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RESEARCH MEMORANDUM

EFFECT OF LEADING-EDGE CHORD-EXTENSIONS ON THE AERODYNAMIC CHARACTERISTICS OF A 45° SWEPTBACK WING-FUSELAGE COMBINATION AT MACH NUMBERS OF 0.40 TO 1.03

By F. E. West, Jr., George Liner, and Gladys S. Martz

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

April 14, 1953

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EFFECT OF LEADING-EDGE CHORD-EXTENSIONS ON THE AERODYNAMIC CHARACTERISTICS OF A 45° SWEPTBACK WING-FUSELAGE COMBINATION AT MACH NUMBERS OF 0.40 TO 1.03

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SUMMARY

An investigation has been conducted in the Langley 16-foot transonic tunnel to determine the effect of leading-edge chord-extensions on the aerodynamic characteristics of a sweptback wing-fuselage combination at Mach numbers of 0.40 to 1.03. The wing had 45° sweep, aspect ratio of 4, taper ratio of 0.6, and NACA 65A006 airfoil sections. The investigation included chord-extensions that covered from 55, 65, or 70 percent of the wing semispan to almost the wing tip. They extended chordwise either 15 or 20 percent of the local basic-wing chord.

Addition of chord-extensions to the basic model usually decreased the magnitude and abruptness of the pitching-moment variations with lift at all Mach numbers, but had only a small effect on the variation of the longitudinal-stability parameter with Mach number at low lift coefficients. The most unsatisfactory pitching-moment characteristics for the model equipped with chord-extensions occurred at Mach numbers of 0.90 and 0.94. Addition of the chord-extensions also generally improved the lift characteristics, decreased lift-drag ratio at low lift coefficients, and increased lift-drag ratio above lift coefficients of about 0.40 or 0.50.

In general, the effect of shifting the inboard end of the chord-extensions from 55 to 70 percent of the wing semispan was to improve the variation of pitching moment with lift, cause slightly poorer lift characteristics, and cause only slight changes in lift-drag ratio. Increasing chord-extension chord length from 15 to 20 percent of the local basic-wing chord had only slight effects on the pitching-moment and lift characteristics but produced a detrimental effect on lift-drag ratio. The largest effect of drooping the chord-extensions from 0° to 2.2° was to increase lift-drag ratio.

INTRODUCTION

One of the current problems at subsonic and transonic speeds is to improve the undesirable longitudinal stability characteristics of sweptback wings designed for use at transonic speeds. Typical examples of these undesirable characteristics are shown in reference 1 for low subsonic speeds and in reference 2 for high subsonic and transonic speeds.

The longitudinal-stability problem at low subsonic speeds has been greatly alleviated by the addition to sweptback wings of fences or leading-edge devices such as chord-extensions, extensible flaps, and slats (for example, see refs. 3 to 5). These devices were primarily effective because they delayed to higher angles of attack flow separation on the upper surface of the outboard sections. As this flow separation over the outboard sections has also been observed at high subsonic speeds (ref. 6) for moderate and high angles of attack, it seemed possible that the devices used at low speeds might also improve the longitudinal stability characteristics of sweptback wings at high subsonic and transonic speeds. Of these devices, leading-edge chord-extensions appeared most suitable for use at high subsonic and transonic speeds as the rather limited amount of low-speed data (refs. 3 and 4) indicate that they usually provide the highest lift-drag ratios. They also are structurally simple, and tests at supersonic speeds (ref. 7) showed no detrimental effects of the extensions on lift, drag, or pitching moment.

Hence, an investigation of several leading-edge chord-extensions has been made on a 45° sweptback wing-fuselage combination in the Langley 16-foot transonic tunnel at Mach numbers from 0.40 to 1.03. This paper presents the results of the force measurements made during the investigation. Shown are the effects of varying span, chord, and droop of the extensions on the lift, drag, and pitching-moment characteristics. Also shown are data indicating the effect of adding fences to one of the leading-edge chord-extension configurations. The basic-model force data were obtained from reference 8. A few results obtained during the investigation of one of the chord-extension configurations have been published in reference 9.

SYMBOLS

M	free-stream Mach number
R	Reynolds number based on $\bar{c}$
q	free-stream dynamic pressure

S	wing area (basic wing)
b	wing span
b_i	location of inboard end of chord-extension
c	local basic-wing chord
$\bar{c}$	basic-wing mean aerodynamic chord
t_{max}	maximum wing thickness at any spanwise station
α	angle of attack of fuselage center line relative to test-section center line
δ_E	angle of leading-edge chord-extension chord line relative to local wing chord line (positive value indicates droop)
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
C_m	pitching-moment coefficient about $0.25\bar{c}$, $\frac{\text{Pitching moment}}{qS\bar{c}}$
$\frac{dC_L}{d\alpha}$	lift-curve slope
$\frac{dC_m}{dC_L}$	longitudinal-stability parameter
$\frac{(L/D)_E}{(L/D)_B}$	ratio of lift-drag ratio for model with leading-edge chord-extensions to lift-drag ratio for model without leading-edge chord-extensions

Subscripts:

max	maximum

APPARATUS

Tunnel.- The Langley 16-foot transonic tunnel which is a single-return octagonal slotted-throat wind tunnel is described in reference 10. As indicated in this reference the maximum variation of the average Mach number along the test-section center line in the vicinity of the model is about ±0.002.

Model.- The geometric details of the basic model configurations and of the various leading-edge chord-extensions and fences are shown in figure 1. The basic model with its six-component electrical strain-gage balance is the same model described in reference 8.

The steel wing had 45° sweepback of the quarter-chord line, aspect ratio 4, taper ratio 0.6, and NACA 65A006 airfoil sections (see ref. 11 for ordinates) parallel to the plane of symmetry. The wing was designed to have no incidence, dihedral, or twist, and was symmetrically mounted on the fuselage. The ordinates given in figure 1 for the magnesium fuselage correspond to those of a body of revolution having a fineness ratio of 12 that has been reduced in length by cutting off the rear portion to give a fineness ratio of 10.

The leading-edge chord-extensions which extended 15 percent of the local basic-wing chord were investigated with the inboard end located at 55 and 65 percent of the wing semispan. Chord-extensions which extended 20 percent of the local basic-wing chord were investigated with the inboard end located at 65 and 70 percent of the wing semispan. The outboard end for all chord-extensions was at 99 percent of the wing semispan. The chord-extensions at zero droop angle had the same section ordinates back to their point of maximum thickness as the corresponding spanwise wing airfoil sections. When the droop angle was not zero, the ordinates were slightly modified to maintain a smooth fairing in the vicinity of the intersection between the extension chord line and the wing chord line. Between the maximum thickness points of the leading-edge chord-extensions and the wing, the airfoil contour was parallel to the wing chord line. The chord-extensions were fabricated of steel back to the 14-percent wing chord line (the chord line about which the extensions were drooped), and plastic was used to continue the fairing to about the 40-percent wing chord line (maximum thickness of the wing).

Usually the model was tested with the quarter chord of the wing mean aerodynamic chord located at the same longitudinal position as the maximum body diameter. This configuration, known as the wing-normal configuration, is shown mounted in the test section in figure 2. However, tests were also made of a wing-aft configuration which was accomplished by shifting the body forward so that the quarter chord of the mean aerodynamic chord was located $1.197\bar{c}$ to the rear of the maximum body diameter. The sting sleeve which was used with the basic wing-aft configuration (see fig. 1) was not used for the wing-aft configuration with the leading-edge chord-extensions.

Base pressure was measured at two positions that were located a few inches inside the base of the model.

Support system.- The model support system is described in reference 8. The support system was arranged so that the model was located near the center of the tunnel at all angles of attack.

TESTS

Although some data were obtained at a Mach number of 0.40, the force data for the leading-edge chord-extension and fence configurations were usually obtained at Mach numbers from 0.60 to 1.03. For most cases, tests were run by keeping Mach number constant and varying angle of attack. Generally, an angle-of-attack range of -2° to about 26° was obtained at Mach numbers of 0.40 and 0.60 and at higher speeds the maximum obtainable angle of attack decreased progressively with increasing Mach number to 8° at a Mach number of 1.03 because of limited strength of the model support system. However, by strengthening the support strut to increase the allowable stresses some higher angles of attack were obtained for one configuration.

Base pressure was measured for only the 15-percent-chord leading-edge chord-extension configurations. A comparison of these measurements with those for the basic model indicated that for a given sting shape the differences in base pressure were too small to affect drag and, hence, base pressures were not measured for the other configurations.

The estimated accuracy of base pressure coefficient is ±0.005. Estimated accuracy of the force data to be presented is ±0.01 for lift coefficient, ±0.001 for drag coefficient at low lift, ±0.005 for drag coefficient at high lift, and ±0.005 for pitching-moment coefficient. Accuracy of angle of attack is estimated to be better than $\pm0.1^{\circ}$.

The variation of Reynolds number with Mach number shown in figure 3 is based on data for the basic-model, chord-extension, and fence plus chord-extension configurations.

CORRECTIONS

Angle of attack.- The angle of attack has been corrected for support-system deflection due to aerodynamic loading by the method described in reference 8.

Drag.- The drag data presented have not been adjusted for base pressure or sting interference. However, by using the base pressures presented in reference 8 the drag data for the wing-normal configurations can be adjusted to the condition of free-stream pressure at the base of the model.

Tunnel-wall effects.- No tunnel-wall corrections have been applied to the data. Reference 12 indicates that the tunnel-wall effects for this model are small and generally negligible.

RESULTS AND DISCUSSION

Lift, drag, and pitching-moment characteristics of the wing-normal configurations with and without chord-extensions are shown in figures 4 and 5. Characteristics for wing-normal configurations having a change in chord-extension chord length are shown in figure 6. Characteristics for wing-normal configurations equipped with fences are shown in figure 7. Figure 8 shows the lift and pitching-moment characteristics for the wing-aft configuration with and without chord-extensions. Drag characteristics are not shown in figure 8 because the previously noted difference in sting shape between the wing-aft configurations with and without chord-extensions may affect the drag.

In figures 4 to 7 the characteristics for some of the configurations have been presented in more than one figure for purposes of comparison. For these cases, test points and faired curves for a given configuration have been plotted on one figure and only the faired curves have been duplicated on other figures. In order to illustrate the probable characteristics at higher lift coefficients, some of the basic-model pitching-moment curves in figures 4(d) and 5(d) have been extrapolated by using Langley 16-foot transonic tunnel data from reference 12 for a geometrically similar, but smaller model. Inasmuch as basic-model data at a Mach number of 0.40 were not available for the comparisons in figure 5, data from reference 13 for a geometrically similar, but slightly smaller model were used for the basic-model configuration.

Effect of Chord-Extensions on Longitudinal Stability

for Wing-Normal Configuration

Study of the pitching-moment curves of figures 4 and 5 shows that in nearly every instance adding chord-extensions to the basic model improved the pitching-moment characteristics. That is, the magnitude and abruptness of the pitching-moment variations with lift were usually reduced considerably. However, the reductions in the pitching-moment variations were not sufficient to completely eliminate the nonlinearities in the curves for any of the Mach numbers. The most unsatisfactory pitching-moment characteristics for the model equipped with chord-extensions occurred at Mach numbers of 0.90 and 0.94. Somewhat similar effects of Mach number have also been noted in reference 14 for models equipped with chord-extensions or fences and in reference 15 for a model equipped with a drooped nose and fence combination.

Flow phenomena.- Low-speed studies discussed in reference 5 indicate that for wings with large sweepback and leading-edge radii that are small relative to the local chord an upper-surface leading-edge separation vortex is formed at low lift coefficients which moves out along the span and increases in chordwise extent as it moves outboard. The lift coefficient at which the effect of this vortex first becomes apparent for a given wing plan form depends on the leading-edge radius. An increase in leading-edge radius delays the formation of the vortex until higher lift coefficients are attained and also increases the possibility of trailing-edge separation changing the flow conditions. As lift is increased, the vortex effects first become apparent when they cause an increase in the loading over the outboard sections. This increased loading results in an increase in stability such as that shown by the basic-model pitching-moment curve in figure 4 at a lift coefficient of about 0.40 for a Mach number of 0.60. With further increases in lift the flow over the outboard sections separates. This flow separation results in a large destabilizing pitching-moment change similar to that shown for the basic model in figure 4 at a lift coefficient of about 0.60 for a Mach number of 0.60.

For a lifting condition a chord-extension creates a vortex at its inboard end (see ref. 16) which sweeps back across the wing in essentially a streamwise direction and prevents the movement of the leading-edge separation vortex to the outboard sections. The result is that the usual increase in stability at moderate lift coefficients is alleviated and that instability due to the separation is delayed to higher lift coefficients. The chord-extensions may also be effective because of a staggering of the pressure distributions at their inboard ends and because the breaks in the wing surface at the inboard ends act as physical barriers.

A study of the flow (ref. 17) over a model that is geometrically similar but one-third the size of the basic model used in these tests indicates the presence of a separation vortex along the entire leading edge at a Mach number of 0.80. Increasing Mach number above 0.80 appears to cause the vortex region to contract outward along the leading edge until it is apparently eliminated at Mach numbers of about 0.99 and higher. In the Mach number range above 0.80, shocks extending from the wing leading-edge fuselage juncture and the wing trailing-edge fuselage juncture have large effects on the flow and become more predominant as the Mach number is increased. These shocks sweep laterally across the wing and cause separation on the outboard sections.

On the basis of flow studies discussed in references 5, 16, and 17 it therefore seems reasonable that the description of the effect of chord-extensions at low speeds will also basically apply up to Mach numbers of about 0.80 for configurations that correspond closely to those discussed in this paper. The decrease in effectiveness of the chord-extensions at Mach numbers of 0.90 and 0.94 may be because the chord-extensions have little effect on detrimental shock effects.

Effect of chord-extension geometry on pitching moment.- It is difficult to choose the chord-extension configurations that cause the greatest improvement in the pitching-moment characteristics because none of the configurations are outstandingly best at all Mach numbers. A study of figure 6(c) indicates that increasing the length of a given chord-extension from 15 percent to 20 percent of the local basic-wing chord did not have much effect on the variation of pitching-moment coefficient with lift coefficient except at a Mach number of 0.90.

The pitching-moment curves of figure 4(d) indicate that of the 15-percent-chord chord-extensions the one having an inboard-end location at 65 percent of the wing semispan and having a droop angle of about 0° provided the greatest improvement in the pitching-moment characteristics at almost all Mach numbers. Moving the inboard end of this chord-extension 10 percent of the semispan farther inboard appeared to reduce its effectiveness. Drooping the chord-extension having an inboard location at 65 percent of the wing semispan slightly ($\delta_E = 2.2^{\circ}$) apparently delayed the stabilizing tendency at moderate lift coefficients to higher lift coefficients for Mach numbers up to 0.85. This occurred because drooping the chord-extension probably reduced the loading over the outboard sections at moderate lift coefficients.

