Copy
RM L50E16

NACA

RESEARCH MEMORANDUM

SOME EFFECTS OF CHORDWISE FENCES ON THE AERODYNAMIC CHARACTERISTICS OF FOUR MODERATELY SWEPTBACK WINGS IN THE LOW-LIFT RANGE AT TRANSONIC MACH NUMBERS AND AT MACH NUMBER 1.9

By Lawrence D. Guy

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
July 21, 1950

 [redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

SOME EFFECTS OF CHORDWISE FENCES ON THE AERODYNAMIC CHARACTERISTICS OF FOUR MODERATELY SWEPTBACK WINGS IN THE LOW-LIFT RANGE AT TRANSONIC MACH NUMBERS AND AT MACH NUMBER 1.9

By Lawrence D. Guy

SUMMARY

A study of data from available wind-tunnel investigations was made to determine the effects of thin chordwise fences on some of the aerodynamic characteristics of four moderately sweptback wings in a low-lift range at transonic Mach numbers and at Mach number 1.9. The wings were equipped with upper-surface fences of comparable size, having a height above the wing-chord plane of less than 14 percent of the local chord. The data from tests of a small leading-edge vane and a triangular fin on one wing were also included.

The fences introduced no large detrimental effects on lift or pitching moment at transonic or supersonic speeds. A slight increase in the value of the drag coefficient was usually obtained. The increase in drag coefficient generally was less than 0.002 and did not exceed 0.005. In one investigation, the fence effected a more nearly linear variation of the pitching moment with lift coefficient at transonic speeds. There was some evidence of a reduction in aileron effectiveness at a Mach number of 1.9 when the fence or fin was located adjacent to the inboard end of the aileron.

INTRODUCTION

Wing sweepback used on many high-speed aircraft has often been accompanied by longitudinal instability in the subsonic high-lift range due, in part, to a spanwise flow of air in the boundary layer. One device that has met with some degree of success in restricting this spanwise flow is the stall-control fence or vane (references 1 to 8).

[redacted]

No systematic study of fences has been made to determine their optimum size, shape, and position for a range of wing design parameters. In a few instances, however, marked improvement in longitudinal stability has been achieved using fences of arbitrary size and shape (for example, see references 6 and 8). Inasmuch as a nonretractable fence configuration would be desirable, it is of interest to know the effects of fences on the aerodynamic characteristics of sweptback wings at high speeds. Consequently, the data of available wind-tunnel investigations of fences on sweptback wings at transonic and supersonic speeds have been compiled and analyzed. The present paper summarizes the results of this study.

Data are included from investigations in the Langley 8-foot high-speed tunnel, the Langley high-speed 7- by 10-foot tunnel, and the Langley 9- by 12-inch supersonic blowdown tunnel and cover a low-lift range at transonic Mach numbers and at Mach number 1.9. Four of the fences investigated were essentially full chord in length, while the others extended over only a portion of the chord. The fences were all of moderate size having a height above the wing-chord plane of less than 14 percent of the local chord.

SYMBOLS

C_L lift coefficient $\left(\frac{\text{Lift of full-span model}}{qS}\right)$

C_D drag coefficient $\left(\frac{\text{Drag of full-span model}}{qS}\right)$

C_m pitching-moment coefficient; moment about reference axis $\left(\frac{\text{Moment of full-span model}}{qS\bar{c}}\right)$

C_l rolling-moment coefficient; moment about wind axis $\left(\frac{\text{Moment}}{qSb}\right)$

$C_l{}'$ rolling-moment coefficient; moment about body axis $\left(\frac{\text{Moment}}{qSb}\right)$

α angle of attack of the wing chord relative to free-stream direction

S wing area of full-span model

b	wing span
$\bar{c}$	mean aerodynamic chord $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$
c	local chord of airfoil in streamwise direction
y	spanwise distance from plane of symmetry
q	free-stream dynamic pressure
δ_a	aileron deflection measured in plane normal to hinge line (positive when trailing edge is deflected downward)
M_e	effective Mach number over span of bump models
M	free-stream Mach number
R	Reynolds number

MODELS

The geometric characteristics of each model are tabulated in table I, together with the test Mach number and Reynolds number. A typical fence installation is shown in figure 1. Detailed model dimensions are given in figure 2.

All thin chordwise devices protruding from the surface of the wing, with the exception of two configurations, are hereinafter called fences. These two configurations differ radically in size or shape from the rest and, for convenience of notation, one is designated a fin and the other a vane. (See fig. 2(d).) The fences were all mounted on the upper surface of the wing and were of comparable size. The heights above the wing-chord plane were less than 14 percent of the local chord. (See table I.) Outboard locations of fences for each configuration are shown in figure 2 in percent of semispan.

Two fences, rectangular in shape, were investigated on model 1 and were mounted parallel to the free air stream. The upper edge of these fences had a height above the wing-chord plane of 11.5 percent of the chord. The larger of the two fences extended from 5.7 percent of the chord forward of the leading edge to the trailing edge. The smaller fence extended from the same point ahead of the leading edge to 40.3 percent of the chord. (See fig. 2(a).)

A fence having a full chord length and a constant height above the wing upper surface of 60 percent of the maximum local airfoil thickness was used on models 3 and 4. (See table I for maximum fence height in percent chord.) This fence was also used in model 2 but modified to extend over only 95 percent of the chord measured from the trailing edge. Also on model 2 a fence of greater height than the constant-height fence, but with a length of only 68 percent of the chord, was investigated. Both fences mounted on model 2 were inclined outboard at an angle of 1.8° to the plane of symmetry (fig. 2(b)).

In addition to the constant-height fence, a triangular fin and a leading-edge vane were tested separately on model 4. The vane was similar to a configuration found to be effective in the low-speed investigation of reference 1.

TESTS

The semispan model 1 was tested in the Langley high-speed 7- by 10-foot tunnel utilizing the transonic-bump method for obtaining transsonic speeds. ($M = 0.6$ to 1.10). A description of the balance, by means of which force and moment data were obtained, and also a discussion of factors affecting the test results obtained in this tunnel are presented in reference 9.

The investigation of the complete airplane model 2 was conducted in the Langley 8-foot high-speed tunnel, which is of the closed-throat, single-return type. A plaster liner was installed in the tunnel at the minimum section, extending upstream to form the subsonic test section ($M = 0.6$ to 0.95) and downstream to form the supersonic test section ($M = 1.2$). A description of the balance system used to obtain force and moment data is given in reference 10. A discussion of factors affecting the test results obtained in this tunnel are presented in reference 11.

Semispan models 3 and 4 were investigated in the Langley 9- by 12-inch supersonic blowdown tunnel at a Mach number of 1.9. A description of the balance system used to obtain force and moment data and also the discussion of test conditions influencing the results of this investigation are given in reference 12.

RESULTS AND DISCUSSION

Data from investigations of models 1 and 2 at transonic speeds are presented in figures 3 and 4, respectively. (These figures are in the same form as they are in references 9 and 10.) Some aerodynamic characteristics of models 3 and 4 at a Mach number of 1.9 are presented in figures 5 to 7.

