NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

WIND-TUNNEL INVESTIGATION OF AN NACA 23012 AIRFOIL WITH

A 0.30-AIRFOIL-CHORD DOUBLE SLOTTED FLAP

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NACA

WASHINGTON

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SUMMARY

Tests to determine the effect of flap position and
deflection on the aerodynamic characteristics of an NACA
23012 airfoil with a double slotted flap having a chord
30 percent of the airfoil chord (0.30c) were conducted
in the LMAL 7— by 10-foot tunnel. In addition, a few
tests were made to determine the aerodynamic section
characteristics as affected by the size and shape of the
fore flap, by movement of the fore flap and rear flap as
a unit, and by variation in the airfoil lower lip. Con-
tours of rear—flap—nose position for various values of
maximum section lift coefficient, section profile-drag
coefficient, and section pitching-moment coefficient are
presented at three selected fore-flap positions for vari-
ous rear—flap deflections. The complete aerodynamic sec-
tion characteristics are given at the three selected fore-
flap positions for the optimum—lift and optimum—drag po-
sitions of the rear flap at several deflections. Polars
of the section profile—drag coefficient at the flap po-
sitions and deflections for optimum lift and optimum
drag are shown. A discussion is given of the relative
merits of the present arrangement as compared with a
0.2566c and a 0.40c slotted flap, a 0.30c Fowler flap,
and a 0.40c double slotted flap on the same airfoil.

The optimum deflection of the rear flap within the
range investigated at each position of the 0.117c fore
flap was 60° in almost all cases and the maximum lift of
the airfoil was obtained with the fore flap deflected
25° in the rearmost of the three selected positions.
The use of the 0.1467c fore flap provided a slightly
higher maximum section lift coefficient than was obtained
with the smaller fore flap. The 0.30c double slotted
flap (0.117c fore flap) gave a maximum section lift coef-
ficient (3.30) that was higher than that of the 0.2566c
or 0.40c single slotted flaps, approximately equal to

that of the 0.30c Fowler flap, but about 0.16 less than
that of the 0.40c double slotted flap. The profile-drag
coefficients of the 0.30c double slotted flap were higher
than those of the 0.30c Fowler and the 0.40c double
slotted flaps over the entire lift range and higher than
those of the two single slotted flaps in the range of
section lift coefficients below 2.7. The negative sec-
tion pitching-moment coefficients at maximum section
lift coefficient produced by the 0.30c double slotted
flaps were equal to those of the 0.30c Fowler flap and
were greater than those produced by other slotted flaps
on the same airfoil.

INTRODUCTION

An extensive investigation of various high-lift
devices has been undertaken by the NACA to furnish in-
formation applicable to the aerodynamic design of wing-
flap combinations for improved safety and performance of
airplanes. A high-lift device capable of producing high
lift with variable drag for landing and high lift with
low drag for take-off and initial climb is believed to
be desirable. Other desirable characteristics are: no
increase in drag with the flap neutral, small change in
pitching moment with flap deflection, low forces required
to operate the flap, and freedom from possible hazard due
to icing.

Aerodynamic data on the NACA 23012 airfoil have been
made available for single slotted flaps in references 1
and 2, for a Fowler flap having a chord 30 percent of the
airfoil chord (0.30c) in reference 3, and for a 0.40c
double slotted flap in reference 4.

The data presented in reference 4 indicated that the
double slotted flap gave higher lift than the single
slotted flap and had lower drag at high section lift coef-
ficients. The double slotted flap also had higher lift
than the Fowler flap.

Although an investigation essentially the same as
that reported herein had been planned at LMAL several
years ago, no tests were made at that time because of
other projects of greater interest. Renewed interest
of designers and manufacturers in devices capable of

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producing very high lift on combat airplanes, however,
led to the present investigation, in which tests were
made of a 0.30c double slotted flap on the NACA 23012
airfoil (fig. 1). It was believed that this device
would combine the advantageous aerodynamic character-
istics of the 0.40c double slotted flap (reference 4)
with the structural advantages of the small single
slotted flap (reference 1). The small size of the
fore flap would also allow the use of simpler doors for
sealing the break in the airfoil lower surface with the
flaps retracted.

APPARATUS AND TESTS

Models

The basic airfoil used in these tests had a chord
of 3 feet and a span of 7 feet. The model was constructed
of laminated pine and was built to the NACA 23012 profile;
the ordinates for the section are presented in table I.
This airfoil had previously been used for the investiga-
tions reported in references 1, 2, and 4. The trailing-
edge section of the model ahead of the flap was equipped
with lips of steel plate rolled to the airfoil contour
and extending back to the flap in order to provide the
basic airfoil contour when the flap was retracted (fig. 1).

The double slotted flap consisted of a fore flap and
a rear flap. Two fore flaps (A and B) were used in this
investigation. The larger one designated fore flap B was
used in only a few tests to determine the effect of in-
creased thickness and chord. The two fore flaps were of
different profile, as shown in figure 2, and were built
to the ordinates given in table I. Fore flap A was con-
structed of laminated wood and had a trailing-edge of
1/16-inch steel plate. Fore flap B had an upper surface
and trailing-edge of dural and a lower surface of laminated
wood.

