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WIND-TUNNEL STUDY TO EXPLORE THE USE OF SLOT SPOILERS TO MODULATE THE FLAP-INDUCED LIFT OF A WING

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SUMMARY

This report presents the results of a preliminary study to explore a proposed new concept for achieving direct lift control on an airplane. The concept employs variable-width slot-type spoilers to modulate the lift increment produced by a deflected flap. The study utilized a NACA 2509 constant-chord airfoil model wing modified to provide various size slots on both the wing and flap sections. Each configuration was tested through an angle-of-attack range of -2° to 16° in a low-speed tunnel with a 12-foot octagonal test section at the Langley Research Center. The tests were conducted at a Reynolds number of approximately 410 000. The results indicate that the use of a variable-width slot is effective in controlling the lift increment obtained from flap deflection and that there is relatively little change in drag coefficient associated with slot-width changes.

INTRODUCTION

Direct lift control is being considered for use on general aviation aircraft as a possible means to improve the piloting task during approach and landing. One of the potential problems in implementing a direct-lift-control system on a light airplane is the type of drive system to be employed. To date all the flight-tested direct-lift-control systems, employing flaps or spoilers, have been driven by some form of electro-hydraulic system which is not commonly found on light airplanes. A direct-lift-control system suitable for general aviation aircraft should be lightweight, simple, and inexpensive.

Such a system has been conceived which consists of a variable width slot across the leading edge of a flap. The slot would vent a portion of the higher pressure air at the lower surface into the lower pressure air passing over the upper surfaces and, in effect, act as a spoiler. For direct lift control, a portion of the flap-induced lift would be spoiled and the lift control would be effected by symmetrically increasing or decreasing the slot widths as required. The present concept could also be used for lateral control by varying slot widths differentially. The use of spoiler devices for lateral control is not new and has been discussed in reference 1.

In order to determine the feasibility of the concept, a wing-flap combination was used for exploratory tests in a low-speed tunnel with a 12-foot octagonal test section at the Langley Research Center. For comparison, tests were also made with small fence-type spoilers. This report presents the results of the investigation.

SYMBOLS

C_L	lift coefficient
C_D	drag coefficient
C_m	pitching-moment coefficient (referenced to $0.250c_w$)
α	angle of attack, deg
b	wing span, inches (meters)
c_w	wing chord, inches (meters)
c_f	flap chord, inches (meters)
l_w	distance from wing leading edge to spoiler position on wing, inches (meters)
l_f	distance from flap trailing edge to spoiler position on flap, inches (meters)
x	width of slot spoiler, inches (meters)
y	height of fence spoiler, inches (meters)

Subscript:

max	maximum

WING MODEL AND TEST ARRANGEMENT

The wing model used for the study had a NACA 2509 airfoil section with a 72-inch (1.82-m) span and 12.87-inch (0.33-m) constant chord. (See fig. 1.) The wing had two flap sections, each of which was 32.75 inches (0.83 m) long and $3\frac{3}{4}$ inches (0.10 m) wide. A three-component force balance was installed at the 25-percent chord line in the center of the wing and mounted as shown in the photograph of figure 2. The various configurations of slots and fence-type spoilers tested are shown in figure 3. In each configuration, the slot and fence spoilers covered the same spanwise position along the flap sections as shown in figure 1.

TEST CONDITIONS

The tunnel speed for all tests was set to provide a dynamic pressure of 4.34 pounds per square foot (207.4 N/m^2). The corresponding Reynolds number was approximately 410 000. Structural limitations of the model prevented testing at higher pressures. Each model configuration was tested through an angle-of-attack range of -2° to 16°. The basic wing was tested with 0° and 30° flap deflection; configurations with slot- and fence-type spoilers were tested with the flaps set at 30° only. The flap-wing juncture was sealed for all tests.

RESULTS AND DISCUSSION

Lift, drag, and pitching-moment coefficients for the configurations investigated are presented in figures 4 to 9. No corrections were applied to the data since only relative effectiveness of the spoilers was of interest in this exploratory study.

Slot Located on Flap

Figure 4 presents data for the flap slot configurations C_1, C_2, and C_3 compared with the basic wing configurations A and B. These data indicate that all the slot widths are effective in reducing the values of lift coefficient below those of the basic flap, configuration B. Values for the $0.039c_w$ slot (configuration C_1) show a reduction of about 60 percent of the C_L increment between configurations A and B throughout the angle-of-attack range.

At a given α, there is little change in C_D between the unslotted configuration (configuration B) and the fully opened slot (configuration C_1). For angles of attack below 10°, the decrease in C_D for configuration C_1 is about 10 to 20 percent of the increment due to flap deflection. The decrease in pitching moment of C_1 is about 50 percent of the pitching-moment increment between configurations A and B.

Figure 5 presents comparisons between two locations of the $0.010c_w$ slot on the flap configurations C_3 and C_4 and the tapered slot configuration D. The results indicate that slot effectiveness is dependent on both shape and position.

Slot Located on Wing

The data of figure 6 show comparisons between the wing slot configurations E_1, E_2, and E_3 and the basic wing configurations A and B. It should be noted that the C_L curve for configuration B in figure 6 is slightly lower at $C_{L,max}$ than the corresponding curve of figures 4 and 7. This effect probably was a result of the additional bracing that was added to support the flap with the wing slot open. At an angle of attack of 0°, the $0.039c_w$ wing slot (configuration E_1) shows a reduction in C_L of about 50 percent of the increment due to flap deflection. Near $C_{L,max}$, however, the $0.039c_w$ slot has effectively reduced all the lift increment of the flap. Thus, the slot located on the wing decreases both the magnitude of lift and slope of the lift curve.

