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RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

INVESTIGATION OF THE STABILITY AND CONTROL CHARACTERISTICS OF A $\frac{1}{20}$-SCALE MODEL OF THE CONSOLIDATED VULTEE XB-53 AIRPLANE WITH A FULL-SPAN LEADING-EDGE SLAT IN THE LANGLEY FREE-FLIGHT TUNNEL

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[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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INVESTIGATION OF THE STABILITY AND CONTROL CHARACTERISTICS OF A $\frac{1}{20}$-SCALE MODEL OF THE CONSOLIDATED VULTEE XB-53 AIRPLANE WITH A FULL-SPAN LEADING-EDGE SLAT IN THE LANGLEY FREE-FLIGHT TUNNEL

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SUMMARY

An investigation of the low-speed, power-off stability and control characteristics of a $\frac{1}{20}$-scale model of the Consolidated Vultee XB-53 airplane equipped with full-span leading-edge slats has been conducted in the Langley free-flight tunnel. In this investigation it was found that the full-span leading-edge slat gave about the same maximum lift coefficient as was obtained with the outboard single slotted flap and inboard slat. The stability and control characteristics were greatly improved except near the stall where the characteristics with the full-span slat were considered unsatisfactory because of a loss of directional stability and a slight nosing-up tendency.

INTRODUCTION

An investigation of the low-speed, power-off stability and control characteristics of a $\frac{1}{20}$-scale model of the Consolidated Vultee XB-53 airplane has been conducted in the Langley free-flight tunnel. The XB-53 is a jet-propelled, sweptforward, tailless bomber design.

Force- and flight-test data of the flaps-up and flaps-down configurations were presented in reference 1 and indicated low directional stability, large adverse yawing moments due to ailerons with flaps down, and large negative dihedral which resulted from the extreme dihedral change caused by the outboard flap which was designed for the airplane.

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In an attempt to eliminate the outboard flap and its undesirable characteristics, tests were made in the Langley free-flight tunnel using a full-span leading-edge slat instead of the outboard single slotted flap and inboard leading-edge slat. The results of these tests are presented herein.

SYMBOLS

S	wing area, square feet
$\bar{c}$	mean aerodynamic chord, feet
c	wing chord, feet
b	wing span, feet
c_s	slat chord, feet
q	dynamic pressure, pounds per square foot
ρ	air density, slugs per cubic foot
α	angle of attack, degrees
β	angle of sideslip, degrees
C_L	lift coefficient (Lift/qS)
C_D	drag coefficient (Drag/qS)
C_m	pitching-moment coefficient (Pitching moment/$qS\bar{c}$)
C_n	yawing-moment coefficient (Yawing moment/qSb)
C_l	rolling-moment coefficient (Rolling moment/qSb)
C_Y	lateral-force coefficient (Lateral force/qS)
C_{Y_β}	rate of change of lateral-force coefficient with angle of sideslip, per degree ($\delta C_Y/\delta\beta$)
C_{n_β}	rate of change of yawing-moment coefficient with angle of sideslip, per degree ($\delta C_n/\delta\beta$)
C_{l_β}	rate of change of rolling-moment coefficient with angle of sideslip, per degree ($\delta C_l/\delta\beta$)

APPARATUS

Wind Tunnel

The investigation was made in the Langley free-flight tunnel which was designed to test free-flying dynamic models. A complete description of the tunnel and its operation is given in reference 2.

The force tests, made to determine the static aerodynamic characteristics of the model, were made on the free-flight-tunnel six-component balance which is described in reference 3. This balance rotates in yaw with the model such that all forces and moments are measured with respect to the stability axes. A sketch showing the positive directions of the forces and moments and the definition of the stability axes is given in figure 1.

Model

The $\frac{1}{20}$-scale model used in the present investigation was the same model used in the tests of reference 1. For the present tests it was fitted with a full-span leading-edge slat of 0.15 chord and a stall-control vane which were used in place of the outboard single slotted flap and inboard leading-edge slat. A three-view sketch of the model is shown as figure 2, a photograph of the model is shown as figure 3, and the location and pertinent dimensions of the full-span slat and stall-control vane are shown as figure 4.

TESTS

Force Tests

All force tests were made on the free-flight-tunnel balance at a dynamic pressure of 3.0 pounds per square foot which corresponds to about 34 miles per hour at standard sea-level conditions and to a test Reynolds number of 309,000 based on the mean aerodynamic chord of 0.961 foot.

Force tests were made to determine the lift, drag, and pitching-moment characteristics of the model with the full-span leading-edge slat and the stall-control vane on for an angle-of-attack range from -8° to 20°. Force tests were also made over the same angle-of-attack range at $\pm 5^\circ$ yaw to determine the lateral stability characteristics of the model with the full-span slat on and with various spanwise locations of the stall-control vane.

Flight Tests

Flight tests with the full-apan leading-edge slat extended and the stall-control vane located at $0.5\frac{b}{2}$ were made over a lift-coefficient range from $C_L = 0.75$ to 0.94. All flight tests were made with the extension on the vertical tail described in reference 1.

RESULTS AND DISCUSSION

Force Tests

The results of force tests made to determine the longitudinal and lateral stability characteristics of the model equipped with the full-span leading-edge slat are presented in figures 5 to 8.