Of the 20-percent-chord chord-extensions (fig. 5(d)), it appears that if the entire lift range for Mach numbers up to 0.90 are considered a chord-extension starting at 70 percent of the wing semispan improved the pitching-moment characteristics slightly more than a chord-extension of the same droop angle which started at 65 percent of the semispan.

The effect of slightly drooping one of the 20-percent-chord chord-extensions was similar to that noted for the 15-percent-chord chord-extensions.

Longitudinal-stability parameter.- Figure 9 shows the effect of two chord-extension configurations on the variation of the longitudinal-stability parameter with lift coefficient for several Mach numbers. At each Mach number, addition of chord-extensions to the basic model considerably reduced this variation and usually increased the lift coefficient at which trim might be achieved with a given tail configuration.

Figure 10 shows that the effect of the chord-extensions on the variation of the longitudinal-stability parameter with Mach number at lift coefficients of 0 and 0.40 for the wing-normal configurations was generally slight. None of the chord-extension configurations exhibited the abrupt changes in stability that occurred for the basic model at Mach numbers above 0.98 for a lift coefficient of 0.40.

Effect of Chord-Extensions on Lift for Wing-Normal Configurations

In general, the lift curves of figures 4 and 5 show that the addition of chord-extensions to the basic wing-normal configuration increased the lift-curve slopes at low lift coefficients, made the lift curves more linear at the lower Mach numbers, and increased lift coefficient at the higher angles of attack.

Usually, when the angle-of-attack range was sufficient for the lift curves to extend some distance beyond the linear range, the effect of the chord-extensions was to alleviate the decrease in lift-curve slope at the high angles of attack. This alleviation often resulted in an increase in lift coefficient of about 0.1 at a given angle of attack which was considerably greater than the increases to be expected from the additional wing area provided by the chord-extensions. The main exception to this alleviating of the decrease in lift-curve slope occurred at a Mach number of 0.90.

For most Mach numbers the chord-extensions with greater spans (figs. 4 and 5) appeared to provide the better lift characteristics. The effects of a small change in chord-extension droop angle (figs. 4 and 5) or chord length (fig. 6) were slight.

Lift-curve slope at lift coefficients of 0 and 0.4.- Figure 11 shows the effect of the chord-extensions on the variation of lift-curve slope of the wing-normal configurations with Mach number at lift coefficients of 0 and 0.40.

For Mach numbers below 0.94, the basic-model lift-curve slope increased as the lift coefficient increased from 0 to 0.40. This increase was probably due to the leading-edge separation vortex, previously discussed, causing exceptionally large increases in lift over the outboard wing sections. A somewhat similar increase in lift-curve slope also is shown for one of the chord-extension configurations $\left(0.20c, b_1 = 0.70b/2, \delta_E = 0.4^\circ\right)$ at a Mach number of 0.60. An increase of this magnitude may be due to errors that are less than the stated estimated accuracy. For the other chord-extension configurations, the lift-curve slope was only slightly affected by increasing lift coefficient from 0 to 0.4.

Addition of chord-extensions to the model caused increases in lift-curve slope at the higher Mach numbers (fig. 11) that appear to be essentially due to the additional area of the chord-extensions.

Effect of Chord-Extensions on Drag and Lift-Drag Ratios of Wing-Normal Configurations

The drag curves of figures 4(b) and (c) and 5(b) and (c) show that the effect of adding chord-extensions to the basic wing-normal configuration was to increase drag coefficient at low lift coefficients and usually to decrease it at moderate and high lift coefficients. Increasing Mach number usually made the increase at low lift coefficients greater and the decrease at moderate and high lift coefficients smaller.

Zero-lift drag.- The effect on the variation of zero-lift drag coefficient with Mach number of adding chord-extensions to the basic model is shown in figure 12. In general, this effect was to increase zero-lift drag coefficient at the lower Mach numbers and to cause larger increases in zero-lift drag in the drag-rise Mach number range. Changes in chord-extension geometry usually had no consistent effect throughout the Mach number range. However, drooping one of the 20-percent-chord chord-extensions had a favorable effect in the drag-rise Mach number range.

Lift-drag ratios.- Figure 13 shows a relative comparison of the variation of maximum lift-drag ratios with Mach number between the basic wing-normal configuration and the wing-normal configurations equipped with chord-extensions. Usually the addition of chord-extensions to the model caused decreases in maximum lift-drag ratio. Decreasing chord-extension span and chord length and increasing droop angle generally increased the maximum lift-drag ratios of the model when equipped with chord-extensions.

A comparison of the variations of lift-drag ratio with lift coefficient between the basic wing-normal configuration and the wing-normal configurations equipped with chord-extensions is shown at several Mach numbers in figure 14. The addition of chord-extensions usually decreased lift-drag ratio at the lower lift coefficient and increased it at lift coefficients above approximately 0.40 or 0.50. The magnitude of these increases at the higher lift coefficients generally becomes less with increasing Mach number. Increasing chord-extension droop angle and decreasing chord-extension chord length usually increased the lift-drag ratio of the chord-extension configurations. Changes in chord-extension span had little effect.

Effect of Chordwise Fences on the Aerodynamic Characteristics of a Wing-Normal Configuration

In an effort to improve the pitching-moment characteristics of the chord-extension configurations at Mach numbers of 0.90 and 0.94 a limited amount of data were obtained for two fence configurations at these Mach numbers and also as a matter of interest at several other Mach numbers. It was conjectured that the fences would prevent low-energy air in the trailing region from flowing outboard and aggravating shock-induced flow separation over the tip sections. The low-energy air may have been reaching the tip sections either because the vortices from the chord-extensions were too weak to prevent it or because they were raised sufficiently above the wing surface to allow flow underneath them. The results shown in figure 7(c) indicate that the fences seem to be rather ineffective at all Mach numbers. This may be because the fences were not of sufficient size. The effect of the fences on the lift (fig. 7(a)) and drag (fig. 7(b)) characteristics of the chord-extension configuration usually was slight and inconsistent.

Effect of Chord-Extensions on the Pitching-Moment and Lift Characteristics of a Wing-Aft Configuration

Some data were obtained to determine if chord-extensions would also be effective on a configuration with the wing in the aft position. The results shown in figure 8(b) indicate that chord-extensions were effective in improving the variation of pitching-moment coefficient with lift coefficient at all of the test Mach numbers except 0.94. Unfortunately, the data at a Mach number of 0.94 are too limited to tell if the chord-extensions would be beneficial at high lift coefficients.

The lift curves of figure 8(a) show that adding the chord-extensions to the basic wing-aft configuration made the lift curves more linear up to a Mach number of 0.90. However, this addition of chord-extensions did not increase lift coefficients at high angles of attack as much as adding the same chord-extensions to the basic wing-normal configuration (see fig. 5).

CONCLUSIONS

Results of a transonic wind-tunnel investigation of the effect of leading-edge chord-extensions on the aerodynamic characteristics of a 45° sweptback wing-fuselage combination at Mach numbers of 0.40 to 1.03 indicate the following conclusions:

1. Addition of chord-extensions to the basic-model configurations usually decreased the magnitude and abruptness of the variations of pitching-moment coefficient with lift coefficient for all Mach numbers. The effect of the chord-extensions on the variation of longitudinal-stability parameter with Mach number at low lift coefficients was usually small. The most unsatisfactory pitching-moment characteristics for the model equipped with chord-extensions occurred at Mach numbers of 0.90 and 0.94.

2. Addition of chord-extensions to the basic wing-normal configuration also generally improved the lift characteristics, increased zero-lift drag, decreased lift-drag ratio at low lift coefficients, and increased lift-drag ratio above lift coefficients of about 0.40 or 0.50.

3. In general, the effect of shifting the inboard end of the chord-extensions from 55 to 70 percent of the wing semispan was to improve the variation of pitching-moment coefficient with lift coefficient, cause slightly poorer lift characteristics, cause no consistent change in zero-lift drag, and cause only slight changes in lift-drag ratio.

4. Increasing chord-extension chord length from 15 to 20 percent of the local basic-wing chord usually had only a slight effect on the variation of pitching-moment coefficient with lift coefficient, only a slight effect on the lift characteristics, no consistent effect on zero-lift drag, and a detrimental effect on lift-drag ratio.

5. Usually increasing chord-extension droop angle from about 0° to 2.2° slightly increased the variation of pitching-moment coefficient with lift coefficient up to Mach number of 0.85, had only a slight effect on the lift characteristics, had no consistent effect on zero-lift drag, and caused an increase in lift-drag ratio.

6. The effect of chordwise fences near the trailing edge on the aerodynamic characteristics of a model equipped with chord-extensions was small and inconsistent.

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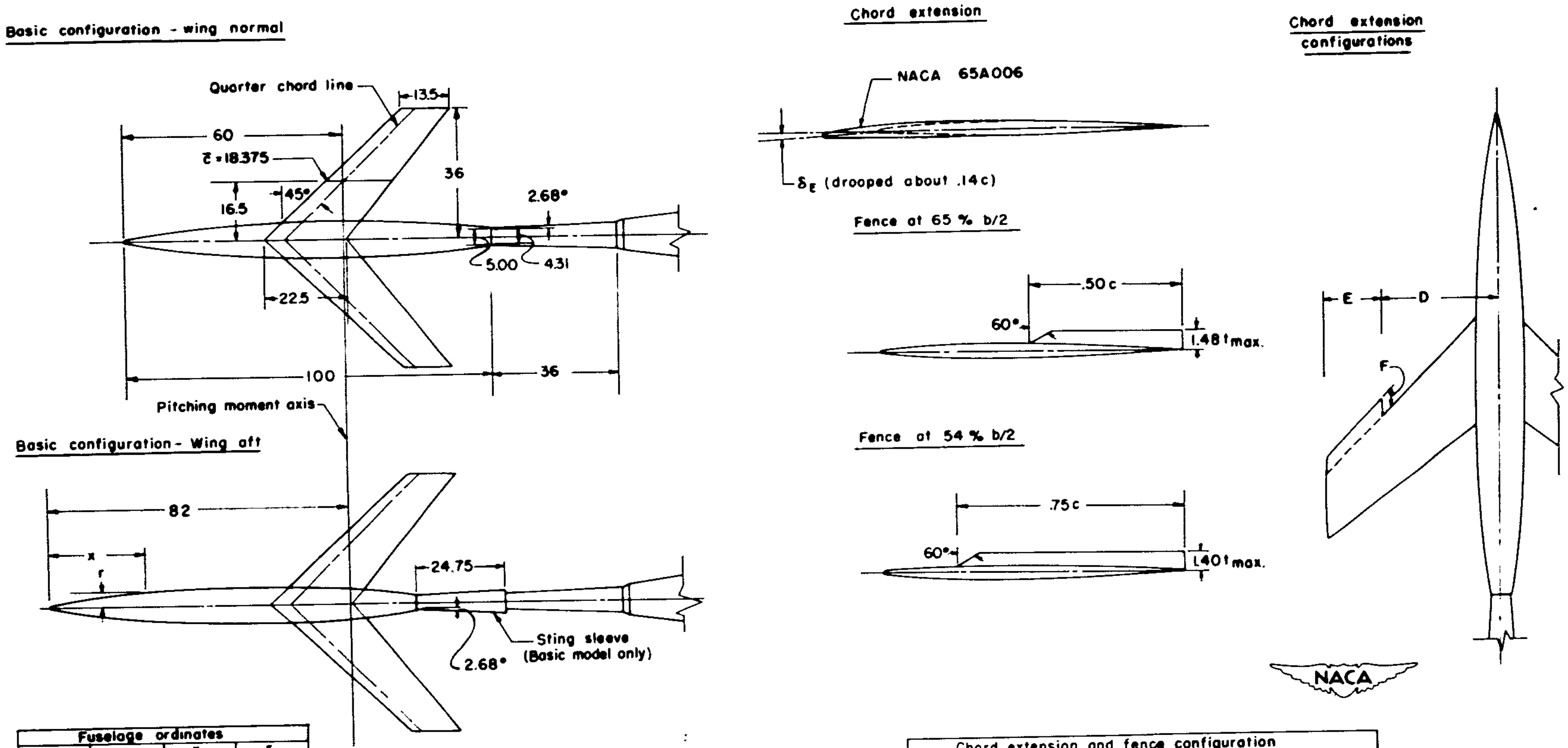


Fuselage ordinates			
x	r	x	r
0	0	42.00	4.719
0.60	0.277	48.00	4.896
0.90	.358	54.00	4.971
1.50	.514	60.00	5.000
3.00	.866	66.00	4.955
6.00	1.446	72.00	4.828
9.00	1.936	78.00	4.610
12.00	2.365	84.00	4.274
18.00	3.112	90.00	3.754
24.00	3.708	96.00	3.031
30.00	4.158	100.00	2.500
36.00	4.489	L.E.R.	0.060

Wing data	
Taper ratio	0.6
Aspect ratio	4.0
Wing area	9 sq. ft.
Airfoil section	NACA 65A006 parallel to plane of symmetry

Chord extension and fence configuration						
D % b/2	E % b/2	F % c	δ_E	Extension area % S	Fence sta % b/2	Wing position
55	44	15	0°	5.71	off	normal
65	34	15	0°	4.28	off	normal
65	34	15	2.2°	4.28	off	normal
65	34	15	2.2°	4.28	65	normal
65	34	15	2.2°	4.28	54	normal
65	34	20	2.2°	5.71	off	normal
70	29	20	2.2°	4.80	off	normal
70	29	20	0.4°	4.80	off	normal
70	29	20	0.4°	4.80	off	aft

Figure 1.- Dimensions of the basic model and of the leading-edge chord-extensions and fences. All dimensions are in inches.

Figure 2.- Three-quarter view showing wing-normal configuration with leading-edge chord-extensions (0.15c, $b_i = 0.65b/2$, $\delta_E \approx 0^\circ$) mounted in the test section.

