NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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WIND-TUNNEL INVESTIGATION OF THE EFFECT OF TAB BALANCE ON TAB AND CONTROL-SURFACE CHARACTERISTICS

By Jack D. Brewer and M. J. Queijo

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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WIND-TUNNEL INVESTIGATION OF THE EFFECT OF TAB BALANCE ON TAB AND CONTROL-SURFACE CHARACTERISTICS

By Jack D. Brewer and M. J. Queijo

SUMMARY

An investigation was conducted to furnish data on the effect of tab balance on tab and control-surface characteristics. The airfoil tested had a modified NACA 65_1-012 contour with a plain flap having a chord equal to 25 percent of the wing chord and with a tab having a chord equal to 25 percent of the flap chord and having several nose shapes and overhang lengths.

The results of the investigation indicated that, in general, tab balance affected tab hinge-moment characteristics in much the same manner that flap balance affects flap hinge-moment characteristics. A moderate amount of tab balance did not seem to have any adverse effect on flap hinge-moment characteristics. Transition strips placed near the leading edge of an airfoil reduced the effectiveness of either plain or balanced tabs. Opening the tab gap reduced the tab effectiveness, but the reduction became less as the tab balance was increased.

Application (by an approximate method) of the results to two typical airplanes indicated that the addition of overhang balance to spring tabs was an effective means of reducing the control forces of spring-tab ailerons. Tabs with sealed internal balances were generally less effective in reducing aileron control forces than tabs with round-nose overhangs of the same balance length.

INTRODUCTION

Some means of balancing the excessive aerodynamic forces on the control surfaces have been found necessary in the designs of large airplanes and high-speed airplanes. Results of tests reported in references 1 to 3 show spring tabs to be one of the most effective means of obtaining aerodynamic balance. In some cases, however, the control forces become quite large even with a spring-tab arrangement. A spring-tab analysis presented by Gates of Great Britain indicates that a large part of the control forces for spring-tab ailerons may

result from tab hinge moments. Some data (references 4 and 5) are available on plain-tab hinge moments but little, on balanced-tab hinge moments. The present tests were conducted in the $2\frac{1}{2}$- by 6-foot test section of the Langley stability tunnel to provide such tab data in order to investigate the practicability of using tab balance to reduce control forces. The effects of transition strips and tab gap on hinge-moment characteristics were also investigated.

SYMBOLS

c_l airfoil section lift coefficient

c_{h_f} flap (or aileron) section hinge-moment coefficient

c_{h_t} tab section hinge-moment coefficient

P_{R_f} resultant flap (or aileron) balance-pressure coefficient $\left(P_{f_{Lower}} - P_{f_{Upper}}\right)$

P_{R_t} resultant tab balance-pressure coefficient $\left(P_{t_{Lower}} - P_{t_{Upper}}\right)$

P_f pressure coefficient above or below flap (or aileron) seal

P_t pressure coefficient above or below tab seal

c chord of basic airfoil with flap and tab neutral, feet

c_f flap (or aileron) chord from flap (or aileron) hinge line to trailing edge with tab neutral, feet

c_t tab chord from tab hinge line to trailing edge, feet

c_{b_f} flap (or aileron) balance chord, distance from hinge line to a point midway between points of attachment of flexible seal of sealed internal balance, feet

c_{b_t} tab balance chord; distance from tab hinge line to leading edge of exposed overhang balance or to a point midway between points of attachment of flexible seal of sealed internal balance, feet

y_1 distance from plane of symmetry to inboard end of aileron, feet

y_o distance from plane of symmetry to outboard end of aileron, feet

δ_f flap (or aileron) deflection with respect to airfoil, degrees

$\Delta\delta_f$ total deflection of right and left flaps (or ailerons), degrees

δ_t tab deflection with respect to flap, degrees

α angle of attack, degrees

ϕ trailing-edge angle, degrees (See fig. 1.)

F control force, pounds

k_1 ratio between angular deflection of control (stick or wheel) and aileron deflection with spring tab fixed

k_2 ratio between angular deflection of control (stick or wheel) and tab deflection with aileron fixed

k_3 spring constant, ratio of control (stick or wheel) force to spring-tab deflection when aileron is held fixed and airspeed is zero, pounds per degree

F_1, F_2' correlation factors defined on page 41 of reference 9

V indicated airspeed, miles per hour

$$\Delta c_{h_{t_\alpha}} = c_{h_{t_\alpha}}{}_{\text{Balanced tab}} - c_{h_{t_\alpha}}{}_{\text{Plain tab}}$$

$$\Delta c_{h_{t_{\delta_t}}} = c_{h_{t_{\delta_t}}}{}_{\text{Balanced tab}} - c_{h_{t_{\delta_t}}}{}_{\text{Plain tab}}$$

$$c_{l_\alpha} = \left(\frac{\partial c_l}{\partial \alpha}\right)_{\delta_f, \delta_t}$$

$$c_{l_{\delta_f}} = \left(\frac{\partial c_l}{\partial \delta_f}\right)_{\alpha, \delta_t}$$

$$c_{l_{\delta_t}} = \left(\frac{\partial c_l}{\partial \delta_t}\right)_{\alpha, \delta_f}$$

$$c_{h_{f_\alpha}} = \left(\frac{\partial c_{h_f}}{\partial \alpha}\right)_{\delta_f, \delta_t}$$

$$c_{h_{f_{\delta_f}}} = \left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha,\delta_t}$$

$$c_{h_{f_{\delta_t}}} = \left(\frac{\partial c_{h_f}}{\partial \delta_t}\right)_{\alpha,\delta_f}$$

$$c_{h_{t_\alpha}} = \left(\frac{\partial c_{h_t}}{\partial \alpha}\right)_{\delta_t,\delta_f}$$

$$c_{h_{t_{\delta_f}}} = \left(\frac{\partial c_{h_t}}{\partial \delta_f}\right)_{\alpha,\delta_t}$$

$$c_{h_{t_{\delta_t}}} = \left(\frac{\partial c_{h_t}}{\partial \delta_t}\right)_{\alpha,\delta_f}$$

$$P_{R_{f_\alpha}} = \left(\frac{\partial P_{R_f}}{\partial \alpha}\right)_{\delta_f,\delta_t}$$

$$P_{R_{f_{\delta_f}}} = \left(\frac{\partial P_{R_f}}{\partial \delta_f}\right)_{\alpha,\delta_t}$$

$$P_{R_{f_{\delta_t}}} = \left(\frac{\partial P_{R_f}}{\partial \delta_t}\right)_{\alpha,\delta_f}$$

$$P_{R_{t_\alpha}} = \left(\frac{\partial P_{R_t}}{\partial \alpha}\right)_{\delta_t,\delta_f}$$

$$P_{R_{t_{\delta_f}}} = \left(\frac{\partial P_{R_t}}{\partial \delta_f}\right)_{\alpha,\delta_t}$$

$$P_{R_{t_{\delta_t}}} = \left(\frac{\partial P_{R_t}}{\partial \delta_t}\right)_{\alpha,\delta_f}$$

The subscripts outside the parentheses of the foregoing partial derivatives indicate factors held constant during measurement of the derivatives.

APPARATUS AND TESTS

The tests of the present investigation were conducted in the $2\frac{1}{2}$- by 6-foot test section of the Langley stability tunnel. The model had an airfoil chord of 2 feet and spanned the throat of the tunnel. Photographs of the model in the tunnel are presented in figure 2. The part of the model forward of the 75-percent-chord station was made of laminated mahogany and had an NACA 65_1-012 contour, but from the 75-percent-chord station to the trailing edge the wing had flat sides forming a trailing-edge angle of 13.5°. The ordinates of the modified airfoil are given in table I.

The model had a plain flap constructed of laminated mahogany with a steel central web to which a steel tab was attached; the flap chord was 25 percent of the airfoil chord. The tab had a chord equal to 25 percent of the flap chord and was equipped with several brass nose pieces of various shapes and overhang lengths. The dimensions of the flap and tab are shown in figure 1. The ordinates of the tab nose shapes are given in table II.

The part of the model forward of the 75-percent-chord station was attached rigidly to disks that were mounted flush with the tunnel walls. Clearance gaps of approximately 1/16 inch were left between the disks and the ends of the control surfaces.

The lift on the model was measured with an integrating manometer; flap hinge moments were measured with a calibrated spring balance; tab hinge moments were measured by calibrated electric strain gages; and the pressure differences (resultant balance pressures) were measured by U-tube manometers.

All of the tests were made at a dynamic pressure of 155.5 pounds per square foot. The corresponding Reynolds number and Mach number are 4.59×10^6 and 0.34, respectively.

The greater part of the tests were made with transition strips attached to the upper and lower surfaces of the model. The transition strips were made by cementing No. 60 carborundum grains to Scotch cellulose tape in a strip $\frac{1}{4}$ inch wide. The tape was attached to the model so that the leading edges of the carborundum strips were at the 1.0-percent-chord station.

Tests were made with the tab gap sealed and open for the round tab nose shapes (gap = 0.004c). The tab gap was open for all other tests. The flap gap was sealed for all tests.

CORRECTIONS

Corrections applied to the test data for the effect of jet boundaries are based on the equations of reference 6. The methods of reference 6 were extended in order to obtain the corrections to flap hinge-moment coefficient and resultant balance-pressure coefficient. The equations used in making the corrections were:

$$c_l = 0.963c_l'$$

$$\alpha = \alpha' + 0.231c_l \left(\delta_f=0^\circ, \delta_t=0^\circ\right)$$

$$c_{h_f} = c_{h_f}' + 0.0087c_l'$$

$$P_{R_f} = P_{R_f}' - 0.042c_l'$$

Primed values refer to the uncorrected value.

The corrections do not take into account the tunnel-wall boundary-layer effects or the effects of the gaps between the ends of the control surfaces and the end disks. The angle-of-attack correction does not take into account the small effect of lift resulting from tab and flap deflections. The corrections for c_{h_t} and for P_{R_t} were found to be very small and were neglected.

RESULTS AND DISCUSSION

Presentation of Data

The data are presented as plots of airfoil section lift coefficient, flap section hinge-moment coefficient, tab section hinge-moment coefficient, and the resultant flap balance-pressure coefficient as functions of flap deflection, for all model configurations tested, in figures 3 to 19. The resultant tab balance-pressure coefficient is presented for the plain tab only in figure 3(d). The same coefficients are plotted against angle of attack

in figures 20 to 27 (for $\delta_f = 0^\circ$ and $\delta_t = 0^\circ$). Parameter values obtained from these figures are presented in table III. The effects of tab nose shape and tab overhang length on the tab hinge-moment parameters are shown in figures 28 and 29. Figure 30 shows the effect of tab balance on flap section hinge-moment coefficient. The effects of fixing transition and of sealing the tab gap on tab hinge-moment parameters are indicated in figure 31.

Effects of Tab Nose Shape and Overhang

In figure 28 the parameters $c_{h_{t_\alpha}}$, $c_{h_{t_{\delta_f}}}$, and $c_{h_{t_{\delta_t}}}$ become more positive as the nose shape is changed from sharp to blunt or as the tab overhang is increased. In general, the parameters are affected by tab balance in the manner that should be expected on the basis of previously obtained test results for the effects of flap balance on flap hinge-moment characteristics (references 4, 7, and 8). Neither tab overhang nor tab nose shape generally has any appreciable effect on the parameters $c_{h_{f_{\delta_f}}}$ or $c_{h_{f_\alpha}}$. The tab hinge-moment effectiveness increases as the tab nose shape is changed from sharp to blunt. Increasing the tab overhang length causes the tab to become more effective with the blunt and round nose shapes but causes irregular results for the tab with the elliptical and sharp nose shapes.

A correlation of the effects of overhang balances for ailerons is expressed (equations (23) and (24) of reference 9) in terms of a factor F_1 related to overhang length and a factor F_2' related to balance nose shape. The relations of these factors to the geometry of the balance are given in reference 9. The correlation has been applied to the tab balances of the present investigation and the results are compared with the experimental values of the parameters $c_{h_{t_\alpha}}$ and $c_{h_{t_{\delta_t}}}$. The comparison given in figure 29 shows that application of the correlation, in its present form, to tabs results in overestimating the effects of the balances on tab hinge moments. The poor agreement between the present experimental results and the correlation probably is caused by the large difference between the tab-chord ratio ($c_t = 0.06c$) of the present tests and the aileron-chord-ratio range ($c_f = 0.155c$ to $0.30c$) used in developing the correlation. Symbols representing different nose shapes for constant overhang lengths and symbols representing different overhang lengths for constant nose shapes fall close, however, to the same line. This agreement indicates that the relative importance of nose shape and overhang length is given accurately by the present correlation. Therefore, the correlation given in reference 9 can possibly be made to

apply to almost any control surface or tab if factors related to the chord ratio were used in addition to the factors F_1 and F_2'.

Figure 30, a plot of flap section hinge-moment coefficient against flap deflection for various ratios of tab deflection to flap deflection shows that the presence of a round-tab balance of $0.50c_t$ length does not greatly alter the effect of the tab on the flap hinge moments. Because a rather extreme tab balance was used for this comparison, tab balance, apparently, is not likely to have any serious adverse effects on flap hinge-moment characteristics for practical installations.

Effects of Transition Strips and Tab Gap

The effects of fixing transition and of sealing the tab gap on hinge-moment parameters are shown in figure 31. Placing transition strips at the 0.01c station causes all the hinge-moment parameters except $c_{h_{t_\alpha}}$ to become less negative than they were for the condition of transition strips off; $c_{h_{t_\alpha}}$ becomes less positive.

Opening the tab gap causes $c_{h_{f_\alpha}}$ and $c_{h_{f_{\delta_f}}}$ to become less negative but generally has little effect on $c_{h_{t_\alpha}}$, $c_{h_{t_{\delta_f}}}$, and $c_{h_{t_{\delta_t}}}$. The tab-effectiveness parameter $c_{h_{f_{\delta_t}}}$ becomes less negative when the tab gap is unsealed, but the change is much less for a balanced tab than for a plain tab.

Application of Data to Two Typical Airplanes

In order to illustrate the effects of tab nose shape and tab overhang length on aileron control forces, the hinge-moment data obtained in the present investigation were applied to two typical airplanes having the characteristics listed in table IV. Airplane 1 is a typical fighter-type airplane and airplane 2 is a typical large (transport or heavy bomber) airplane. The ailerons were assumed to be equipped with spring tabs having various spring strengths.

The control force per degree aileron deflection was estimated for each of the tab-nose configurations and for several assumed aileron balances at an assumed indicated airspeed of 300 miles per hour.

The procedure used for estimating the aileron control forces is necessarily approximate since the calculations are based on two-dimensional data. Reliable aspect-ratio corrections for the hinge-moment parameters of partial-span control surfaces or for tabs have not been developed. A qualitative indication of the effects of tab nose shape and tab overhang length on control forces is believed, however, to be obtainable by neglecting all aspect-ratio corrections to the hinge-moment parameters. A correction must be applied to the airfoil section tab-effectiveness parameter $c_{h_{f_{\delta_t}}}$, however, when the tab span is less than the aileron span. The tab correlation given in reference 9 was used to evaluate this correction. On the basis of this assumption, calculations of the control force per degree aileron deflection have been made by means of equation (40) of reference 9. Because of the limitations of the method that have been pointed out, the absolute values of the control force per degree aileron deflection are not considered to be of much significance, but the trends indicated by variation in the tab configuration are believed to be reliable. The hinge-moment parameters of ailerons or tabs with sealed internal balances were calculated by methods described in reference 10 by use of the hinge-moment parameters of plain sealed ailerons and tabs and the resultant balance-pressure parameters. The results of the calculations are presented in figures 32 and 33 as plots of control force per degree aileron deflection against tab overhang length for the nose shapes tested and for several assumed values of aileron balance and spring strength. Figure 32 presents the results obtained for airplane 1 and figure 33 presents the results obtained for airplane 2.

In general, increasing the tab overhang length or the bluntness of the tab nose shape decreases the control force. The results presented in figures 32 and 33 have been summarized in figure 34, which shows the ratio of control force with a balanced tab to control force with a plain tab plotted against spring constant for various values of aileron balance. Figure 34 shows that the effectiveness of the tab balance in reducing control force is practically independent of aileron balance and that the effectiveness decreases as the value of k_3 increases. The greatest percent of reduction occurs for the servotab $(k_3 = 0)$.

Calculations were made of the control forces for several assumed sealed internal balances on the tab by using the plain tab data and the tab balance pressures. The results are plotted in figure 35. Control-force curves obtained from figures 32 and 33 for the tabs with round-nose overhangs are included in figure 35 for comparison. In general, the control forces for a sealed internally balanced tab with a plain nose are greater than for a tab with a round nose overhang of the same balance length.

Figure 36 shows the variation of control force per degree aileron deflection with airspeed for various aileron and spring-tab balance conditions and indicates the great reduction in control force possible with balanced spring tabs throughout the speed range.

All of the foregoing control-force results were calculated by the comparatively simple method given in reference 9, which assumes linear variations of aileron and tab hinge-moment coefficients with aileron deflection, spring-tab deflection, and angle of attack. A more difficult, but more accurate, method considering the actual nonlinear aileron and tab curves is given in reference 11. In order to check the validity of the control-force results obtained by the linear method, a plot showing the effect of tab balance on the variation of control force with aileron deflection is presented in figure 37, as determined by references 9 and 11. Although differences in the two sets of results exist, especially at large aileron deflections, figure 37 shows that the trends indicated by the results obtained from the linear method are reliable.

CONCLUSIONS

An investigation was conducted in the $2\frac{1}{2}$- by 6-foot test section of the Langley stability tunnel of a two-dimensional wing model having a modified NACA 65_1-012 contour with a plain flap having a chord equal to 25 percent of the wing chord and with a tab having several nose shapes and overhang lengths and having a chord equal to 25 percent of the flap chord. The results of the investigation and the application (by an approximate method) of the results to aileron control forces indicated the following conclusions:

1. In general, tab hinge-moment characteristics were affected by tab balance in much the same way that flap hinge-moment characteristics are affected by flap balance.

2. A moderate amount of tab balance would have no adverse effect on flap hinge-moment characteristics.

3. The tab effectiveness decreased when transition strips were placed near the leading edge of the airfoil. Opening the tab gap reduced the tab effectiveness, but the reduction decreased as the tab balance increased.

4. The addition of overhang balance to spring tabs was an effective means of reducing the control forces of spring-tab ailerons.

5. Tabs with sealed internal balances were generally less effective in reducing aileron control forces than tabs with round-nose overhangs of the same balance length.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., June 10, 1947

REFERENCES

1. Morgan, M. B., Morris, D. E., and Bethwaite, C. F.: Flight Tests of Spring Tab Ailerons on a Spitfire. R. & M. No. 2029, British A.R.C., 1942.

2. Rogallo, F. M., and Purser, Paul E.: Wind-Tunnel Investigation of a Plain Aileron with Various Trailing-Edge Modifications on a Tapered Wing. III - Ailerons with Simple and Spring-Linked Balancing Tabs. NACA ARR, Jan. 1943.

3. Imlay, Frederick H., and Bird, J. D.: Wind-Tunnel Tests of Hinge-Moment Characteristics of Spring-Tab Ailerons. NACA ARR No. 4A26, 1944.

4. Sears, Richard I.: Wind-Tunnel Data on the Aerodynamic Characteristics of Airplane Control Surfaces. NACA ACR No. 3L08, 1943.

5. Holtzclaw, Ralph W., and Crane, Robert M.: Wind-Tunnel Investigation of Ailerons on a Low-Drag Airfoil. III - The Effect of Tabs. NACA ACR No. 4H15, 1944.

6. Allen, H. Julian, and Vincenti, Walter G.: The Wall Interference in a Two-Dimensional-Flow Wind Tunnel with Consideration of the Effect of Compressibility. NACA Rep. No. 782, 1944.

7. Riebe, John M., and McKinney, Elizabeth G.: Wind-Tunnel Investigation of Control-Surface Characteristics. XXII - Medium and Large Aerodynamic Balances of Two Nose Shapes and a Plain Overhang Used with a 0.20-Airfoil-Chord Flap on an NACA 0009 Airfoil. NACA ARR No. L5F06, 1945.

8. Goett, Harry J., and Reeder, J. P.: Effects of Elevator Nose Shape, Gap, Balance, and Tabs on the Aerodynamic Characteristics of a Horizontal Tail Surface. NACA Rep. No. 675, 1939.

9. Langley Research Department: Summary of Lateral-Control Research. (Compiled by Thomas A. Toll.) NACA TN No. 1245, 1947.

10. Fischel, Jack: Hinge Moments of Sealed-Internal-Balance Arrangements for Control Surfaces. II - Experimental Investigation of Fabric Seals in the Presence of a Thin-Plate Overhang. NACA ARR No. L5F30a, 1945.

11. Deters, Owen J.: Estimation of Control Forces of Spring-Tab Ailerons from Wind-Tunnel Data. NACA TN No.1333, 1947.

TABLE I

ORDINATES FOR MODIFIED NACA 65_1-012 AIRFOIL

[Station and ordinates in percent airfoil chord]

Station	Ordinate
0	0
1.25	1.39
2.50	1.88
5.00	2.61
7.50	3.17
10.00	3.65
15	4.40
20	4.97
25	5.41
30	5.72
40	6.00
50	5.76
60	4.94
70	3.74
75	3.06
80	2.46
85	1.87
90	1.28
95	0.69
100	0.10
L. E. radius: 1.00	

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TABLE II

ORDINATES OF TAB NOSE SHAPES

[Station and ordinates in percent airfoil chord; stations measured from forward end of overhang]

Station	Ordinates						
	$0.35c_t$ overhang				$0.50c_t$ overhang		
	Blunt nose	Round nose	Elliptical nose	Sharp nose	Round nose	Elliptical nose	Sharp nose
0	0	0	0	0.063	0	0	0.063
.063	.519	.344	.227	.086	.361	.191	.078
.125	.754	.475	.322	.110	.503	.275	.094
.208	.875	.604	.406	.141	.635	.355	.116
.313	.958	.713	.489	.181	.757	.431	.142
.458	1.020	.825	.579	.236	.915	.515	.179
.625	1.020	.908	.658	.299	.975	.591	.222
.792	1.003	.957	.718	.362	1.035	.652	.264
.938	.985	.974	.759	.418	1.063	.697	.301
1.146	.961	.961	.807	.497	1.072	.750	.355
1.354	.936	.936	.838	.578	1.047	.792	.408
1.563	.912	.912	.856	.655	1.022	.824	.434
1.771	.887	.887	.862	.733	.998	.849	.514
1.979	.862	.862	.856	.813	.973	.866	.567
2.188	.838	.838	.838	.838	.948	.871	.620
2.396					.924	.879	.673
2.813					.916	.865	.779
3.125					.838	.838	.838

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TABLE III

PARAMETER VALUES FOR MODIFIED NACA 65_1-012 AIRFOIL WITH 0.25c FLAP AND VARIOUS $0.25c_f$ TABS

[Values measured at $\alpha = 0^\circ$, $\delta_f = 0^\circ$, and $\delta_t = 0^\circ$]

c_{b_t}/c_t	Balance nose shape	Tab nose gap	Transition strips	c_{l_α}	$c_{l_{\delta_f}}$	$c_{l_{\delta_t}}$	$c_{h_{f_\alpha}}$	$c_{h_{f_{\delta_f}}}$	$c_{h_{f_{\delta_t}}}$	$c_{h_{t_\alpha}}$	$c_{h_{t_{\delta_f}}}$	$c_{h_{t_{\delta_t}}}$	$P_{R_{f_\alpha}}$	$P_{R_{f_{\delta_f}}}$	$P_{R_{f_{\delta_t}}}$	$P_{R_{t_\alpha}}$	$P_{R_{t_{\delta_f}}}$	$P_{R_{t_{\delta_t}}}$
0.134	Plain	Sealed	On	0.105	0.054	0.020	-0.0025	-0.0088	-0.0115	0.0001	-0.0012	-0.0073	0.024	0.079	0.014	0.004	0.013	0.044
	Plain	Sealed	Off	.108	.062	.021	-.0032	-.0112	-.0138	.0003	-.0026	-.0085	.030	.090	.013	.007	[a].018	[a].051
	Plain	Open	On	.105	.053	.014	-.0022	-.0084	-.0098	0	-.0015	-.0072	.026	.076	.011			
	Plain	Open	Off	.107	.060	.016	-.0027	-.0100	-.0120	.0006	-.0026	-.0086	.030	.089	.010			
.35	Blunt	Open	On	.106	.053	.014	-.0022	-.0082	-.0108	.0006	-.0008	-.0039	.024	.076	.012			
	Round	Sealed	On	.105	.056	.019	-.0026	-.0092	-.0115	.0006	-.0006	-.0049	.025	.080	.010			
	Round	Sealed	Off	.112	.060	.020	-.0032	-.0109	-.0144	.0007	-.0014	-.0059	.031	.087	.013			
	Round	Open	On	.104	.053	.014	-.0022	-.0079	-.0106	.0004	-.0010	-.0050	.026	.076	.011			
	Round	Open	Off	.108	.057	.016	-.0028	-.0094	-.0130	.0011	-.0014	-.0063	.030	.093	.009			
	Elliptical	Open	On	.106	.051	.010	-.0022	-.0080	-.0092	.0004	-.0012	-.0056	.025	.076	.006			
	Sharp	Open	On	.107	.050	.011	-.0022	-.0080	-.0089	0	-.0015	-.0065	.026	.078	.006			
.50	Round	Sealed	On	.109	.055	.018	-.0029	-.0094	-.0120	.0016	.0005	-.0008	.028	.076	.012			
	Round	Sealed	Off	.109	.061	.021	-.0033	-.0111	-.0150	.0020	.0007	-.0008	.030	.086	.012			
	Round	Open	On	.104	.050	.014	-.0022	-.0078	-.0116	.0013	.0006	-.0014	.024	.074	.011			
	Round	Open	Off	.109	.054	.019	-.0031	-.0093	-.0143	.0019	.0005	-.0012	.031	.084	.010			
	Elliptical	Open	On	.104	.051	.010	-.0022	-.0078	-.0093	.0015	.0008	-.0037	.024	.074	.005			
	Sharp	Open	On	.104	.048	.008	-.0021	-.0078	-.0091	.0006	-.0002	-.0054	.024	.074	.005			

[a]Data not presented.

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TABLE IV

GEOMETRIC CHARACTERISITCS OF TYPICAL AIRPLANES

	Airplane 1	Airplane 2
Control-stick length or control-wheel radius, r, feet	1.33	0.75
Ratio of control (stick or wheel) deflection to aileron deflection, k_1	1.00	10.00
Ratio of control (stick or wheel) deflection to tab deflection, k_2	-0.333	-3.333
Aileron span, b_a, feet	9.85	24.40
Root-mean-square aileron chord, $\bar{c}_a$, feet	1.42	4.25
Wing span, b, feet	49.0	130
Wing area, S_w, square foot	400	2816
Tab span, b_t, feet	2.38	8.0
Root-mean-square tab chord, $\bar{c}_t$, feet	0.354	1.06
Wing aspect ratio, A_w	6.0	6.0
Location of inboard end of aileron, $\frac{y_i}{b/2}$	0.564	0.600
Location of outboard end of aileron, $\frac{y_o}{b/2}$	0.966	0.975
Wing taper ratio, λ	0.25	0.45
Weight, pounds	13,000	80,000

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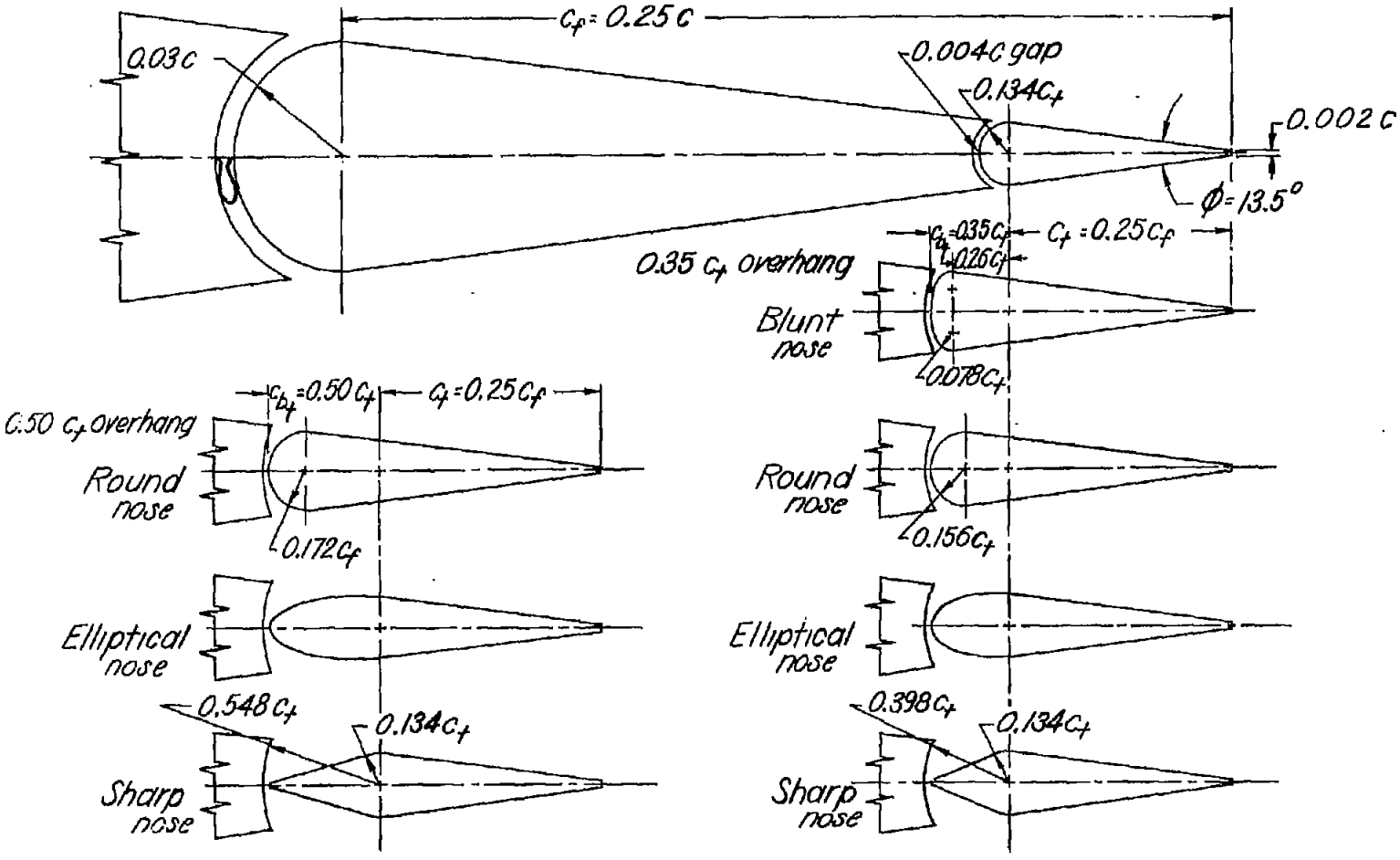

Figure 1.- Dimensions of flap and tab with various nose shapes tested on modified NACA 65,-012 airfoil.