The lift, drag, and pitching-moment characteristics of the model equipped with the full-span leading-edge slat and the stall-control vanes at a spanwise location of $0.5\frac{b}{2}$ are presented in figure 5 along with corresponding data from reference 1 for the flap-retracted and flap-deflected configurations. These data indicate that about the same maximum lift coefficient was obtained with the full-span leading-edge slat as was obtained with the outboard single slotted flaps, but that the maximum lift coefficient occurred at a higher angle of attack with the full-span slat. The high angle of attack at which maximum lift is obtained might be objectionable for the airplane in that a longer landing gear might be required.

The data of figure 5 also indicate that the full-span slat eliminated the large change in pitching moment obtained with the outboard flap. About the same static margin was provided by the full-span slat configuration at high lift coefficients, but there was a slight nosing-up tendency at the stall with the full-span slat.

The results of tests made with the full-span leading-edge slat off, but with the stall-control vane located spanwise at $0.5\frac{b}{2}$ are presented in figure 6 along with data of reference 1 for the flap-retracted configuration with the inboard slat on and off. These data indicate that the vane was not as effective as the inboard leading-edge slat in providing longitudinal stability at the stall.

Presented in figure 7 are the results of tests made to determine the most promising spanwise location of the stall-control vane from the standpoint of directional stability. These data indicate that of the three spanwise locations tested, the $0.5\frac{b}{2}$ position resulted in the directional stability C_{n_β} holding up to the highest angle of attack.

Presented in figure 8 are the variations with angle of attack of the directional stability parameter C_{n_β}, the effective dihedral parameter $-C_{l_\beta}$, and the effective side area parameter $-C_{Y_\beta}$ for the free-flight-tunnel model equipped with either the full-span leading-edge slat or with the outboard single slotted flap. These data indicate that the use of the full-span leading-edge slat eliminated the large negative dihedral caused by deflecting the outboard flap. These data also show that at low angles of attack more directional stability was obtained with the full-span leading-edge slat than with the outboard flap. At high angles of attack, however, there was a sharp reduction in directional stability with the full-span slat, whereas with flaps down there was an increase in directional stability at higher angles of attack. The use of the stall-control vane with the full-span slat delayed the drop off in directional stability to a higher angle of attack but did not eliminate the drop off.

Although no aileron effectiveness tests were made with the full-span leading-edge slat, it is believed that the aileron yawing moment would be approximately the same as was reported in reference 1 for the flaps retracted configuration and therefore much less adverse than with the outboard flaps extended.

Flight Tests

The flight tests made with the full-span leading-edge slat and stall-control vane and with the vertical tail extension on indicated that at low and moderate lift coefficients the flight characteristics of the model were good when aileron and rudder control were used together for lateral control. When the ailerons were used as the sole means of lateral control there was some adverse yawing, but the yawing motions were very small compared to the increasing yawing motions which resulted in crashes in the flap extended, aileron alone flights. As a result of these tests it appeared that at low and moderate lift coefficients the full-span leading-edge slat and stall-control vane configuration was definitely better than the outboard flap configuration because the adverse aileron yawing moments were less, the directional stability was greater, and the dihedral characteristics were better.

The flight tests indicated unsatisfactory stability near the stall. The model yawed to large angles and had a slight nosing-up tendency that resulted in a stall in which the model yawed, pitched, and then rolled off out of control. This behavior is probably associated with the loss of directional stability at the stall as shown in figure 8 and the reduction of longitudinal stability at the stall as shown in figure 5. The stall of the model with the full-span leading-edge slat was very similar to that obtained with the flap-up configuration without the inboard leading-edge slat that was reported in reference 1.

CONCLUDING REMARKS

The results of the free-flight-tunnel stability and control investigation of the $\frac{1}{20}$-scale model of the Consolidated Vultee XB-53 airplane with a full-span leading-edge slat and stall-control vanes may be summarized as follows:

1. The full-span leading-edge slat gave about the same maximum lift coefficient as the outboard single slotted flaps although the angle of maximum lift was greater with the slat and there was a slight nosing-up tendency at the stall.

2. The use of the full-span leading-edge slat eliminated the large negative dihedral associated with the outboard single slotted flap.

3. At low angles of attack more directional stability was obtained with the full-span leading-edge slat than with the outboard flap. At high angles of attack, however, there was a sharp reduction in directional stability with the full-span slat, whereas with flaps down there was an increase in directional stability at high angles of attack.

4. At low and moderate lift coefficients the flight characteristics were satisfactory. At high lift coefficients the flight characteristics were considered unsatisfactory because the yawing motions resulting from low directional stability combined with the nosing-up tendency resulted in a stall in which the model yawed, pitched, and then rolled off out of control.

5. The flight characteristics near the stall might be made satisfactory by use of a more effective stall-control device than the vane used in these tests so that the directional stability would be maintained at a satisfactory value through the stall.

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1. Bennett, Charles V.: Investigation of the Stability and Control Characteristics of a $\frac{1}{20}$-Scale Model of the Consolidated Vultee XB-53 Airplane in the Langley Free-Flight Tunnel. NACA RM No. L7J17, Army Air Forces, 1947.

2. Shortal, Joseph A., and Osterhout, Clayton J.: Preliminary Stability and Control Tests in the NACA Free-Flight Wind Tunnel and Correlation with Full-Scale Flight Tests. NACA TN No. 810, 1941.

3. Shortal, Joseph A., and Draper, John W.: Free-Flight-Tunnel Investigation of the Effect of the Fuselage Length and the Aspect Ratio and Size of the Vertical Tail on Lateral Stability and Control. NACA ARR No. 3D17, 1943.