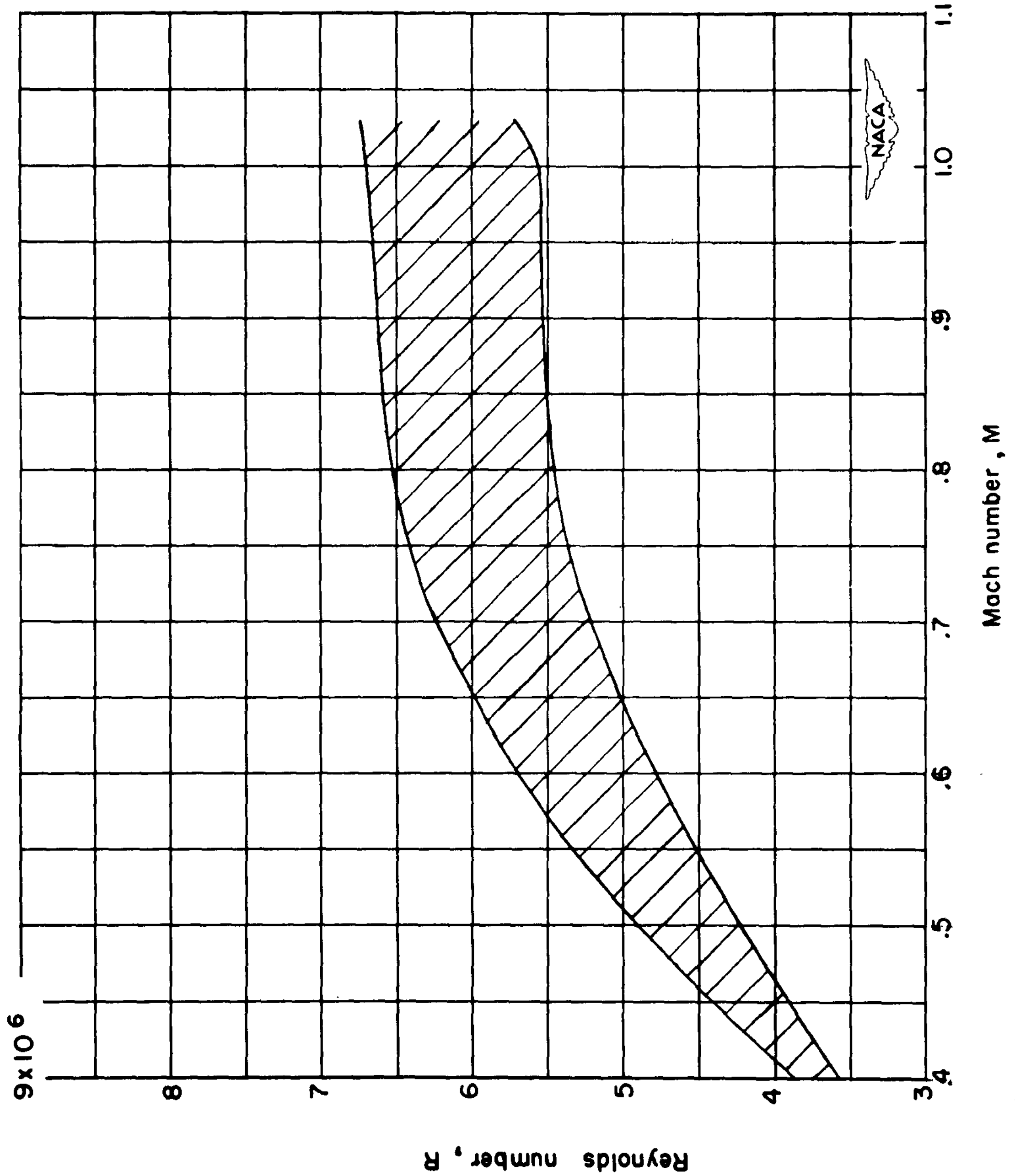
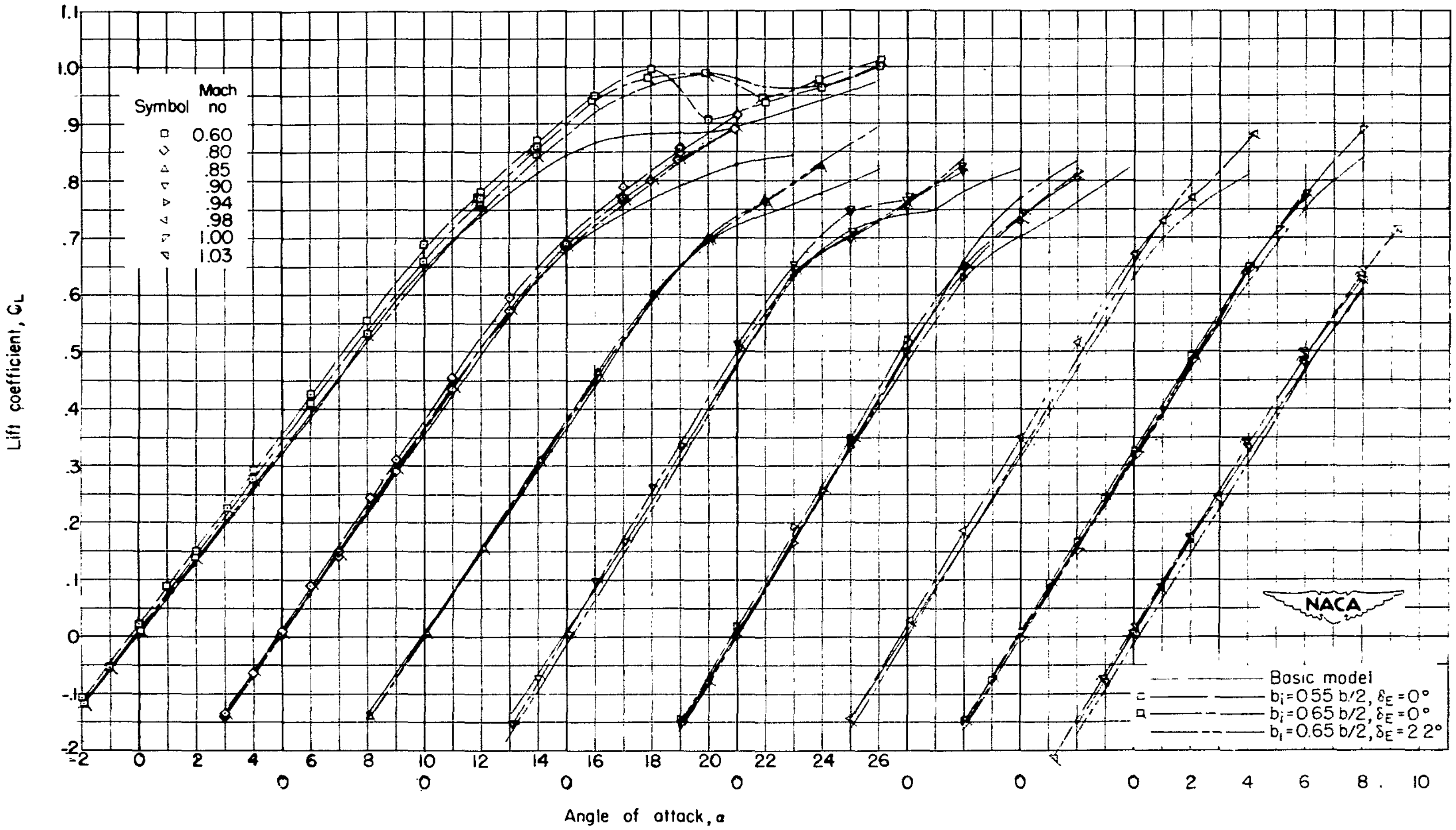
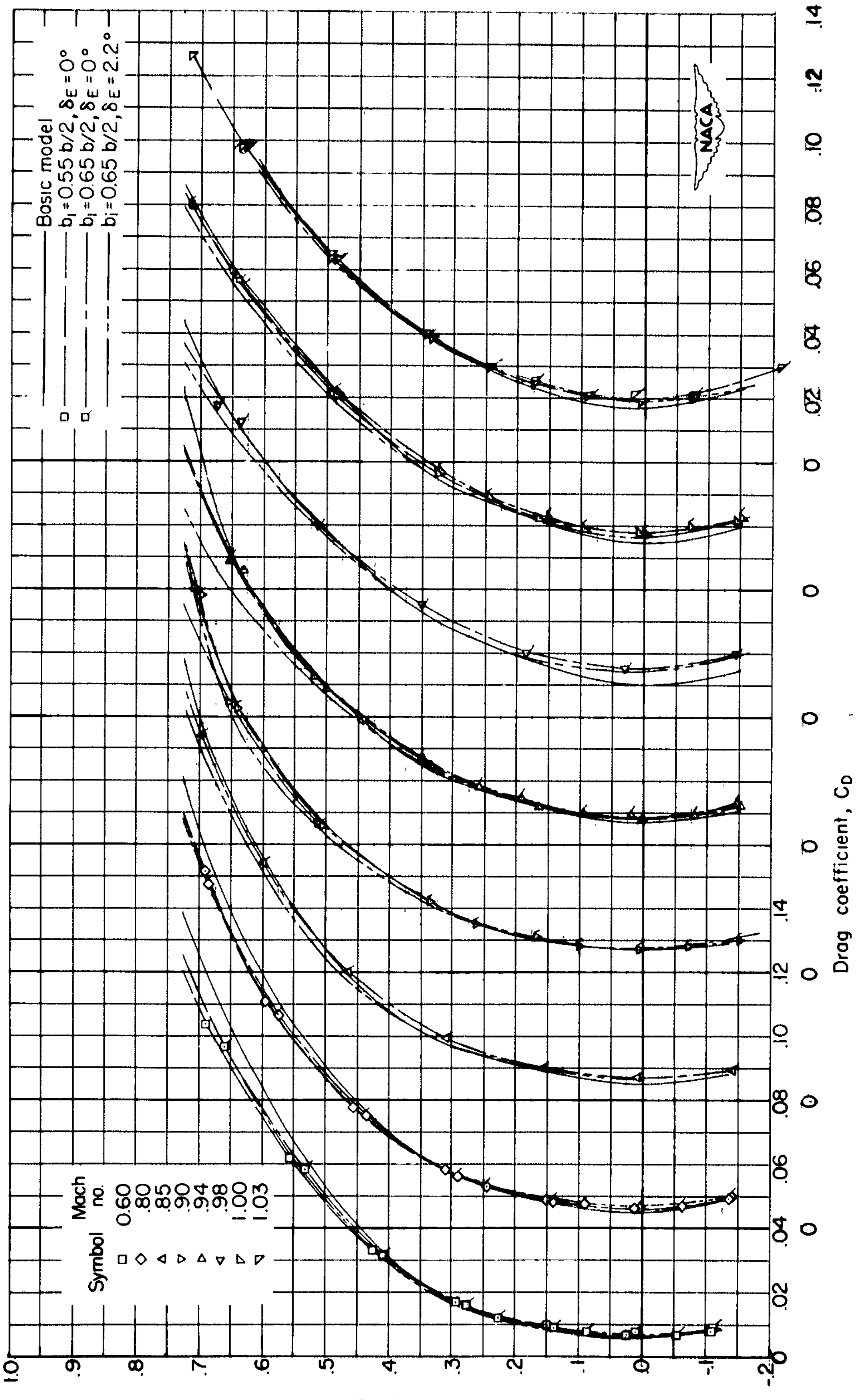


Figure 3.- Variation of Reynolds number with Mach number.



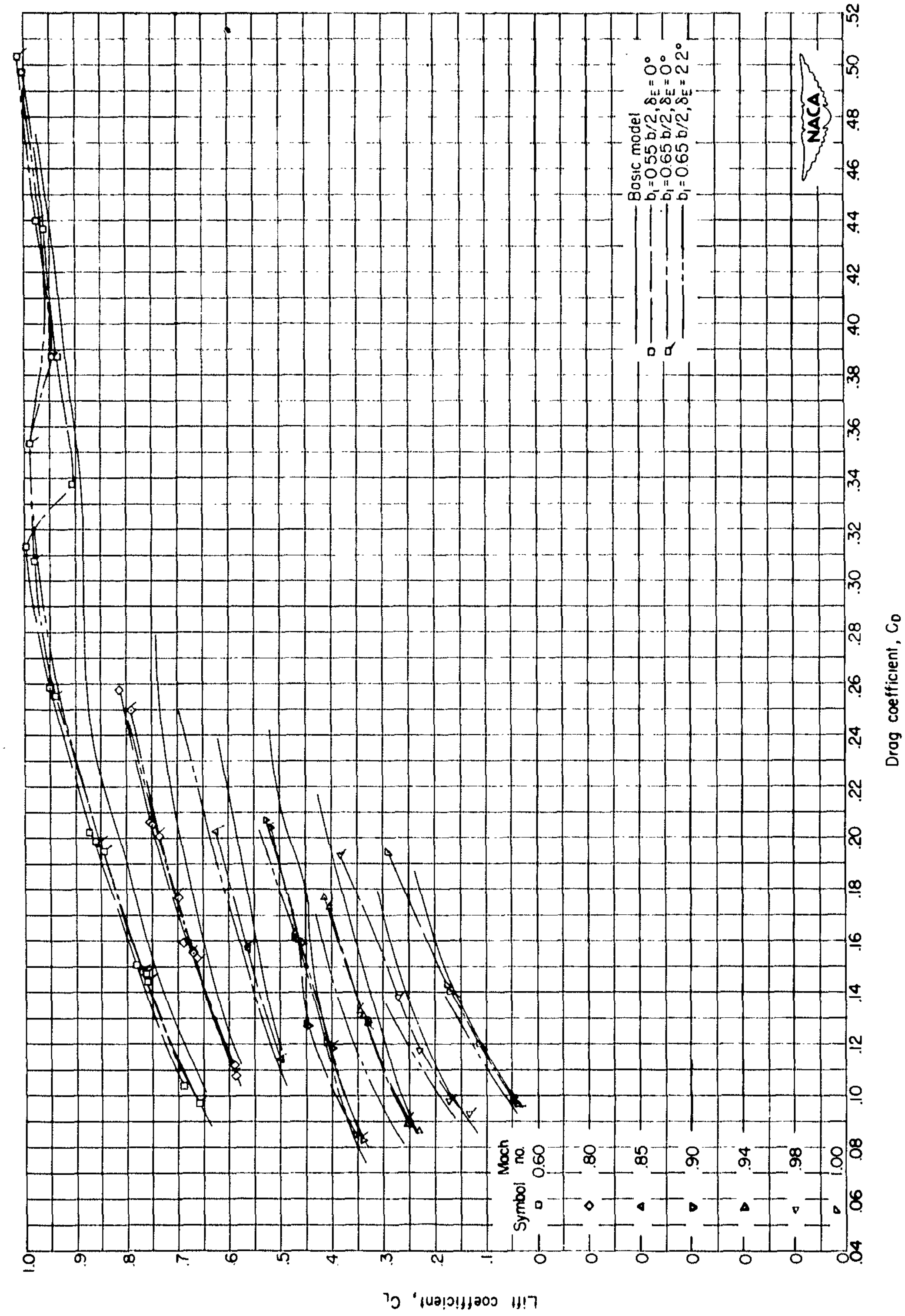
(a) Lift.

Figure 4.- Effect of 15-percent-chord leading-edge chord-extensions on the aerodynamic characteristics of the wing-normal configuration.



