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WIND-TUNNEL INVESTIGATION OF A SECTION OF THE

HORIZONTAL TAIL SURFACE FOR THE BELL XP-63 AIRPLANE

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NACA

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MEMORANDUM REPORT

for the

Materiel Division, U. S. Army Air Corps

WIND-TUNNEL INVESTIGATION OF A SECTION OF THE

HORIZONTAL TAIL SURFACE FOR THE BELL XP-63 AIRPLANE

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INTRODUCTION

At the request of the Materiel Division, U. S.
Army Air Corps, force tests have been conducted on
a model of a section of the XP-63 horizontal tail
surface in the 4- by 6-foot closed-throat vertical
wind tunnel of the National Advisory Committee for
Aeronautics. The tests were made to determine the
aerodynamic section characteristics of a modified
low-drag airfoil with a $0.26c$ flap having a
$0.305c_f$ overhang and a $0.40c_f$ tab. The model
was tested with several elevator nose shapes and
with a gap of $0.001c$ at the elevator nose and also
with the gap sealed. Because a conventional con-
trol surface or elevator is comparable to a flap on
an airfoil, these terms are used synonymously in
this report.

MODEL AND APPARATUS

The 2-foot chord by 4-foot span model was made of mahogany and was furnished by the Bell Aircraft Corporation. The model had an airfoil section which conformed to the NACA 66,2x-009 profile ahead of the 75-percent chord station, but had a modified trailing edge rear of this station. The ordinates for the modified section are given in table I. The flap had a chord of 0.26 of the airfoil chord measured from the flap hinge axis to the airfoil trailing-edge. The flap overhang ahead of the hinge axis was 0.305 of the flap chord and the tab chord was 0.40 of the flap chord. Two flap-nose shapes were originally constructed for the tests, and these nose shapes are shown in figure 1. The blunt nose on this drawing will hereafter be referred to as the Bell blunt nose and the radial nose as the NACA blunt nose. After the preliminary tests of the NACA and Bell blunt-nose shapes had been completed, a third nose shape, the NACA medium nose, (see fig. 1) was designed and tested.

The tests were made in the NACA 4- by 6-foot vertical wind tunnel which has a closed test chamber and return passage. The regular three-component balance was used to measure the lift, drag, and

pitching moments. The flap hinge moments were measured by a special hinge-moment balance. Because the model completely spanned the test chamber, except for small clearances at each end, two-dimensional flow was approximated.

TESTS

The dynamic pressure was maintained constant throughout the tests at 15 pounds per square foot corresponding to an airspeed of about 76 miles per hour at standard sea-level conditions. The test Reynolds number was approximately 1,430,000 and the effective Reynolds number of the tests was approximately 2,760,000, based on a turbulence factor of 1.93 for the 4- by 6-foot vertical tunnel.

The angle-of-attack range was from the negative to the positive stall for all flap deflections. The flap was tested over a range of deflections from 0° to 30° in 5° increments with each of the flap-nose shapes and with the 0.001c gap at the flap nose. Tests were also made with the NACA blunt-nose flap with the gap sealed with grease. The tab tests were made with the NACA blunt-nose flap and with the tab and flap gaps sealed with grease at tab deflections of 0°, $\pm 10^\circ$, and $\pm 15^\circ$ for flap deflections of 0°, 10°, 15° and 20°.

After the completion of the regular test program, the
irregularities on the surfaces of the model caused
by the flap and tab nose cut-outs were completely
faired with modeling clay and a test was made with
the flap and tab neutral to determine the minimum
drag of the model.

RESULTS

The results are given in the form of section co-
efficients of lift, drag, pitching moments, and flap
hinge moments.

$$c_l = \frac{l}{qc}$$

$$c_{d_o} = \frac{d_o}{qc}$$

$$c_m = \frac{m}{qc^2}$$

$$c_{h_f} = \frac{h_f}{qc_f^2}$$

where

c_l airfoil section lift coefficient

c_{d_o} airfoil section profile-drag coefficient

c_m airfoil section pitching-moment coefficient
about quarter-chord point of airfoil

c_{h_f} flap section hinge-moment coefficient

and

l airfoil section lift

d_o airfoil section profile drag

m airfoil section pitching moment about

     quarter-chord point of airfoil

h_f flap section hinge moment

q dynamic pressure lb/sq ft
c chord of airfoil with flap and tab neutral
c_f chord of flap with tab neutral

a_o angle of attack for airfoil of infinite

     aspect ratio

δ_f flap deflection with respect to airfoil

δ_t tab deflection with respect to flap

     Only the values of the lift coefficients have been corrected for tunnel effects. The tunnel correction for drag is large but no satisfactory method of applying a correction for drag has been found. In any case the drag results of the low-drag type of wing in a turbulent air stream are not believed to be reliable.

     The aerodynamic section characteristics of the airfoil with the Bell blunt- and the NACA blunt- and medium-flap-nose shapes and with the 0.001c gap at the flap nose are presented in figures 2, 3, and 4, respectively. The aerodynamic section characteristics are presented for the sealed-gap condition of the NACA blunt-nose flap in figure 5.

The profile drag coefficients for the faired model, and the model with the various flap-nose-shape and gap variations, are plotted for flap and tab neutral in figure 6. With the faired-model condition as a basis, the drag-coefficient increments caused by flap deflections are plotted in figure 7 for angles of attack of $\pm 8^{\circ}$, $\pm 4^{\circ}$ and 0°. While the absolute values of the profile-drag coefficients are uncorrected, it is believed that the values of the increments are free from tunnel effects.

The results of the tab tests of the airfoil with the NACA blunt-nose flap and with tab and flap gaps sealed are presented in figures 8, 9, 10, and 11 for flap deflections of 0°, 10°, 15°, and 20°, respectively, with tab deflection of 0°, $\pm 10^{\circ}$, and $\pm 15^{\circ}$ for each flap deflection.

DISCUSSION

In order that the test program might be kept at a minimum to expedite the forwarding of the data, a very brief analysis of the results was made at the completion of the flap-nose-shape tests for the $0.001c$ gap condition. The purpose of this analysis was to determine which flap-nose shape should be used for the sealed gap and the tab tests. The values of c_l as affected by flap-nose shape are

plotted against δ_f in figure 12 for angles of
attack of $-8°$, $0°$, and $8°$. The hinge-moment char-
acteristics of the Bell blunt-nose flap, the NACA
blunt-nose flap, and the NACA medium-nose flap,
respectively, are plotted against α_o and δ_f for
the $0.001c$ gap condition. (See figs. 13 to 15.)
The nose shapes were also compared in figure 16,
where the increments of c_l and the increments of
c_{h_f} caused by flap deflection are plotted for a
high negative angle of attack, $0°$ angle of attack,
and a high positive angle of attack. On the basis
of this analysis it was concluded that the NACA
blunt-nose flap was the most satisfactory from a
consideration of both the lift effectiveness and
the balance effectiveness of the flap. Accordingly,
the sealed-gap tests and the tab tests were made
using only the NACA blunt-nose flap. Plots of c_l
versus δ_f, c_{h_f} versus α_o, c_{h_f} versus δ_f for the
NACA blunt-nose flap with the gap sealed are
presented in figures 17 and 18.

In addition to the drag data presented in
figures 6 and 7, the following table of uncorrected
minimum profile-drag coefficients is presented.

Model condition	$c_{d_{o_{min}}}$ (uncorrected)
Model faired	0.0082
Model { with Bell blunt-nose flap, 0.001c gap	0.0088
Model { with NACA blunt-nose flap, 0.001c gap	0.0092
Model { with NACA blunt-nose flap, gap sealed	0.0092
Model { with NACA medium-nose flap, 0.001c gap	0.0091

By the use of aerodynamic parameters (reference 1) and the data from tests of a conventional airfoil with a 0.30c flap (reference 2) the characteristics of an NACA 0009 airfoil with a 0.26c flap having a $0.305c_f$ overhang have been estimated. In the following table a brief comparison of the control-surface characteristics of the modified low-drag airfoil and the conventional airfoil has been made for the condition of infinite aspect ratio.