The rear flap (0.2566c) tested was the one used in
the investigations reported in references 1 and 4. The
rear-flap profile is shown in figure 1 and the ordinates
are given in table I.

Both the fore flap and the rear flap were attached
to the main portion of the airfoil by special fittings

that permitted them to be moved and deflected indepen-
dently. Both the fore flap and the rear flap also
pivoted about their respective nose points at any
position; increments of 5° deflection were allowed for
the fore flap and increments of 10° deflection for the
rear flap. The nose point of either flap is defined
as the point of tangency of the leading-edge arc and
a line drawn perpendicular to the flap chord. The
deflection of either flap was measured between its
respective chord and the chord of the main airfoil.

The models were made to a tolerance of ±0.015 inch.

Tests

The model was so mounted in the closed test section
of the LMAL 7- by 10-foot tunnel as to completely span
the jet except for small clearances at each end. (See
references 1 and 5.) The main airfoil was rigidly
attached to the balance frame by torque tubes that
extended through the upper and lower boundaries of the
tunnel. The angle of attack of the model was set by
rotating the torque tubes with a calibrated drive from
outside the tunnel. This type of installation closely
approximates two-dimensional flow and the section char-
acteristics of the model being tested can therefore be
determined.

A dynamic pressure of 16.37 pounds per square foot
was maintained for all the tests. This dynamic pres-
sure corresponds to a velocity of about 80 miles per
hour under standard atmospheric conditions and to an
average test Reynolds number of approximately 2,190,000.
Because of the turbulence in the wind tunnel, the effec-
tive Reynolds number R_e (reference 6) was approximately
3,500,000. For all tests, R_e is based on the chord of
the airfoil with the flaps retracted and on a turbulence
factor of 1.6 for the wind tunnel.

No tests were made of the plain airfoil nor of the
model with the double slotted flap completely retracted
because the characteristics of the plain airfoil had
previously been investigated and reported in reference 1.

Because of the large number of tests involved in
determining the optimum positions of the double slotted
flap, a preliminary survey was made to determine the

optimum final position and deflection of fore flap A.
Three positions of the fore flap were selected. Po-
sitions 1 and 2 were chosen arbitrarily and the deflec-
tion for position 2 was the optimum as determined from
a survey with the rear flap deflected 40°, 50°, and 60°.
Position 3 was the optimum final position and deflection
of fore flap A as determined with the rear flap deflected
50° and 60°. Tests were thereafter made at each of these
three positions and deflections of the fore flap, as pre-
viously determined, to obtain the maximum lift and the
optimum position of the rear flap at several deflections.
Tests were made with fore flap B at various deflections
and positions in the region of the optimum position of
fore flap A, and with the rear flap deflected 60° and
70° in the region of its optimum position as determined
from tests with fore flap A. In addition, in order to
determine the effect on the aerodynamic characteristics,
tests were made with the lower lip of the airfoil trailing-
edge section in its normal position on the contour, de-
flected 13.5° within the airfoil contour in order to pro-
vide a smoother slot entry, and also completely removed.

An angle-of-attack range from -6° to the angle of
attack for maximum lift was covered in 2° increments for
each test. No data were obtained for angles of attack
above the stall because of the unsteady condition of the
model. Lift, drag, and pitching moment were measured at
each angle of attack.

RESULTS AND DISCUSSION

Coefficients and Symbols

All the test results are given in standard section
nondimensional coefficient form corrected for tunnel-wall
effect and turbulence as explained in reference 1.

c_l section lift coefficient (l/qc)

c_{d_o} section profile-drag coefficient (d_o/qc)

$c_{m(a.c.)_o}$ section pitching-moment coefficient about
     aerodynamic center of plain airfoil
$$\left[m_{(a.c.)_o}/qc^2 \right]$$

$\left[c_{m(a.c.)_0}\right]_{c_{l_{max}}}$ section pitching-moment coefficient at maximum section lift coefficient

$c_{l_{max}}$ maximum section lift coefficient

$c_{d_{0_{min}}}$ minimum section profile-drag coefficient

where

l section lift

d_0 section profile drag

$m_{(a.c.)_0}$ section pitching moment about aerodynamic center of plain airfoil

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

c chord of basic airfoil with flap fully retracted

V velocity, feet per second

ρ mass density of air

and

R_e effective Reynolds number

l_t distance from aerodynamic center of airfoil to center of pressure of tail, expressed in airfoil chords