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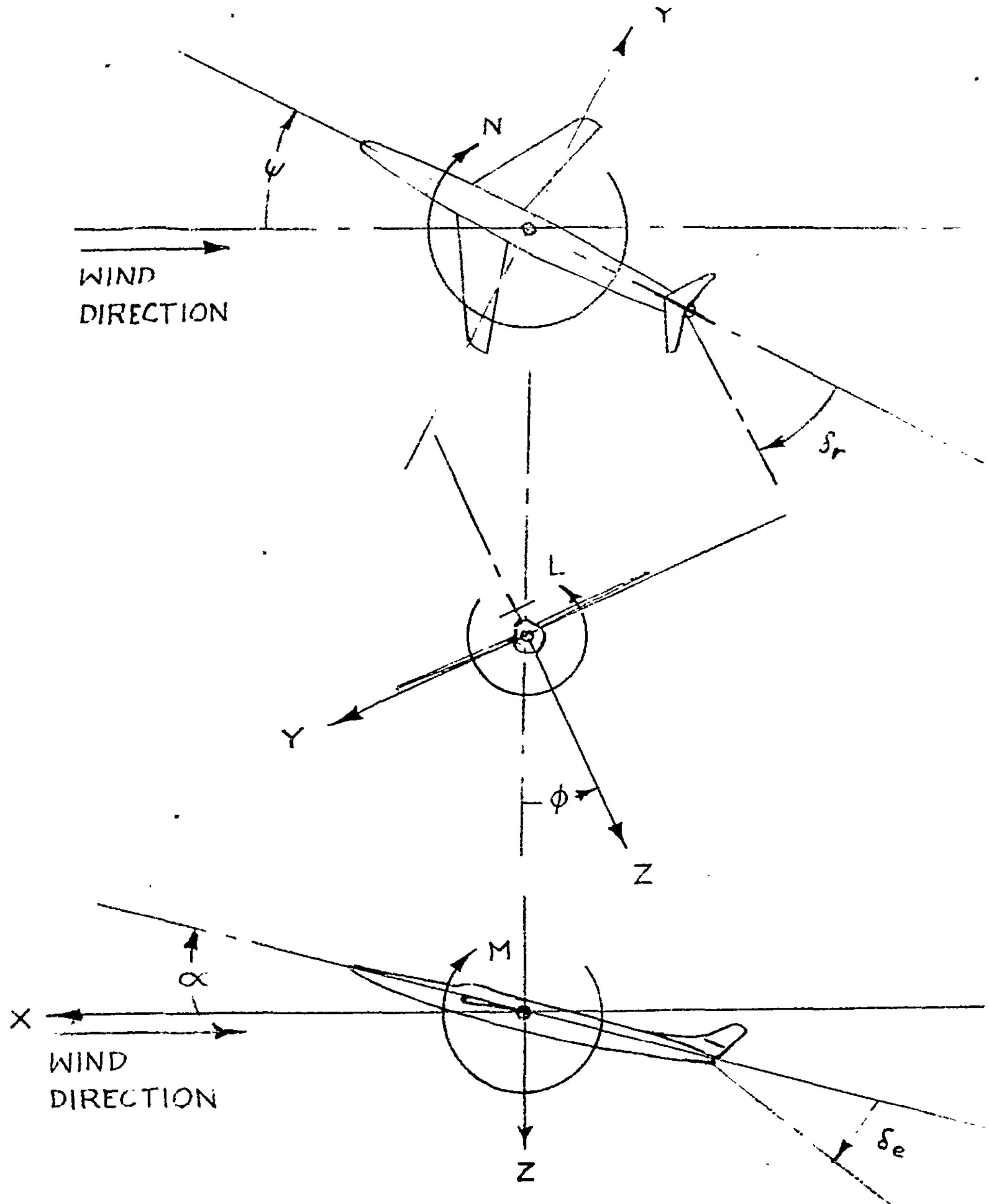

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Figure 1.- The stability system of axes. Arrows indicate positive directions of moments, forces, and control-surface deflections. This system of axes is defined as an orthogonal system having their origin at the center of gravity and in which the Z-axis is in the plane of symmetry and perpendicular to the relative wind, the X-axis is in the plane of symmetry and perpendicular to the Z-axis, and the Y-axis is perpendicular to the plane of symmetry.