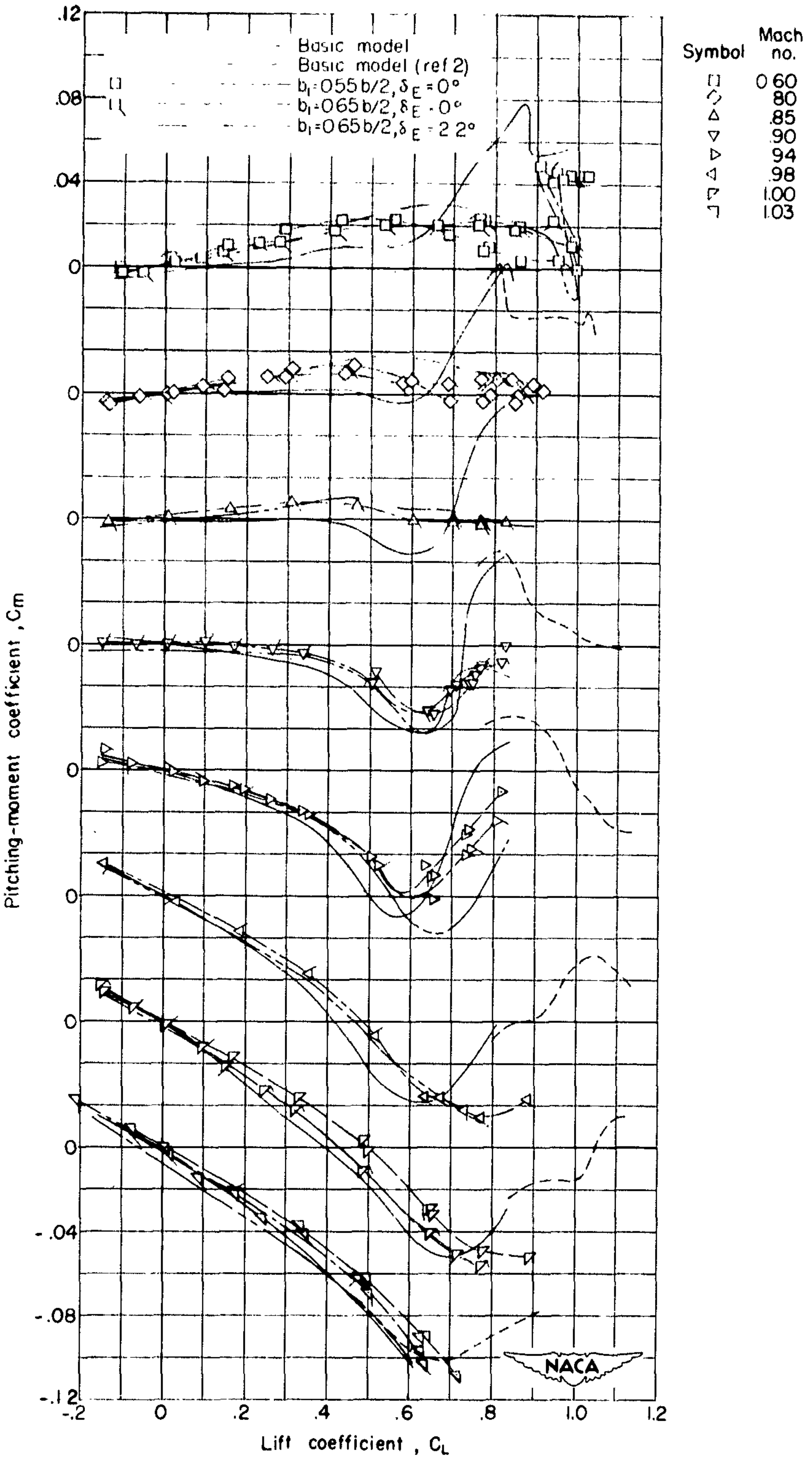
(b) Drag up to moderate lifts.

Figure 4.- Continued.



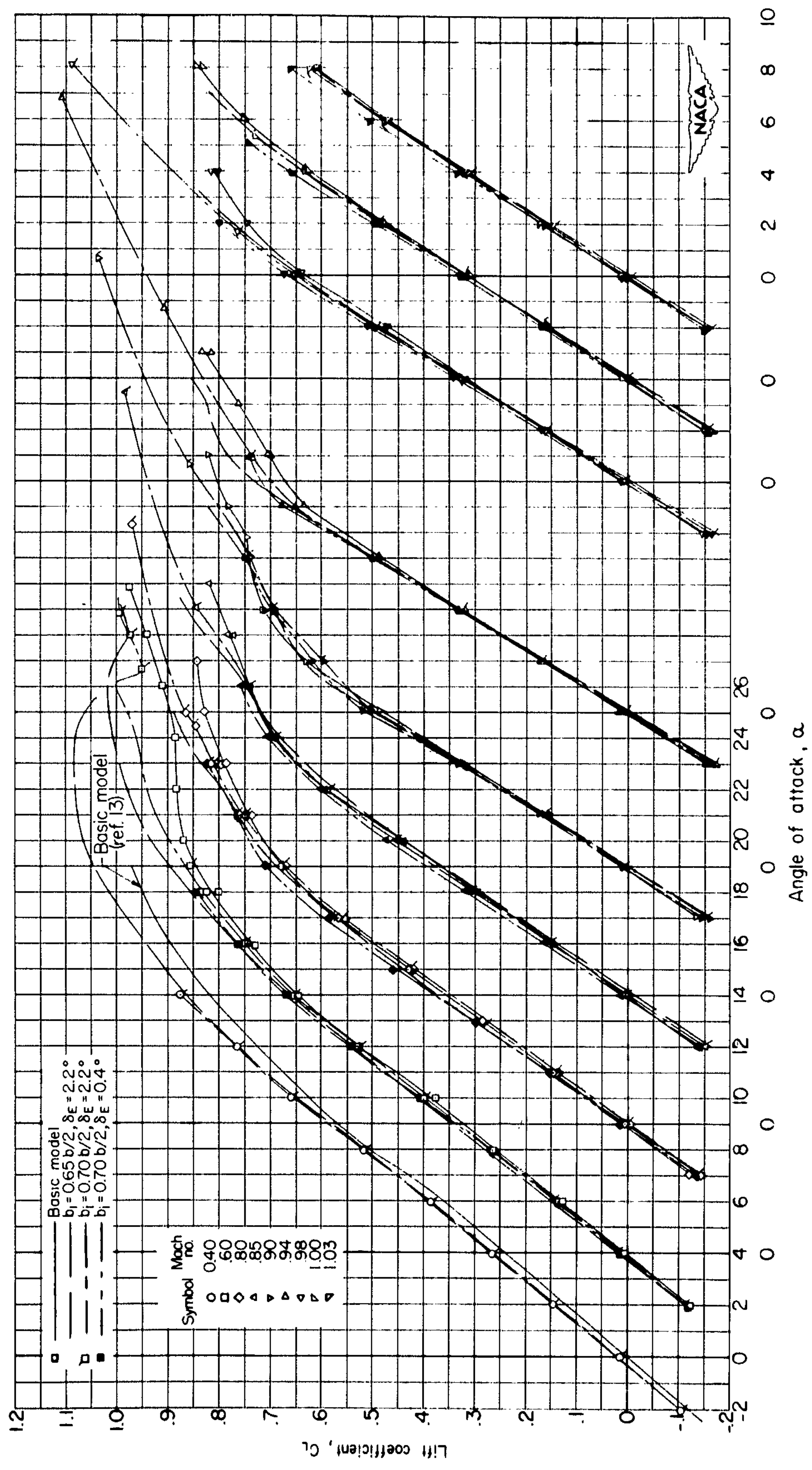
(c) Drag at high lifts.

Figure 4.- Continued.



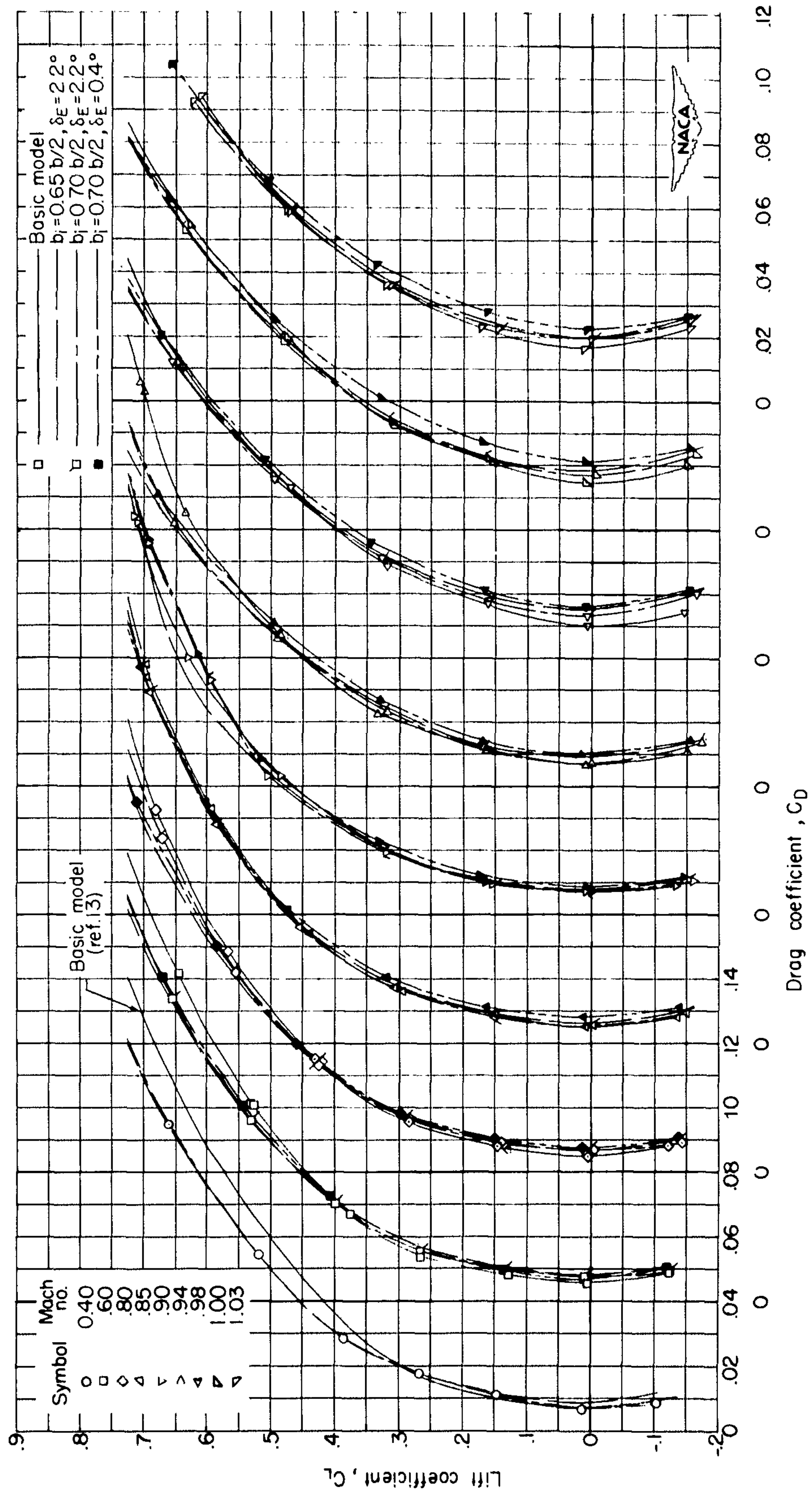
(d) Pitching moment.

Figure 4.- Concluded.



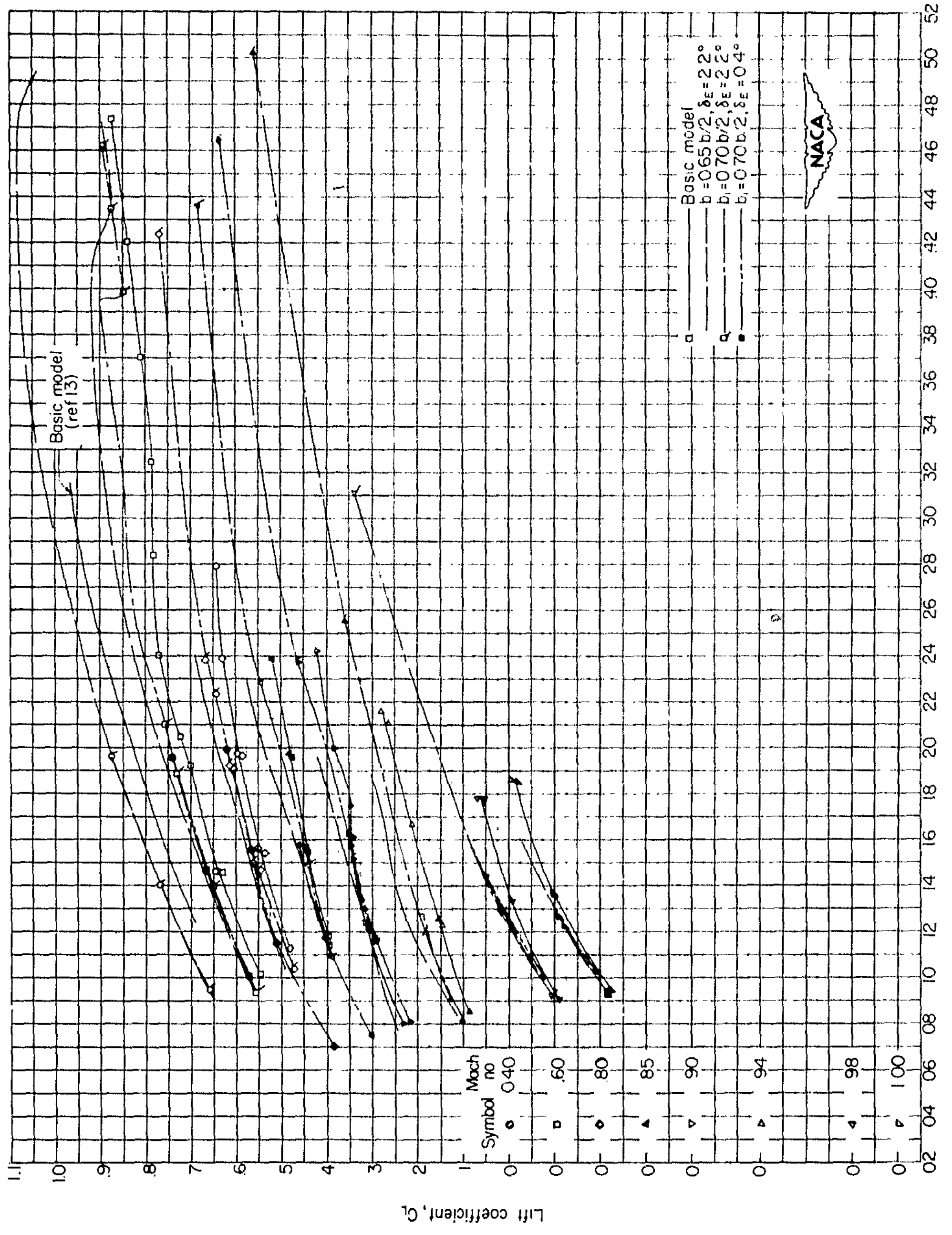
(a) Lift.