Comparison of Slot Spoilers With Fence Spoilers

In order to provide a basis for comparing the effectiveness of the slot spoiler concept with the more conventional fence-type spoilers, configurations F, G, and H were tested.

Figure 7 shows the results of configuration F compared with the basic wing configurations A and B. Configurations F_1 and F_2 consisted of $0.019c_w$ and $0.046c_w$ high fences installed on the flap near the leading edge. (See fig. 2.) It is apparent that neither spoiler configuration F_1 or F_2 was effective in reducing lift and, in fact, tended to increase the lift above that of the basic 30° flap. This slight increase in lift is possibly brought about by turbulence induced by the spoiler in the boundary layer giving slightly better flow adhesion over the flap. Tufts located along the flap indicated that the flow was not separated by the fence spoilers.

Comparison of the results for the $0.019c_w$ fence spoiler located on the wing at the 68-percent chord (configuration G) and the slotted flap configurations C_1 and C_4 is shown in figure 8. At lower angles of attack, the fence spoiler decreased the lift to approximately the same value as the $0.039c_w$ slot (configuration C_1); however, it loses effectiveness with increasing angle of attack and approaches the C_L curve of the $0.010c_w$ slot (configuration C_4) near $C_{L,max}$.

Figure 9 gives the results for configuration H (fence spoiler at the 30-percent chord) compared with the slot configuration C_1 and the basic wing configurations A and B. Above an angle of attack of about 4°, the fence spoiler is more effective in reducing the lift than the slot; however, the drag increment is considerably greater than that for the slotted configuration and the pitching moment is somewhat nonlinear.

CONCLUDING REMARKS

Based on the results of this investigation, it was apparent that the use of a variable-width slot was effective in controlling the increment of lift obtained from flap deflection. At a given angle of attack, there was little drag coefficient change associated with slot-width changes. Slot location, shape, and width were shown to affect the magnitude of lift control achieved.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., May 3, 1968,
126-61-04-07-23.

REFERENCE

1. Langley Research Staff (Compiled by Thomas A. Toll): Summary of Lateral-Control Research. NACA Rep. 868, 1947. (Supersedes NACA TN 1245.)

