NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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LOW-SPEED EXPERIMENTAL INVESTIGATION OF A THIN, FAIRED, DOUBLE-WEDGE AIRFOIL SECTION WITH NOSE AND TRAILING-EDGE FLAPS

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LOW-SPEED EXPERIMENTAL INVESTIGATION OF A THIN, FAIRED, DOUBLE-WEDGE AIRFOIL SECTION WITH NOSE AND TRAILING-EDGE FLAPS

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SUMMARY

A faired, double-wedge airfoil section, 4.23 percent thick, was investigated with plain nose and trailing-edge flaps. The nose flap was 0.16 of the airfoil chord and the trailing-edge flap was 0.25 of the airfoil chord. Section lift, drag, and pitching-moment data are presented for a Reynolds number of 5,800,000 and a Mach number of 0.17.

A maximum lift coefficient of 1.96 was obtained with combined nose and trailing-edge flap deflections of 30° and 60°, respectively. The maximum lift coefficient of the basic section with flaps undeflected was 0.84.

The possibility of a considerable reduction in profile drag at high lift coefficients over that of the plain airfoil was indicated for suitable combinations of nose and trailing-edge flap deflections.

INTRODUCTION

Although thin, sharp-edged airfoil sections are intended primarily for operation at supersonic speeds, the safe operation of piloted aircraft equipped with such sections requires a knowledge of the characteristics of these sections at low speeds. Thin airfoil sections generally develop low maximum lift coefficients, and sharp-edged sections are further characterized by large variations of profile drag with lift. To overcome these deficiencies, both nose and trailing-edge flaps have been proposed for use with such airfoils.

As there are presently available little data as to the characteristics of thin, sharp-edged airfoil sections, an investigation of a faired, double-wedge airfoil with plain nose and trailing-edge flaps was undertaken. The force and moment characteristics obtained with a 16-percent-chord nose flap and a 25-percent-chord trailing-edge flap are presented herein. The tests were made in the Ames 7- by 10-foot wind tunnel No. 1.

NOTATION

The results are presented in the form of standard NACA coefficients which are defined as follows:

c_{d_o}	section profile-drag coefficient (D/qc)
c_l	section lift coefficient (L/qc)
c_m	section pitching-moment coefficient, referred to the quarter-chord point (M/qc^2)
c	airfoil chord, feet
D	drag per unit span, pounds per foot
L	lift per unit span, pounds per foot
M	pitching moment per unit span, pound-feet per foot
q	free-stream dynamic pressure, pounds per square foot
α_o	section angle of attack, degrees

MODEL AND TESTS

The airfoil section tested was obtained by rounding the midsection of a symmetrical double wedge with an arc tangent to the surface at 42.5 and 57.5 percent of the chord. The resulting airfoil had a thickness of 4.23 percent of the chord. A plain nose flap of 16-percent chord and a plain trailing-edge flap of 25-percent chord were incorporated on the model. A section drawing of the model is shown in figure 1. Both the nose and trailing-edge flaps were made of metal in order to make the leading- and trailing-edge thicknesses as small as possible. The remainder of the model was built of wood on a steel spar and covered with a thin aluminum skin. The flaps were connected to the central portion of the model by a continuous hinge, and rubbing contact was maintained between the radius of the deflected flap and the skirt on the fixed portion of the airfoil.

Lift, drag, and pitching-moment data were obtained from the wind-tunnel balance system. The results thus obtained included the forces acting on the turntables at either end of the model (fig. 2). It has been found in previous investigations that, with the exception of the drag, the effect of these turntables on the results obtained is negligible. Some additional drag data were obtained by surveys of the wake behind the model, but these results were limited in extent because the wake was wider than the available survey rake except for a small range of angles of attack and flap deflections. Comparison of the drag results obtained by the two methods of measurement indicated that, although it was not possible to establish the tare of the turntables for all conditions, the drag results obtained from the balance system are satisfactory for indicating, qualitatively, the effects of flap deflection on the drag of the model.

The tests were carried beyond maximum lift except for certain combinations of nose and trailing-edge flap deflections where severe shaking or buffeting of the model occurred near maximum lift. When this condition was encountered, it was impossible to determine the maximum lift coefficient. However, it is believed that the highest lift coefficient measred, before buffeting made it impossible to obtain further results, was very nearly the maximum.

The tests were made at a Reynolds number of approximately 5,800,000 and a Mach number of approximately 0.17. The results were corrected for constraint of the tunnel walls by the methods outlined in reference 1.

RESULTS AND DISCUSSION

The lift and pitching-moment characteristics of the model with various flap deflections are presented in figure 3. The drag results obtained from wake surveys are shown in figure 4, and additional drag results from the balance system for a greater range of flap deflections and lift coefficients are shown in figure 5. The variation of maximum lift coefficient with nose flap deflection for various deflections of the trailing-edge flap is shown in figure 6.

Maximum Lift Characteristics

The maximum lift coefficient of the basic airfoil section was 0.84, and, as shown in figure 3(a), the lift varied linearly with angle of attack to nearly maximum lift. There were no discontinuities evident in this lift curve. A maximum lift coefficient of 1.73 was obtained for a 60° deflection of the trailing-edge flap with the nose flap undeflected. It is possible that a slightly higher maximum lift coefficient might have been obtained for greater trailing-edge flap deflections; however, a flap deflection of 60° was the maximum tested. With the nose flap alone deflected, a maximum lift coefficient of 1.28 was obtained with 30° deflection. For combined deflections of the nose and trailing-edge flaps of 30° and 60°, respectively, a maximum lift coefficient of 1.96 was obtained. The variation of maximum lift coefficient with nose flap deflection, as shown in figure 6, indicates that the nose flap was more effective in increasing maximum lift for the smaller trailing-edge flap deflections.

For all of the nose flap deflections investigated, except 35°, the results could be repeated without difficulty. With the nose flap at 35°, however, a considerable range of maximum lift values was obtained on repeated runs. An attempt was made to find an indication of the cause of this inconsistency in results by the application of roughness at several locations on the nose flap.[1] The results of this investigation are shown in figure 7 and indicate no conclusive information as to the reason for the diverse maximum lift characteristics.

Pitching-Moment Characteristics

The variation of pitching-moment coefficient with lift coefficient for the basic airfoil section with flaps undeflected, shown in figure 3(a), indicates that the aerodynamic center moved forward from the quarter-chord point until a lift coefficient of approximately 0.5 was attained. The aerodynamic center above this lift coefficient moved rearward at an increasing rate as the lift coefficient was further increased. Trailing-edge flap deflection resulted in large negative pitching moments and a pronounced variation of the location of aerodynamic center with lift coefficient. Deflection of the nose flap resulted in moderate negative pitching moments and delayed the rearward movement of the aerodynamic center to higher lift coefficients.

Drag Characteristics

Although it was not possible to correct the drag results obtained from the balance system for the tare of the end plates, the drag results obtained by both the wake survey and balance system clearly indicate the usefulness of the nose flap, and, to a lesser extent, the trailing-edge flap, in reducing the drag at high lift coefficients (figs. 4 and 5). The drag results shown in figure 4 indicate that by the use of suitable combinations of nose and trailing-edge flap deflections it is possible to obtain profile-drag coefficients of the same order of magnitude as those obtained for thicker conventional airfoil sections not equipped with nose flaps. The drag results presented in figure 5 indicate similar beneficial effects of nose flap deflection with even the largest trailing-edge flap deflections tested.

CONCLUDING REMARKS

The results obtained in this investigation of a faired, double-wedge airfoil section with plain nose and trailing-edge flaps are summarized as follows:

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[1] The roughness applied extended over approximately 1 percent of the chord with number 60 carborundum grains distributed as uniformly as possible over this length.

1. A maximum lift coefficient of 0.84 was obtained for the basic airfoil. For individual deflections of the nose and trailing-edge flaps of 30° and 60°, respectively, maximum lift coefficients of 1.28 and 1.73 were obtained. Simultaneously deflecting the nose flap 30° and the trailing-edge flap 60° produced a maximum lift coefficient of 1.96.

