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# TECHNICAL NOTE

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# LONGITUDINAL AERODYNAMIC CHARACTERISTICS AT LOW SUBSONIC SPEEDS OF A HIGHLY SWEPT DELTA WING UTILIZING NOSE DEFLECTION FOR CONTROL

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## SUMMARY

An investigation has been conducted in the Langley 7- by 10-foot transonic tunnel at low subsonic speeds to determine the longitudinal aerodynamic characteristics associated with deflection of the nose section of a highly swept delta wing having an aspect ratio of 1.33. In order to illustrate the effectiveness of this forward control, the longitudinal control characteristics are also presented for the wing with upper- and lower-surface split flaps located at the trailing edge.

Comparison between the longitudinal aerodynamic characteristics of the wing utilizing the nose control and those of the wing utilizing the upper-surface split flap located at the trailing edge indicated similar control effectiveness for high control deflections ($15^{\circ}$) and similar values of trimmed lift-drag ratio with increasing lift coefficient. Use of the nose control, however, indicated a lower value of trimmed angle of attack for a given value of trimmed lift coefficient than that realized from use of the upper-surface split flap. Further reductions in trimmed angle of attack for a given value of trimmed lift coefficient may be realized from deflection of the lower-surface split flap at the wing trailing edge in combination with the nose control and would be accompanied by large reductions in lift-drag ratio.

## INTRODUCTION

The National Aeronautics and Space Administration is currently conducting general research programs to determine the aerodynamic characteristics of configurations suitable for lifting reentry and glide flight from hypersonic to low subsonic speeds. Numerous planforms have been proposed and tested throughout this wide range of Mach numbers. (See, for example, refs. 1 to 7.) One of the major problem areas is the determination of the most favorable landing configuration. Since the design planforms are basically determined from the standpoint of hypersonic performance and aerodynamic heating requirements, these configurations will have excessively high landing speeds and sinking rates because of the high sweeps and low aspect ratios prevalent. For the all-wing type of configuration, the inability to take advantage of high-lift devices at the trailing edge because of the large nose-down moments produced results in high angles of attack being required to obtain reasonable lift coefficients for landing. In addition, the use of trailing-edge controls to trim the basic wing results in lift losses at a given angle of attack. If, however, the configuration were able to take advantage of forward or nose controls for trim, landing attitudes could possibly be reduced for given values of lift coefficients, and the use of high-lift devices in combination with the nose control might be feasible. The use of nose controls has also indicated considerable control effectiveness at hypersonic speeds (ref. 7).

The present investigation was initiated to determine the longitudinal aerodynamic characteristics at subsonic speeds of a highly swept delta wing utilizing nose deflection for control. In order to illustrate the effectiveness of this forward control, the longitudinal control characteristics are also presented for the wing with upper- and lower-surface split flaps located at the trailing edge. In addition, results obtained with the use of the forward control in combination with a lower-surface trailing-edge split flap are presented to show the feasibility of such a control system for landing.

## SYMBOLS

All data presented in this report are referenced to the wind-axis system, and the moment reference point has been adjusted so that the low-lift stability is approximately -0.05 mean aerodynamic chord. All coefficients are based on the planform area and mean aerodynamic chord of the wing.

| | |
|---|---|
| $A$ | aspect ratio |
| $b$ | wing span, ft |
| $C_D$ | drag coefficient, $\frac{\text{Drag}}{qS}$ |
| $C_L$ | lift coefficient, $\frac{\text{Lift}}{qS}$ |
| $C_m$ | pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS\bar{c}}$ |
| $\bar{c}$ | wing mean aerodynamic chord, ft |
| $c_r$ | wing root chord. in. |
| $L/D$ | lift-drag ratio |
| $(L/D)_{max}$ | maximum lift-drag ratio |
| $(L/D)_{trim}$ | trimmed lift-drag ratio |
| $q$ | dynamic pressure, lb/sq ft |

| | |
|---|---|
| $S$ | wing planform area, sq ft |
| $S_f$ | area of wing trailing-edge split flap (upper or lower surface), sq ft |
| $S_n$ | area of wing nose control, sq ft |
| $\alpha$ | angle of attack, deg |
| $\alpha_{trim}$ | trimmed angle of attack, deg |
| $\Delta C_D$ | incremental drag coefficient due to deflection of control |
| $\Delta C_L$ | incremental lift coefficient due to deflection of control |
| $\Delta C_m$ | incremental pitching-moment coefficient due to deflection of control |
| $\delta_{f,L}$ | deflection of lower-surface trailing-edge split flap (positive when trailing edge is downward), deg |
| $\delta_{f,u}$ | deflection of upper-surface trailing-edge split flap (positive when trailing edge is upward), deg |
| $\delta_n$ | deflection of nose control (positive when leading edge is upward), deg |

## MODEL

The delta wing was of constant thickness with rounded leading edges and blunt trailing edges. The wing, which was identical to wing 1 of reference 6, had an aspect ratio of 1.33. Details of the planforms and of the three controls employed are presented in figure 1. The upper- and lower-surface trailing-edge controls each comprised 18.8 percent of the total wing area, was 0.25 inch thick, and could be deflected 15°. The area of the forward control was 11.1 percent of the total wing area, and this control could be deflected to a maximum of 15°. The gap between the deflected nose and the remaining portion of the wing was sealed for all tests.

The fuselage employed was the same as the minimum fuselage presented in reference 6.

## TESTS AND CORRECTIONS

The present investigation was conducted in the Langley 7- by 10-foot transonic tunnel at a Mach number of 0.20, corresponding to a Reynolds number per foot of approximately $1.50 \times 10^6$.

The model was sting supported, and forces and moments were measured by use of a three-component internally mounted strain-gage balance.

Blockage corrections determined by the method of reference 8 have been applied to the dynamic pressure and drag coefficient. No base-pressure corrections have been applied to the data.

## DISCUSSION

Figure 2 presents the effects of nose control on the longitudinal aerodynamic characteristics of the basic wing configuration. The use of this control results in slight increases in lift coefficient in the moderate angle-of-attack range ($\alpha = 0^\circ$ to $10^\circ$) and provides trim conditions to the maximum lift obtained. Reductions in longitudinal stability level (at low lift coefficients) from approximately -0.05 to approximately 0 at $\delta_n = 15^\circ$ are also noted. Use of the upper-surface trailing-edge split flap to provide trim (fig. 3) results in rather large reductions in lift coefficients; however, higher control effectiveness at low control deflection is indicated for this control than for the forward control. Reductions in longitudinal stability level are also noted for the higher control deflections $\delta_{f,u} = 10^\circ$ and $15^\circ$.

In figure 4 are shown the effects of deflection of the lower-surface trailing-edge split flap on the longitudinal aerodynamic characteristics of the wing. Figures 5 to 8 present the longitudinal characteristics associated with various deflections of this flap in combination with various nose-control deflections. Increases in lift are noted up to an angle of attack of approximately $20^\circ$ as the lower-surface split-flap deflection is increased (fig. 4). Deflection of the nose control to $15^\circ$, however, is required to trim the configuration with $10^\circ$ or less deflection of the wing lower-surface trailing-edge split flap (figs. 5 to 8).

The effects of control deflection on the variation of lift-drag ratio with lift coefficient for the three controls employed are presented in figures 9 to 11. Figure 12 presents the effects of deflection of the lower-surface split flap on this variation for a nose deflection of $15^\circ$. The resultant pitching-moment variation with lift coefficient for each configuration is also presented in figures 9 to 12 to indicate trimmed lift coefficients and the associated trimmed lift-drag ratios. Rather large reductions in lift-drag ratio are noted with increasing deflection of either the nose control or the upper-surface trailing-edge split flap (figs. 9 and 10, respectively). An interesting point to note from figure 12 for the lower-surface trailing-edge split flap deflected in combination with the nose control is that low deflection of this flap $\left(\delta_{f,L} = 5^\circ\right)$ results in an increase in the value of $(L/D)_{max}$ over that obtained for the configuration having the flap at zero deflection.

Comparison of values of $(L/D)_{trim}$ and $\alpha_{trim}$ for the nose control with those for the upper-surface trailing-edge split flap indicates similar values of $(L/D)_{trim}$; however, the nose control provides a given trimmed lift coefficient at a lower angle of attack than does the upper-surface trailing-edge split flap. (See fig. 13.) This reduction in $\alpha_{trim}$ is significant from the standpoint of reducing landing and take-off attitudes, determined by the required lift coefficients for take-off or landing.

Even lower values of trimmed angle of attack (or, at a given angle of attack, higher values of trimmed lift coefficient) may also be realized from use of the forward control in combination with the lower-surface trailing-edge split flaps when the configuration attitude is restricted by ground-clearance considerations rather than by lift-drag-ratio restrictions. Large reductions in lift-drag ratio were noted from deflection of the lower-surface split flaps in combination with the maximum nose-control deflection required to trim. (See figs. 11 and 12.)

Effects on $\Delta C_L$, $\Delta C_D$, and $\Delta C_m$ due to a $15^{\circ}$ deflection of the three controls are presented in figure 14. Large reductions in lift coefficients are produced by deflection of the upper-surface trailing-edge split flap throughout the angle-of-attack range; whereas, slight increases in lift coefficients are produced by deflection of the nose control from $\alpha = 0^{\circ}$ to approximately $15^{\circ}$. Both of these controls, however, are seen to produce equivalent increments in positive pitching moment. This relationship is the reason for the forward control having a lower value of $\alpha_{trim}$ at a given trimmed lift coefficient. The effects of control deflection on incremental drag coefficient indicate considerably larger increases produced by the nose control; however, as previously noted in figure 13, the trimmed lift-drag ratios are essentially the same for either of these controls. From analysis of the effects on lift and drag due to deflection of the forward control, the large positive pitching moments produced by deflections of this control appear to arise from a combination of the positive lift carried by this control ahead of the moment reference point, the drag acting above the moment reference, and an increase in the induced camber.

## CONCLUDING REMARKS

An investigation has been conducted in the Langley 7- by 10-foot transonic tunnel at low subsonic speeds to determine the longitudinal aerodynamic characteristics associated with deflection of the nose section of a highly swept delta wing having an aspect ratio of 1.33. In order to illustrate the effectiveness of this forward control, the longitudinal control characteristics are also presented for the wing with upper- and lower-surface split flaps located at the trailing edge.

Comparison between the longitudinal aerodynamic characteristics of the wing utilizing the nose control and those of the wing utilizing the upper-surface split flap located at the trailing edge indicated similar control effectiveness for high control deflections ($15^{\circ}$) and similar values of trimmed lift-drag ratio with increasing lift coefficient. Use of the nose control, however, indicated a lower value of trimmed angle of attack for a given value of trimmed lift coefficient than that realized from use of the upper-surface split flap. Further reductions in trimmed angle of attack for a given value of trimmed lift coefficient may be realized from deflection of the lower-surface split flap at the wing trailing edge in combination with the nose control and would be accompanied by large reductions in lift-drag ratio.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., July 19, 1962.