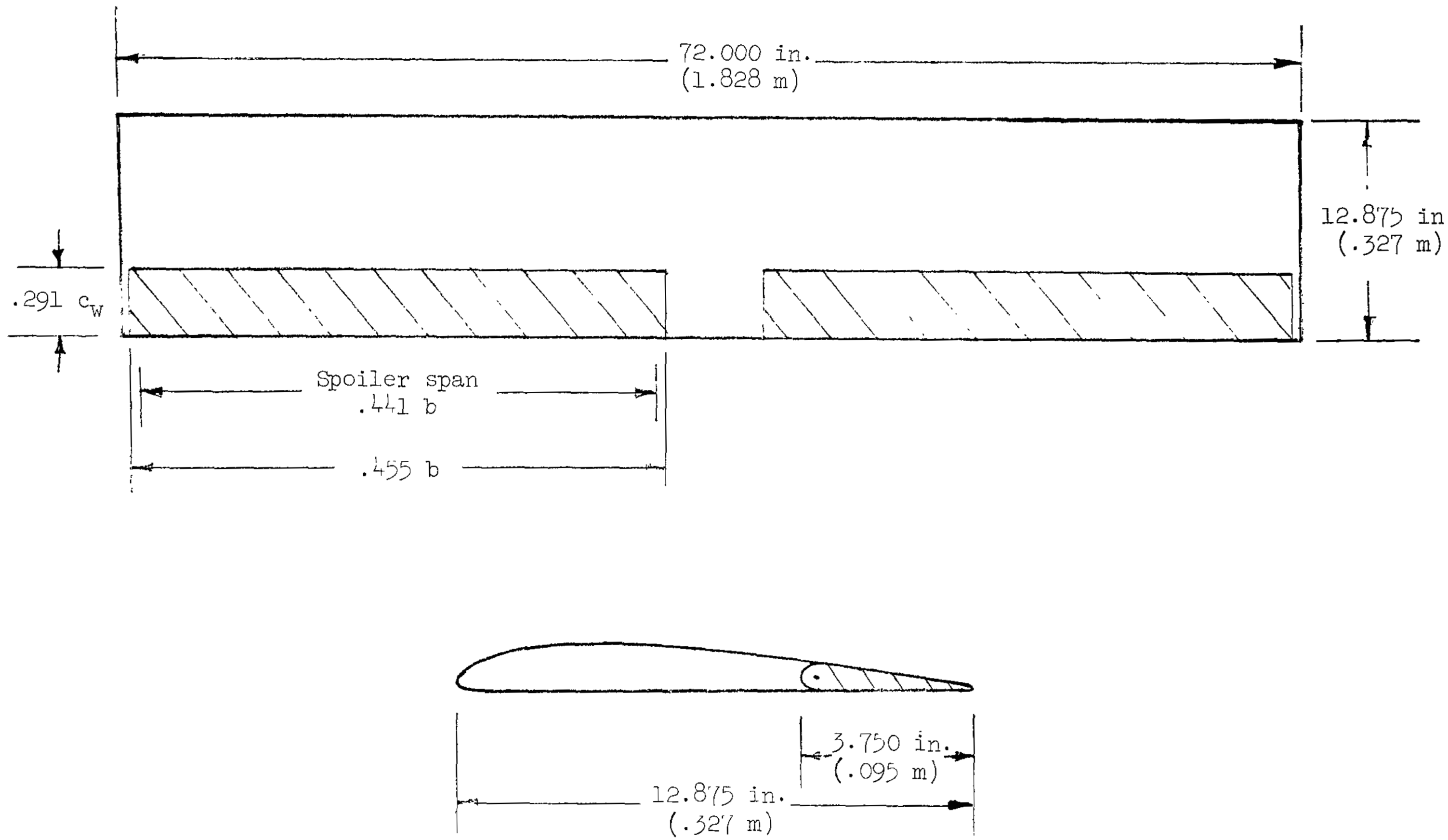

Figure 1.- Sketch of model wing.

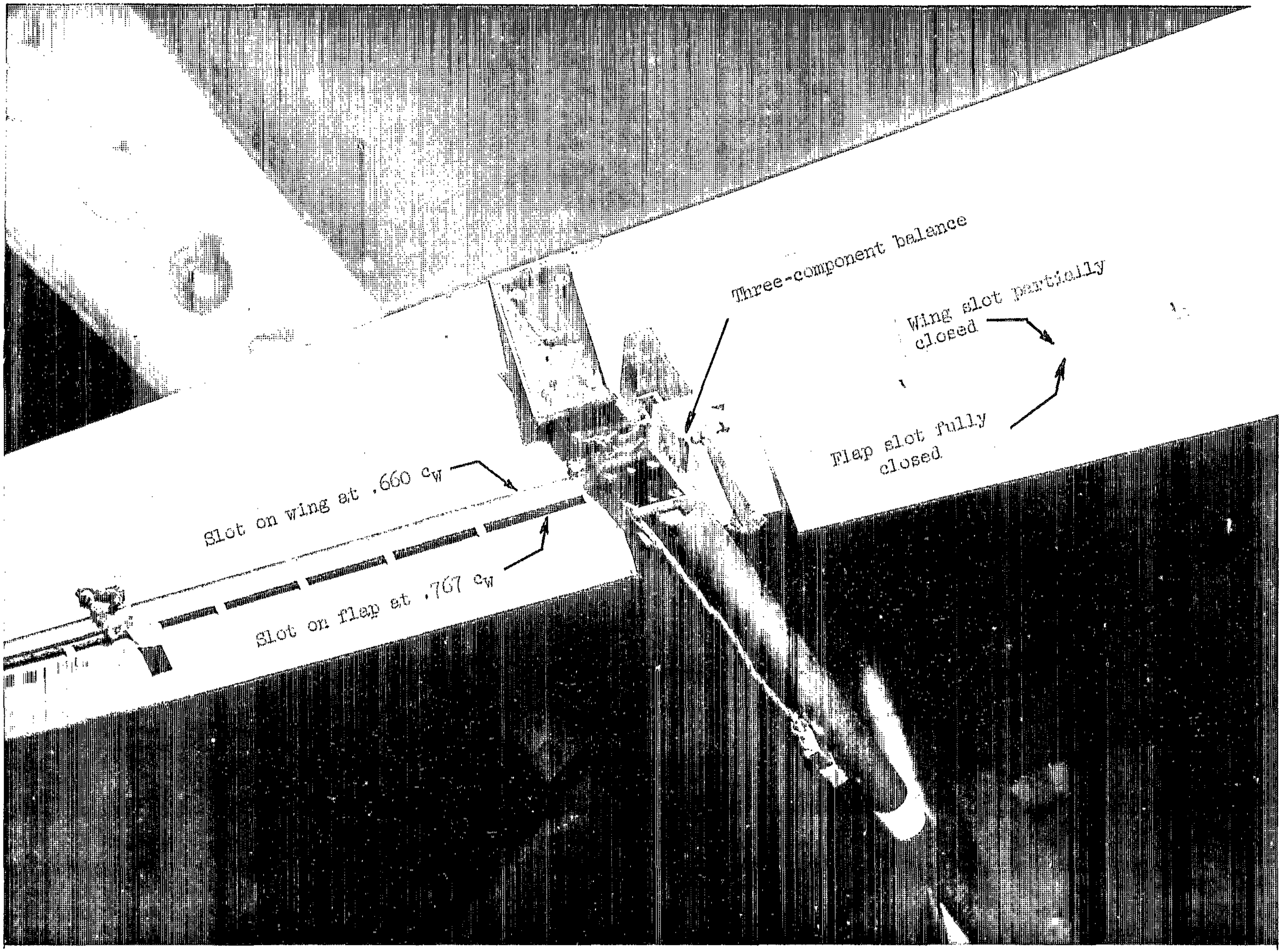

Figure 2.- Photograph of wing model sting mounted in tunnel.

