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WIND-TUNNEL INVESTIGATION OF CONTROL-SURFACE CHARACTERISTICS

III - A SMALL AERODYNAMIC BALANCE OF VARIOUS NOSE SHAPES USED WITH A 30-PERCENT-CHORD FLAP ON AN NACA 0009 AIRFOIL

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III - A SMALL AERODYNAMIC BALANCE OF VARIOUS NOSE SHAPES USED WITH A 30-PERCENT-CHORD FLAP ON AN NACA 0009 AIRFOIL

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SUMMARY

Tests have been made in the NACA 4- by 6-foot vertical wind tunnel of an NACA 0009 airfoil with a 30-percent-chord flap having a small amount of aerodynamic balance. In the investigation the effect of balance nose shape and gap at the nose of the flap has been determined. A few tests were made to determine the effectiveness of a tab on the balanced surface. The complete section aerodynamic characteristics of some of the arrangements tested are given. A partial analysis of the data has been made, and the results are discussed.

The results indicate that, in general, the lift effectiveness of the flap was unaffected by the addition of a small amount of aerodynamic overhang, and the balance effectiveness of the flap was increased. The blunt-nose shape gave the greatest reduction in flap section hinge-moment coefficient for moderate flap deflections, but for flap deflections greater than 20° the medium flap nose was the most effective in this respect. The presence of a gap at the flap nose reduced the lift effectiveness and the balance effectiveness of the flap for all of the test conditions except when the angle of attack and the flap deflection were both positive. The effects caused by the presence of a gap increased as the taper of the flap nose shape increased. The characteristics of the tab were generally unaffected by aerodynamic overhang and flap nose shape. The minimum profile-drag coefficient of the airfoil with the flap having the most tapered nose shape was about 15 percent greater than for the airfoil with the blunt nose flap.

INTRODUCTION

The recent increases in speed and size of airplanes have produced control forces of such magnitude that it has become increasingly important to reduce hinge moments on the controls and thus to reduce the forces on the control stick. In an effort to obtain a satisfactory solution of the problem, the NACA has instituted an extensive investigation to determine the aerodynamic characteristics of control surfaces and to present adequate data for control-surface design. Because a conventional control surface is merely a flap on an airfoil, these two terms are used synonymously. As a part of this investigation, some of the effects of flap nose shape and gap on a typical horizontal tail of finite span were determined in the full-scale tunnel and are reported in reference 1.

The more basic part of the investigation is, however, being made in a two-dimensional flow. The first part of the two-dimensional flow investigation was the determination of the section characteristics for airfoil-flap combinations using plain flaps with sealed gaps at the flap nose. Flaps of various sizes from 0 to 100 percent of the airfoil chord were tested. (See references 2, 3, and 4.) The data presented in references 2, 3, and 4 have been analyzed and parameters for determining the characteristics of a thin symmetrical airfoil with a plain flap of any chord and with the gap at the flap nose sealed are given in reference 5. The results of force tests of a plain flap with various gaps at the flap nose are presented in reference 6.

The present report gives the results of tests of an airfoil having a 30-percent-chord flap with a 20-percent-flap-chord overhang and a 20-percent-flap-chord tab. The tests were made to determine the effect of various flap nose shapes and several sizes of gap at the flap nose on the aerodynamic characteristics of the airfoil-flap-tab combination. In order that the data might be made immediately available, only a very limited analysis of the results has been made.

APPARATUS AND MODEL

The tests were made in the NACA 4- by 6-foot vertical wind tunnel (reference 7), modified as described in reference 2 for force tests of a model in a two-dimensional flow. A three-component balance system has been installed in the tunnel. On this balance the aerodynamic forces of lift and drag and the pitching moments are measured independently and simultaneously. The hinge moments of the flap and the tab are measured with special torque-rod balances built into the model.

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The 2-foot-chord by 4-foot-span model was the same model used for the investigation in reference 6, but with modifications so that tests could be made with a small overhanging balance on the flap. (See fig. 1.) The model was made of laminated mahogany to the NACA 0009 profile, the stations and ordinates of which are given in table I. The flap chord, measured from the flap-hinge axis to the airfoil trailing edge, is 30 percent of the airfoil chord. The overhanging balance ahead of the flap-hinge axis is 20 percent of the flap chord. The flap nose shape and the gap between the flap nose and the airfoil were varied by detachable flap nose blocks and airfoil tail blocks ahead of the flap nose. The nose shapes tested are shown in figure 1 and were developed to give a systematic variation of flap nose shape profile. The stations and ordinates for the various flap nose shapes are given in table II. The nose shapes are identified by numbers 0, 8, 20, 28, 28A, and 31 to indicate the approximate degrees the flap may be deflected before the $0.20c_f$ overhanging flap nose protrudes beyond the contour of the airfoil profile. Nose shapes 8, 20, 28, and 31 are modified conic sections. Nose 28A is an application of a nose profile used in the tests of reference 1. The blunt nose, nose shape 0, was obtained by making the leading-edge radius approximately one-half the airfoil section thickness at the radius center. The tab was made of brass, and the nose radius is approximately one-half the airfoil thickness at the tab-hinge axis. The gap between the tab and the flap was fixed at 0.1 of 1 percent of the airfoil chord.

The model, when mounted in the tunnel, completely spanned the test section. With this type of installation, two-dimensional flow is approximated and the section characteristics of the airfoil, flap, and tab can be determined. The model was attached to the balance frame by torque tubes, which extended through the sides of the tunnel. (See reference 2.) The angle of attack was set from outside the tunnel by rotating the torque tubes with an electric drive. Flap and tab deflections were set inside the tunnel and were held by friction clamps on the torque rods which were used in measuring the hinge moments.

TESTS

The tests were made at a dynamic pressure of 15 pounds per square foot which corresponds to an air velocity of about 76 miles per hour at standard sea-level conditions. The effective Reynolds number of the tests was approximately 2,760,000. (Effective Reynolds number = test Reynolds number X turbulence factor. The turbulence factor of the 4- by 6-foot vertical tunnel is 1.93.)

The six flap nose shapes were tested first with the tab neutral and the gap at the flap nose 0.5 of 1 percent of the airfoil chord. The preliminary results indicated that a satisfactory investigation of flap nose shape characteristics could be made by testing only the blunt-nose shape, 0, the medium-nose shape, 20, and the sharp-nose shape, 31, and these nose shapes will hereafter be referred to as blunt, medium, and sharp. Accordingly, the tests were continued with the 0.005c gap and the three flap nose shapes previously mentioned to determine the effects of flap nose shape variation on the characteristics of a $0.20c_f$ tab. The tests of the blunt-, medium-, and sharp-nose shapes were finally extended to determine the effects of gap sizes at the flap nose of 0.001c, 0.010c, and with the gap sealed. Lift, drag, and pitching moments of the airfoil and hinge moments of the flap and tab were measured. For each flap and tab deflection, force tests were made throughout the angle-of-attack range from negative to positive stall at 2° increments of angle of attack except near the airfoil stall, where 1° increments in angle of attack were used.

RESULTS

Symbols

The coefficients and symbols used in this report are defined as follows:

c_l airfoil section lift coefficient $\left(\frac{l}{qc}\right)$

c_{d_o} airfoil profile-drag coefficient $\left(\frac{d_o}{qc}\right)$

c_m airfoil section pitching-moment coefficient about the quarter-chord point $\left(\frac{m}{qc^2}\right)$

c_{h_f} flap section hinge-moment coefficient $\left(\frac{h_f}{qc_f^2}\right)$

c_{h_t} tab section hinge-moment coefficient $\left(\frac{h_t}{qc_t^2}\right)$

where

l airfoil section lift

d_o airfoil profile drag

m airfoil section pitching moment about quarter-chord point of airfoil

h_f flap section hinge moment

h_t tab section hinge moment

c chord of basic airfoil with flap and tab neutral

c_f flap chord (measured from flap-hinge axis to flap trailing edge, tab neutral)

c_t tab chord

q dynamic pressure $(\frac{1}{2}\rho V^2)$

and α_o angle of attack from zero lift for airfoil of infinite aspect ratio

δ_f flap deflection with respect to airfoil

δ_t tab deflection with respect to flap

Precision

The accuracy of the data is indicated by the deviation from zero of the lift and moment coefficients at zero angle of attack and flap deflection. The maximum error in effective angle of attack at zero lift appears to be about $\pm 0.2^\circ$. The flap deflections were set to within $\pm 0.2^\circ$. Tunnel corrections, experimentally determined in the 4- by 6-foot vertical tunnel, were applied to lift coefficients only. The hinge-moment coefficients, therefore, are probably higher than would be obtained in free air; hence the values presented are considered to be conservative. The increments of drag coefficients should be reasonably independent of tunnel effect, although the absolute values of drag coefficient are subject to an undetermined correction. Inaccuracies in the airfoil and flap section data presented are thought to be negligible relative to the inaccuracies that will be incurred in the application of the data to finite airfoils.

Summary of Test Results

In order that the results for the tests of the various model configurations may be more easily found, a table has been prepared giving the model arrangements tested and the figure numbers for the plots of the corresponding data.

Flap nose shape	Gap size	Flap deflection (deg)	Tab deflection (deg)	Results (fig.)
(Blunt), 0				
8				
(Medium), 20		0,5,10,15,20,25,30,45	0	2a,b
28				
28A	0.005c			
(Sharp), 31				
Blunt				
Medium		0	0,±10,±15,±20,±30	10,13a
Sharp		10,25	0,-10,-15,-20,-30	11,12,13b
	sealed			3a
Blunt	0.001c			3b
	0.005c	0,5,10,15,20,25,30		3c
	0.010c			3d
	sealed			4a
Medium	0.001c		0	4b
	0.005c	0,5,10,15,20,25,30		4c
	0.010c			4d
	sealed			5a
Sharp	0.001c			5b
	0.005c	0,5,10,15,20,25,30		5c
	0.010c			5d

DISCUSSION

The airfoil section lift coefficients and the flap section hinge-moment coefficients of the NACA 0009 airfoil with a 0.30c flap having an aerodynamic overhang of $0.20c_f$ and a gap of 0.005c at the flap nose are plotted against angle of attack for the flap neutral in figure 2(a), and against flap deflections for several angles of attack in figure 2(b), to show the effect of six variations of flap nose shape. The data in figures 2(a) and (b) indicate that the effect of flap nose shape could be determined satisfactorily by considering only the 0 or blunt-, 20 or medium-, and 31 or sharp-flap nose shapes. For this reason only the points for the blunt-, medium-, and sharp-flap nose shapes have been faired. The results of the tests to determine the section characteristics of the airfoil and blunt nose flap having the gap at the flap nose sealed are given in figure 3(a), with a gap of 0.001c in figure 3(b), with a gap of 0.005c in figure 3(c), and with a gap of 0.010c in figure 3(d). In figures 4(a), (b), (c), and (d) and figures 5(a), (b), (c), and (d) the results of tests for the various gap conditions for the flap with medium- and sharp-flap nose shapes, respectively, are presented.

Lift

The slope of the airfoil section lift curve, $\left(\frac{\partial c_l}{\partial \alpha_0}\right)_{\delta_f}$, in agreement with the results in reference 1, was only slightly affected by variations of flap nose shape. (See fig. 2(a).) The value of $\left(\frac{\partial c_l}{\partial \alpha_0}\right)_{\delta_f}$ for the airfoil with the blunt nose flap and a 0.005c gap was about 0.094, which is in satisfactory agreement with the value obtained with a plain flap and 0.005c gap in reference 6.

The effect of flap nose shape on the variation of c_l with δ_f was significant. For flap deflection from 0° to 15° or 20° the flap with the blunt-nose shape gave the highest values of c_l at the several angles of attack investigated (fig. 2(b)). For flap deflections greater than 20°, the flap with the medium-nose shape gave the highest

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values of c_l. At α of -8° and 0°, the $c_{l_{max}}$ for the medium nose flap occurred at $\delta_f = 30^{\circ}$, and at $\alpha = 8^{\circ}$ the $\delta_{f_{max}}$ was about 25°. The sharp-flap nose shape was generally inferior to the blunt- and medium-nose shapes throughout the range of flap deflections.

In general, for all flap nose shapes, increases in the size of the gap at the flap nose caused the slope $\left(\frac{\partial c_l}{\partial \alpha_o}\right)_{\delta_f}$ to decrease, and the curves became increasingly nonlinear at high angles of attack, resulting in reduced values of c_l at these angles of attack (figs. 3, 4, and 5). The flap lift effectiveness, $\left(\frac{\partial \alpha_o}{\partial \delta_f}\right)_{c_l}$, was also greatly affected by the presence of a gap. Increases in the gap size gave decreases in the value of $\left(\frac{\partial \alpha_o}{\partial \delta_f}\right)_{c_l}$, and the magnitude of these decreases was greatest at the high values of c_l. This gap effect also increased with increase of sharpness of the flap nose.

Pitching Moments

With the blunt nose flap neutral and the gap sealed, the rate of change of pitching-moment coefficient with lift coefficient, $\left(\frac{\partial c_m}{\partial c_l}\right)_{\delta_f}$, was about 0.010 (fig. 3(a)) which is in agreement with the value obtained in reference 6. The most noticeable effect of the gap on c_m was the reduction in $\left(\frac{\partial c_m}{\partial \delta_f}\right)_{c_l}$, which was observed at high values of c_l. This reduction is indicated by an increase in slope of pitching-moment-coefficient curves for the various values of δ_f (figs. 3(c), (d), 4(c), (d), and 5(c), (d)).

Hinge Moments of the Flap

The parameter $\left(\frac{\partial c_{h_f}}{\partial \alpha_o}\right)_{\delta_f}$ was generally unaffected by changes in flap nose shape (fig. 2(a)). The value of $\left(\frac{\partial c_{h_f}}{\partial \alpha_o}\right)_{\delta_f}$ for the blunt nose flap and a 0.005c gap was about -0.0060, which, when compared with the value of -0.0068 computed from the plain flap results of reference 6, indicated that the $0.20c_f$ overhang on the flap reduced the value of $\left(\frac{\partial c_{h_f}}{\partial \alpha_o}\right)_{\delta_f}$ slightly.