2. The aerodynamic center of the basic airfoil section moved forward slightly from the quarter-chord point as the lift coefficient was increased to about 0.5. At higher lifts an increasingly rapid rearward movement of the aerodynamic center occurred. Deflection of the trailing-edge flap resulted in much more negative pitching moments and accentuated the variation of aerodynamic-center location with lift coefficient. Deflection of the nose flap resulted in slightly more negative pitching moments and delayed the rearward movement of the aerodynamic center to higher lift coefficients.

3. Considerable reduction in drag at high lift coefficients was noted for suitable combinations of nose and trailing-edge flap deflections.

Ames Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Moffett Field, Calif., June 13, 1949.

REFERENCE

1. Allen, H. Julian, and Vincenti, Walter G.: Wall Interference in a Two-Dimensional-Flow Wind Tunnel with Consideration of the Effect of Compressibility. NACA Rep. 782, 1944.

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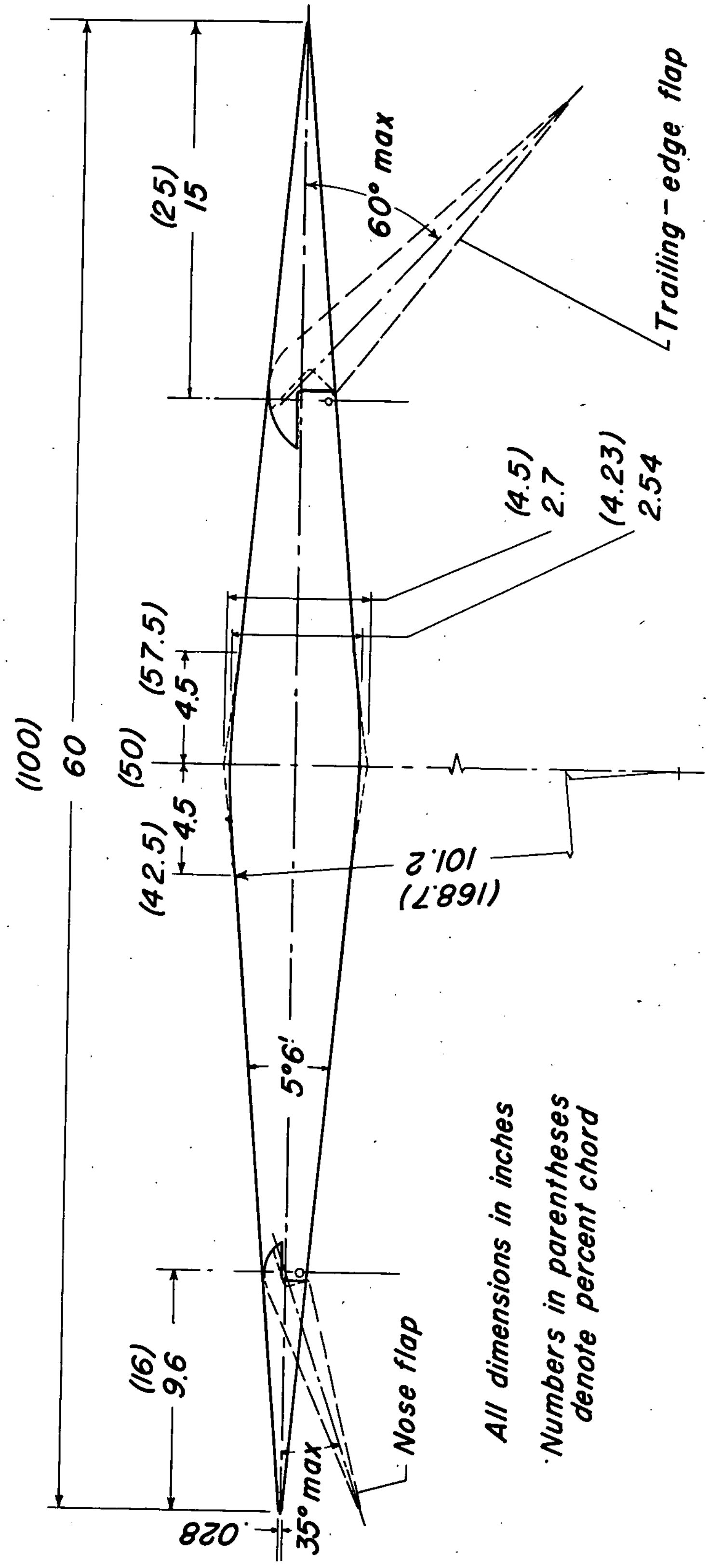

All dimensions in inches

Numbers in parentheses denote percent chord

Figure 1.-The faired, double-wedge airfoil with nose flap and trailing-edge flap.

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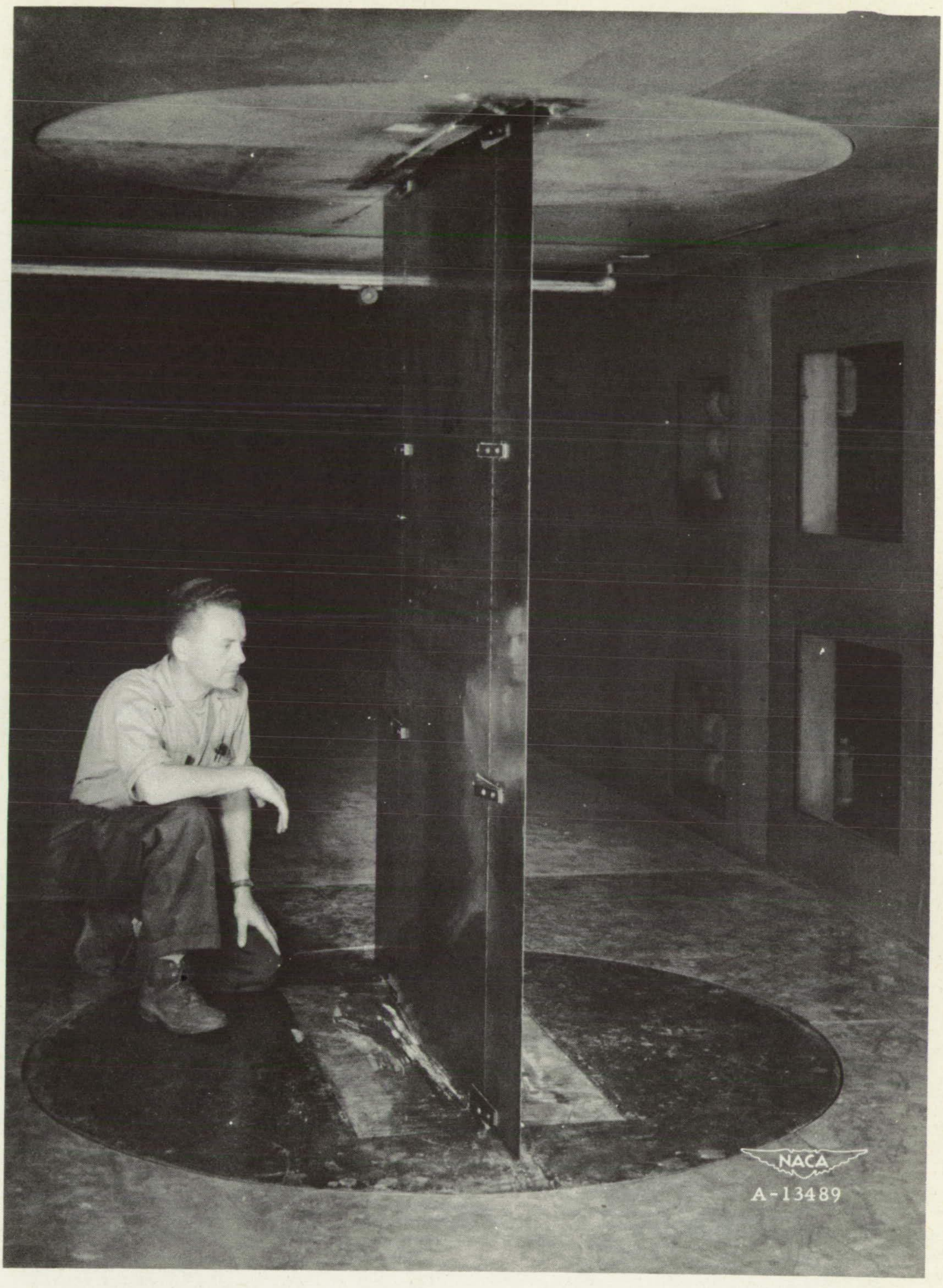

Figure 2.- The faired, double-wedge airfoil model installed in the wind tunnel.