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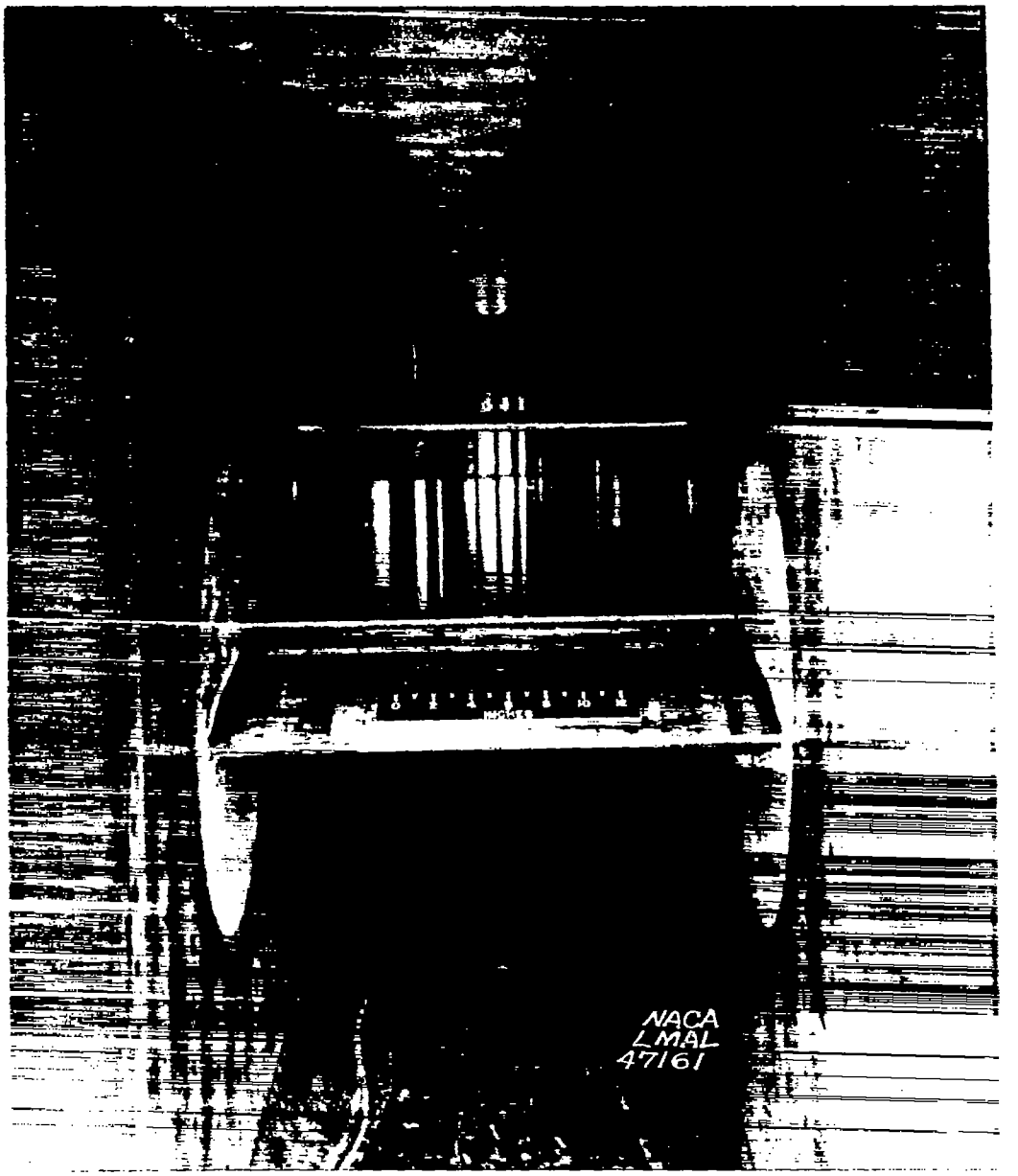
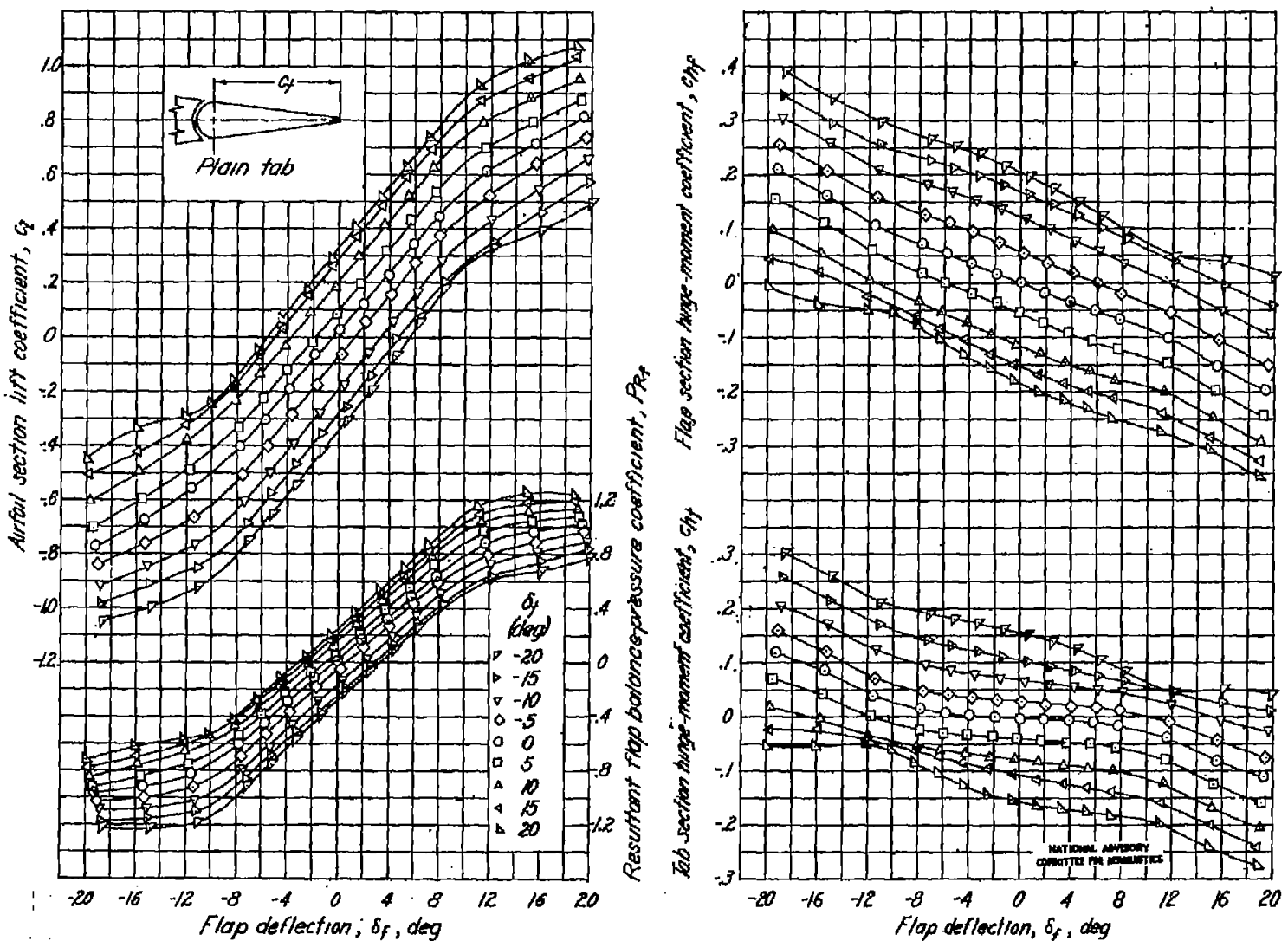


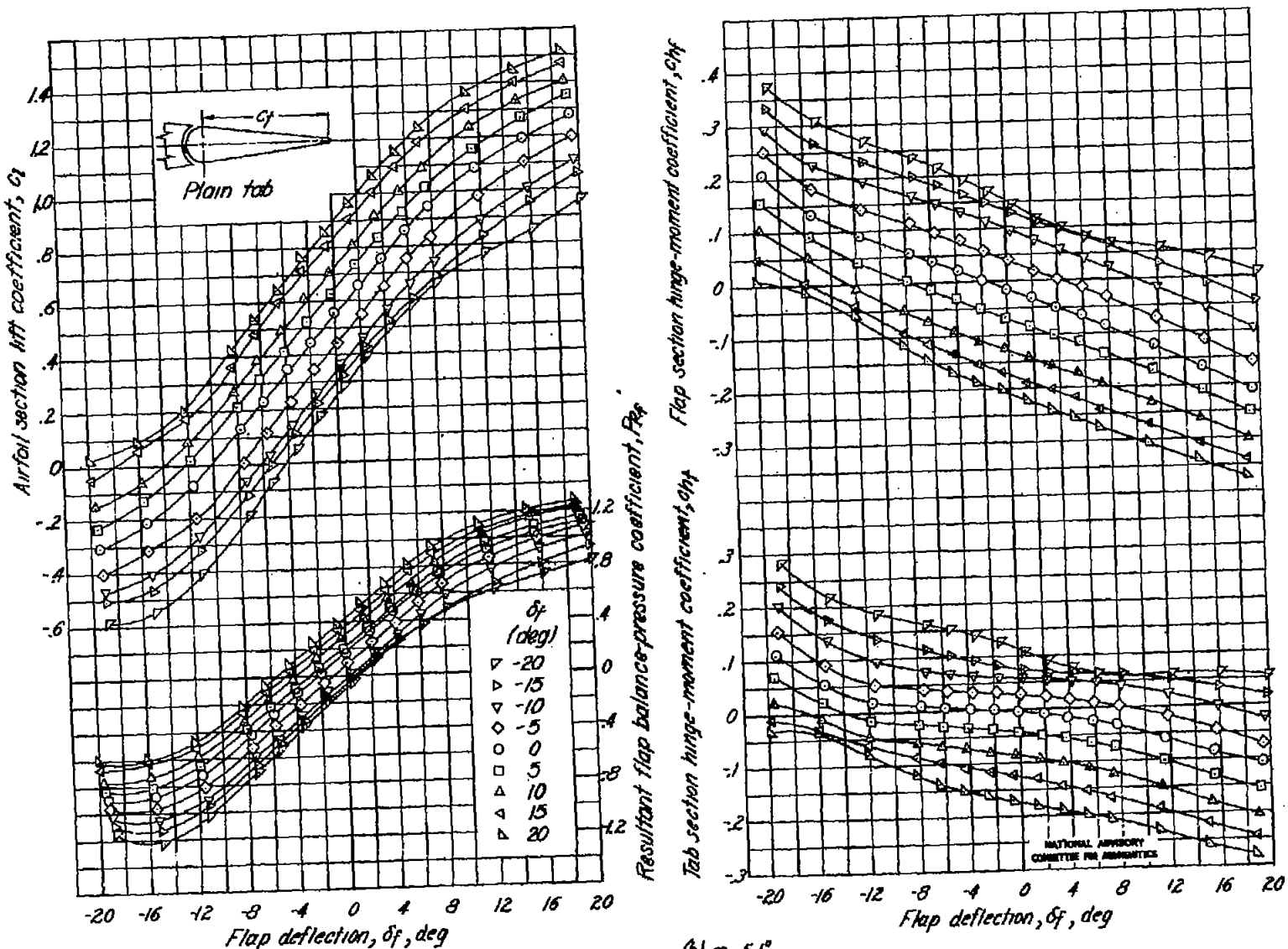
(b) Front view. $\alpha = -10^{\circ}$; $\delta_f = -15^{\circ}$; $\delta_t = 20^{\circ}$.

Figure 2.- Concluded.



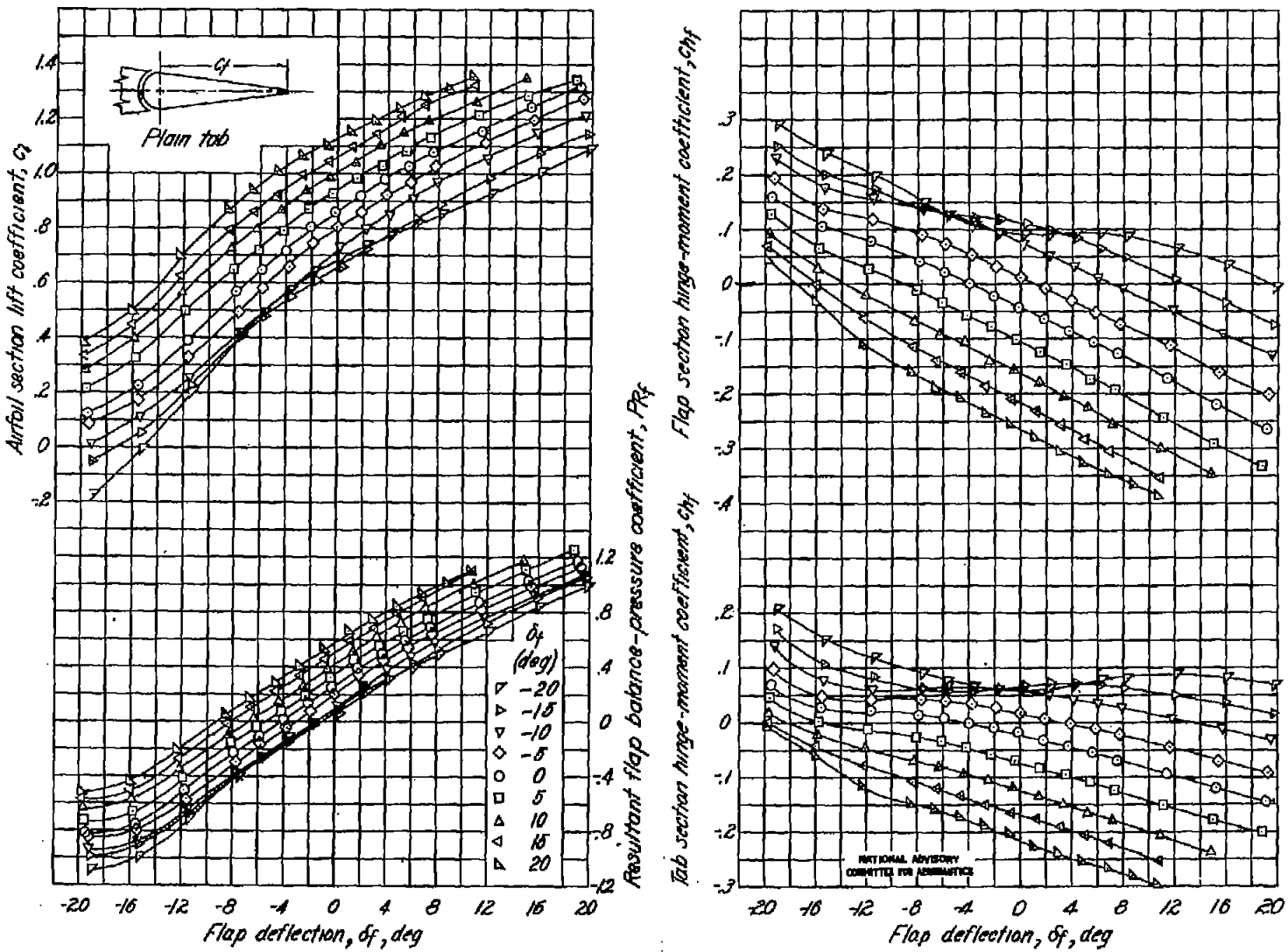
(a) α, 0°

Figure 3.-Section aerodynamic characteristics of modified NACA 65_1-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, plain; tab gap, sealed; transition strips at 0.01c.



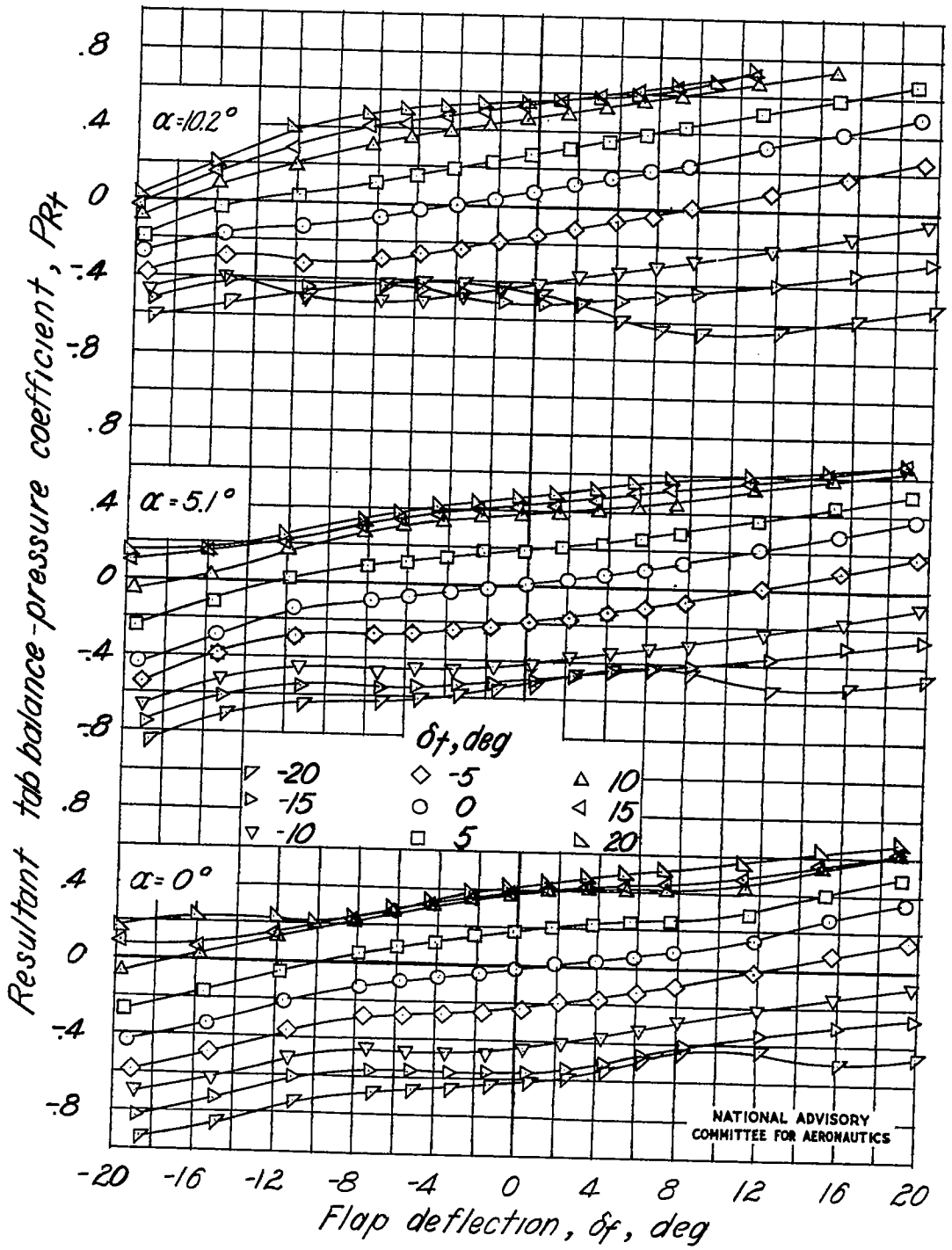
(b) α, 5.1°.

Figure 3.-Continued.



(c) α, 10.2°.

Figure 3.- Continued.



(d) Variation of P_{R_t} with δ_f.

Figure 3.- Concluded.

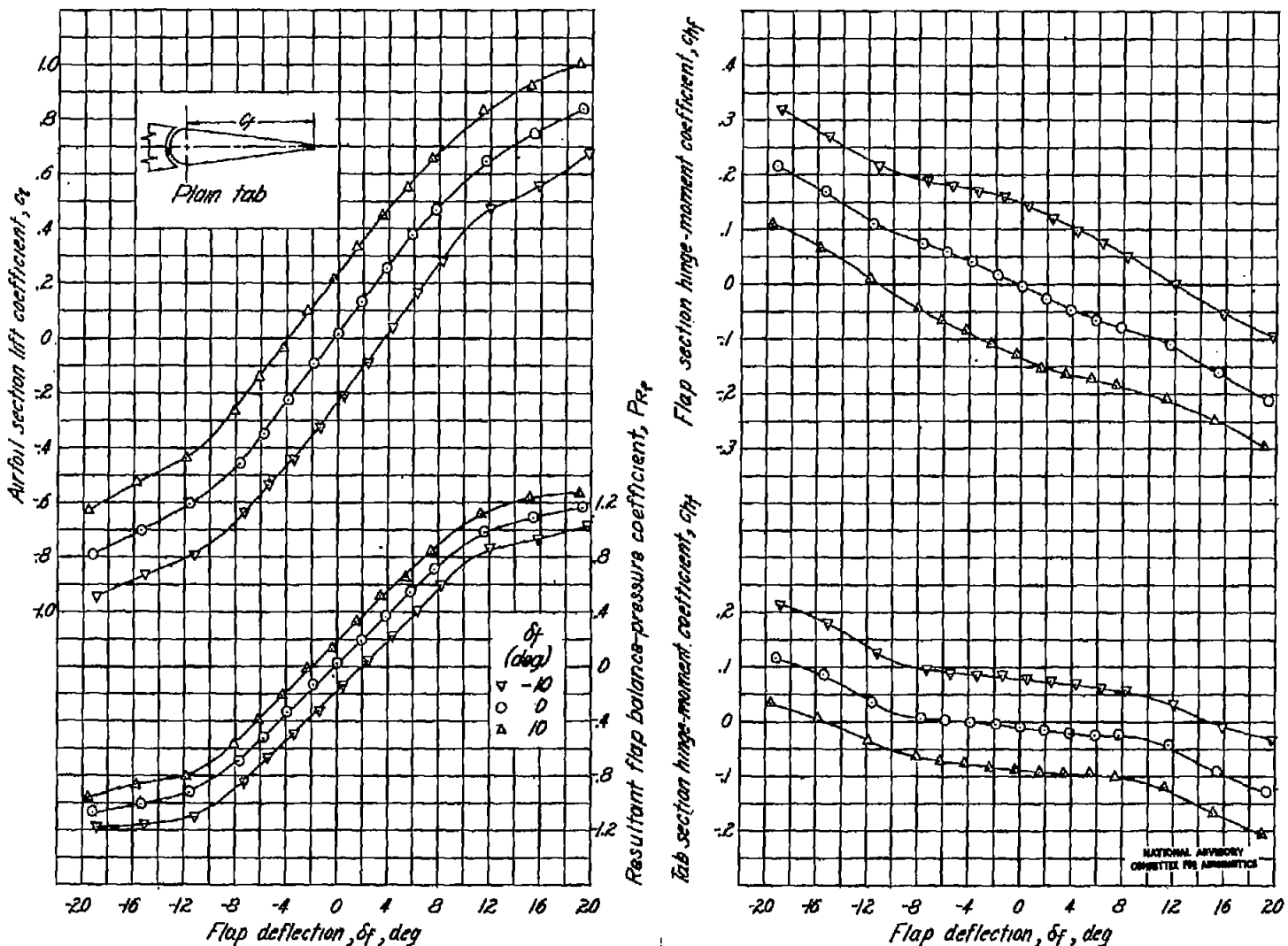
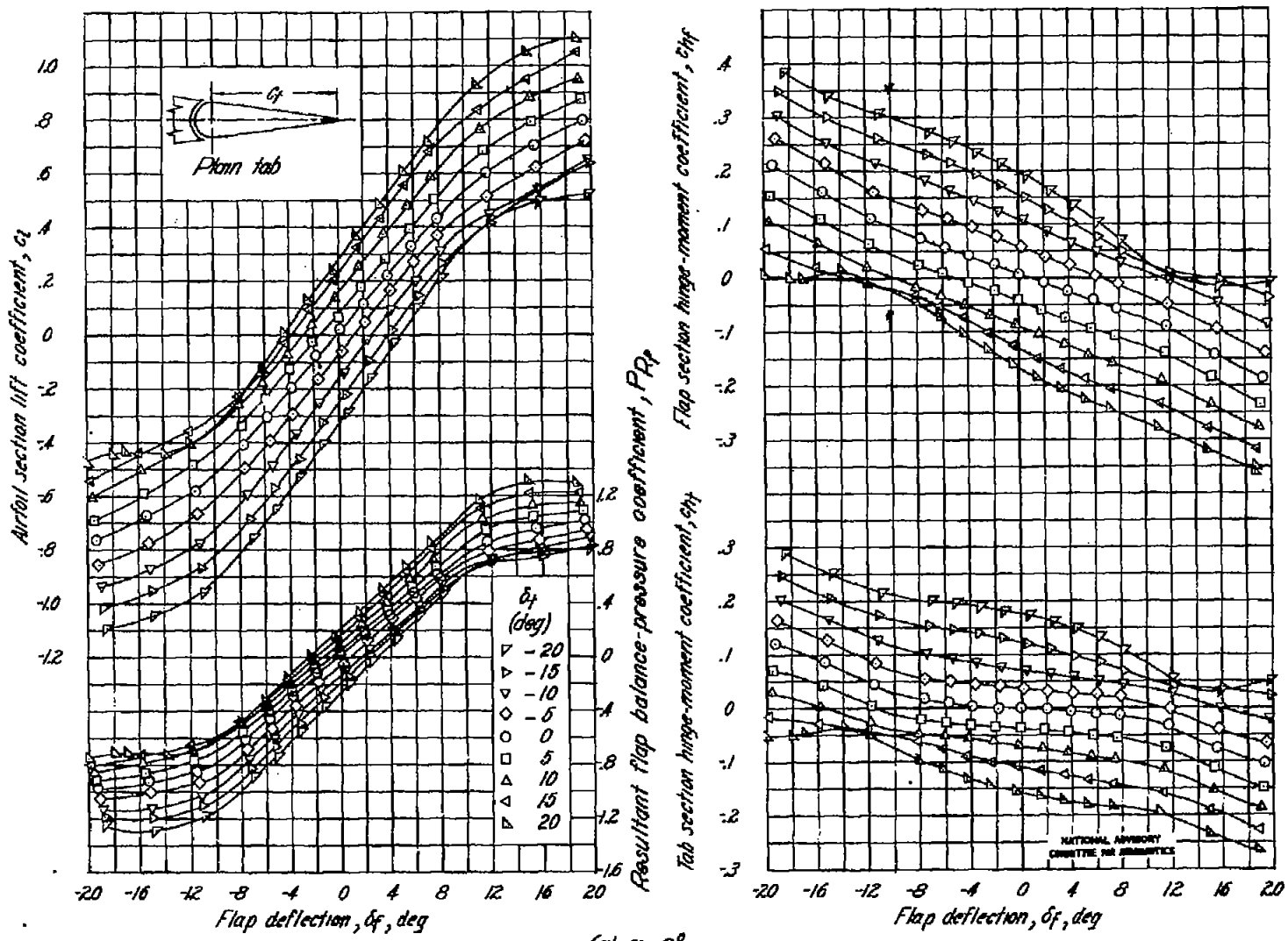
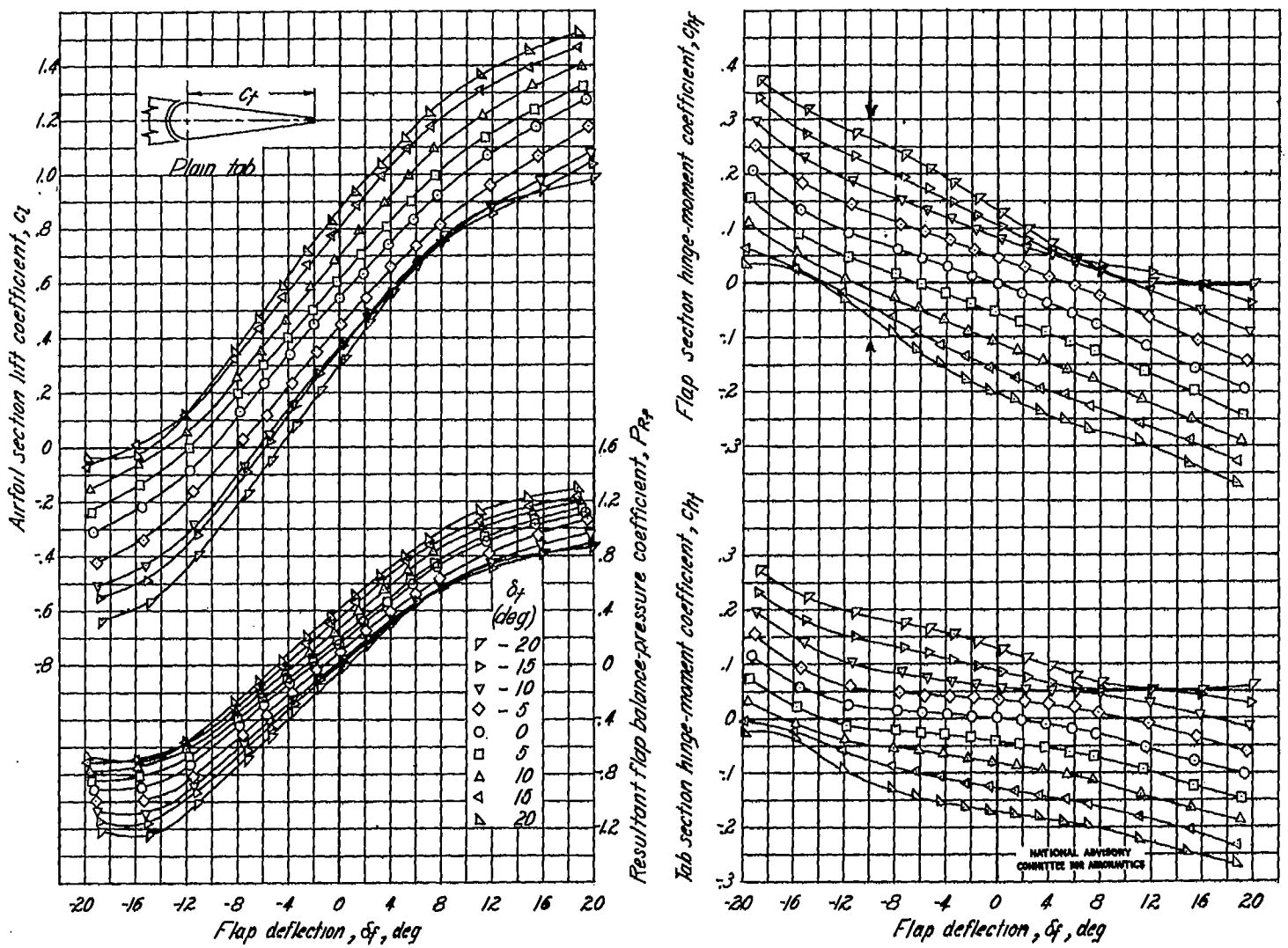


Figure 4.-Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, plain; tab gap, sealed; transition strips off; α, 0°.



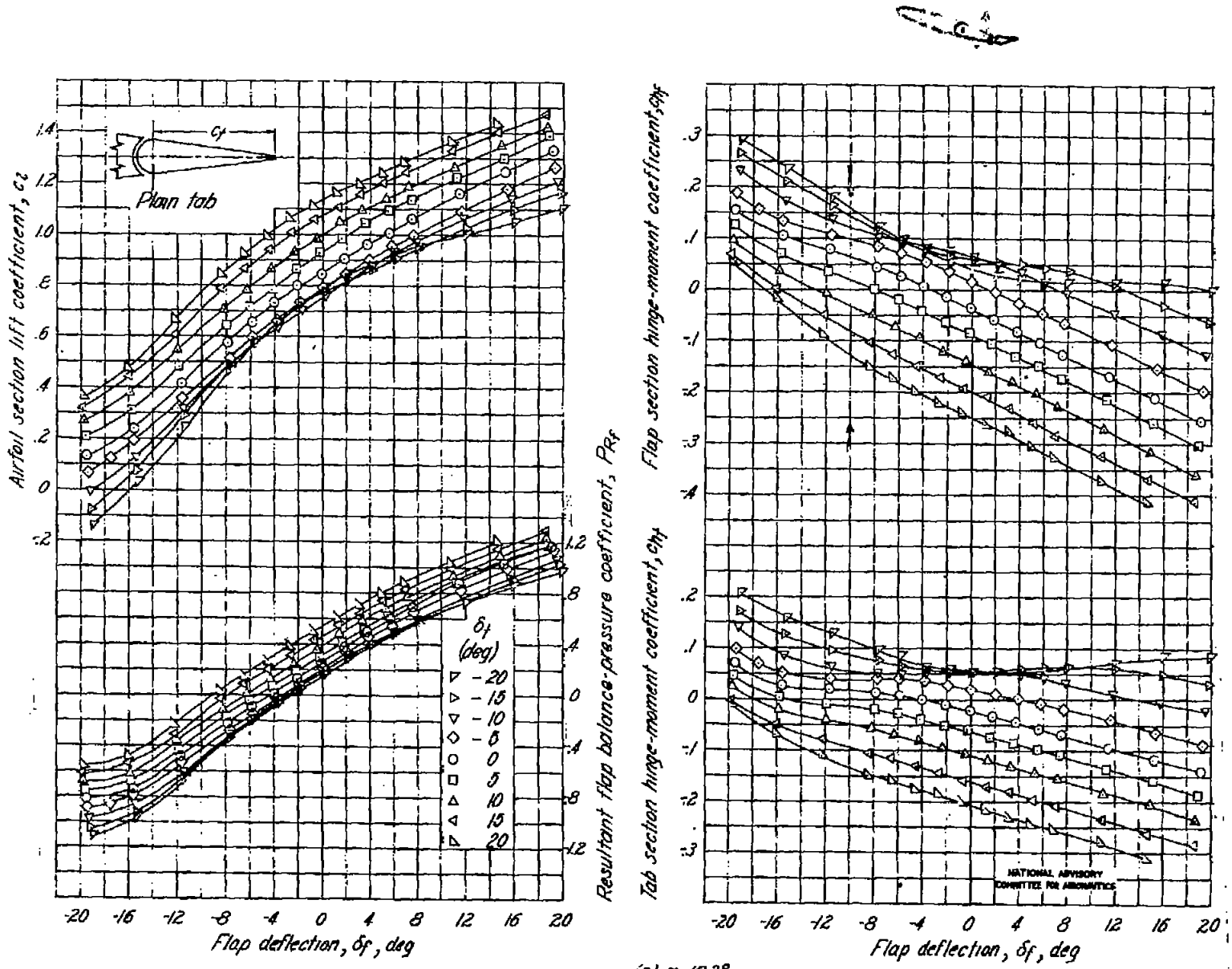
(a) α, 0°.

Figure 5.-Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, plain; tab gap, open; transition strips at 0.01 c.



(b) α, 5.1°

Figure 5.- Continued.



(c) α, 10.2°.

Figure 5.-Concluded.