The variation of c_{h_f} with δ_f for several angles of attack, as presented in figure 2(b), shows that the flap with the blunt-nose shape had the lowest values of c_{h_f} for small values of δ_f, while the medium-flap nose shape gave the smallest values of c_{h_f} at the high flap deflections. In general, regardless of the flap nose shape, the flap with the $0.20c_f$ overhang gave lower values of $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$ than did the plain flap reported in reference 6. The reductions in the value of $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$ for the flap having the $0.20c_f$ overhang and a 0.005c gap, when compared with the value obtained for the plain flap, were from 18 to 25 percent, depending on the flap nose shape.

The effect of the presence of a gap and of gap size on the variation of the flap hinge-moment coefficient with lift coefficient as shown by the data presented in figures 3, 4, and 5 is negligible. At a given value of c_l, however, the value of $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{c_l}$ increases slightly as the gap is increased.

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Criterion of Balance Effectiveness

A criterion of balance effectiveness is the increment in flap-hinge-moment coefficient, Δc_{h_f}, for a given increment in lift coefficient, Δc_l. Figure 6 shows this characteristic for the flap with the blunt nose at angles of attack of -8°, 0°, and 8° for the various gap arrangements tested. Similar cross plots are presented in figure 7 for the flap having the medium nose and in figure 8 for the sharp nose flap.

<u>Effect of gaps</u>.- In general, the results indicate that as the gap size increased the Δc_{h_f} for a given Δc_l increased, but the smallest increases in c_{h_f} were obtained with the blunt nose flap. At the large negative angle of attack and for large positive flap deflections the sealed-gap condition resulted in the highest values of Δc_l and the lowest values of Δc_{h_f}, regardless of the flap nose shapes. In a like manner, the sealed-gap condition at $\alpha_0 = 0°$ proved to be the best arrangement for all values of δ_f greater than 20° with the medium nose flap, where with the 0.010c gap the values of Δc_l were the highest. For the high-positive angle-of-attack condition the sealed gap was best for the sharp nose flap at all flap deflections, while the medium nose flap at values of δ_f greater than 15° gave higher values of Δc_l with the 0.010c gap than with the gap sealed. The best results for the high angle-of-attack condition and the blunt nose flap were obtained with the 0.005c gap.

<u>Effect of flap nose shape</u>.- As a result of the foregoing analysis, the flaps with the blunt-, medium-, and sharp-nose shapes with gaps sealed were compared to give an indication of the effect of nose shape on the balance effectiveness. This comparison is shown in figure 9. For angles of attack of -8° and 0° and at all positive flap deflections up to about 20°, the blunt-nose shape gave the least increment in flap hinge-moment coefficient for a given lift coefficient increment. At $\alpha_0 = 8°$ the blunt nose flap with a sealed gap was only slightly better than the other shapes for flap deflections up to 10°, from which point it became the poorest shape. If the gap at the nose of the blunt flap was 0.005c, however, this flap shape would be superior to the other flap shapes for values of δ_f between 20° and 25°. At $\delta_f = 25°$ the

medium nose flap (fig. 7(c)) gave a slightly larger value of Δc_l, but it appears that the gain in c_l would not compensate for the large values of Δc_{h_f} throughout the lower range of flap deflections.

Tab

The increments of lift coefficient and flap hinge-moment coefficient caused by tab deflections at angles of attack of -8°, 0°, and 8° are presented in figures 10(a), (b), and (c) for $\delta_f = 0^\circ$, in figures 11(a), (b), and (c) for $\delta_f = 10^\circ$, and in figures 12(a), (b), and (c) for $\delta_f = 25^\circ$. The results indicate that for $\delta_f = 0^\circ$ and 10° the magnitude of the increments of c_l and c_{h_f} caused by tab deflections are approximately the same as for the tab on the plain flap (reference 6). In figures 12(a), (b), and (c) the separation of the increment curves may be attributed to the greater effectiveness of the flap with the medium-flap nose shape than with the other flap nose shapes at $\delta_f = 25^\circ$ as indicated in figure 2(b). In general, it appears that for an unstalled flap, the increments in the airfoil section lift coefficient and flap-section hinge-moment coefficient caused by moderate tab deflections are independent of flap nose shape and small amounts of aerodynamic overhang. Because the increments of c_{h_f} and c_l caused by tab deflection are generally independent of flap nose shape except that the medium-flap nose shape maintained tab effectiveness at larger values of δ_f, only the section characteristics of the airfoil and the flap with the medium nose and $0.20c_f$ tab as affected by tab deflection are presented in figure 13.

Drag

The profile-drag coefficients for the airfoil and flap with the blunt-, medium-, and sharp-nose shapes are plotted for $\delta_f = 0^\circ$ and 5° for the various gap arrangements tested in figure 14. The results indicate that the minimum profile-drag coefficient was obtained with the blunt nose flap and with the gap sealed. Using the blunt-

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nose shape and sealed-gap condition as a basis, the increments of profile-drag coefficient with the medium-flap nose shape and sealed gap was about 0.0008, while with the sharp-nose shape and sealed gap the increment in profile-drag coefficient was 0.0015. Because of a relatively large unknown tunnel correction, the drag coefficients cannot be considered as absolute; however, the relative values should be independent of tunnel effects.

Parameters

The use of aerodynamic parameters (reference 5) is a direct means by which the characteristics of the different flap nose shapes and the various amounts of aerodynamic balance may be compared. While it is not within the scope of this paper to make a complete analysis by this method, it is important that, in general, the effects of flap aerodynamic overhang, nose shape, and gap on the parameters be treated.

In agreement with the results of reference 6, the value of $\left(\frac{\partial c_l}{\partial \alpha_o}\right)_{\delta_f}$ for the blunt nose flap neutral and gap sealed was 0.097. As previously discussed, the value of this parameter decreased as the gap size increased. The flap effectiveness $\left(\frac{\partial \alpha_o}{\partial \delta_f}\right)_{c_l}$ for the blunt flap with gap sealed was -0.57, and this value decreased slightly as the taper of the flap nose increased. This value of the lift effectiveness for a 0.30c flap having a $0.20c_f$ blunt overhang is in exact agreement with the effectiveness of the 0.30c plain flap in reference 6 and indicates that the effectiveness of a flap is not affected by a small flap overhang.

Two parameters of major concern to the designer of a control surface are the flap hinge-moment parameters $\left(\frac{\partial c_{h_f}}{\partial \alpha_o}\right)_{\delta_f}$ and $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$. As previously pointed out in the discussion of the results, for the three nose shapes most completely investigated and with gaps sealed, $\left(\frac{\partial c_{h_f}}{\partial \alpha_o}\right)_{\delta_f}$ was about -0.0060, which shows a slight reduction in the value of this parameter for a flap having a small overhang when compared to the plain flap value of -0.0068.

The value of $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$ varied with flap nose shape. With the blunt-nose shape the value was -0.0088, and this was the lowest value obtained with the $0.20c_f$ overhang on the flap. The values of $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$ for the medium and sharp nose flaps were -0.0102 and -0.0110, respectively. The value of $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$ for the plain flap was about -0.0120, indicating that the reductions in the value of this parameter caused by the $0.20c_f$ overhang are dependent on flap nose shapes. From this discussion it would also follow that the parameter for free-control effectiveness, $\left(\frac{\partial \delta_f}{\partial \alpha_o}\right)_{c_{h_f}} = 0$, will be highest for the blunt nose flap.

The effect of gap on the values of the parameters was quite marked. As the gap was increased, in general the parameters $\left(\frac{\partial c_l}{\partial \alpha_o}\right)_{\delta_f}$, $\left(\frac{\partial \alpha_o}{\partial \delta_f}\right)_{c_l}$, and $\left(\frac{\partial c_{h_f}}{\partial \alpha_o}\right)_{\delta_f}$ were decreased, while the value of $\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$ increased slightly. The changes increased in magnitude as the angle of attack, flap deflection, or lift coefficient increased. These changes in the values of the parameters indicate a nonlinear variation of the aerodynamic coefficient, and when the nonlinear variation is large, parameters cannot be used to determine accurately the aerodynamic characteristics of a control surface.

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CONCLUSIONS

The results of the tests show that for a given lift coefficient the reduction in flap section hinge-moment coefficient obtainable by the addition of a small aerodynamic overhanging balance will change with the variation of the flap nose shape and the size of the gap at the flap nose. The blunt nose flap gave the greatest reduction in flap hinge-moment coefficient for moderate flap deflections, but for flap deflections greater than 20°, the medium nose flap was the most effective in this respect. In general, the lift effectiveness of the flap was the same as for a plain flap and was unaffected by the small amount of aerodynamic overhanging balance.

The characteristics of the tab appear to be independent of flap nose shape and the small amount of flap overhang for the unstalled conditions of the airfoil-flap-tab combinations.

For negative and zero angles of attack the gap at the flap nose reduced the balance effectiveness at positive deflections of the flap, and as the taper of the flap nose increased, the reduction in effectiveness increased. At high positive angles of attack and flap deflections, the test data indicate that a 0.005c gap might improve the balance effectiveness of a flap having blunt or medium nose.

The minimum profile-drag coefficient was obtained with the blunt nose flap neutral and with the gap sealed. As the taper of the flap nose was increased, the profile-drag coefficient increased.

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TABLE I.- ORDINATES FOR NACA 0009 AIRFOIL

[Stations and ordinates in percent of wing chord]

Stations	Upper surface	Lower surface
0	0	0
1.25	1.42	-1.42
2.5	1.96	-1.96
5	2.67	-2.67
7.5	3.15	-3.15
10	3.51	-3.51
15	4.01	-4.01
20	4.30	-4.30
25	4.46	-4.46
30	4.50	-4.50
40	4.35	-4.35
50	3.97	-3.97
60	3.42	-3.42
70	2.75	-2.75
80	1.97	-1.97
90	1.09	-1.09
95	.60	-.60
100	(.10)	(-.10)
100	0	0
L. E. radius: 0.89		

TABLE II.- FLAP NOSE SHAPE

[Stations and ordinates for 0.30c flap with $0.20c_f$ overhang on NACA 0009 airfoil]

Nose shape	0	8	20	28	28A	31
Stations (percent c)	Ordinates (percent c)					
0	0	0	0	0	0	0
.25	----	----	.55	.34	↑ Fair to flap nose radius ↓	↑ Fair with straight line tangent to radius ↓
.50	----	1.16	.79	.49		
1.00	----	1.58	1.13	.76		
2.00	----	2.10	1.59	1.15		
2.74	----	----	----	----	1.24	
3.00	↑ Fair to airfoil profile aft of flap nose radius ↓	2.40	1.93	1.46	----	
4.00		2.58	2.18	1.75	----	
5.00		2.70	2.41	1.98	----	
6.00		2.71	2.52	2.17	1.90	
6.75		----	----	----	----	2.06
7.00		2.68	2.59	2.33	----	↑ Make fair with 10.25 radius ↓
7.73		↑ Fair to airfoil profile ↓	----	----	2.26	
8.00			2.60	2.44	↑ Fair to airfoil profile ↓	
8.50			2.58	----		
9.00			↑ Fair to airfoil profile ↓	2.49		
9.50				2.48		
10.25				2.42		2.42
10.40	2.41	2.41	2.41	2.41	2.41	2.41
Nose rad	2.95	1.45	0.58	0.20	0.50	----