Parameter	Test Results Modified NACA 66,2x-009 Airfoil, 0.26c NACA blunt-nose flap, $0.305c_f$ overhang, sealed gap.	Estimated Results (refs. 1 & 2) NACA 0009 Airfoil, 0.26c NACA blunt-nose flap, $0.305c_f$ overhang, sealed gap.
$\left(\dfrac{\partial c_l}{\partial a_0}\right)_\delta$	0.094	0.097
$\left(\dfrac{\partial c_l}{\partial \delta_f}\right)_{a_0}$	.052	.053
$\left(\dfrac{\partial a_0}{\partial \delta_f}\right)_{c_l}$	-.55	-.55
$\left(\dfrac{\partial c_{h_f}}{\partial a_0}\right)_\delta$	-.0020	-.0037
$\left(\dfrac{\partial c_{h_f}}{\partial \delta_f}\right)_{a_0}$	-.0050	-.0053
$\left(\dfrac{\partial \delta_f}{\partial a_0}\right)_{c_{h_f}=0}$	-.40	-.70
$\left(\dfrac{\partial c_m}{\partial c_l}\right)_\delta$	.0010	.0010
$\left(\dfrac{\partial c_m}{\partial \delta_f}\right)_{c_l}$	-.0095	-.0095
$c_{l_{max}}\begin{cases} a_0 \\ -8^\circ \\ 0^\circ \\ 8^\circ \end{cases}$	0.22 at $\delta_f = 20^\circ$ 0.79 at $\delta_f = 15^\circ$ 1.26 at $\delta_f = 25^\circ$	0.28 at $\delta_f = 20^\circ$ 0.85 at $\delta_f = 16^\circ$ 1.36 at $\delta_f = 11^\circ$
$c_{d_{0_{min}}}$	0.0092 (uncorrected)	0.0098 (uncorrected)

Langley Memorial Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va., August 29, 1941.

REFERENCES

1. Ames, Milton B., Jr., and Sears, Richard I.:
        Determination of Control-Surface Character-
        istics from NACA Plain-Flap and Tab Data.
        NACA TN No. 796, 1941.

2. Ames, Milton B., Jr.: Preliminary Data of a
        Wind-Tunnel Investigation of an NACA 0009
        Airfoil with a 0.30c Flap Having a
        Systematic Variation of Flap Nose Shape
        and Aerodynamic Overhang. NACA ARR,
        Aug. 1941.

TABLE-I. Ordinates for Modified NACA 66,2x-009 Airfoil
(Stations and Ordinates in percent of wing chord)

Stations	Upper Surface	Lower Surface
0	0	0
.5	.65	-.65
.75	.78	-.78
1.25	.96	-.96
2.50	1.29	-1.29
5	1.78	-1.78
7.5	2.17	-2.17
10	2.50	-2.50
15	3.05	-3.05
20	3.48	-3.48
25	3.83	-3.83
30	4.10	-4.10
35	4.29	-4.29
40	4.43	-4.43
45	4.49	-4.49
50	4.48	-4.48
55	4.40	-4.40
60	4.20	-4.20
65	3.86	-3.86
70	3.35	-3.35
75	2.79	-2.79
80	2.18	-2.18
96.06	.60	-.60
	L.E. Radius: .55	T.E. Radius: .10

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Note: See Bell Aircraft Corp. drawing No. 24-943-005 for reference.

Bell blunt nose flap

0.454"R

1.906"R

1.930"R

0.024" gap

1.906"

6.250"

NACA blunt nose flap

0.82"R

1 3/16"

NACA medium nose flap

1"R   90°

0.5"R

Scale : Full size for
24"chord model
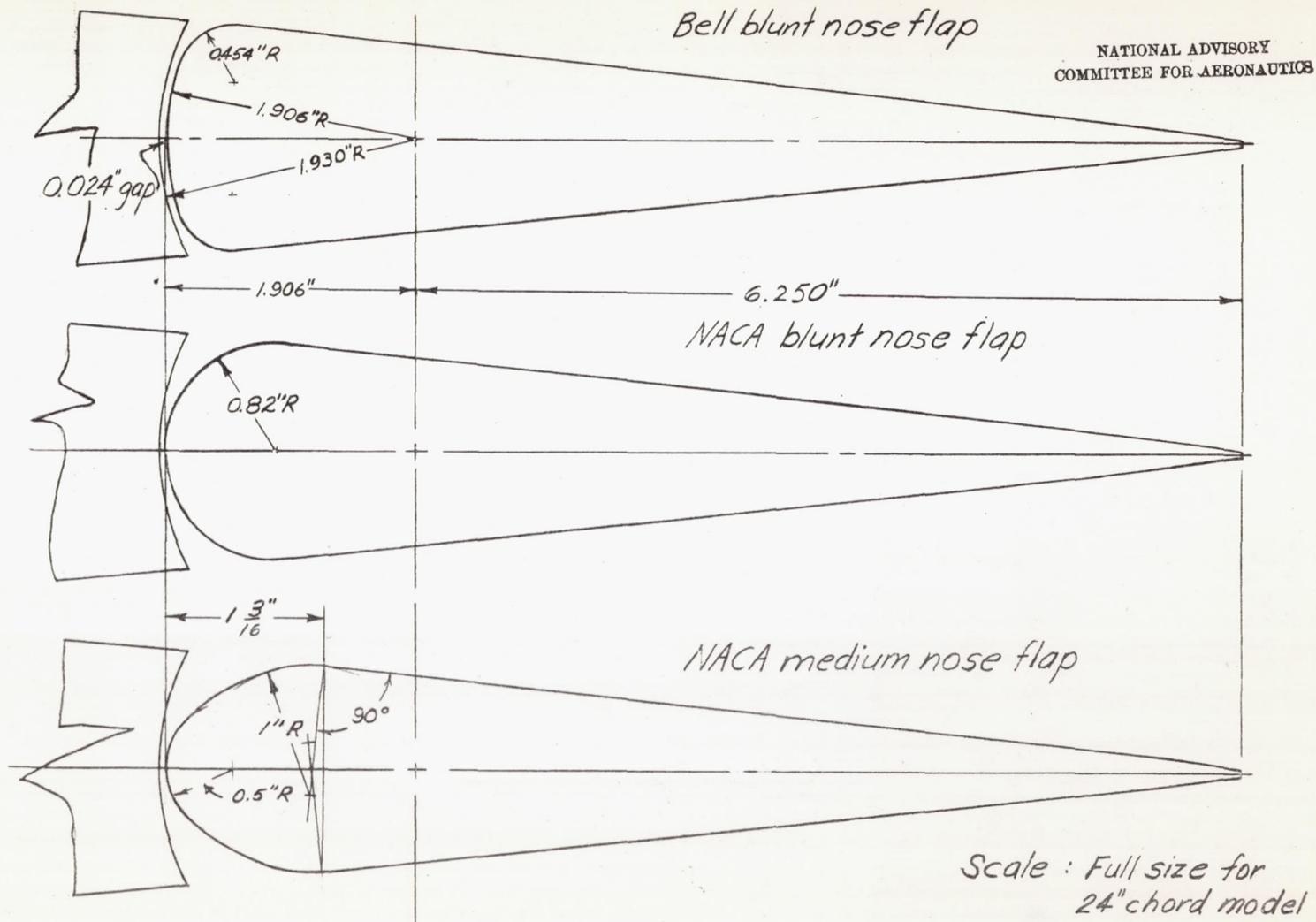
Figure-1. Flap nose shapes tested on XP-63 horizontal tail section
24" chord model.