The exact increment of drag coefficient due to fences was difficult to evaluate since the increments in each case were of the same order as the experimental accuracy of the investigations and in no case greater than 0.005. In general, the fences caused a slight rise in drag coefficient, which normally did not exceed 0.002, an amount equal to about 5 percent of the total drag coefficient for these wings. In the case of model 1 (fig. 3), a slight decrease in C_D was noted at subsonic Mach numbers. A triangular fin protruding from both upper and lower surfaces of model 4 increased the drag coefficient about 0.0025 at a Mach number of 1.9 (fig. 7). Use of a small leading-edge vane caused no discernible effect on drag at a Mach number of 1.9 (fig. 7).

The effect of fences on the lift coefficient was small and of minor importance. The slight change in lift-curve slopes due to a fence on model 1 and a fin on model 4 were negligible.

The effect of fences on the longitudinal stability of models 2, 3, and 4 appeared, in general, to be small. For model 1, however, a more linear variation of pitching moment with lift coefficient was produced at Mach numbers above and below sonic velocity for the range of lift coefficients attained in the investigation (fig. 3). This effect of fences appeared as a slight stabilizing trend in the pitching-moment characteristics below sonic velocity and a destabilizing trend above sonic velocity. In a similar investigation (reference 13) of a wing having a leading-edge sweepback of 60.9°, but otherwise the same geometric characteristics as model 1, the same linearizing effect on the pitching-moment curves was shown for Mach numbers from 0.7 to 1.15. The leading-edge vane (found to improve the longitudinal stability of a wing at low speeds, reference 1) had no effect on pitching moment at a Mach number of 1.9 (fig. 7).

A decrease in aileron effectiveness of model 4 at a Mach number of 1.9 was produced by the addition of a triangular fin, which protruded from both upper and lower surfaces of the wing adjacent to the inboard end of the aileron (fig. 7). Also a full-chord, upper-surface fence, which improved the low-speed aileron effectiveness of a similar swept-back wing (reference 7), produced a slight decrease in effectiveness for up-aileron deflections greater than 6° when the fence was located at the inboard end of the aileron (fig. 6(b)). However, moving the fence inboard 9 percent of the semispan resulted in about the same aileron effectiveness as the plain wing. A leading-edge vane located at the same spanwise station as the inboard end of the aileron caused a negligible loss of effectiveness (fig. 7).

CONCLUDING REMARKS

A study was made of available wind-tunnel investigations of thin chordwise fences on four moderately sweptback wings in the low-lift range at transonic Mach numbers and at Mach number 1.9. The results indicate no large detrimental effects on lift or pitching moment at transonic or supersonic speeds. The increase in drag coefficient attributable to fences was of about the same order as the experimental accuracy of the investigations and was generally less than 0.002. The effect of fences on the lift coefficient was small. In the transonic speed range, the pitching-moment variation with lift coefficient for one wing was found to be more linear when fences were used. At a Mach number of 1.9, aileron effectiveness appeared to be reduced when the fence or fin was located adjacent to the inboard end of the aileron but was not influenced when the fence was moved slightly inboard.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va.

REFERENCES

1. Weil, Joseph, Comisarow, Paul, and Goodson, Kenneth W.: Longitudinal Stability and Control Characteristics of an Airplane Model Having a 42.8° Sweptback Circular-Arc Wing with Aspect Ratio 4.00, Taper Ratio 0.50, and Sweptback Tail Surfaces. NACA RM L7G28, 1947.

2. Graham, Robert R., and Conner, D. William: Investigation of High-Lift and Stall-Control Devices on an NACA 64-Series 42° Sweptback Wing with and without Fuselage. NACA RM L7G09, 1947.

3. Hopkins, Edward J.: A Wind-Tunnel Investigation at Low Speed of Various Lateral Controls on a 45° Sweptback Wing. NACA RM A7L16, 1948.

4. Guryansky, Eugene R., and Lipson, Stanley: Effect of High-Lift Devices on the Longitudinal and Lateral Characteristics of a 45° Sweptback Wing with Symmetrical Circular-Arc Sections. NACA RM L8D06, 1948.

5. Koven, William, and Graham, Robert R.: Wind-Tunnel Investigation of High-Lift and Stall-Control Devices on a 37° Sweptback Wing of Aspect Ratio 6 at High Reynolds Numbers. NACA RM L8D29, 1948.

6. Foster, Gerald V., and Fitzpatrick, James E.: Longitudinal-Stability Investigation of High-Lift and Stall-Control Devices on a 52° Sweptback Wing with and without Fuselage and Horizontal Tail at a Reynolds Number of 6.8×10^6. NACA RM L8I08, 1948.

7. Spooner, Stanley H., and Woods, Robert L.: Low-Speed Investigation of Aileron and Spoiler Characteristics of a Wing Having 42° Sweepback of the Leading Edge and Circular-Arc Airfoil Sections at Reynolds Numbers of Approximately 6.0×10^6. NACA RM L9A07, 1949.

8. Woods, Robert L., and Spooner, Stanley H.: Effects of High-Lift and Stall-Control Devices, Fuselage, and Horizontal Tail on a Wing Swept Back 42° at the Leading Edge and Having Symmetrical Circular-Arc Airfoil Sections at a Reynolds Number of 6.9×10^6. NACA RM L9B11, 1949.

9. Weil, Joseph, and Goodson, Kenneth W.: Aerodynamic Characteristics of a Wing with Quarter-Chord Line Swept Back 45°, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L9A21, 1949.

10. Osborne, Robert S.: High-Speed Wind-Tunnel Investigation of the Longitudinal Stability and Control Characteristics of a $\frac{1}{16}$-Scale Model of the D-558-2 Research Airplane at High Subsonic Mach Numbers and at a Mach Number of 1.2. NACA RM L9C04, 1949.

11. Ritchie, Virgil S., Wright, Ray H., and Tulin, Marshall P.: An 8-Foot Axisymmetrical Fixed Nozzle for Subsonic Mach Numbers up to 0.99 and for a Supersonic Mach Number of 1.2. NACA RM L50A03a, 1950.

12. Goin, Kennith L.: Investigation at a Mach Number of 1.9 and a Reynolds Number of 2.2×10^6 of Several Flap-Type Lateral-Control Devices on a Wing Having 42.7° Sweepback of the Leading Edge. NACA RM L9A18a, 1949.

13. King, Thomas J., Jr., and Myers, Boyd C., II: Aerodynamic Characteristics of a Wing with Quarter-Chord Line Swept Back 60°, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L9G27, 1949.