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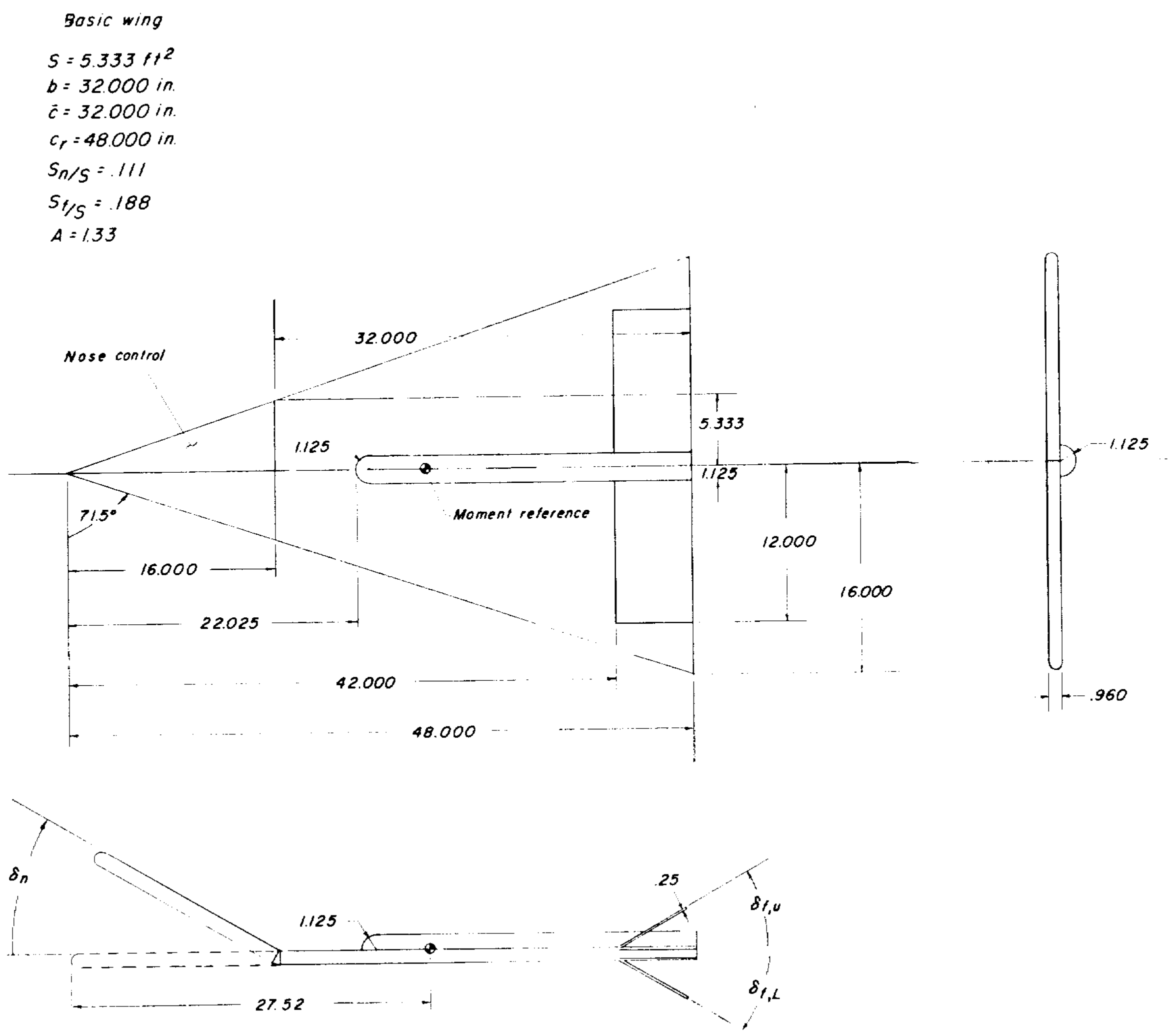



Figure 1.- Geometric characteristics of configuration investigated. Arrows indicate positive sense of control deflections. (All dimensions are in inches unless otherwise noted.)

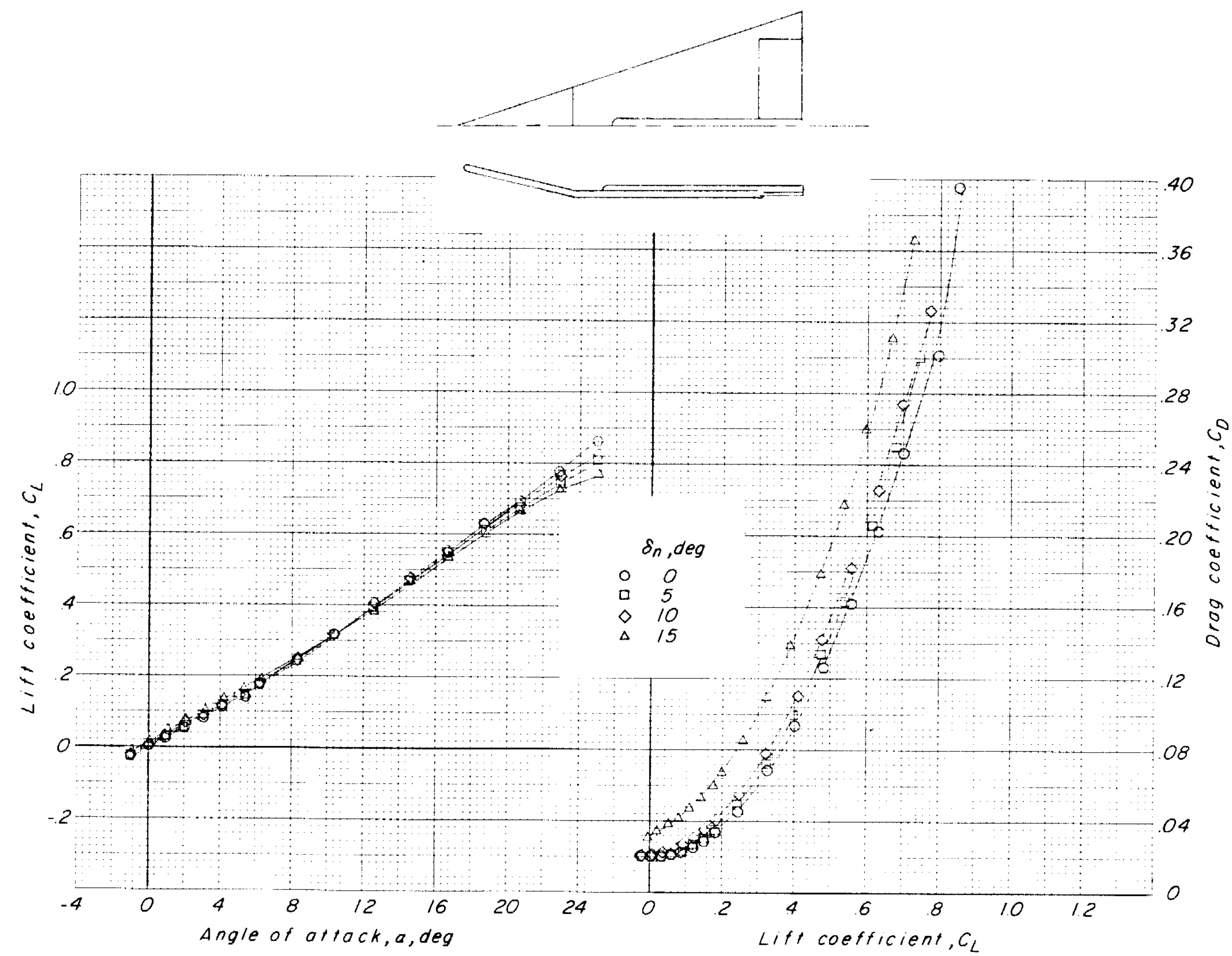



Figure 2.- Effects of deflection of the nose control on longitudinal aerodynamic characteristics of delta wing. $\delta_{f,L} = 0^{\circ}$; $\delta_{f,u} = 0^{\circ}$.

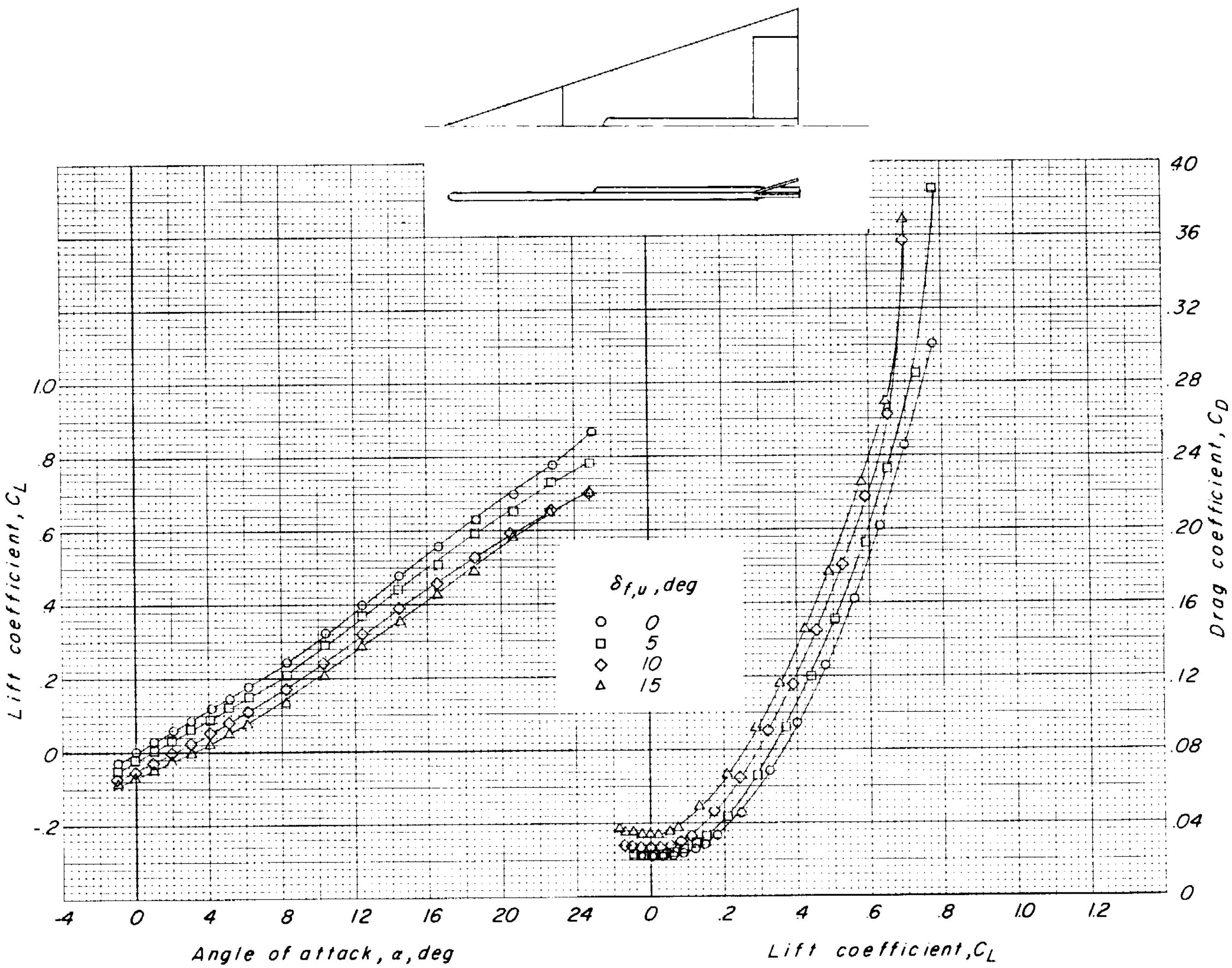
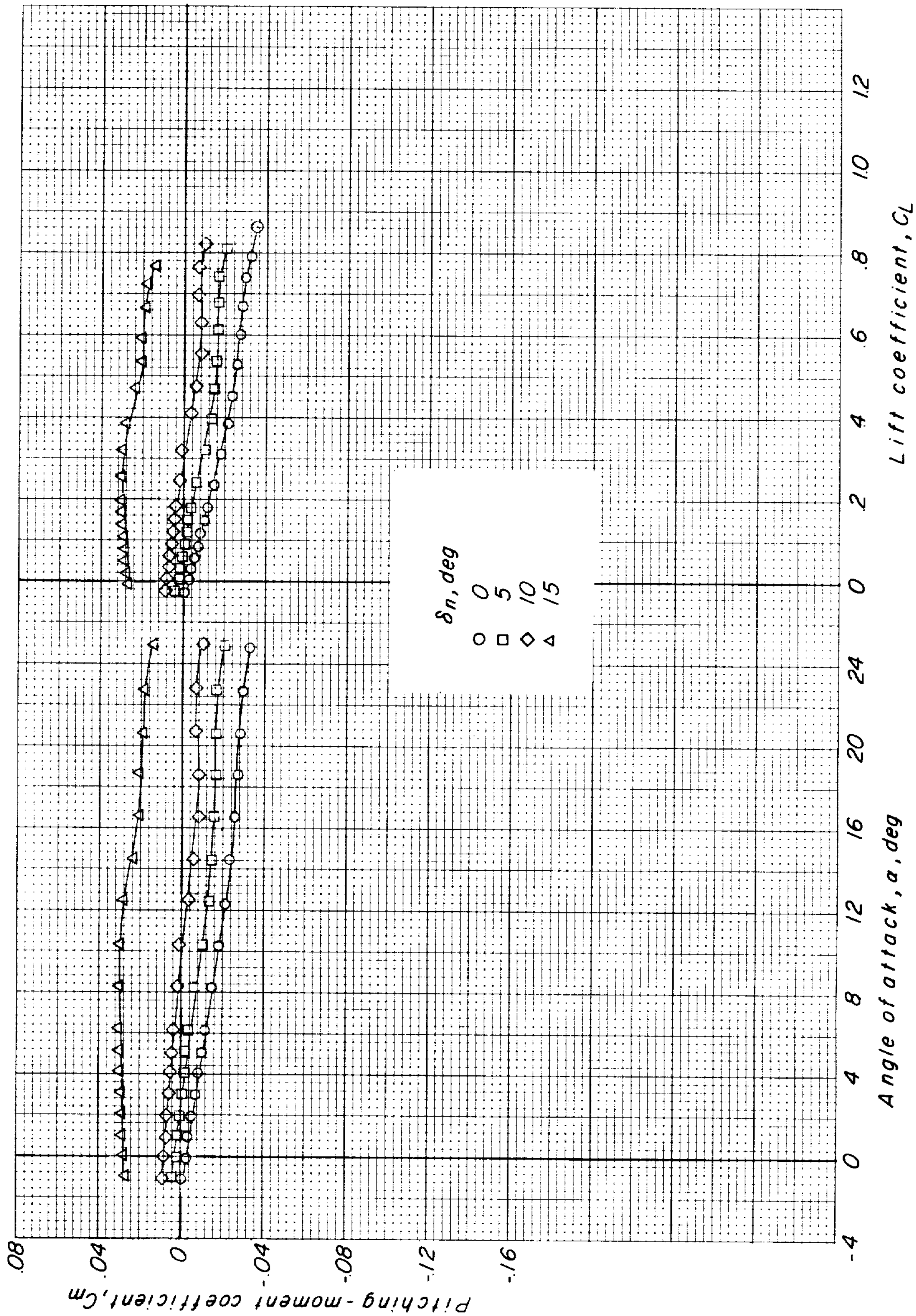