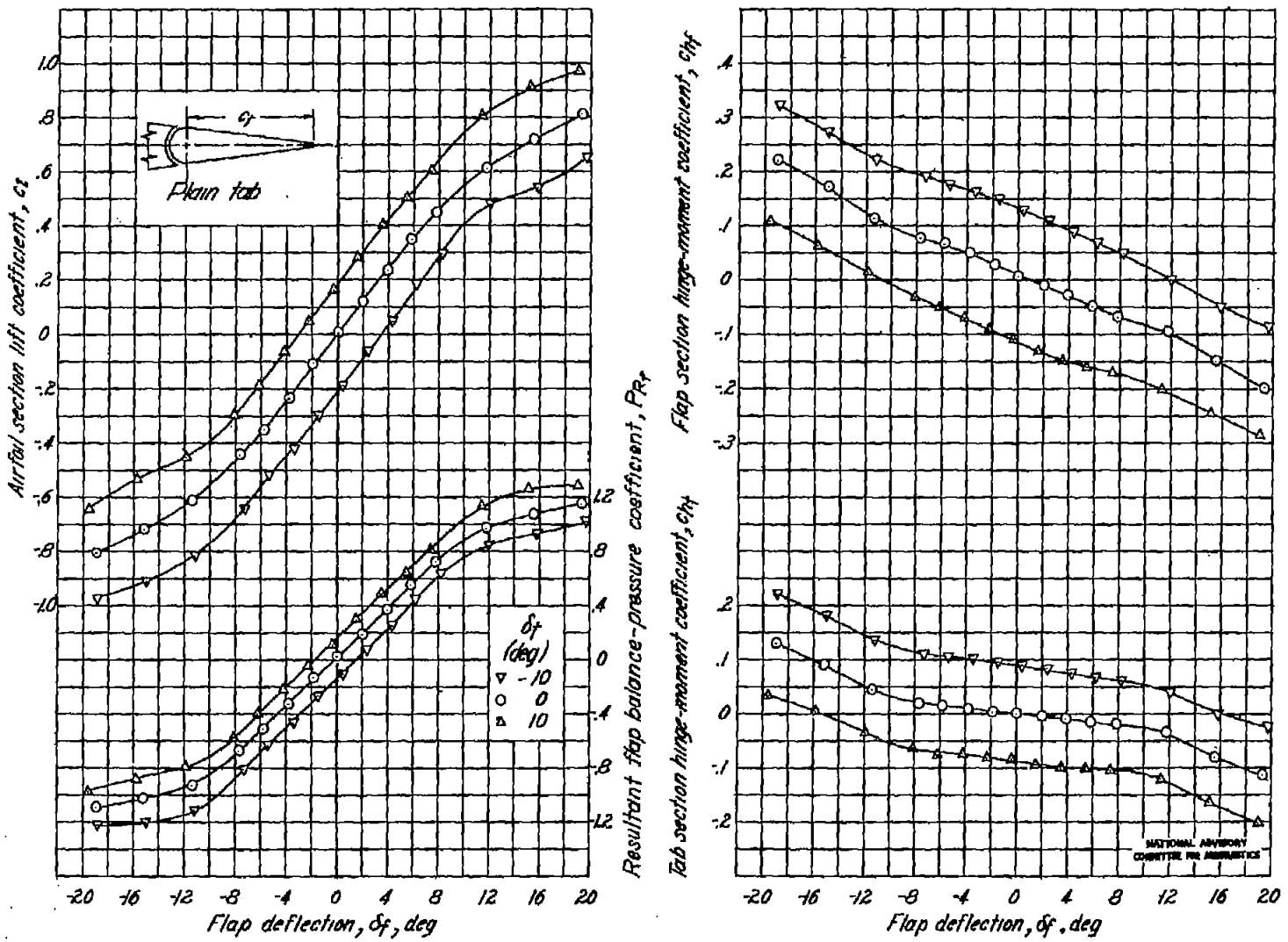
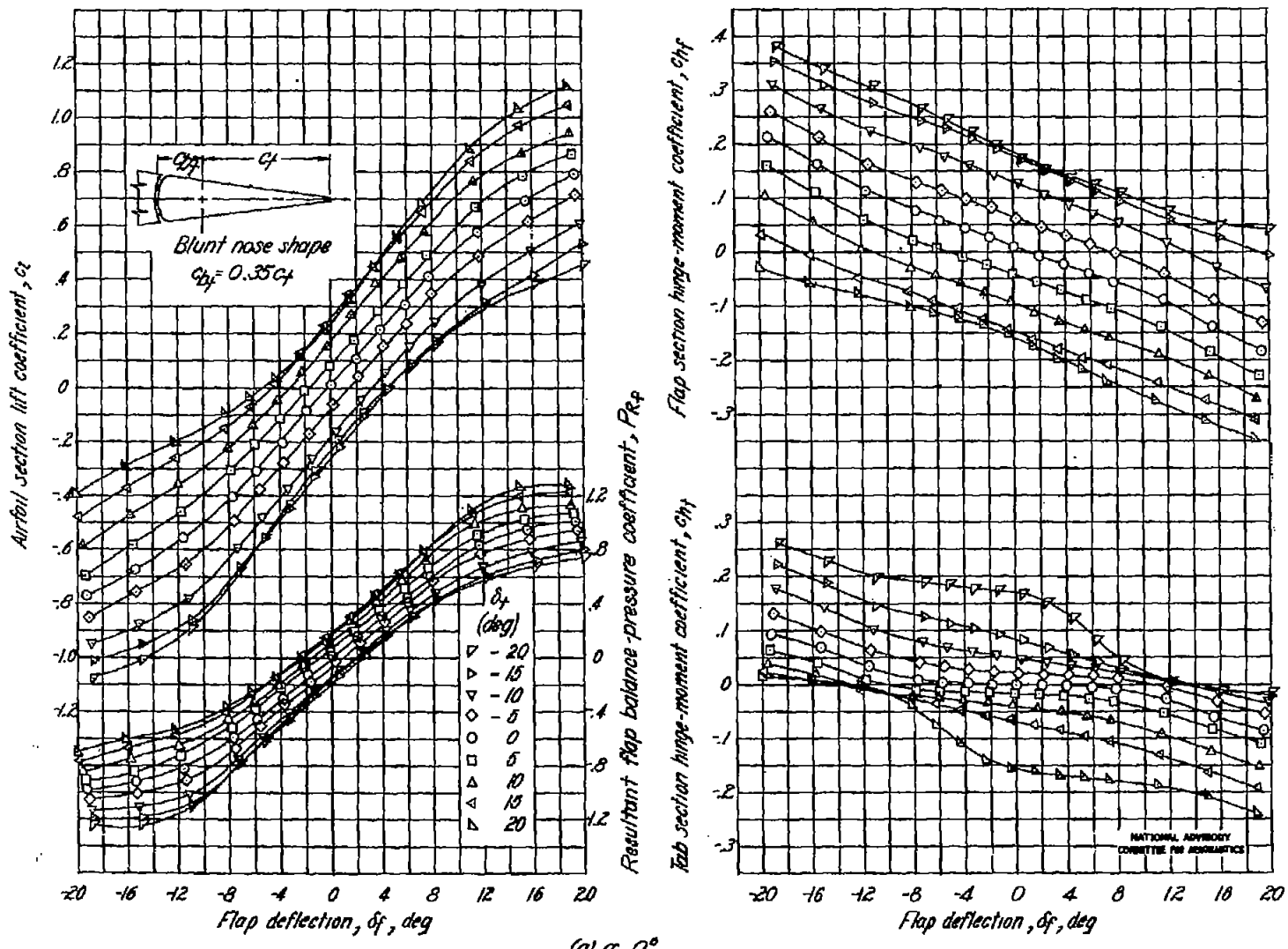
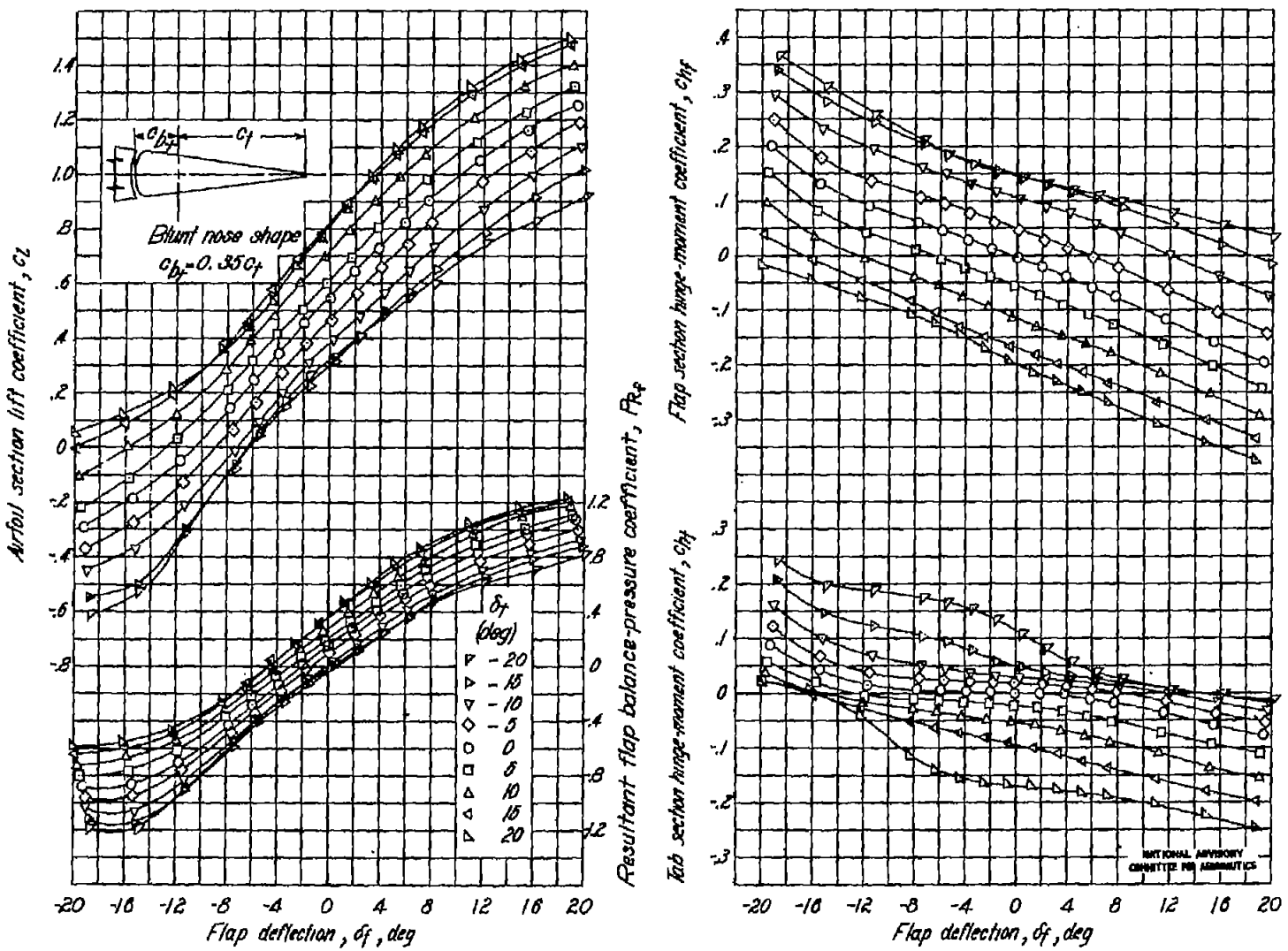


Figure 8.- Section aerodynamic characteristics of modified NACA 65,-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, plain; tab gap, open; transition strips off; α, 0°.

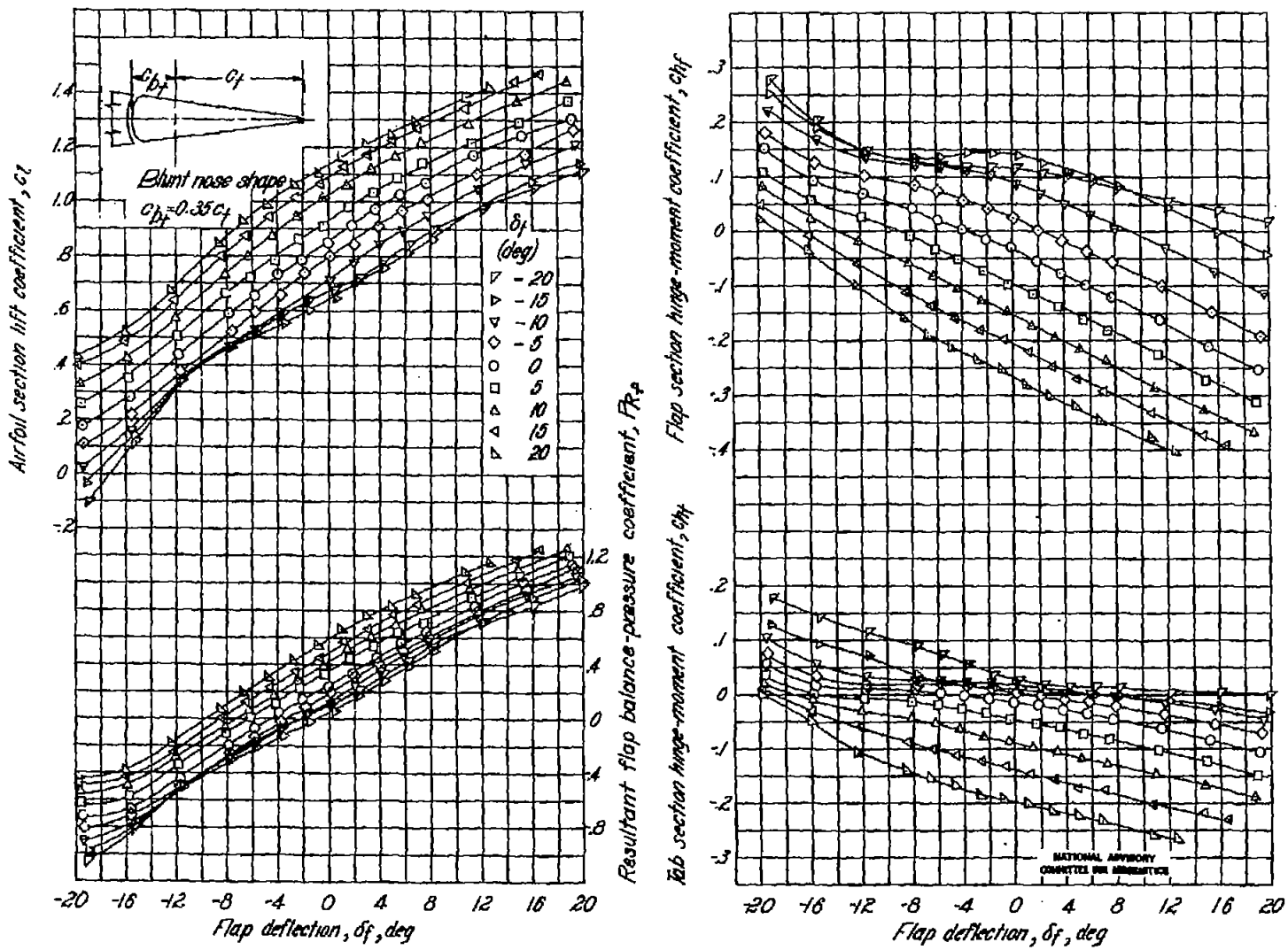


(a) α, 0°.

Figure 7.-Section aerodynamic characteristics of modified NACA 65,-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, blunt; c_{b_f}, 0.35 c_f; tab gap, open; transition strips at 0.01c.

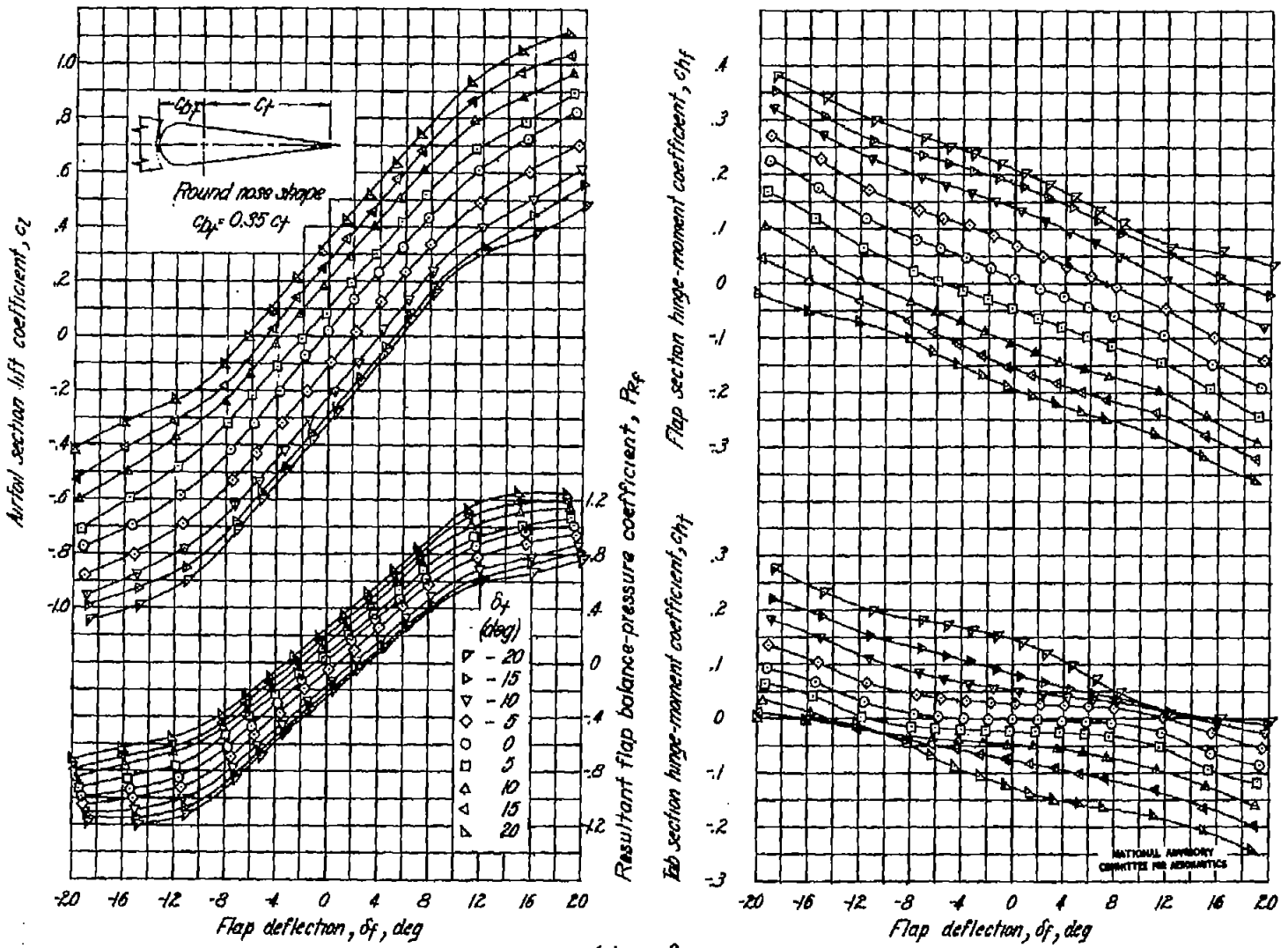


(b) α, 5.1°.
Figure 7.-Continued.



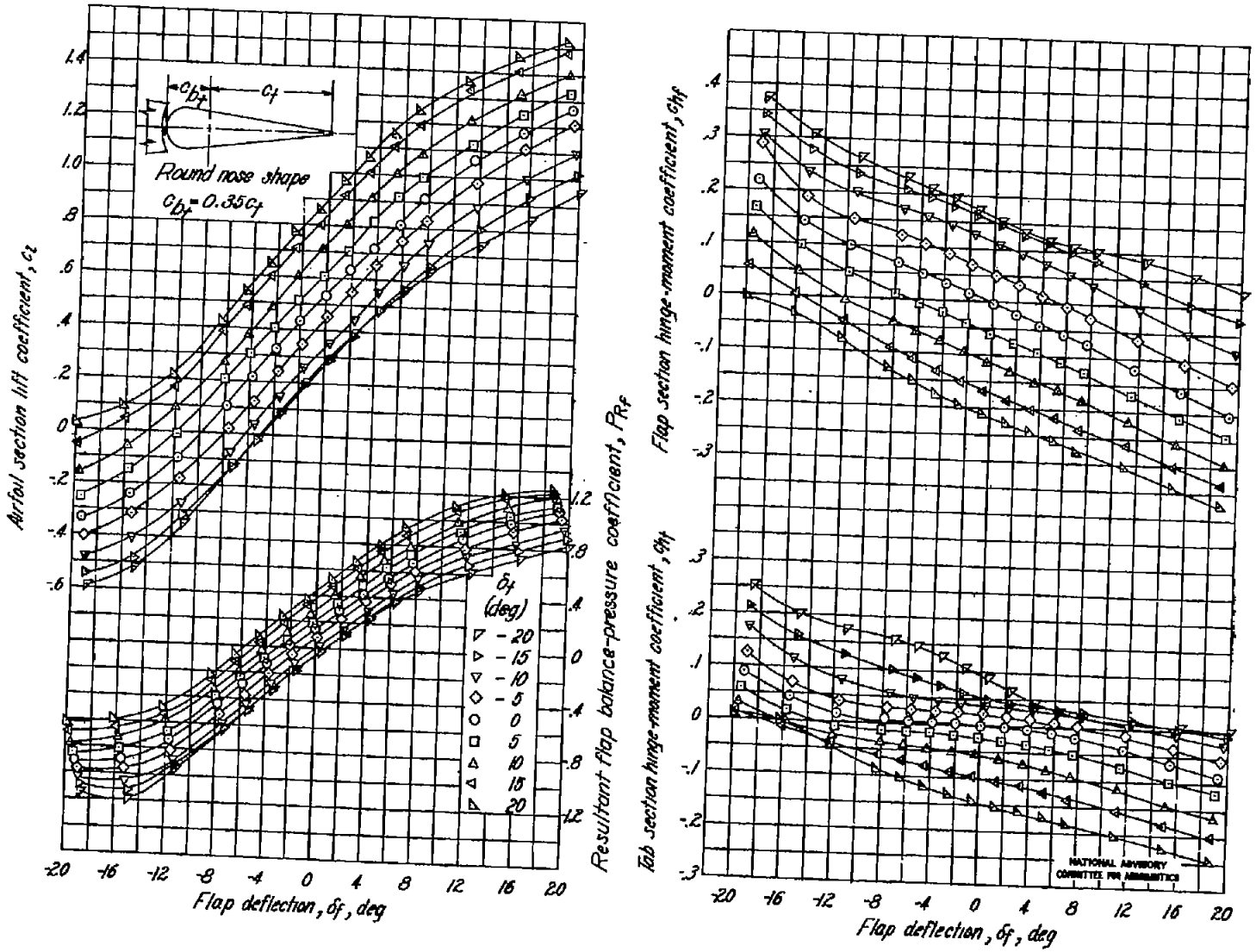
(c) α, 10.2°.

Figure 7.- Concluded.



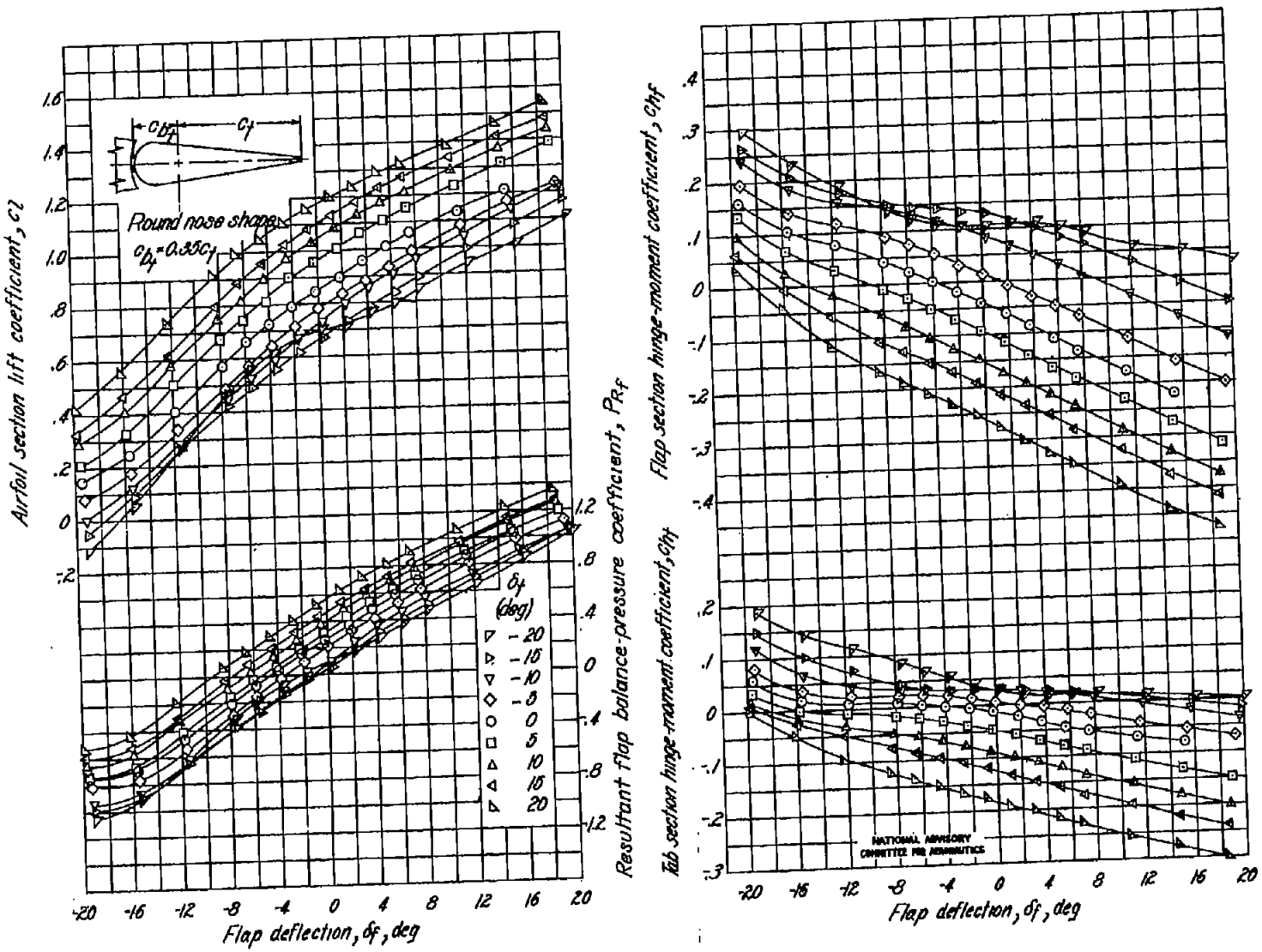
(a) α, 0°.

Figure 8.-Section aerodynamic characteristics of modified NACA 65,-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_f}, 0.35c_f; tab gap, sealed; transition strips at 0.01c.



(b) α_t, 5.1°.

Figure 8.-Continued.



(c) α, 10.2°.

Figure 8.- Concluded.

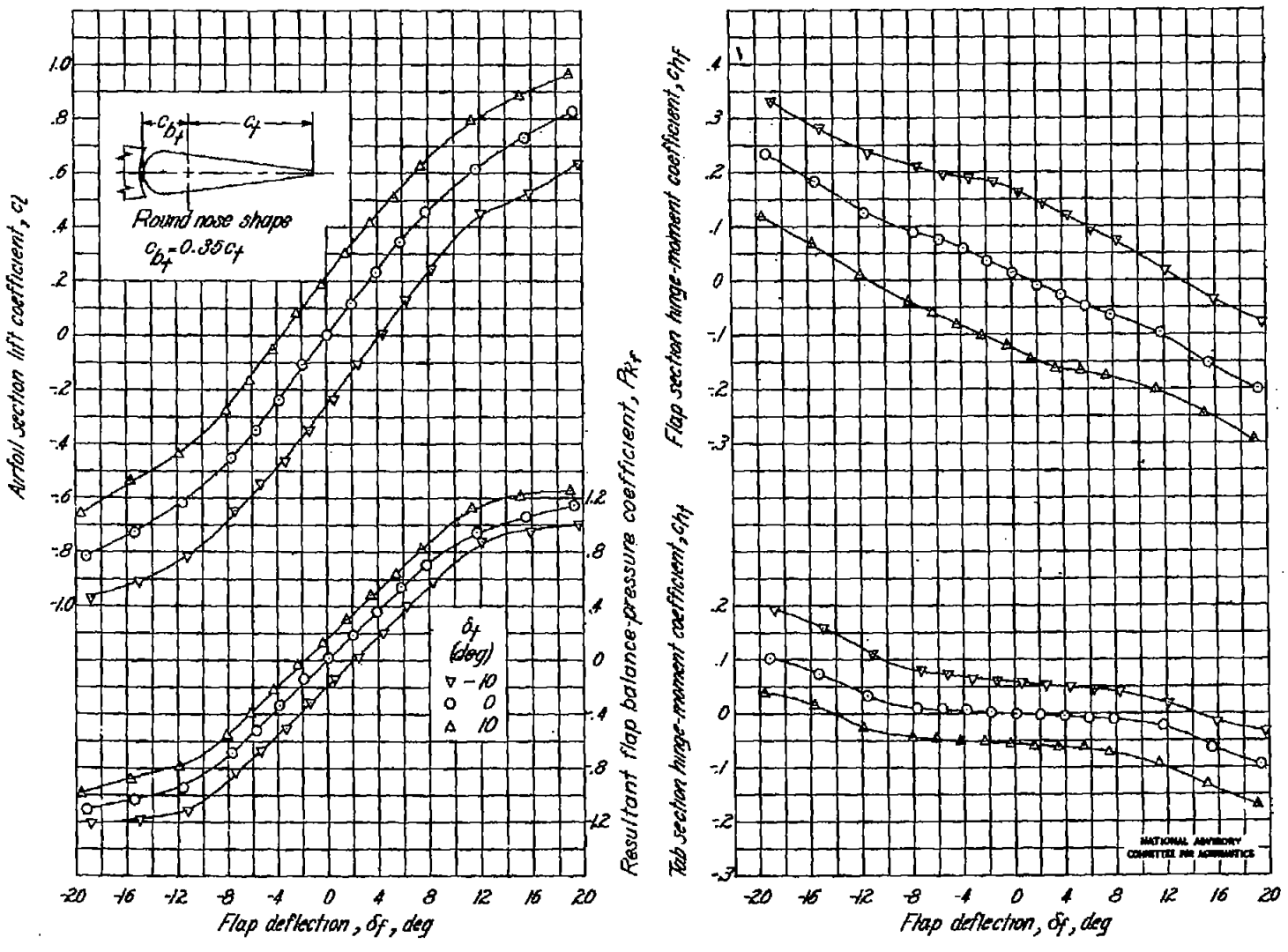
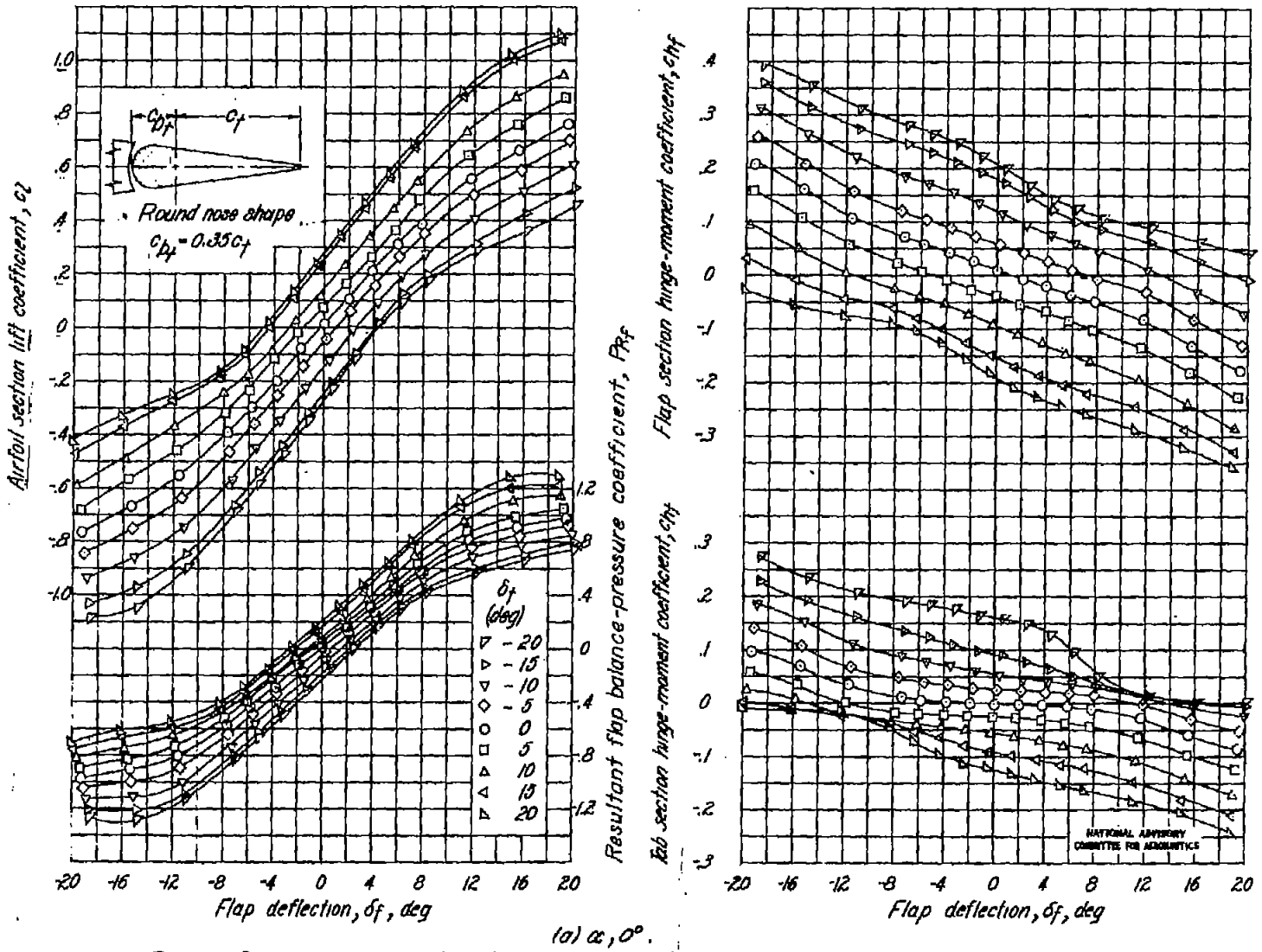
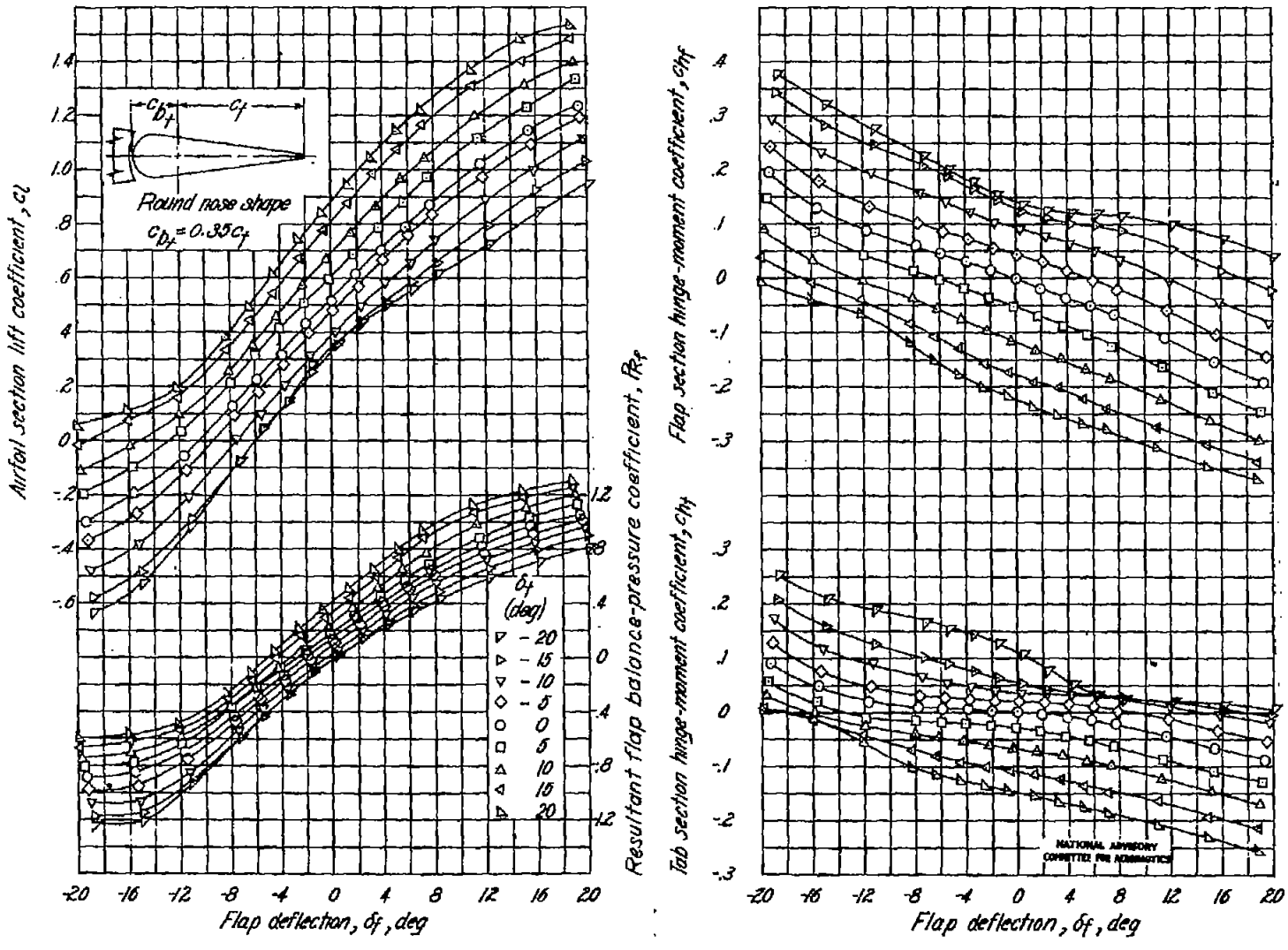


Figure 9.-Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c$_f$ tab. Tab nose shape, round; c_{b_f}, 0.35 c$_f$; tab gap, sealed; transition strips off; α, 0°.



