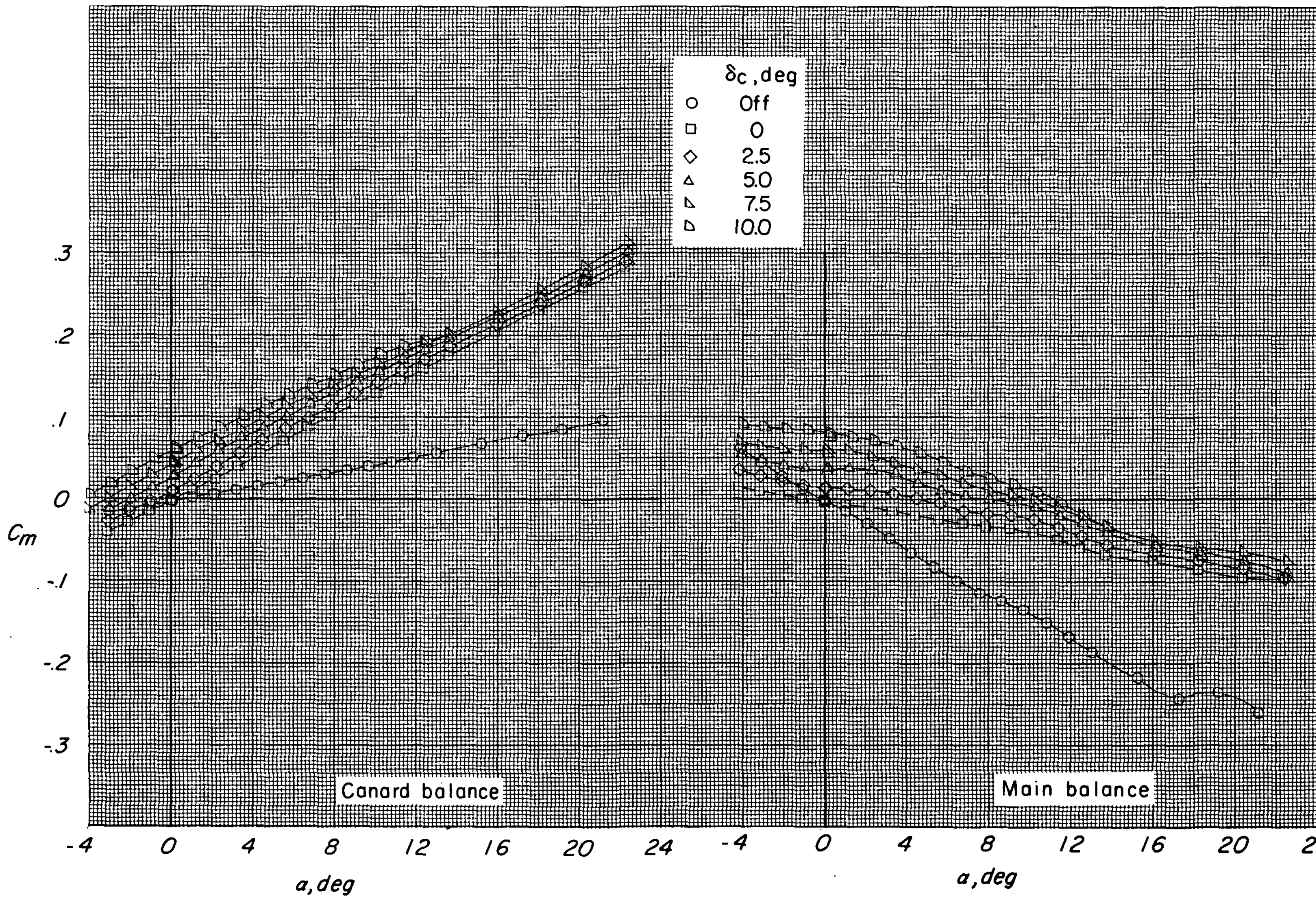


Figure 7.- Effect of canard deflection on the longitudinal aerodynamic characteristics of wing II ($\Lambda = 44^{o}$) for $z/\bar{c} = 0.185$, $l/\bar{c} = 1.14$, and $M = 0.7$.