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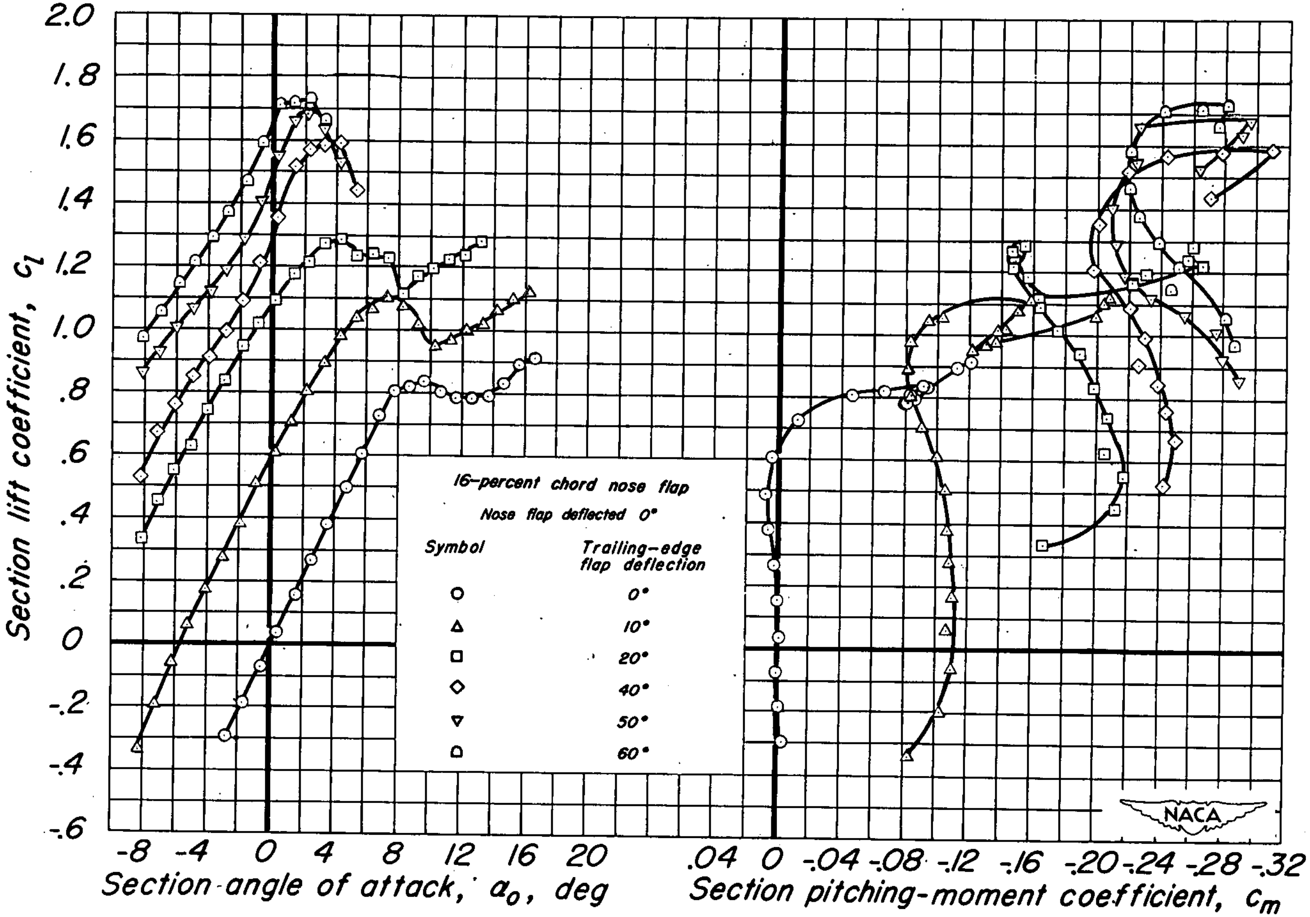
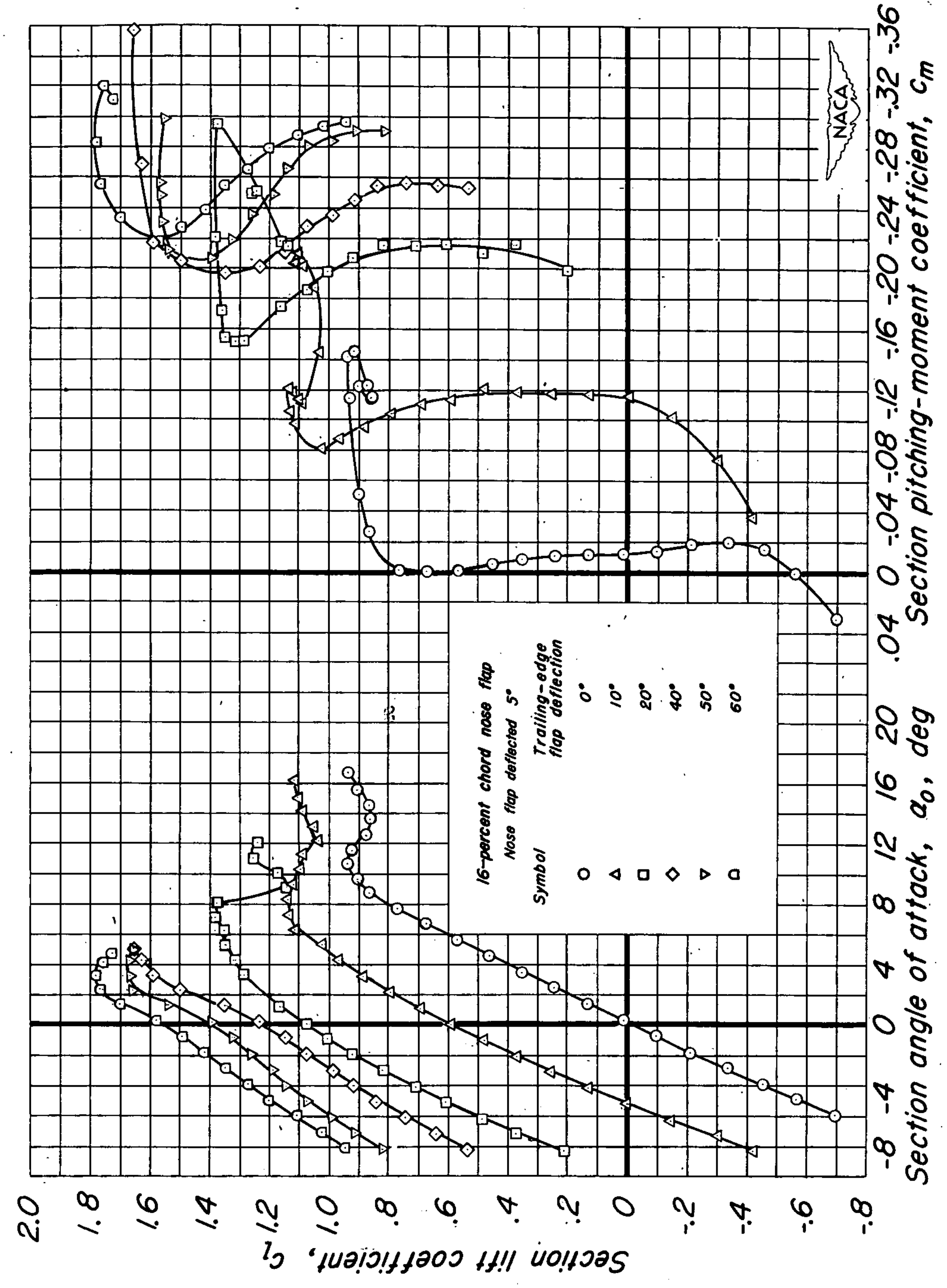