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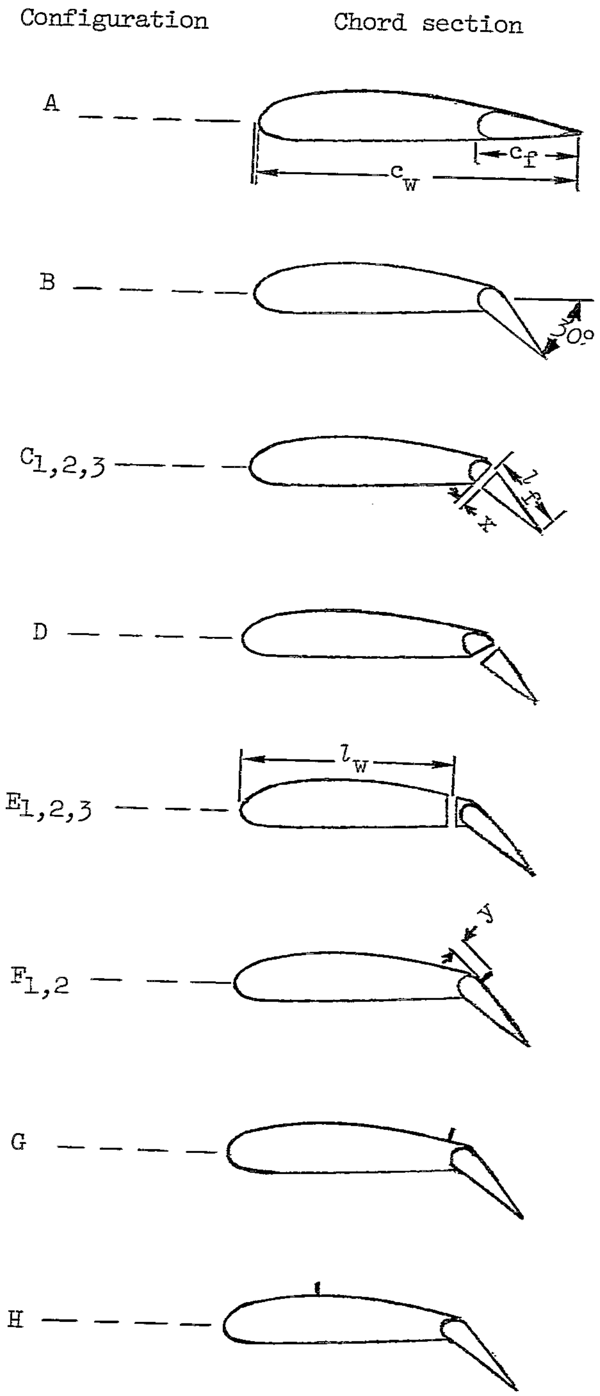

c_w = 12.785 inches (.327 meter)

c_f = 3.750 inches (.095 meter)

Slot location l_f/c_w		Slot width x/c_w
C_1	.235	.039
C_2	.245	.019
C_3	.249	.010
C_4	.220	.010

	l_f/c_w	x/c_w
D	.220	.010 to .294 (tapered)

	l_w/c_w	x/c_w
E_1	.664	.039
E_2	.677	.019
E_3	.685	.010

Spoiler location l_f/c_w		Spoiler height y/c_w
F_1	.254	.019
F_2	.254	.046

	l_w/c_w	y/c_w
G	.685	.019

	l_w/c_w	y/c_w
H	.300	.019

Figure 3.- Chord section view of configurations tested.