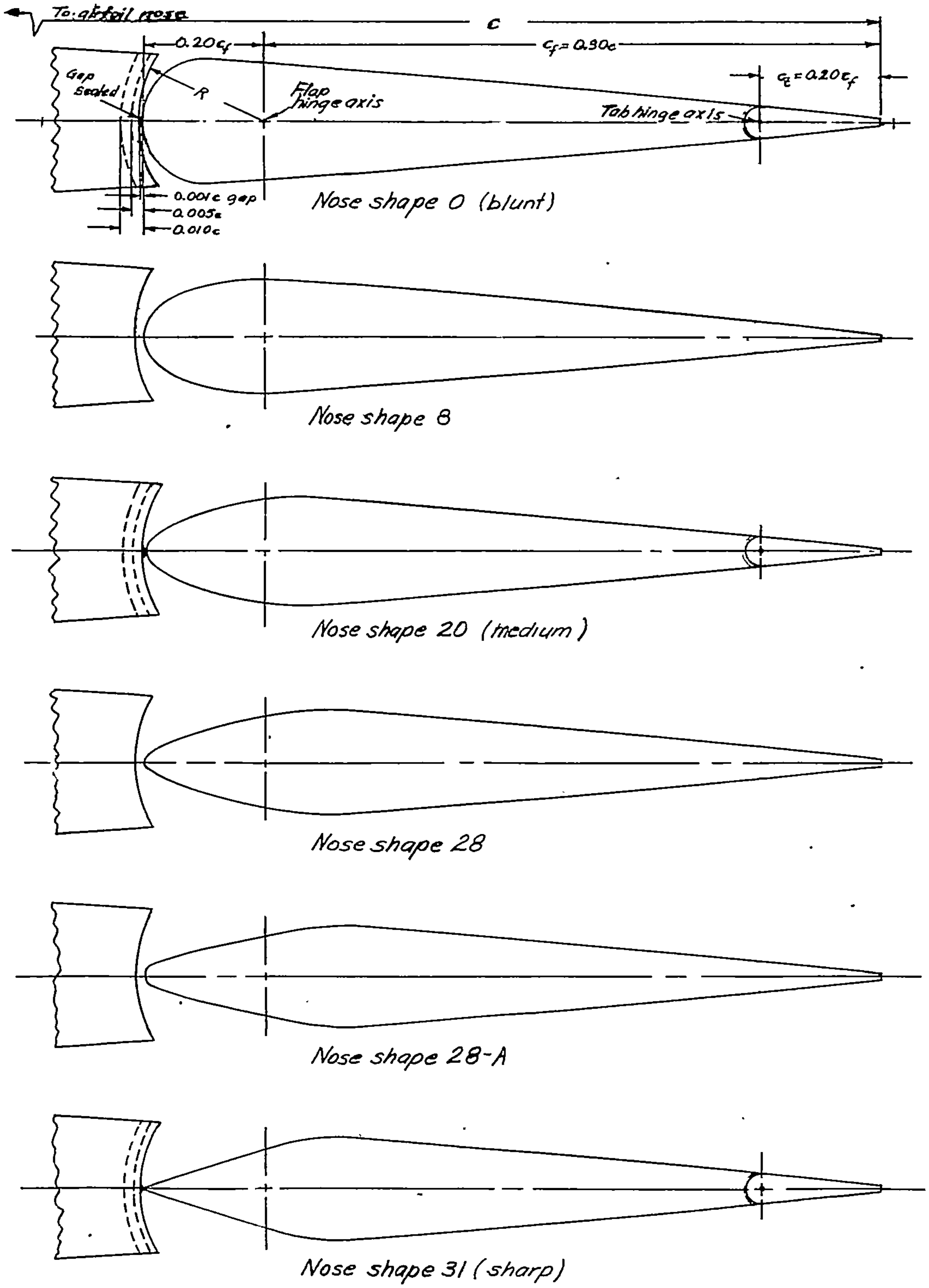
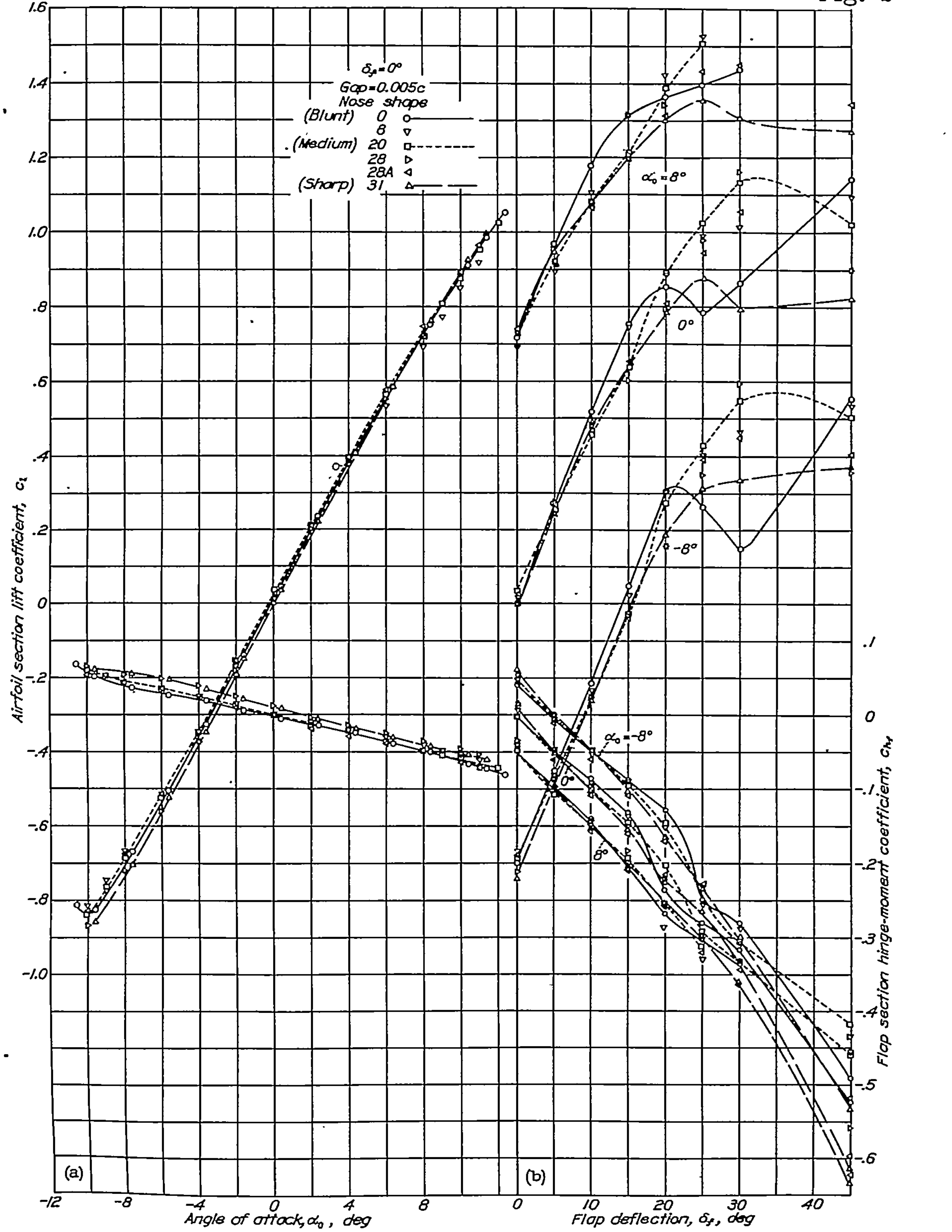


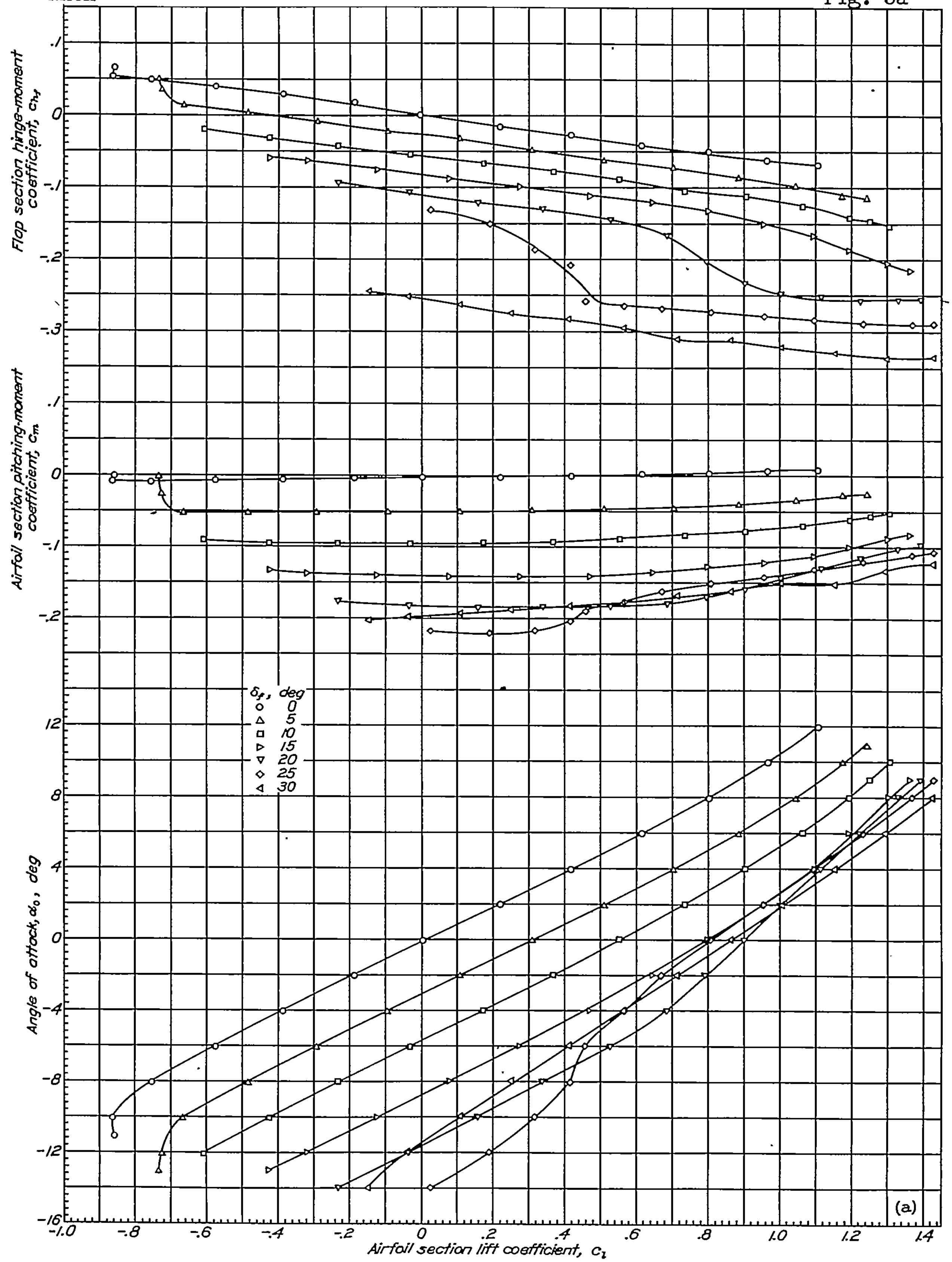
Figure 1.– Diagram of 0.30c flap with 0.20 c_f overhang for NACA 0009 airfoil showing flap nose shape and gap variations and 0.20 c_f tab.



(a) Airfoil section lift and flap section hinge moment coefficients against angle of attack, $\delta_t = 0^\circ$.

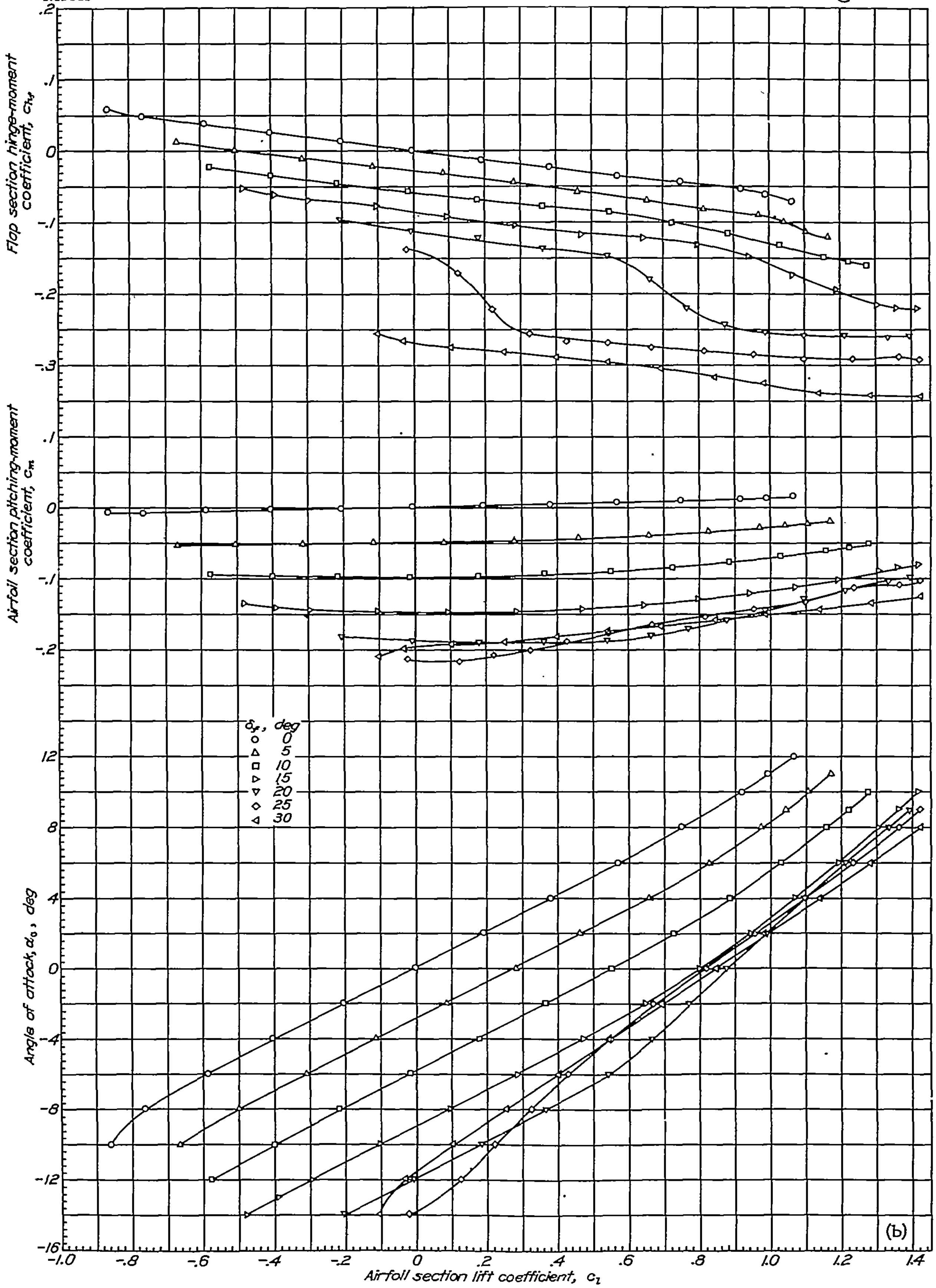
(b) Airfoil section lift and flap section hinge moment coefficients against flap deflection for $\alpha_o = -8^\circ$, 0°, and 8°. $\delta_t = 0^\circ$.

Figure 2.- NACA 0009 airfoil with 0.30c flap having $0.20c_f$ overhang and various nose shapes.