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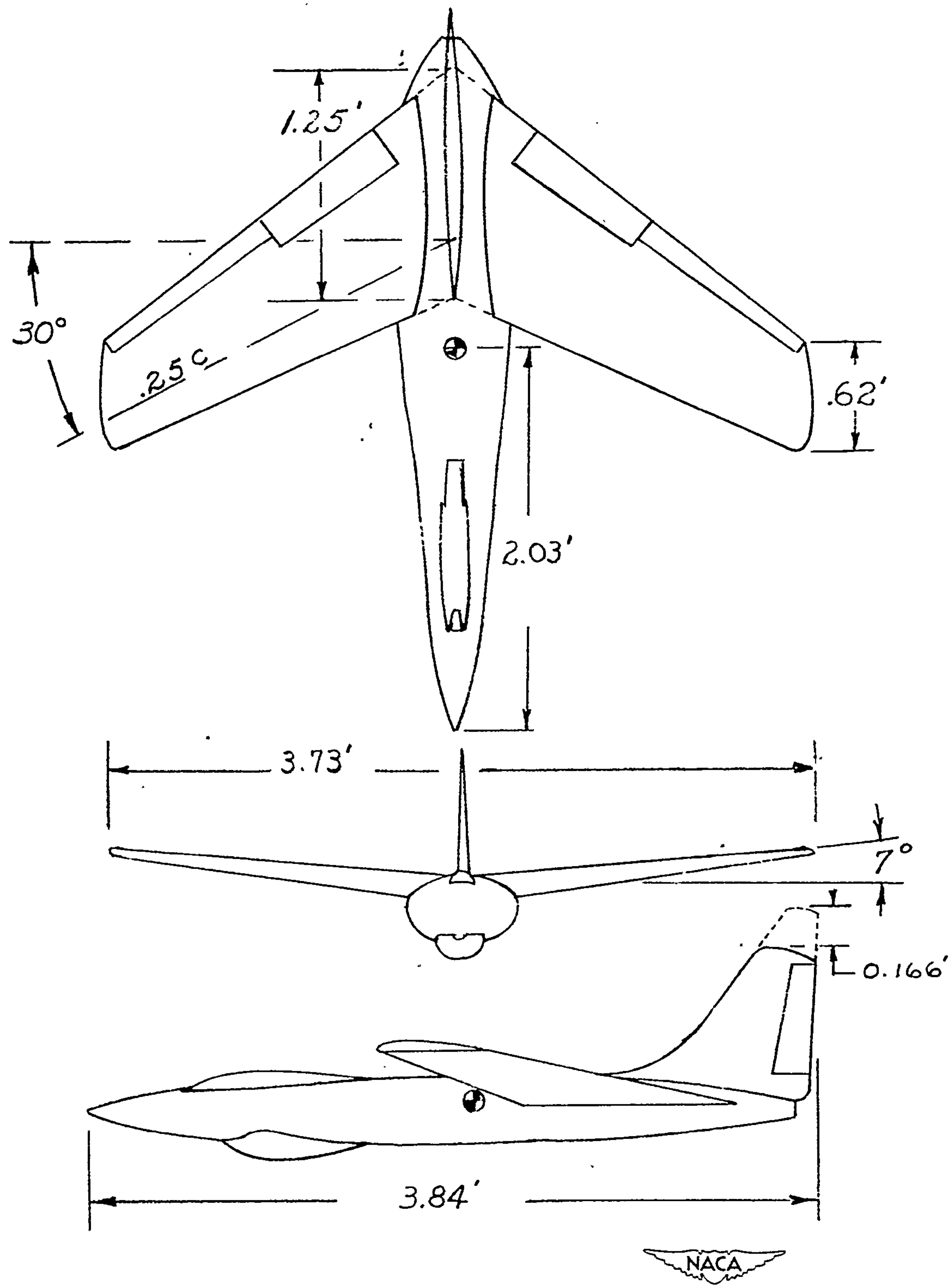

Figure 2.- Three-view sketch of the 1/20-scale model of the Consolidated-Vultee XB-53 airplane.

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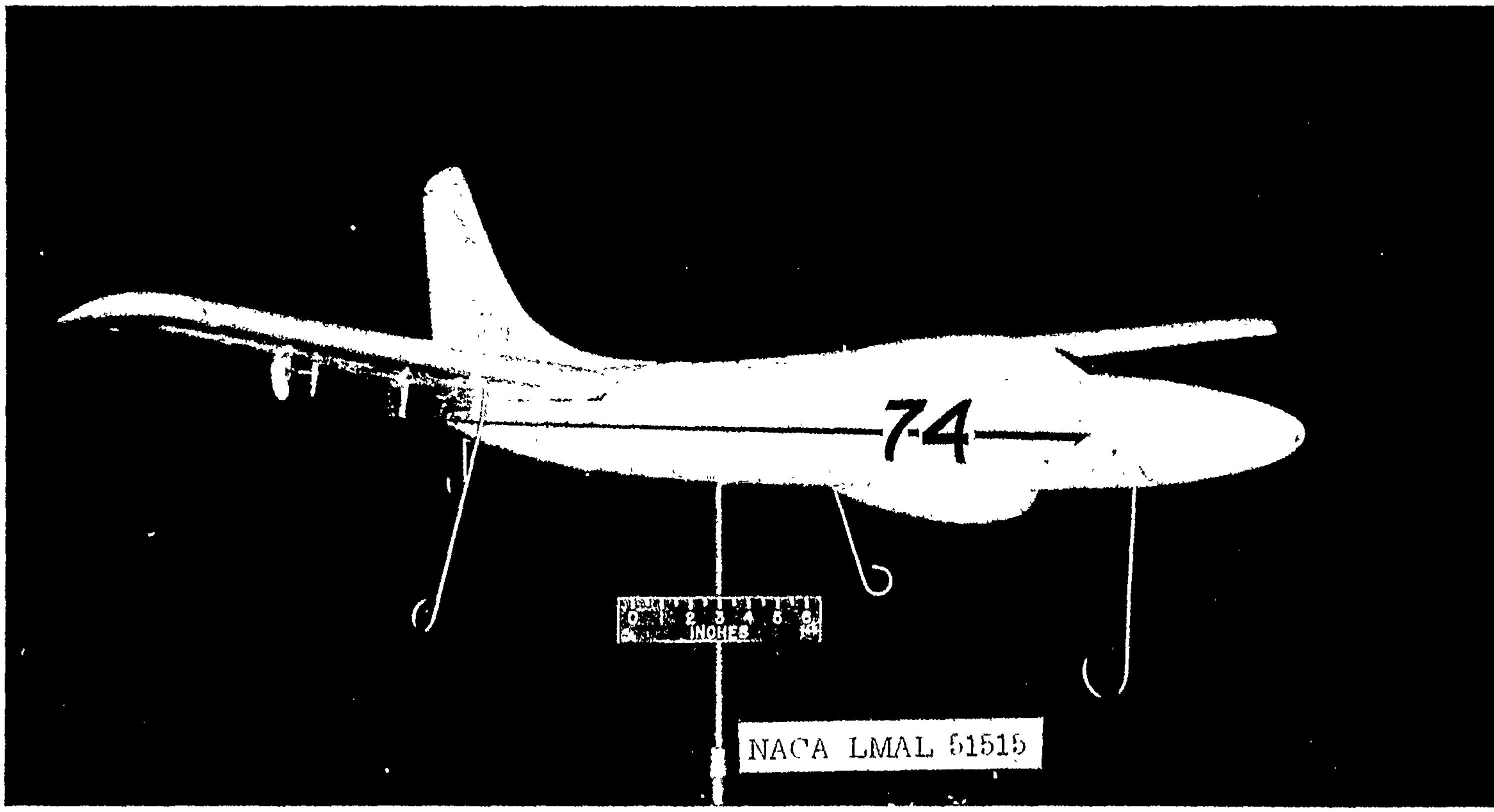