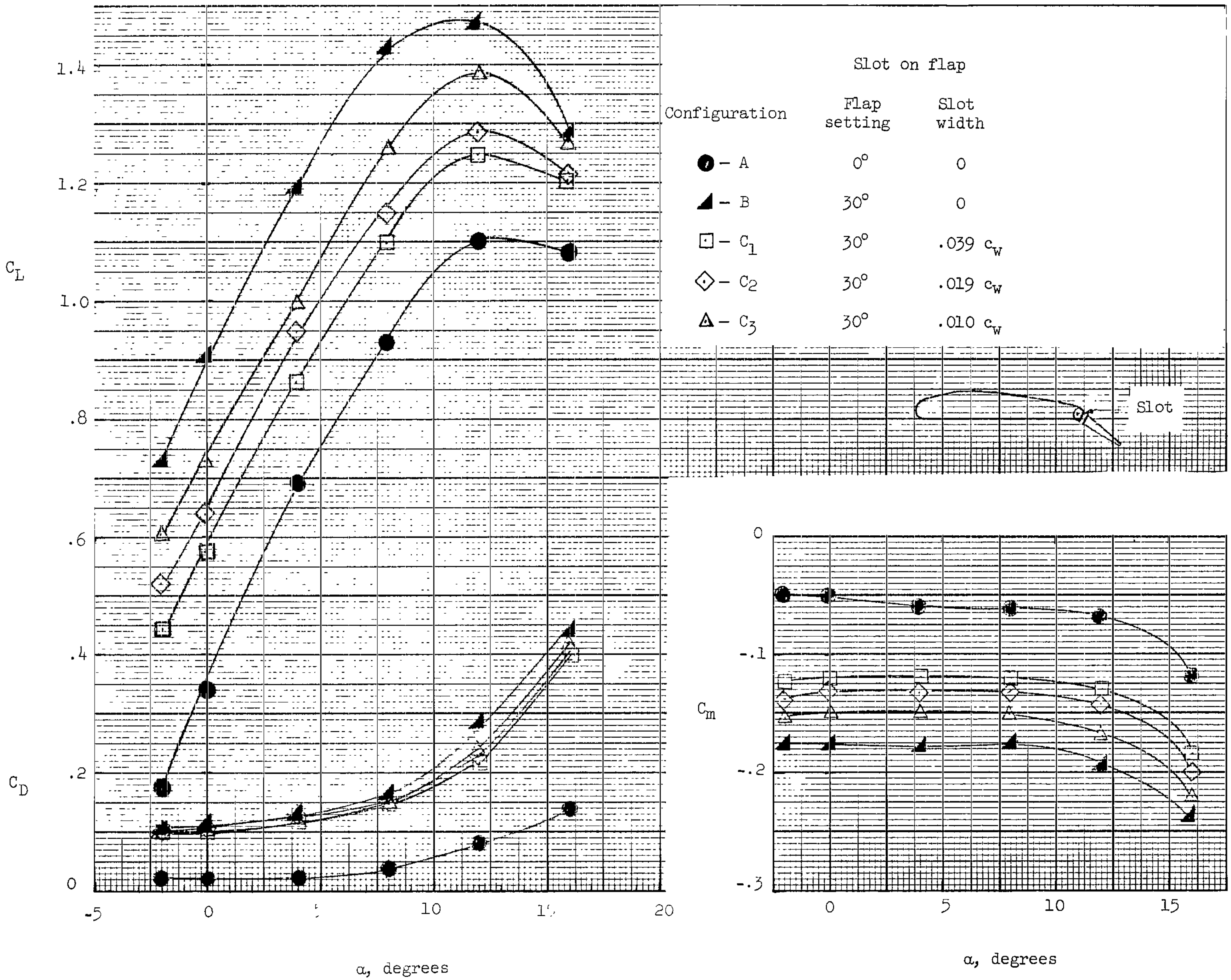

Figure 4.- Comparison of longitudinal characteristics between various size slots located on the flap and the basic wing configuration.

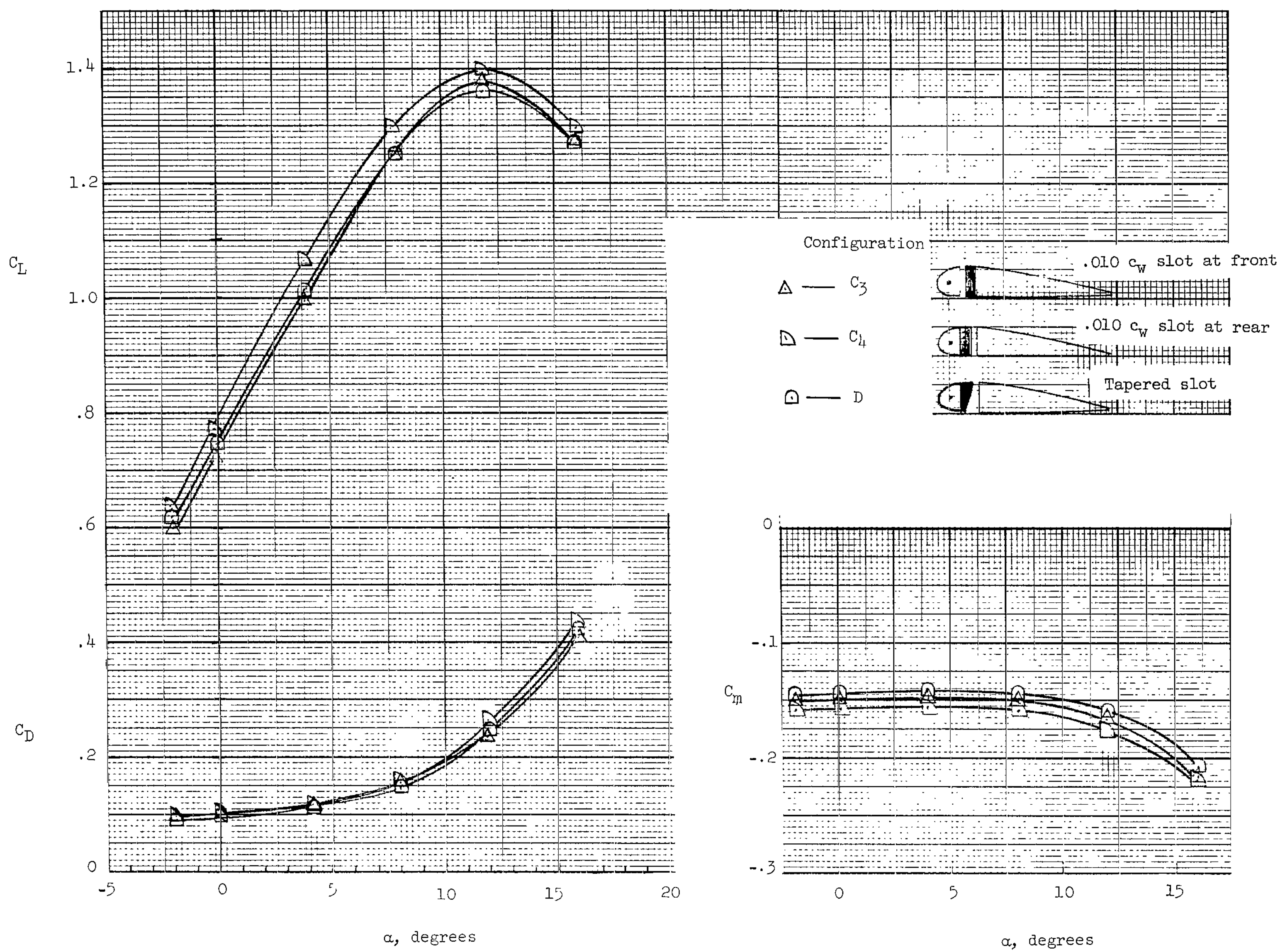

Figure 5.- Effect of $0.010c_W$ slot location and shape on longitudinal characteristics.