α_0 angle of attack for infinite aspect ratio

δ_{f_1} fore-flap deflection, measured between fore-flap chord and airfoil chord

δ_{f_2} rear-flap deflection, measured between rear-flap chord and airfoil chord

x_1 distance from airfoil upper-surface lip to fore-flap-nose point, measured parallel to airfoil chord and positive when fore-flap-nose point is ahead of lip

y_1 distance from airfoil upper-surface lip to
              fore-flap-nose point, measured perpendi-
              cular to airfoil chord and positive when
              fore-flap-nose point is below lip

x_2 distance from fore-flap trailing edge to
              rear-flap-nose point, measured parallel
              to airfoil chord and positive when rear-
              flap-nose point is ahead of fore-flap
              trailing edge

y_2 distance from fore-flap trailing edge to
              rear-flap-nose point, measured perpendi-
              cular to airfoil chord and positive when
              rear-flap nose is below fore-flap trailing
              edge

Precision

The accuracy of the various measurements is believed
to be within the following limits:

α_0, degrees . . . . ± 0.1

$c_{l_{max}}$ . . . . ± 0.03

$c_{m(a.c.)_0}$ . . . . ± 0.003

$c_{d_{o_{min}}}$ . . . . ± 0.0003

$c_{d_o(c_l = 1.0)}$ . . . . ± 0.0006

$c_{d_o(c_l = 2.5)}$ . . . . ± 0.002

δ_{f_1} and δ_{f_2}, degrees . . . . ± 0.2

Flap position . . . . $\pm 0.001c$

No corrections were determined (or applied) for the
effect of the airfoil or flap fittings because of the
large number of tests required. It is believed that their
effect, however, is small and that the relative values of
the results would not be appreciably affected.

Plain Airfoil

The complete aerodynamic section characteristics of the plain NACA 23012 airfoil (from reference 1) are presented in figure 3. Inasmuch as these data have previously been discussed (reference 1), no further discussion is considered necessary.

Determination of Optimum Flap Configurations

Maximum lift.- The data presented in figures 4 to 6 represent the results of the maximum-lift investigation with fore flap A at each of the three previously determined positions and with the rear flap deflected and located at points over a considerable area with respect to the fore flap. The results are presented as contours of the position of the rear-flap-nose point at various deflections for given lift coefficients.

Complete maximum lift data for the rear-flap-nose positions with the fore flap in the least extended of the three positions (identified herein as position 1) are given in figure 4, showing the rear flap deflected in 10° increments from 10° to 60°. The contours with the fore flap in the intermediate and extended positions (positions 2 and 3) are given in figures 5 and 6, respectively. Because it is unlikely that small rear-flap deflections would ever be used with these extended fore-flap positions, data for the small rear-flap deflections were not obtained. The figures show that all the contours are closed, except that for $\delta_{f_2} = 10°$ at position 1, which indicates that the contour would close at an impractical rear-flap-nose position.

At each of the fore-flap positions, the rear-flap-nose position for maximum lift becomes more critical with increased flap deflection, particularly when δ_{f_2} is 50° and 60°. With increased flap deflection, the position of the rear-flap nose for maximum lift tends to move forward and upward and the gap between the two flaps is thereby decreased. In the following table are given the values of the maximum section lift coefficient obtained at each fore-flap position and the approximate position of the rear-flap nose with respect to the fore-flap trailing edge.

Fore-flap position	Position of rear-flap nose		$c_{l_{max}}$
	Ahead of lip (percent airfoil chord)	Below lip (percent airfoil chord)	
1	2	3	2.74
2	2	2	3.15
3	2	2	3.30

In almost all cases, the highest value of maximum section
lift coefficient for the flap-deflection range investi-
gated was obtained at $\delta_{f_2} = 60°$.

From the contours of rear-flap-nose position for
$c_{l_{max}}$, a designer should be able to determine the best
path to be followed by the rear flap at all deflections
within the range tested, from a consideration of only
maximum section lift coefficient. The range of flap
positions covered was believed sufficient to allow for
any deviations or compromises from the "best lift" path.
Complete aerodynamic section characteristics for the
optimum rear-flap-nose position for both lift and drag
at each fore-flap deflection and position will be pre-
sented subsequently in this report.

Minimum profile drag.- Contours of rear-flap-nose
position for values of minimum section profile-drag co-
efficient at specific section lift coefficients and flap
deflections are presented in figures 7 to 9 for the three
fore-flap positions. A comparison of the contour of fig-
ure 7(a) with the section profile-drag characteristics
of the plain airfoil (fig. 3) indicates that the plain
airfoil gives the lower drag at section lift coefficients
of 1.5 or less.