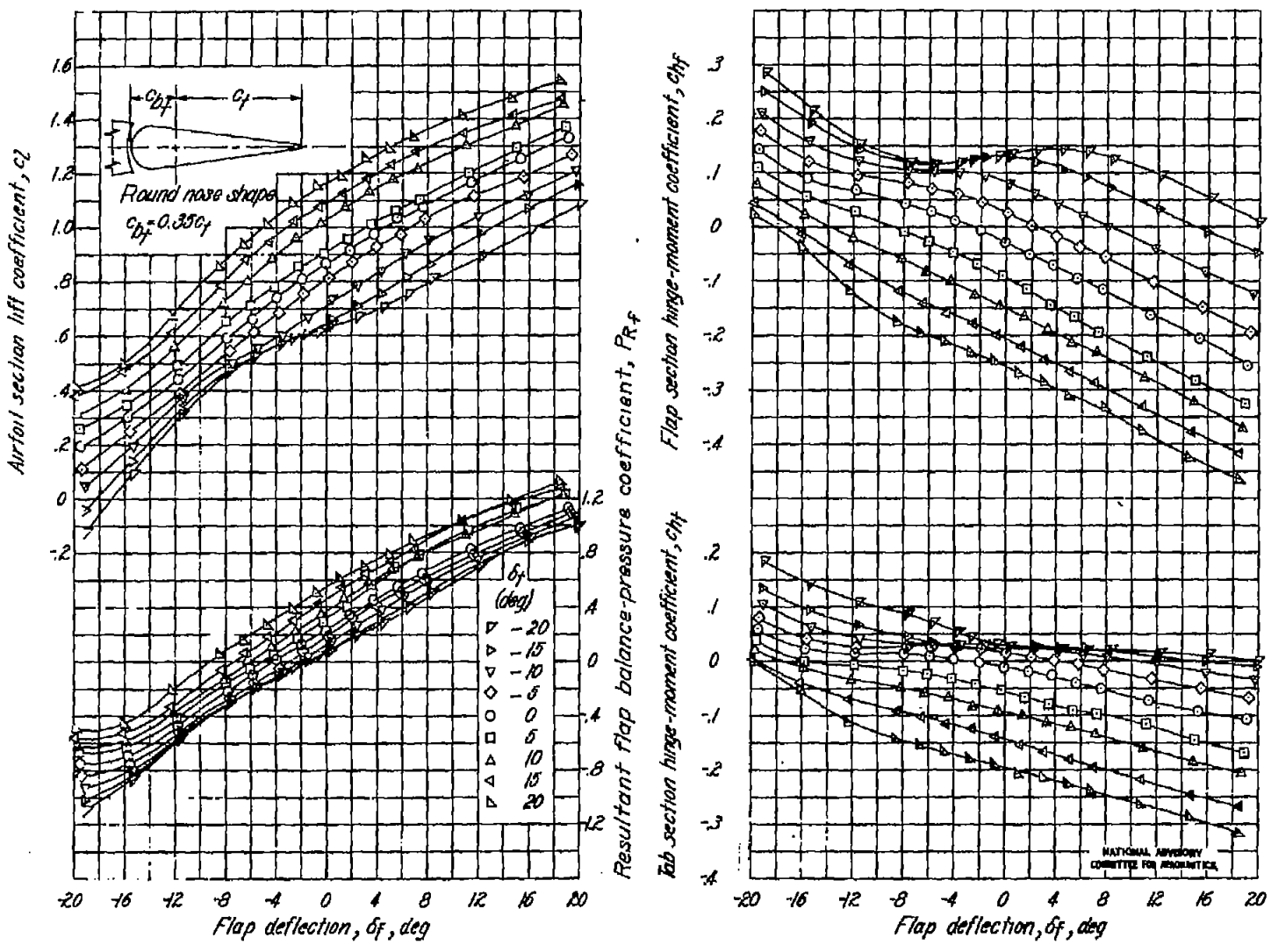
(a) α, 0°.

Figure 10.- Section aerodynamic characteristics of modified NACA 65,-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_f}, 0.35 c_f; tab gap, open; transition strips at 0.01c.



(b) α_t, 5.1°.

Figure 10.- Continued.



(c) α, 10.2°.
Figure 10.- Concluded.

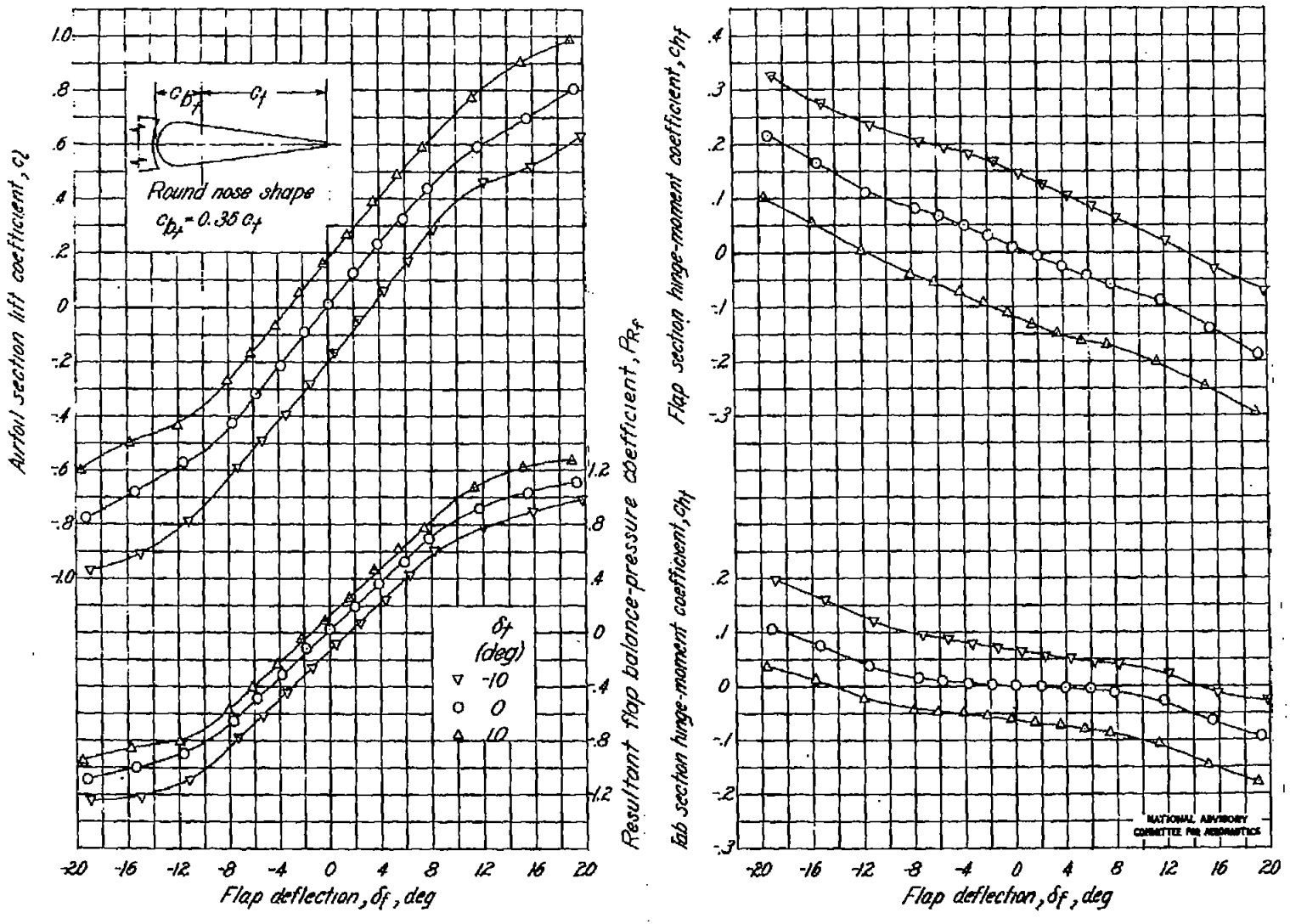
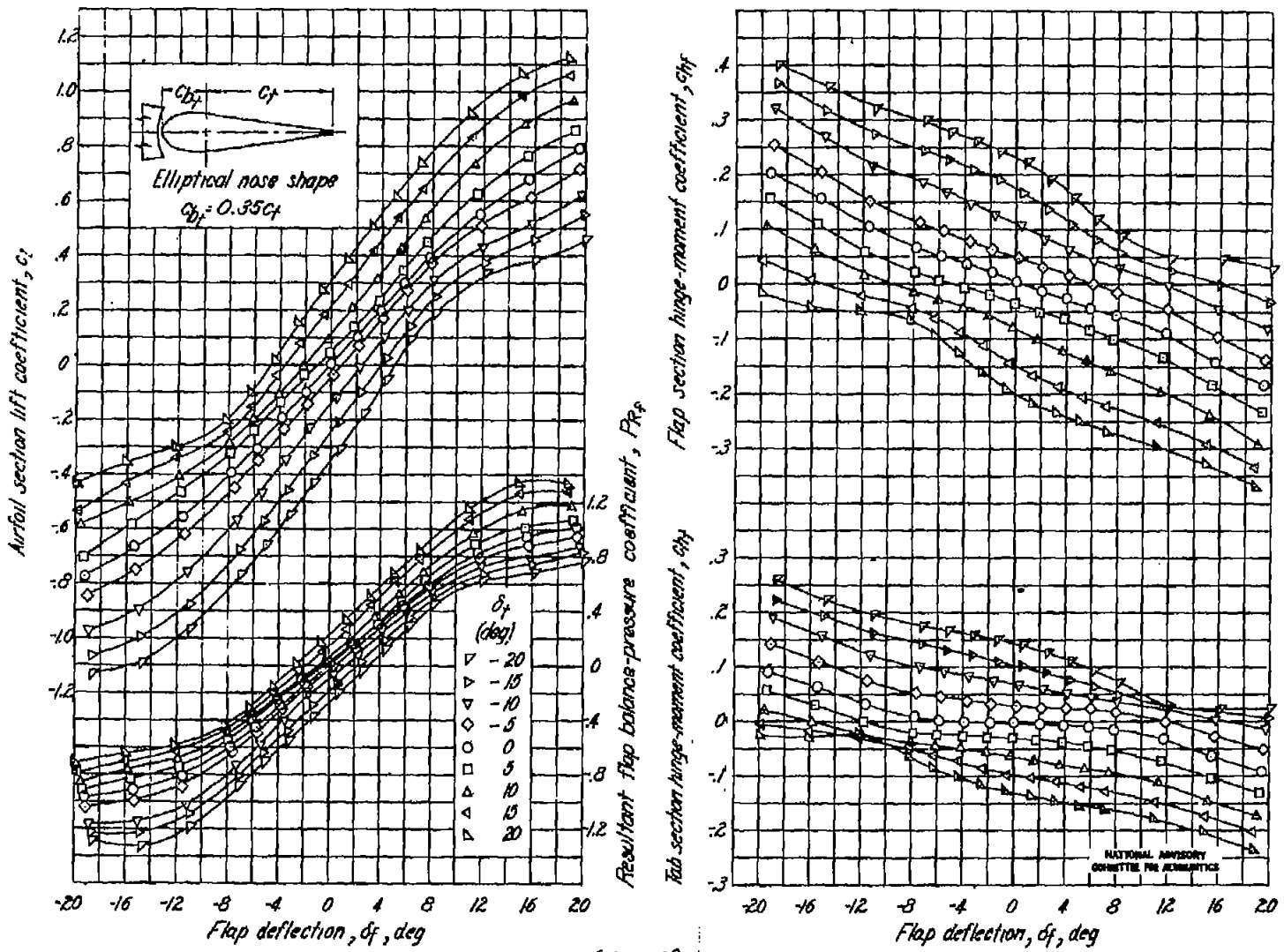
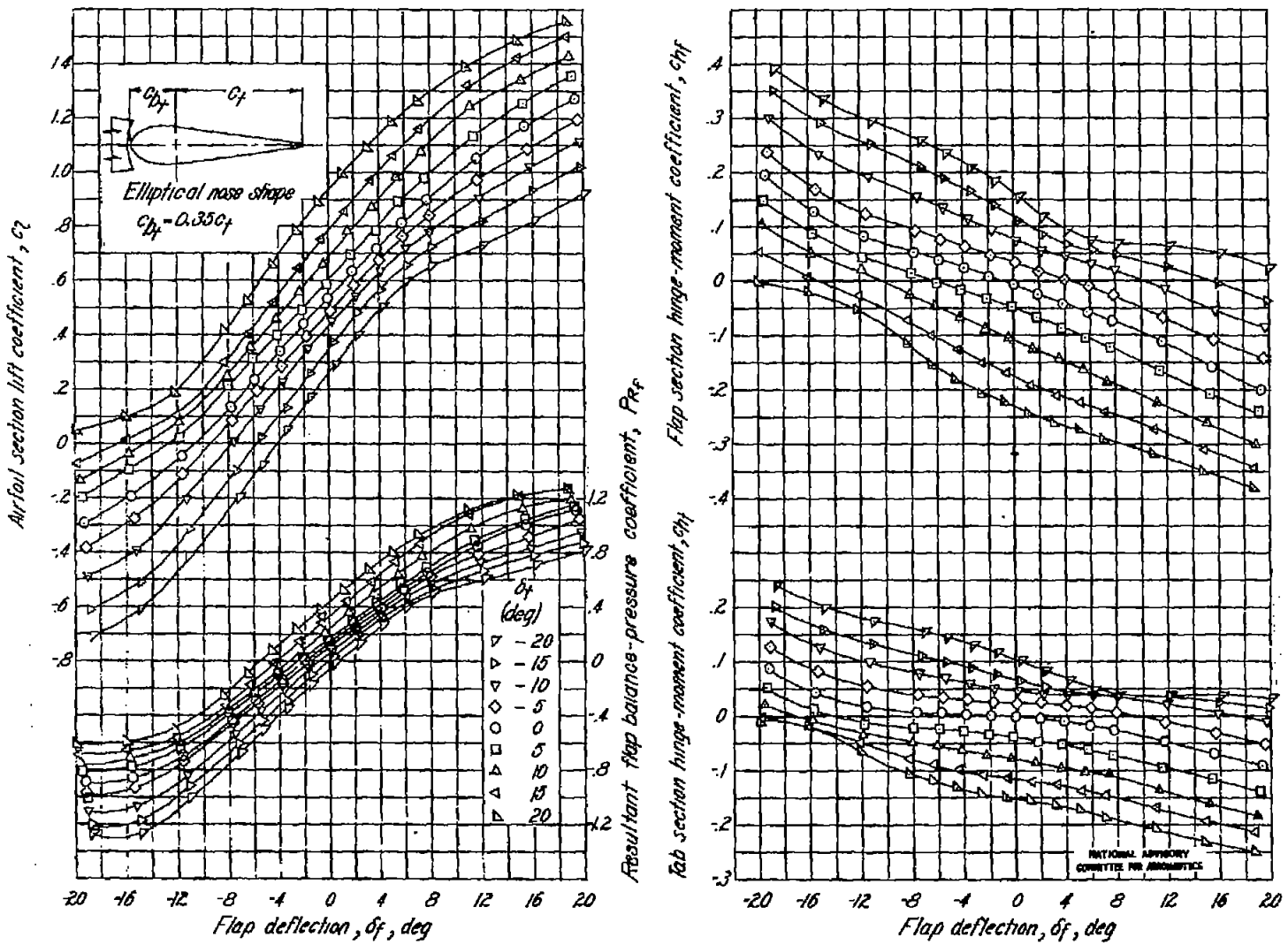


Figure 11.- Section aerodynamic characteristics of modified NACA 65_1-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_t}, 0.35c_t; tab gap, open; transition strips off; α, 0°.



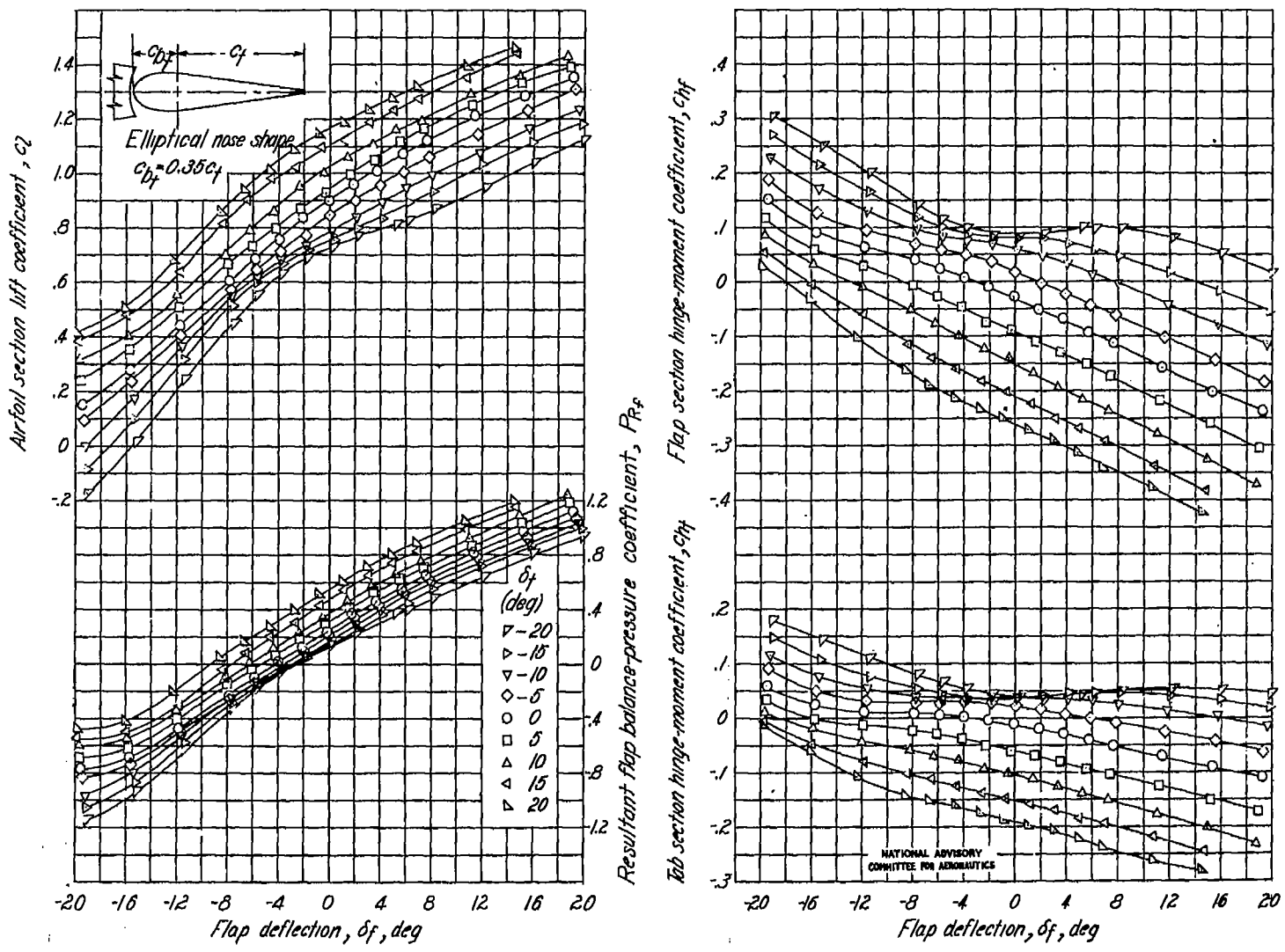
(a) α, 0°.

Figure 12.-Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, elliptical; c_{b_f}, 0.35 c_f; tab gap, open; transition strips at 0.01c.

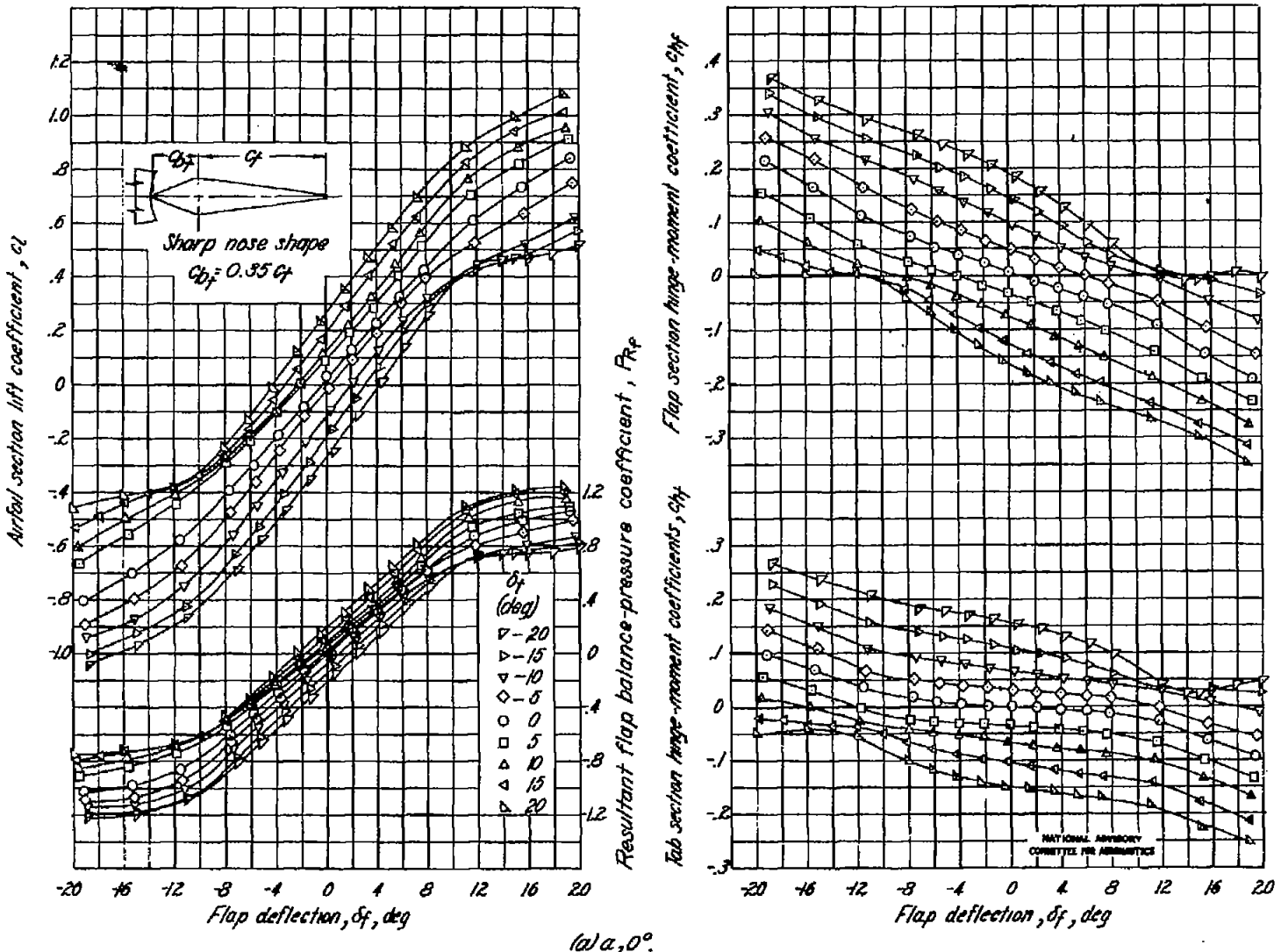


(b) α, 5.1°.

Figure 12.-Continued.

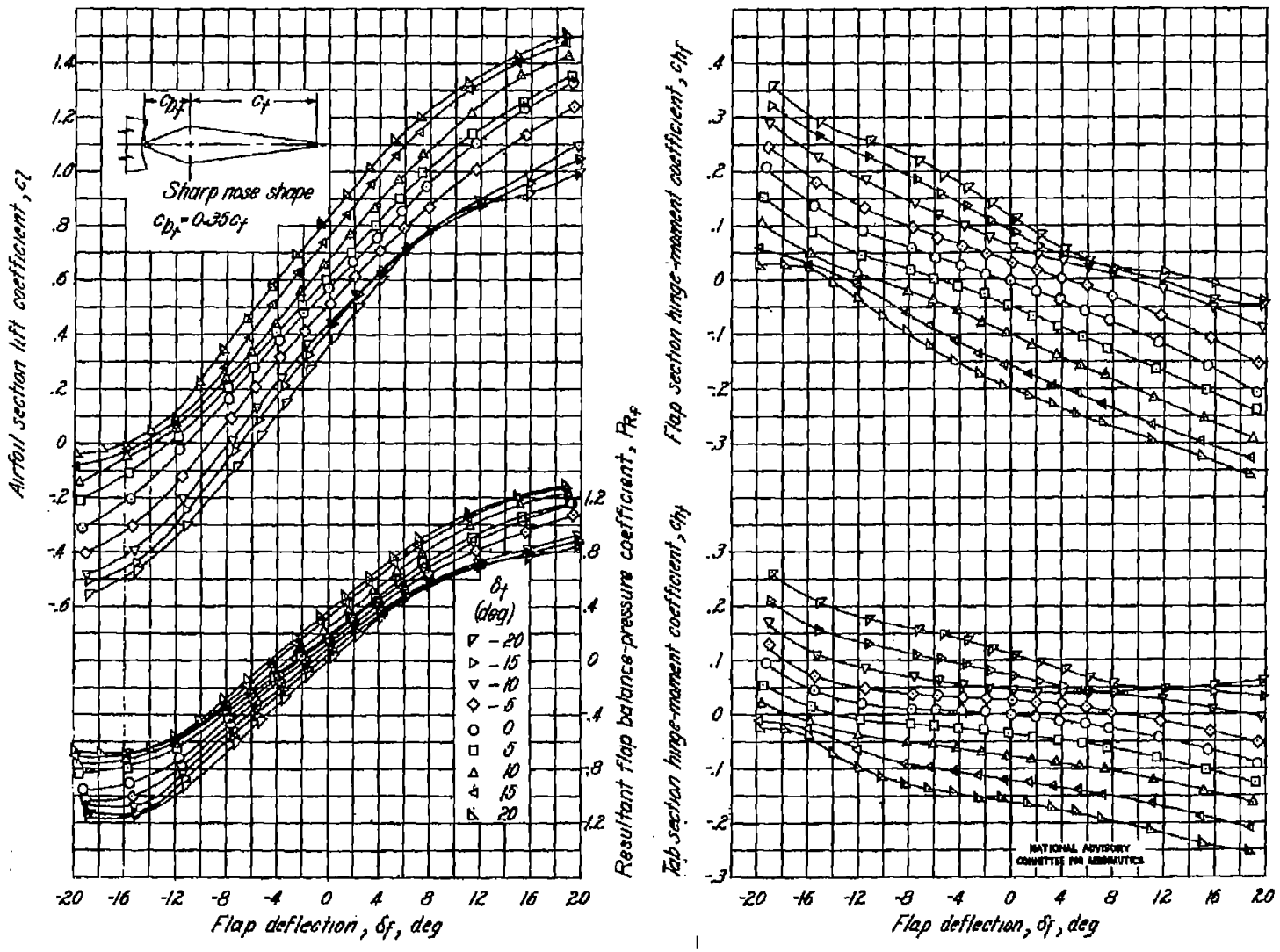


(c) α, 10.2°.
Figure 12.- Concluded.



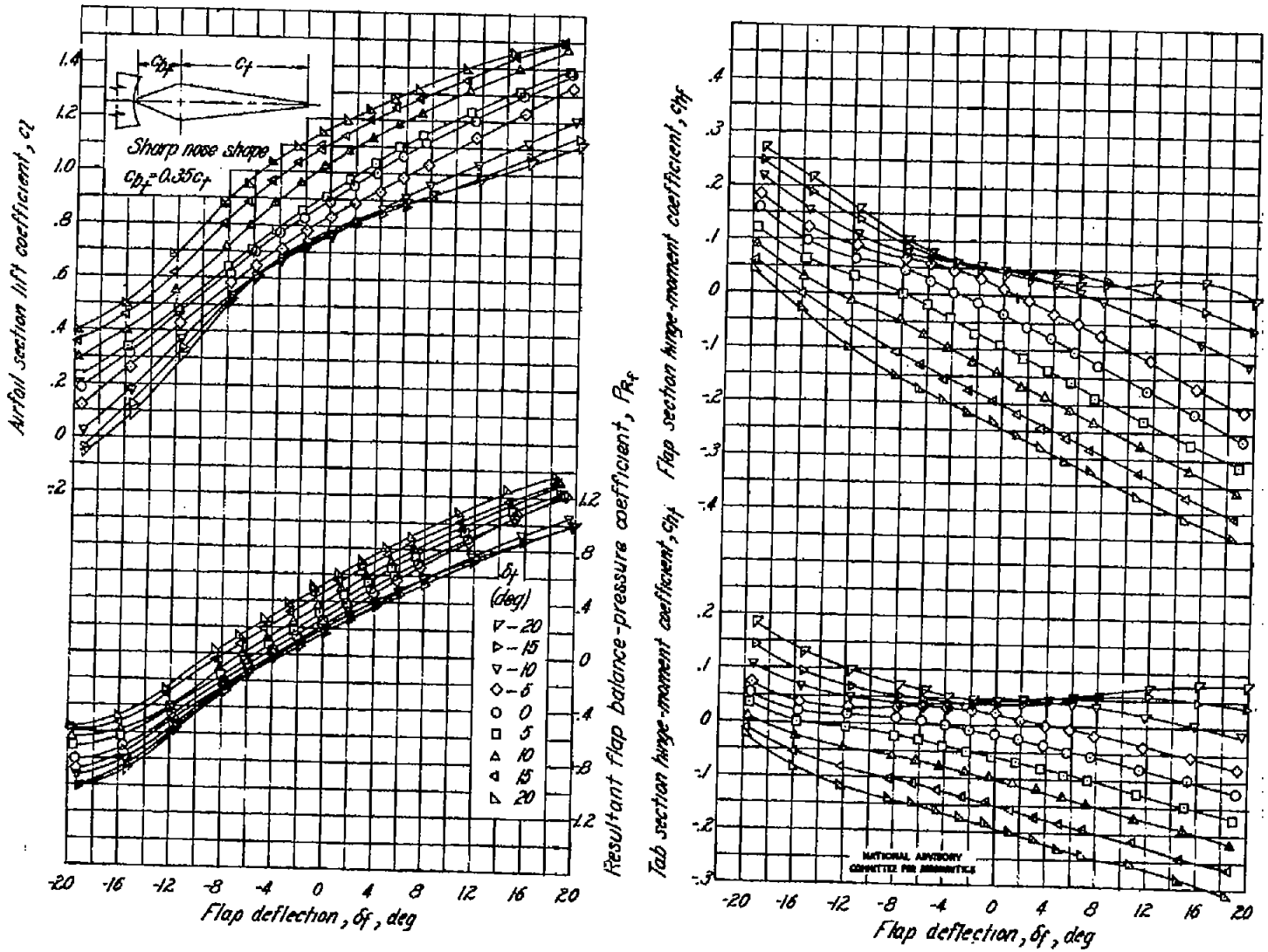
(a) α, 0°.