TABLE I

TABULATION OF TEST CONDITIONS AND CONFIGURATIONS

Model		1	2	3	4
Leading-edge sweepback		46.7°	38.8°	45°	42.7°
Aspect ratio		4.0	3.6	1.8	4.0
Taper ratio		0.60	0.565	1.0	0.5
Airfoil section	Type	NACA 65A-series	NACA 63_1-series	NACA 65A-series	Circular arc
	[1]Thickness	6.0	8.7 root 10.4 tip	7.0	8.0
[2]Maximum fence height		11.5	13.7 and 10.2	7.7	8.8
Configuration		Semispan wing plus fuselage	Complete airplane configuration	Semispan wing in presence of fuselage	Semispan wing alone and in presence of fuselage
Mach number		0.6 to 1.10	0.6 to 0.95 and 1.2	1.9	1.9
R Based on $\bar{c}$		0.58×10^6 to 0.78×10^6	1.55×10^6 to 1.80×10^6	2.3×10^6	2.2×10^6
Test facility		Transonic bump 7- by 10-foot high-speed tunnel	8-foot high-speed tunnel	9- by 12-inch blowdown tunnel	9- by 12-inch blowdown tunnel
Reference		9	10	Unpublished	Unpublished
Figures		2(a) and 3	2(b) and 4	2(c) and 5	2(d) and 6(a) 6(b) and 7

[1]Thickness is in percent chord measured parallel with air stream.
[2]Height is in percent chord measured above chord plane.

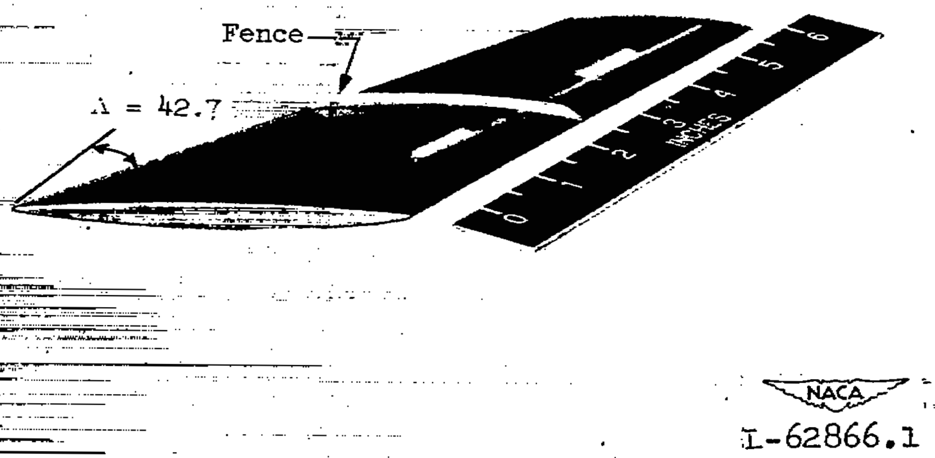
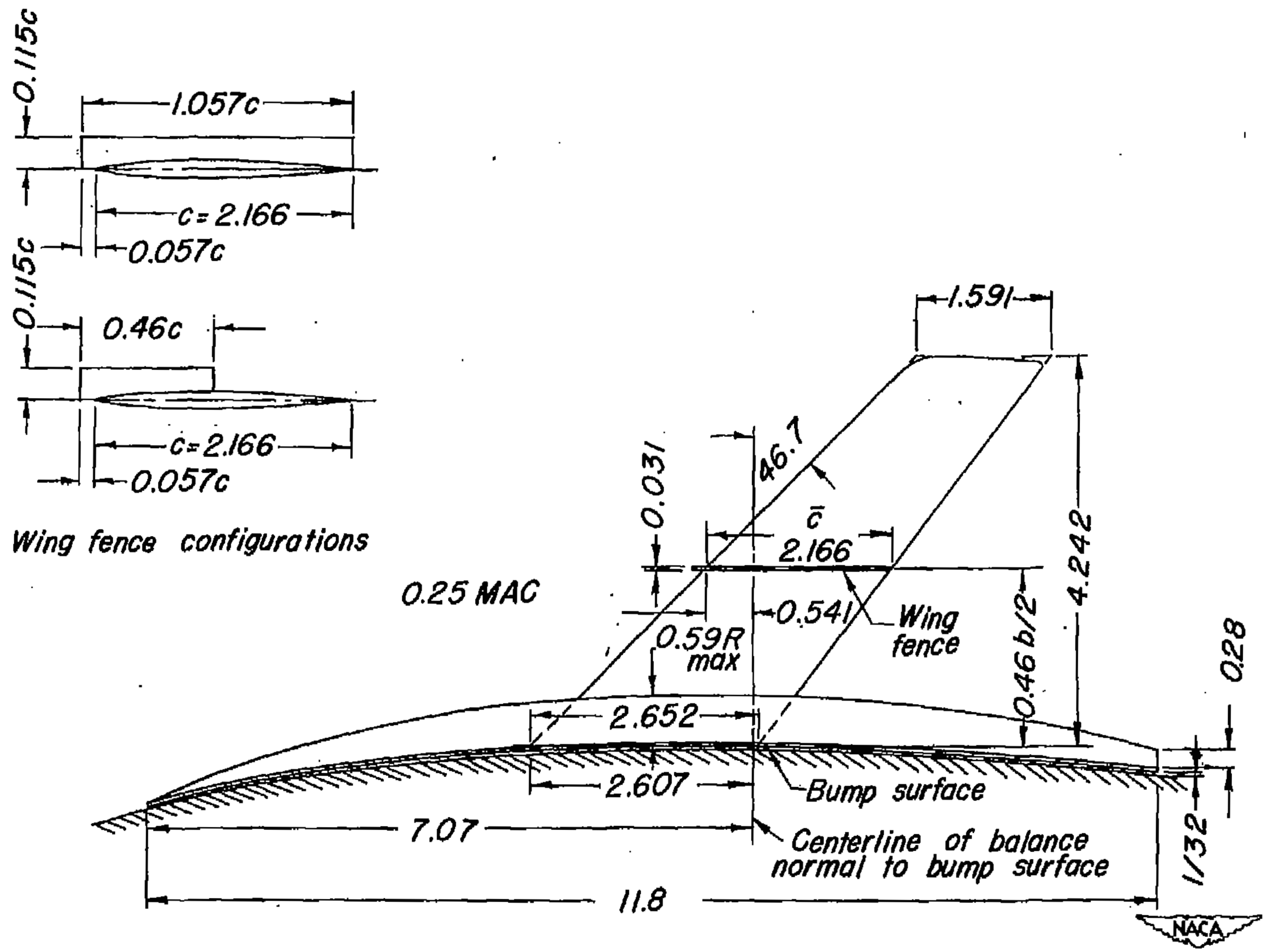
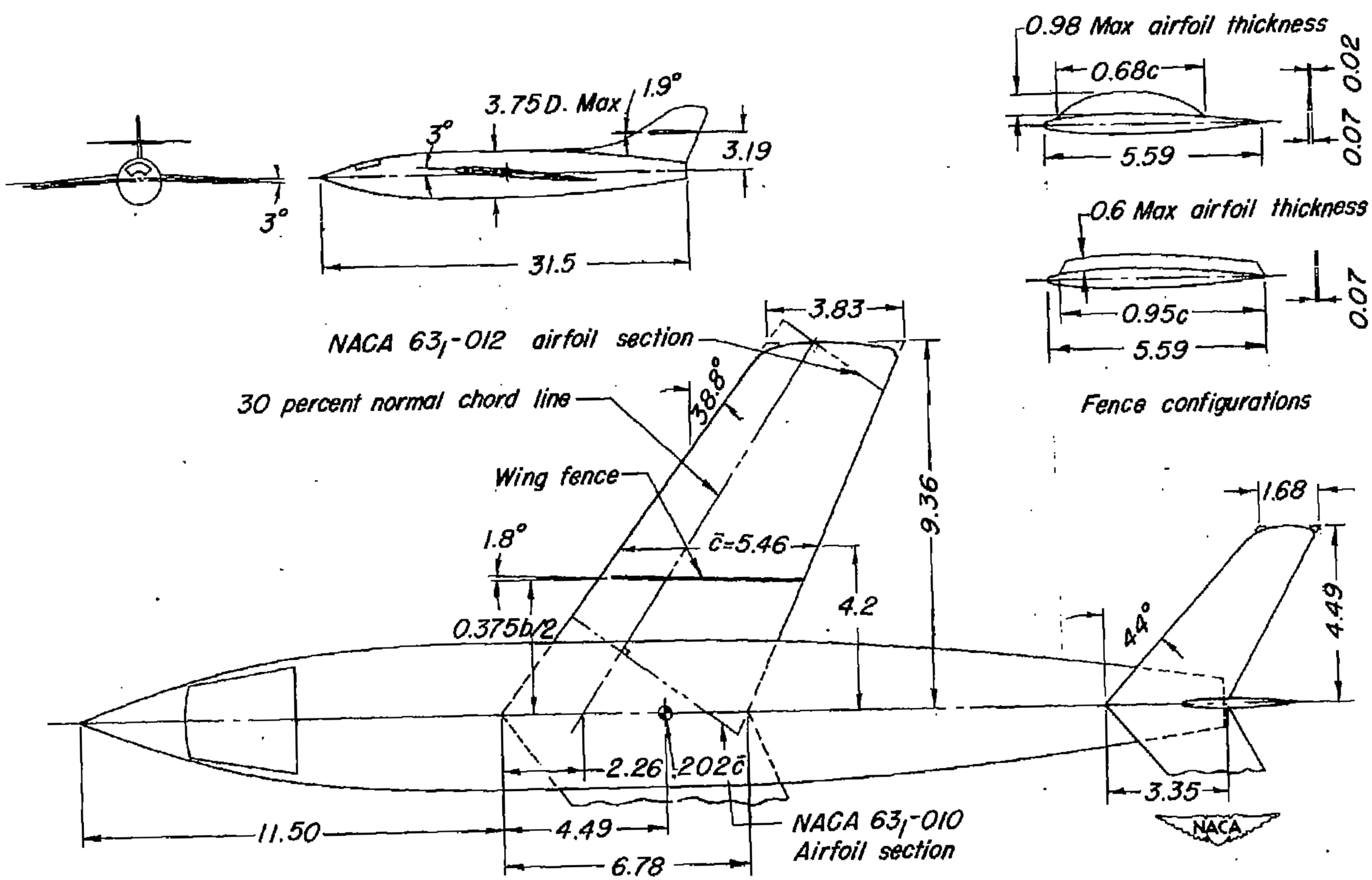