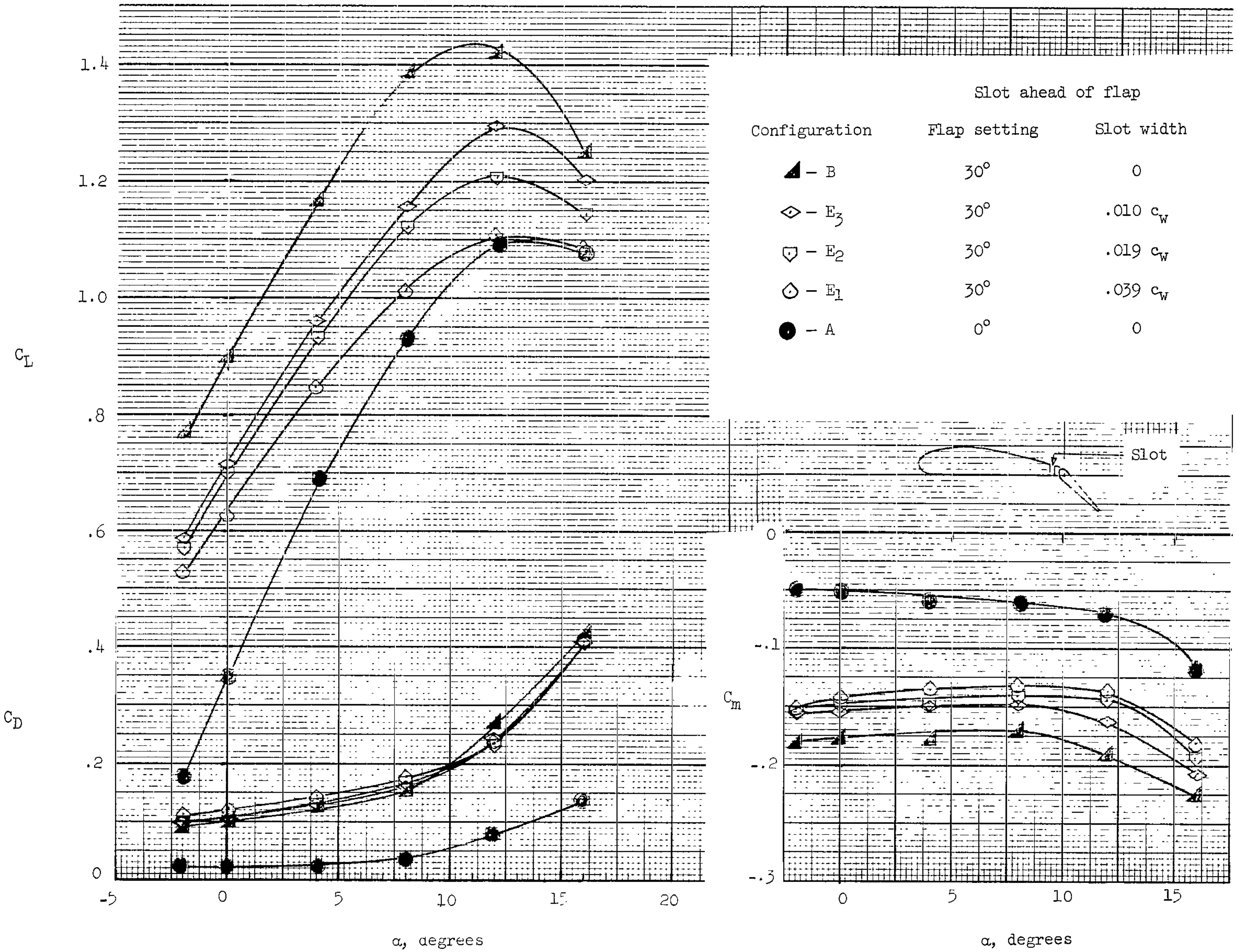

Figure 6.- Comparison of longitudinal characteristics between various size slots, located on the wing, and basic wing configurations.