At position 1, the contours of c_{d_0} are presented
only for values of δ_{f_2} of 10°, 20°, and 30°, since it
is believed that the larger flap deflections at this po-
sition would not be used because the corresponding c_{d_0}
values are quite high. Inasmuch as all the contours at
each of the three fore-flap positions were not closed
about the indicated optimum rear-flap-nose positions, it
is apparent that a sufficient range of rear-flap positions
was not covered and that the true optimum values may exist
at some other positions. The contours also indicate that

more than one region of relatively low drag exists for
several rear-flap deflections. As anticipated, the min-
imum section profile-drag coefficient increased with
deflection of the rear flap at any given lift coeffi-
cient. At the same lift coefficient and rear-flap de-
flection, values of profile-drag coefficient became less
as the fore flap was extended; for example, at $c_l = 1.5$,
$\delta_{f_2} = 30°$, an optimum value of c_{d_0} of 0.050 was ob-
tained at position 2 as compared to a value of 0.063 at
position 1; and at $c_l = 2.5$, $\delta_{f_2} = 50°$, an optimum
value of c_{d_0} of 0.103 was obtained at position 3 as
compared to a value of 0.117 at position 2. The optimum
rear-flap-nose position moved forward and up, closer to
the fore-flap lip as the fore flap was extended and also
as the rear flap was deflected.

For all these contours (figs. 7 to 9), in each po-
sition of the fore flap at high lift coefficients and
flap deflections, a given movement of the rear-flap-nose
point caused a greater change in the value of c_{d_0}.

Inasmuch as the rear-flap-nose positions for maxi-
mum lift and minimum drag generally do not coincide, a
compromise is necessary; therefore, complete aerodynamic
section characteristics are presented for both conditions.

Pitching moment.- The contours of rear-flap-nose
position for values of $c_{m(a.c.)_0}$ at specific flap
deflections and lift coefficients are presented in fig-
ures 10 to 12 for each of the three fore-flap positions.
Because the positive increment of lift usually obtained
with increased flap deflection has its centroid farther
to the rear than does an equal lift increment obtained
by increased angle of attack, an increase in the negative
pitching moment of the airfoil is anticipated when the
flap is deflected. The contours for $c_{m(a.c.)_0}$ tend,
therefore, to close near the region of the rear-flap-nose
position for maximum lift, and the positions of the rear-
flap nose for maximum lift and maximum pitching moment
usually coincide.

The negative section pitching-moment coefficients
usually increased with lift coefficient and flap deflec-
tion and the change in $c_{m(a.c.)_0}$ for a given change in

rear—flap—nose position became larger as both these variables increased. At a given lift coefficient, the negative values of $c_{m(a.c.)_0}$ also increased as the fore flap was extended and deflected. It appears desirable therefore to use the minimum flap deflection or extension necessary to obtain a given lift coefficient.

With these contours of rear—flap position for $c_{m(a.c.)_0}$ available (figs. 10 to 12), a designer can determine or anticipate the section pitching—moment coefficients to be encountered within the range of positions and deflections investigated.

Aerodynamic Section Characteristics of Selected

Optimum Configurations

The complete aerodynamic section characteristics of the airfoil with the optimum—lift and optimum—drag positions of the rear flap at each flap deflection and at each of the three selected fore—flap positions are presented in figures 13 to 15. These figures indicate that the lift—curve slopes decreased with increased flap deflection. The angle of attack for maximum lift usually decreased with increased flap deflection at each position, but in some instances remained practically constant. It will be noted that the aerodynamic section characteristics for optimum lift for $\delta f_2 = 70^0$ are presented only for position 3 (fig. 15(a)). Tests were made at $\delta f_2 = 70^0$ in both positions 2 and 3, but insufficient data were obtained to present the characteristics for the optimum rear—flap position for position 2 or the contours for either fore flap position; however, at position 3, from data gathered at $\delta f_2 = 70^0$ and other deflections, it is believed that the optimum—lift position of the rear flap was attained. The aerodynamic characteristics are therefore given.

The section pitching—moment coefficients in general increased negatively with the rear—flap deflection and as the fore flap was extended. The slopes of the section pitching—moment curves were negative at low angles of attack and low flap deflections and were usually positive at high angles of attack and high flap deflections. At

high section lift coefficients, lower negative values
of $c_{m_{(a.c.)_0}}$ were therefore sometimes obtained with
a large flap deflection than with a small one. It will
be noted in figures 13 and 14 that at $\delta_{f_2} = 50°$ and $60°$,
respectively, the position of the rear flap for maximum
lift coincides with that for minimum drag, indicating
this position to be best from both considerations. In
figures 13(a) and 14(a), the irregularities in the curves
indicate that changing flow conditions existed at $\delta_{f_2} = 60°$.

Increment of maximum Section Lift Coefficient.— The
effect of flap deflection on $\Delta c_{l_{max}}$ for each of the
three fore flap positions is indicated in figure 16.
The increment of maximum section lift coefficient, based
on the maximum section lift coefficient of the plain air-
foil, increased not only with rear-flap deflection but
also as the fore flap was extended and deflected.

The values of $\Delta c_{l_{max}}$ for the optimum-lift rear-
flap positions are higher than those for optimum drag
except at position 1, $\delta_{f_2} = 50°$, and position 2,
$\delta_{f_2} = 60°$, where the two values coincide. The maximum
increment within the range investigated at each fore-flap
position occurred at $\delta_{f_2} = 60°$, except for the optimum-
drag curve of position 1. The maximum increment, which
was obtained at position 3, was about 1.75. In position
1 $\Delta c_{l_{max}}$ increased only slightly for rear-flap deflec-
tions above 30°, and in position 3, the decrease in
$\Delta c_{l_{max}}$ was fairly small between $\delta_{f_2} = 60°$ and $70°$.