Figure 1.- Photograph of model 4 showing fence installed.



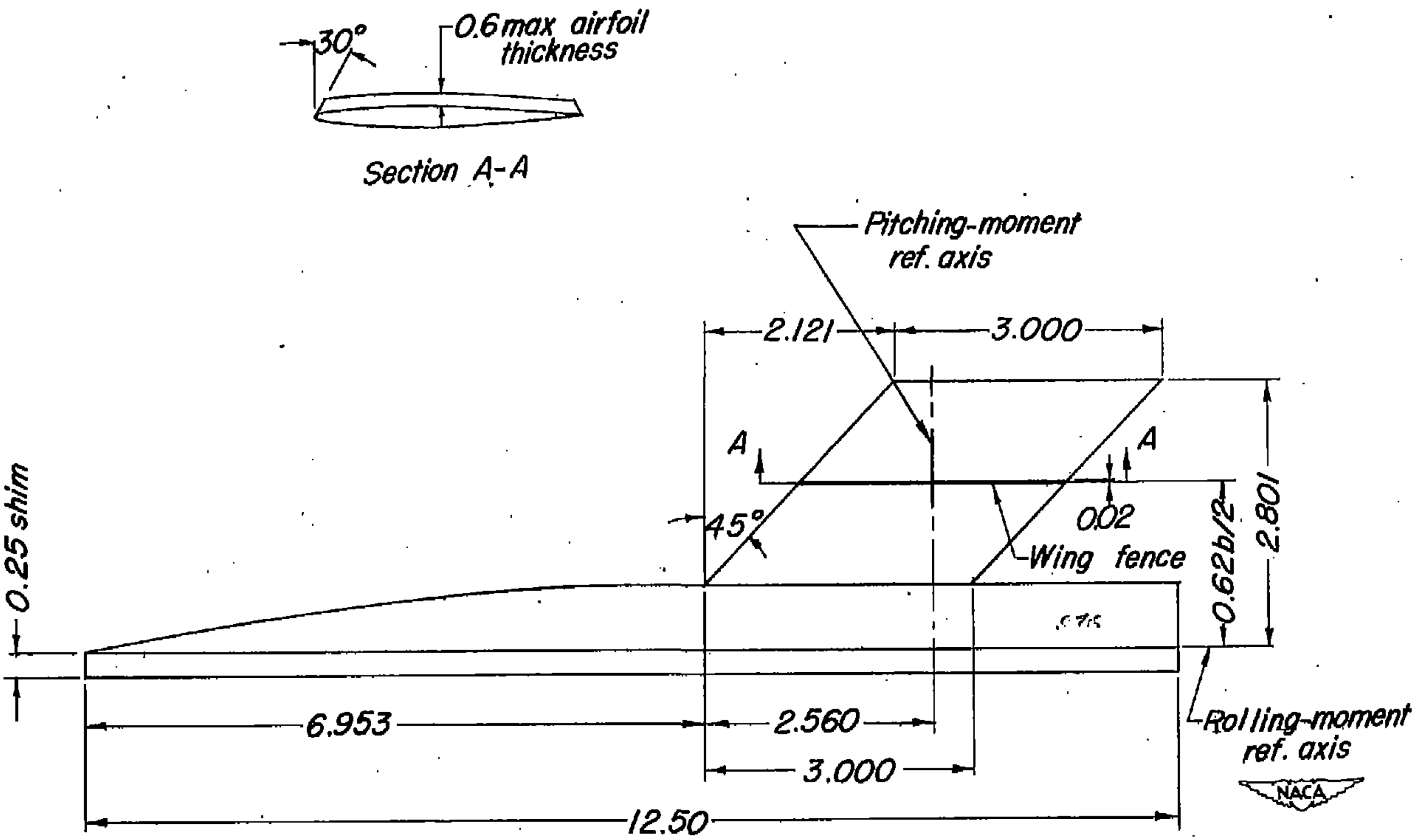
(a) Model 1.

Figure 2.- Details of models. (All dimensions are in inches.)