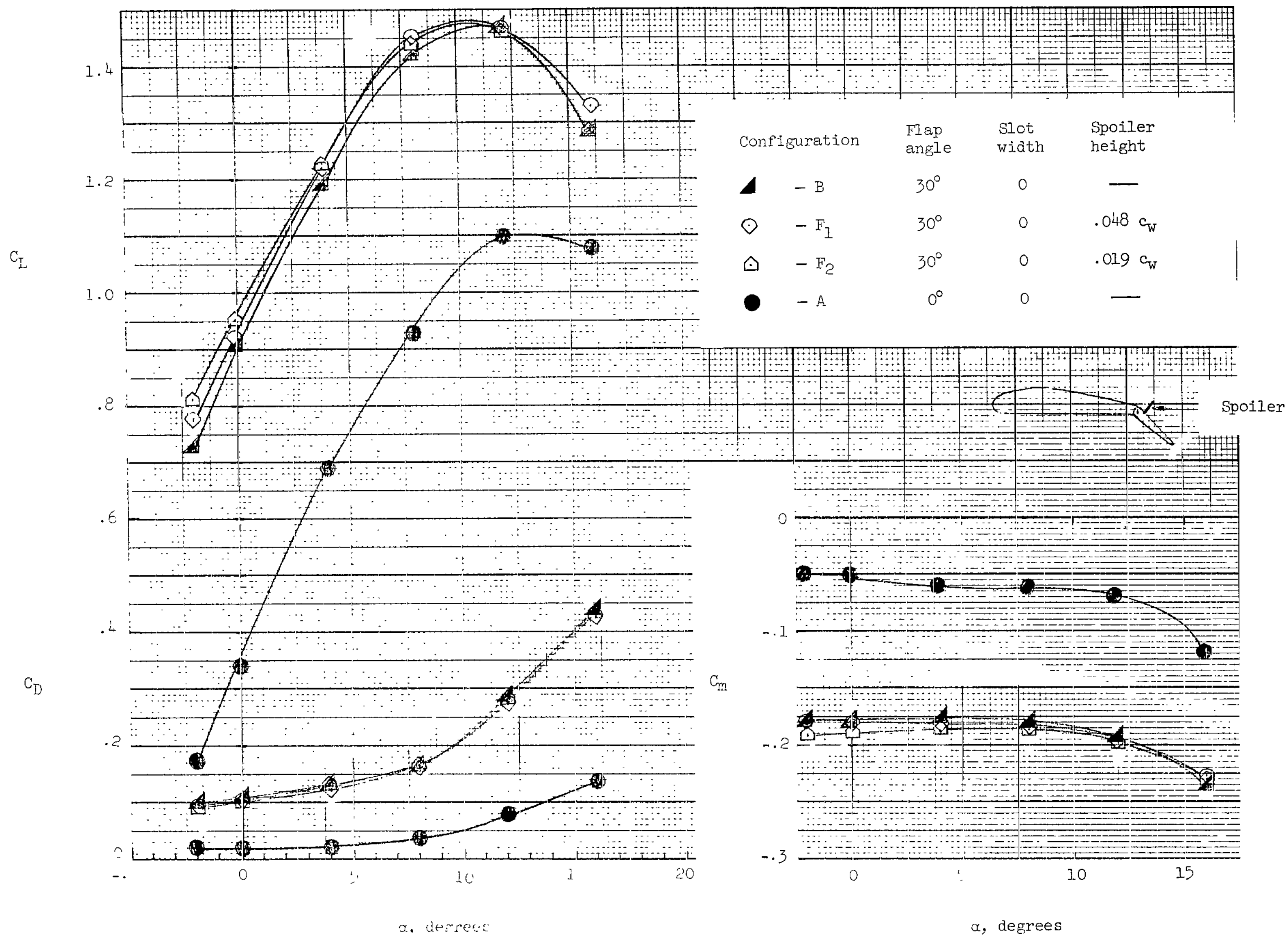

Figure 7.- Comparison between fence spoilers on the flap and basic wing configuration.