Envelope Polar Curves.— The envelope polar curves
of section profile-drag coefficient at each of the fore
flap positions, obtained from figures 13 to 15, and the
envelope polar of the plain airfoil are presented in fig-
ure 17. These polars show the lowest section profile-
drag coefficient obtainable at a given section lift coef-
ficient for the optimum-lift and optimum-drag flap con-
figurations at each fore-flap position.

For section lift coefficients less than 1.5, the
plain airfoil gives the lowest section profile-drag co-
efficient. Position 3 gives in general the lowest values
of c_{d_0} for values of c_l greater than 2.0.

Comparison of Flap Arrangements

A comparison of section profile-drag coefficients
for the 0.2566c and the 0.40c slotted flaps (references
1 and 2), the 0.30c Fowler flap (reference 3), and the
0.40c double slotted flap (reference 4) is presented in
figure 18 with the two envelope polars of the 0.30c
double slotted flap obtained from figure 17. This fig-
ure shows that although the maximum section lift coeffi-
cient of the 0.30c double slotted flap (3.30) is far
better than that obtained with either single slotted
flap, it is below the value of 3.46 obtained with the
0.40c double slotted flap and approximately equals the
value obtained with the 0.30c Fowler flap. This com-
parison also shows that the 0.30c double slotted flap
had a larger profile drag than any of the other arrange-
ments for section lift coefficients greater than 1.2 and
less than 2.7 but had a lower profile drag than either
single slotted flap at section lift coefficients higher
than 2.7. At all values of section lift coefficient,
the 0.30c double slotted flap had larger profile drag
than either the 0.30c Fowler or the 0.40c double slotted
flap arrangements.

The optimum-drag envelope polar of the 0.30c double
slotted flap had values of c_{d_0} that were somewhat lower
than those of the optimum lift polar; this difference in
c_{d_0} amounted to as much as 0.02 at $c_l = 2.9$. At section
lift coefficients less than 1.6 and higher than 3.1 the
polars for optimum lift and optimum drag, however, almost
coincide.

A comparison of the section pitching-moment coeffi-
cients at the maximum section lift coefficients for the
various flap arrangements previously discussed is given
in figure 19. The variation of $\left[c_{m(a.c.)_0}\right]_{c_{l_{max}}}$ with
$c_{l_{max}}$ appears to be dependent upon flap arrangement.
The arrangement reported herein gave higher values of
$\left[c_{m(a.c.)_0}\right]_{c_{l_{max}}}$ than any of the slotted flaps but its
values are approximately equal to those of the Fowler
arrangement.

The loss of airplane maximum section lift coeffi-cient in trimming the airfoil section pitching-moment coefficient is given by the expression

$$\text{Loss of } c_{l_{max}} = \frac{\left[c_{m(a.c.)_0} \right] c_{l_{max}}}{\text{tail length, } l_t}$$

Curves of loss of $c_{l_{max}}$ for tail lengths l_t of 2, 3, and 5 airfoil chord lengths are presented in figure 19 and can be used for determining the effective maximum section lift coefficient.

Effect of Various Modifications on

Aerodynamic Section Characteristics

Effect of moving the two flaps as a unit.- In fig-ures 20 and 21 are presented the aerodynamic section char-acteristics of the airfoil showing the effect of moving the rear flap and fore flap A as a unit. Figure 20 indi-cates that a 0.01c displacement of the flaps upward per-pendicular to the airfoil chord had only a small adverse effect; however, a 0.01c movement of the flaps downward was quite critical because greatly decreased values of c_l and increased values of c_{d_0} were obtained.

The effect of a forward movement of 0.01c of the flaps is shown in figure 21; only a slight effect in the aerodynamic characteristics was obtained.

From these data, it is indicated that some positions and deflections of the flaps are quite critical; that is, a movement of as little as 0.01c may appreciably alter the characteristics obtained.

Effect of the airfoil lower lip.- The effect of de-flecting or removing the lower lip of the airfoil from its normal position is indicated in figures 22 and 23 for different flap configurations. It is indicated in figures 22 and 23 that slightly more favorable section characteristics may be obtained by removing or deflecting the lip. The profile drag appears to be slightly less with the lip off than with the lip deflected. Such a result indicates that a smoother slot entry ahead of the flaps may be desirable. Although no data were obtained at small flap deflections, it is probable that the

smoother slot entry would be even more favorable under such conditions.