Figure 13.- Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, sharp; c_{b_t}, 0.35 c_t; tab gap, open; transition strips at 0.01c.

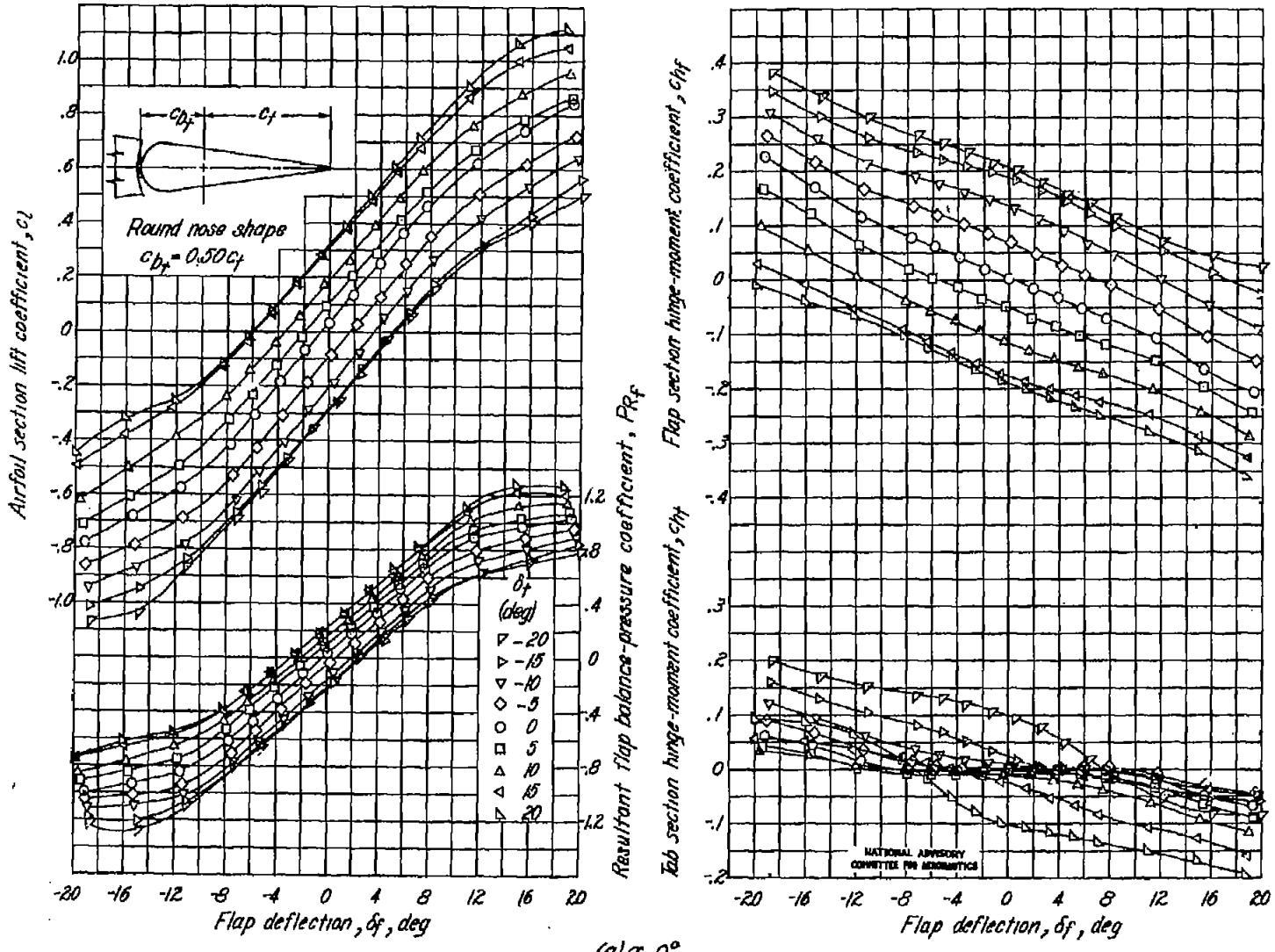


(b) α, 51°

Figure 13.-Continued.

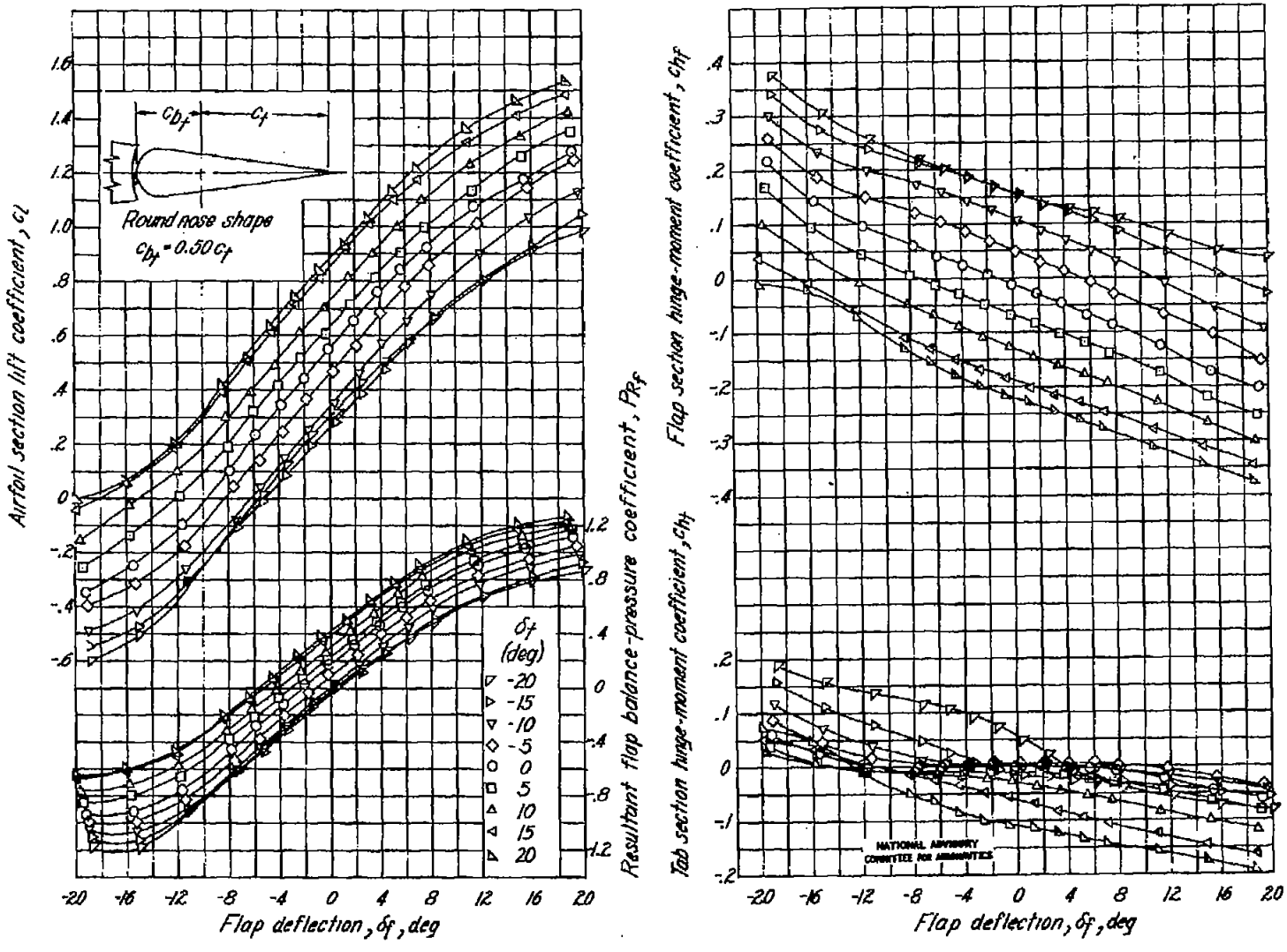


(c) α, 10.2°.
Figure 13.- Concluded.



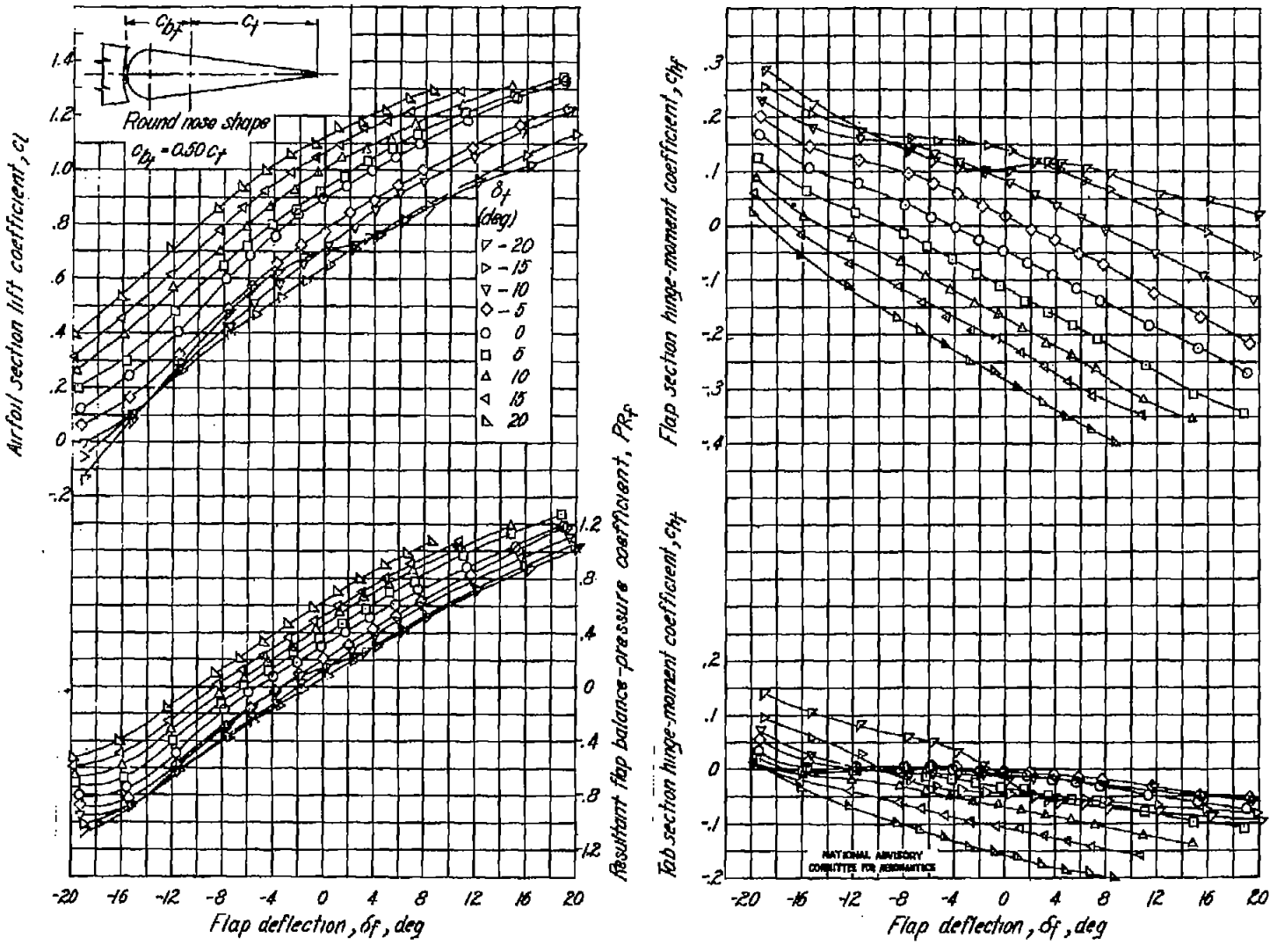
(a) α, 0°.

Figure 14.- Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_t}, 0.50 c_t; tab gap, sealed; transition strips at 0.01 c.



(b) α, 5.1°.

Figure 14.-Continued.



(c) α, 10.2°.
Figure 14.-Concluded.

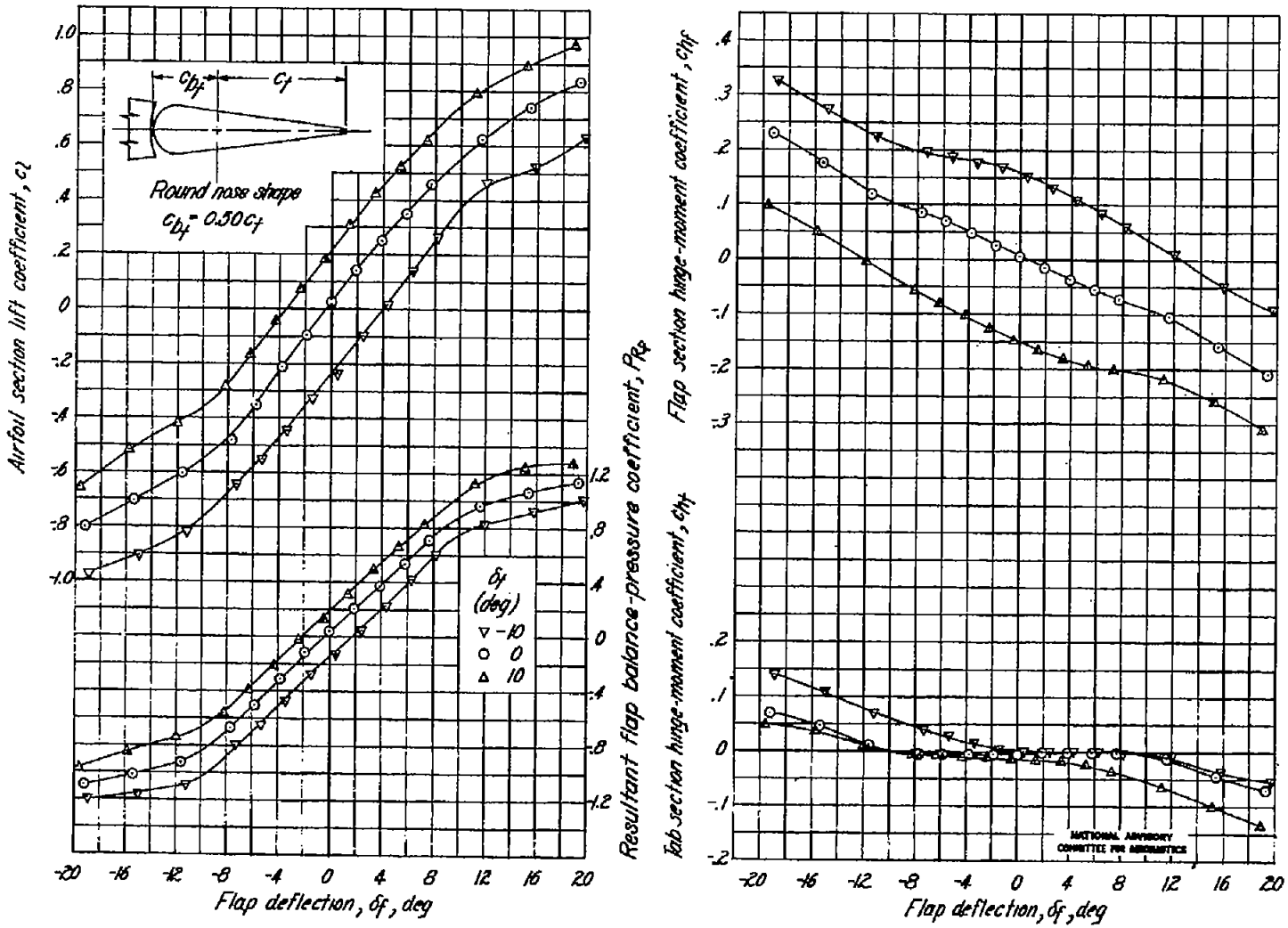
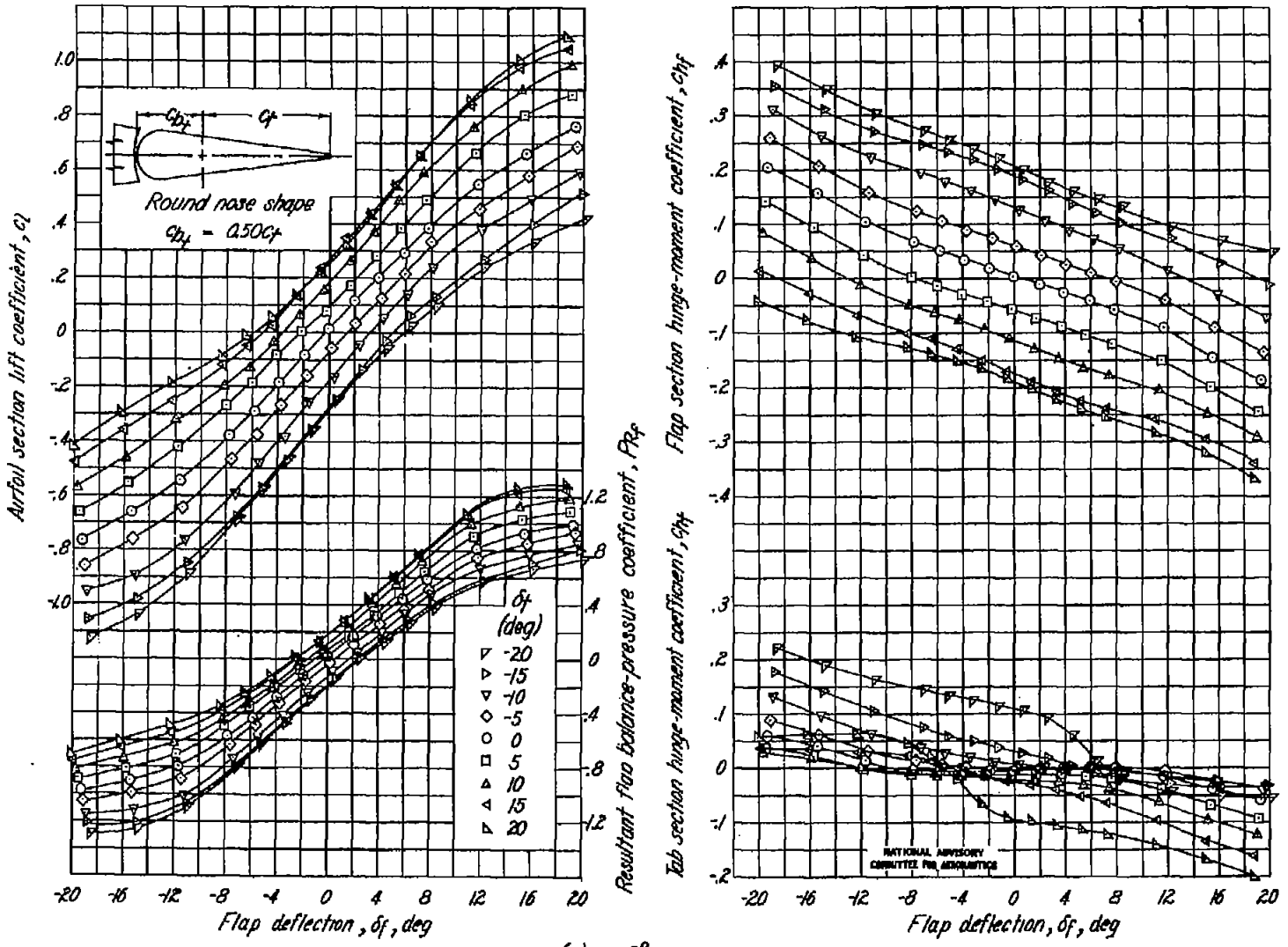
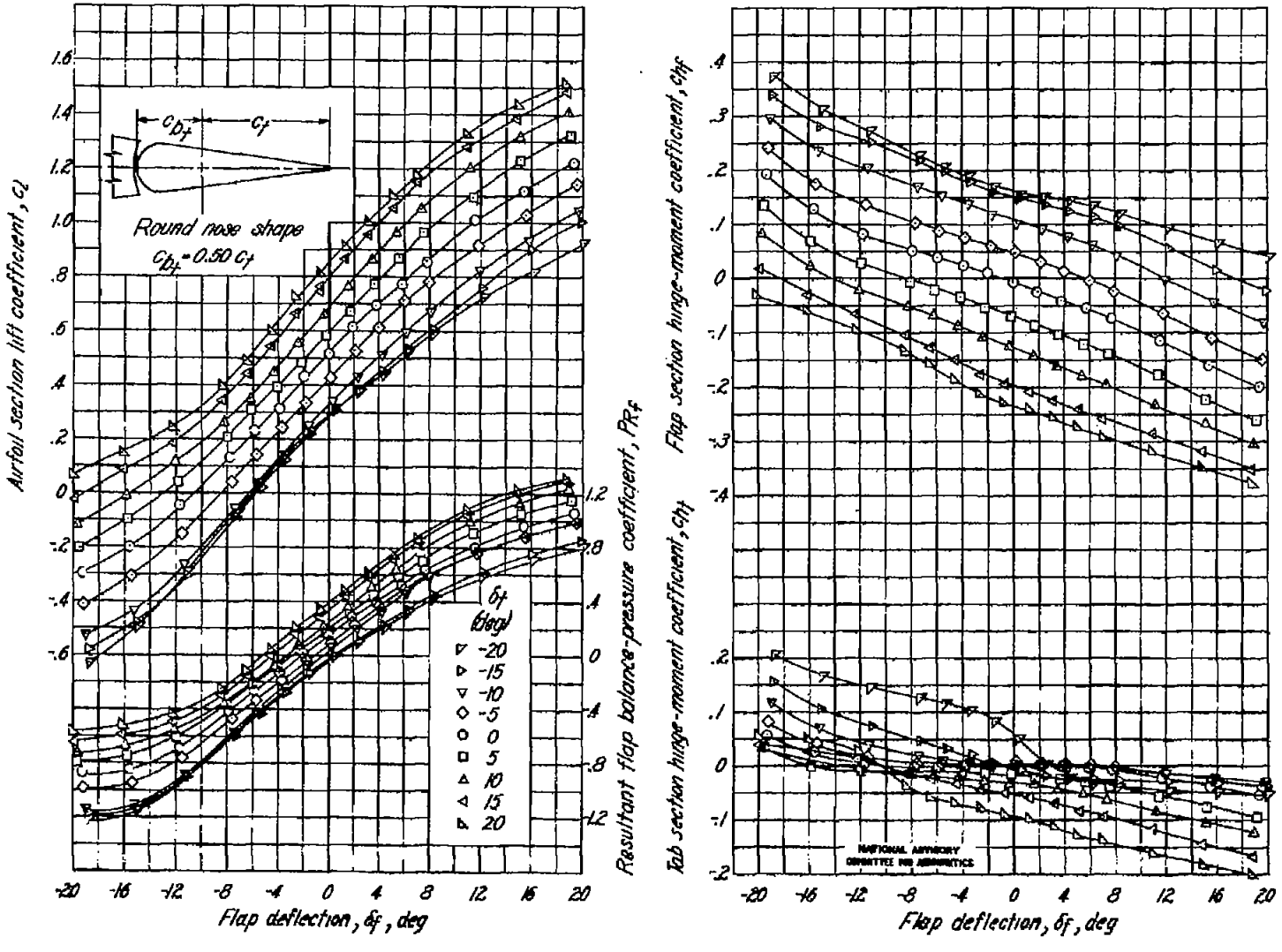


Figure 15.- Section aerodynamic characteristics of modified NACA 65,-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_f}, 0.50c_f; tab gap, sealed; transition strips off; α, 0°.



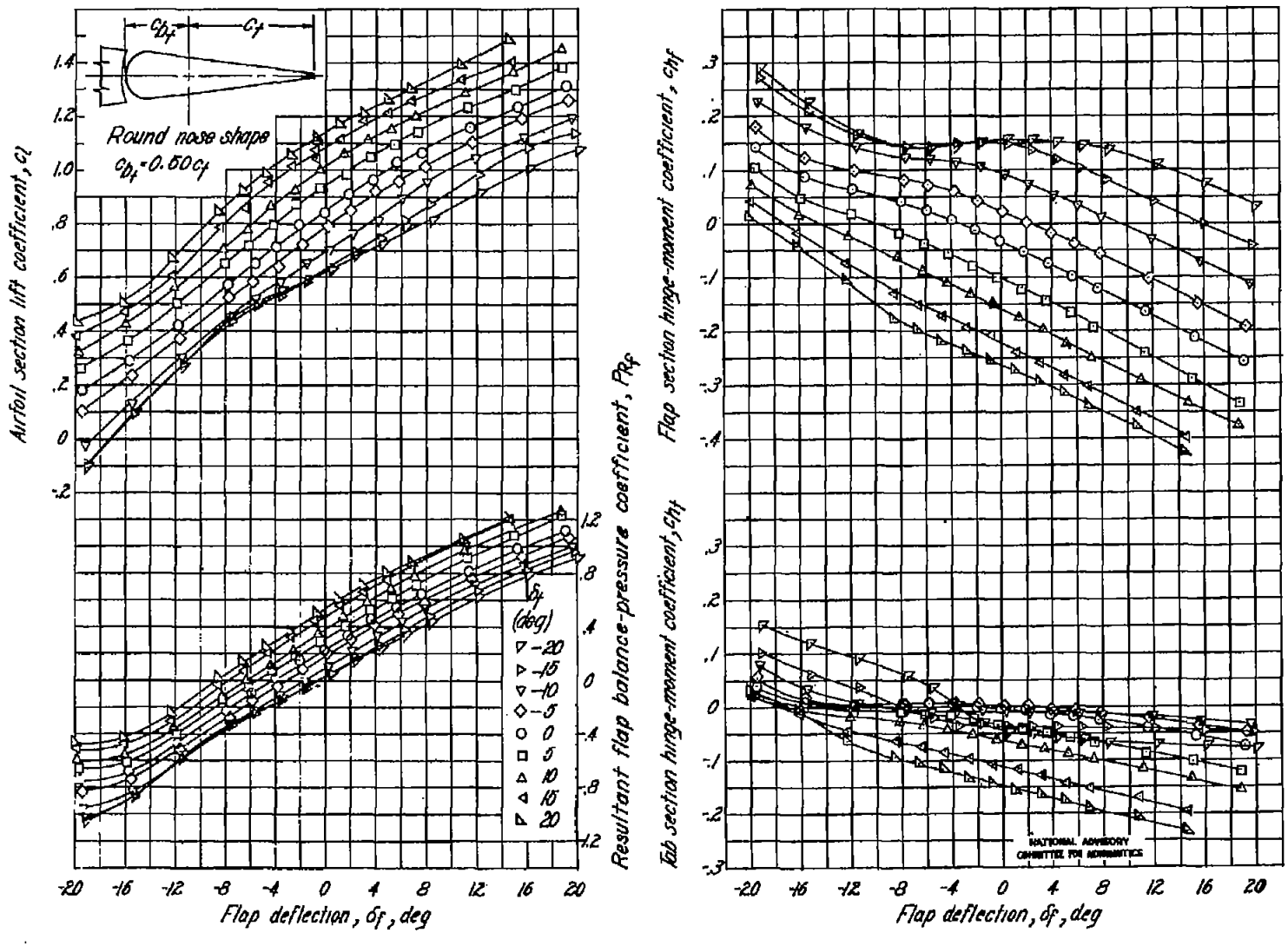
(a) α, 0°.

Figure 16.- Section aerodynamic characteristics of modified NACA 65_1-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_t}, 0.50 c_t; tab gap, open; transition strips at 0.01c.



(b) α, 5.1°.

Figure 16.- Continued.



(c) α, 10.2°.
Figure 16.- Concluded.

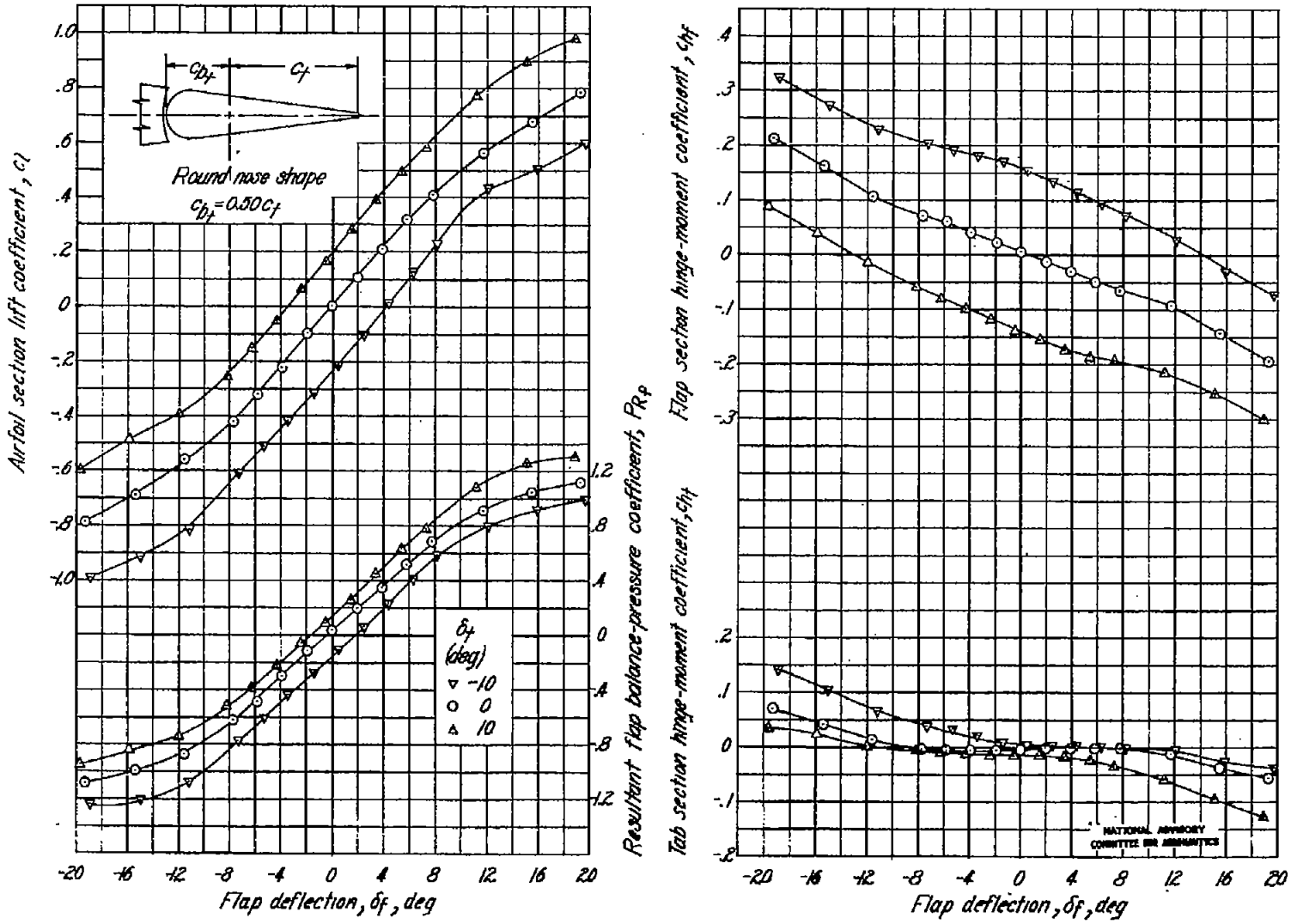
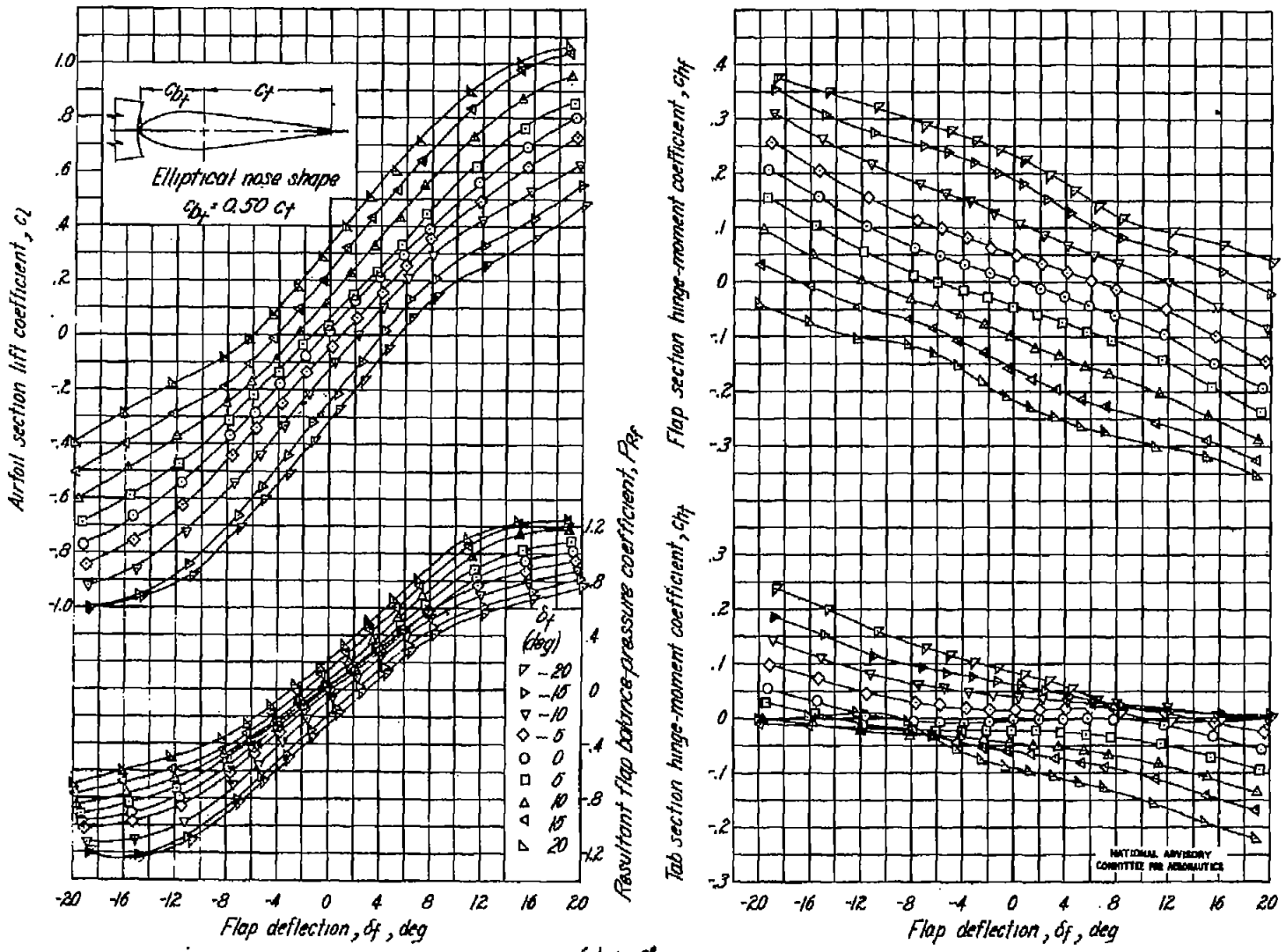
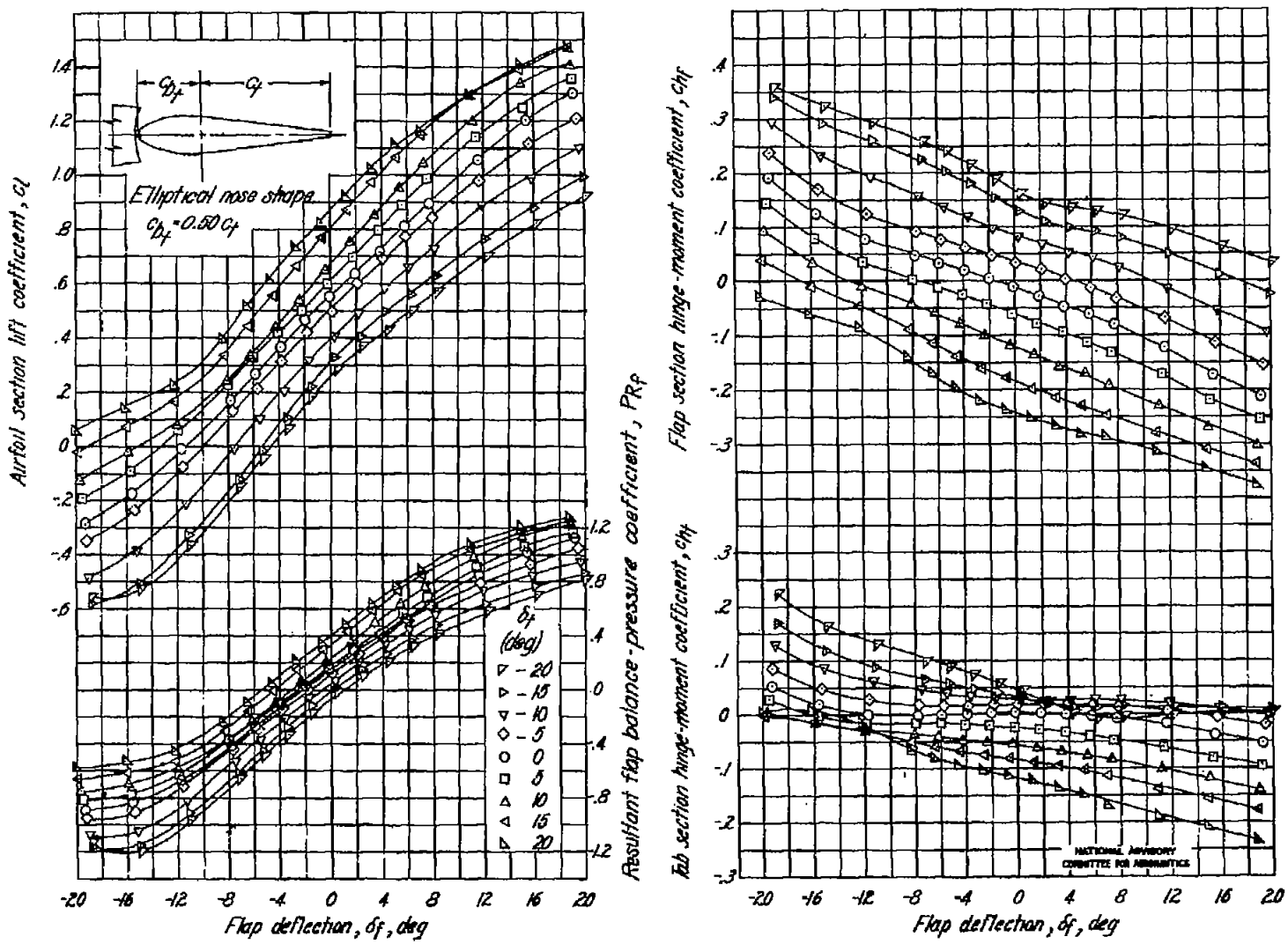