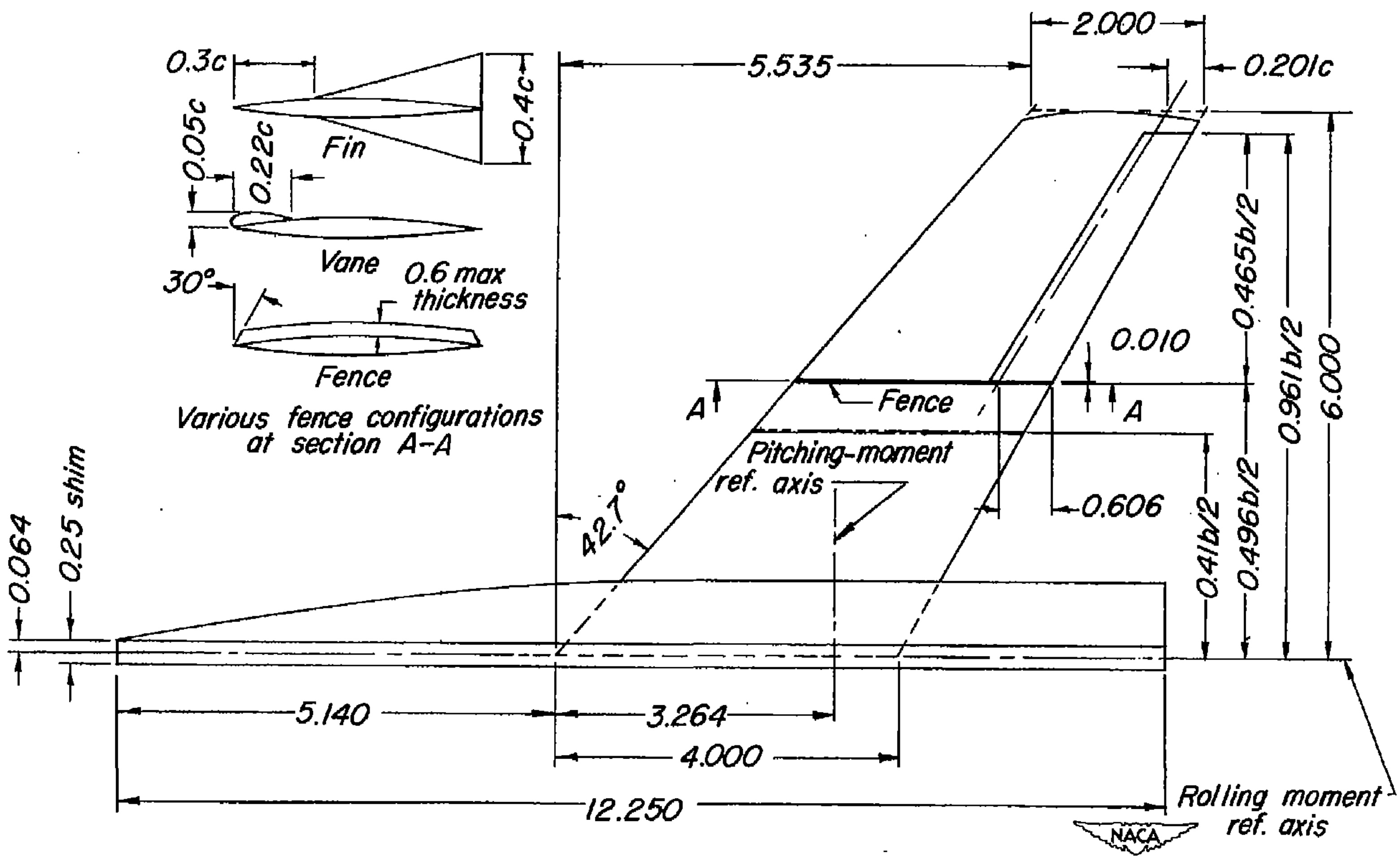
(b) Model 2.

Figure 2.- Continued.



(c) Model 3.

Figure 2.- Continued.



(d) Model 4.

Figure 2.- Concluded.

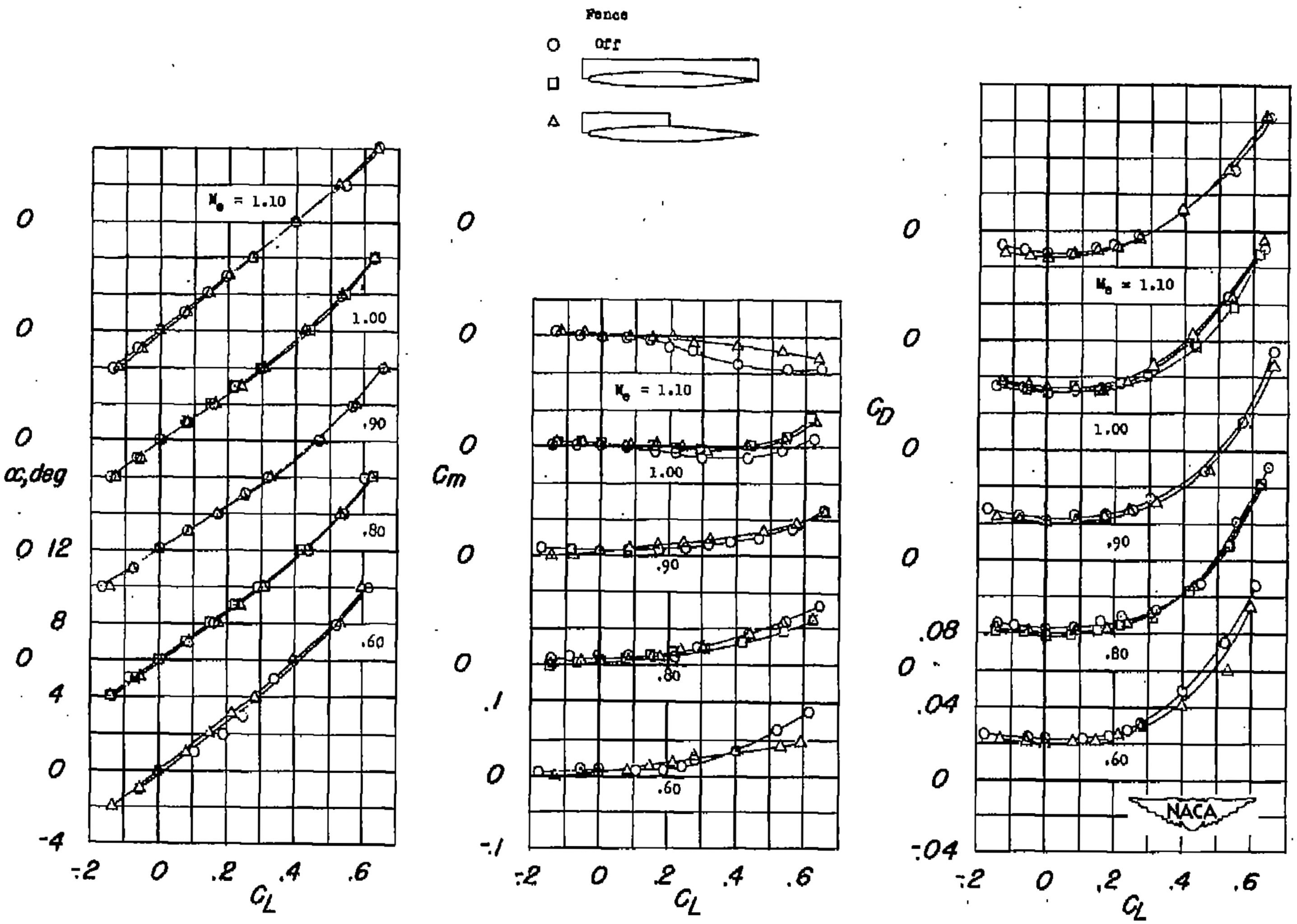


Figure 3.- Effects of fences on the aerodynamic characteristics of model 1 at Mach numbers from 0.6 to 1.175. Leading-edge sweepback = 46.7°; aspect ratio = 4.0.