Effect of fore-flap size.- The effect of fore-flap size on the aerodynamic section characteristics is shown in figure 24. A comparison of the section characteristics of the airfoil for one configuration with fore flap B and two roughly comparable configurations with fore flap A indicates that the size of the fore flap has noticeable but small effects. The characteristics for the optimum position of fore flap B indicate values of c_l, c_{d_o}, and $c_{m(a.c.)_o}$ slightly greater than those of fore flap A at all angles of attack. With fore flap B, a value of $c_{l_{max}}$ of 3.35 was obtained, which is only 0.05 greater than the $c_{l_{max}}$ obtained with fore flap A. The configuration with the smaller fore flap that is more nearly geometrically similar to that of the larger fore flap (that is, with regard to airfoil fore-flap gap and fore-flap rear-flap gap) also gave higher values of the aerodynamic section characteristics at all angles of attack up to 6° than the optimum fore-flap-A configuration but gave lower values than the B configuration. The configuration with the smaller fore flap stalled, however, at a lower angle of attack and gave a value of $c_{l_{max}}$ of only 3.22.

CONCLUSIONS

Tests to determine the effect of flap position and deflection on the aerodynamic characteristics of an NACA 23012 airfoil with a double slotted flap having a chord 30 percent of the airfoil chord (0.30c) were conducted in the LMAL 7- by 10-foot tunnel. The results of these tests indicated that:

1. The use of a 0.30c double slotted flap on the NACA 23012 airfoil gave a maximum section lift coefficient of 3.30 which was larger than that of the 0.2566c and 0.40c single slotted flaps, equal to that of the 0.30c Fowler flap, but less than that of the 0.40c double slotted flap on the same airfoil.

2. The 0.30c double slotted flap gave profile-drag coefficients that were larger than those of the 0.2566c

and 0.40c single slotted flaps for section lift coefficients between 1.2 and 2.7 and were less than those of the single slotted flaps at values of section lift coefficients greater than 2.7; however, over the entire lift range, the present arrangement gave a higher profile drag than the 0.30c Fowler or 0.40c double slotted flaps.

3. The 0.30c double slotted flap gave negative section pitching-moment coefficients that were higher than those of the single and double slotted flaps but approximately equal to those of the Fowler flap at a given maximum section lift coefficient.

4. At high flap deflections and high section lift coefficients, a slight movement of the flaps from the optimum positions sometimes resulted in relatively large decreases in lift and increases in drag.

5. Removing or deflecting the airfoil lower lip improved the aerodynamic characteristics near maximum lift only slightly.

6. The use of a fore flap that was larger in both chord and thickness slightly increased the maximum section lift coefficient but also increased the section profile-drag and section pitching-moment coefficients.

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        Langley Field, Va.

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3. Lowry, John G.: Wind-Tunnel Investigation of an NACA 23012 Airfoil with Several Arrangements of Slotted Flaps with Extended Lips. T.N. No. 808, NACA, 1941.

4. Harris, Thomas A., and Recant, Isadore G.: Wind-Tunnel Investigation of NACA 23012, 23021, and 23030 Airfoils Equipped with 40-Percent-Chord Double Slotted Flaps. Rep. No. 723, NACA, 1941.

5. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. Rep. No. 412, NACA, 1931.

6. Jacobs, Eastman N., and Sherman, Albert: Airfoil Section Characteristics as Affected by Variations of the Reynolds Number. Rep. No. 586, NACA, 1937.

TABLE I

ORDINATES FOR AIRFOIL AND FLAPS

[Stations and ordinates in percent of airfoil chord]

NACA 23012 airfoil			Rear flap			Fore flap A			Fore flap B		
Station	Upper surface	Lower surface	Station	Upper surface	Lower surface	Station	Upper surface	Lower surface	Station	Upper surface	Lower surface
0	----	0	0	-1.29	-1.29	0	0	0	0	0	0
1.25	2.67	-1.23	.40	-.32	-2.05	.5	.81	-.71	1.39	1.72	-1.75
2.5	3.61	-1.71	.72	.04	-2.21	1.0	1.20	-.89	2.78	2.11	-1.97
5	4.91	-2.26	1.36	.61	-2.36	1.5	1.48	-.98	4.17	2.28	-1.78
7.5	5.80	-2.61	2.00	1.04	-2.41	2.0	1.69	-.98	5.56	2.30	-1.22
10	6.43	-2.92	2.64	1.40	-2.41	3.0	1.97	-.74	6.94	2.14	-.528
15	7.19	-3.50	3.92	1.94	-----	4.0	2.10	-.36	8.33	1.92	.222
20	7.50	-3.97	5.20	2.30	-----	5.0	2.12	.08	9.72	1.61	.667
25	7.60	-4.28	5.66	-----	-2.16	6.0	2.04	.44	11.11	1.25	.722
30	7.55	-4.46	6.48	2.53	-----	7.0	1.88	.69	12.50	.806	.50
40	7.14	-4.48	7.76	2.63	-----	8.0	1.61	.84	13.89	.306	.167
50	6.41	-4.17	9.03	2.58	-----	9.0	1.25	.80	14.67	0	-.052
60	5.47	-3.67	10.31	2.46	-----	10.0	.82	.54			
70	4.36	-3.00	15.66	1.68	-1.23	11.0	.34	.16			
80	3.08	-2.16	20.66	.92	-.70	11.67	----	.09			
90	1.68	-1.23	25.66	.13	-.13	11.70	0	-.10			
95	.92	-.70									
100	.13	-.13									

L. E. radius: 1.58
Slope of radius through end of chord: 0.305

L. E. radius: 0.91
Center of L. E. arc:
Upper surface, 0.91
Lower surface, -1.29

L. E. radius: 0.75
Center of L. E. radius located on chord line

L. E. radius: 1.58
Center of L. E. radius located on chord line

Figure 1.- The NACA 23012 airfoil with the 0.30 c double slotted flap.