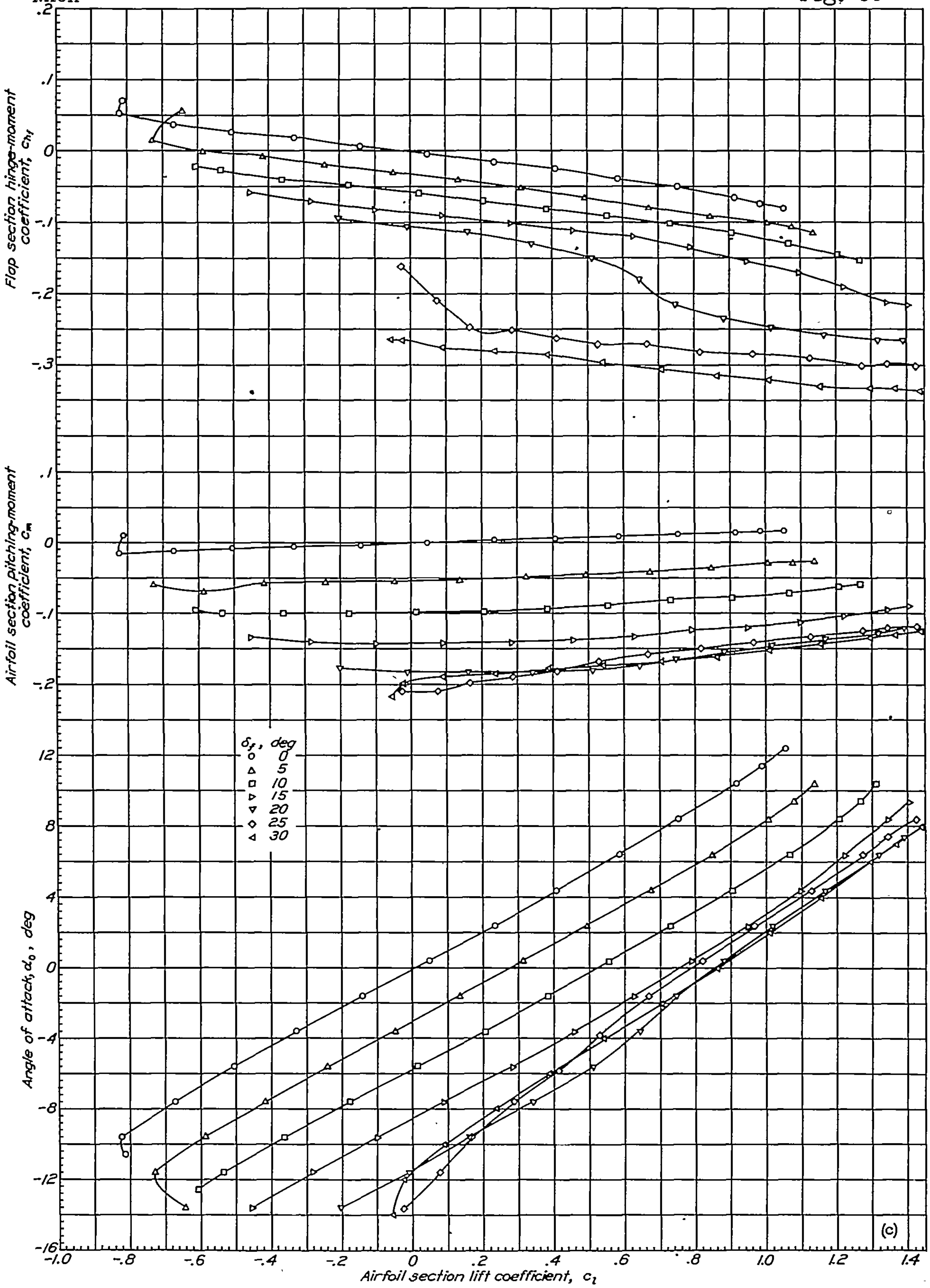
(a) Gap sealed.

Figure 3a to d.- Section characteristics of an NACA 0009 airfoil with a 0.30c flap having a 0.20c_f overhang. Blunt nose flap, δ_t,0°.



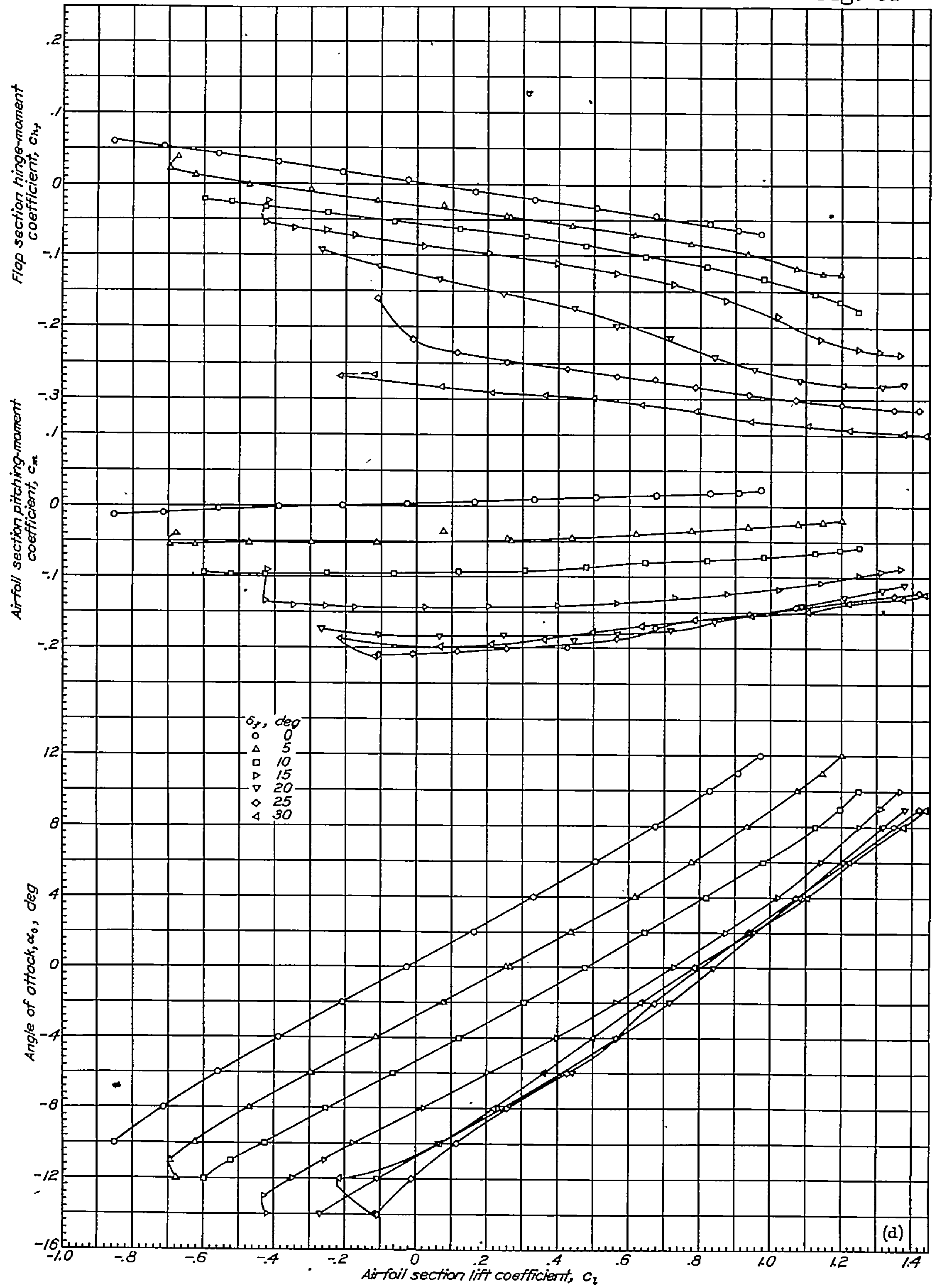
(b) Gap = 0.001c.

Figure 3.- Continued.

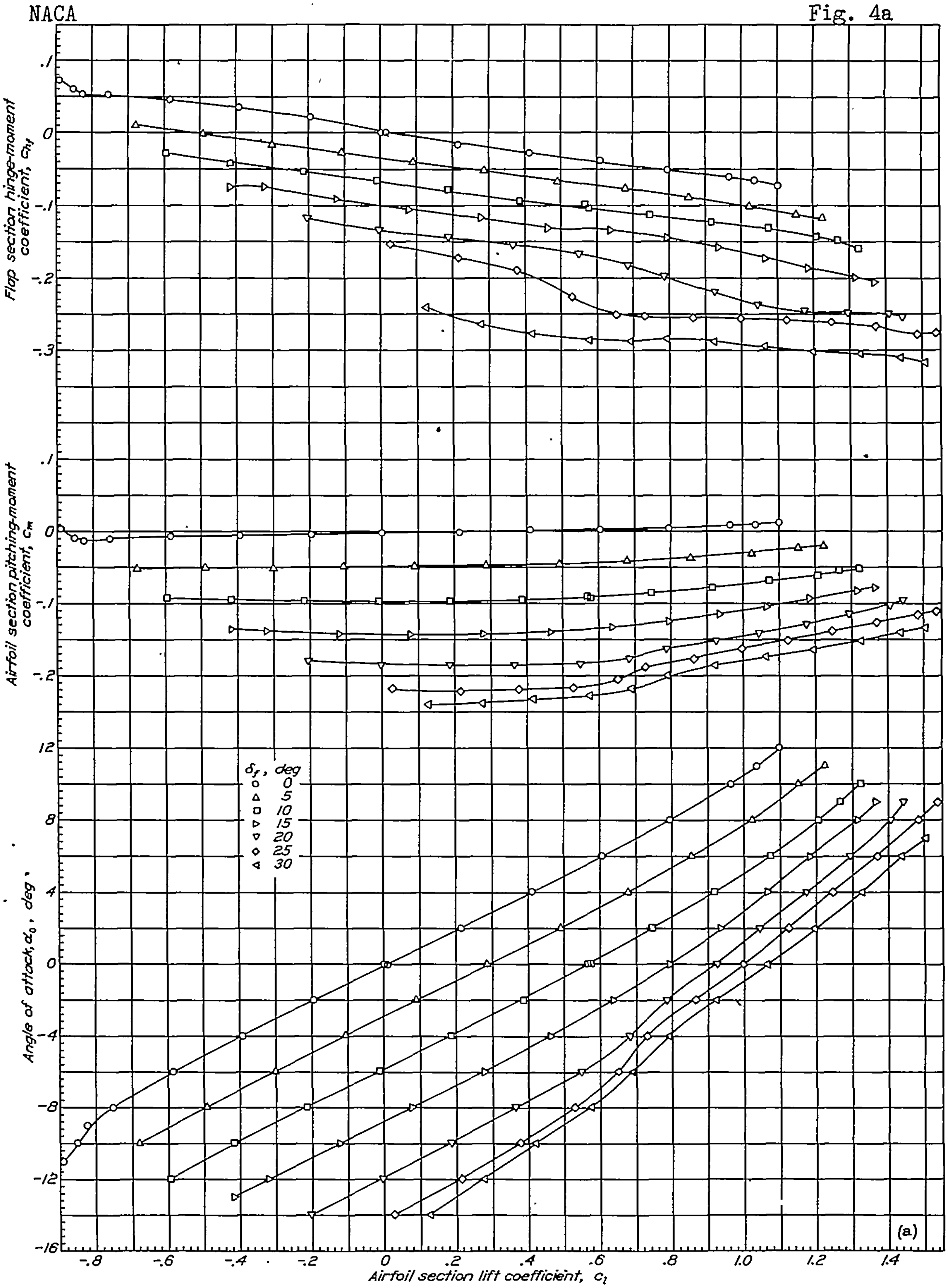


(c) Gap = 0.005c.

Figure 3.- Continued.

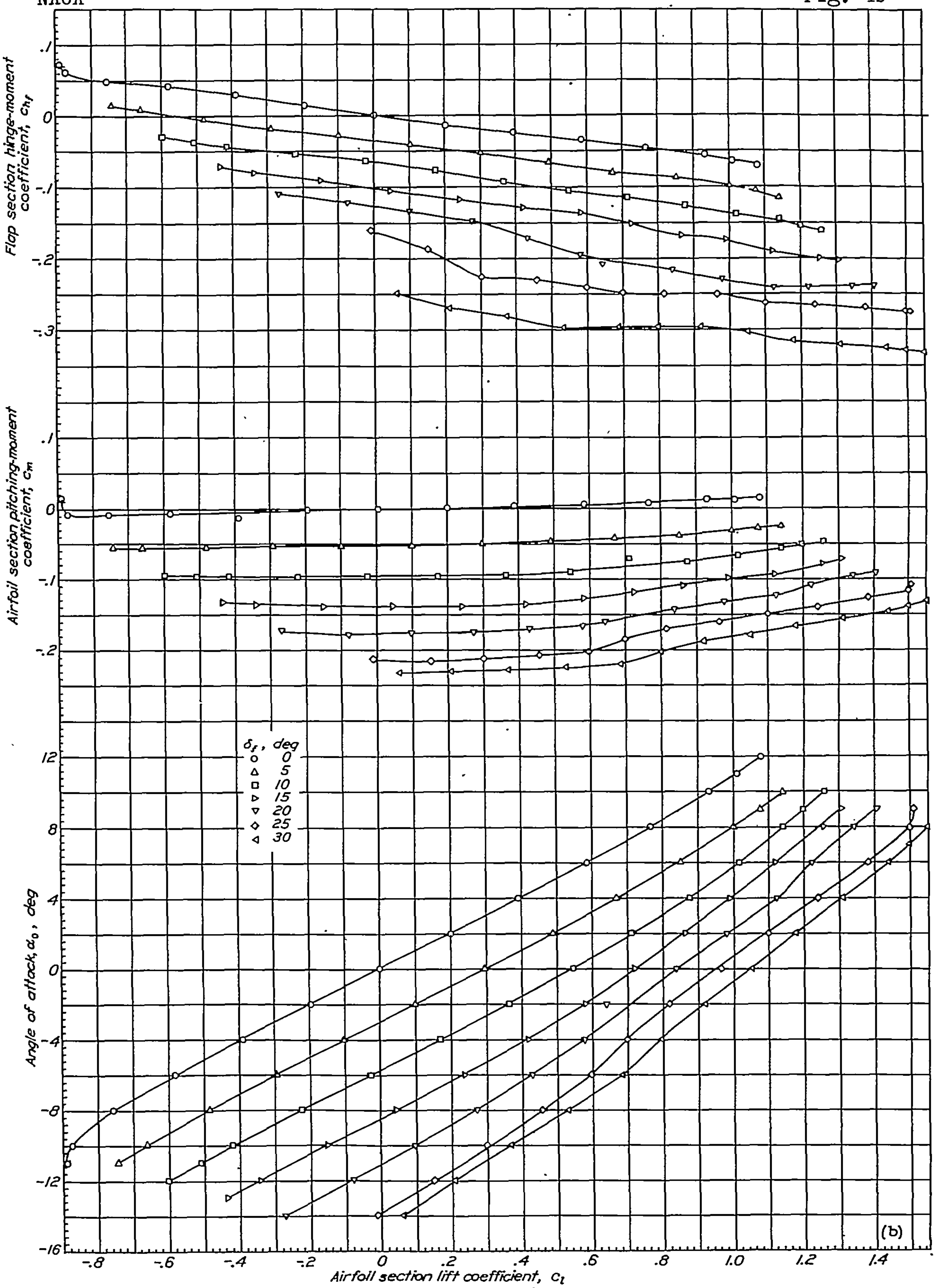


(d) Gap = 0.010c.
Figure 3.- Concluded.