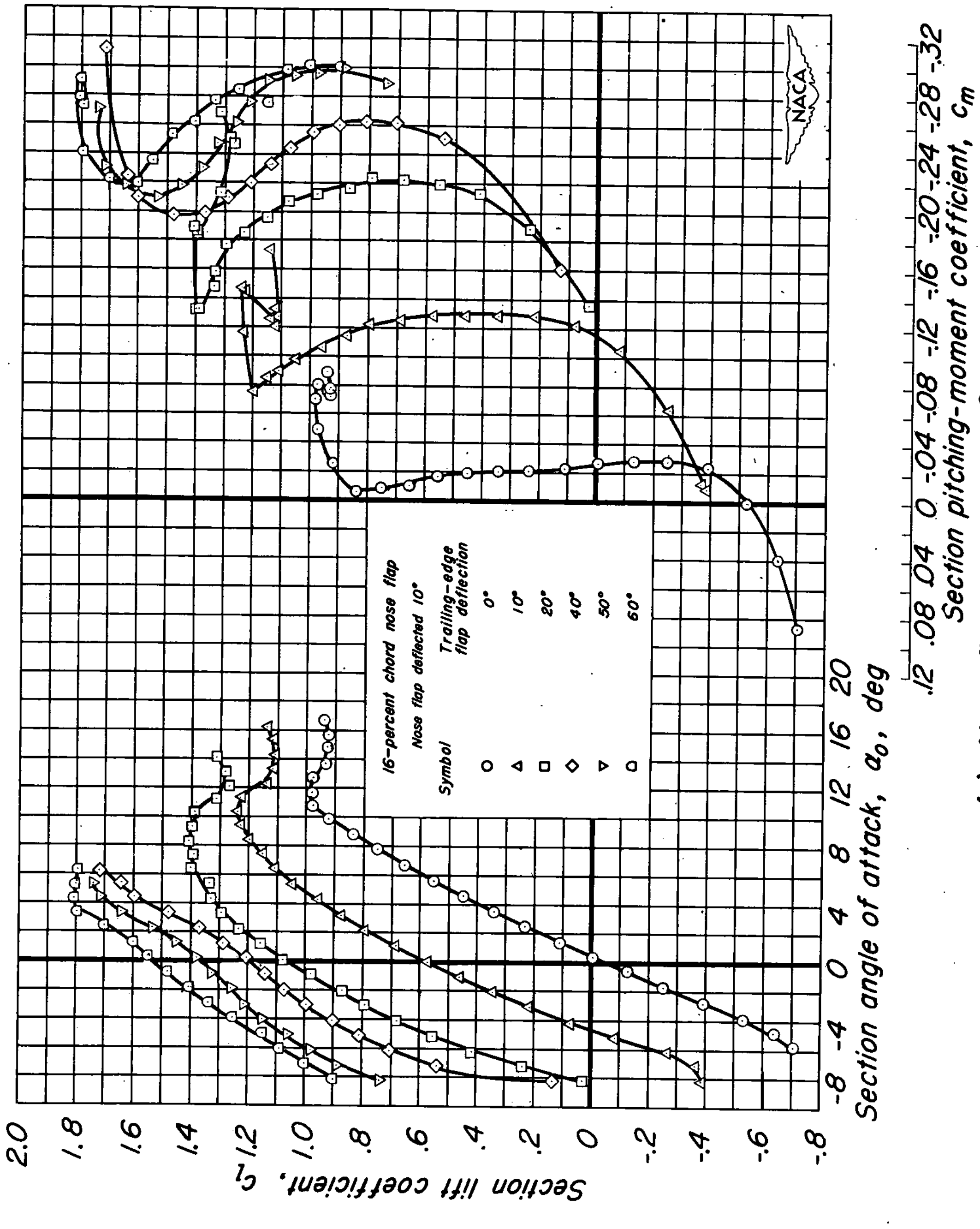
(a) Nose flap deflection, 0°.

Figure 3.– Section lift and pitching-moment characteristics of the model for various deflections of the nose and trailing-edge flaps.



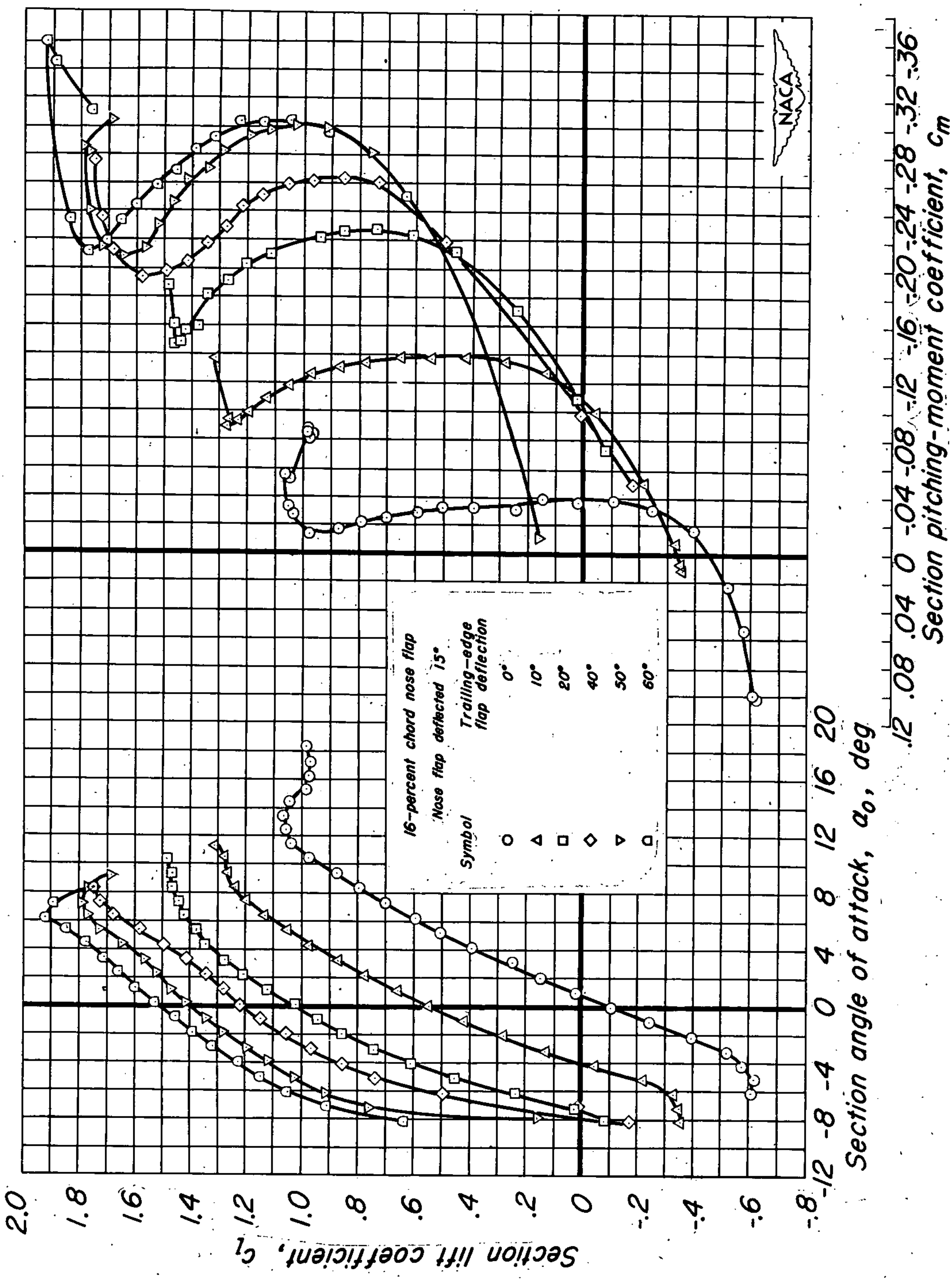
(b) Nose flap deflection, 5°.