Flap section hinge-moment coefficient c_h

Airfoil section pitching-moment coefficient c_m

Angle of attack, α, deg

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

	δ_f, deg
○	0
◁	1
◁	2
△	5
▽	10
◻	15
◇	20
△	25
◁	30

Airfoil section lift coefficient, c_l
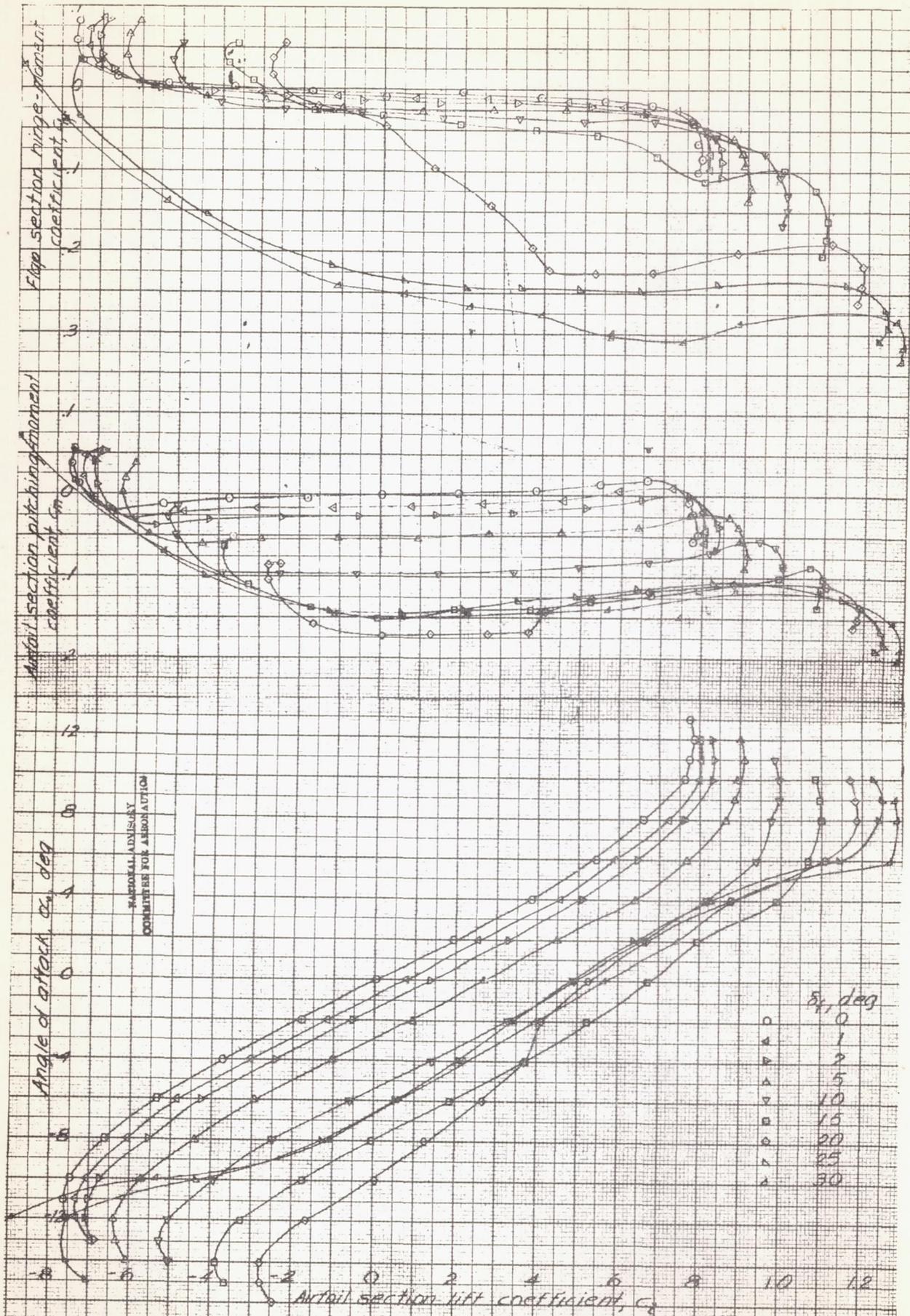
Figure 2. Section characteristics of an airfoil for XP-63 horizontal tail. Bell blunt nose flap. Gap = 0.001c, $\delta_t = 0°$
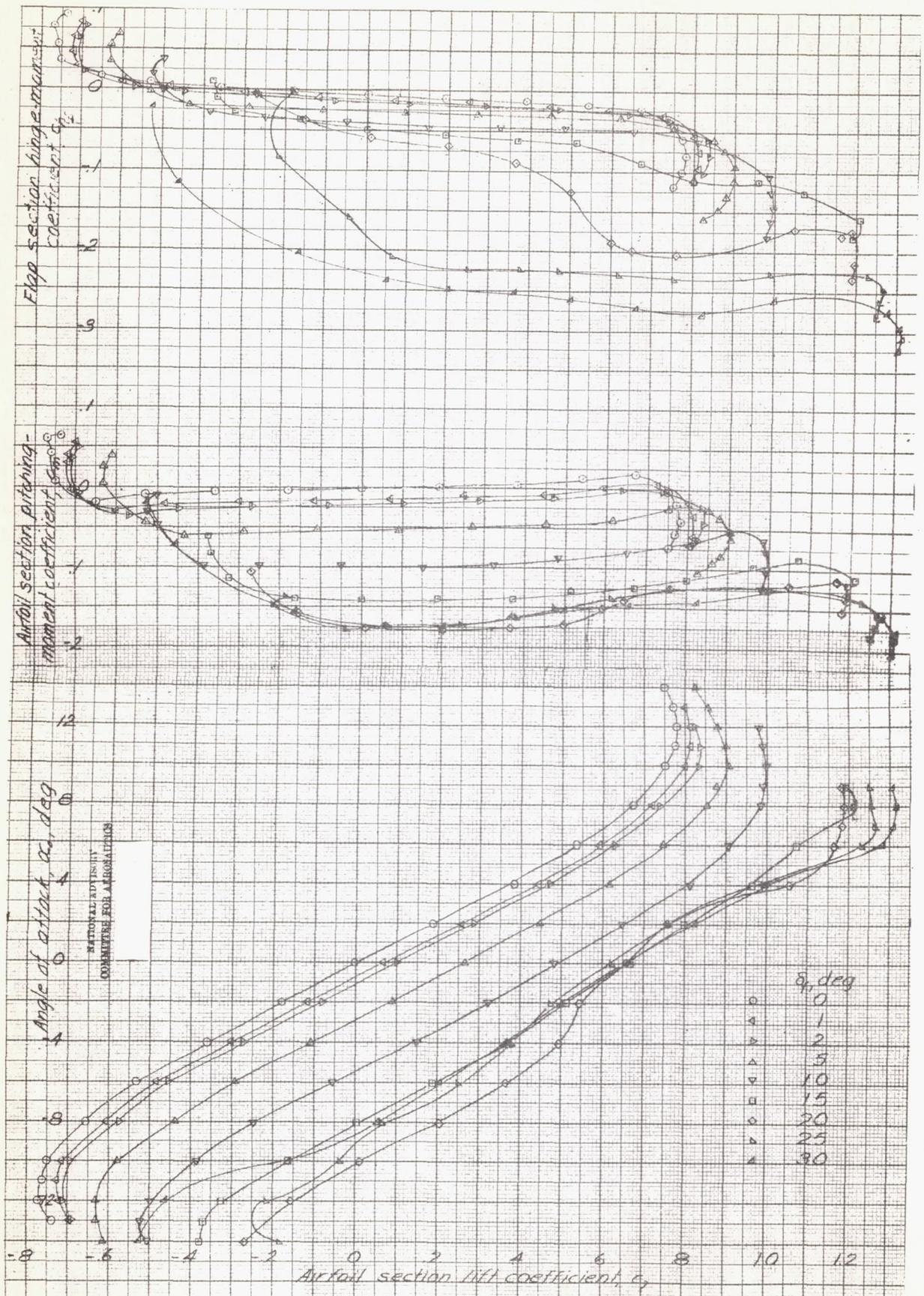
Figure - 3. Section characteristics of an airfoil for XP63 horizontal tail. NACA blunt nose flap. Gap = 0.00lc, $\xi = 0°$