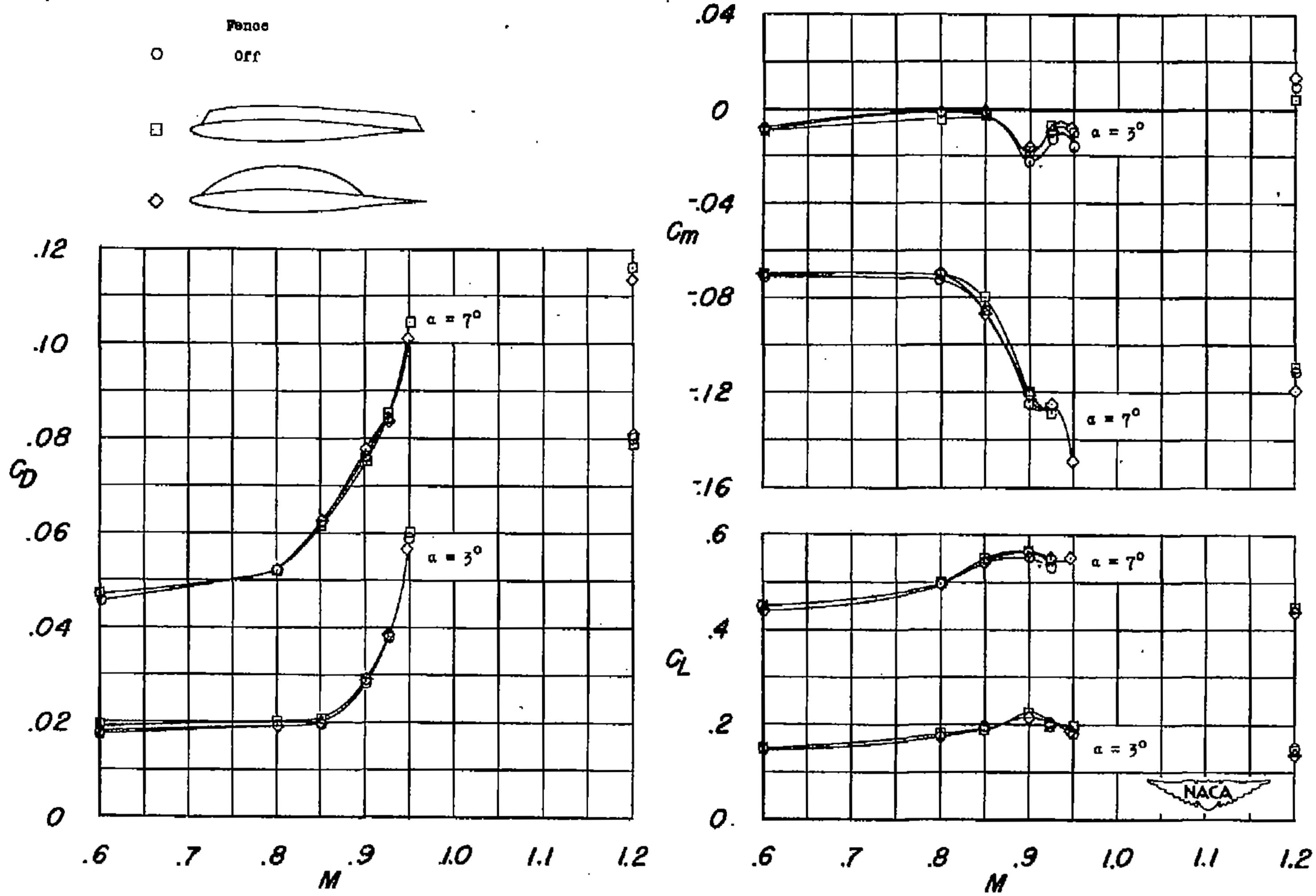


Figure 4.- Effects of fences on the aerodynamic characteristics of model 2 at Mach numbers from 0.6 to 0.95 and 1.2. Leading-edge sweepback = 38.8°; aspect ratio = 3.6.