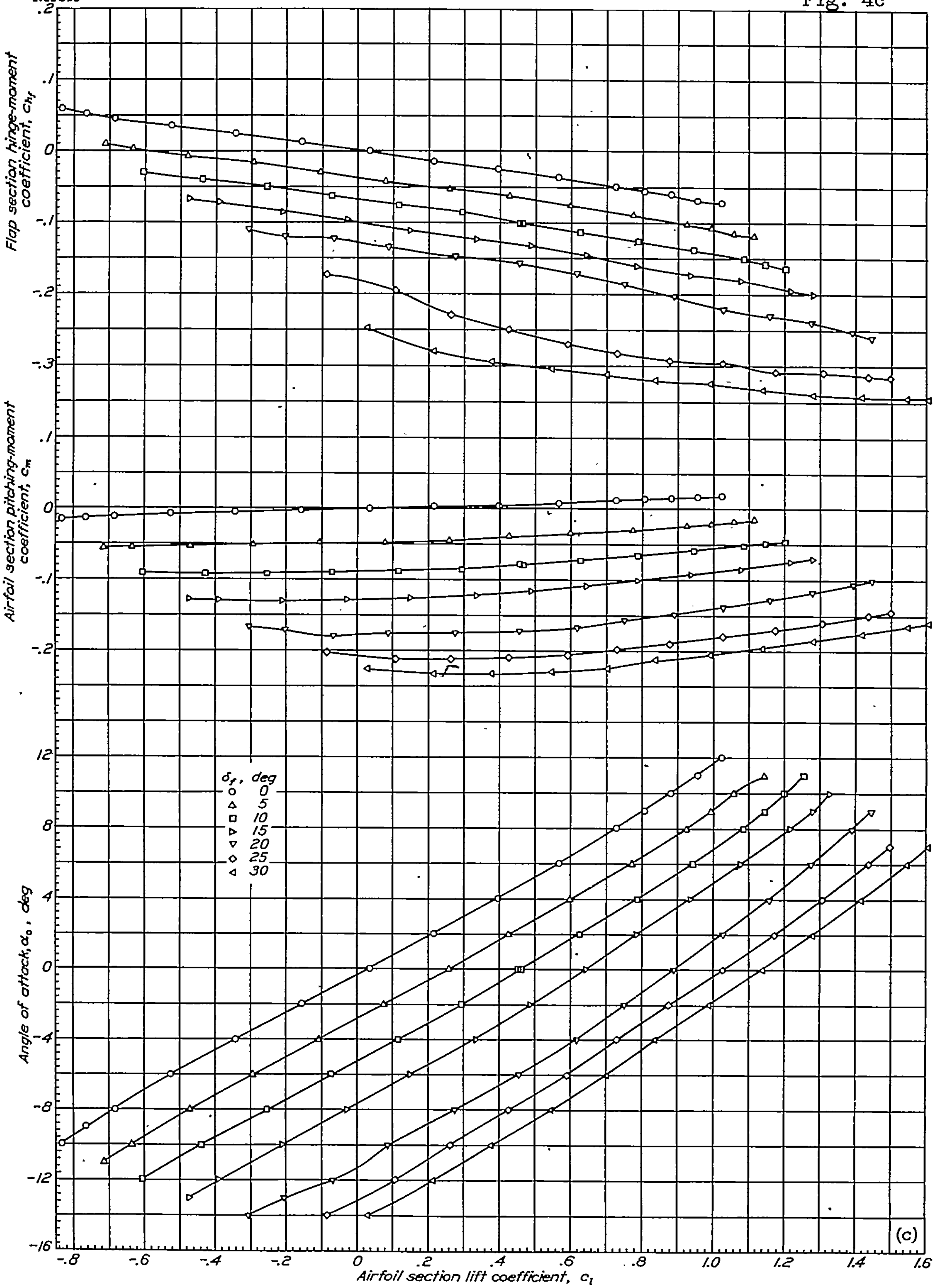
(a) Gap sealed.

Figure 4a to d.- Section characteristics of NACA 0009 airfoil with 0.30c flap having a $0.20c_f$ overhang. Medium nose flap; δ_t, 0°.



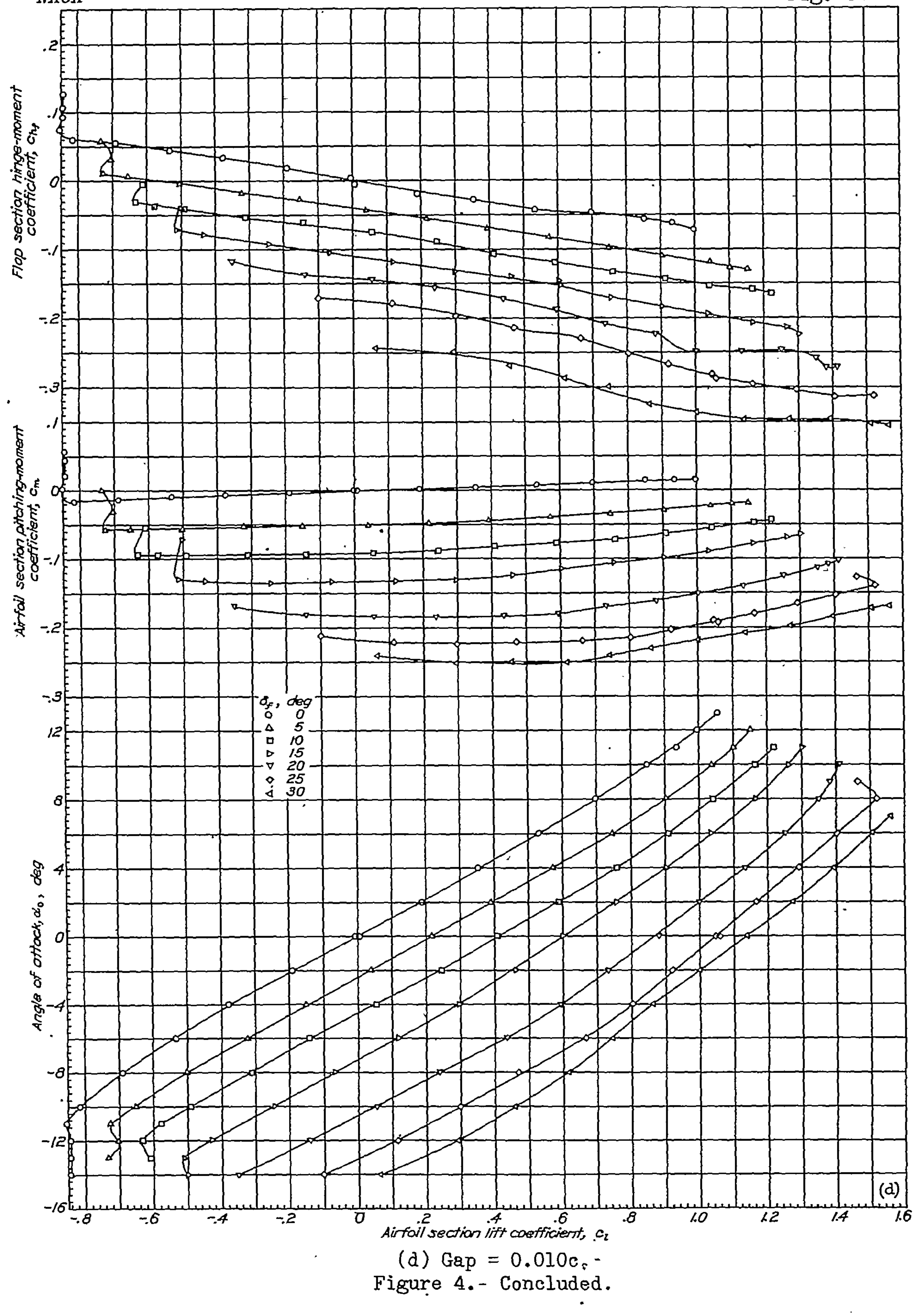
(b) Gap = 0.001c.

Figure 4.- Continued.



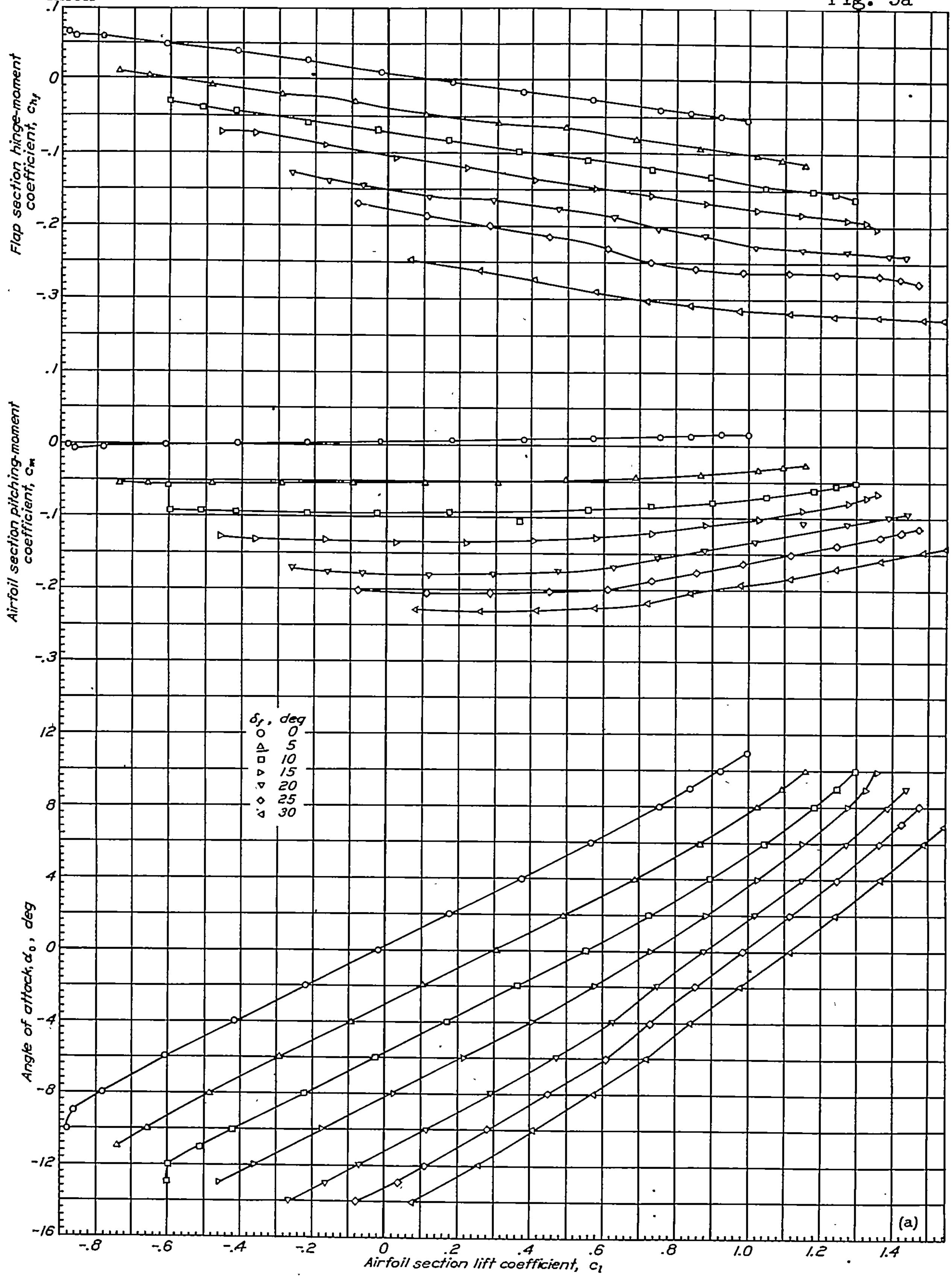
(c) Gap = 0.005c.

Figure 4.- Continued.



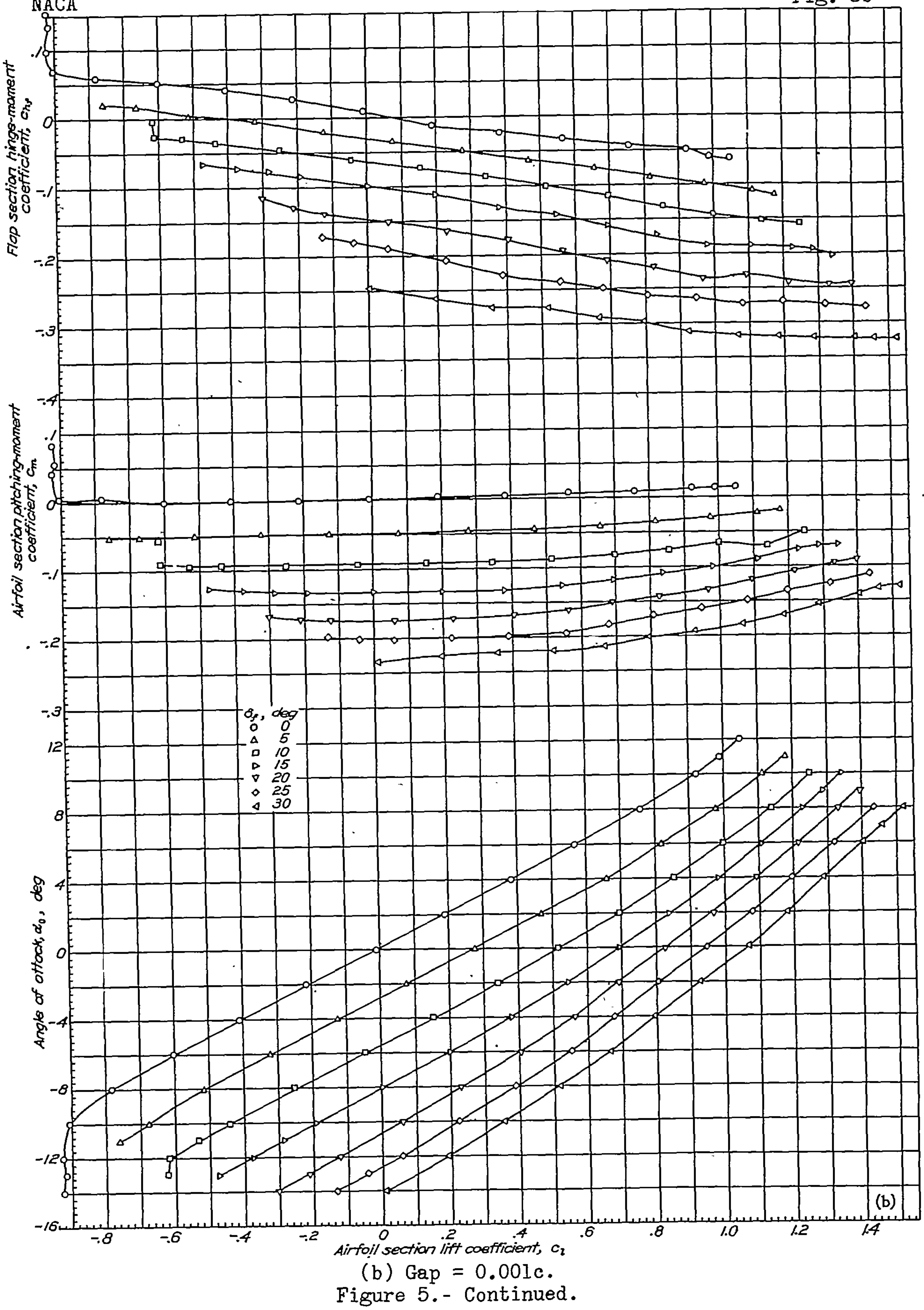
(d) Gap = 0.010c_f.