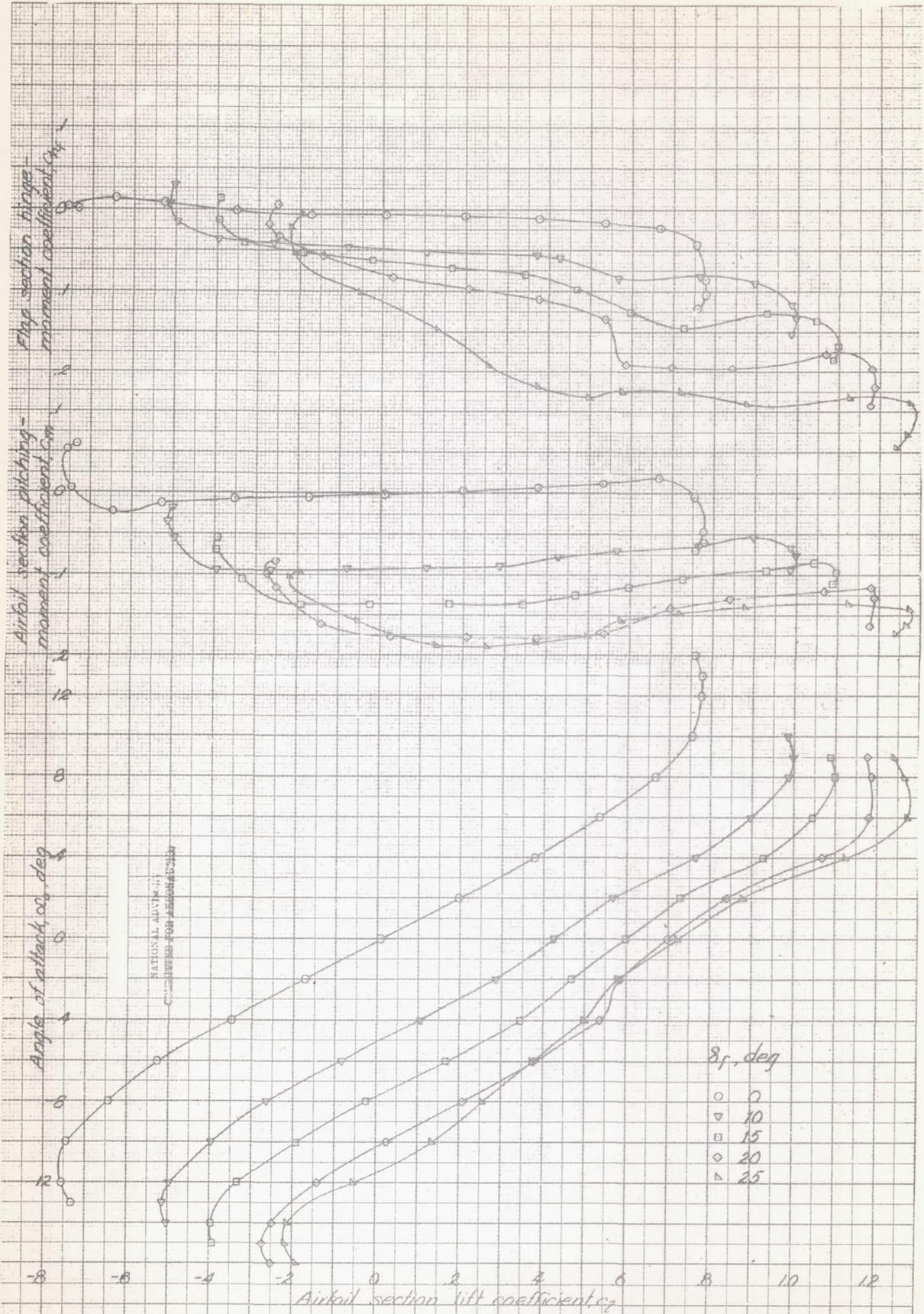
Figure - 4. Section characteristics of an airfoil for XP-63 horizontal tail NACA medium nose flap Gap 0.001c, $\delta_t = 0°$
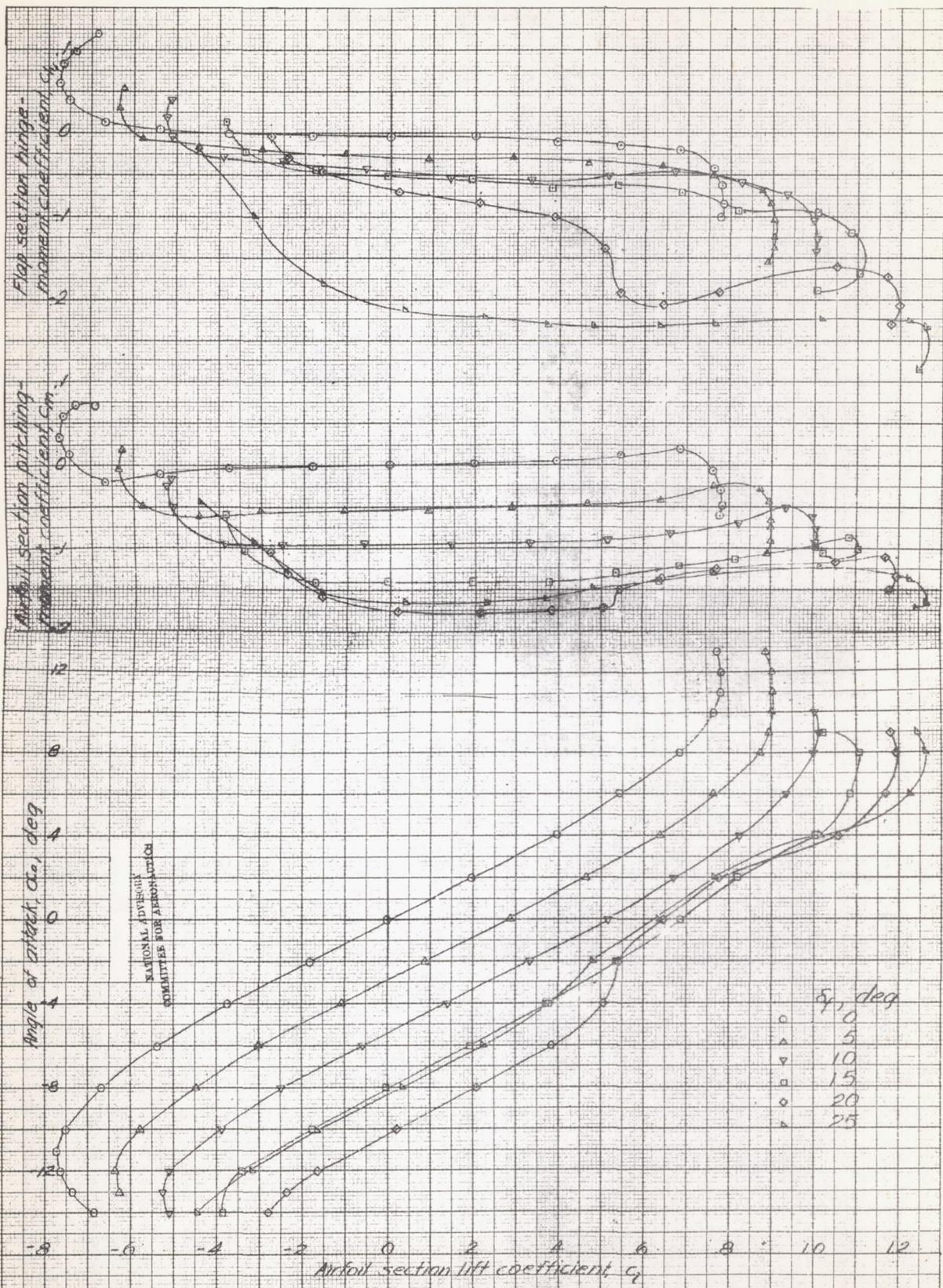
Figure 5.- Section characteristics of an airfoil for XP-63 horizontal tail. NACA blunt nose flap. Gap sealed, $\delta_r = 1°$.
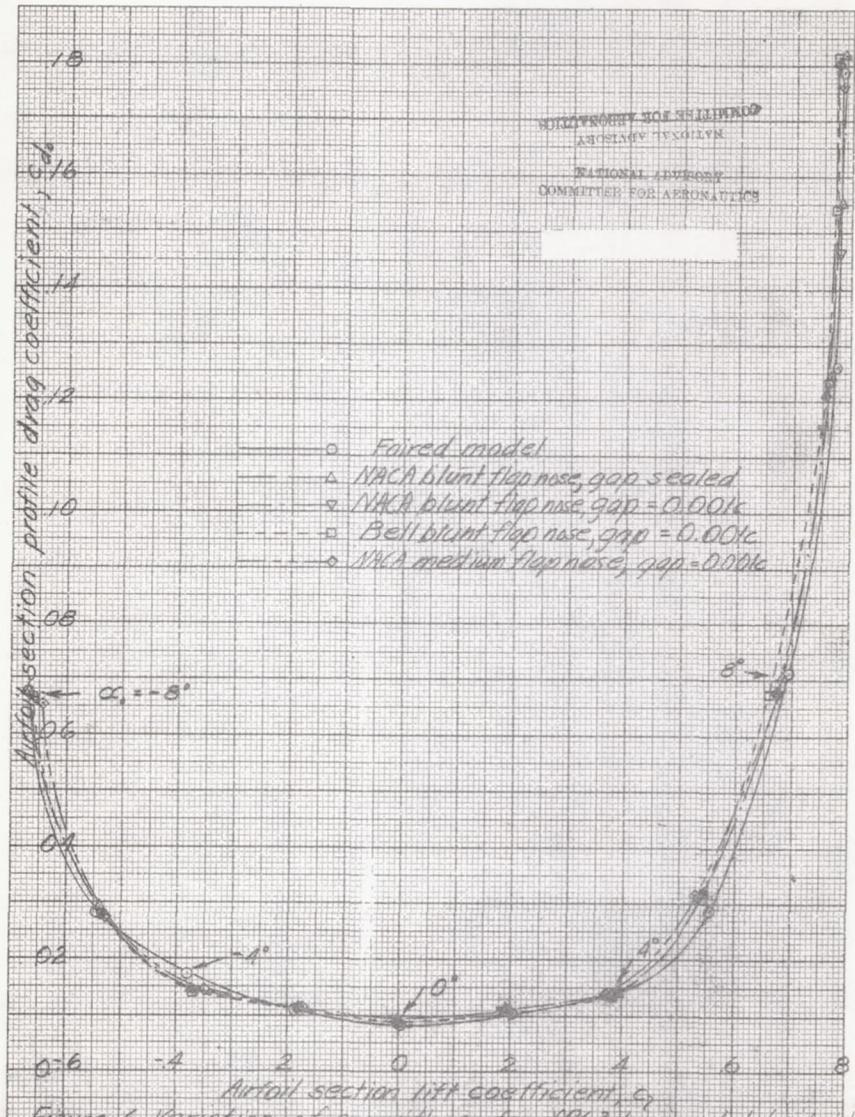
Figure 6.- Variation of c_{d_0} with c_l for the 0063 horizontal tail with various flap nose shapes and gaps. $\delta_f = 0°$; $\delta_t = 0°$.