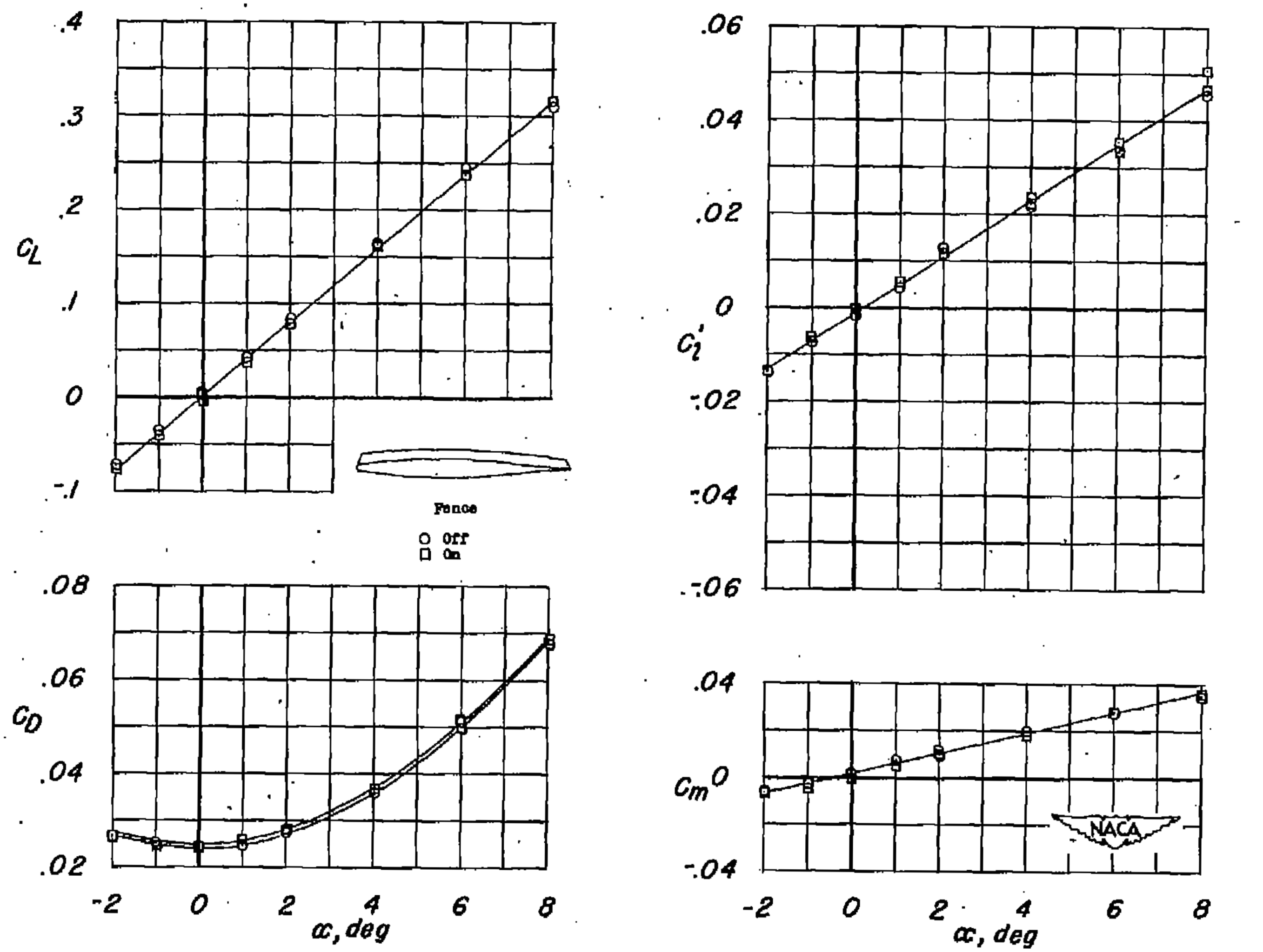
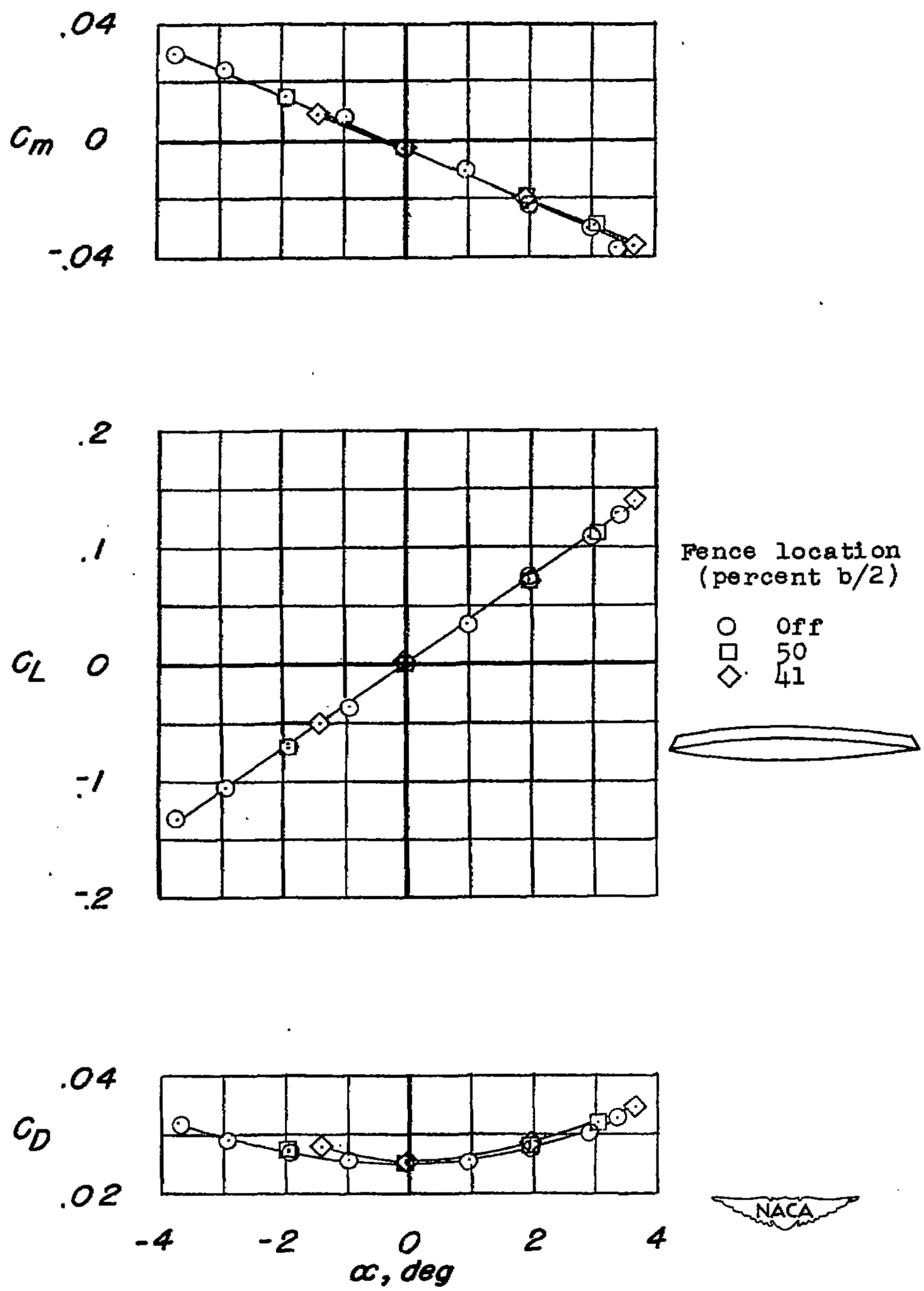