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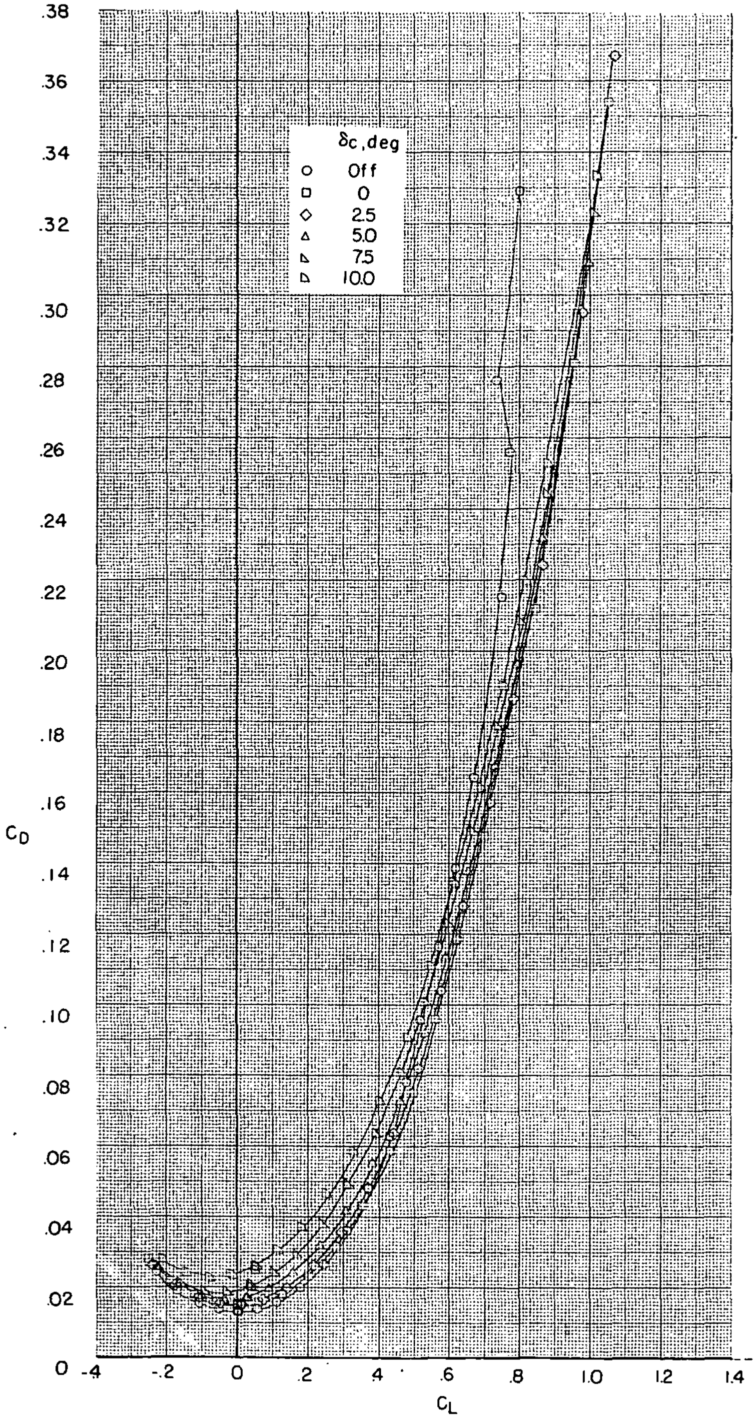

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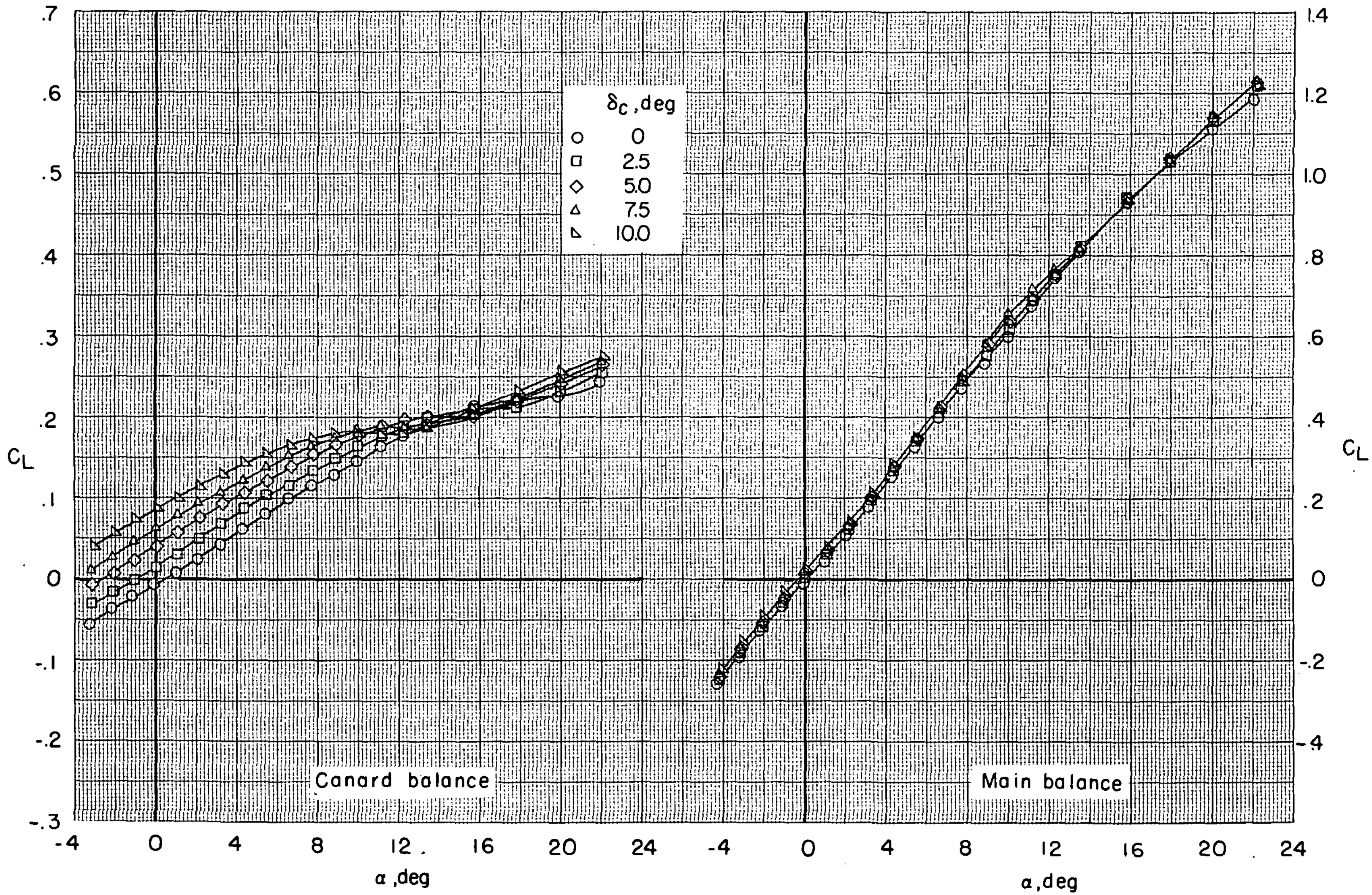