Figure 3.- Photograph of the 1/20-scale model of the Consolidated Vultee XB-53 airplane as tested in the Langley free-flight tunnel.

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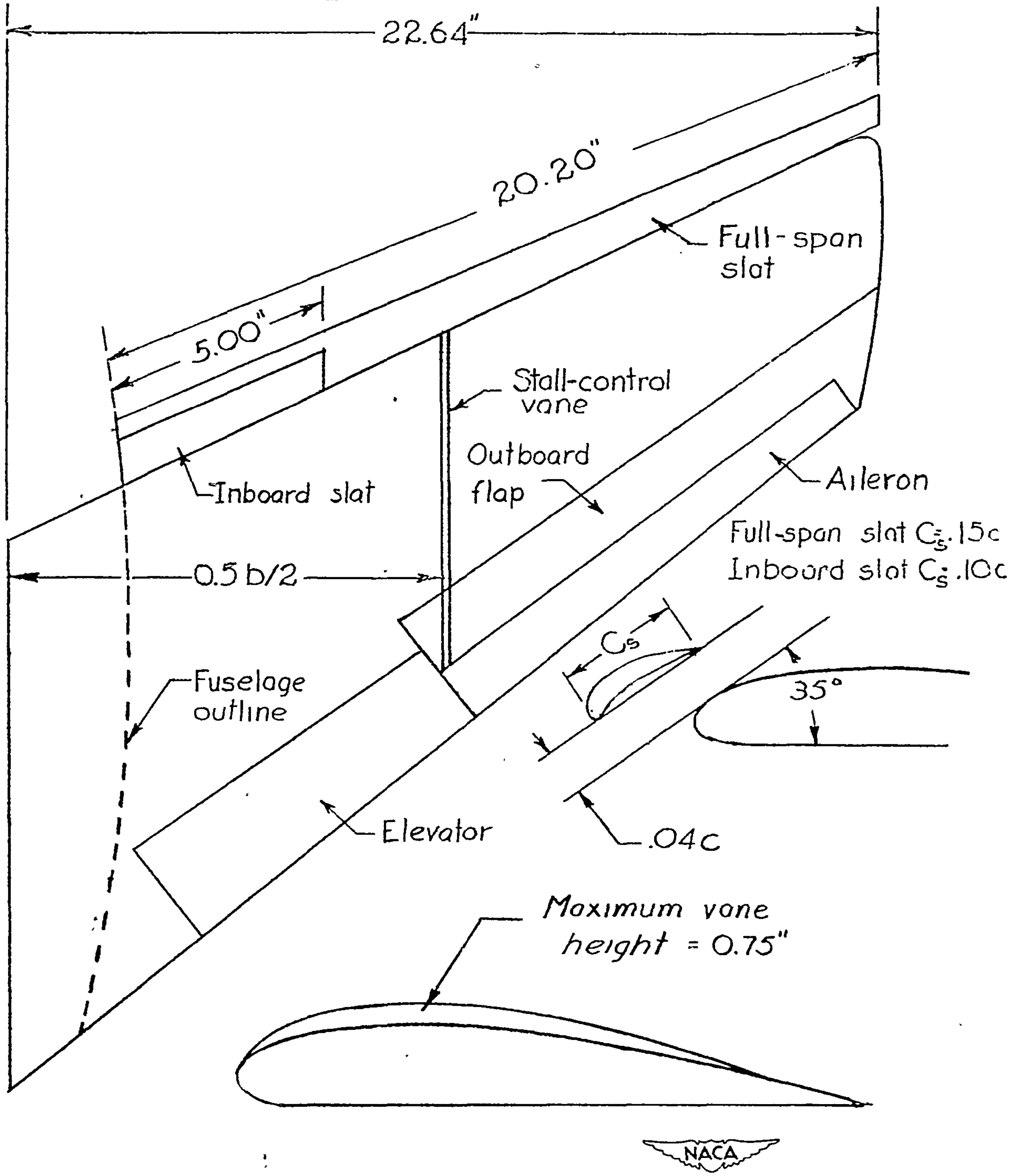

Figure 4.- Sketch of full-span slat and stall-control vane installation on the 1/20-scale model of the Consolidated-Vultee XB-53 airplane.