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.1170c

Chord line

Fore flap A

.1467c

Chord line
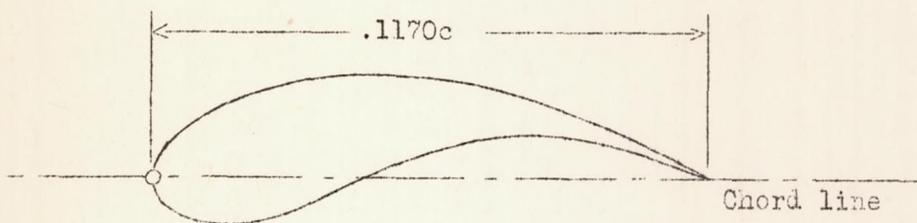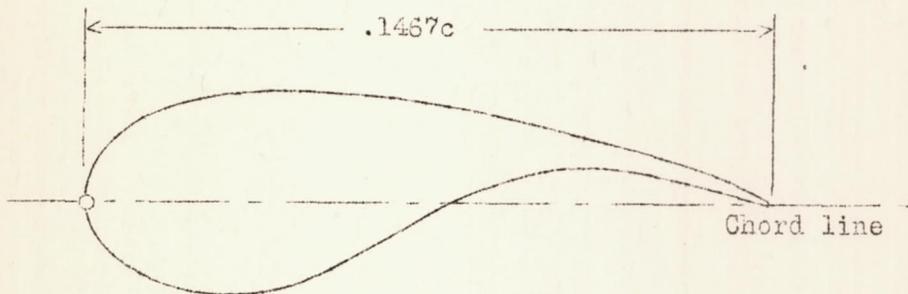
Fore flap B

Figure 2.- Sections of the two fore flaps used in
the investigation.

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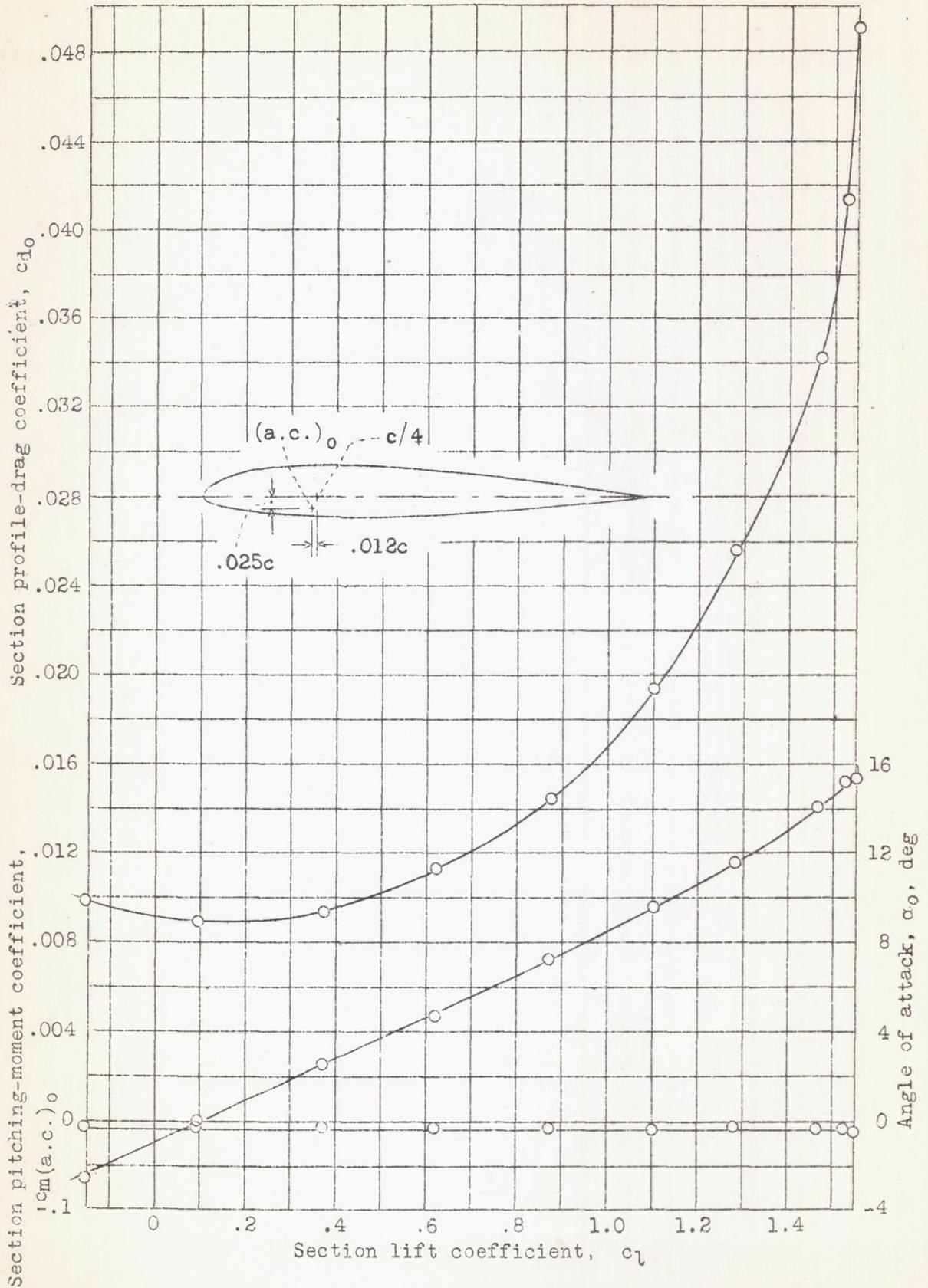
Figure 3.- Aerodynamic section characteristics of NACA 23012 plain
airfoil. (From reference 1.)