Figure 4.- Concluded.



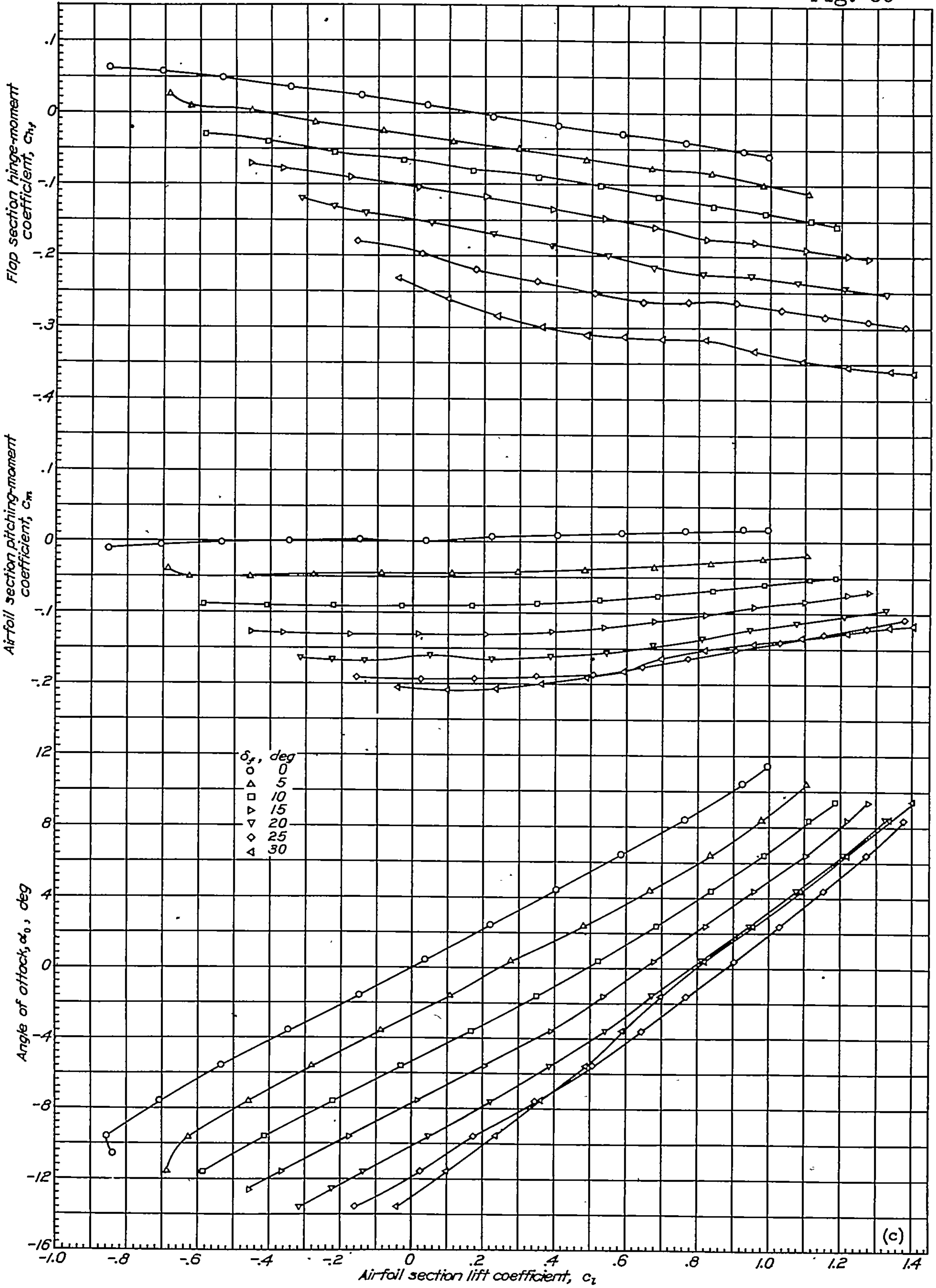
(a) Gap sealed.

Figure 5a to d.- Section characteristics of an NACA 0009 airfoil with 0.30c flap having a 0.20c_f overhang. Sharp nose flap; δ_t, 0°.

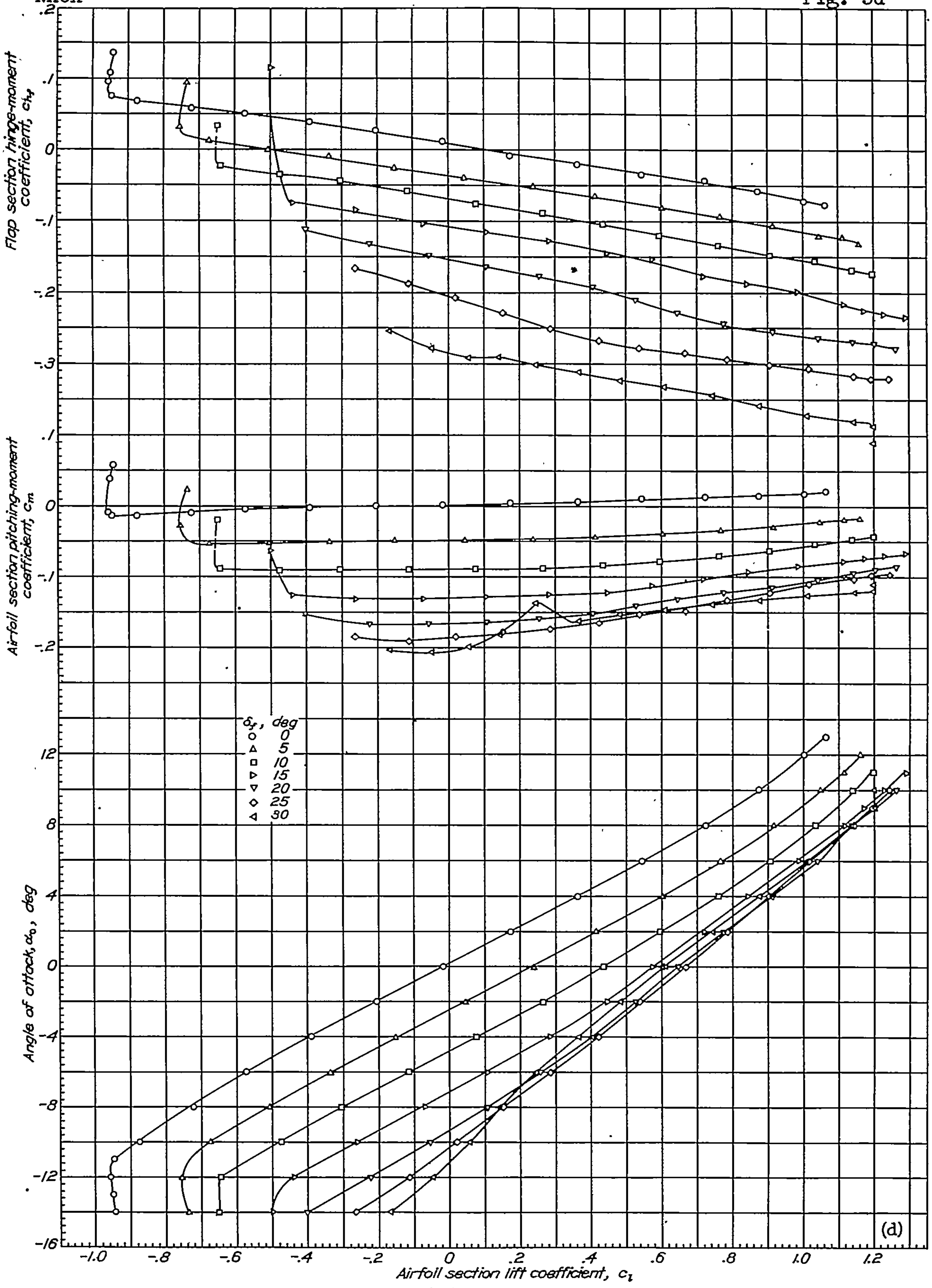


(b) Gap = 0.001c.

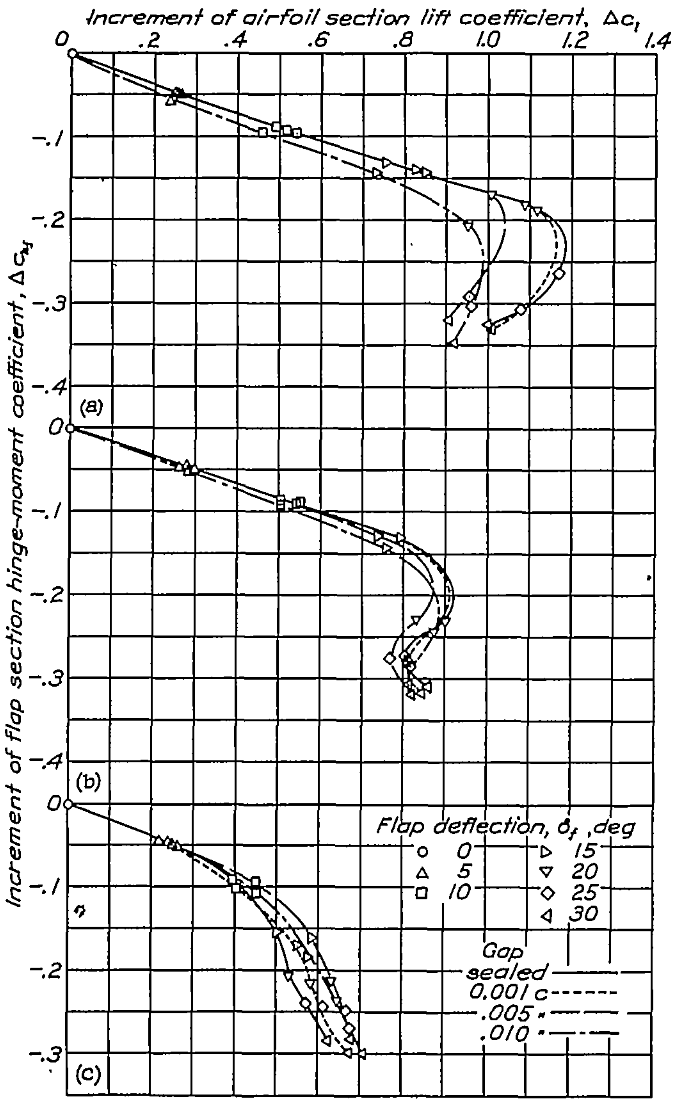
Figure 5.- Continued.



(c) Gap = 0.005c.
Figure 5.- Continued.

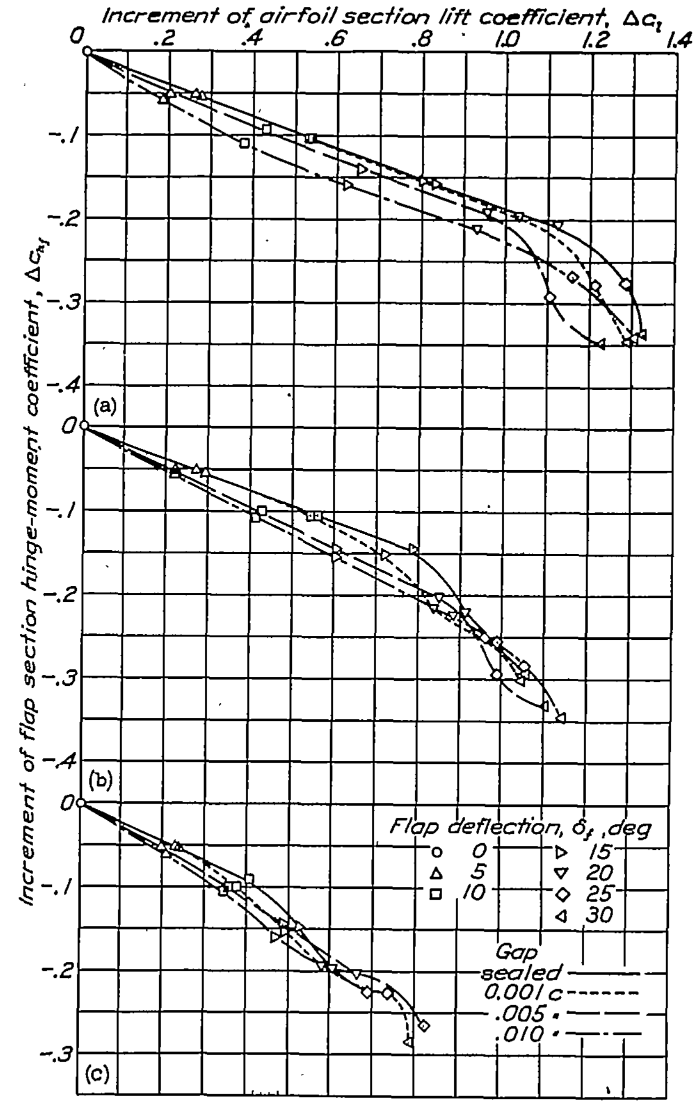


(d) Gap = 0.010c.
Figure 5.- Concluded.