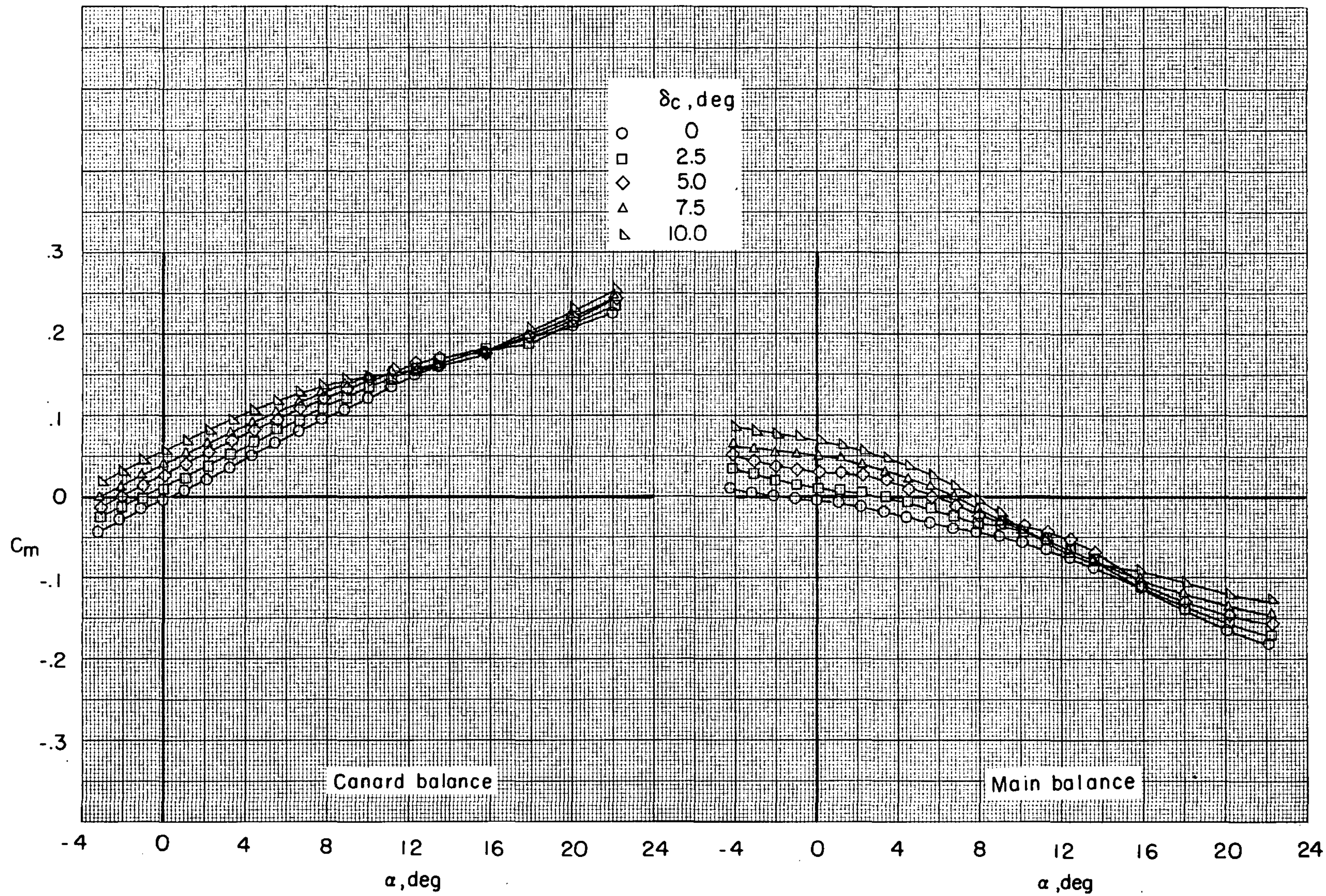


Figure 8.- Effect of canard deflection on the longitudinal aerodynamic characteristics of wing II ($\Lambda = 44^{o}$) for $z/\bar{c} = 0.0$, $l/\bar{c} = 1.14$, and $M = 0.7$.