Figure 17.- Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c$_f$ tab. Tab nose shape, round; c_{b_f}, 0.50 c_f; tab gap, open; transition strips off; α, 0°.



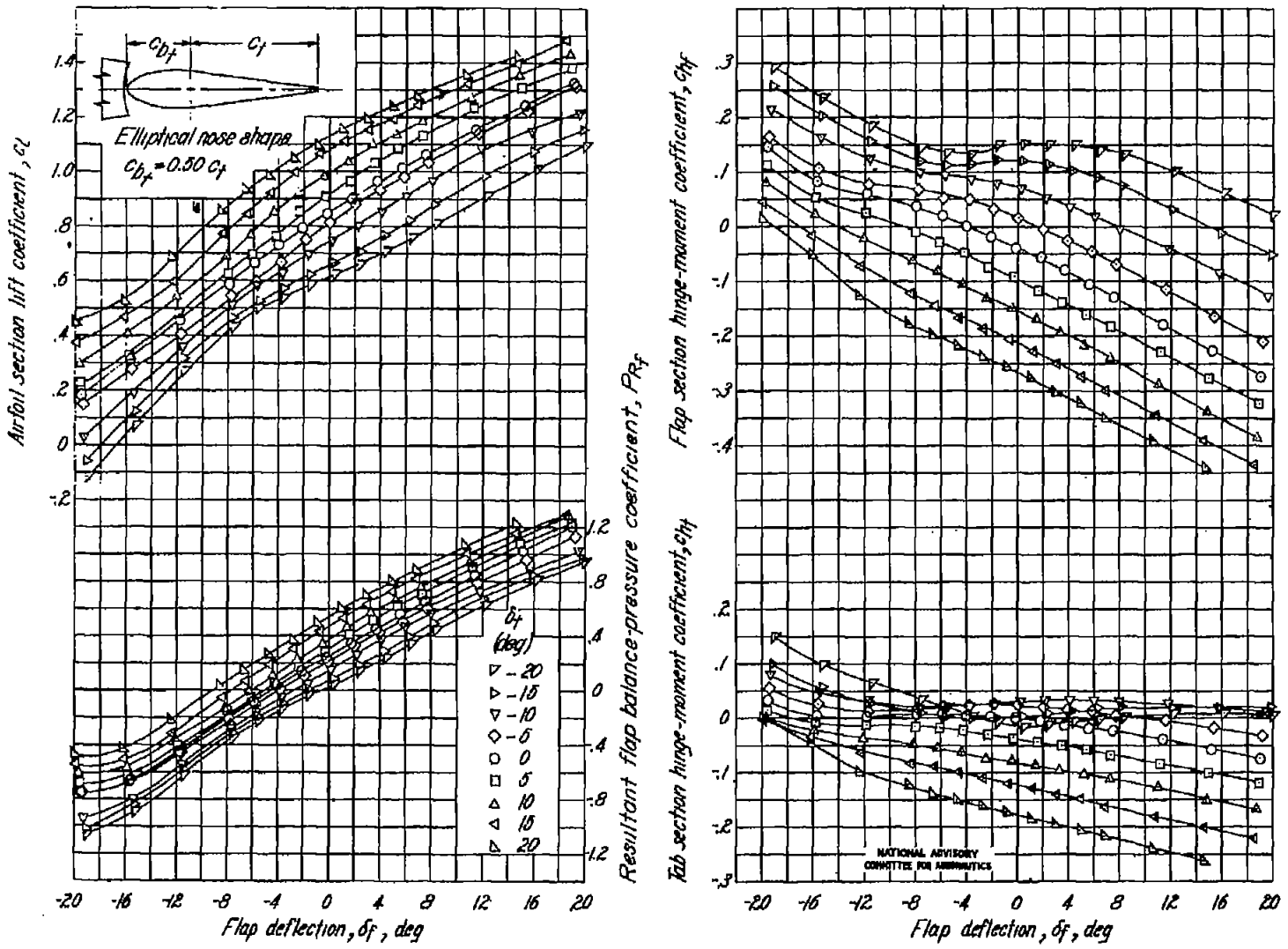
(a) α, 0°.

Figure 18.-Section aerodynamic characteristics of modified NACA 65,-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, elliptical; c_{b_f}, 0.50 c_f; tab gap, open; transition strips at 0.01 c.



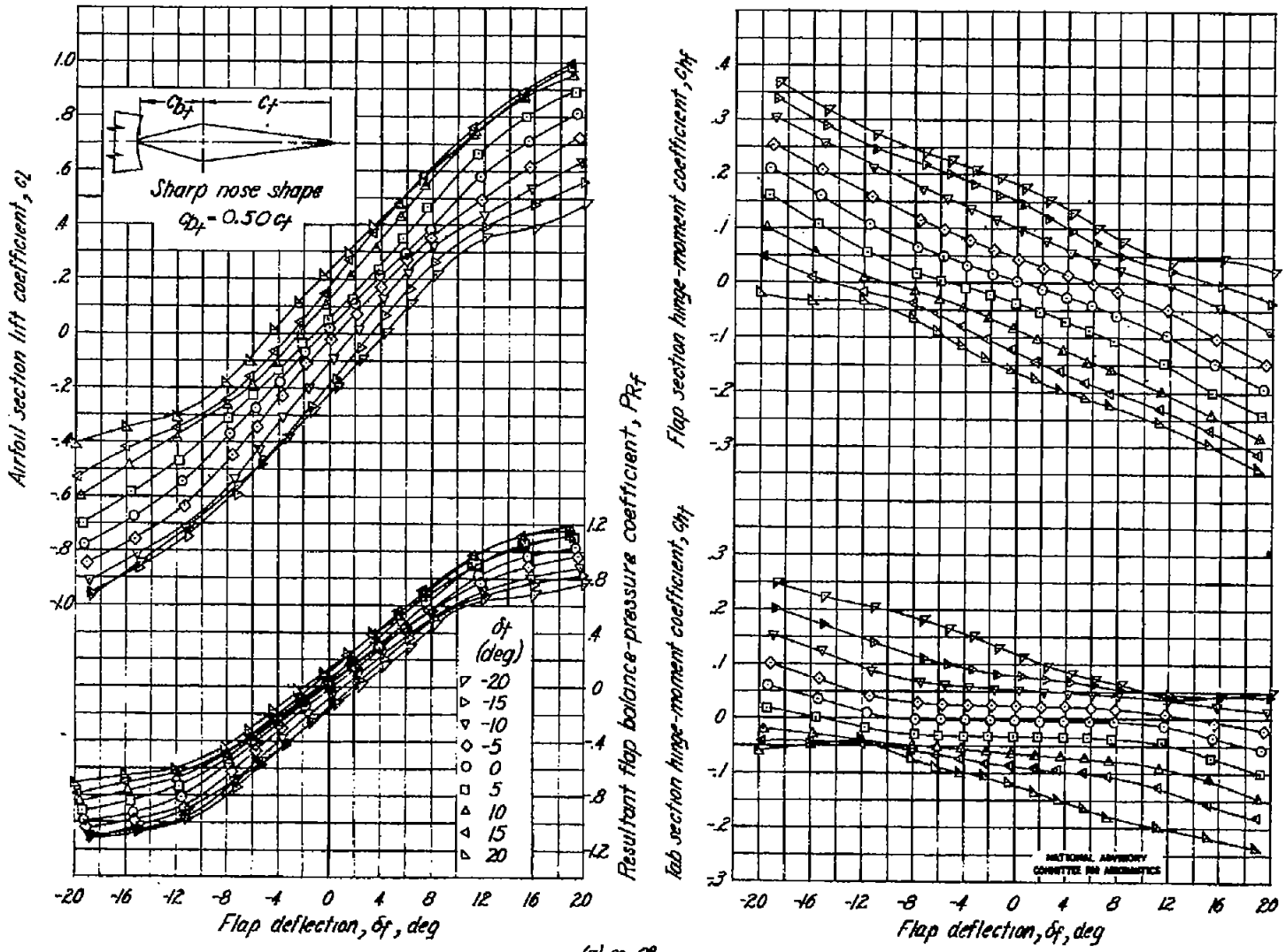
(b) α, 5.1°.

Figure 18.-Continued.



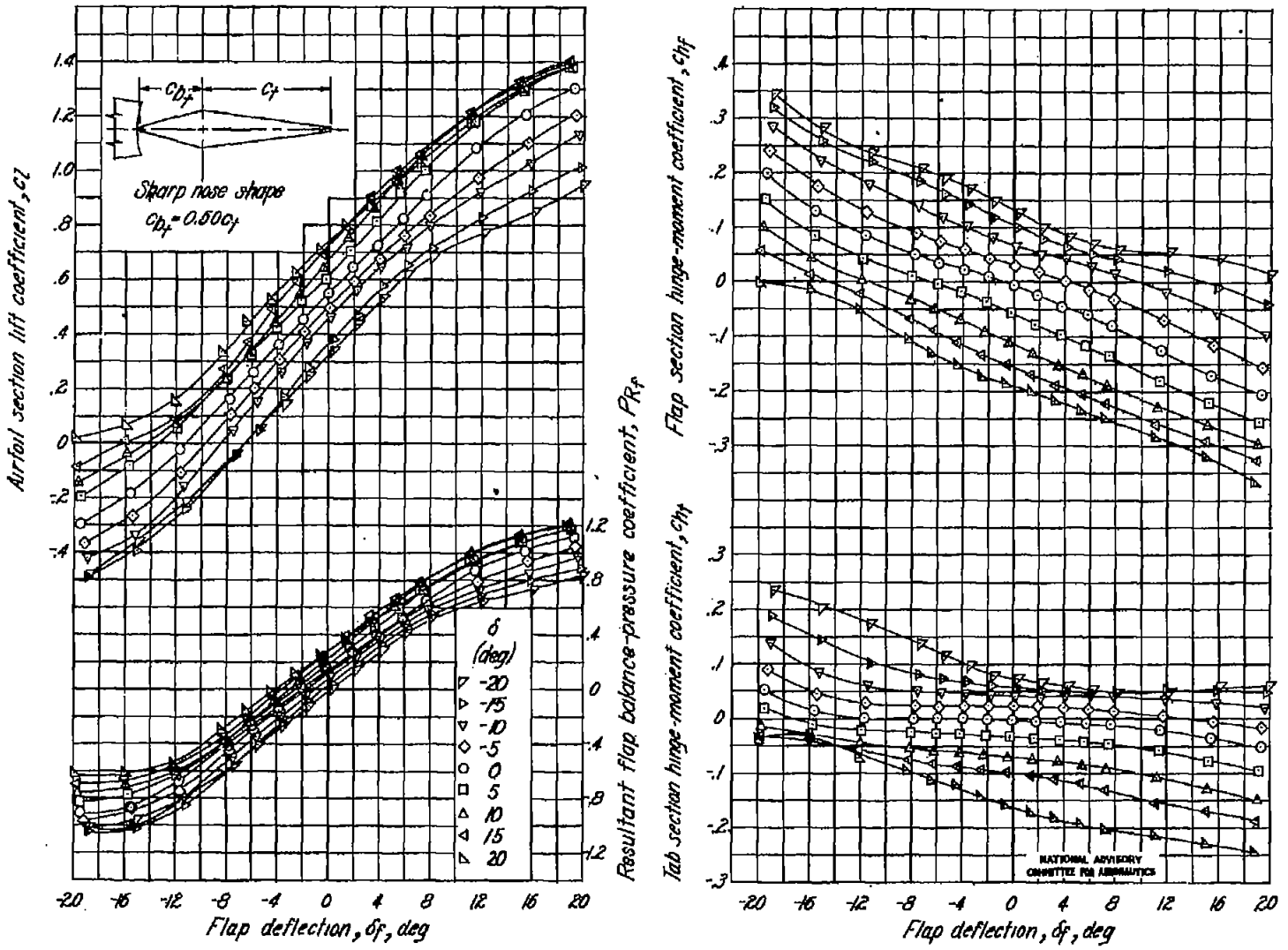
(c) α_l, 10.2°.

Figure 18.-Concluded.



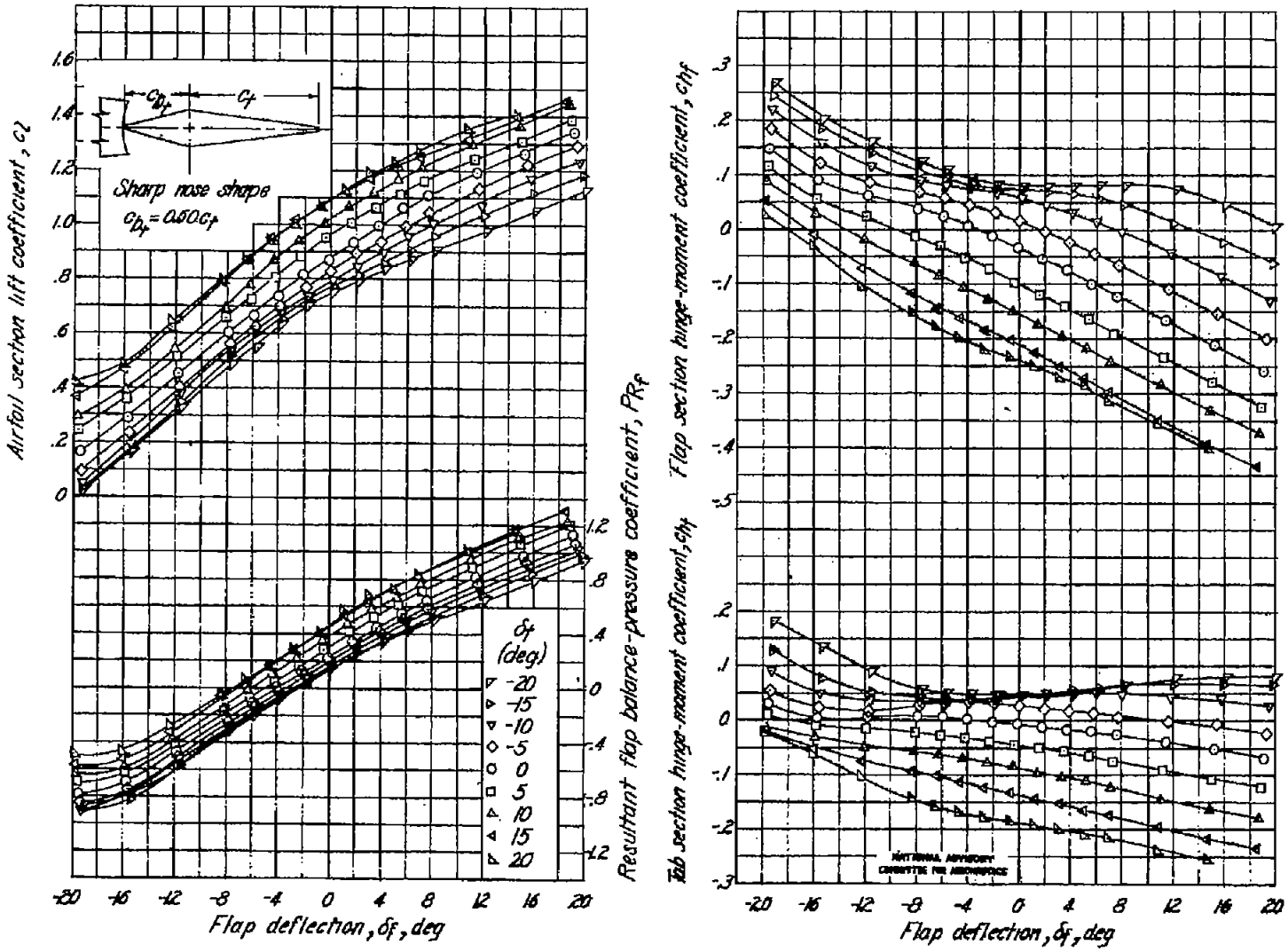
(a) α, 0°

Figure 19.-Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, sharp; c_{b_t}, 0.50 c_t; tab gap, open; transition strips at 0.01 c.



(b) α_l, 5.1°.

Figure 19.-Continued.



(c) α_l, 10.2°.

Figure 19.-Concluded.

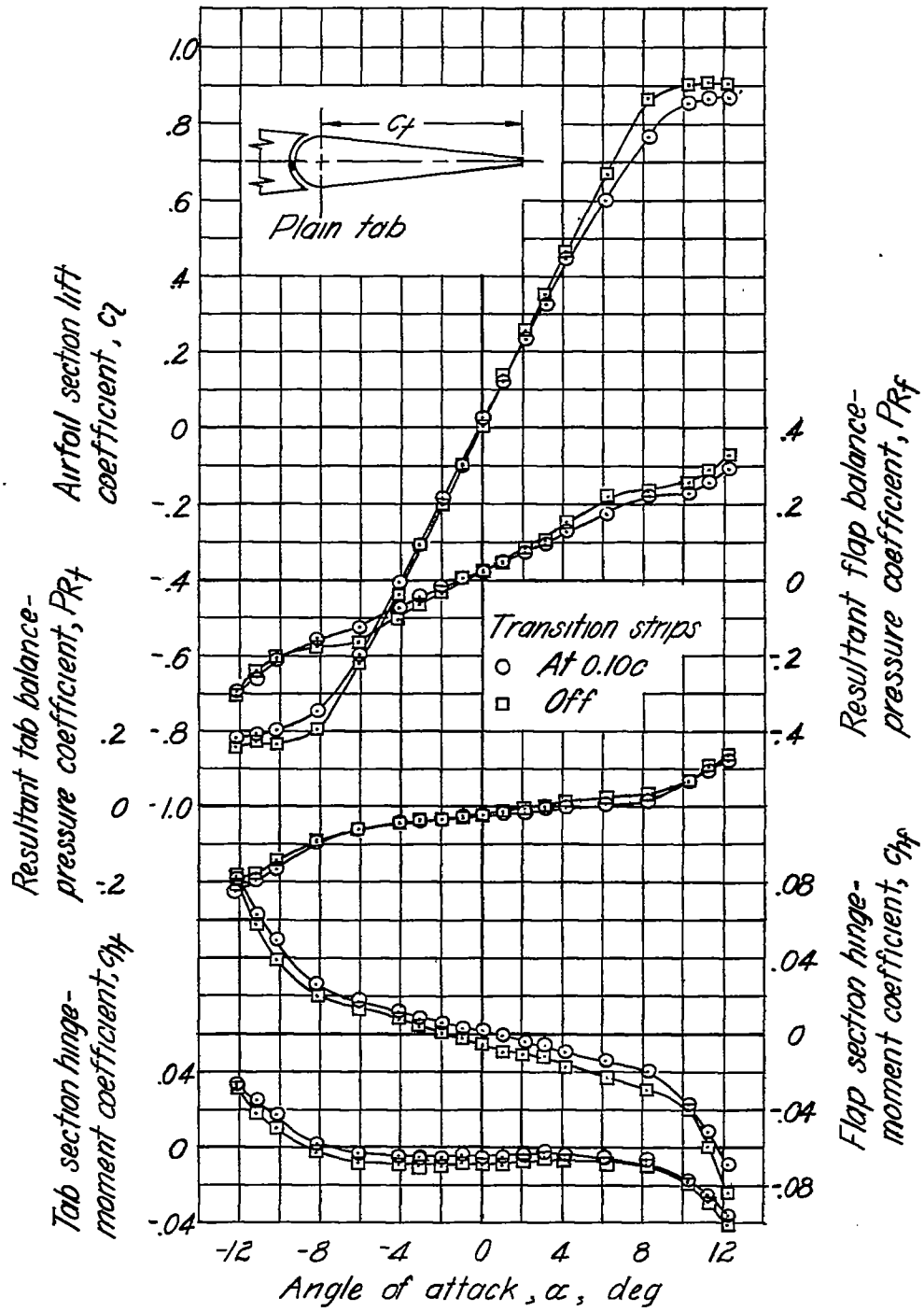


Figure 20.- Section aerodynamic characteristics of modified NACA 65₁-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, plain; tab gap, sealed; δ_f, 0°; δ_t, 0°.

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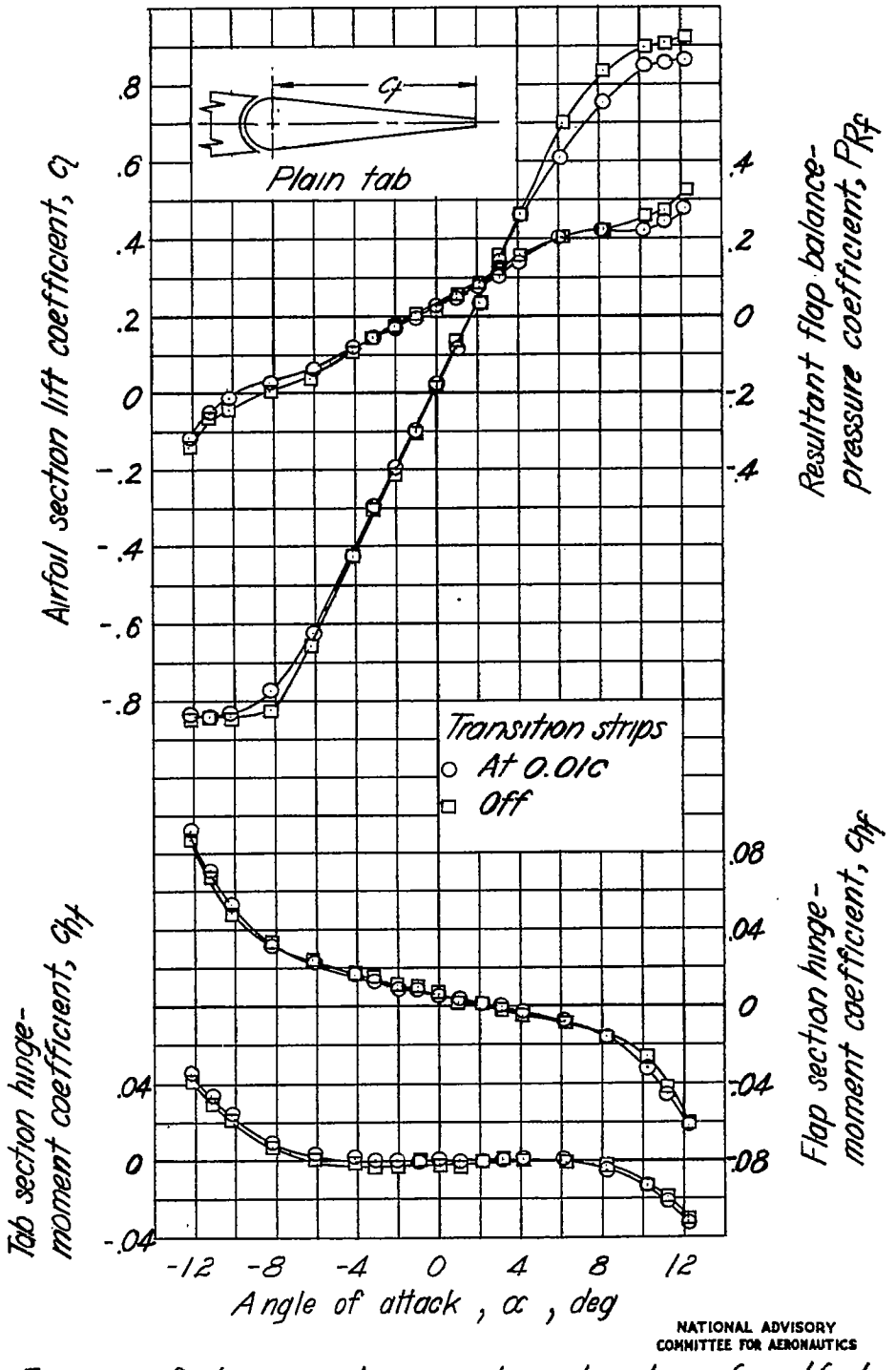

Figure 21.-Section aerodynamic characteristics of modified NACA 65₁-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, plain; tab gap, open; δ_f, 0°; δ_t, 0°.

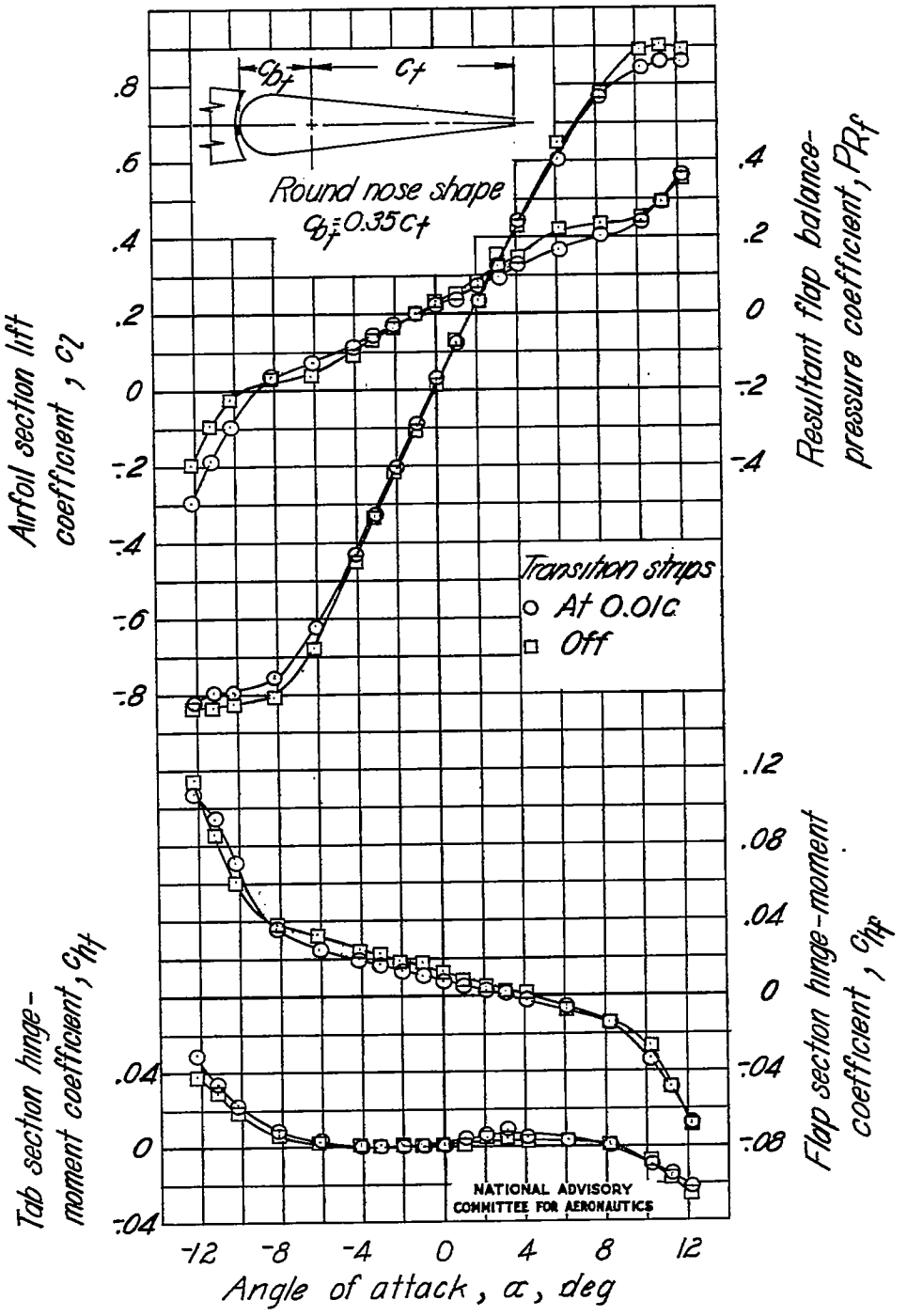

Figure 22.- Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_f}, 0.35 c_f; tab gap, sealed; δ_f,0°; δ_t,0°.