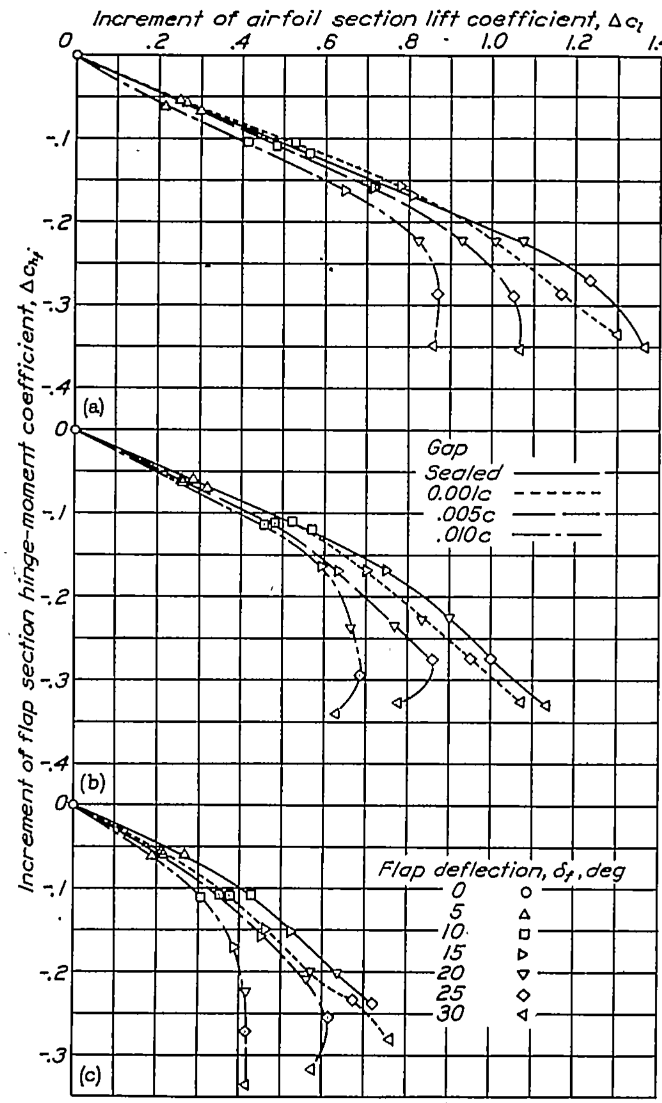
(a) α_0 = -8°, (b) α_0 = 0°, (c) α_0 = 8°.

Figure 6.- Variation of Δc_{h_f} with Δc_l for blunt nose flap and various gaps.



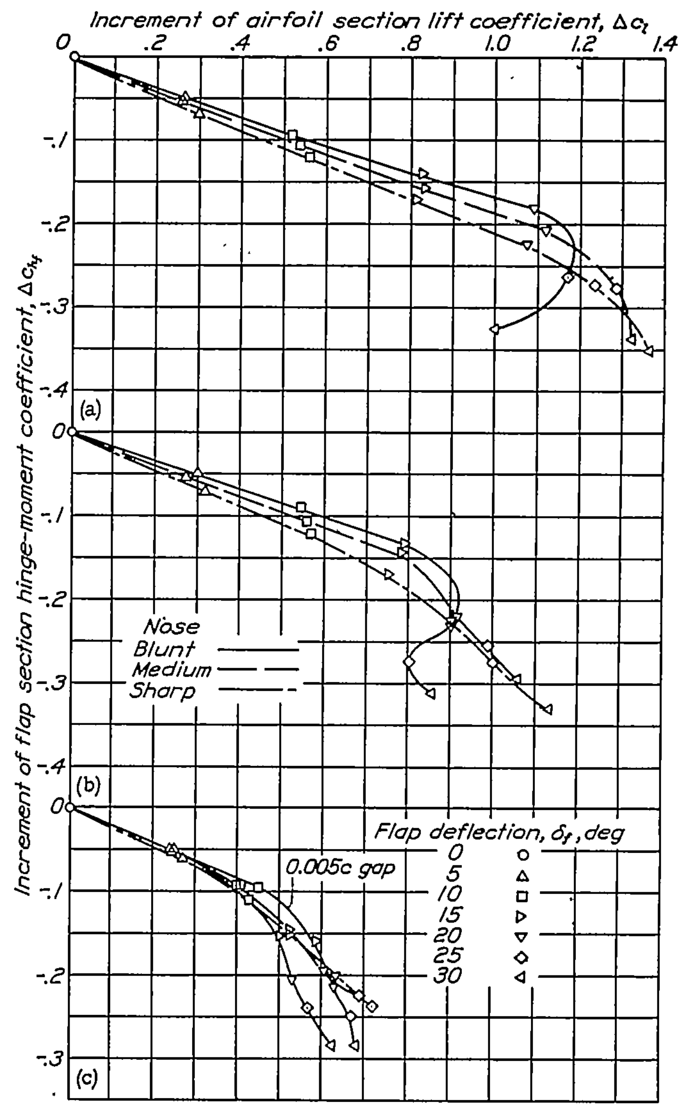
(a) α_0 = -8°, (b) α_0 = 0°, (c) α_0 = 8°.

Figure 7.- Variation of Δc_{h_f} with Δc_l for medium nose flap and various gaps.



(a) α_0 = -8°, (b) α_0 = 0°, (c) α_0 = 8°.

Figure 8.- Variation of Δc_{h_f} with Δc_l for sharp nose flap and various gaps.



(a) α_0 = -8°, (b) α_0 = 0°, (c) α_0 = 8°.

Figure 9.- Comparison of variations of Δc_{h_f} with Δc_l for blunt, medium and sharp nose flaps. Gaps sealed.

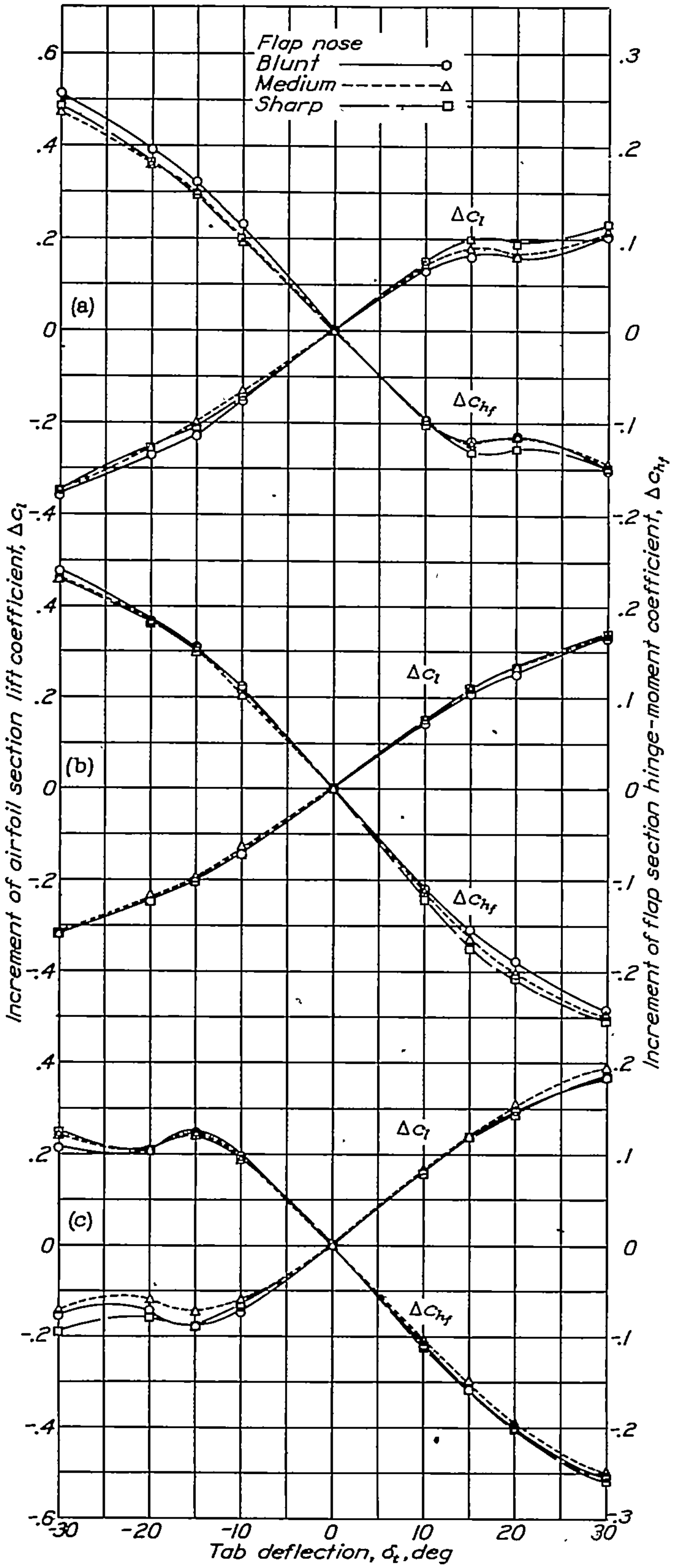
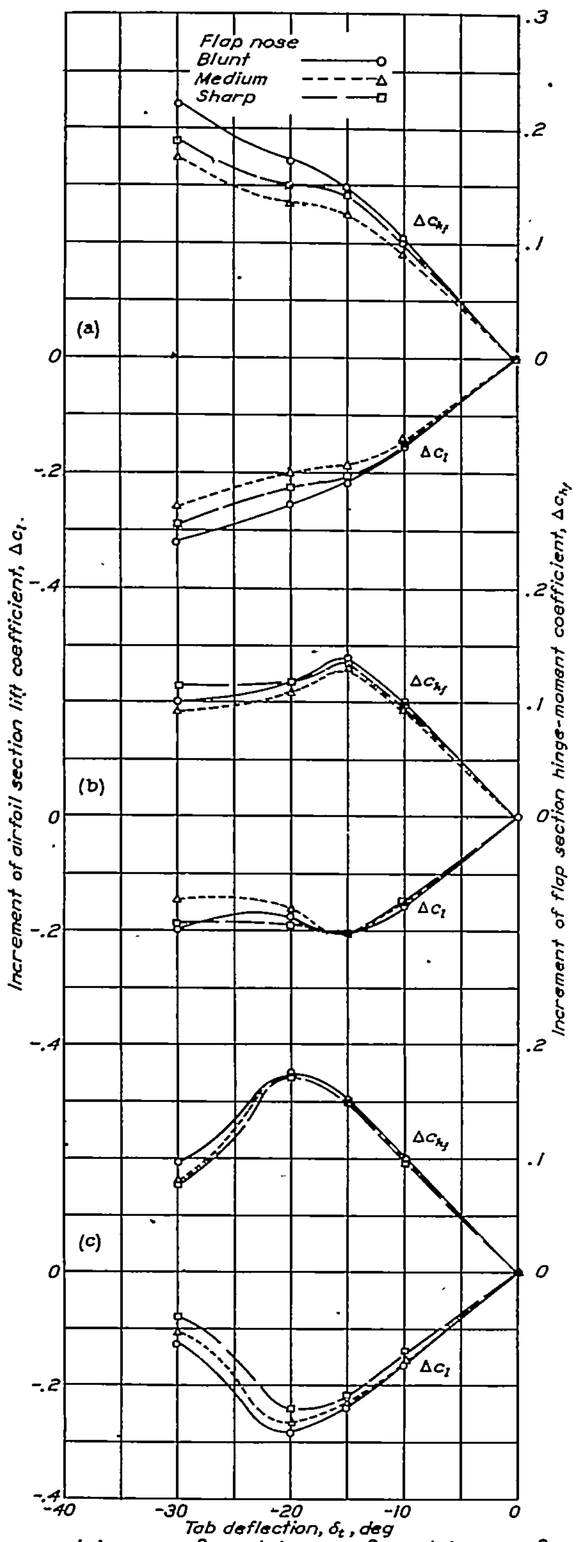


Figure 10.- Effect of flap nose shape on the variation of Δc_l and Δc_{h_f} with δ_t. δ_f, 0^o; gap, 0.005c.