Figure 3.- Effects of deflection of the upper-surface trailing-edge split flap on longitudinal aerodynamic characteristics of delta wing. $\delta_{f,L} = 0^{\circ}$; $\delta_n = 0^{\circ}$.

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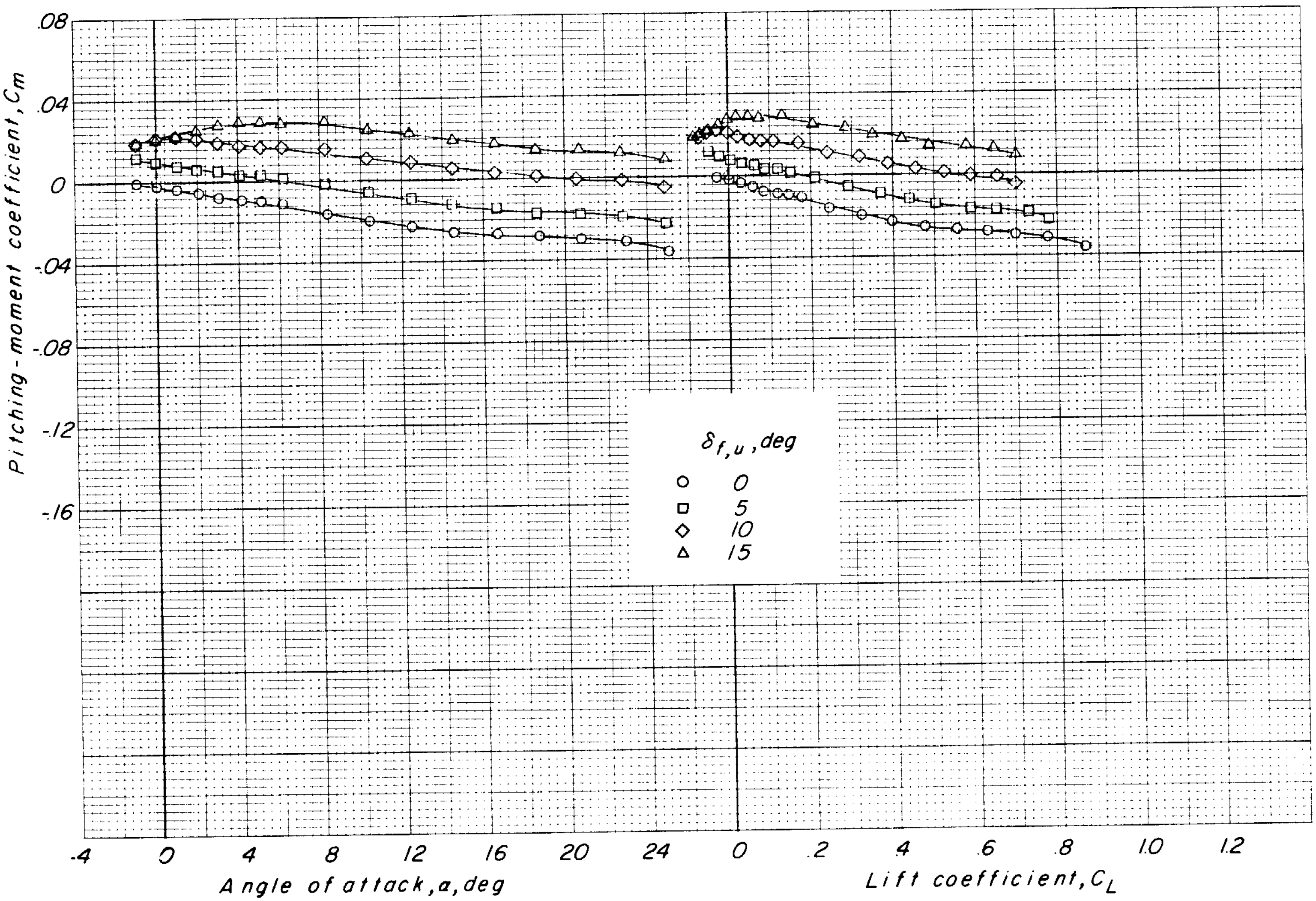


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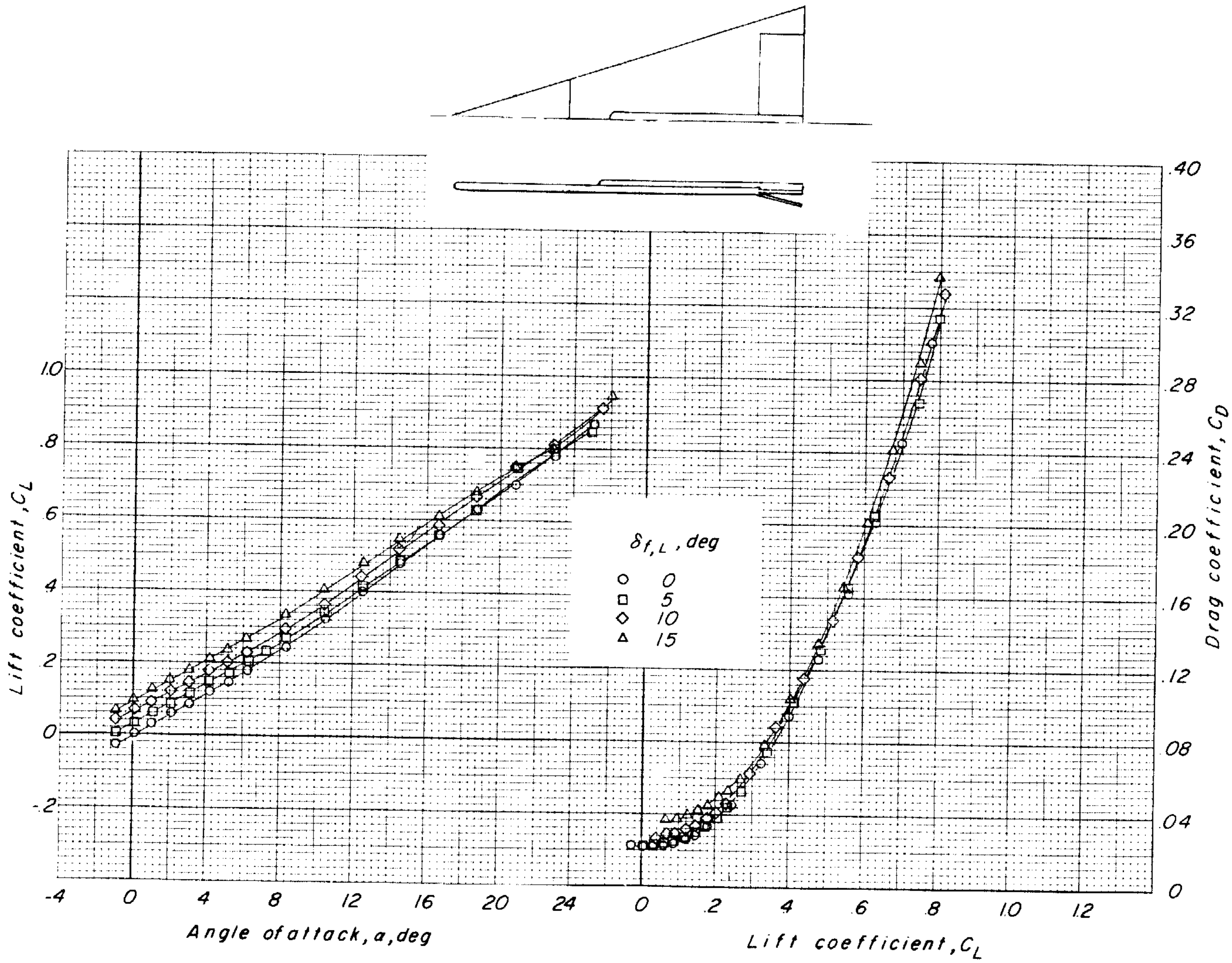



Figure 4.- Effects of deflection of the lower-surface trailing-edge split flap on longitudinal aerodynamic characteristics of delta wing. $\delta_{f,u} = 0^{\circ}$; $\delta_n = 0^{\circ}$.