Figure 3.-Continued.



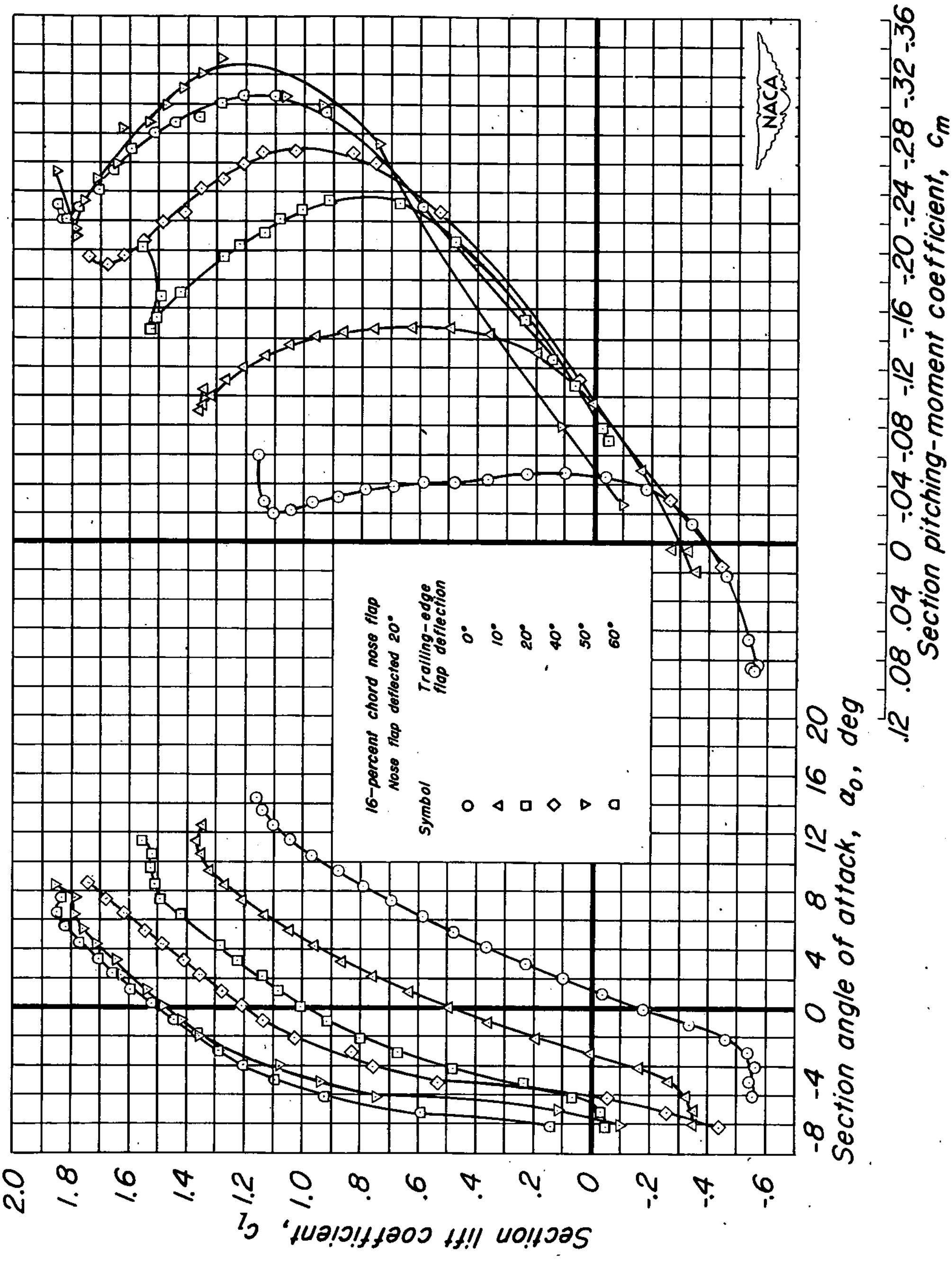
(c) Nose flap deflection, 10°.

Figure 3.-Continued.



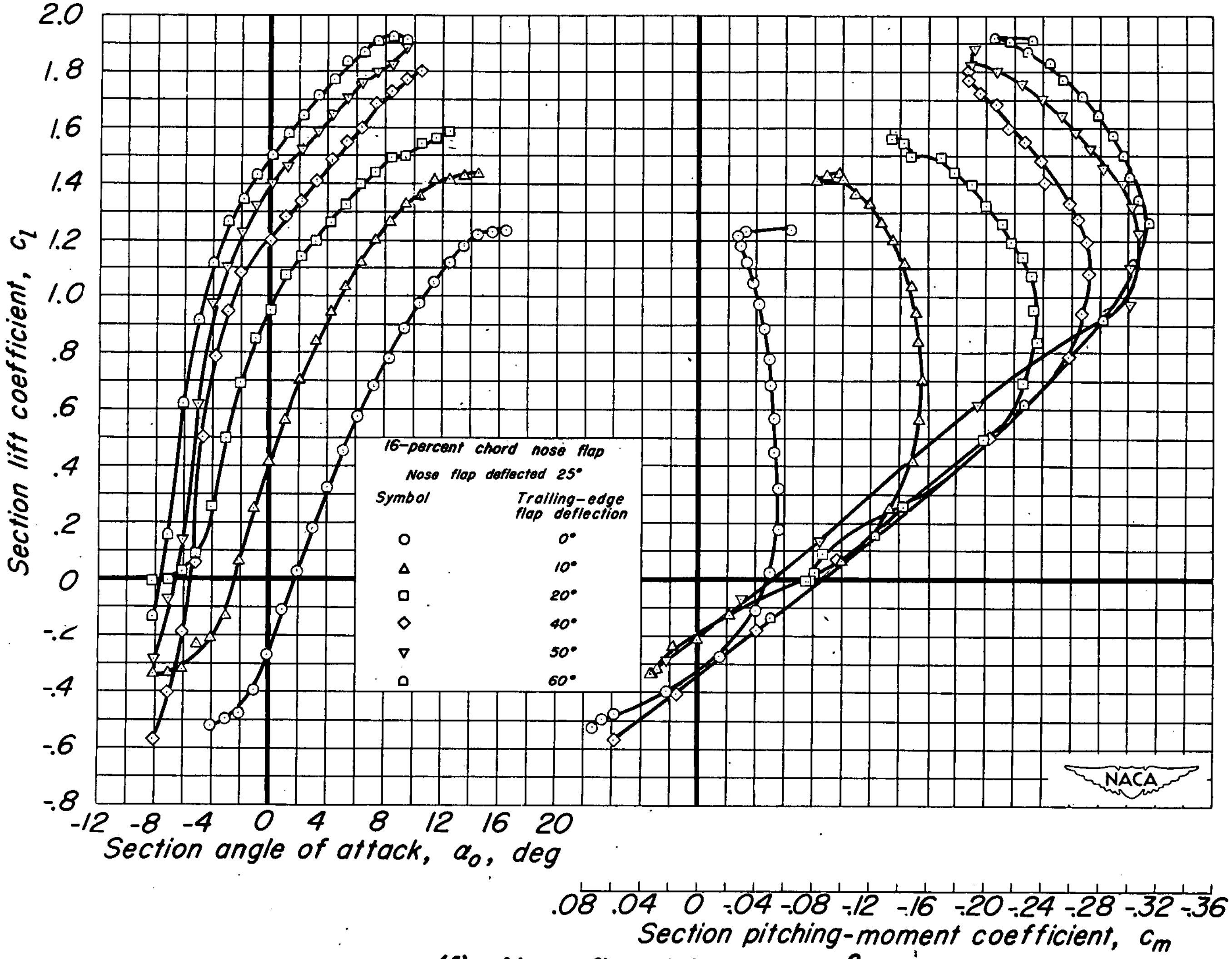
(d) Nose flap deflection, 15°.