Figure 5.- Effect of 20-percent-chord leading-edge chord-extensions on the aerodynamic characteristics of the wing-normal configuration.



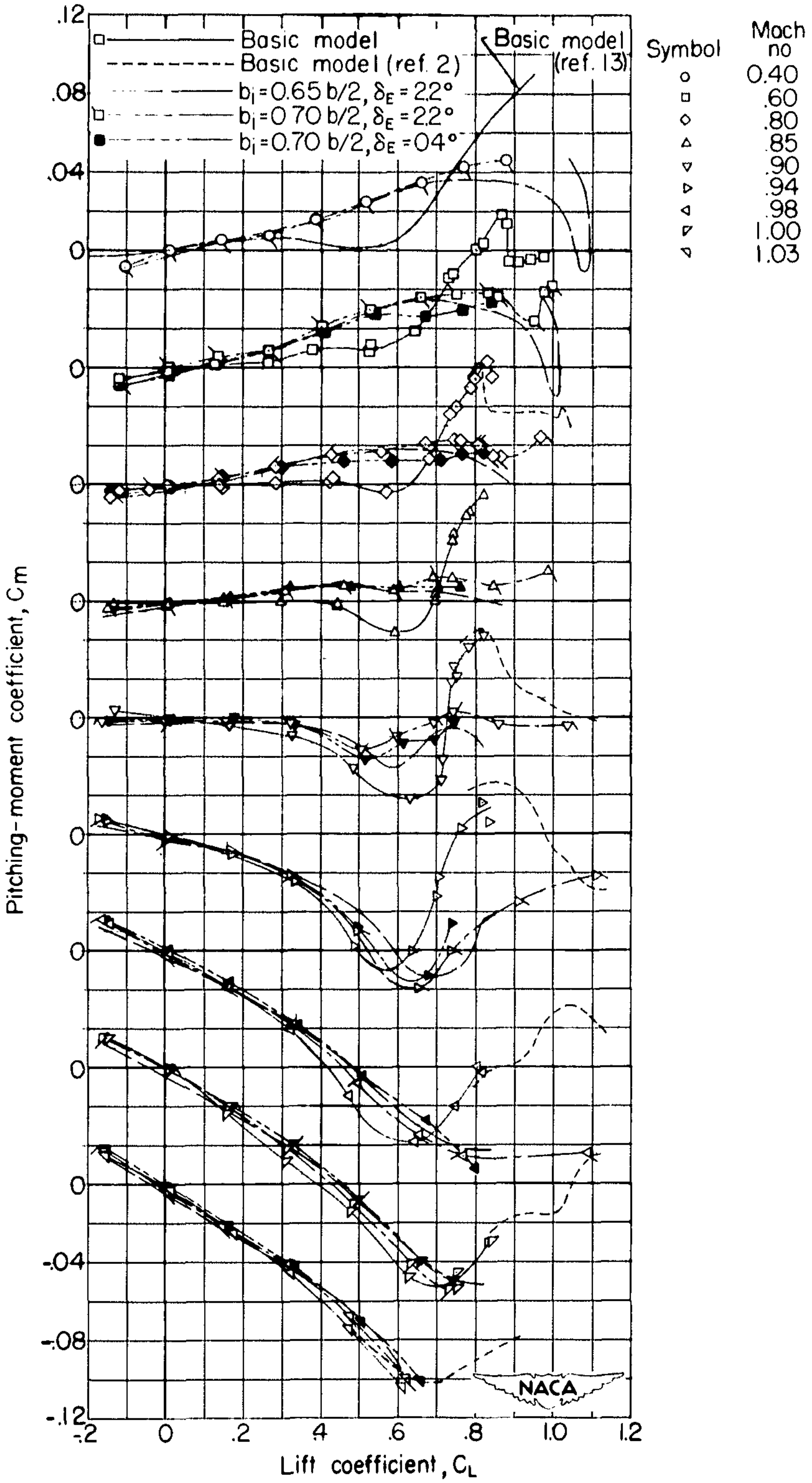
(b) Drag up to moderate lifts.

Figure 5.- Continued.



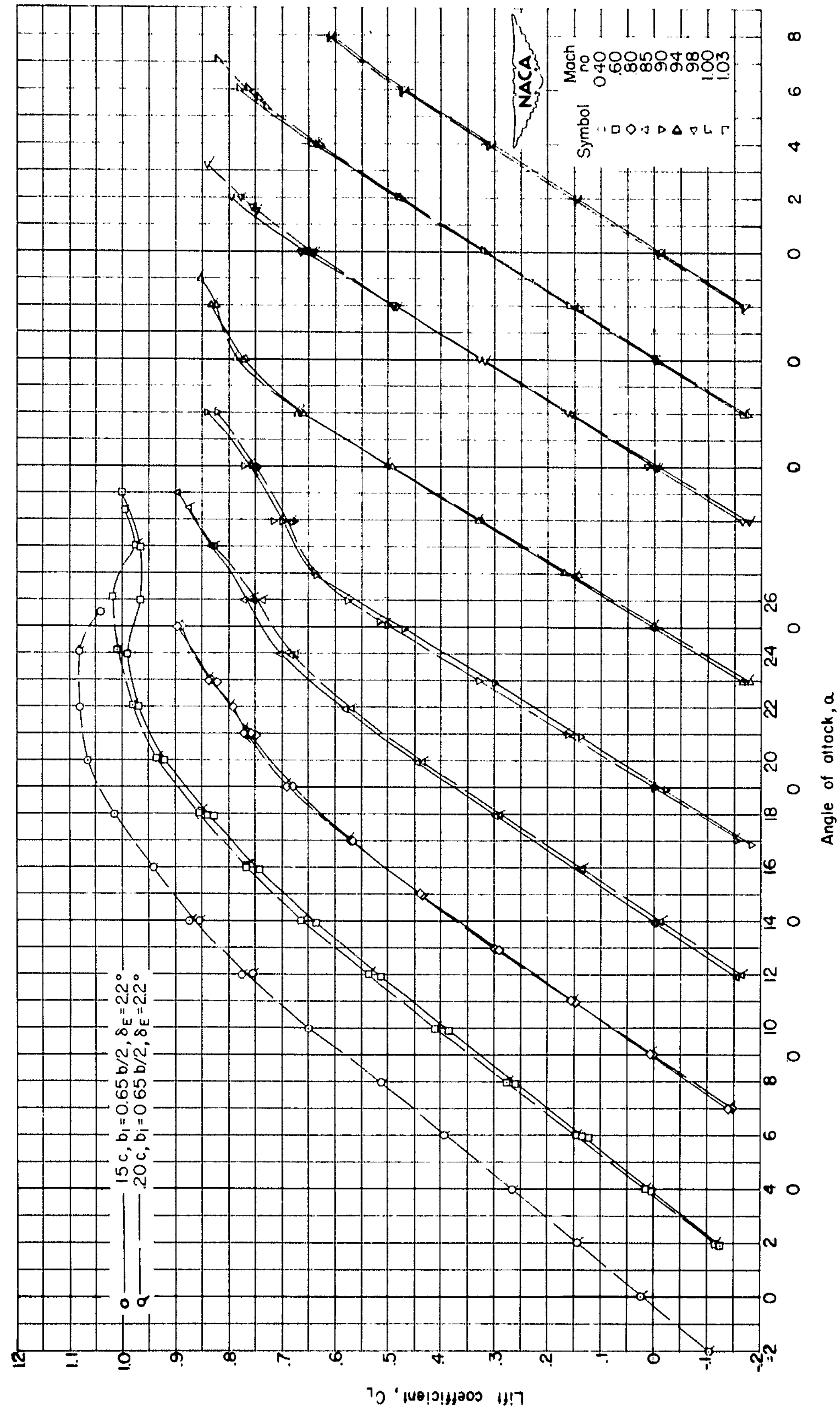
(c) Drag at high lifts.

Figure 5.- Continued.



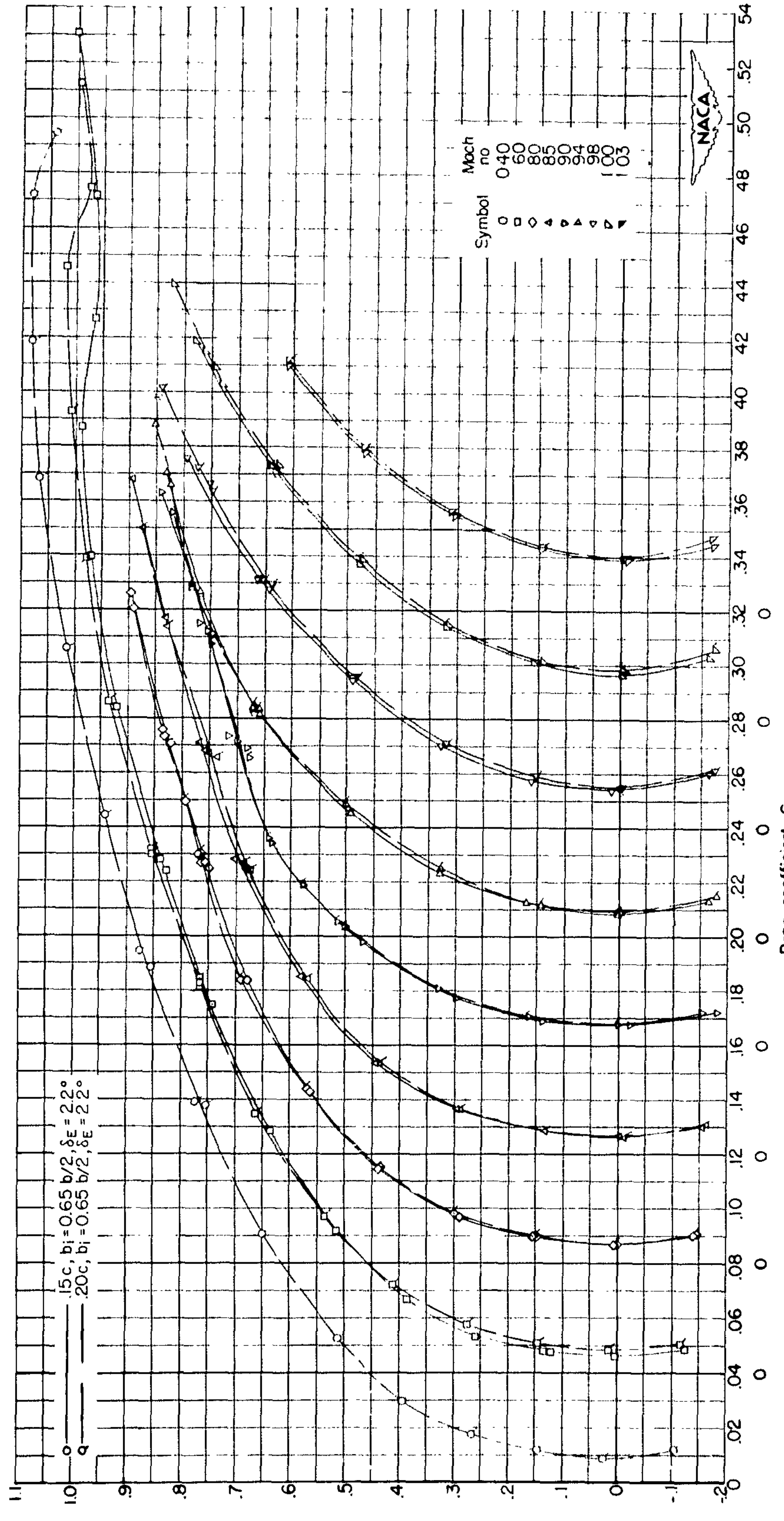
(d) Pitching moment.

Figure 5.- Concluded.



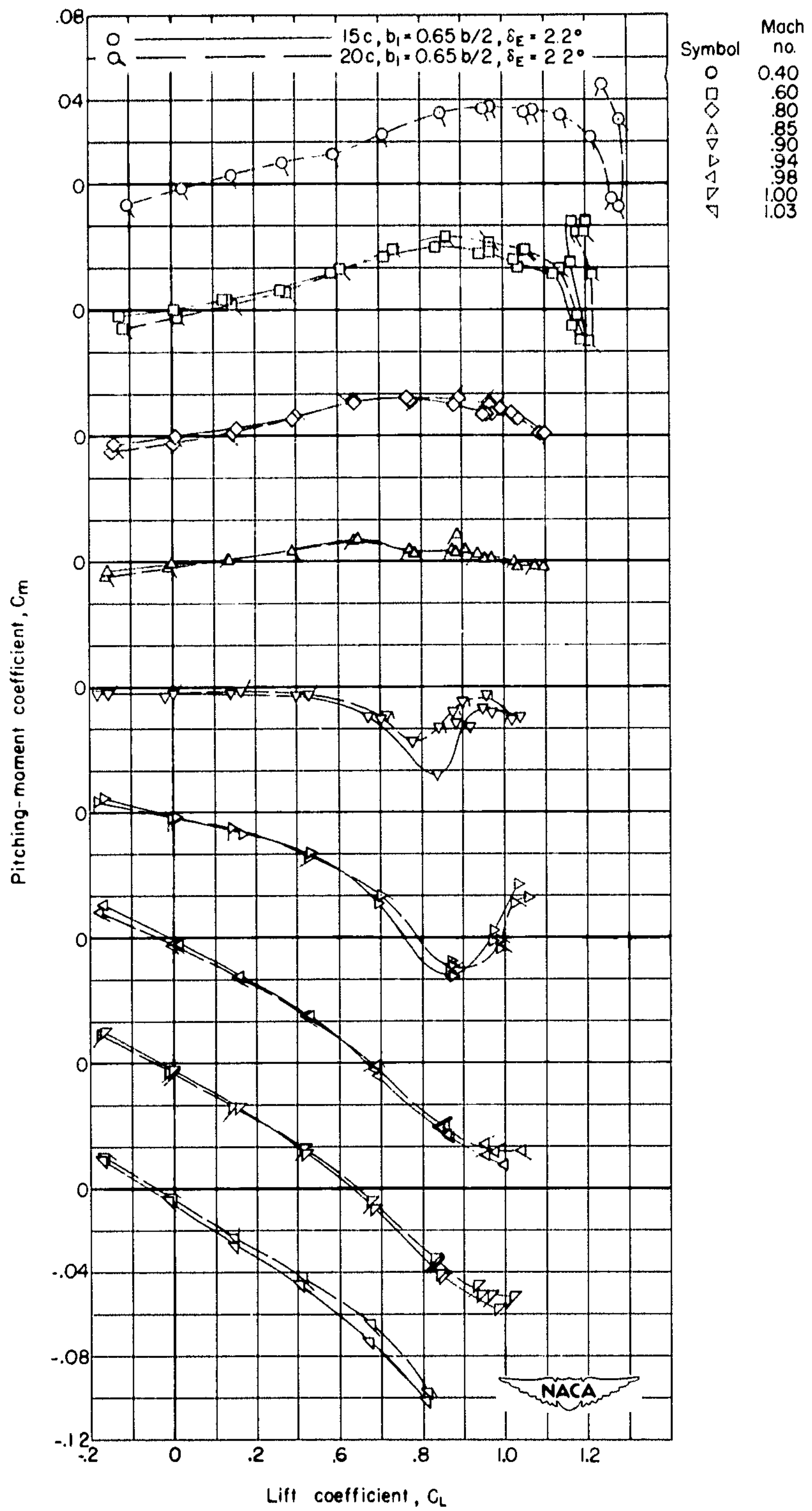
(a) Lift.