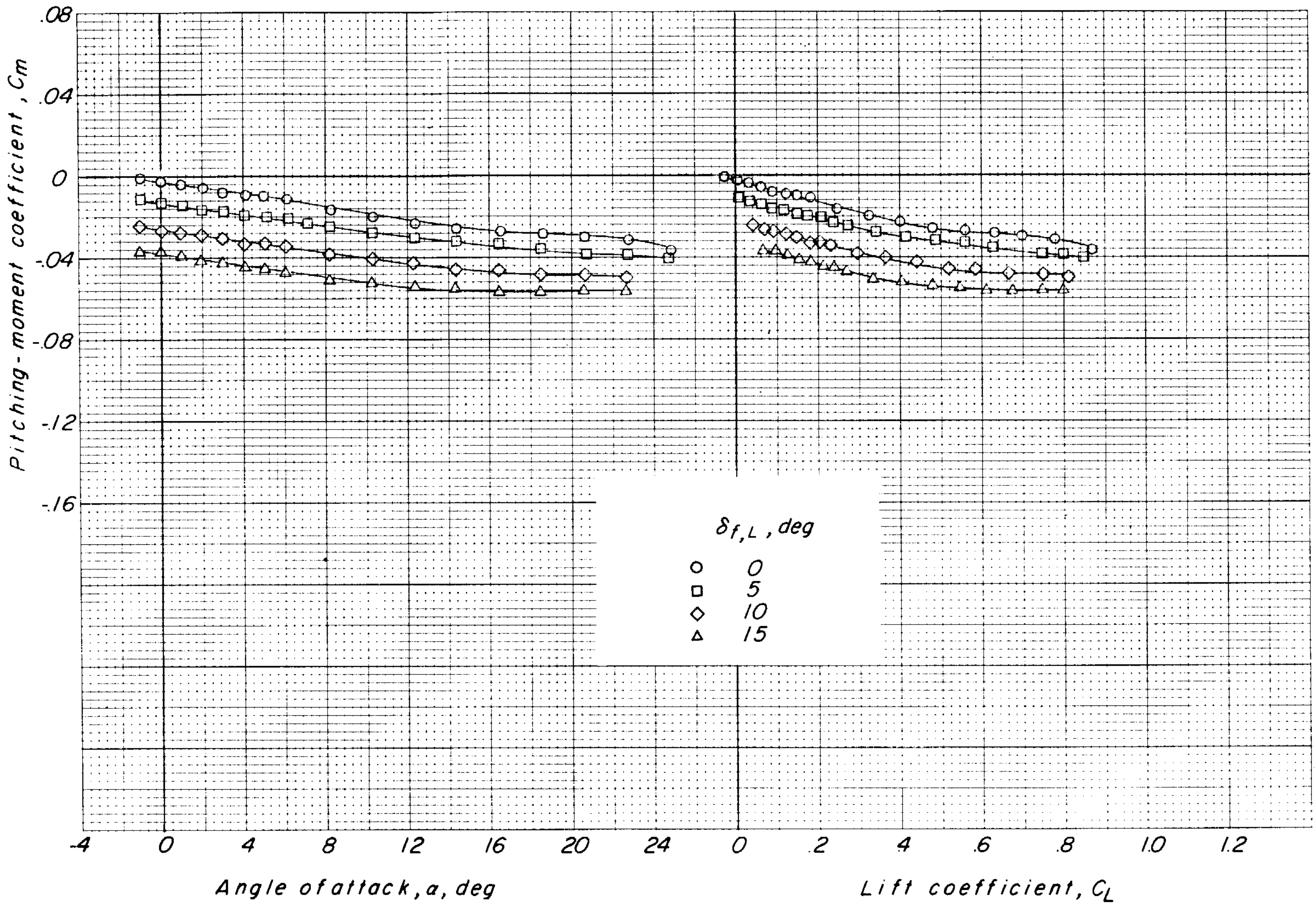



Figure 4.- Concluded.

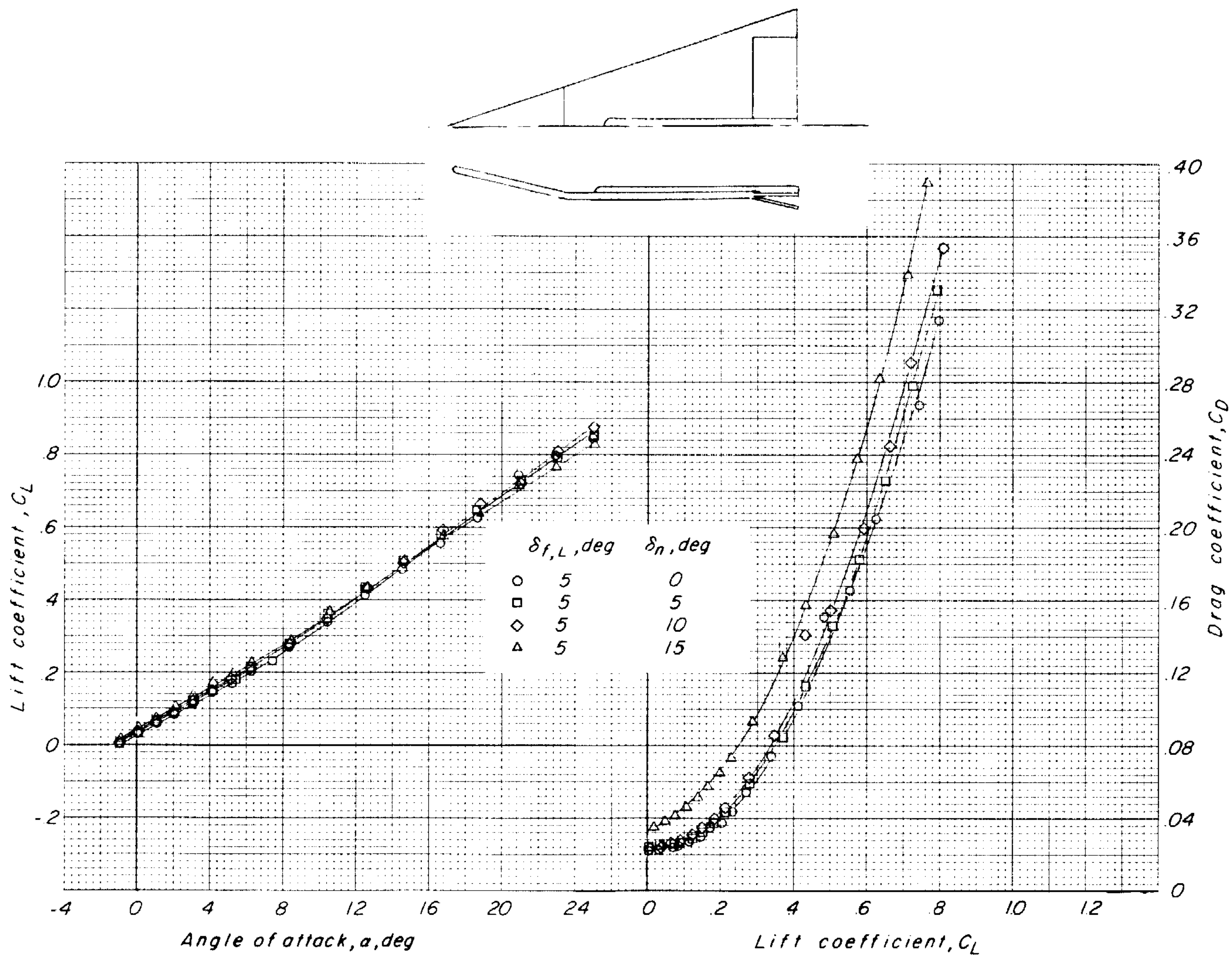
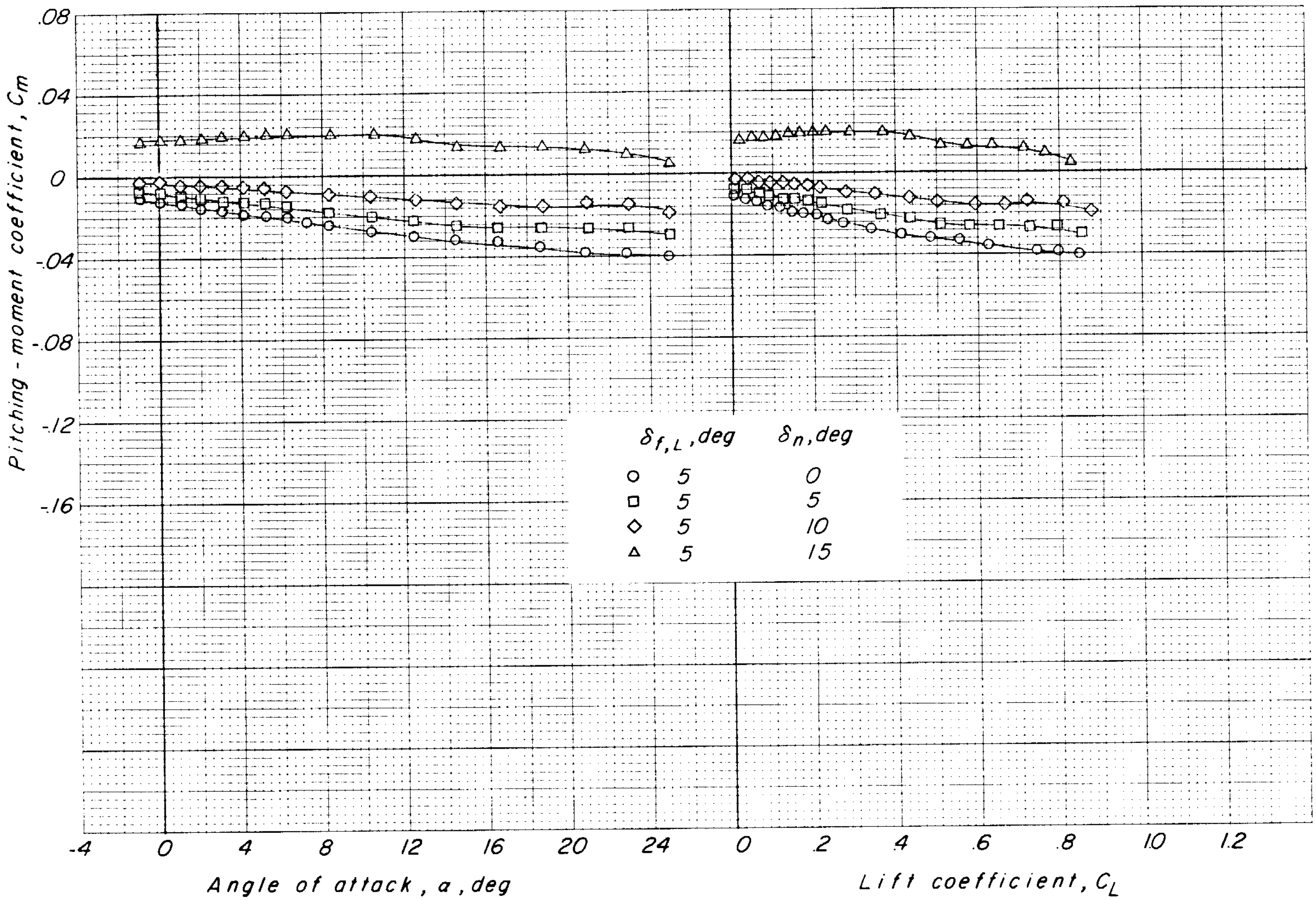



Figure 5.- Effect of nose-control deflection on longitudinal aerodynamic characteristics of delta wing with a lower-surface trailing-edge split flap set at $5^{\circ}$. $\delta_{f,u} = 0^{\circ}$.