Figure 3.-Continued.



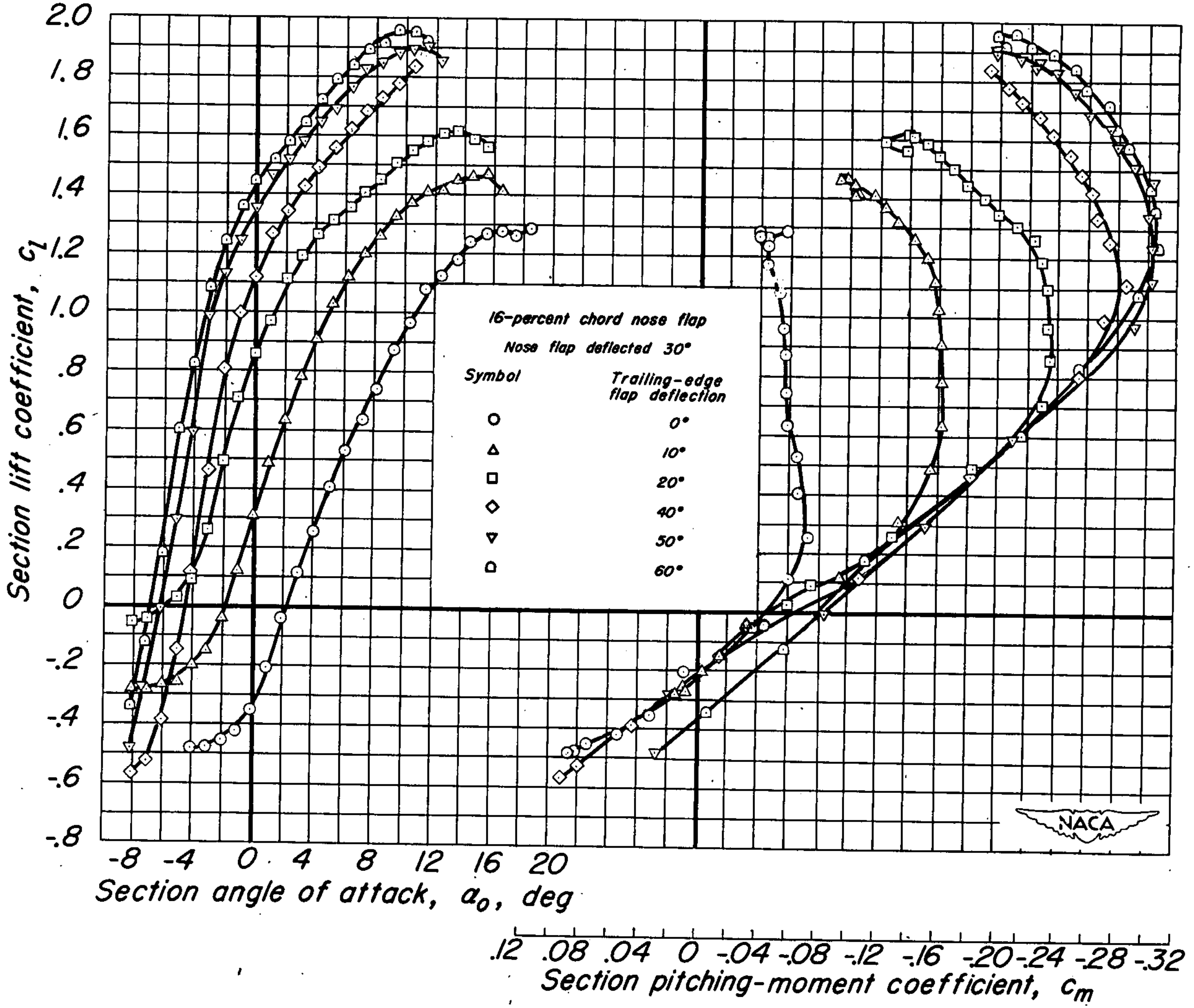
(e) Nose flap deflection, 20°.

Figure 3.- Continued.



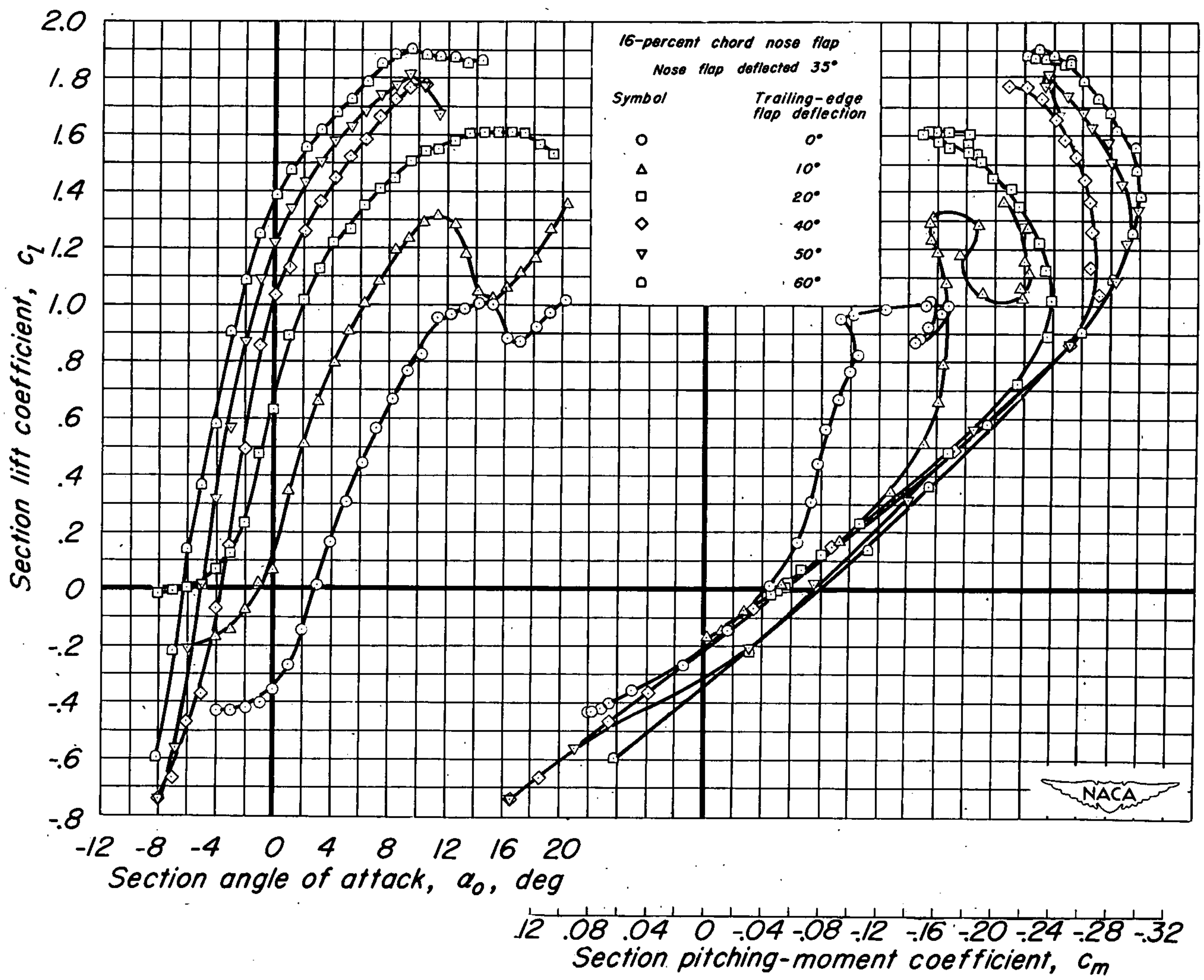
(f) Nose flap deflection, 25°.

Figure 3.–Continued.