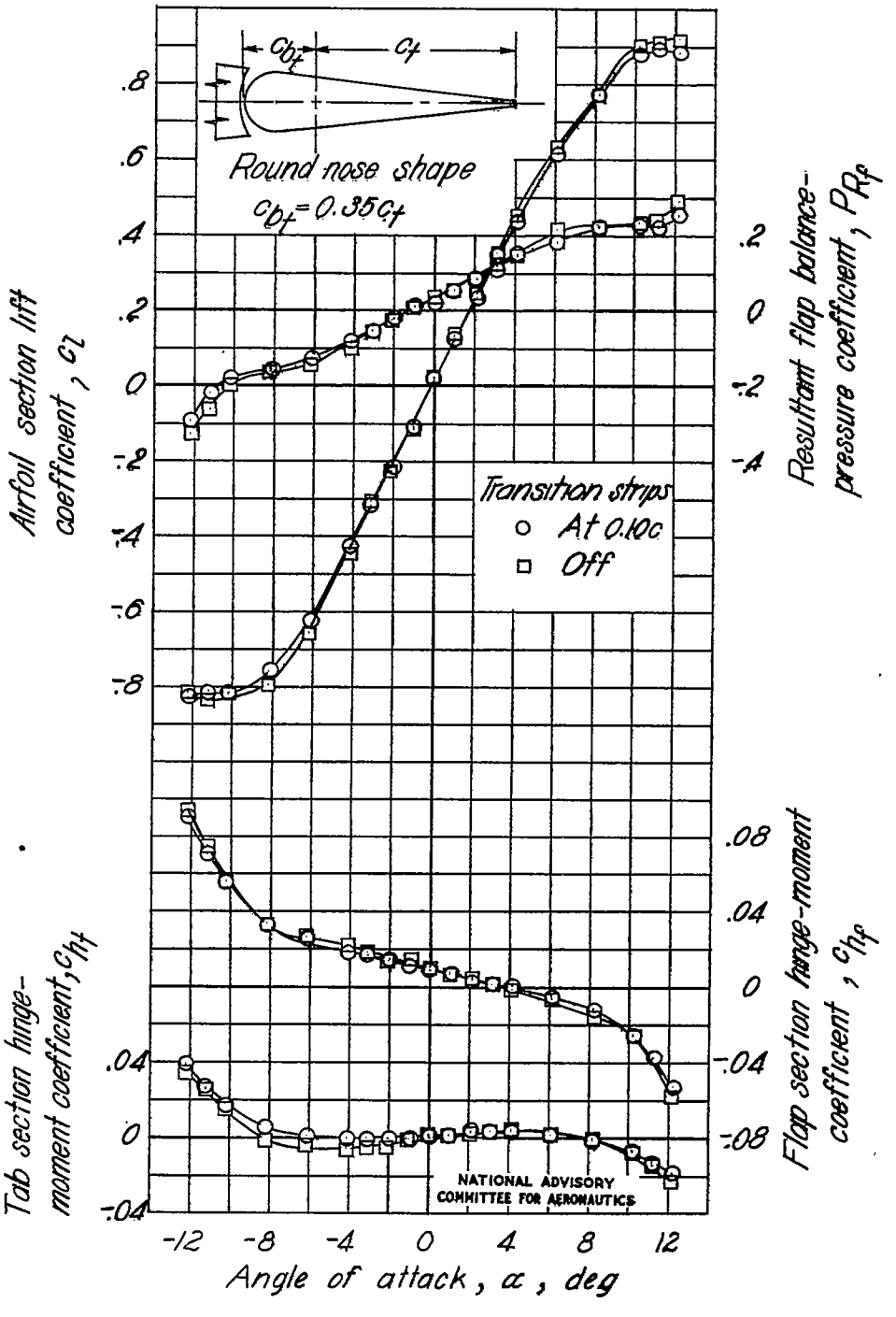

Figure 23.- Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_f}, 0.35 c_f; tab gap, open; δ_f, 0°; δ_t, 0°.

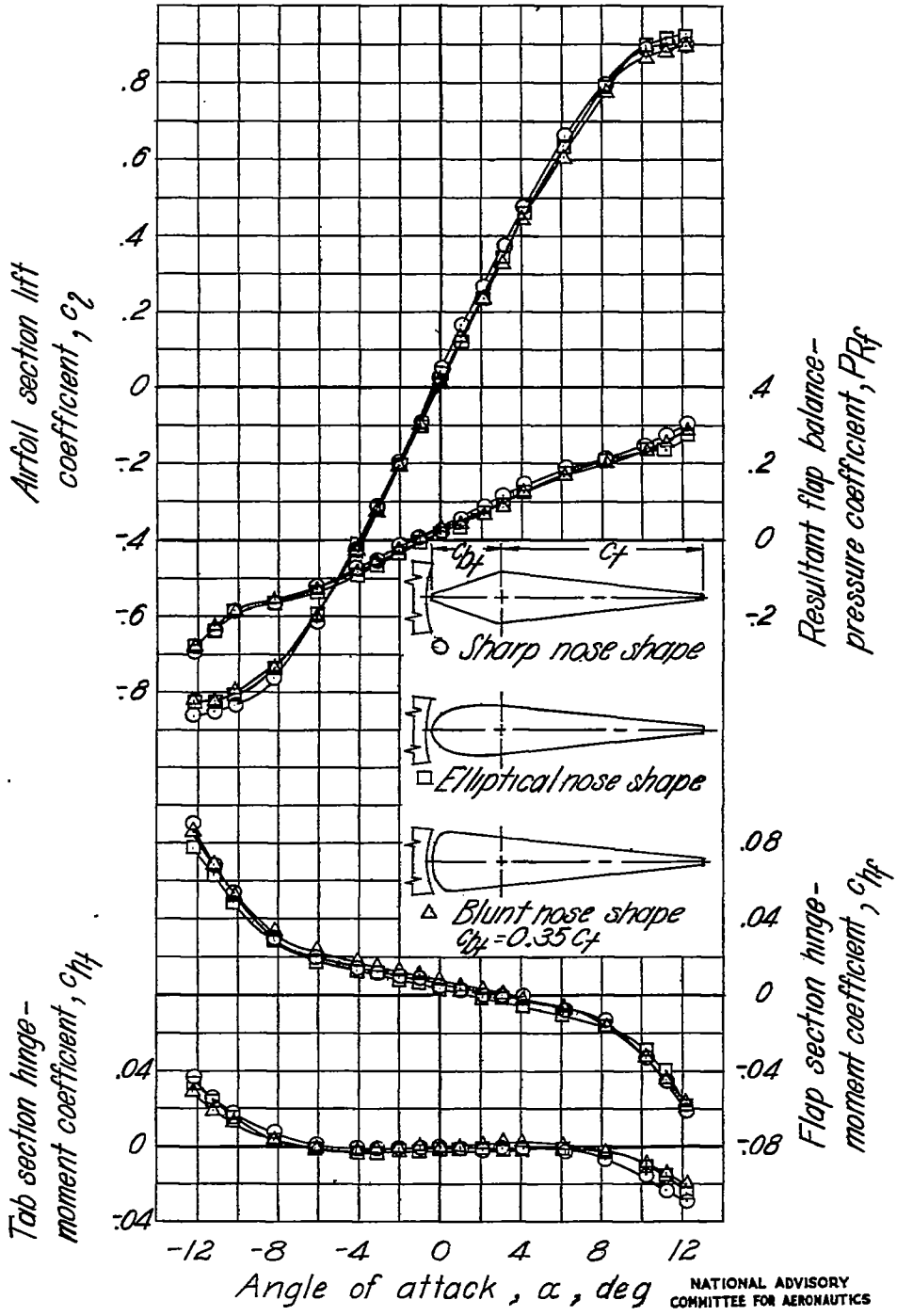

Figure 24.-Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shapes, blunt, elliptical, sharp; c_{b_f}, 0.35 c_f; tab gap, open; transition strips at 0.01c; δ_f, 0°; δ_t, 0°.

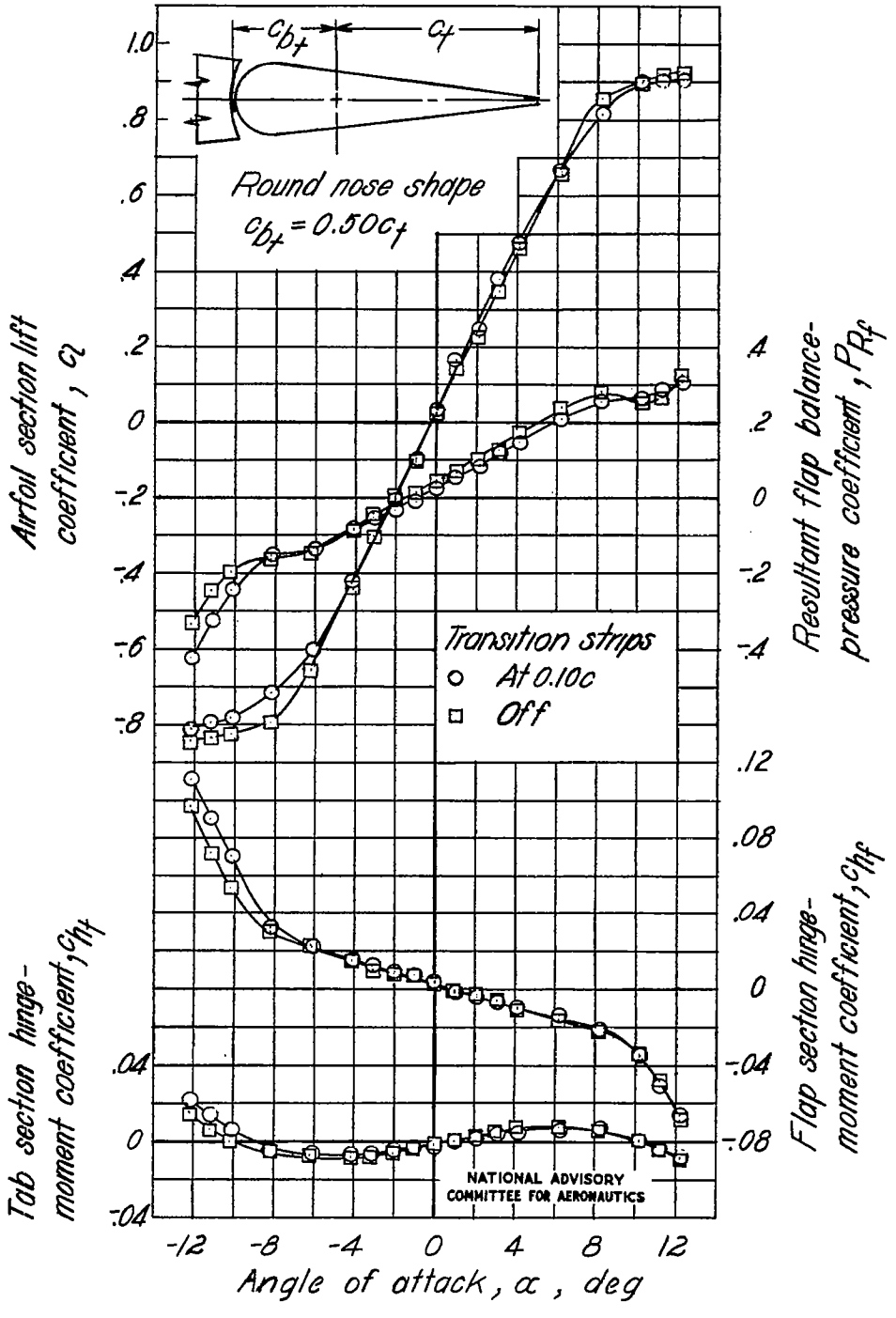

Figure 25.-Section aerodynamic characteristics of modified NACA 65$_1$-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_f}, 0.50 c_f; tab gap, sealed; δ_f, 0°; δ_t, 0°.

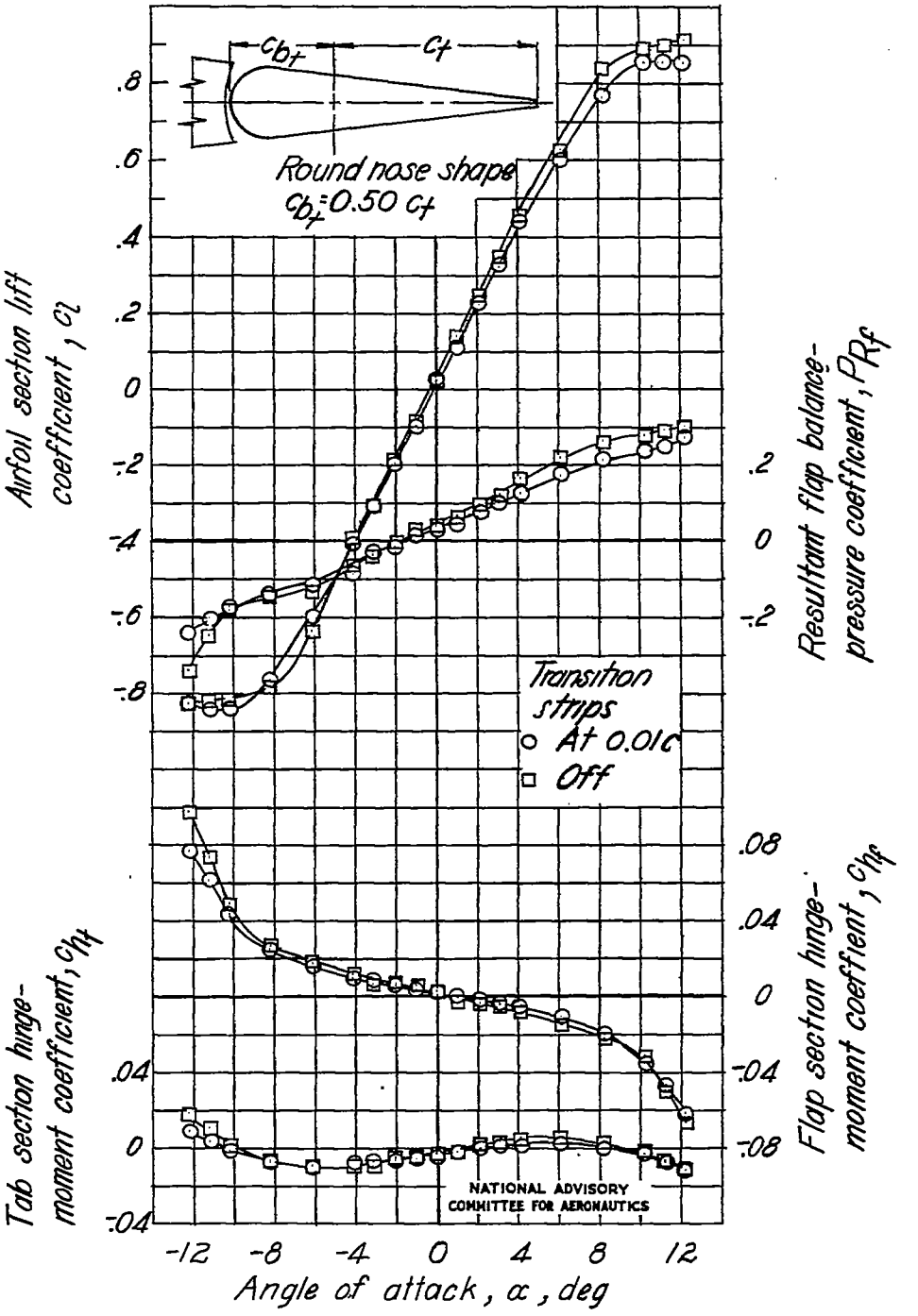

Figure 26.-Section aerodynamic characteristics of modified NACA 65_1-012 airfoil with 0.25c flap and 0.25c_f tab. Tab nose shape, round; c_{b_f}, 0.50c_f; tab gap, open; δ_f, 0°; δ_t, 0°.

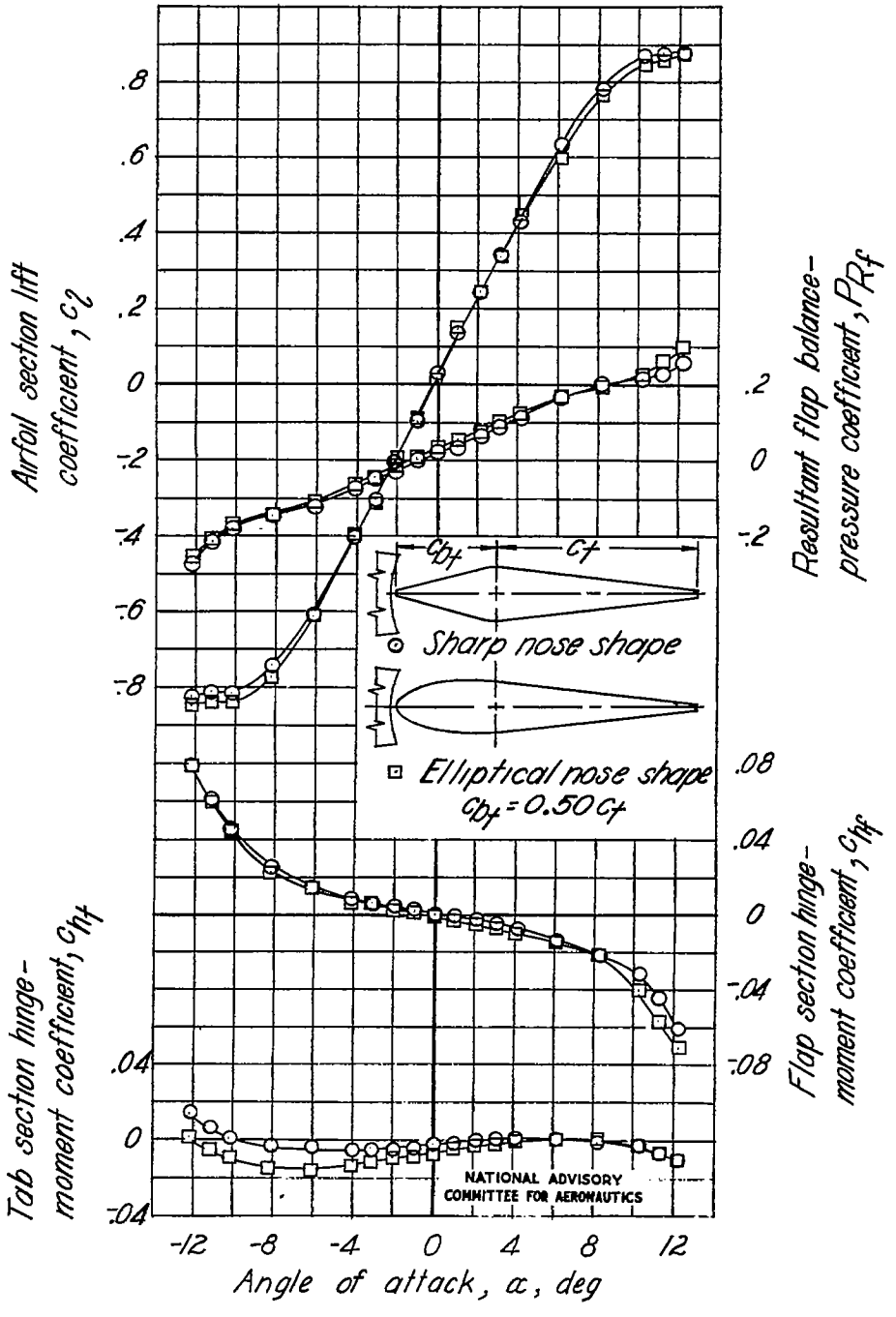

Figure 27.- Section aerodynamic characteristics of modified NACA 65_1-012 airfoil with 0.25c flap and 0.25 c_f tab. Tab nose shapes, elliptical, sharp; c_{b_f}, 0.50 c_f; tab gap, open; transition strips at 0.01 c; δ_f, 0°; δ_t, 0°.

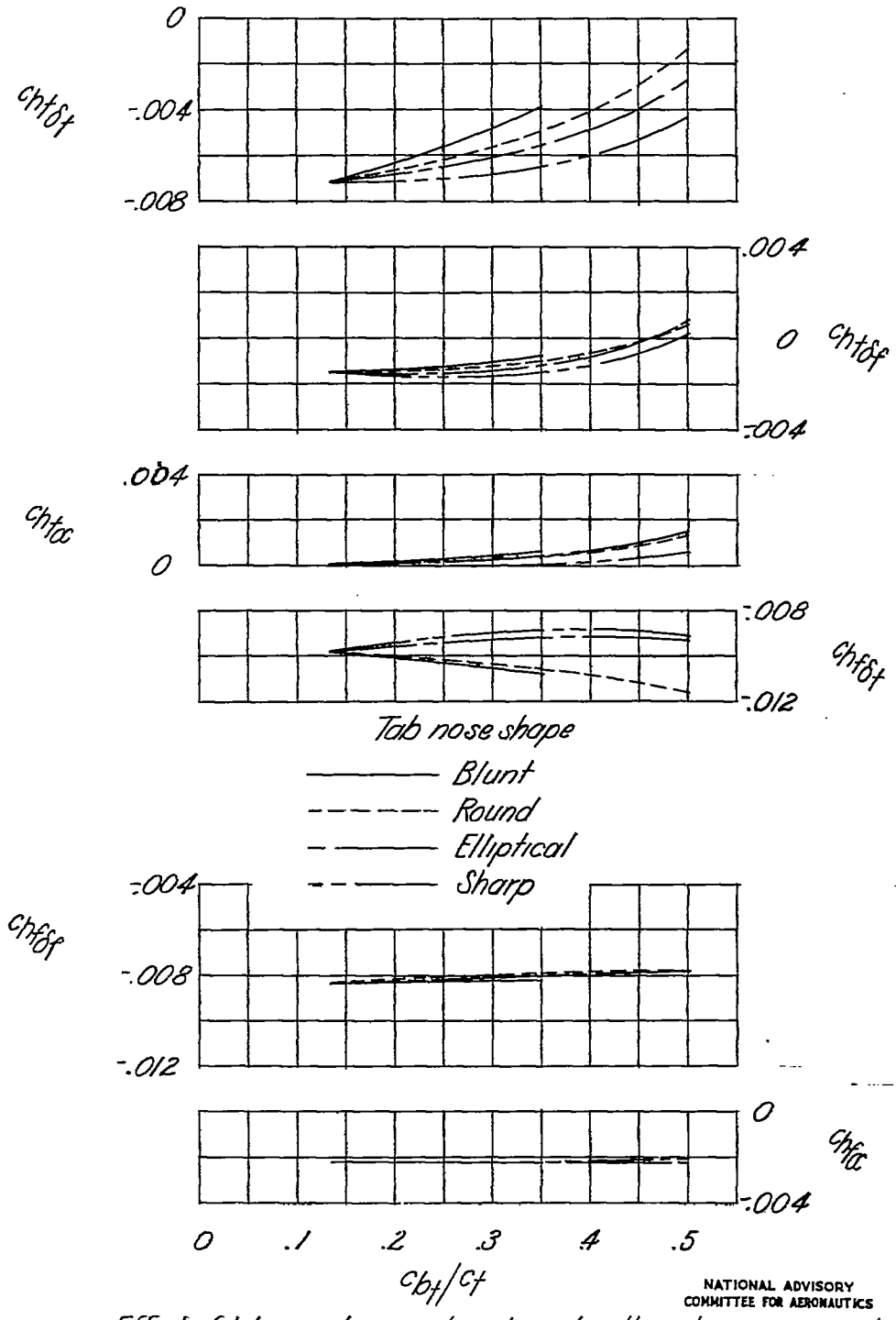

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Figure 28.- Effect of tab nose shape and overhang length on hinge-moment parameters on the modified NACA 65,012 airfoil. Tab gap, 0.004c; transition strips at 0.01c.

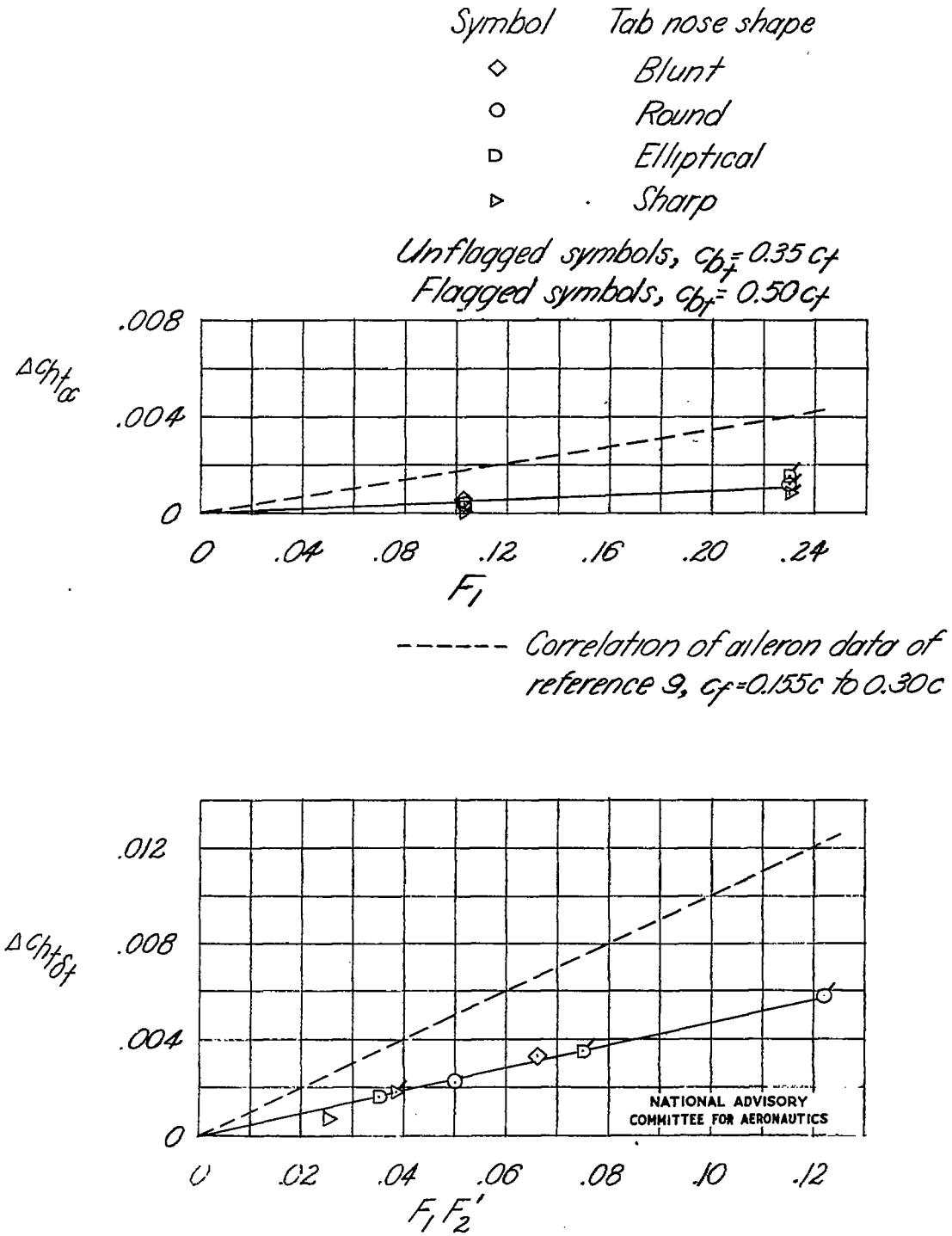

Figure 29.- Effect of tab balance and nose shape on tab hinge-moment parameters.

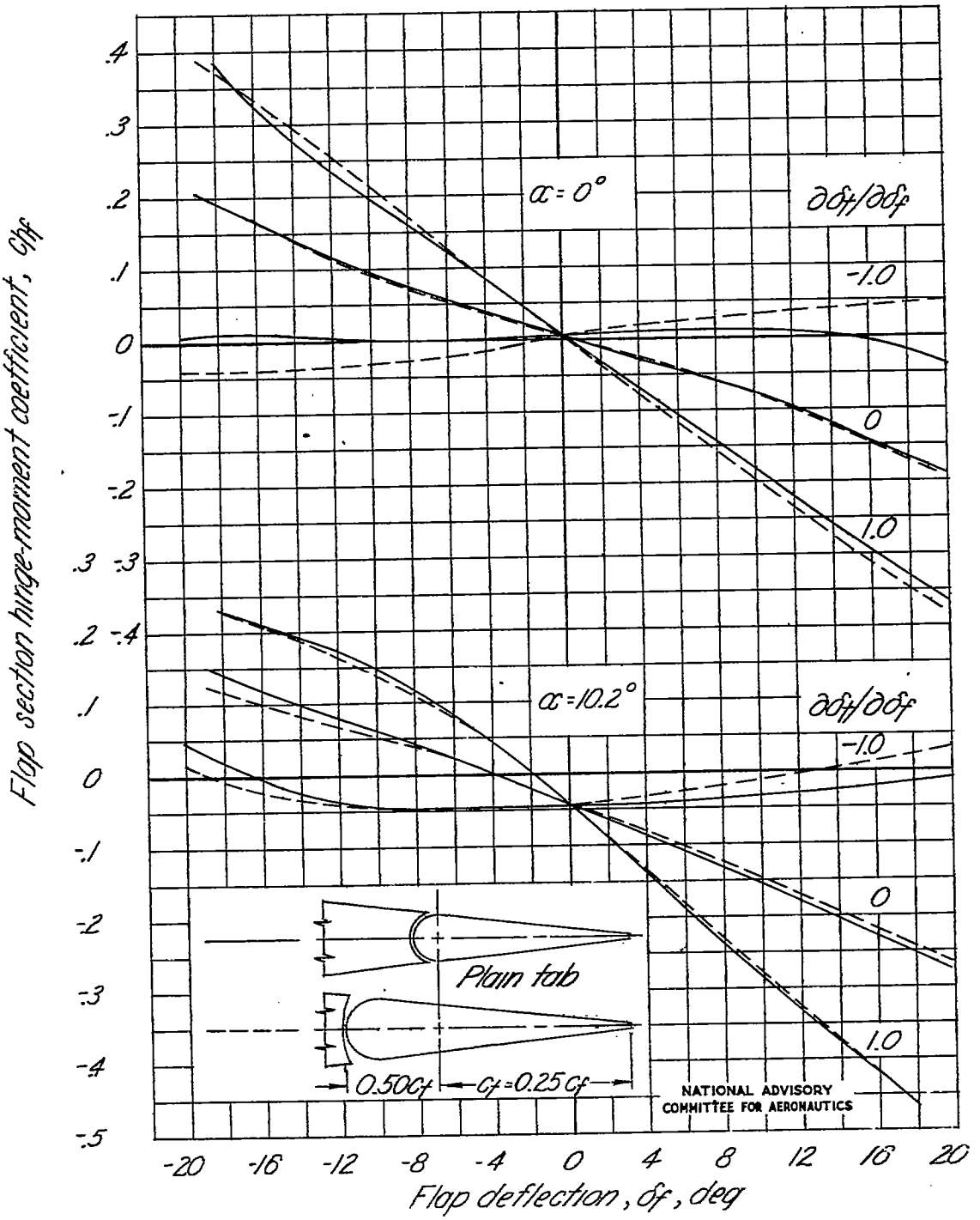

Figure 30.- Effect of tab balance on flap section hinge-moment coefficient of the NACA 65-012 airfoil. Tab gap, 0.004c; transition strips at 0.01c.

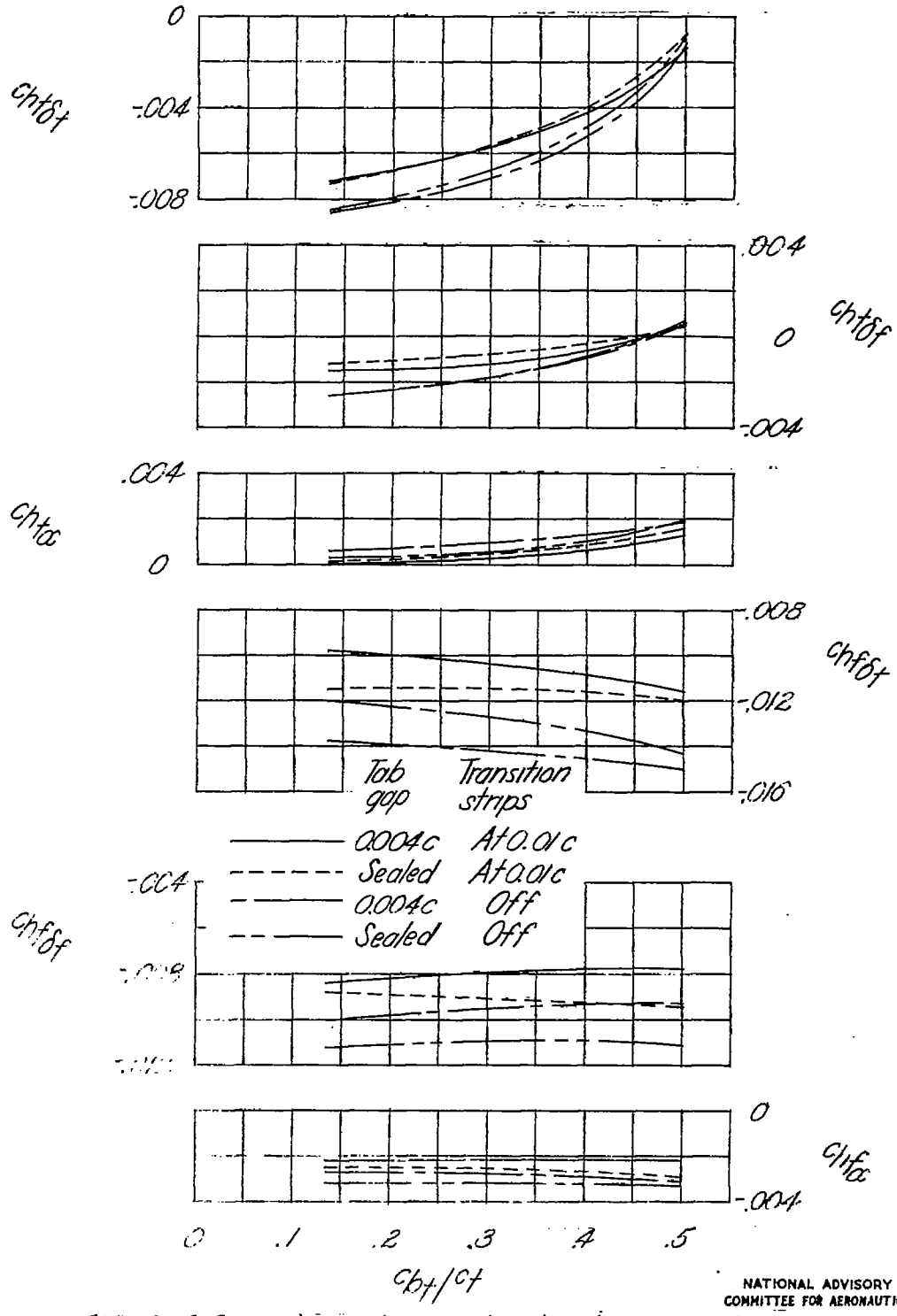

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Figure 31.- Effect of fixing transition and sealing tab gap on hinge-moment parameters on modified NACA 65$_1$-012 airfoil. Round-nose tabs.