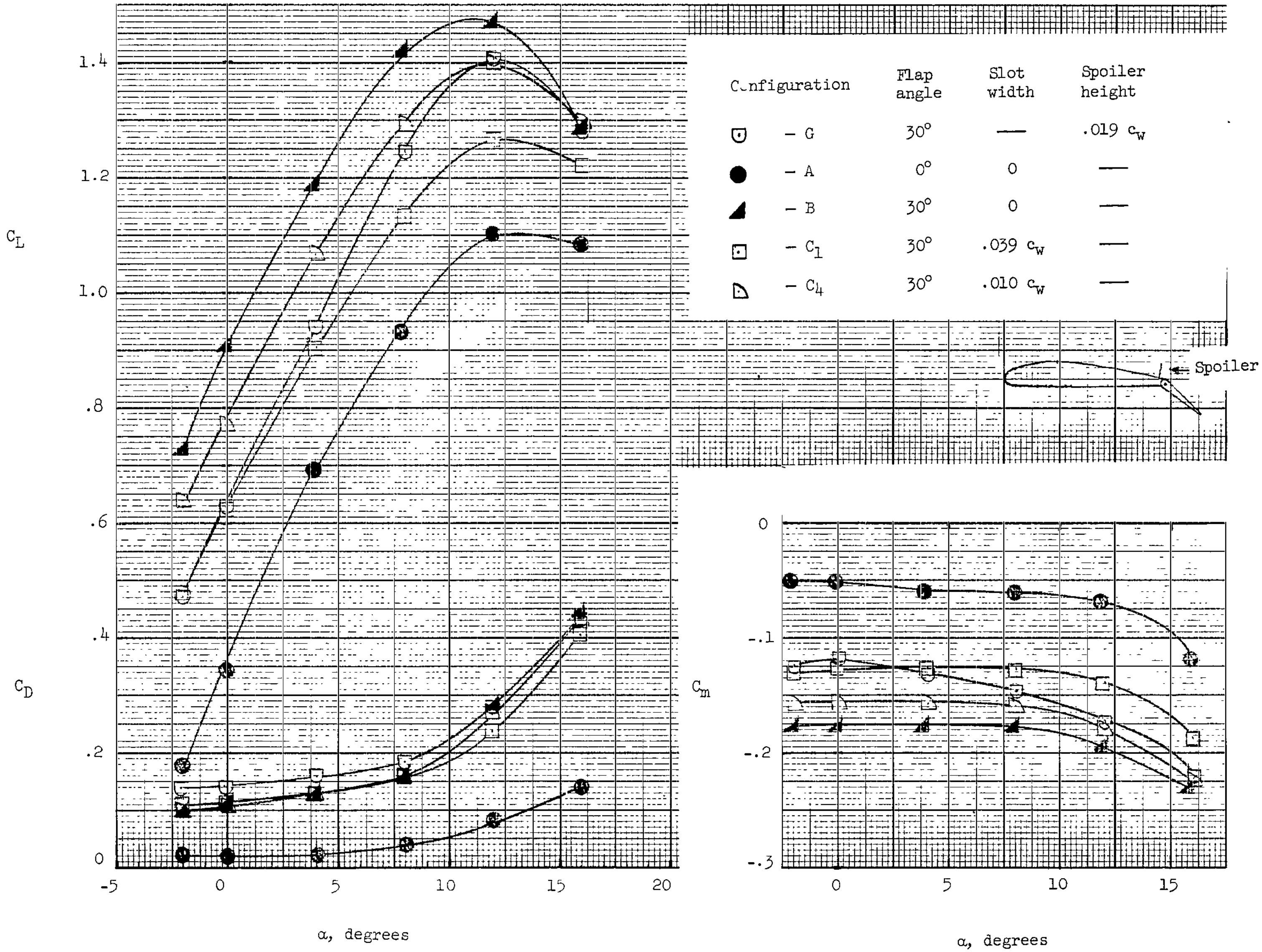

Figure 8.- Comparison between fence spoilers at the 68-percent chord line and basic configuration.

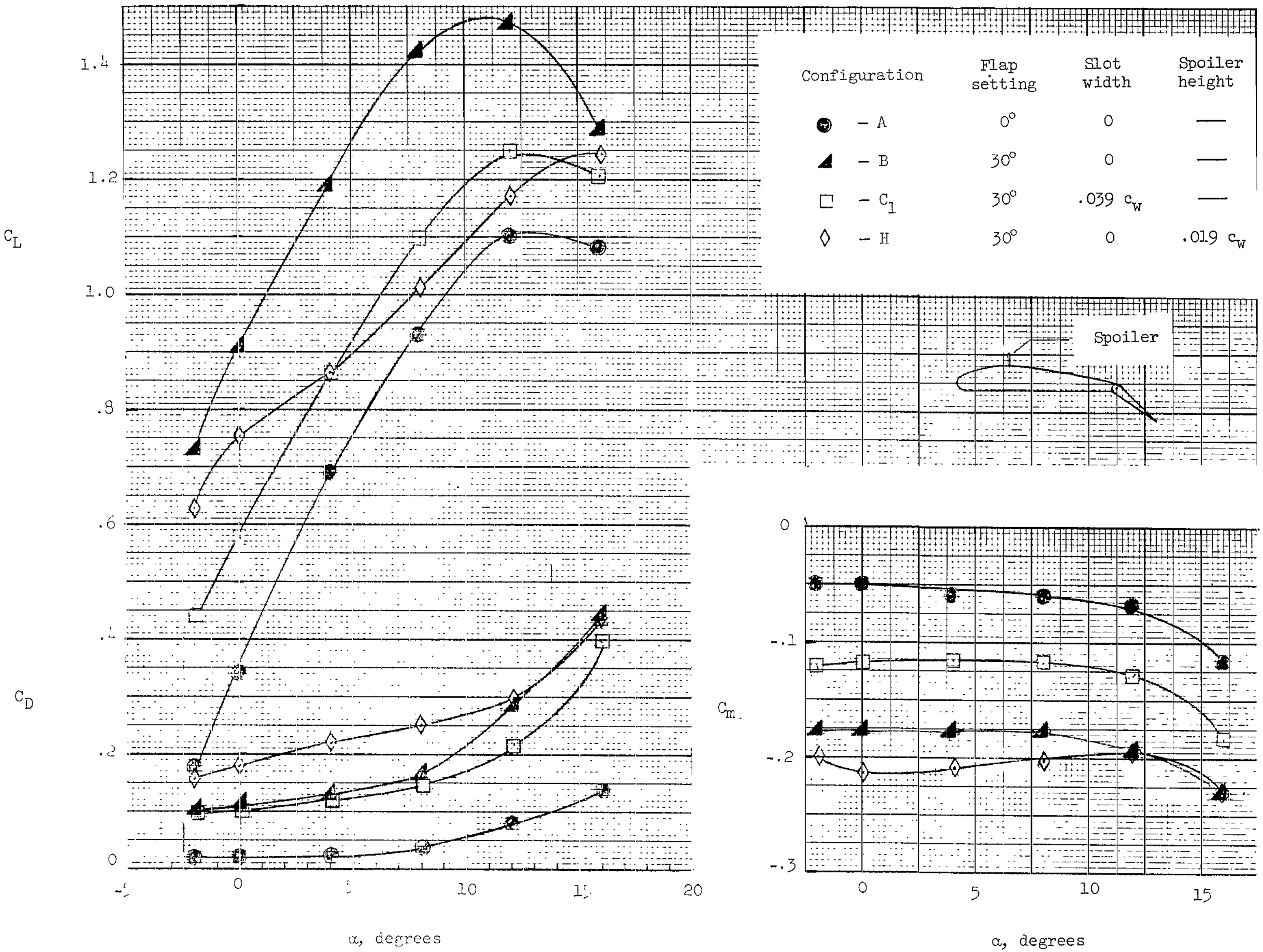

Figure 9.- Comparison of longitudinal characteristics between fence spoiler at the 30-percent chord line, a 0.039c_W slot on the flap; and the basic configuration.

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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