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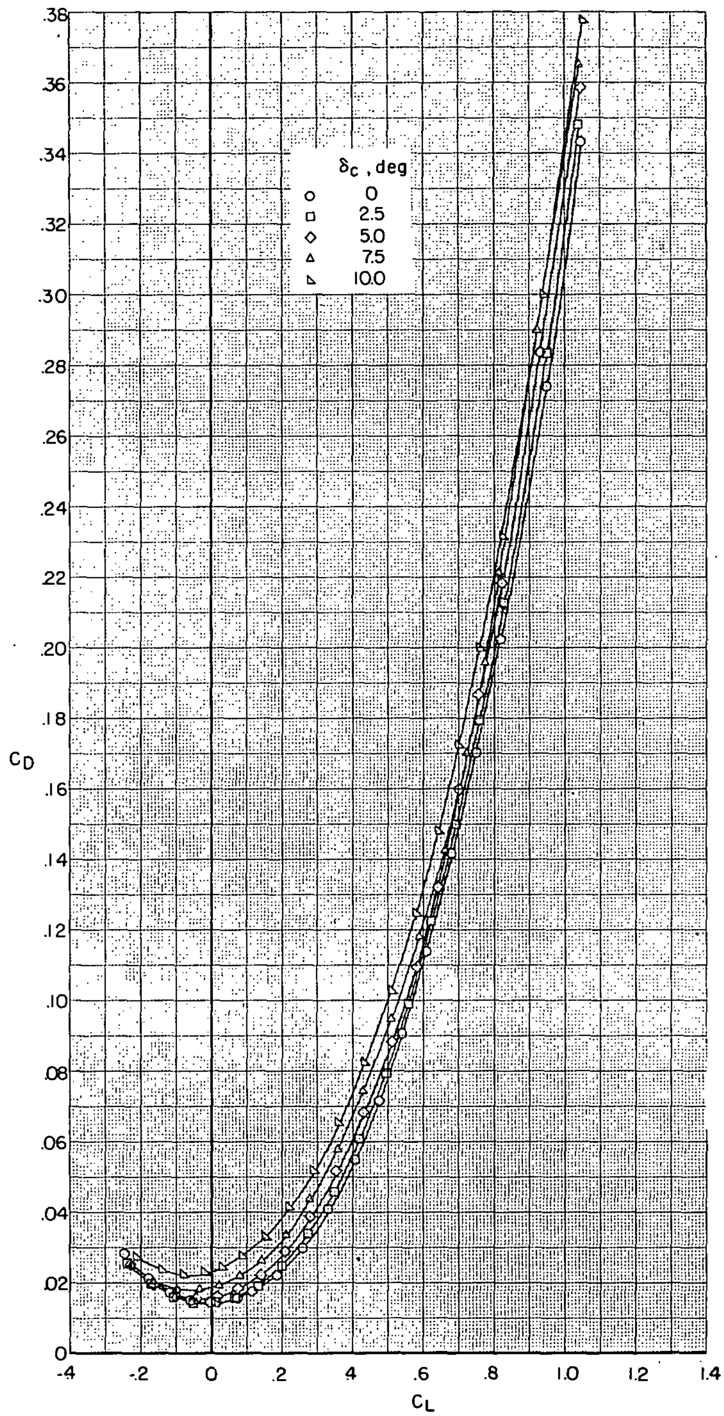

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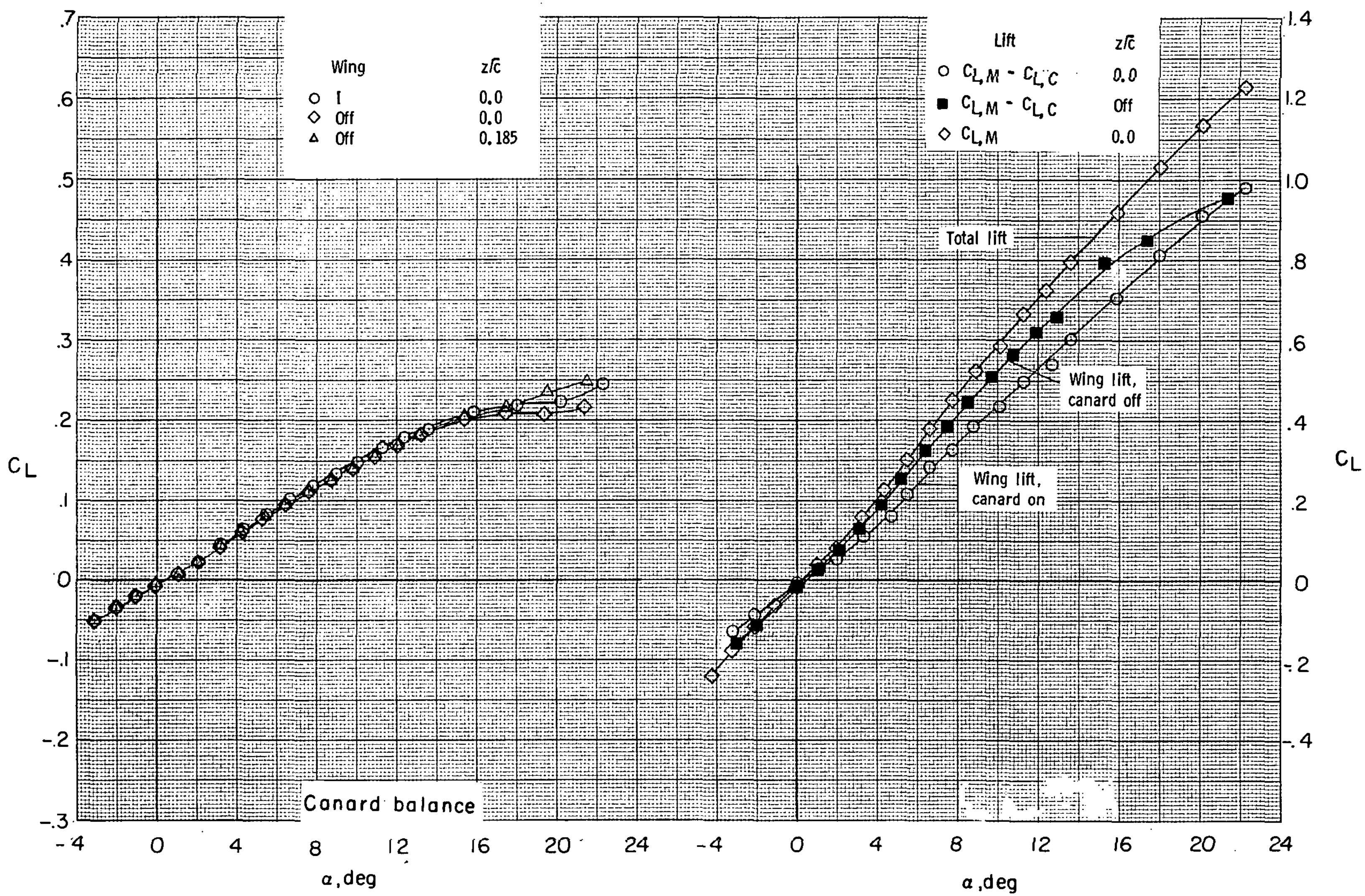

Figure 9.- Canard lift, wing lift, and total model lift as a function of angle of attack for wing I ($\Lambda = 60^{\circ}$) with $\delta_c = 0.0$ at $l/\bar{c} = 1.61$ and $M = 0.7$.