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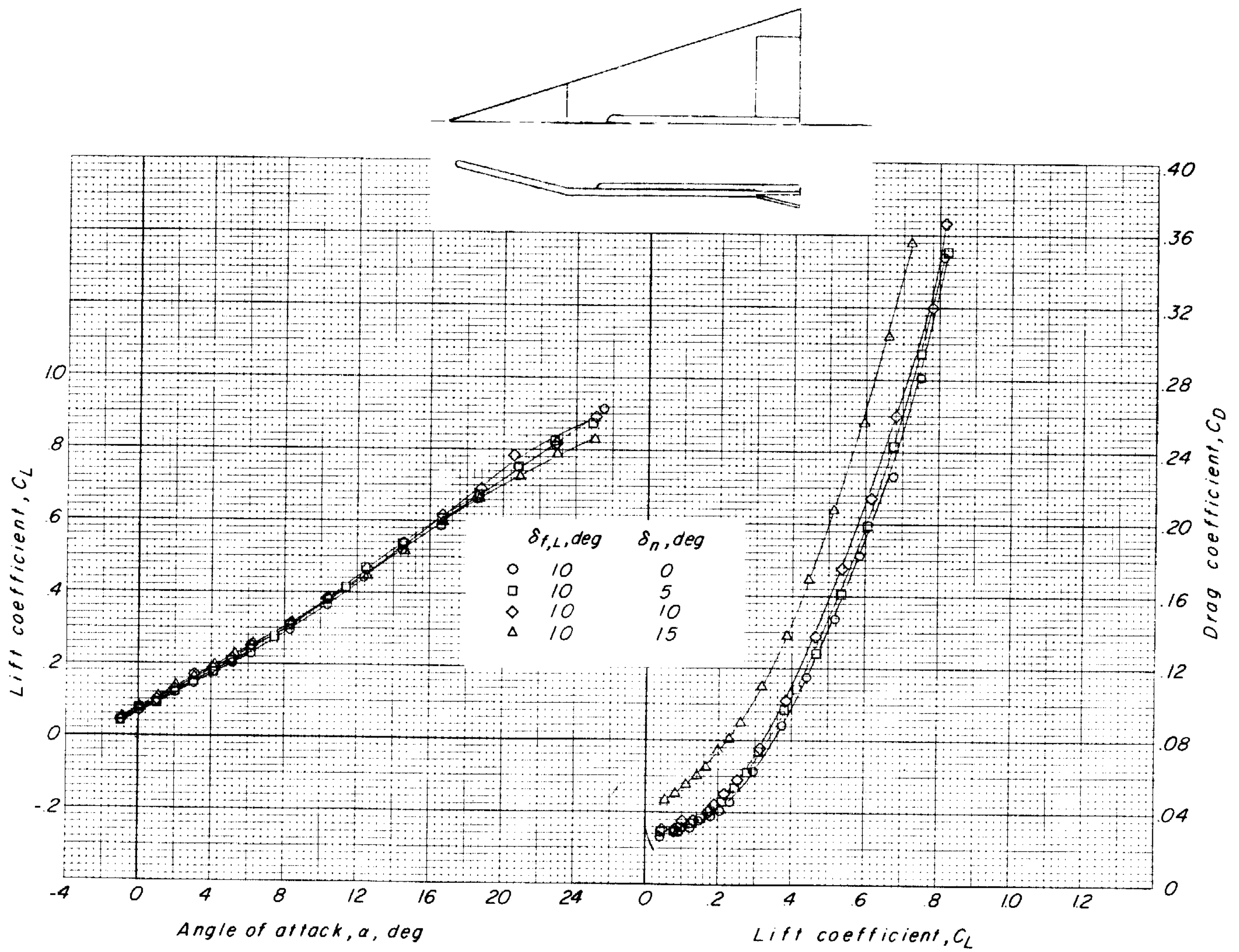
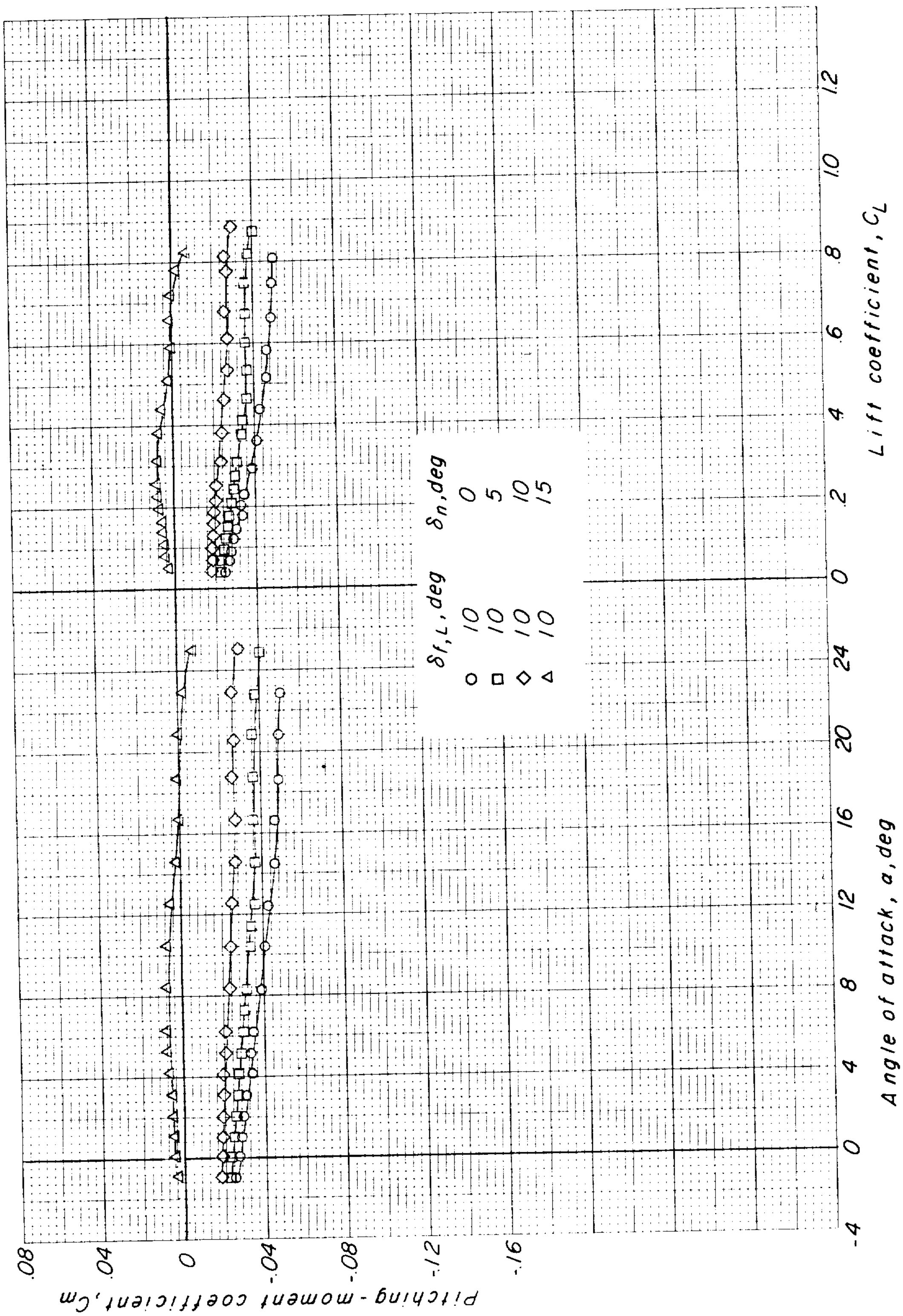



Figure 6.- Effect of nose-control deflection on longitudinal aerodynamic characteristics of delta wing with a lower-surface trailing-edge split flap set at 10°. $\delta_{f,u} = 0°$.

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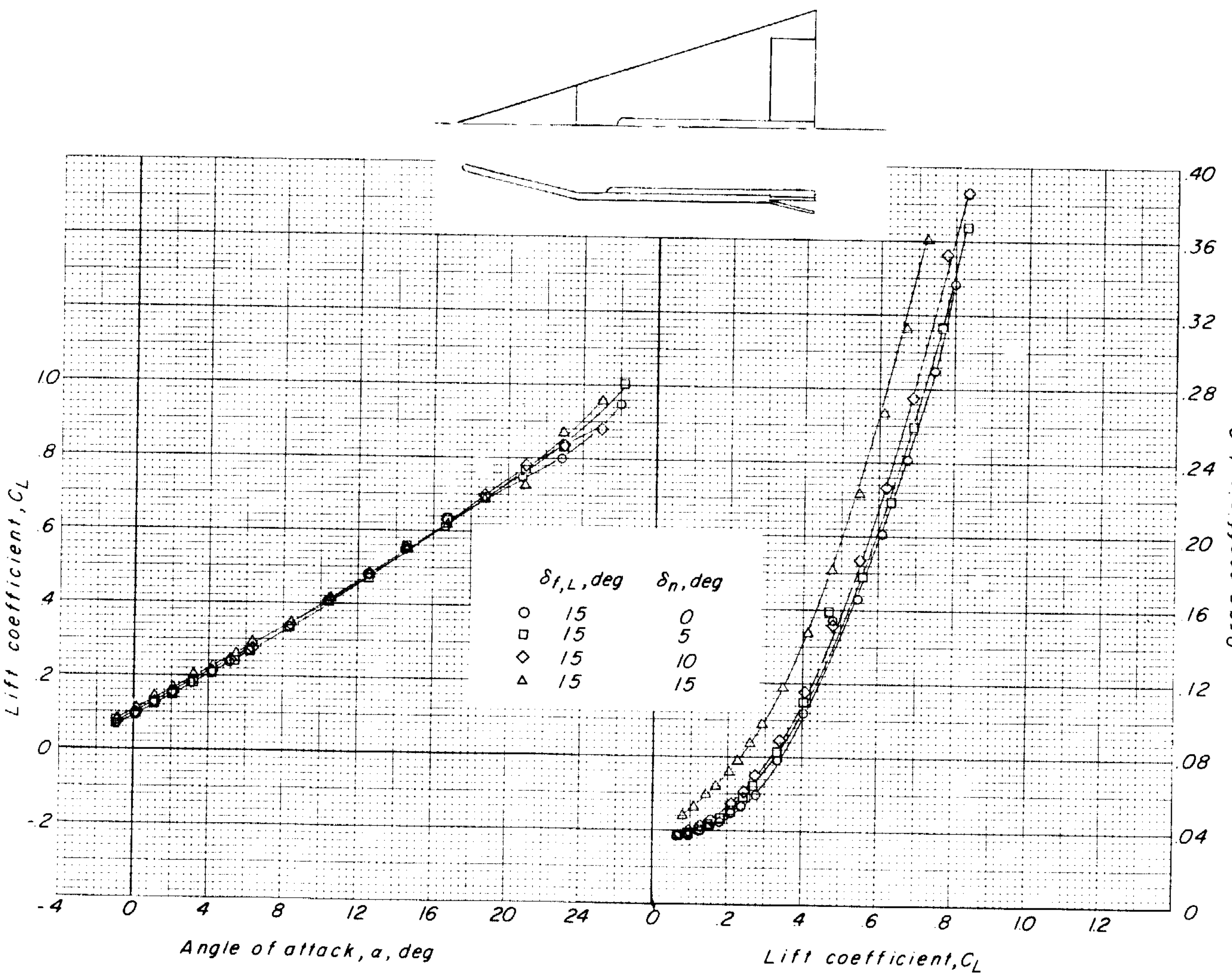
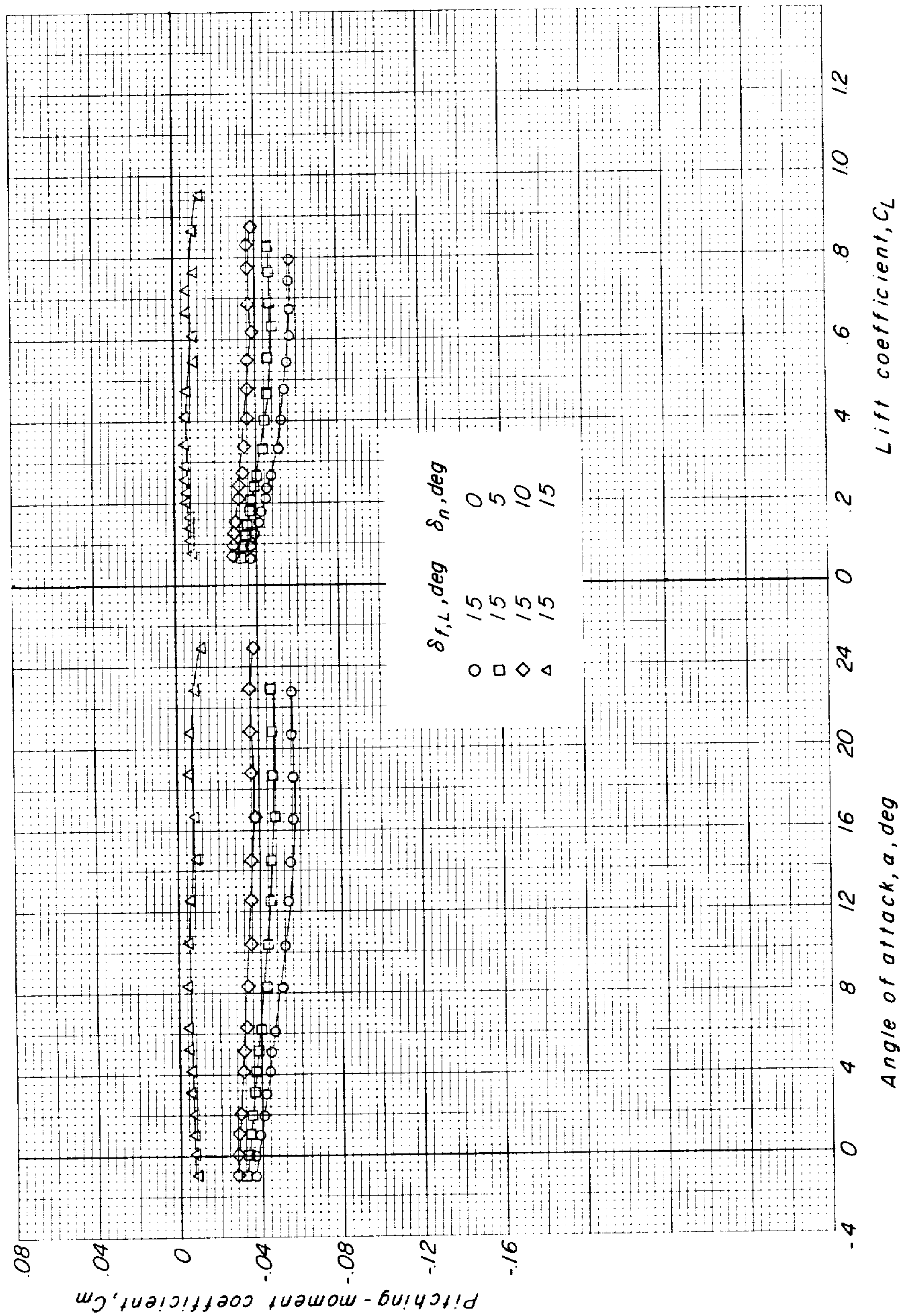