L-573
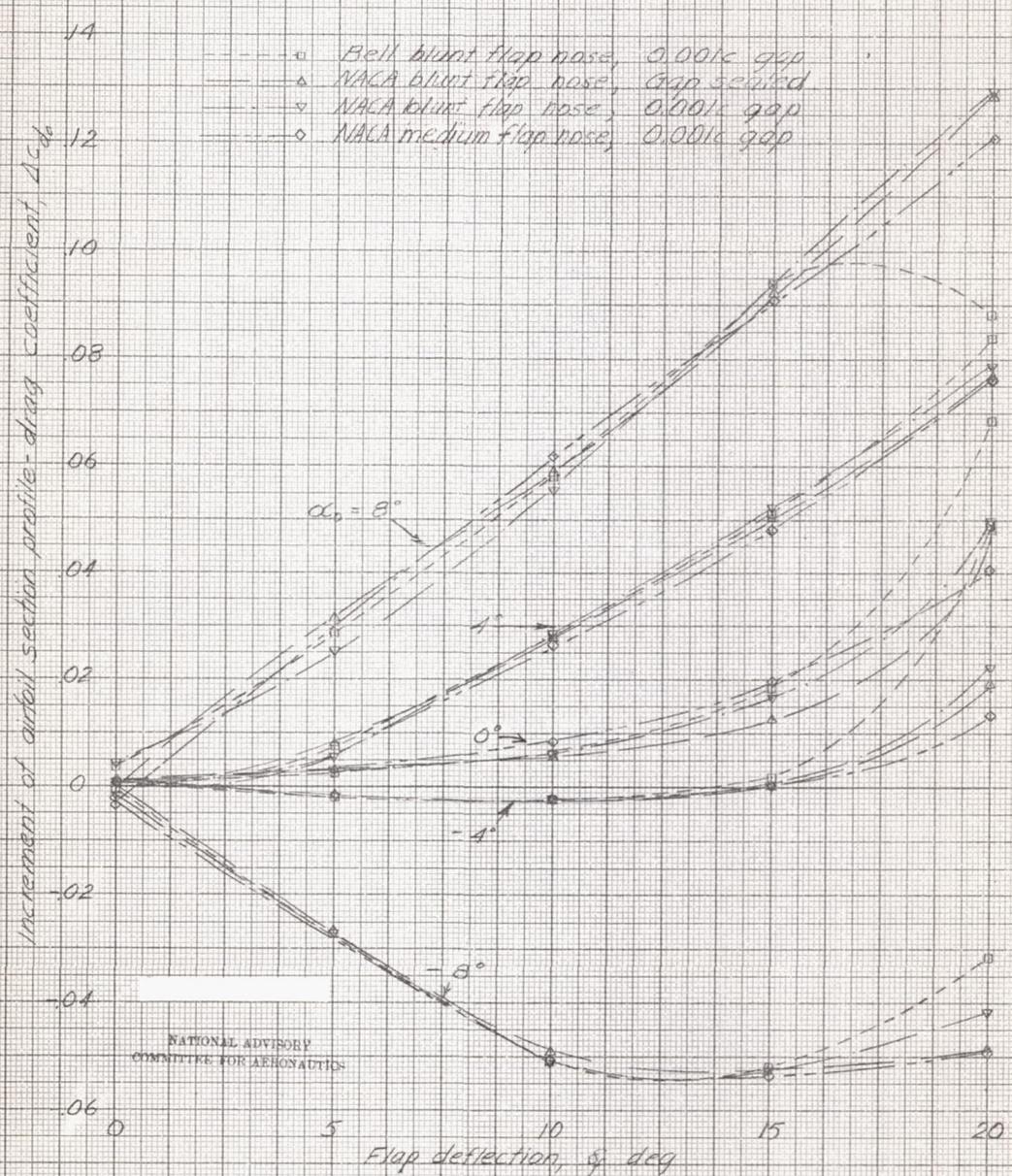
Figure- 7. Increments of airfoil section profile-drag coefficient caused by various flap nose shapes. Faired model with δ=0° and δ_t=0° used as basic condition. (XP-63 horizontal tail).
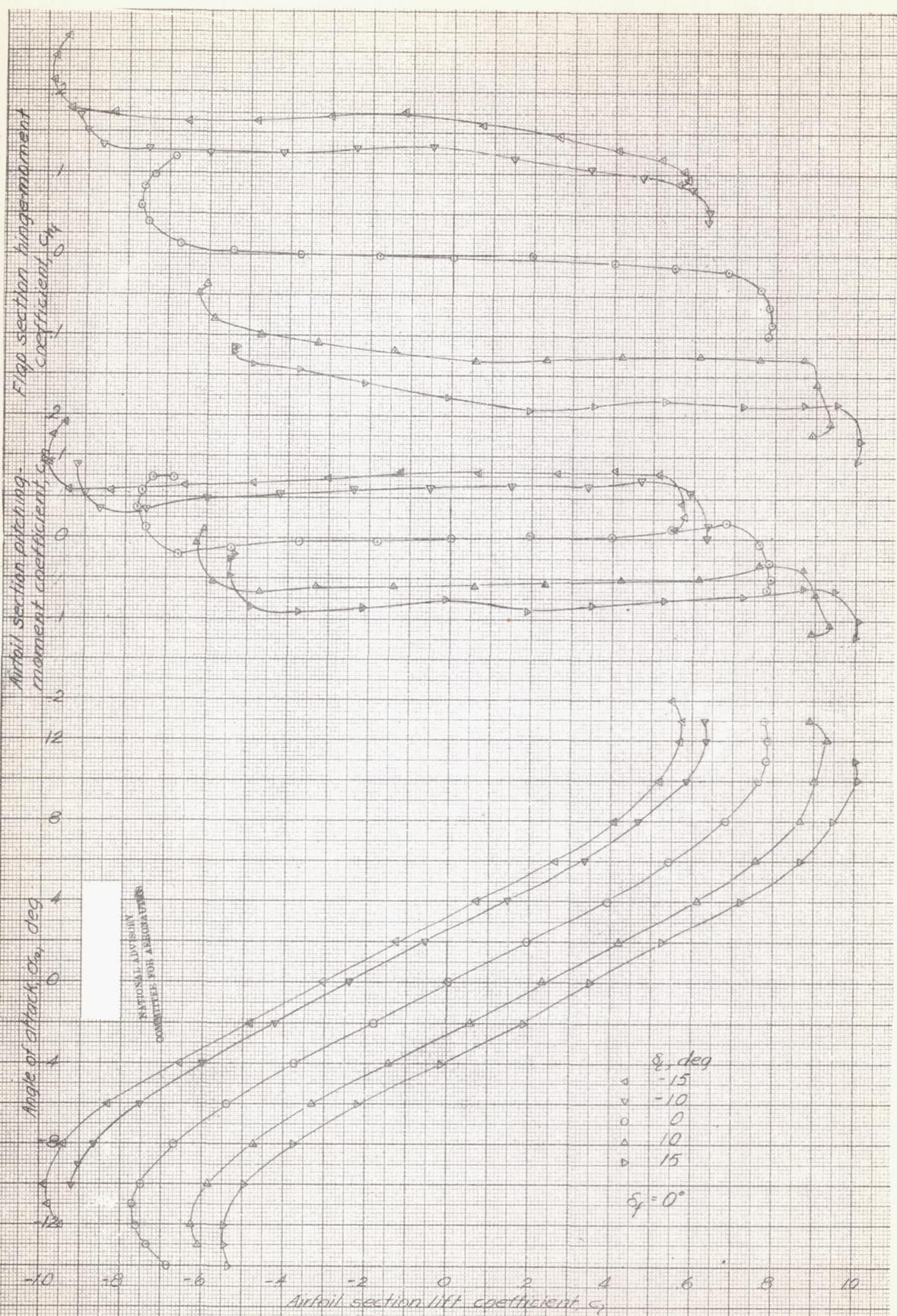
Figure-8. Effect of tab deflection on the aerodynamic section characteristics of the XP-63 horizontal tail airfoil section with NACA blunt nose flap and sealed gap. $\delta_f = 0°$