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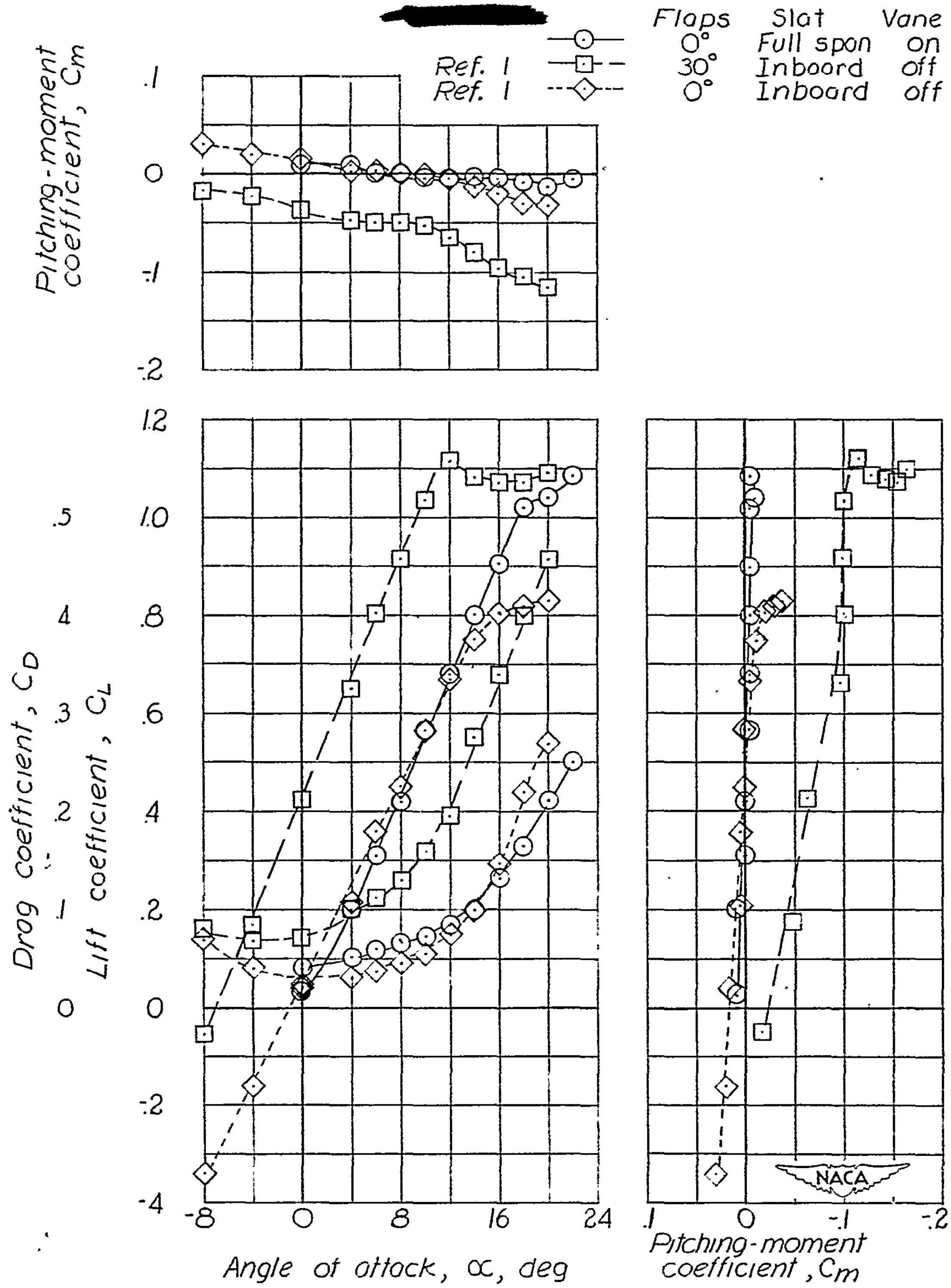

Figure 5.- Comparison of the lift, drag, and pitching-moment characteristics of the 1/20-scale model of the Consolidated Vultee XB-53 airplane equipped with outboard flaps, with inboard slats, and with full-span slats and stall-control vanes. Center of gravity at 0.10 MAC. $\delta_e = \delta_a = -10^{\circ}$.