Figure 6.- Effect of chord length of leading-edge chord-extensions on the aerodynamic characteristics of the wing-normal configuration.



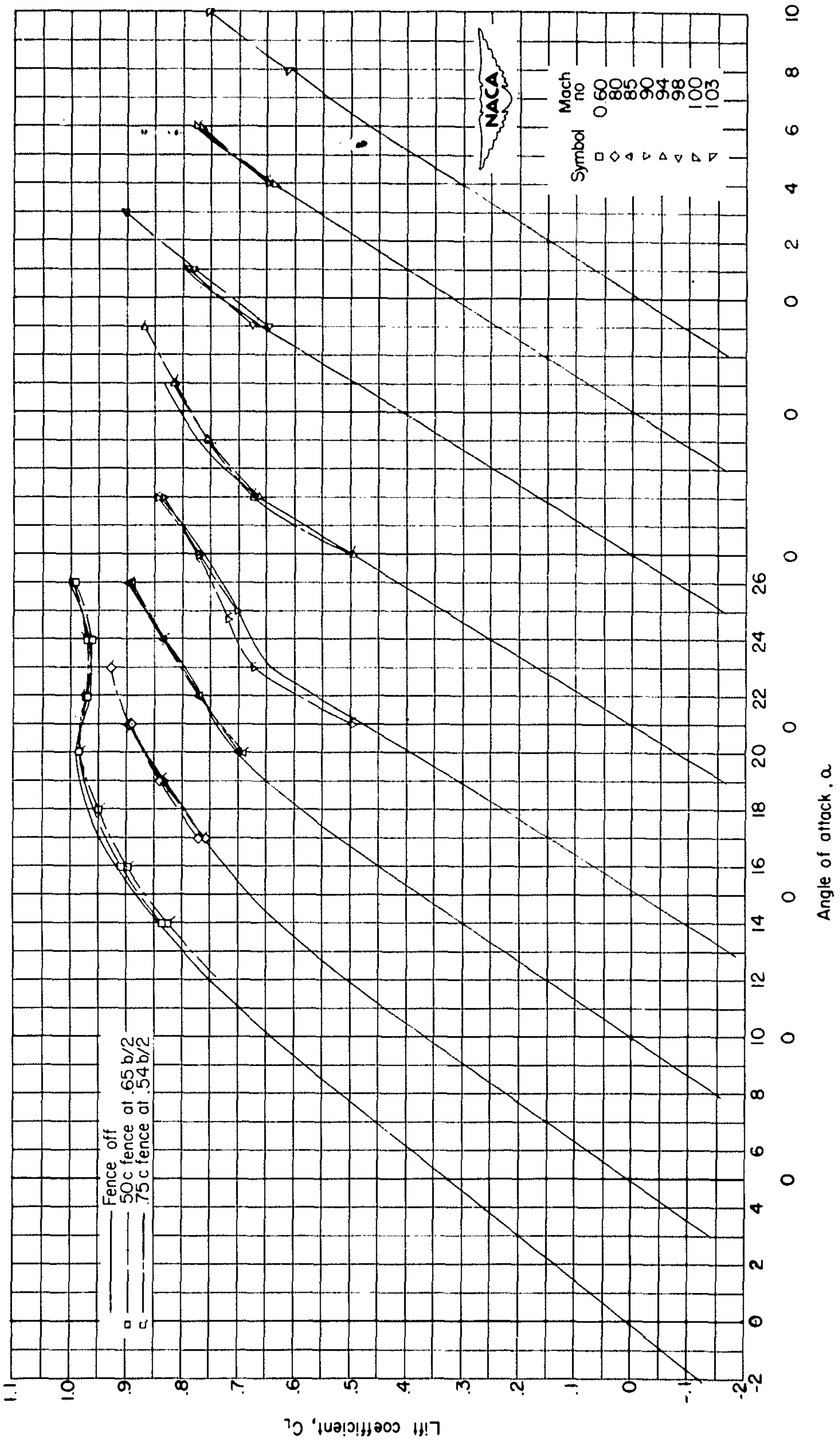
(b) Drag.

Figure 6.- Continued.



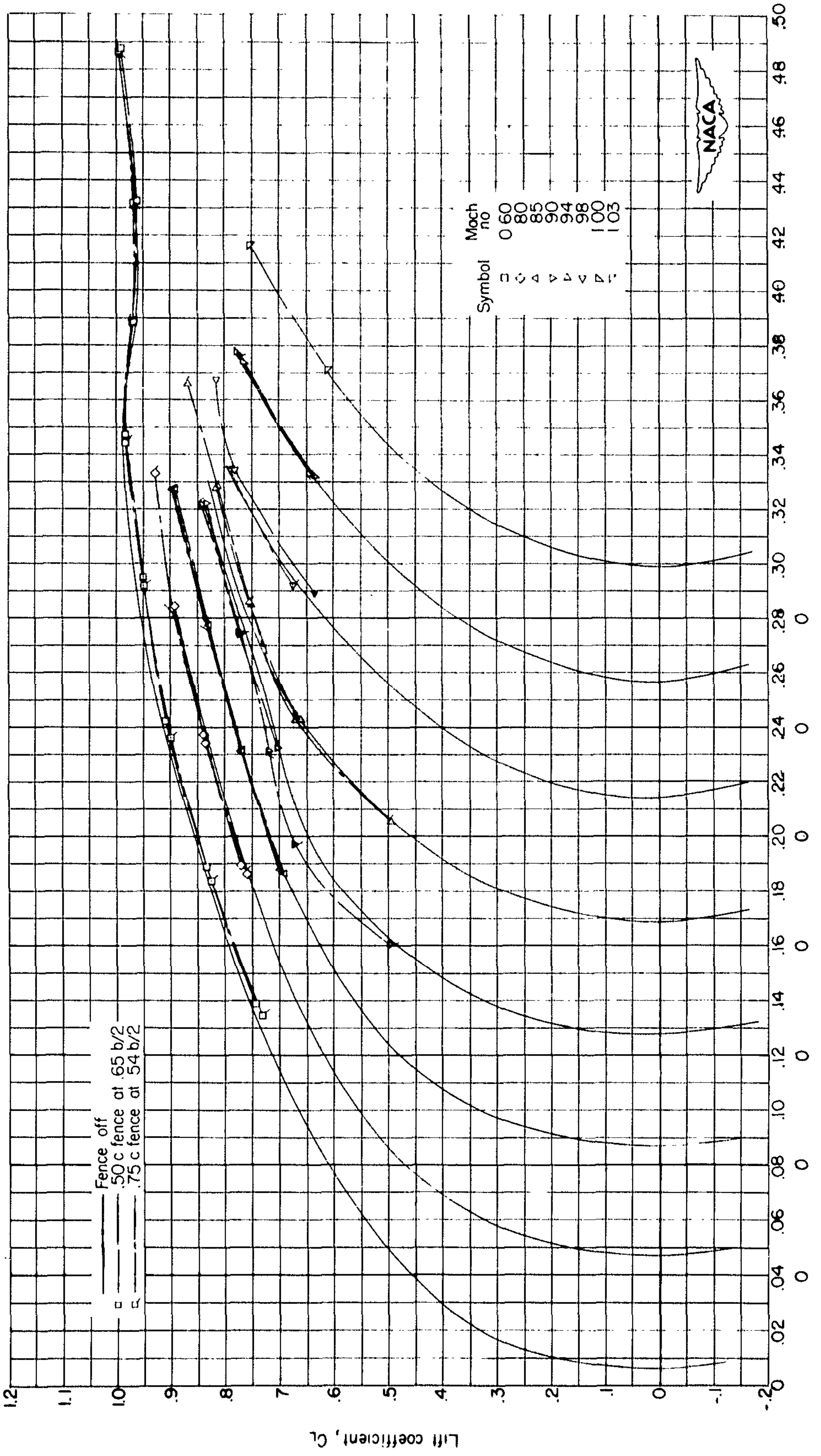
(c) Pitching moment.

Figure 6.- Concluded.



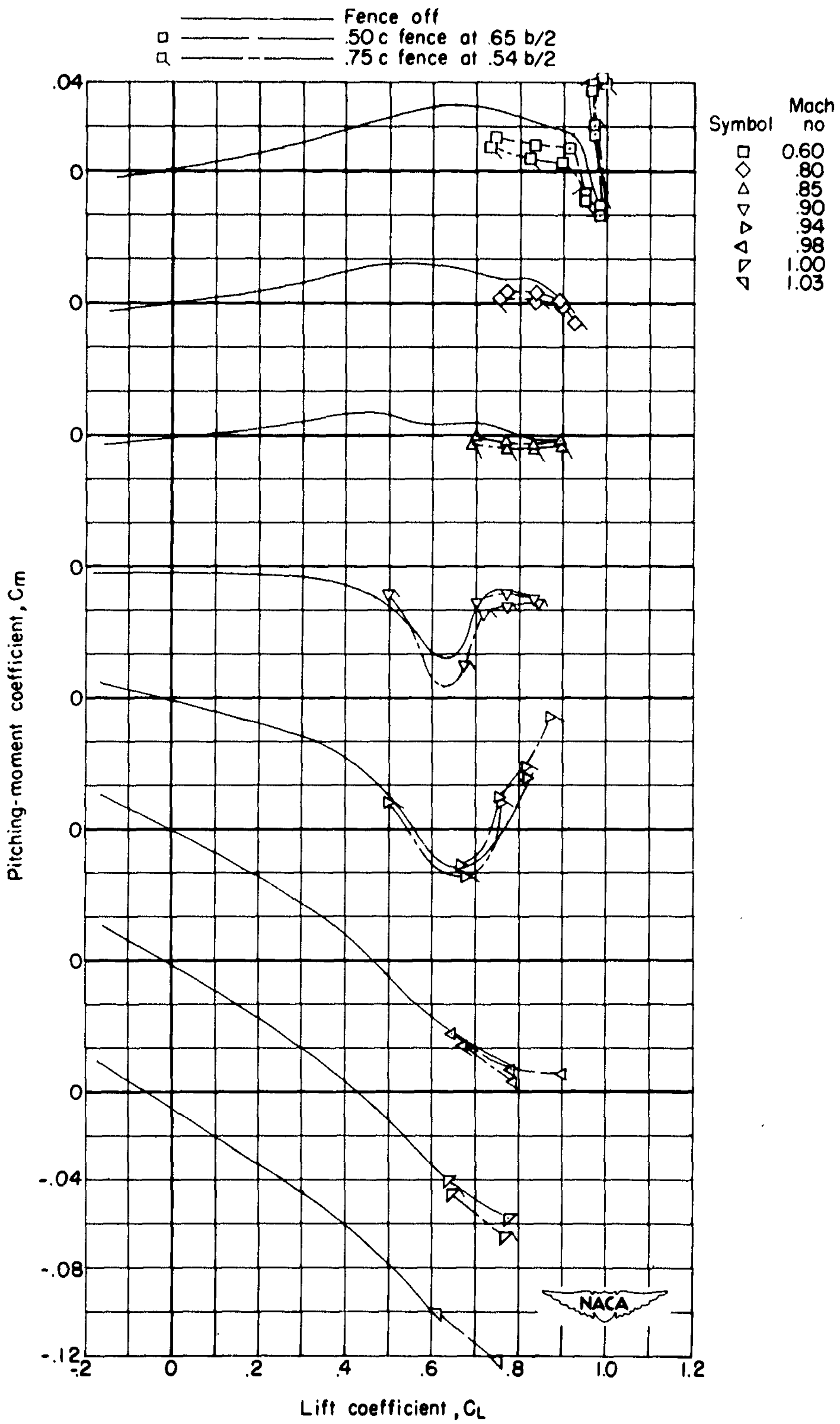
(a) Lift.

Figure 7.- Effect of fences on the aerodynamic characteristics of the wing-normal configuration when equipped with leading-edge chord-extensions (0.15c, b_i = 0.65b/2, δ_E = 2.2°).



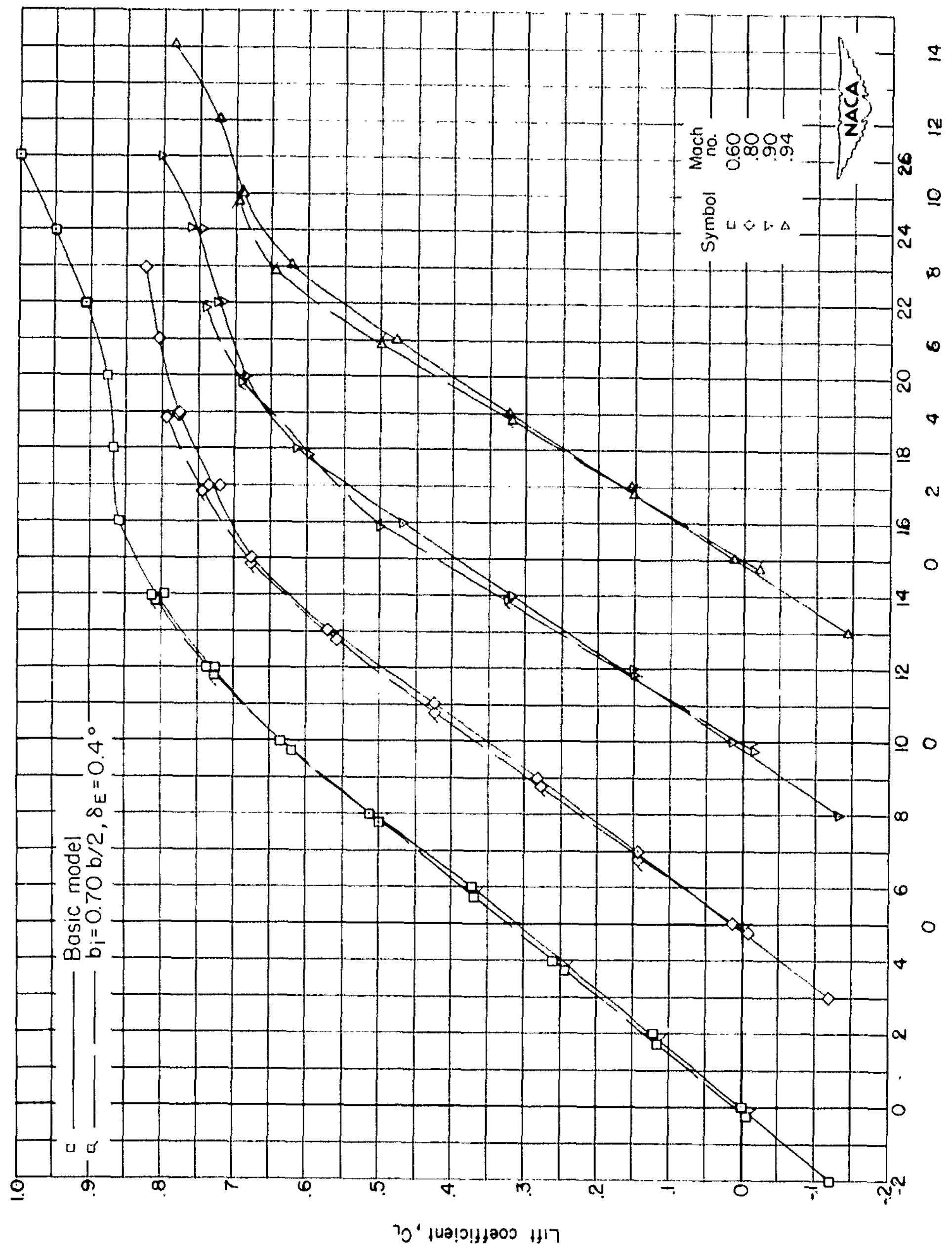
(b) Drag.