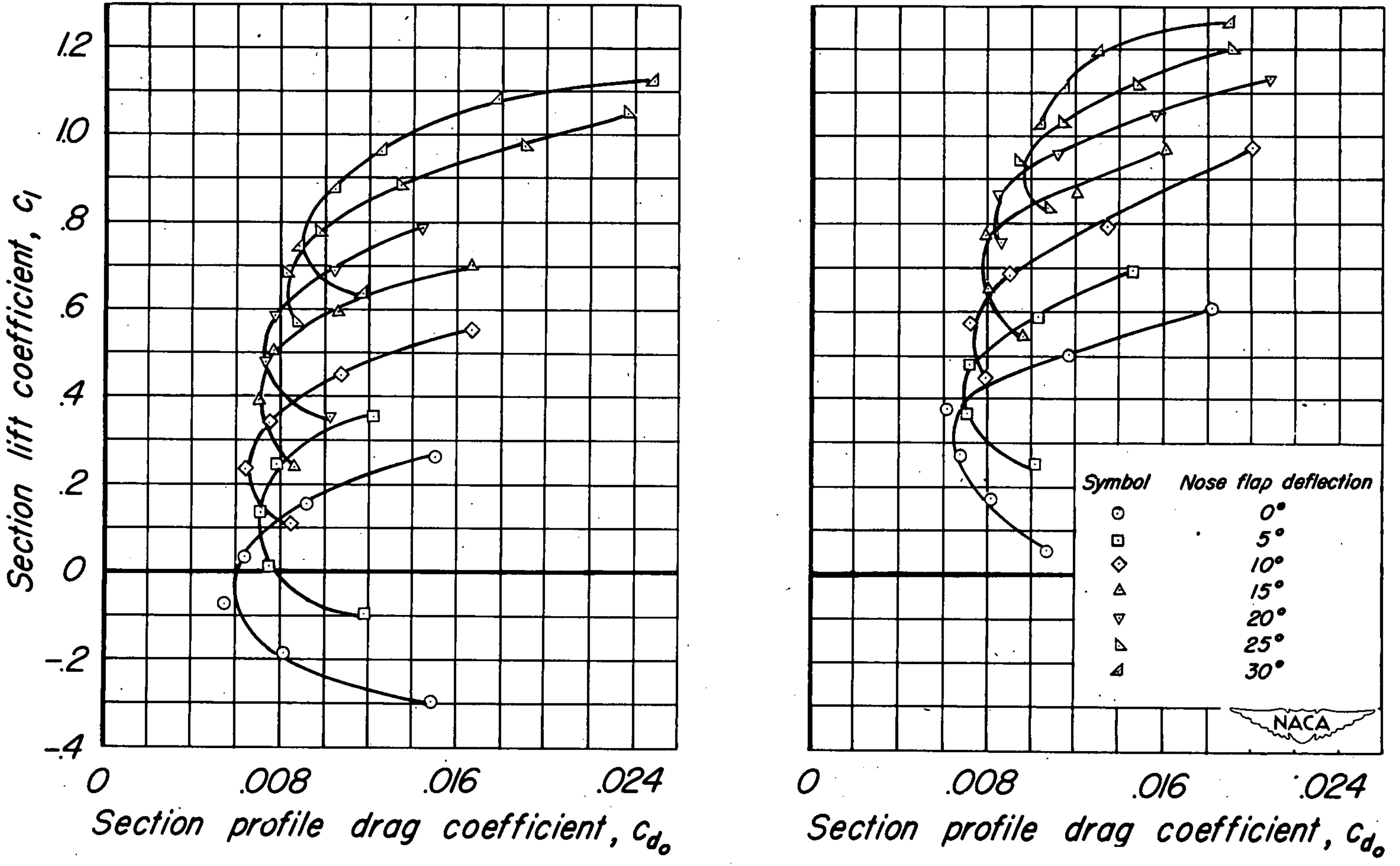
(g) Nose flap deflection, 30°

Figure 3.- Continued.



(h) Nose flap deflection, 35°.

Figure 3.- Concluded.



(a) Trailing-edge flap deflection, 0°.

(b) Trailing-edge flap deflection, 10°.

Figure 4.—Section drag characteristics for two trailing-edge flap deflections as measured by wake surveys.

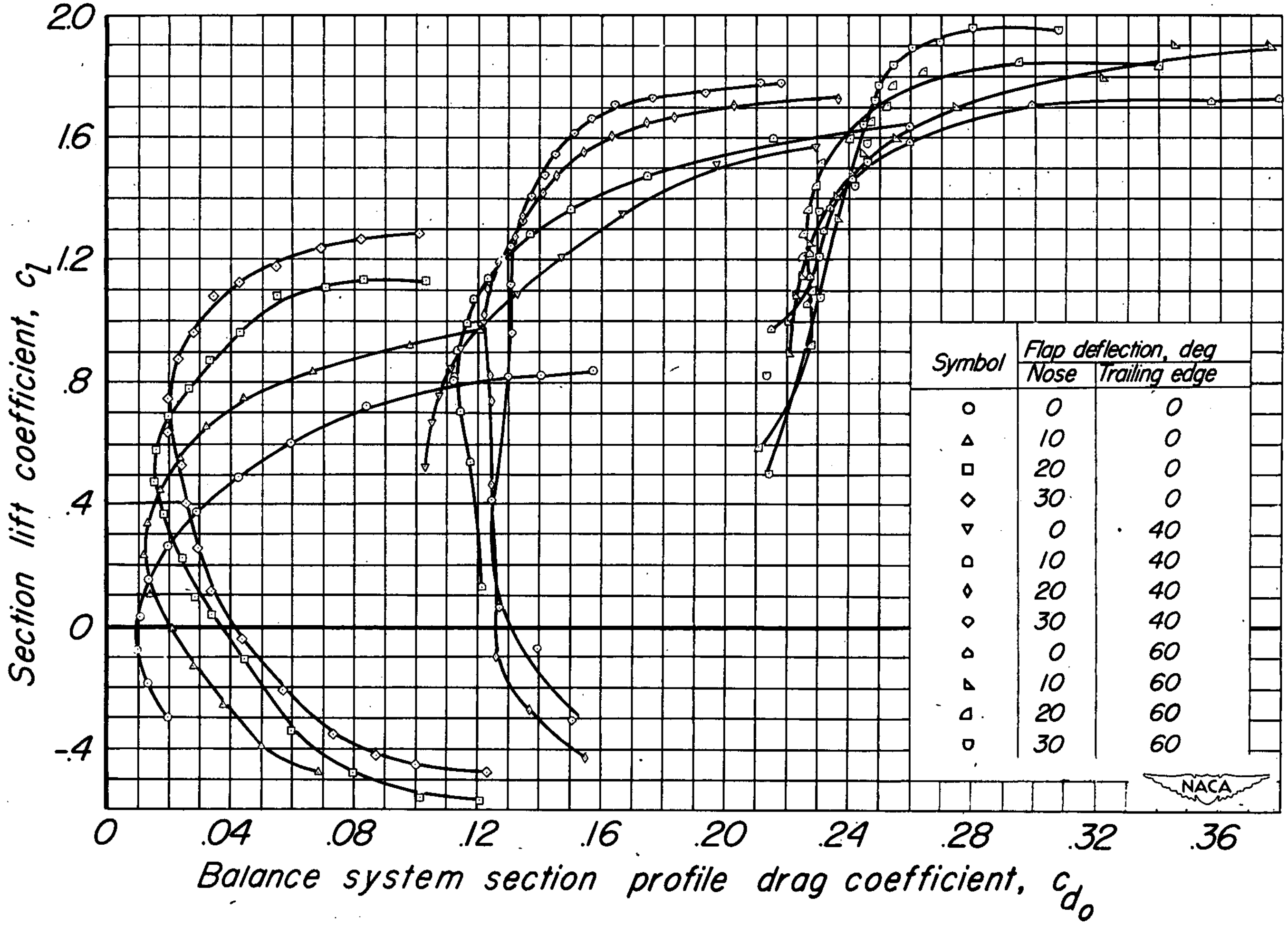


Figure 5.—Section drag characteristics for various deflections of the nose and trailing-edge flaps as measured by the balance system.