250
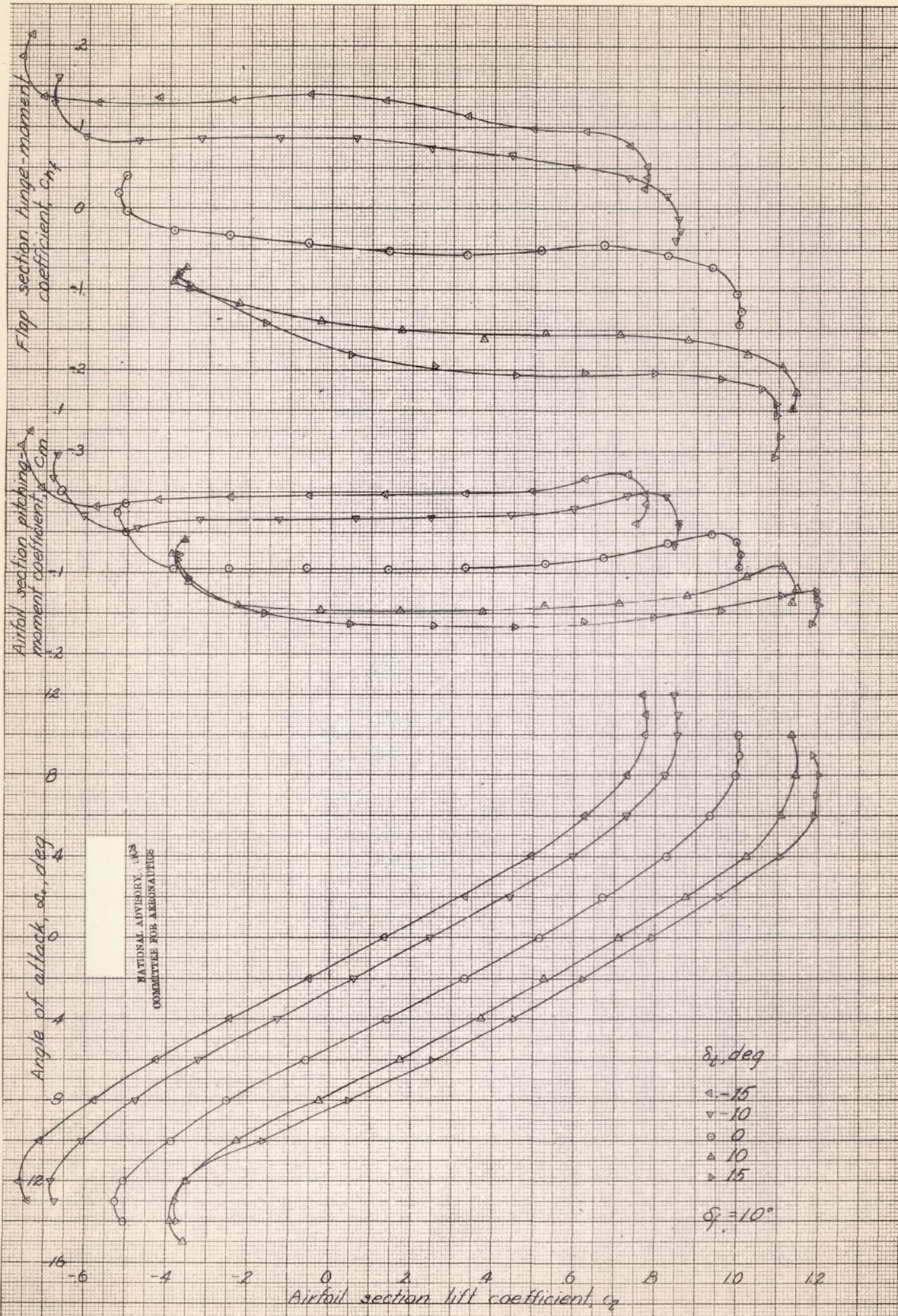
Figure - 9 Effect of tab deflection on the aerodynamic section characteristics of the XP-63 horizontal tail airfoil section with NACA blunt nose flap and sealed gap; $\delta_f = 10°$.

250.