Figure 7.- Effect of nose-control deflection on longitudinal aerodynamic characteristics of delta wing with a lower-surface trailing-edge split flap set at 15°. $\delta_{f,u} = 0°$.

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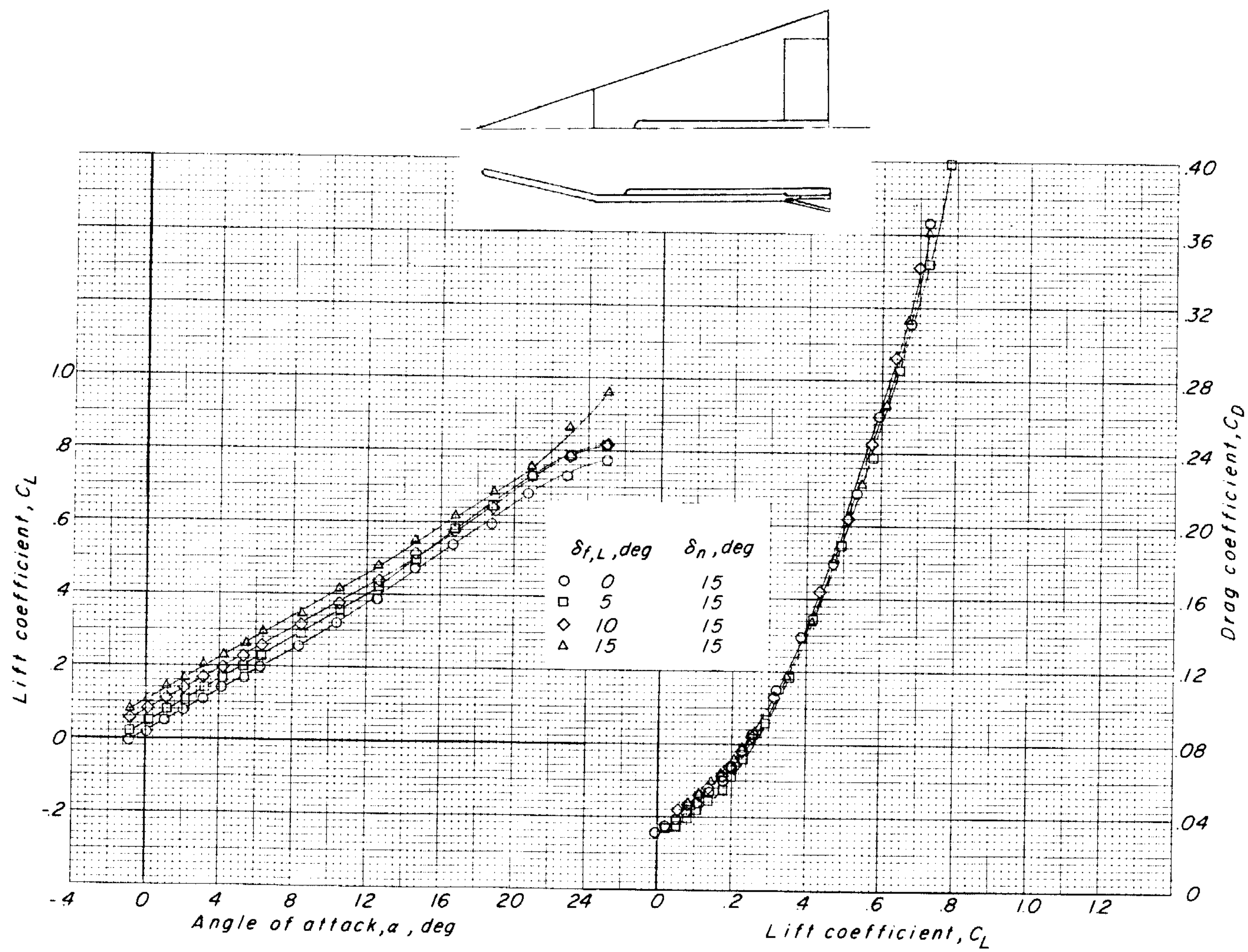
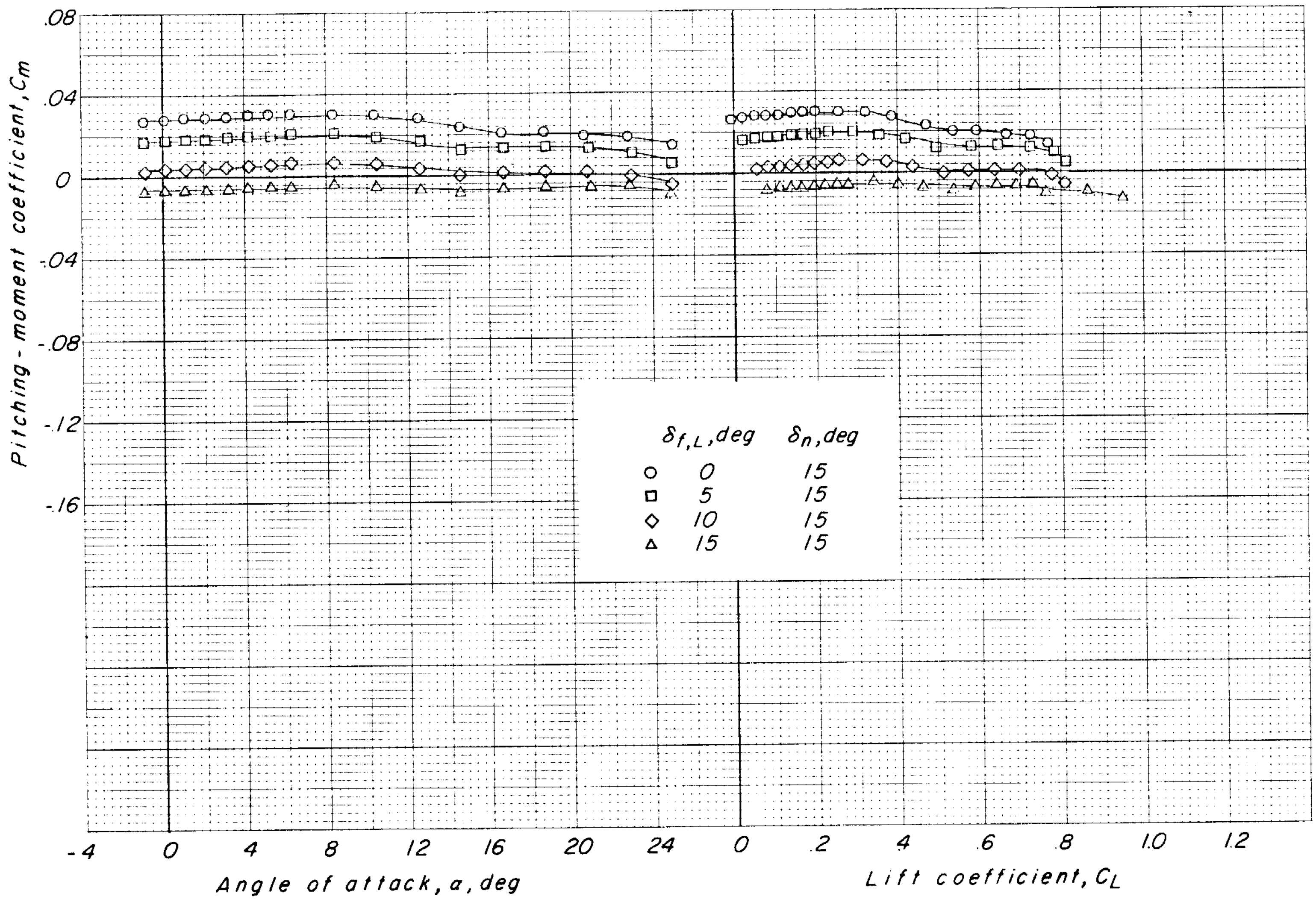



Figure 8.- Effect of deflection of the lower-surface trailing-edge split flap on longitudinal aerodynamic characteristics of delta wing with nose control set at 15°. $\delta_{f,u} = 0^{\circ}$.