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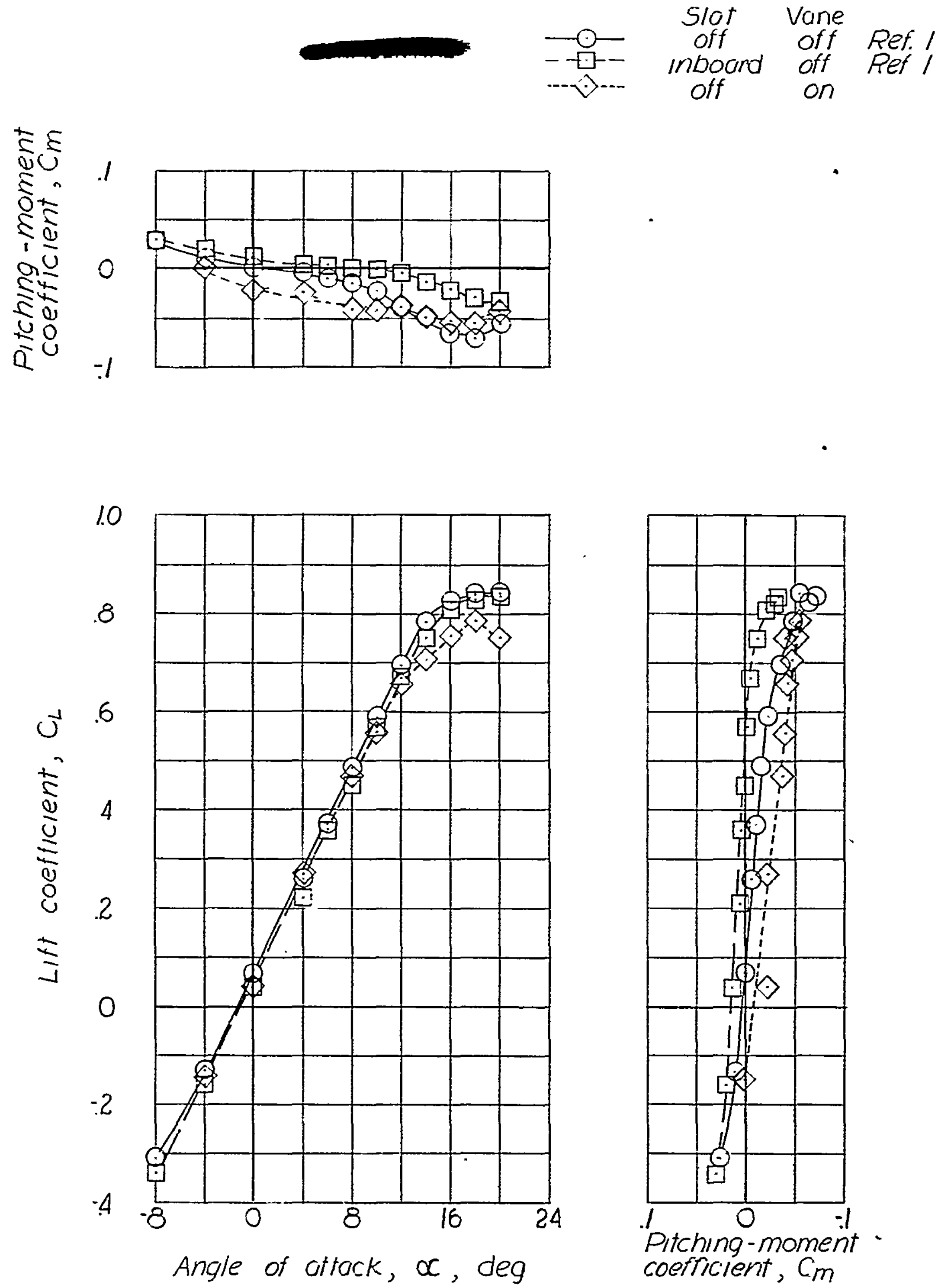

Figure 6.- Comparison of the effect of the stall-control vane at a spanwise location of 0.5b/2 and the inboard slat on the lift and pitching-moment characteristics of the 1/20-scale model of the Consolidated-Vultee XB-53 airplane. $\delta_e = \delta_a = -10^{\circ}$. Center of gravity at 0.10 MAC. [redacted]

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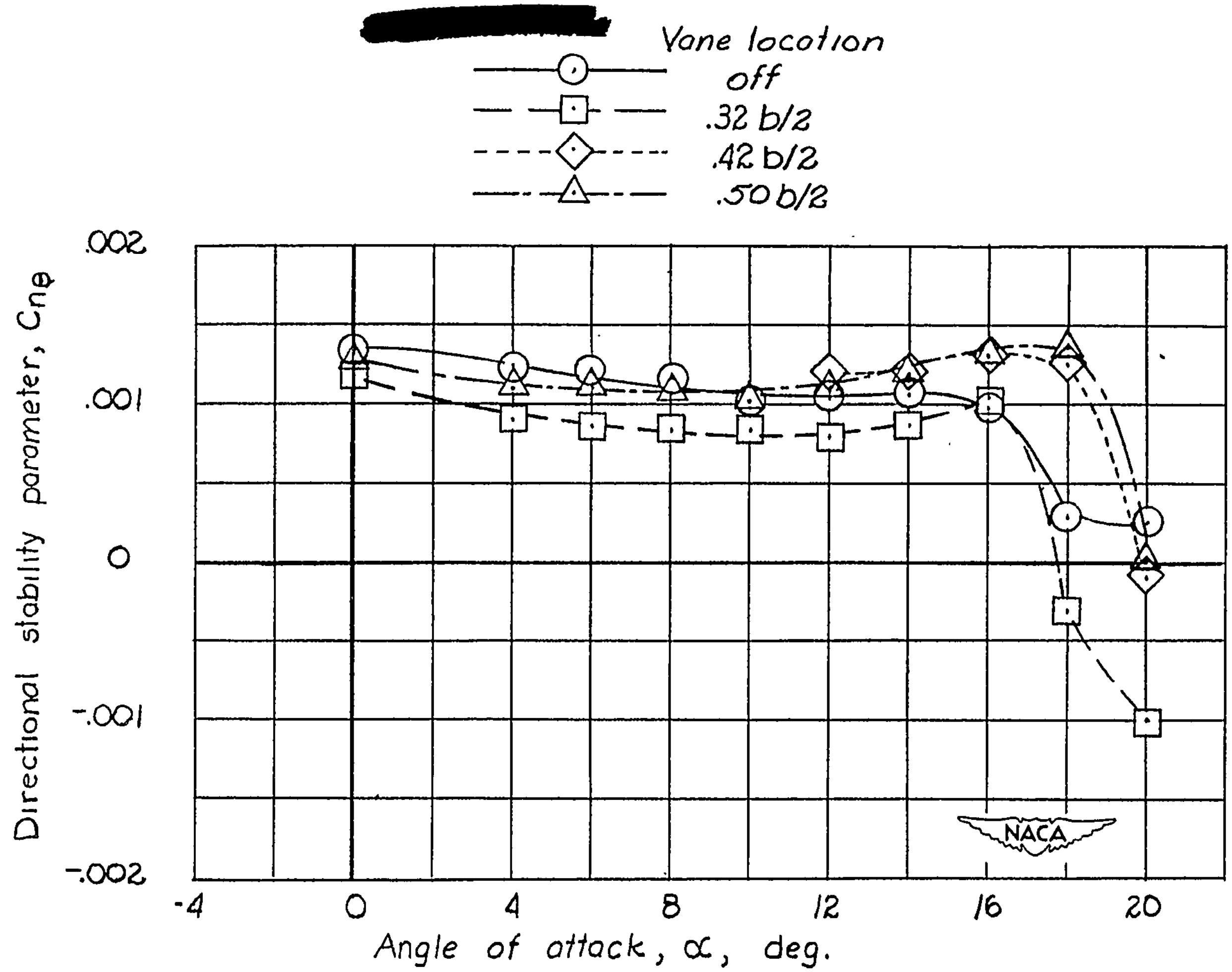