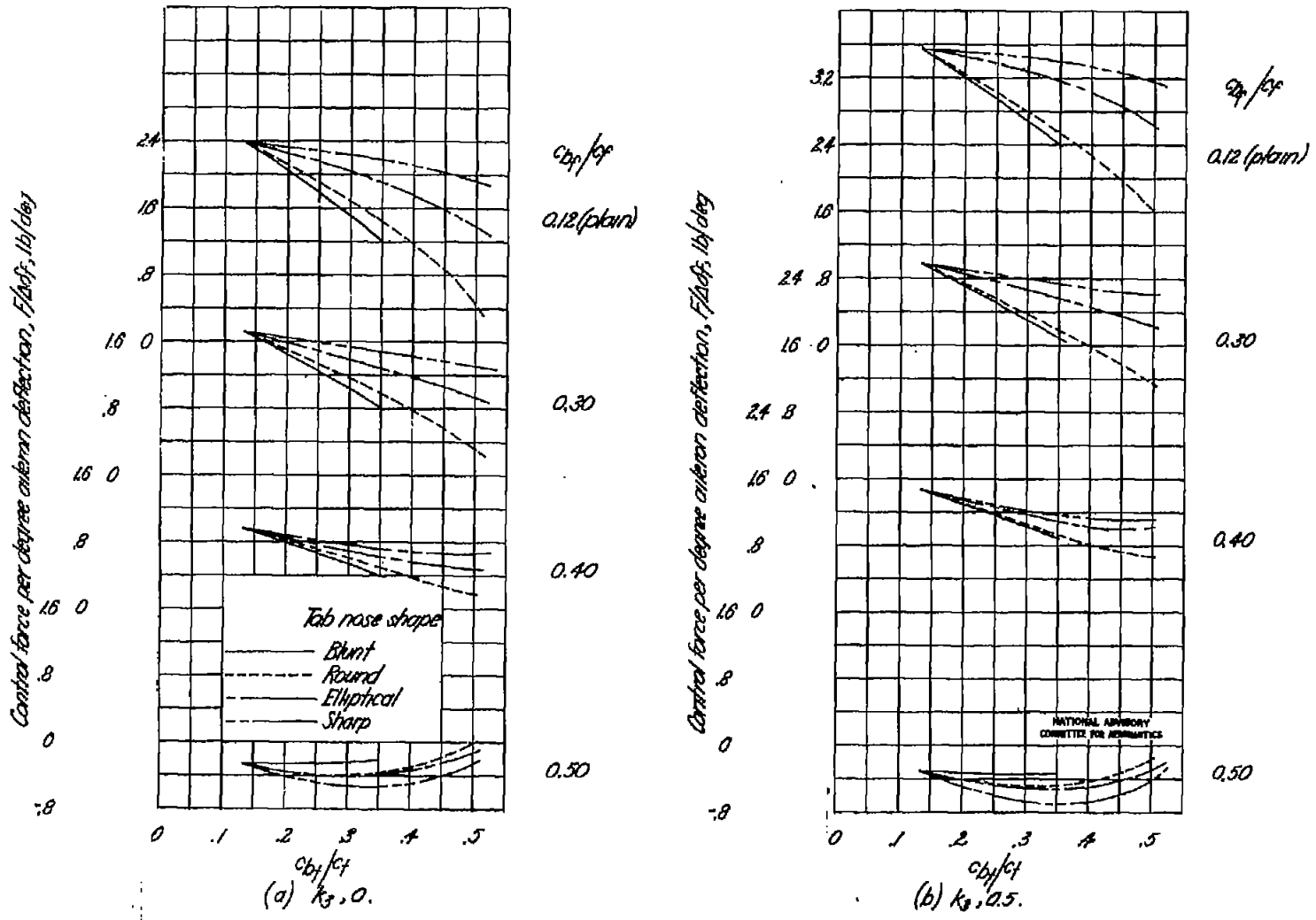
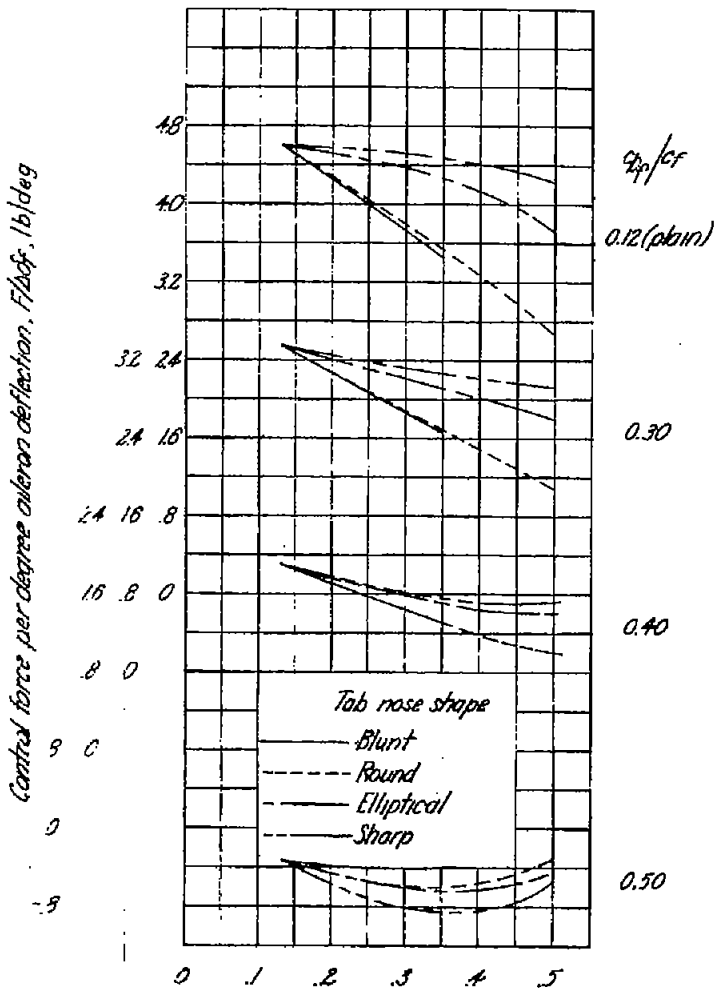
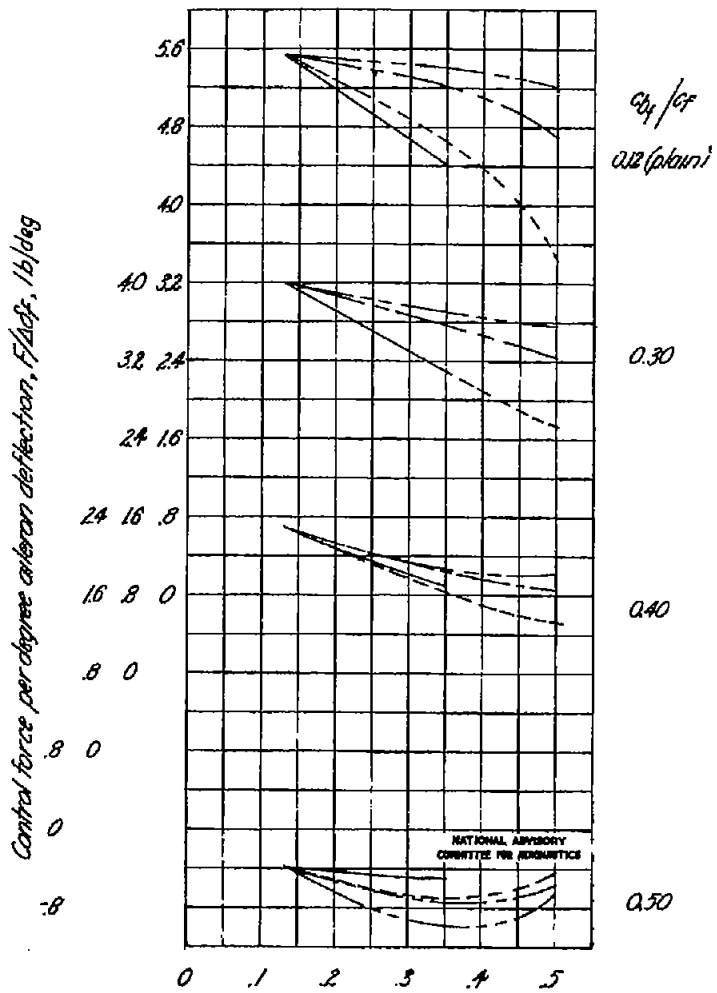


Figure 32.- Variation of $F/\Delta\delta_f$ with c_{bf}/c_f for various tab nose shapes and various aileron balances. Tab gap, 0.004 c; transition strips at 0.01 c; V, 300 miles per hour; airplane 1.



(c) k_3, 1.0.



(d) k_3, 1.5.

Figure 32.-Concluded.

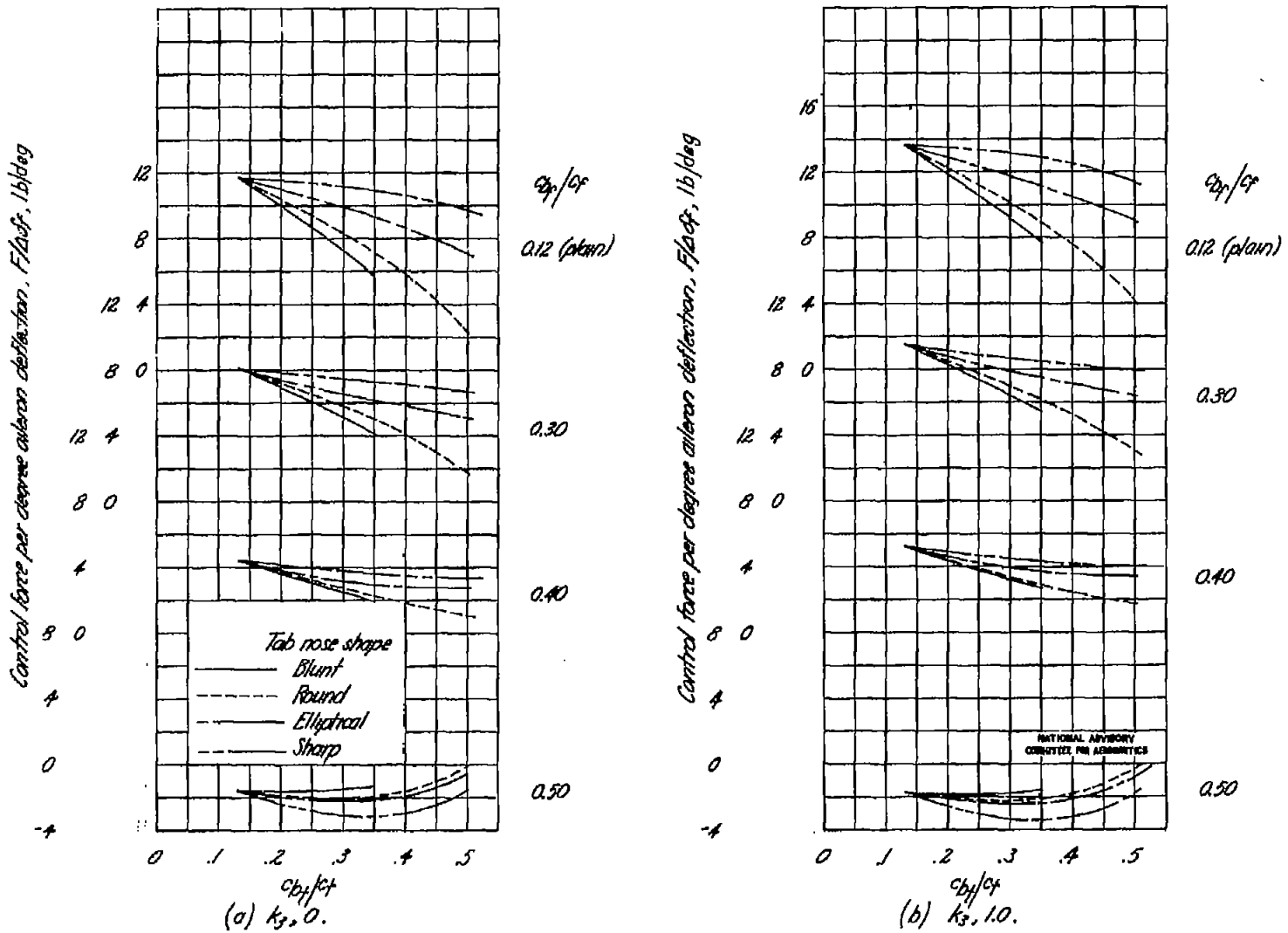
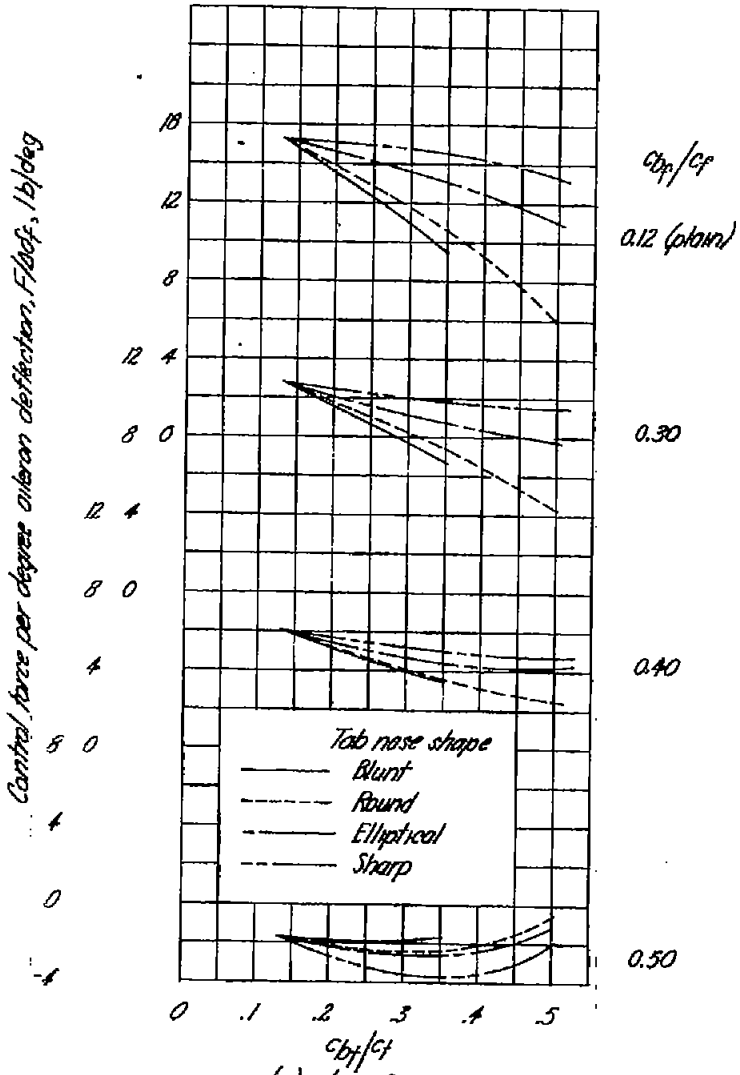
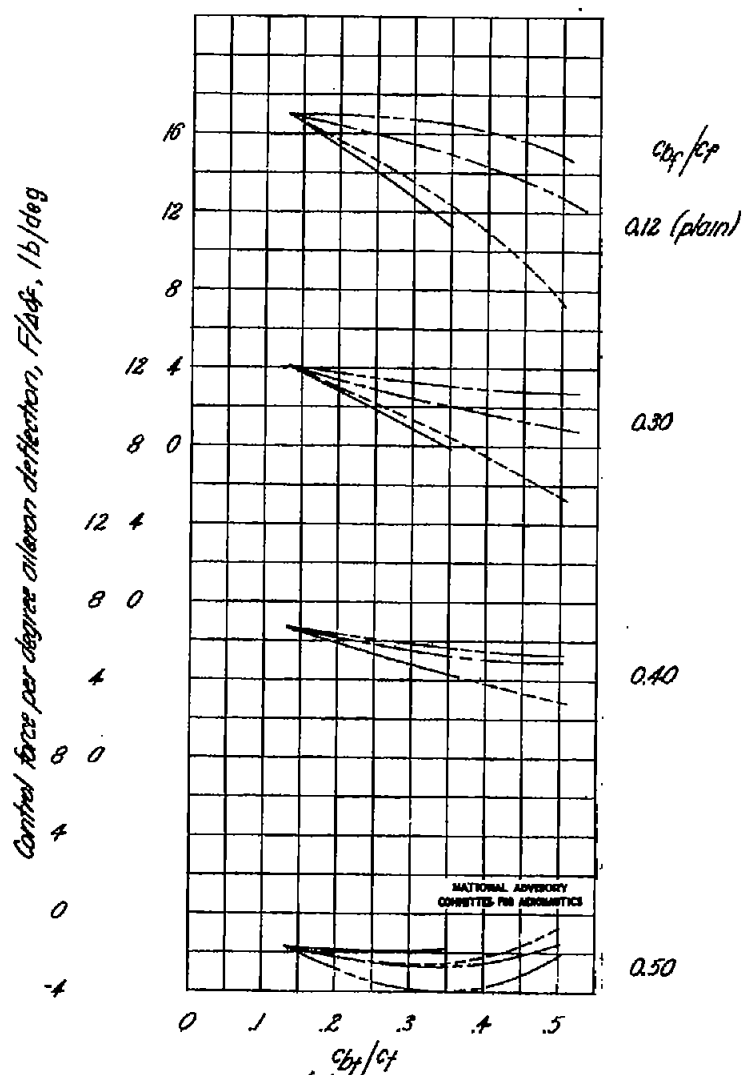


Figure 33.- Variation of $F/\Delta\delta_f$ with c_{b_f}/c_f for various tab nose shapes and various aileron balances. Tab gap, 0.004c; transition strips at 0.01c; V, 300 miles per hour; airplane 2.



(c) k_3, 2.0.



(d) k_3, 3.0.

Figure 33.- Concluded.

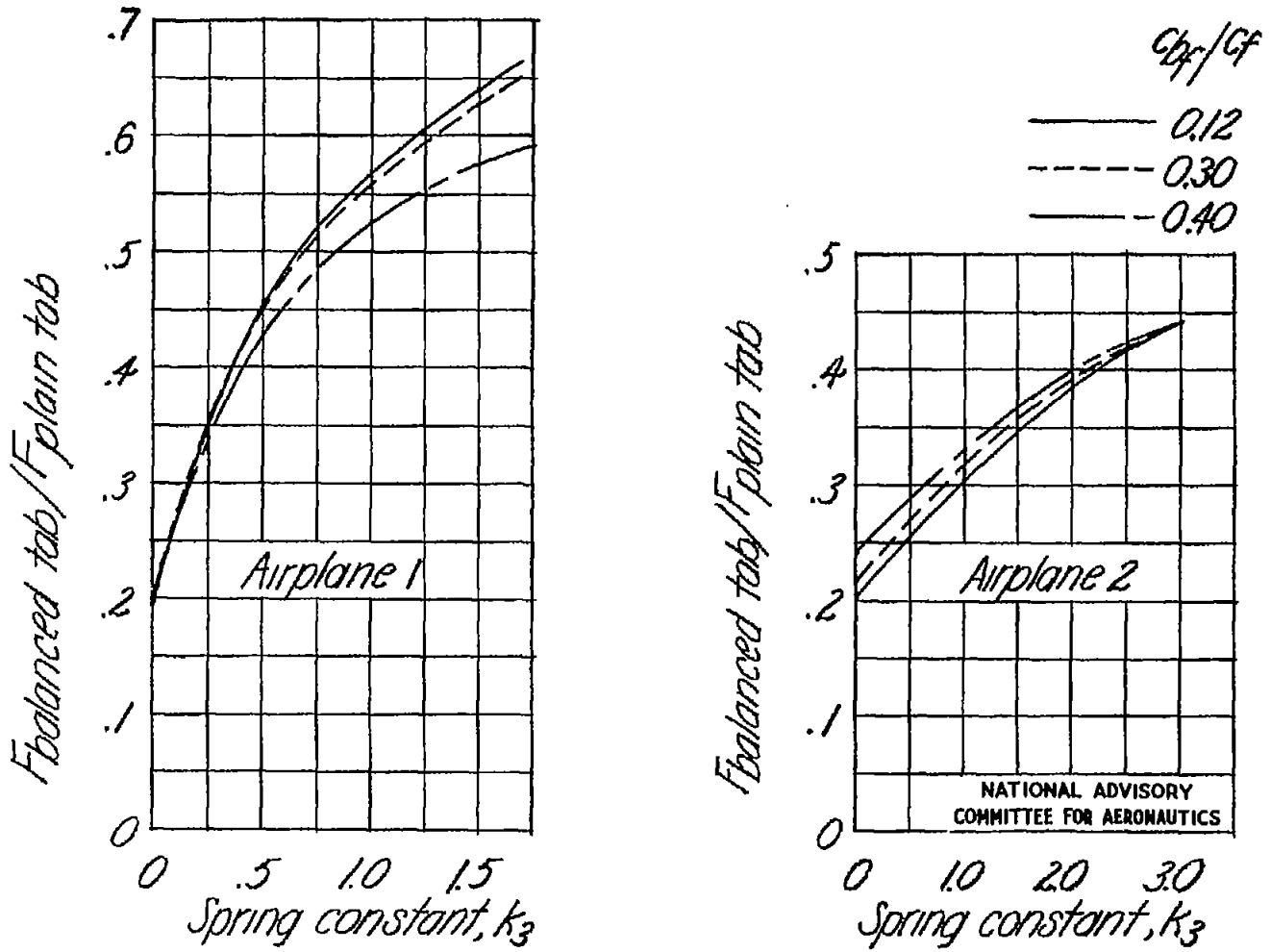


Figure 34.-Variation of control-force ratio with aileron balance and spring strength. Round-nose tab balance, c_{b_f}, 0.50c_f; tab gap, 0.004c; transition strips at 0.01c; V, 300 miles per hour.

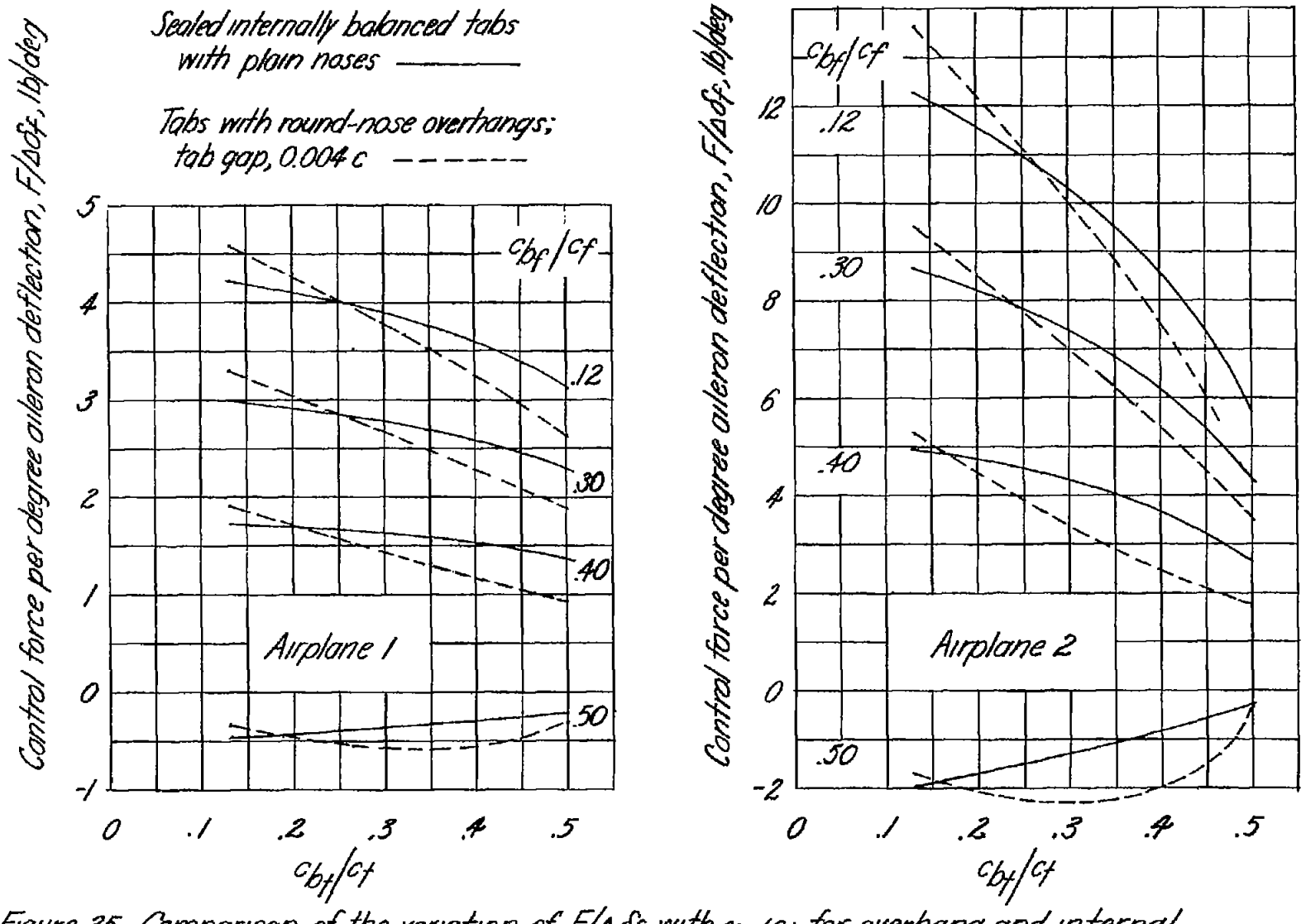


Figure 35.-Comparison of the variation of $F/\Delta\delta_f$ with c_{bt}/c_t for overhang and internal tab balances. Transition strips at 0.01c; k_3, 1.0; V, 300 miles per hour.

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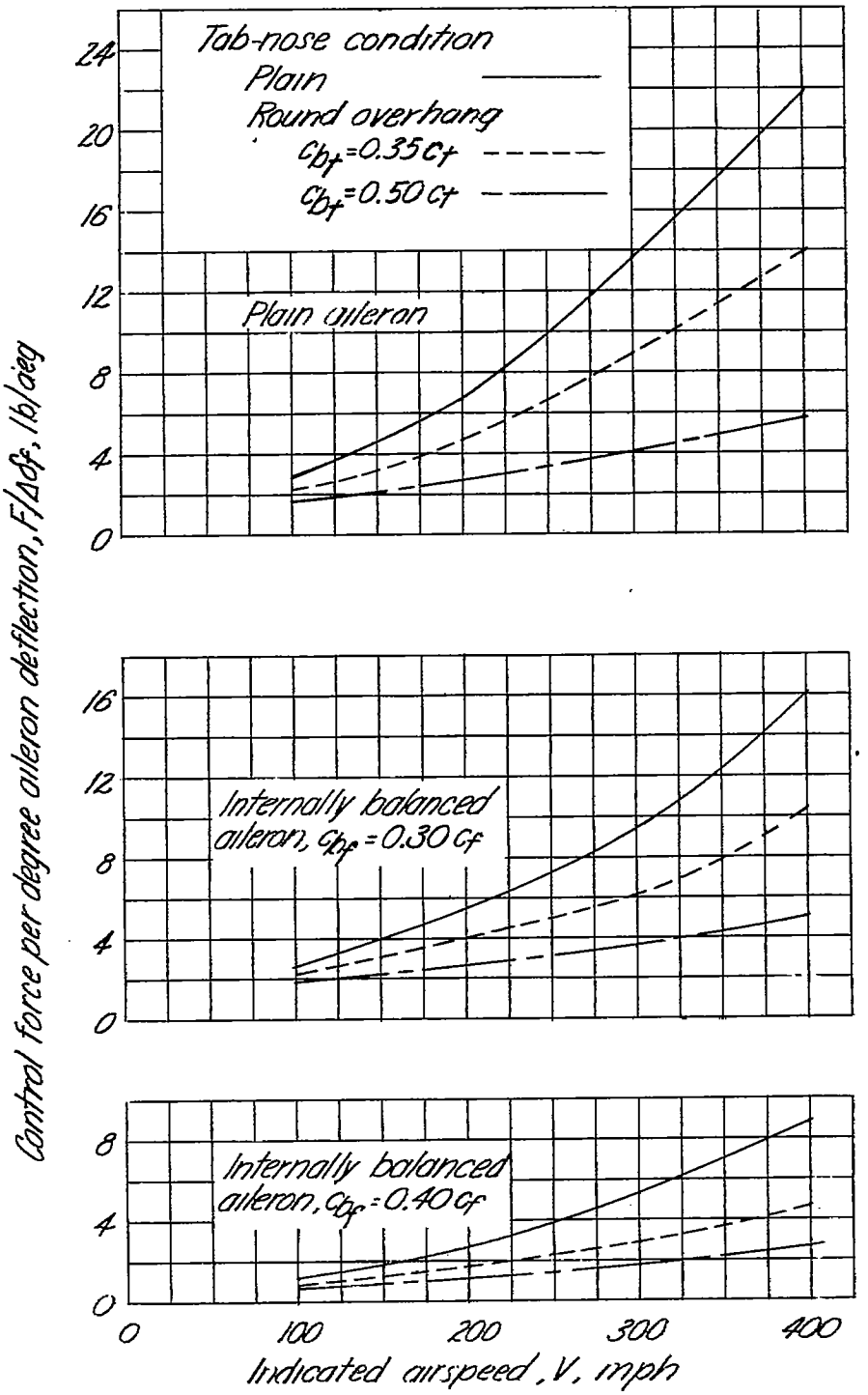

Figure 36.- Variation of $F/\Delta\delta_f$ with airspeed for various aileron and spring-tab balance conditions. k_3, 1.0; airplane 2; tab gap, 0.004c; transition strips at 0.01c.

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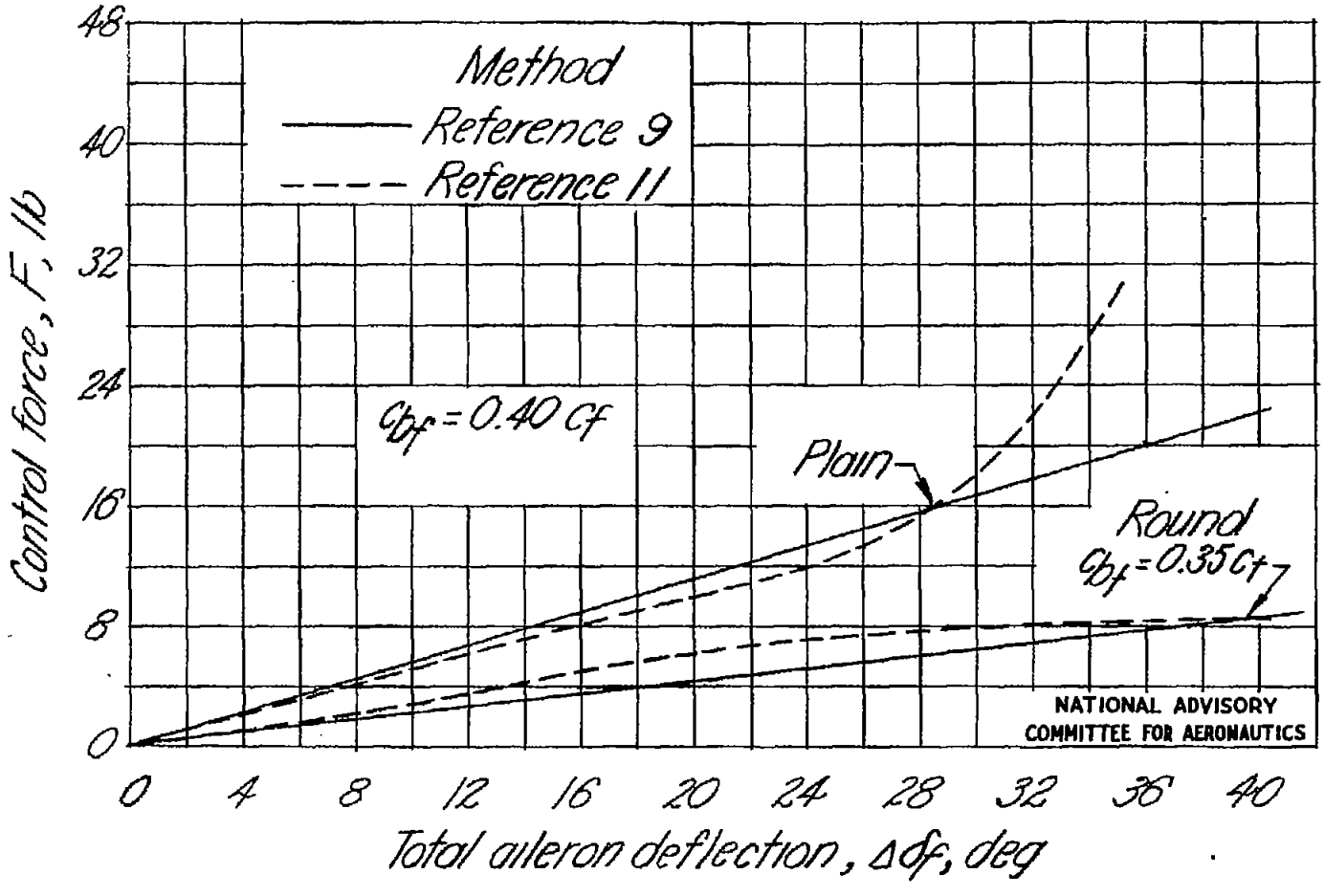

Figure 37.-Effect of tab overhang on the variation of control force with aileron deflection as determined by references 9 and 11. k_3, 1.0; tab gap, 0.004 c; transition strips at 0.01c; V, 300 miles per hour; airplane 1.