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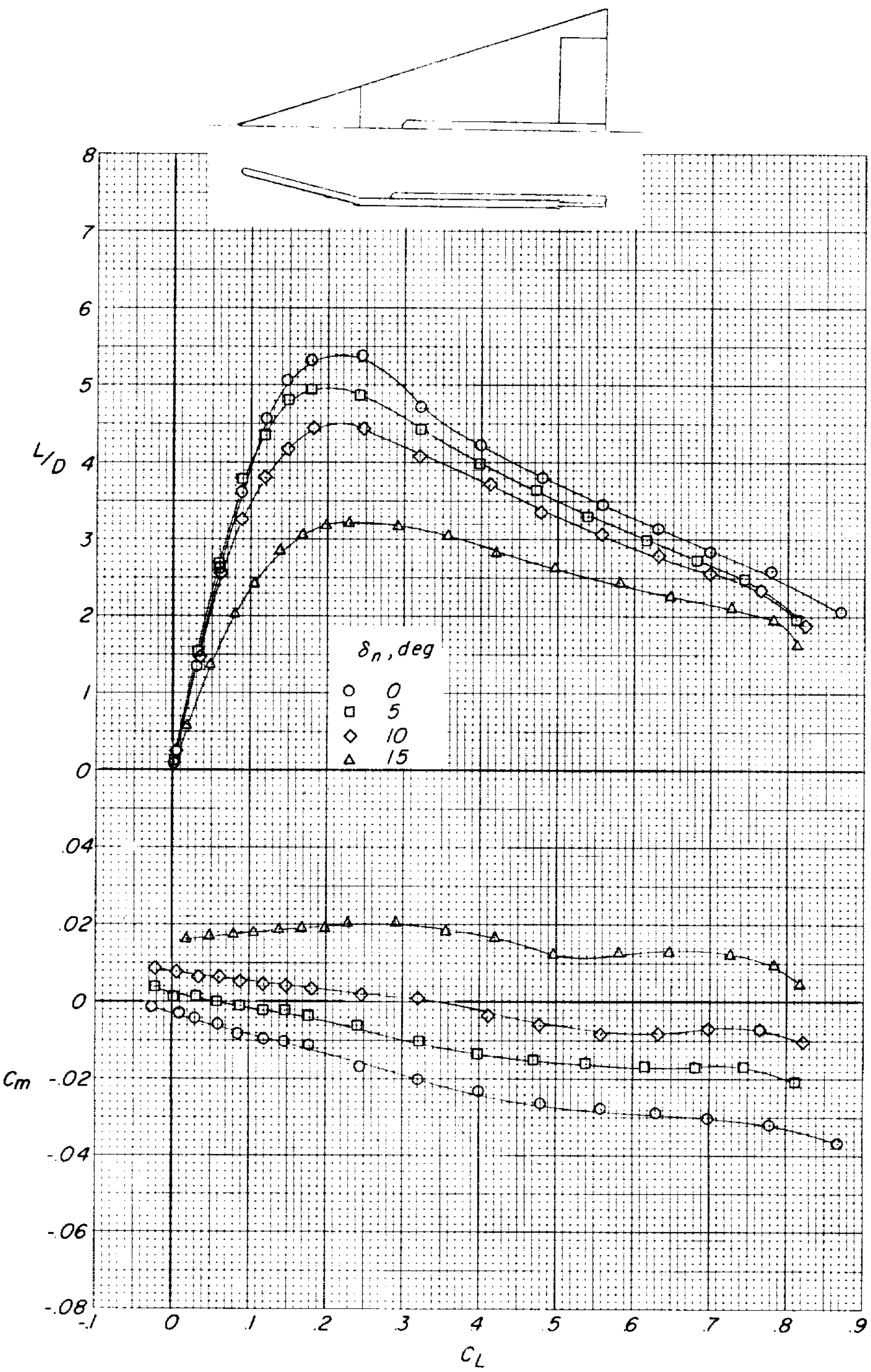


Figure 9.- Effects of deflection of the nose control on lift-drag ratio and trimmed lift characteristics of delta wing. $\delta_{f,L} = 0^{\circ}$; $\delta_{f,u} = 0^{\circ}$.

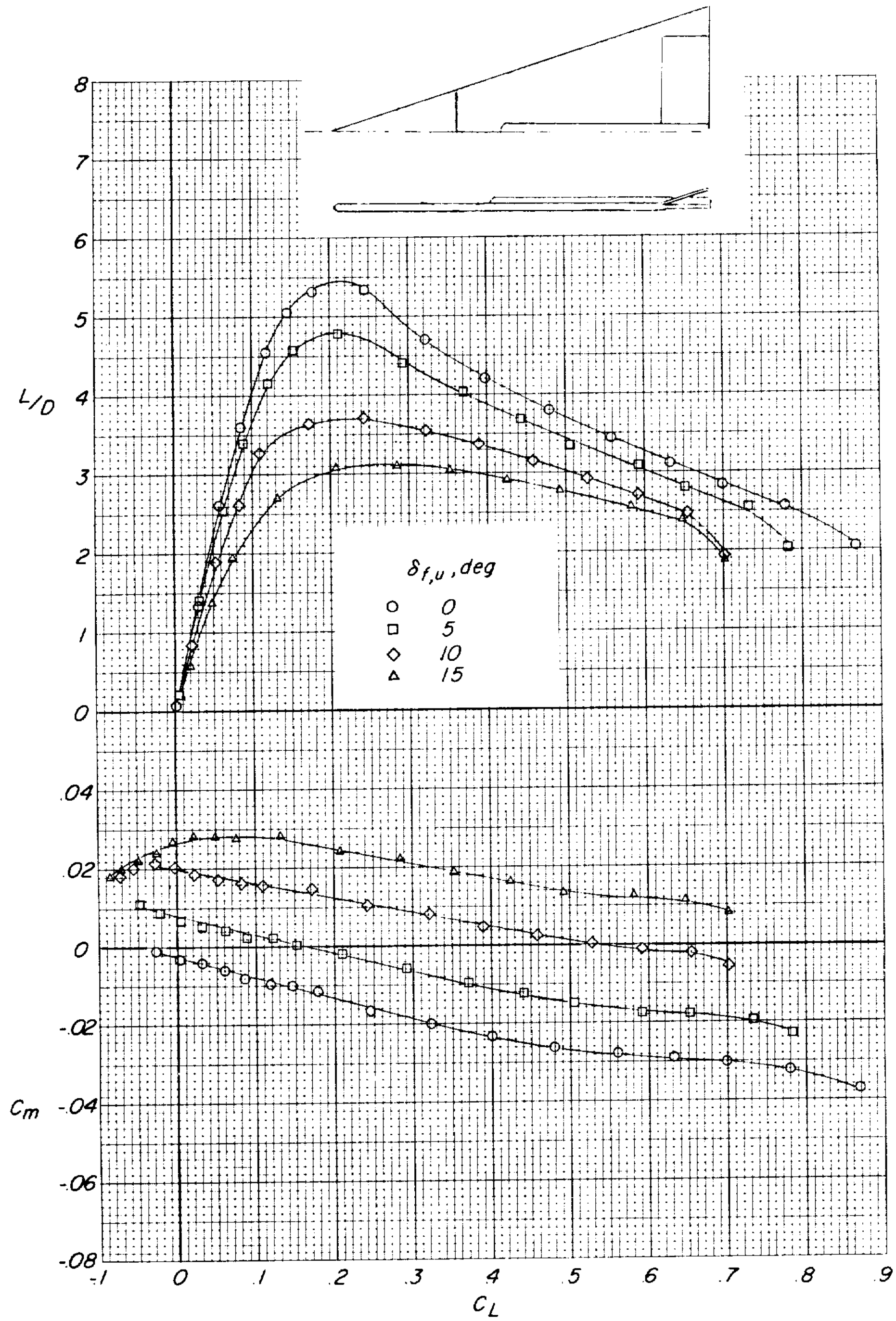


Figure 10.- Effects of deflection of the upper-surface trailing-edge split flap on the lift-drag ratio and trimmed lift characteristics of delta wing. $\delta_{f,L} = 0^{\circ}$; $\delta_n = 0^{\circ}$.

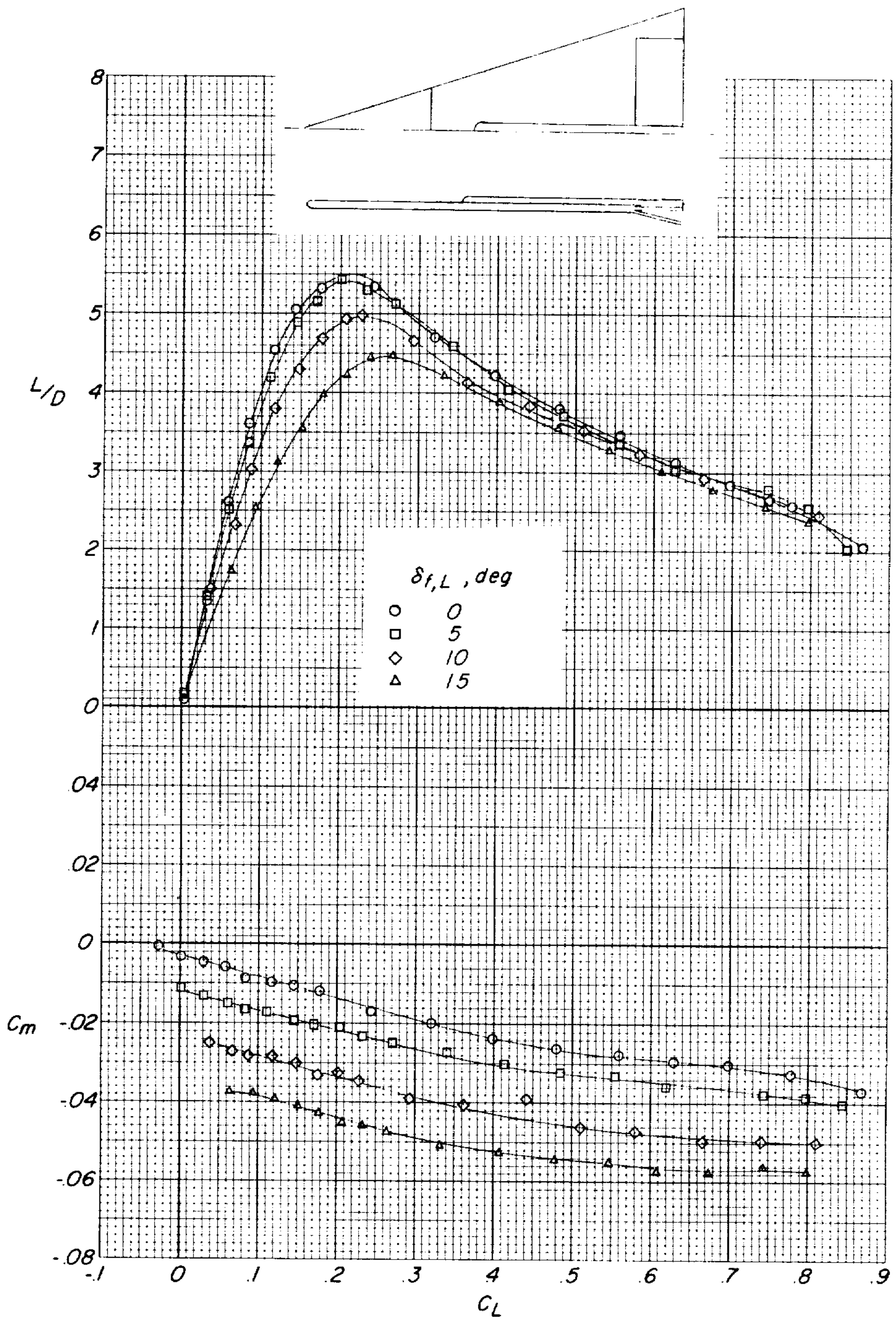


Figure 11.- Effects of deflection of the lower-surface trailing-edge split flap on the lift-drag ratio and trimmed lift characteristics of the delta wing. $\delta_{f,u} = 0^{\circ}$; $\delta_n = 0^{\circ}$.