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COMMITTEE FOR AERONAUTICS

δ_t, deg
◁ -15
▽ -10
○ 0
△ 10
▷ 15

$\delta_f = 15°$
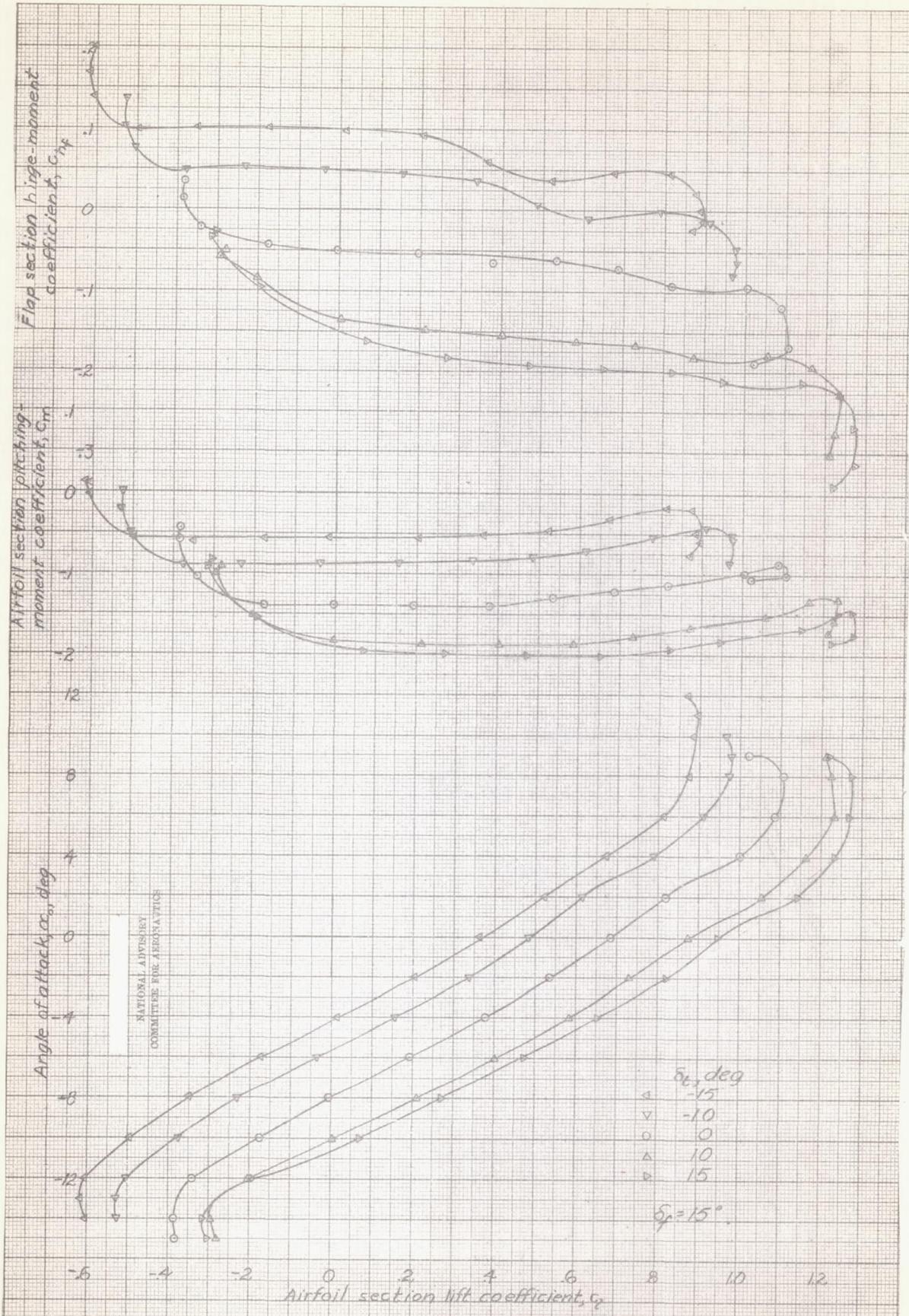
Figure 16. Effect of tab deflection on the aerodynamic section characteristics of the XP-63 horizontal tail airfoil section with NACA blunt nose flap and sealed gap; $\delta_f = 15°$.
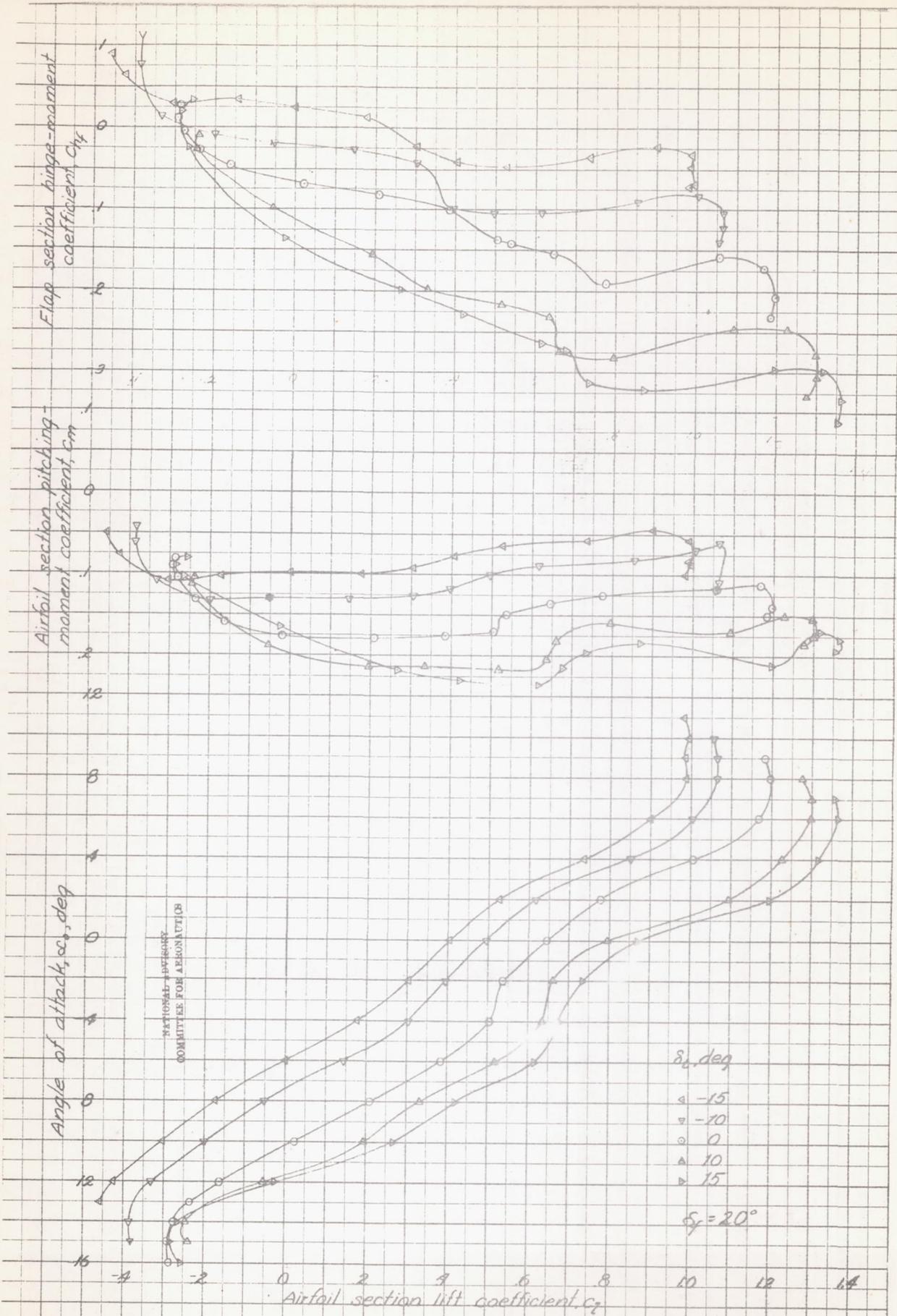
Figure-11 Effect of tab deflection on the aerodynamic section characteristics of the XP-63 horizontal tail airfoil section with NACA blunt nose flap and sealed gap; $\delta_f = 20°$.

Figure 12.— Lift characteristics of airfoil for XP-63 horizontal tail with NACA and Bell flap nose shapes. Gap = 0.001c, $\xi = 0°$.

Flap deflection, δ_f, deg

δ_f, deg
0
5
10
15
20
25
30

$\alpha_0 = -8°$
0°
8°

Flap section hinge-moment coefficient, c_h

Angle of attack α_0, deg

Figure 14.- Hinge moment characteristics of flap with NACA blunt nose. Gap = 0.00k, $\delta_t = 0°$. (XP-63 elevator.)

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Flap deflection, δ_f, deg

δ_f, deg
0
5
10
15
20
25
30

$\alpha_0 = -8°$
0°
8°

NATIONAL ADVISORY
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Flap section hinge-moment coefficient, c_h

Angle of attack α_0, deg

Figure 13.- Hinge moment characteristics of flap with Bell blunt nose. Gap = 0.00k, $\delta_t = 0°$. (XP-63 elevator.)