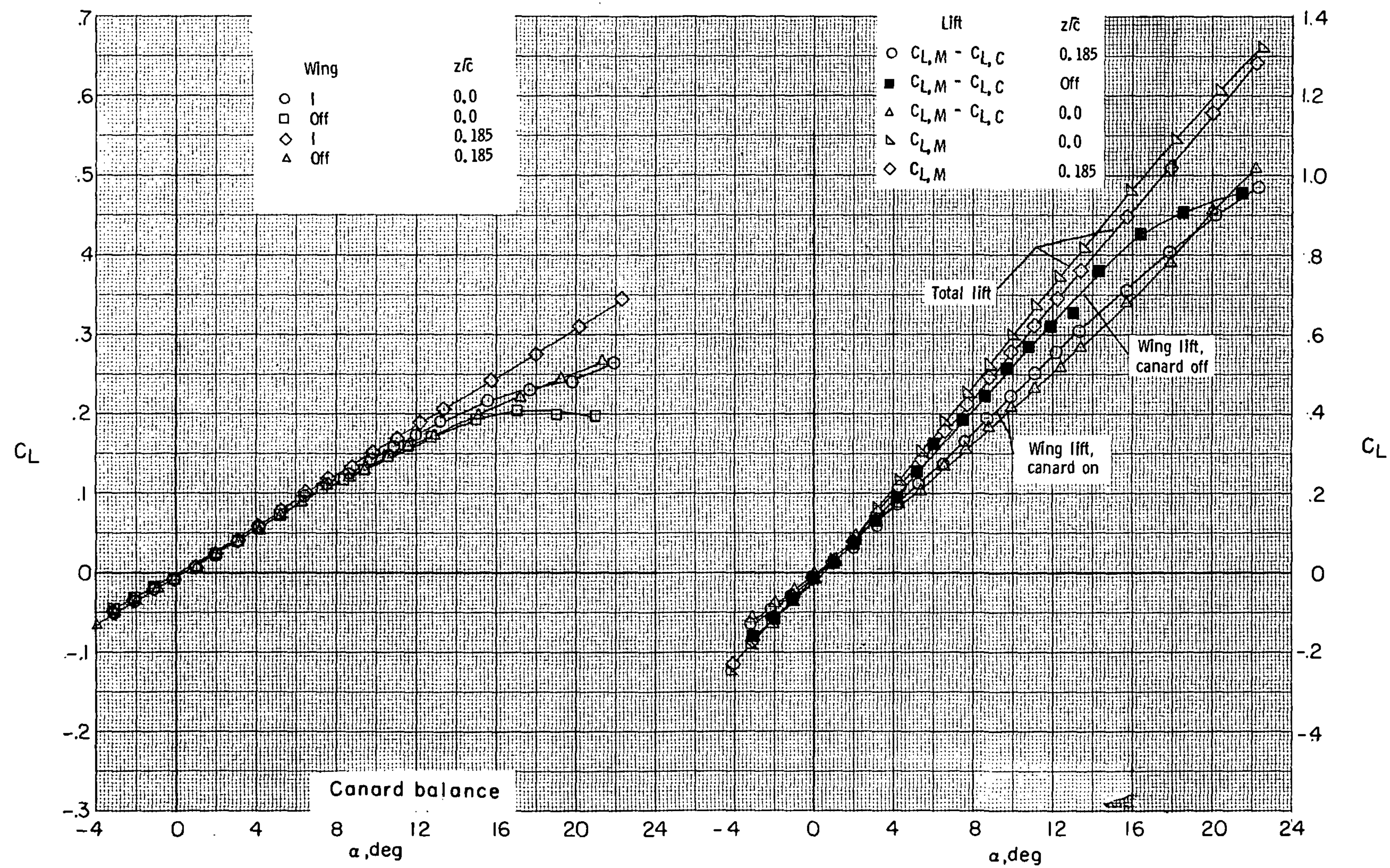

Figure 10.- Canard lift, wing lift, and total model lift as a function of angle of attack for wing I ($\Lambda = 60^{\circ}$) with $\delta_c = 0.0$ at $l/\bar{c} = 1.14$ and $M = 0.7$.