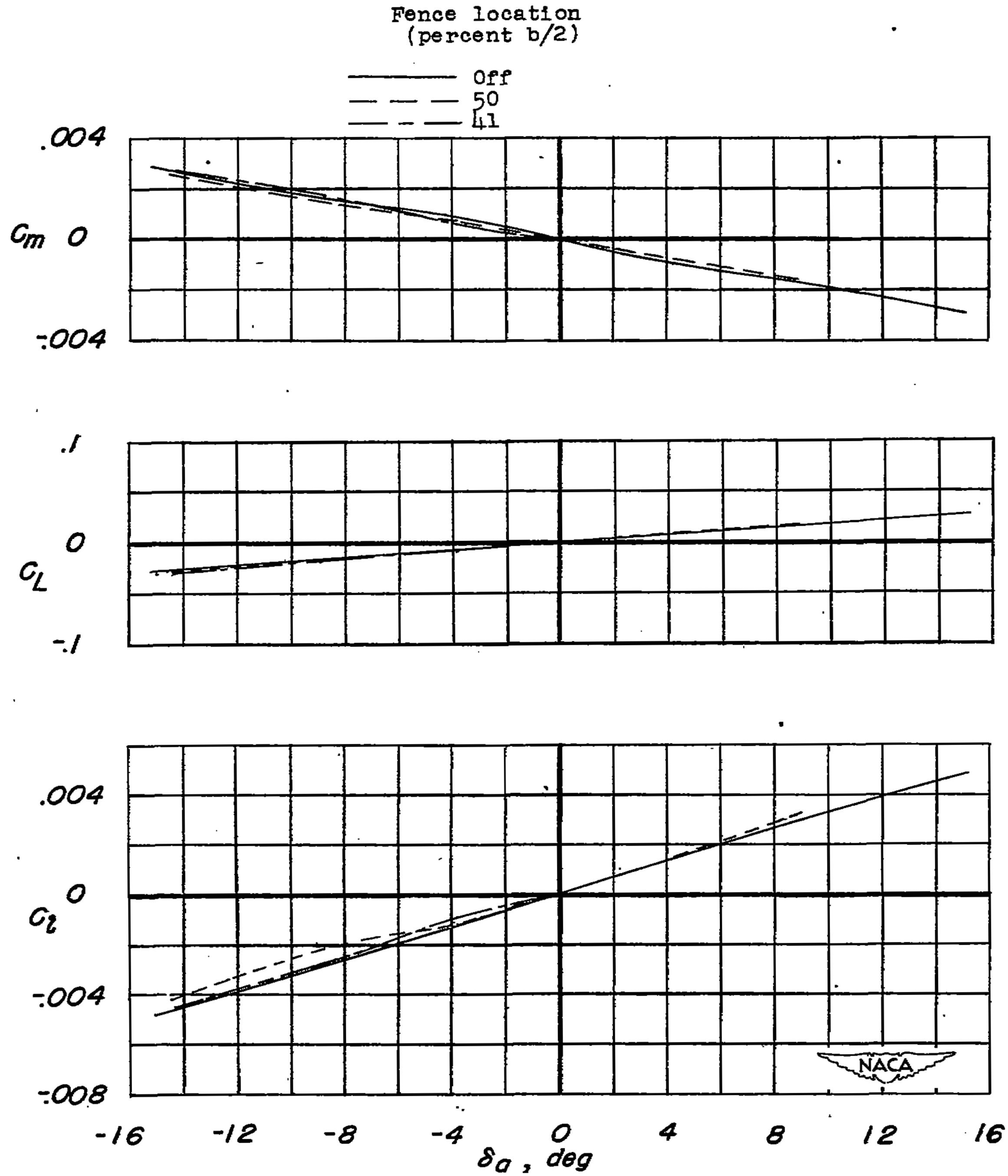
Figure 5.- Effects of a fence on the aerodynamic characteristics of model 3 at a Mach number of 1.9. Leading-edge sweepback = 45°; aspect ratio = 1.8.



(a) C_m, C_L, and C_D against α. $\delta_a = 0$.

Figure 6.- Effects of a fence on the aerodynamic characteristics of model 4 in the presence of a fuselage at a Mach number of 1.9. Leading-edge sweepback = 42.7°; aspect ratio = 4.0.

[redacted]



(b) C_m, C_L, and C_l against δ_a. $\alpha = 0$.

Figure 6.- Concluded.

[redacted]

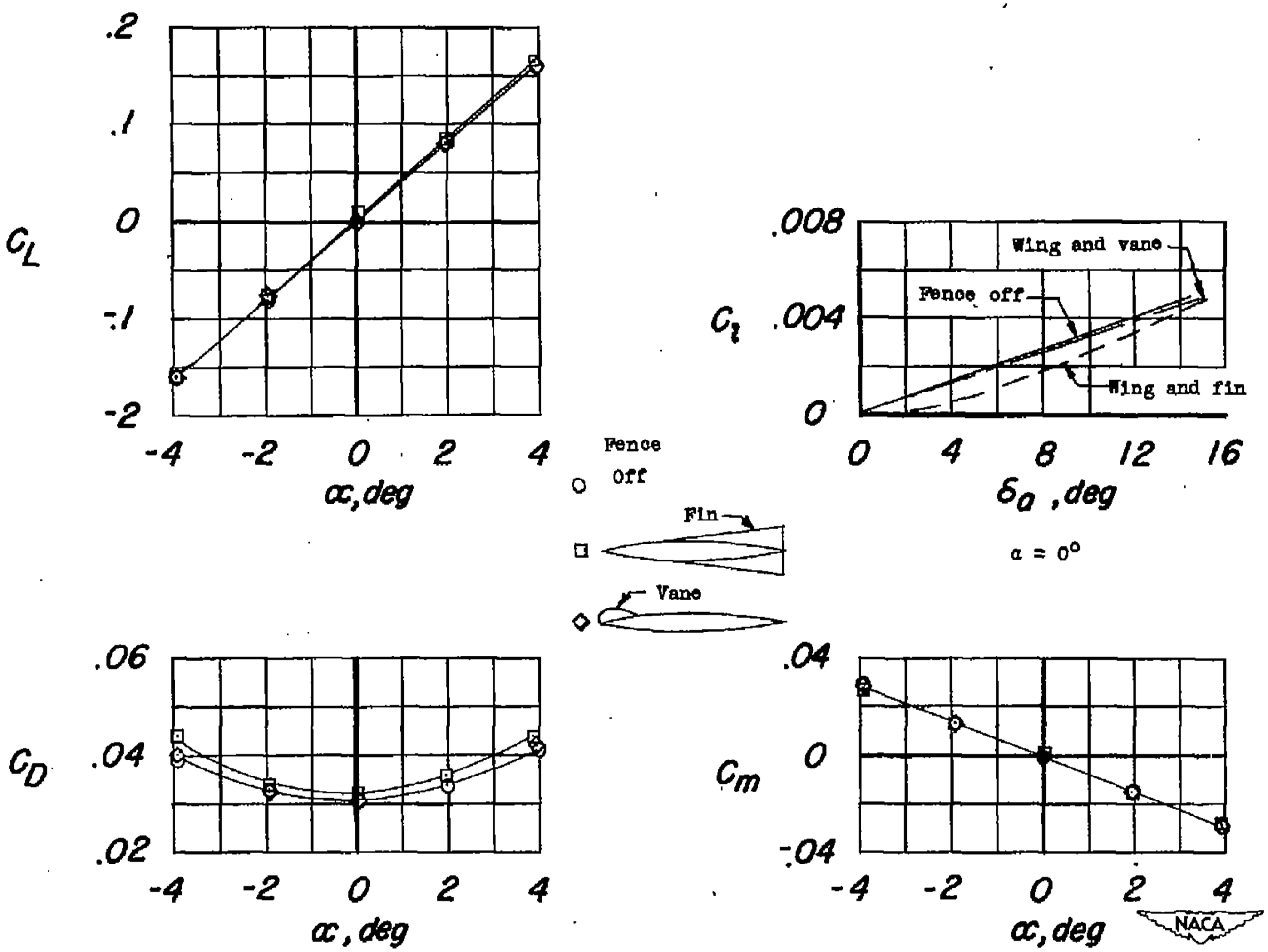


Figure 7.- Effects of a stall-control vane and fin at 50 percent b/2 on the aerodynamic characteristics of model 4 at a Mach number of 1.9; leading-edge sweepback = 42.7°; aspect ratio = 4.0.