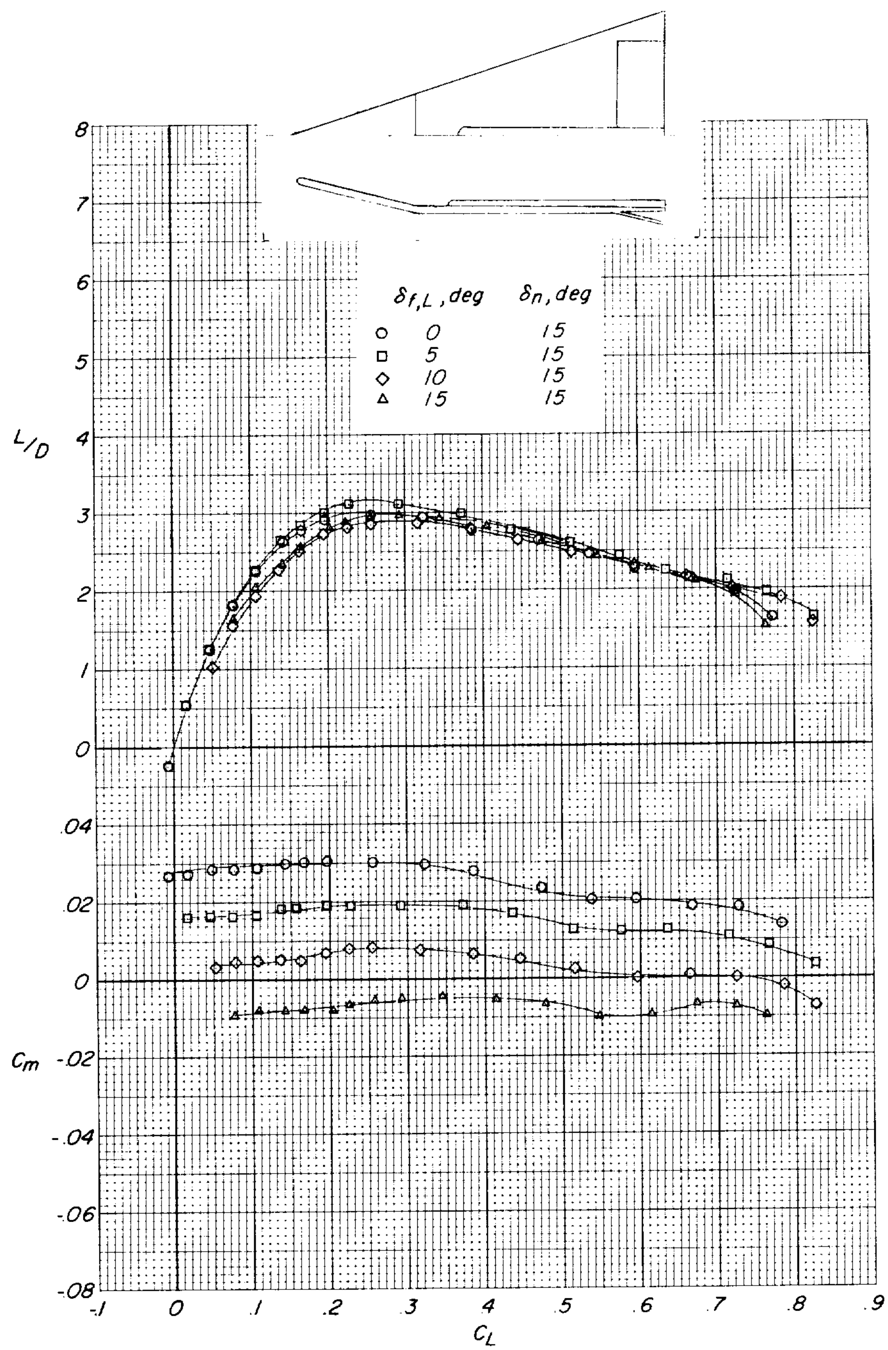


Figure 12.- Effect of deflection of the lower-surface trailing-edge split flap on the lift-drag ratio and trimmed lift characteristics of delta wing with a nose-control deflection of $15^{\circ}$. $\delta_{f,u} = 0^{\circ}$.

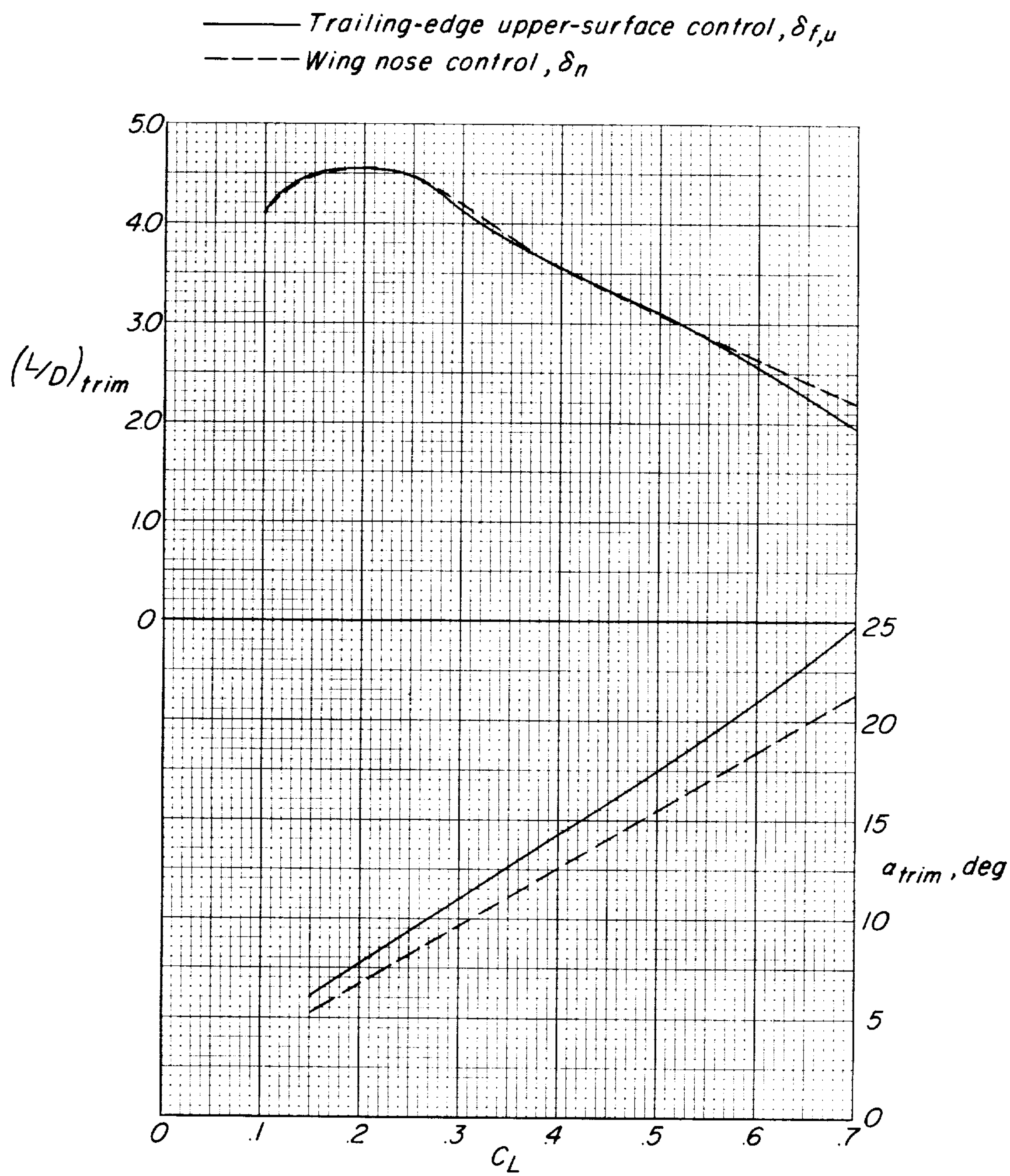


Figure 13.- A comparison of trimmed angles of attack and lift-drag ratios, at various lift coefficients, for the wing with upper-surface trailing-edge split flap and the wing with nose control.

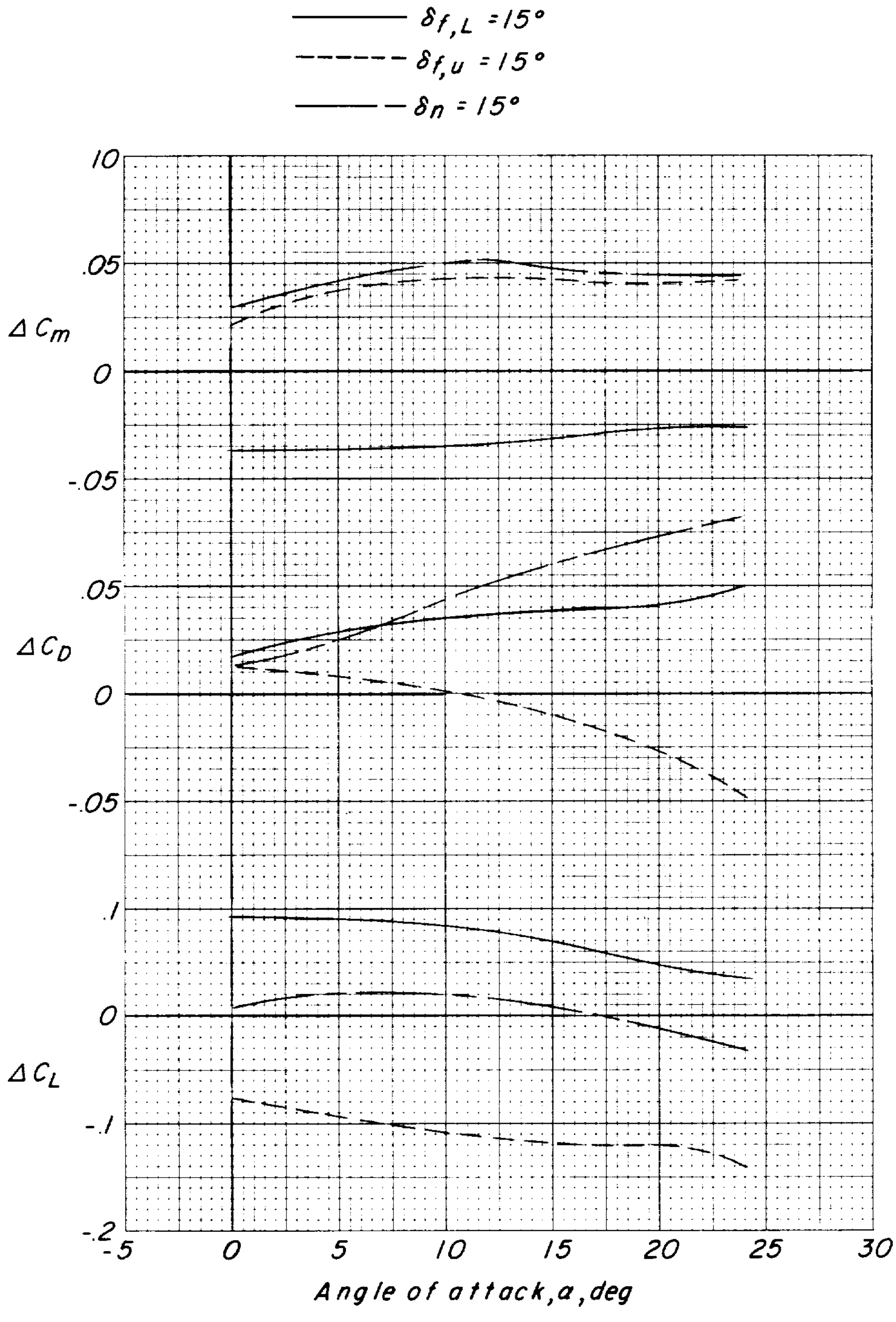


Figure 14.- A comparison of effects on incremental lift, drag, and pitching-moment coefficients due to control deflection for the three types of controls used.