Figure 7.- Continued.



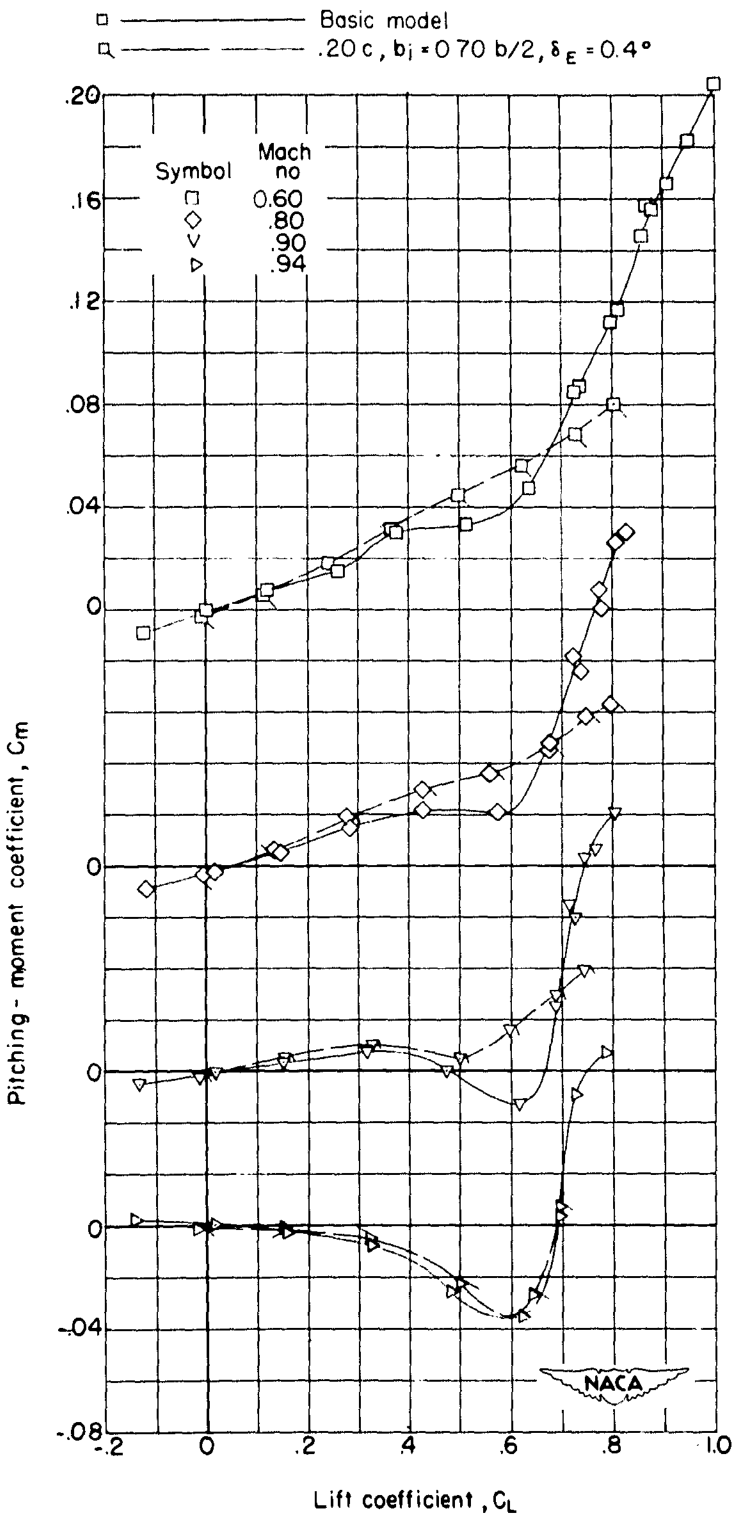
(c) Pitching moment.

Figure 7.- Concluded.



(a) Lift.

Figure 8.- Effect of a 20-percent-chord leading-edge chord-extension on the aerodynamic characteristics of the wing-aft configuration.



(b) Pitching moment.

Figure 8.- Concluded.

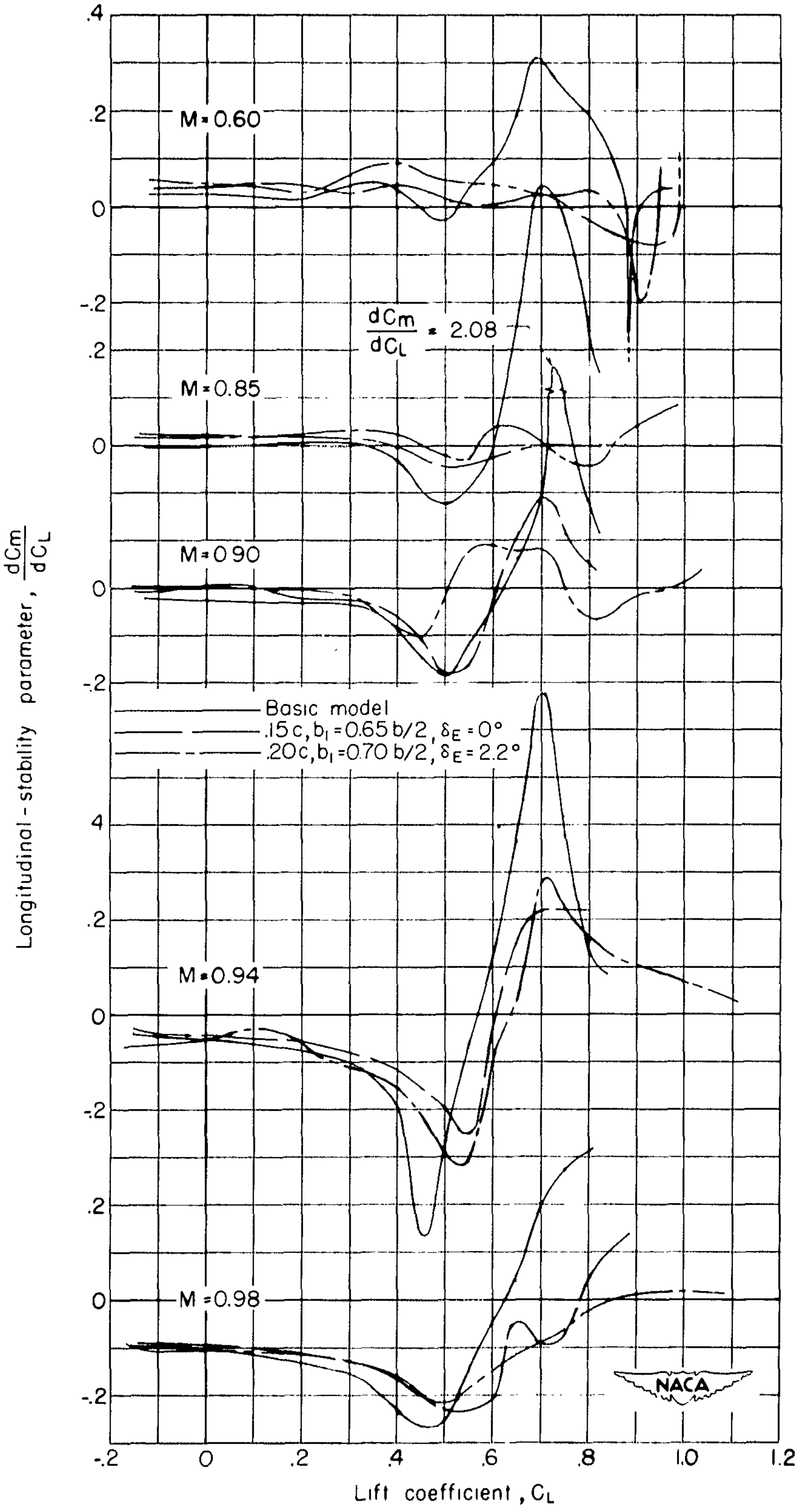
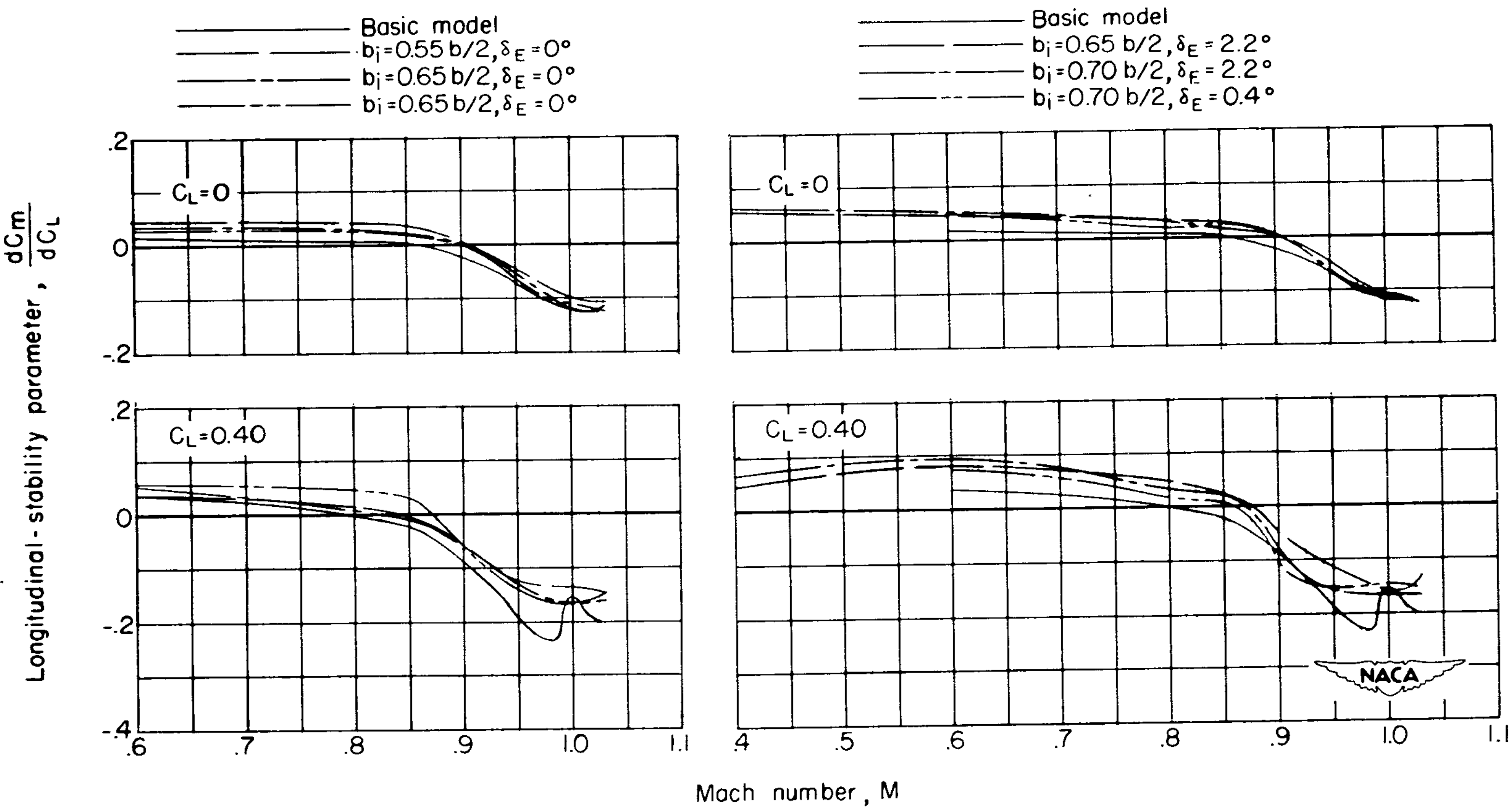