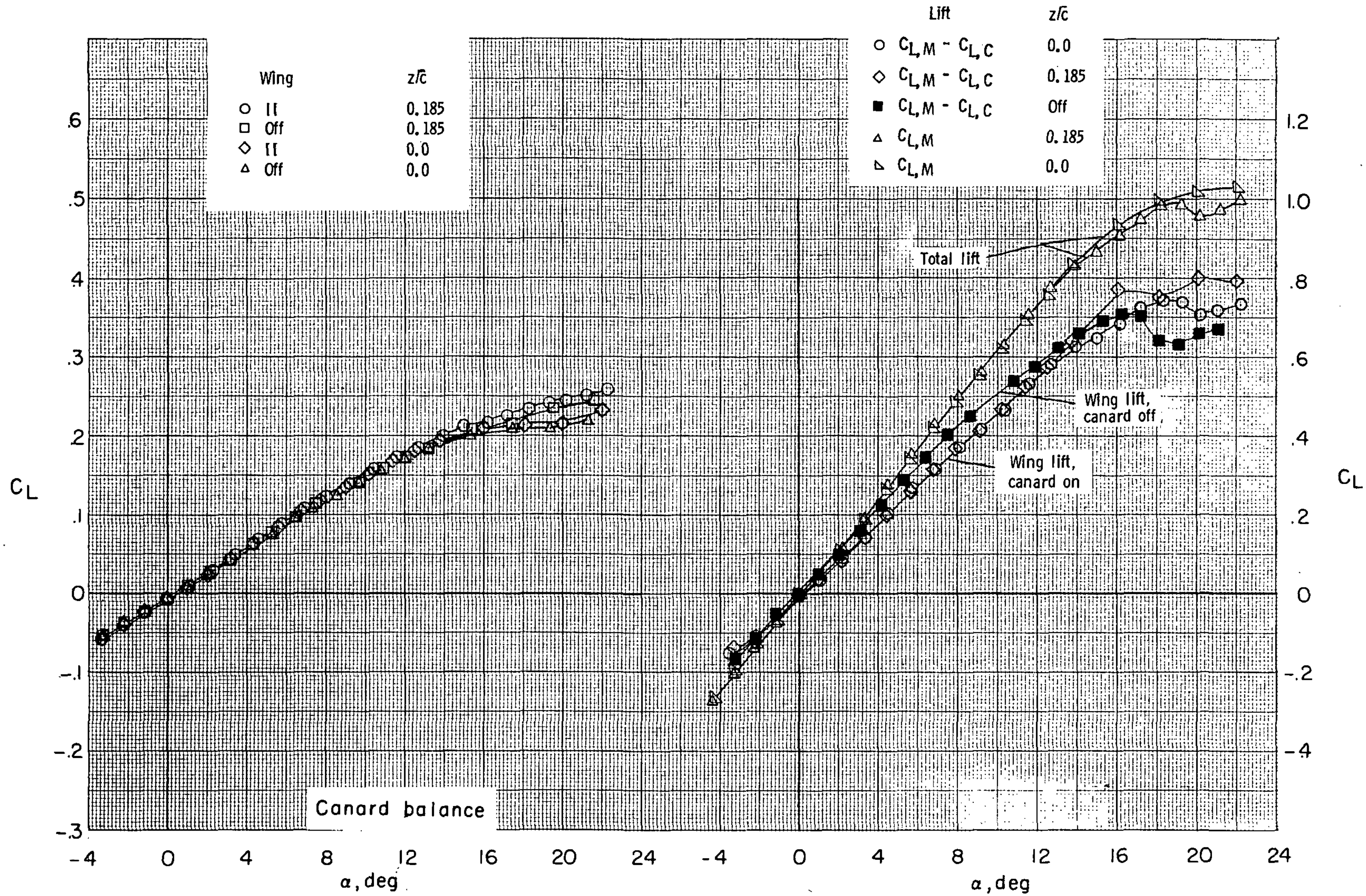

Figure 11.- Canard lift, wing lift, and total model lift as a function of angle of attack for wing II ($\Lambda = 44^{\circ}$) with $\delta_c = 0.0$ at $l/\bar{c} = 1.61$ and $M = 0.7$.