Figure - 15. Hinge moment characteristics of flap with NACA medium nose Gap = 0.00c, $\delta_e = 0°$ (XP-63 elevator).
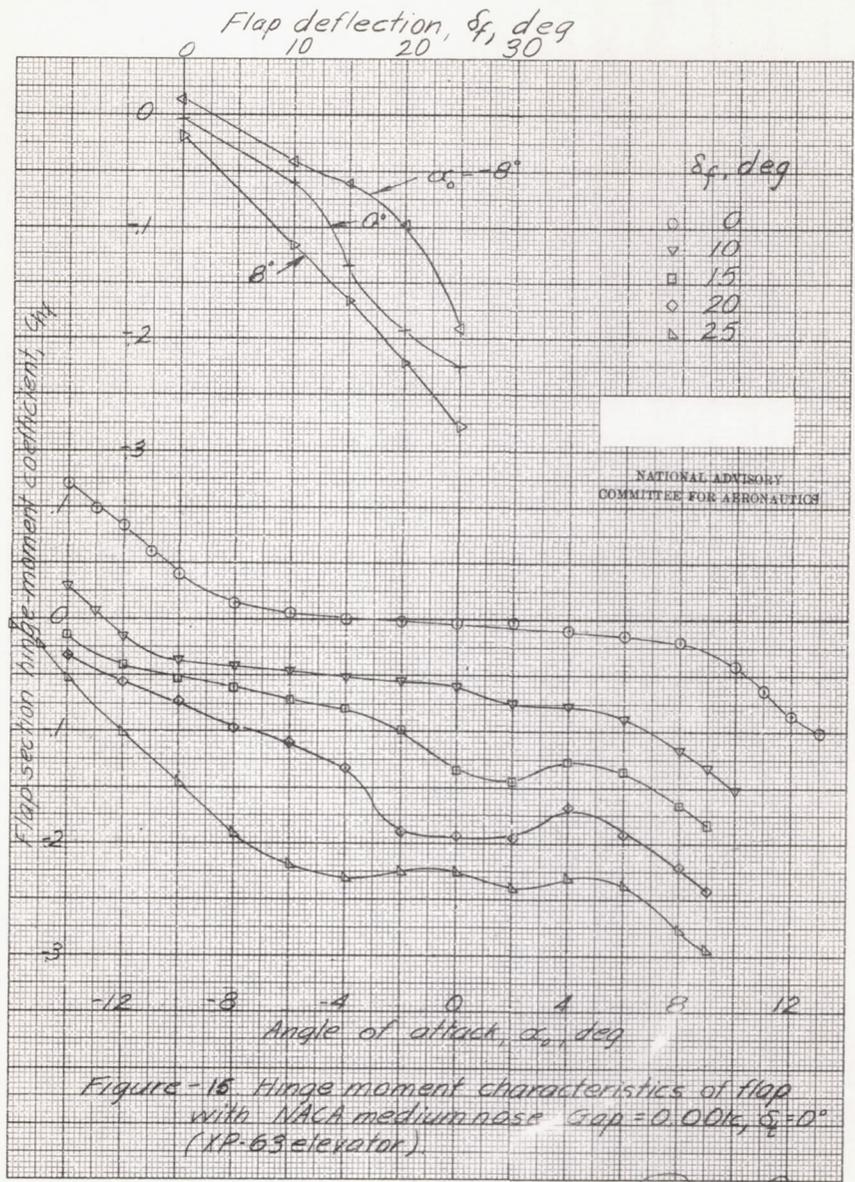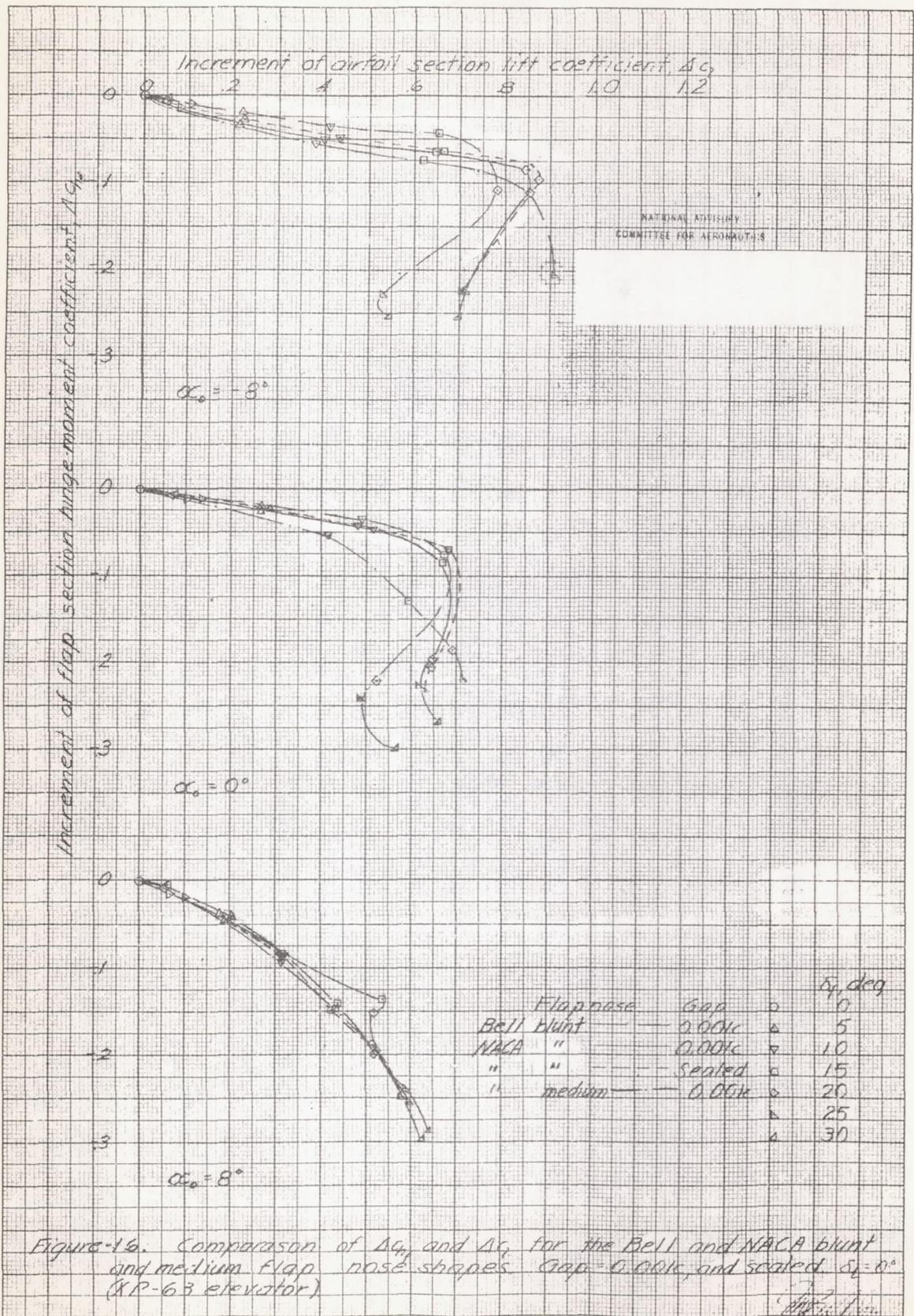
Figure 16. Comparison of Δc_{h_f} and Δc_l for the Bell and NACA blunt and medium flap nose shapes. Gap = 0.001c, and sealed. $\delta_t = 0°$ (XP-63 elevator)
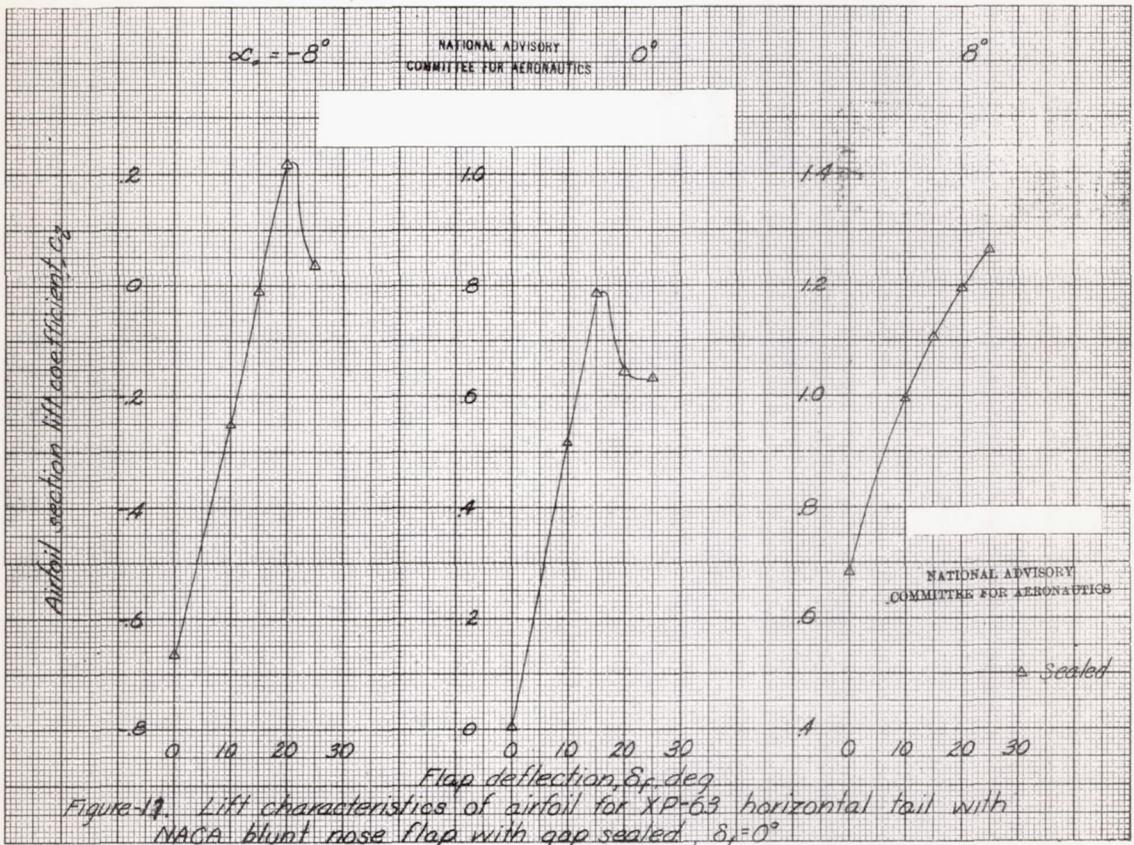
Figure-17. Lift characteristics of airfoil for XP-63 horizontal tail with NACA blunt nose flap with gap sealed, $\delta_t = 0°$

Figure 18.- Hinge moment characteristics of flap
with NACA blunt nose. Gap sealed $\delta_e = 0°$
(XP-63 elevator).