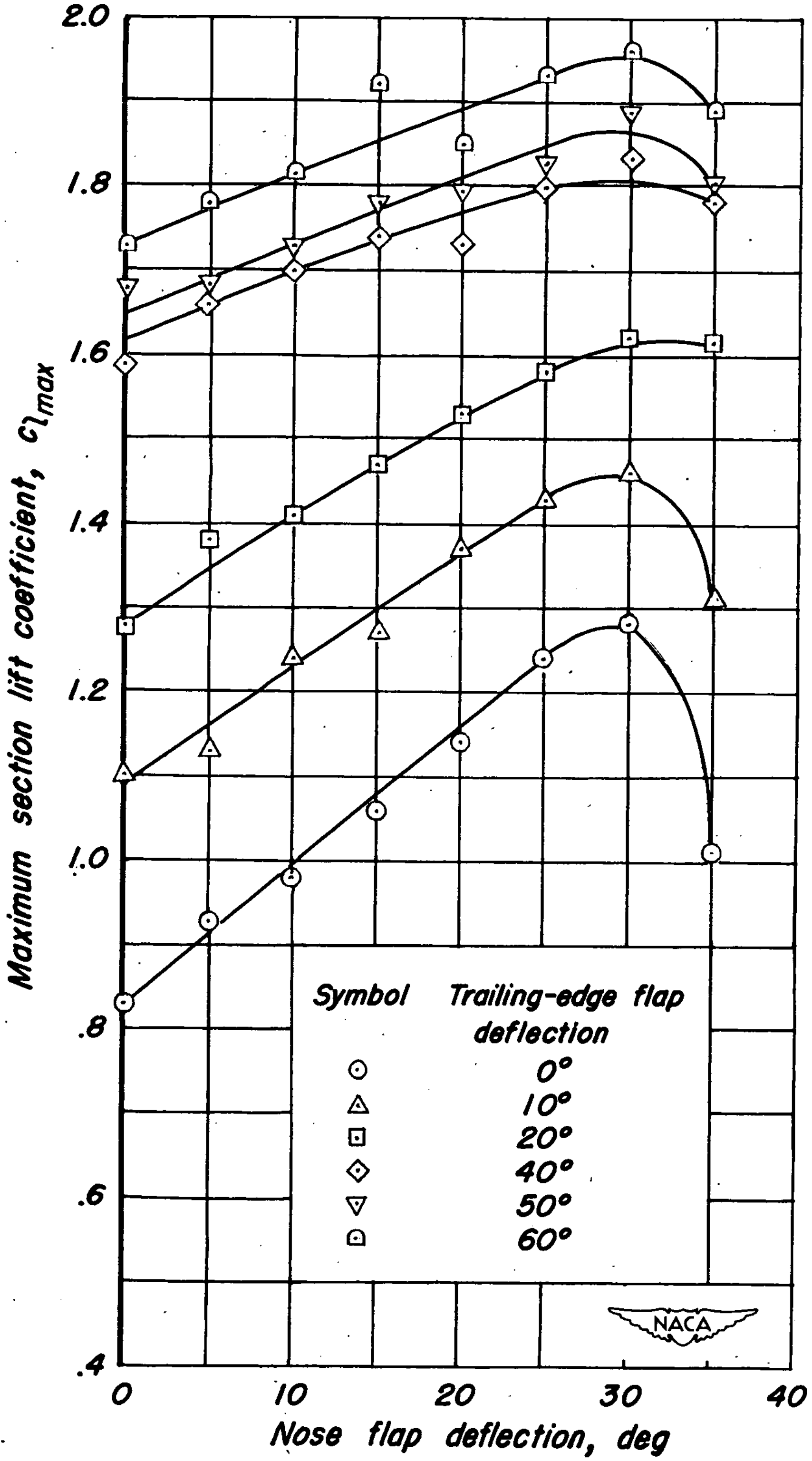


Figure 6.— The variation of maximum section lift coefficient with flap deflection.

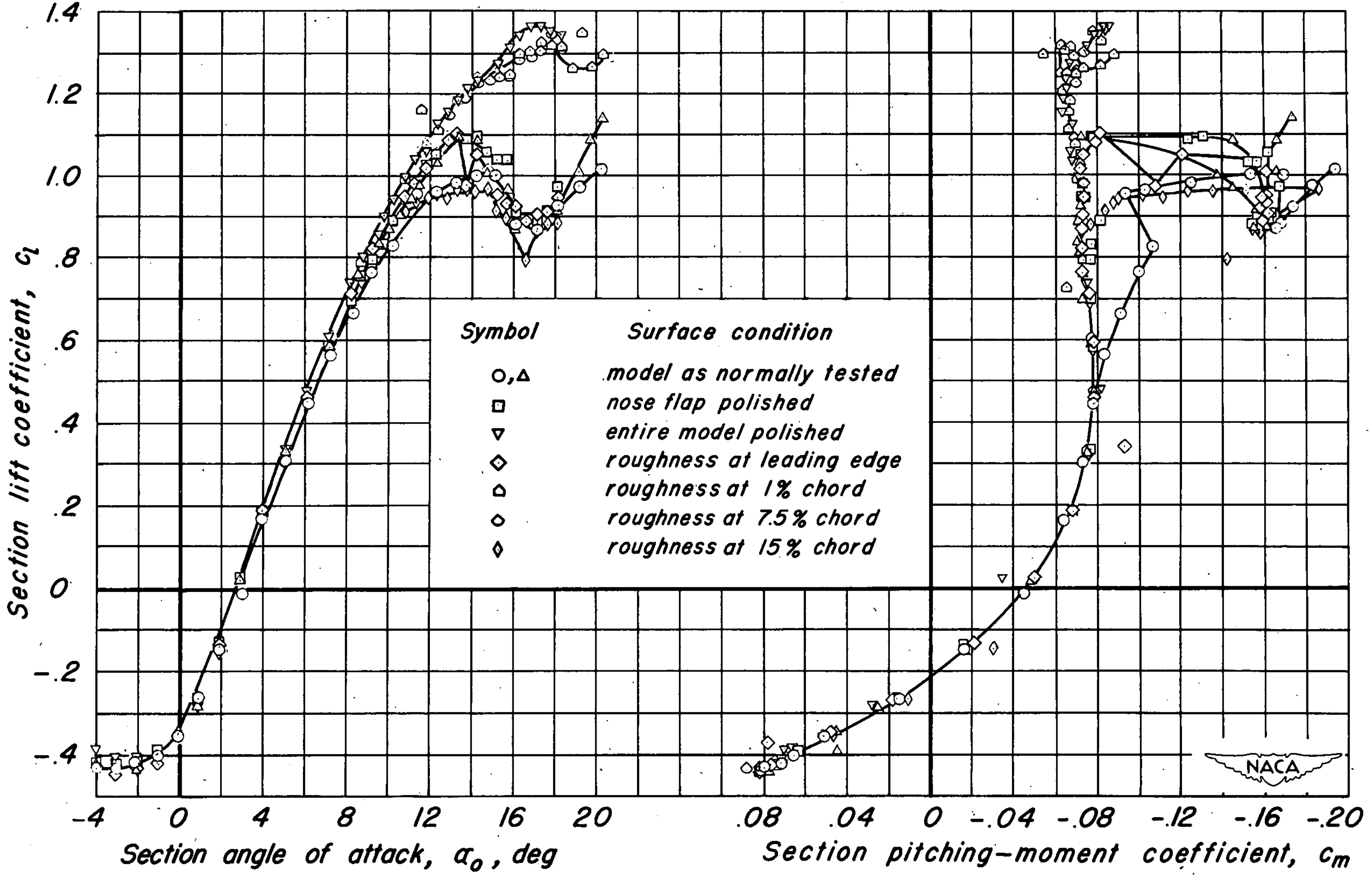


Figure 7.- The variation of lift and pitching-moment characteristics obtained with the nose flap deflected 35° and the trailing-edge flap undeflected.