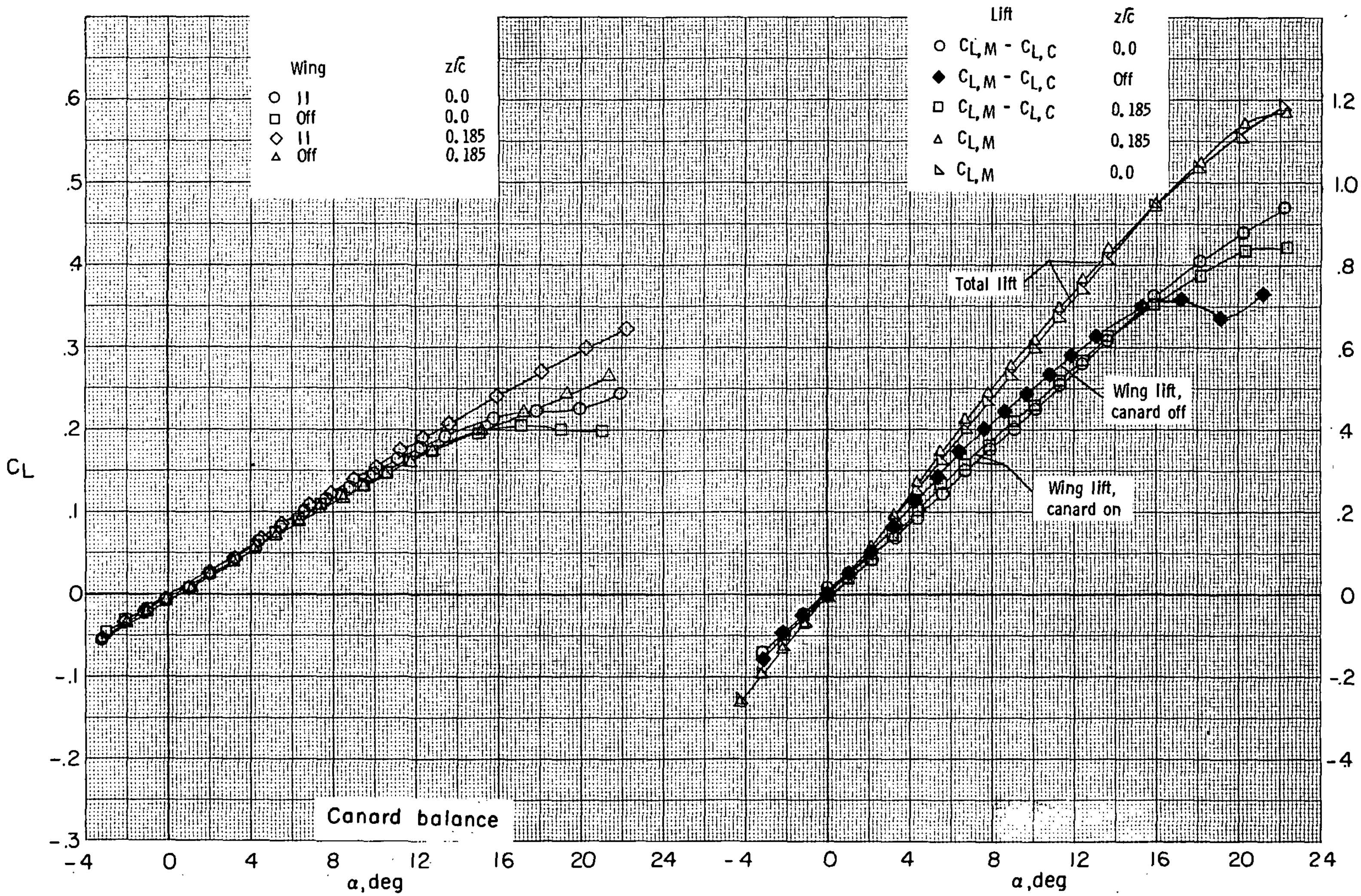

Figure 12.- Canard lift, wing lift, and total model lift as a function of angle of attack for wing II ($\Lambda = 44^{o}$) with $\delta_c = 0.0$ at $l/\bar{c} = 1.14$ and $M = 0.7$.

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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