Figure 7.- Effect of spanwise location of the stall-control vane on the directional stability parameter, C_{n_β}, for the 1/20-scale model of the Consolidated-Vultee XB-53 airplane. Full-span leading-edge slat on. Extension on vertical tail. $\delta_e = \delta_a = 0^\circ$.

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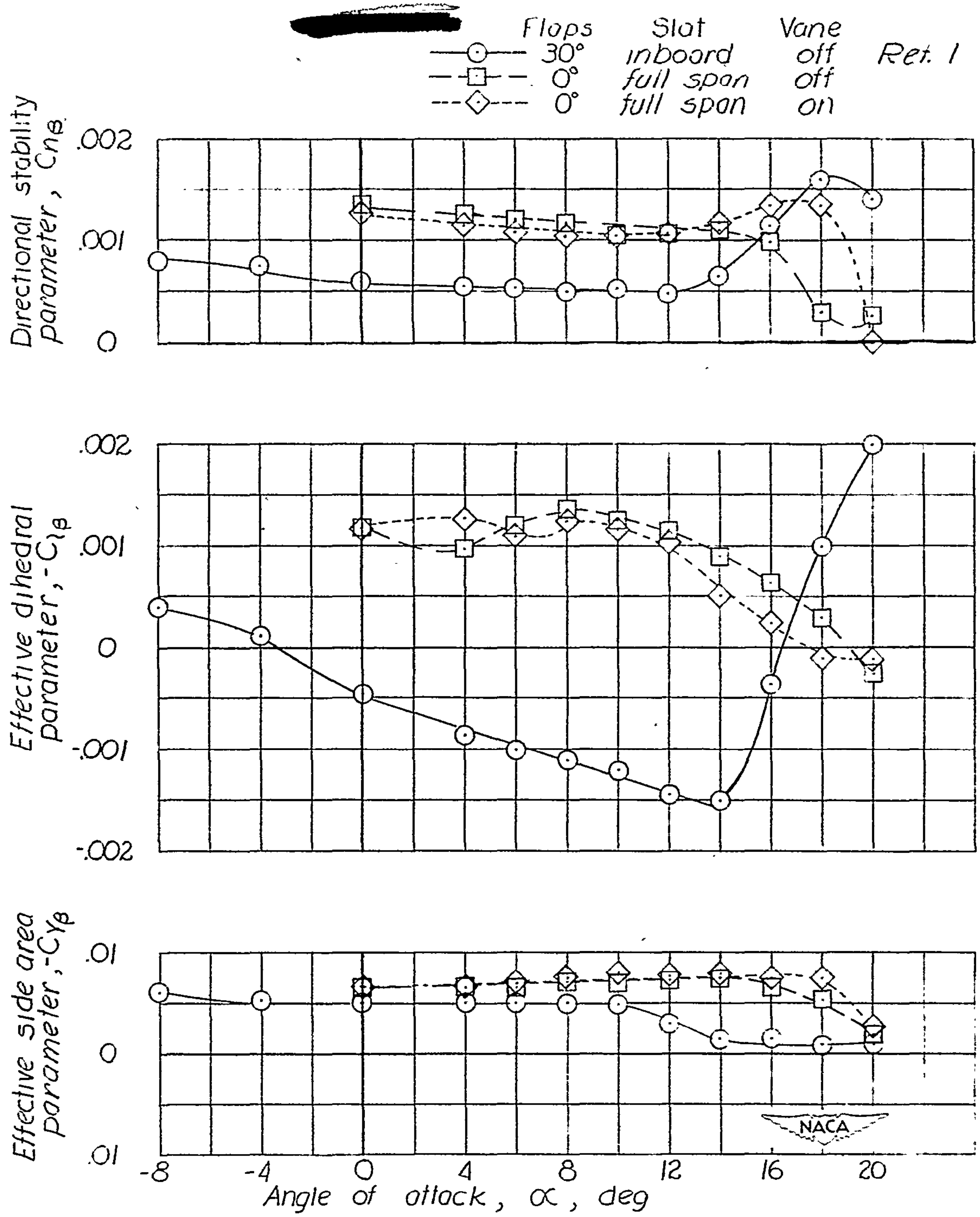

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Figure 8.- Comparison of the lateral stability characteristics of the 1/20-scale model of the Consolidated-Vultee XB-53 airplane with the full-span leading-edge slat and with the outboard single slotted flap. $\delta_e = \delta_a = -10°$. Center of gravity at 0.10 MAC.