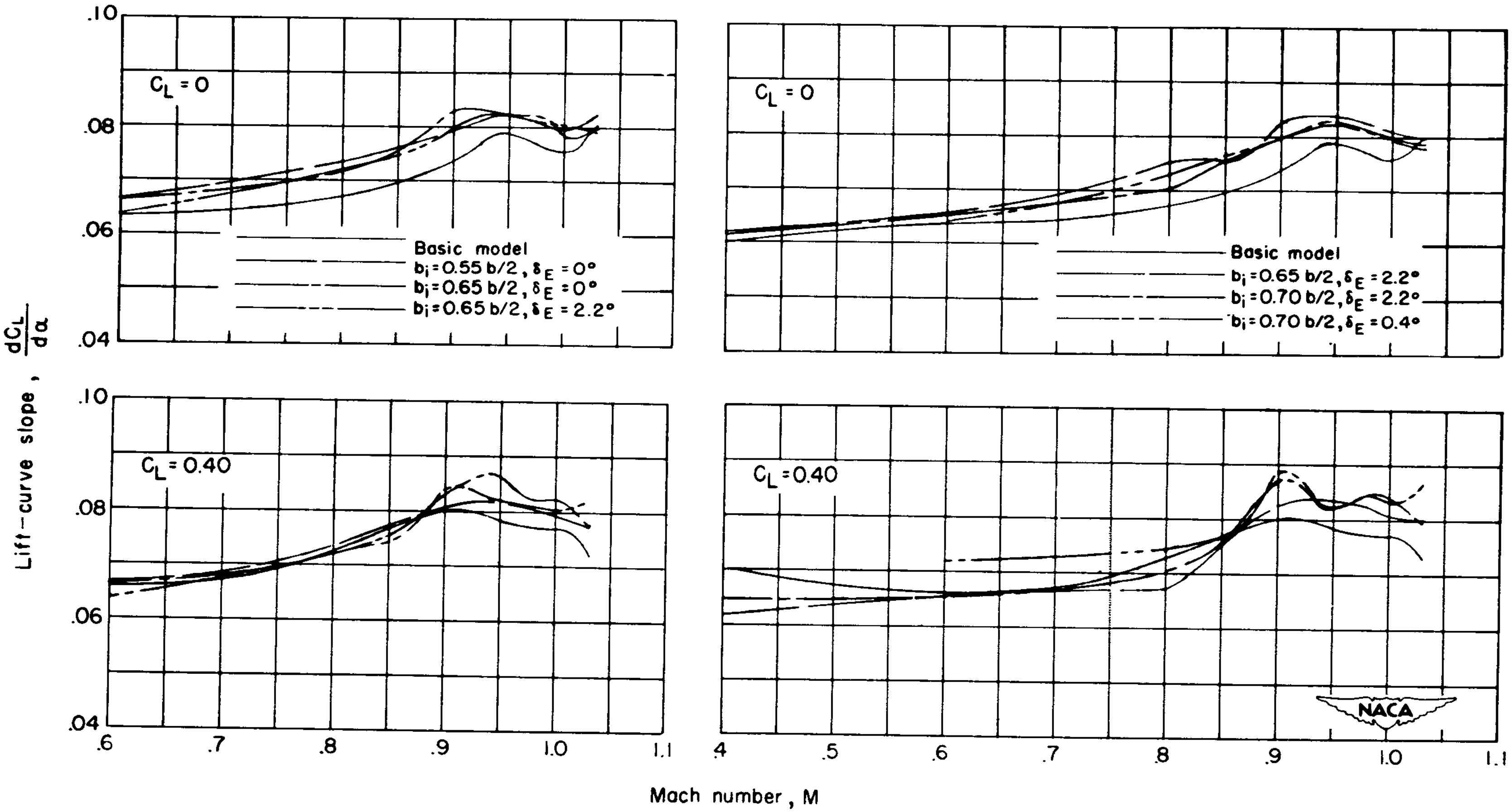
Figure 9.- Variation of longitudinal-stability parameter with lift coefficient at several Mach numbers for three wing-normal configurations.



(a) Effect of span and leading-edge droop of a 15-percent-chord leading-edge chord-extension.

(b) Effect of span and leading-edge droop of a 20-percent-chord leading-edge chord-extension.

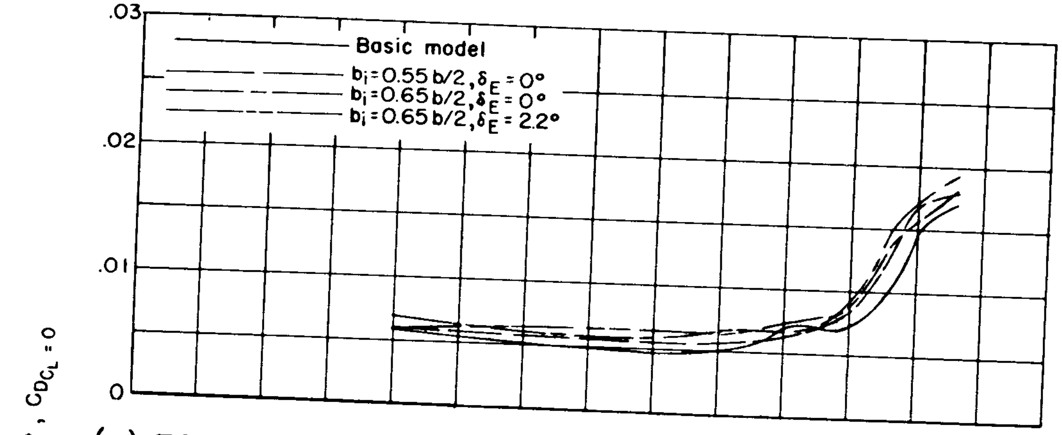
Figure 10.- Variation of longitudinal-stability parameter with Mach number at lift coefficients of 0 and 0.40 for the wing-normal configurations.



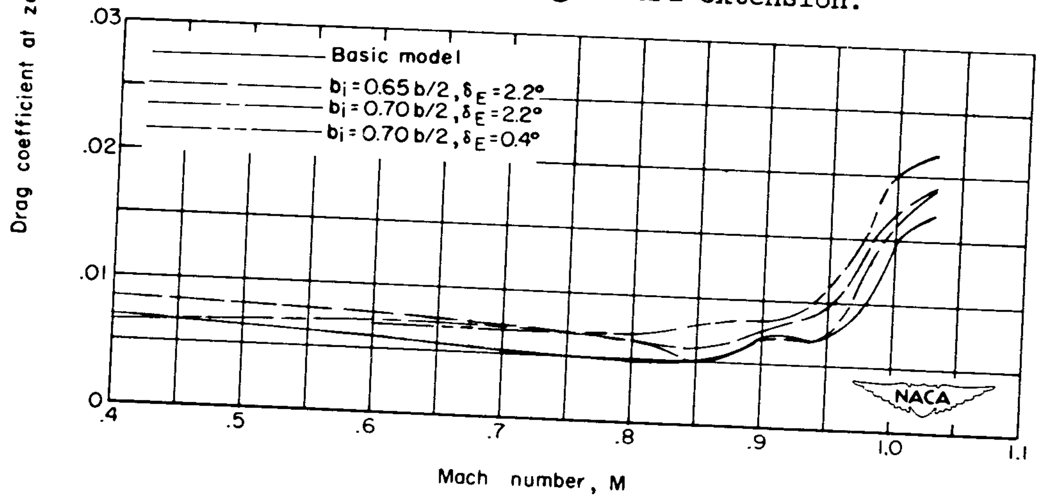
(a) Effect of span and leading-edge droop of a 15-percent-chord leading-edge chord-extension.

(b) Effect of span and leading-edge droop of a 20-percent-chord leading-edge chord-extension.

Figure 11.- Variation of lift-curve slope with Mach number at lift coefficients of 0 and 0.40 for the wing-normal configurations.

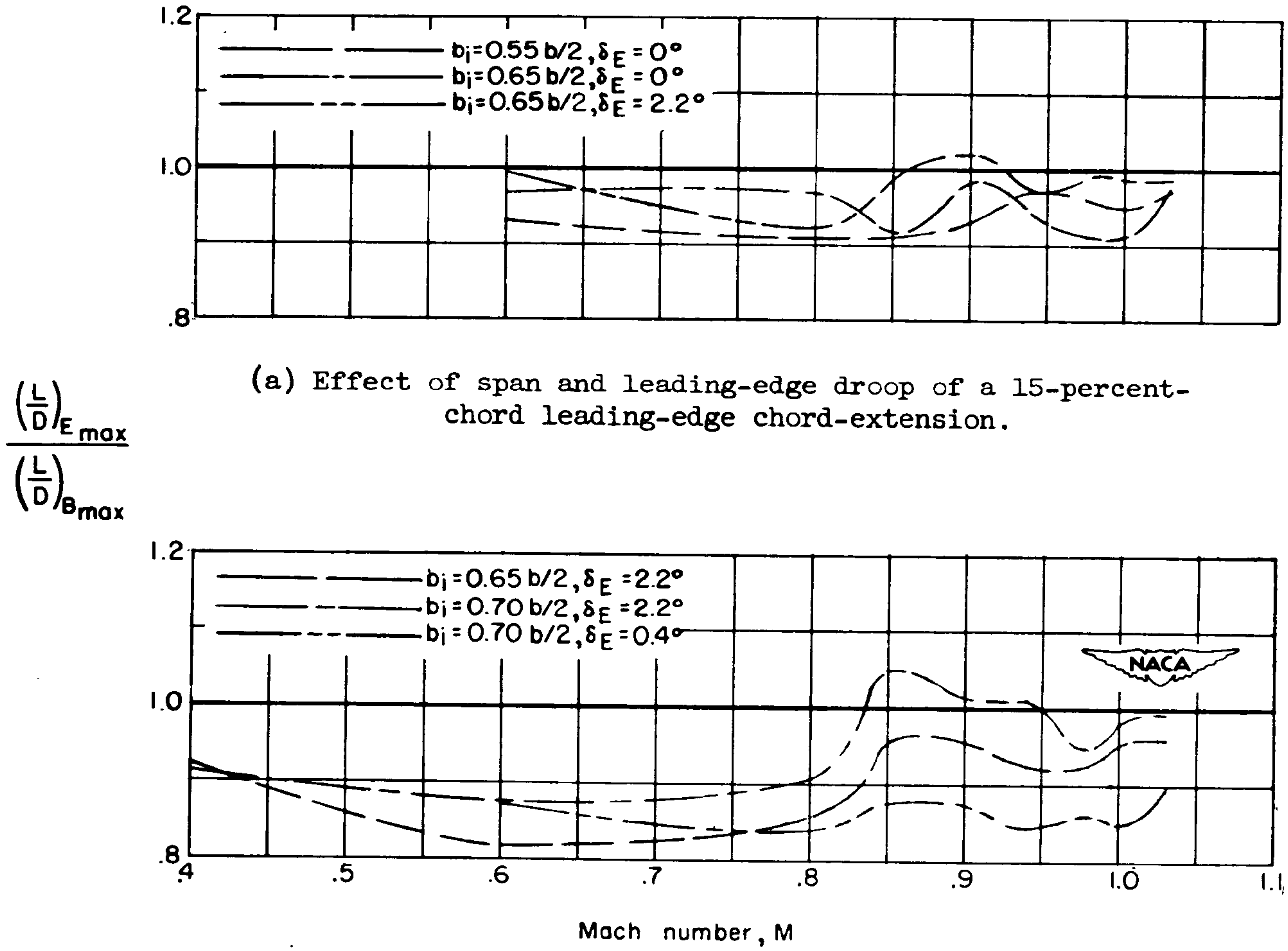


(a) Effect of span and leading-edge droop of a 15-percent-chord leading-edge chord-extension.



(b) Effect of span and leading-edge droop of a 20-percent-chord leading-edge chord-extension.

Figure 12.- Variation of drag coefficient at zero lift with Mach number for the wing-normal configurations.



(a) Effect of span and leading-edge droop of a 15-percent-chord leading-edge chord-extension.

(b) Effect of span and leading-edge droop of a 20-percent-chord leading-edge chord-extension.

Figure 13.- Effect of leading-edge chord-extensions on the maximum lift-drag ratio of the wing-normal configurations.

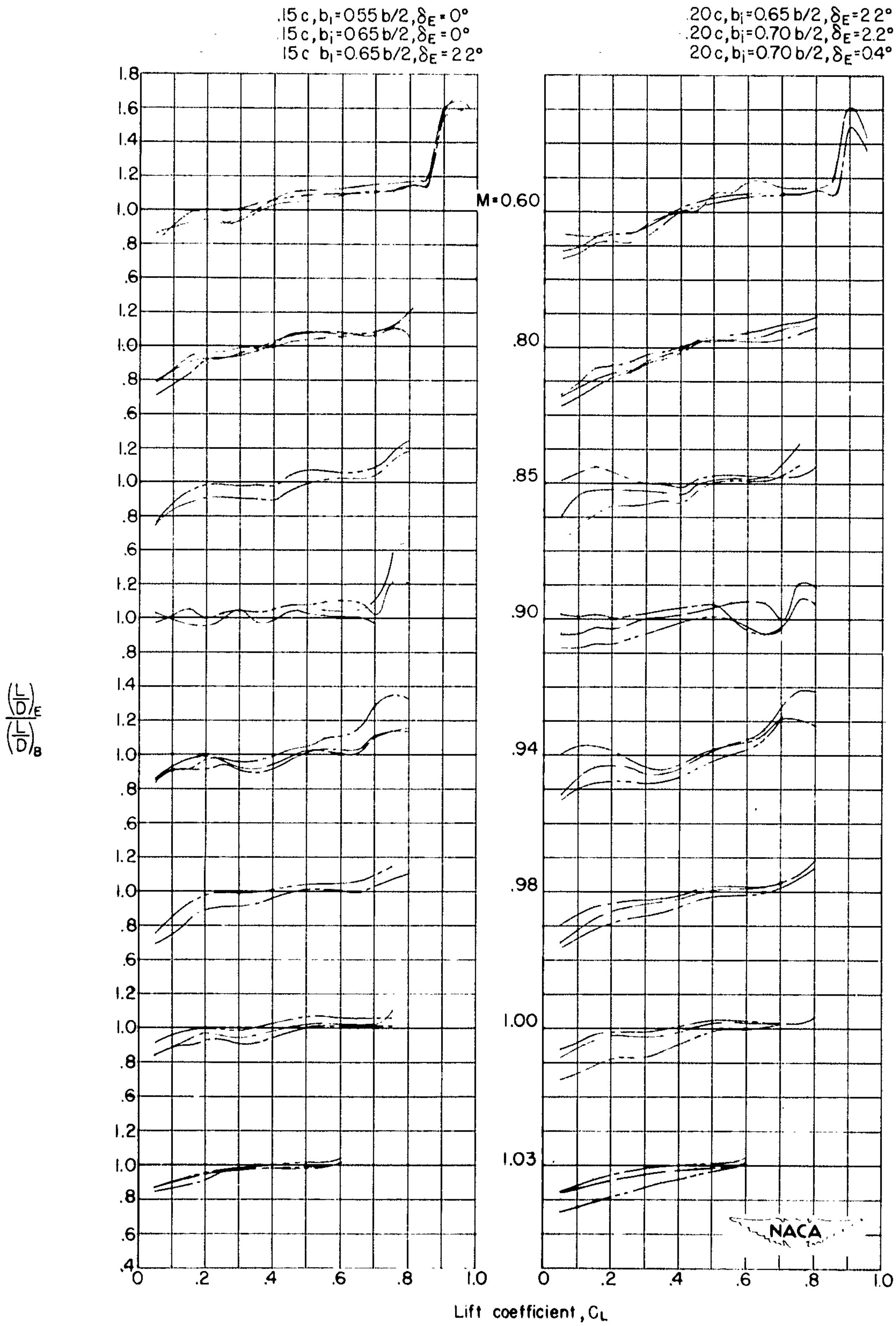


Figure 14.- Effect of leading-edge chord-extensions on the lift-drag ratio of the wing-normal configurations.