(a) $\alpha_0 = -8^o$

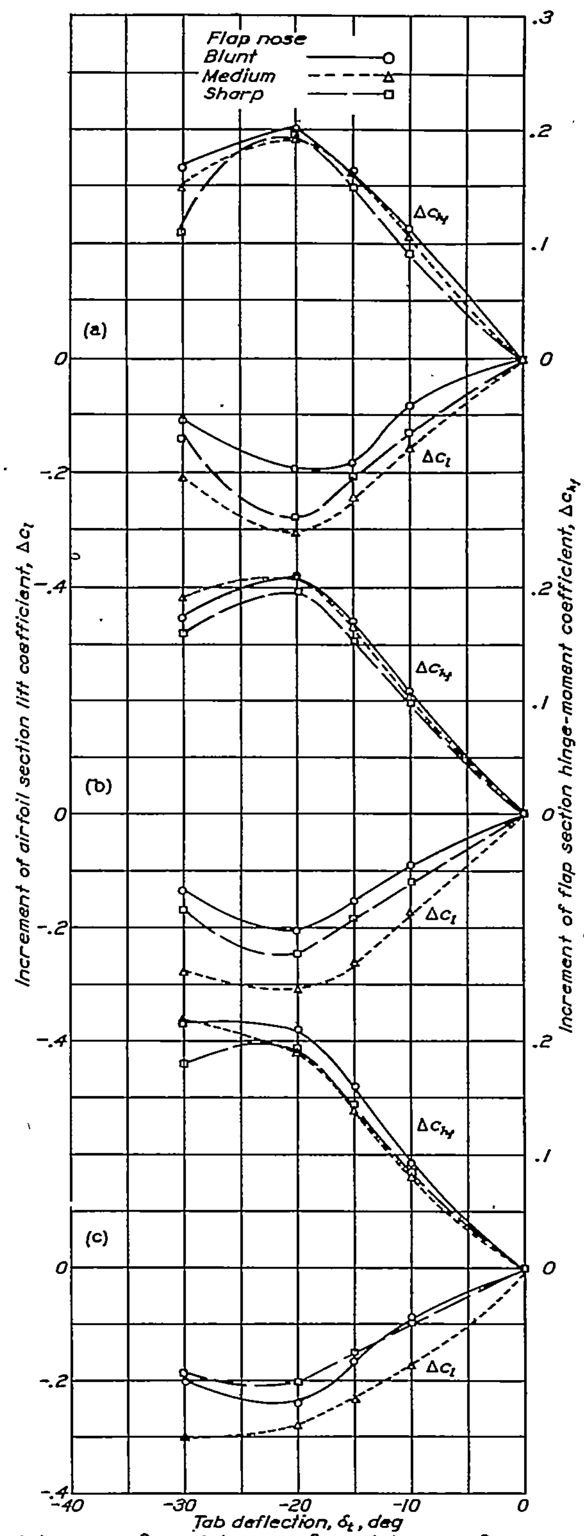
(b) $\alpha_0 = 0^o$

(c) $\alpha_0 = 8^o$



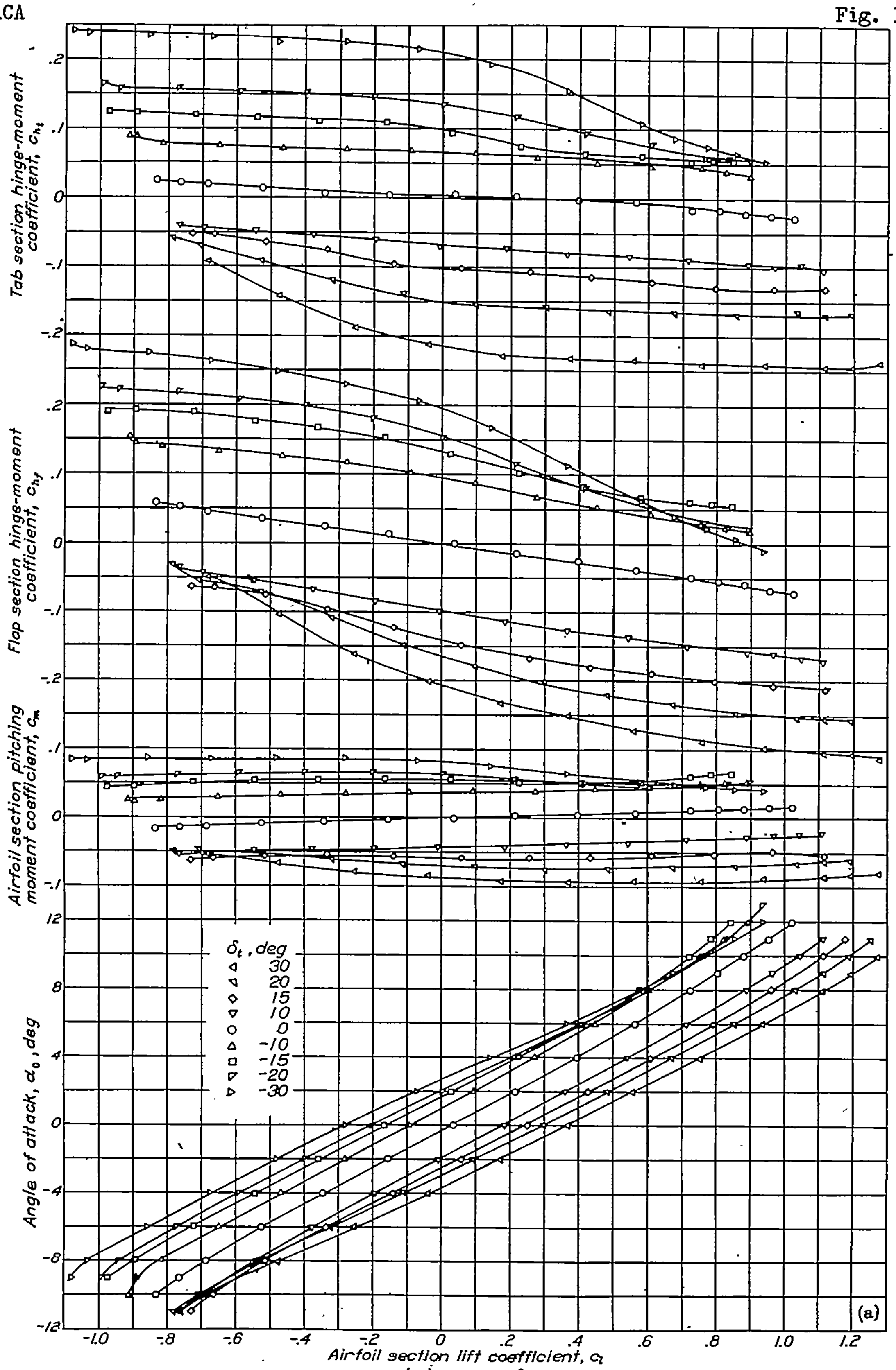
(a) $\alpha_0 = -8^\circ$. (b) $\alpha_0 = 0^\circ$. (c) $\alpha_0 = 8^\circ$.

Figure 11.- Effect of flap nose shape on the variation of Δc_l and Δc_{h_f} with δ_t. δ_f, 10°; gap, 0.005c.



(a) $\alpha_0 = -8^\circ$. (b) $\alpha_0 = 0^\circ$. (c) $\alpha_0 = 8^\circ$.

Figure 12.- Effect of flap nose shape on the variation of Δc_l and Δc_{h_f} with δ_t. δ_f, 25°; gap, 0.005c.



(a) $\delta_f = 0°$

Figure 13a,b.- Effect of tab deflection on the section characteristics of an NACA 0009 airfoil with a 0.30c flap having 0.20c_f overhang and a 0.20c_f tab. Medium nose flap, 0.005c gap.

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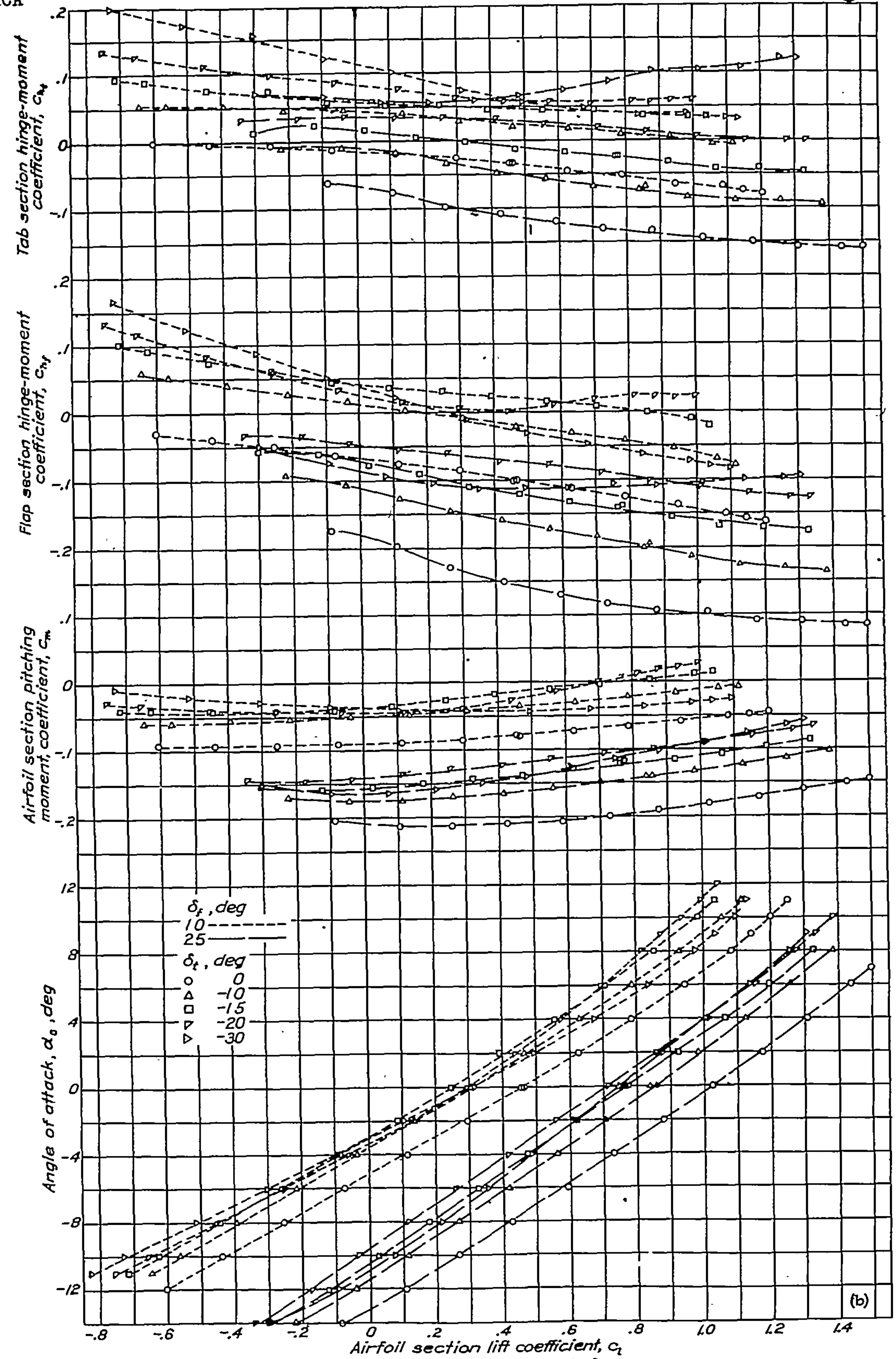

(b) δ_f = 10° and 25°

Figure 13.- Concluded.

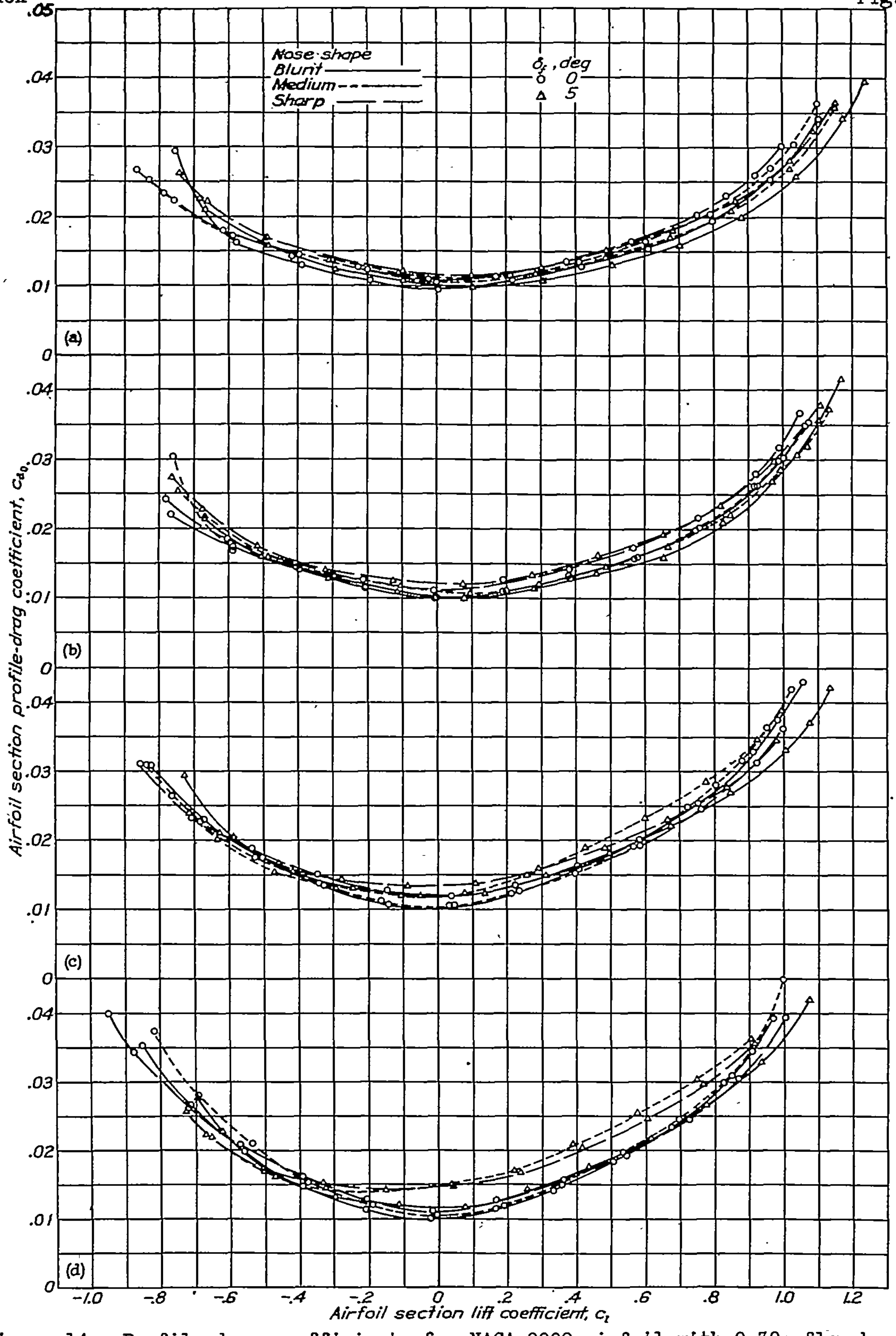

Figure 14.- Profile-drag coefficients for NACA 0009 airfoil with 0.30c flap having a $0.20c_f$ overhang. Blunt, medium, and sharp nose flaps; with gaps sealed, 0.001c, 0.005c, and 0.010c; $\delta_f = 0^{\circ}$ and 5°, $\delta_t = 0^{\circ}$.