(a) $\delta_{f_2} = 10°$.

(b) $\delta_{f_2} = 20°$.
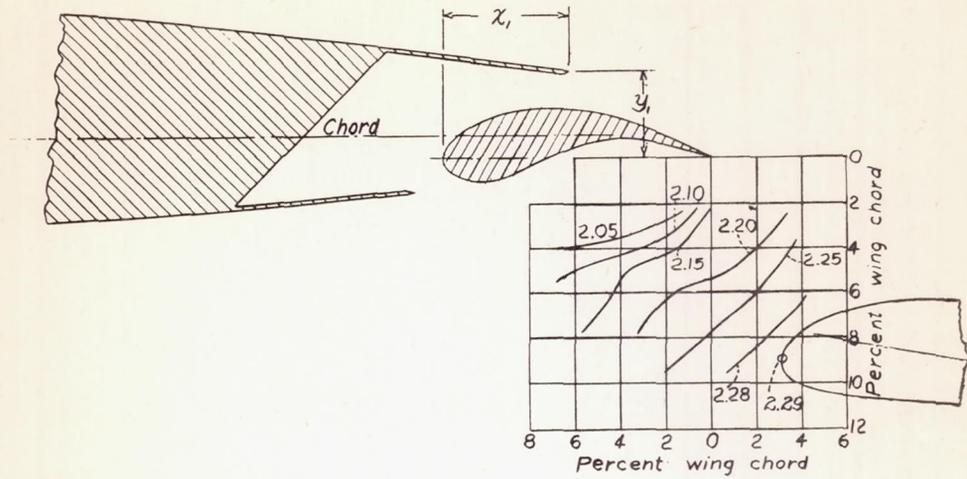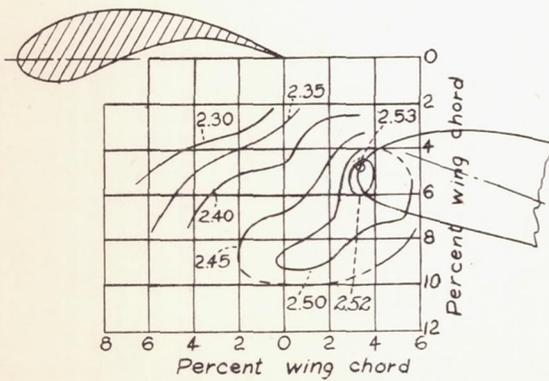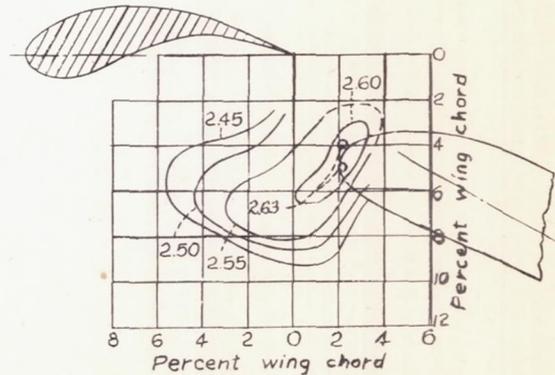
(c) $\delta_{f_2} = 30°$.

Figure 4.- Contours of rear-flap position for $c_{l\,max}$. Fore flap A, position 1; $\delta_{f_1} = 0°$; $x_1 = 5.59$; $y_1 = 3.72$. (Values of x_1, y_1 are given in percent airfoil chord.)

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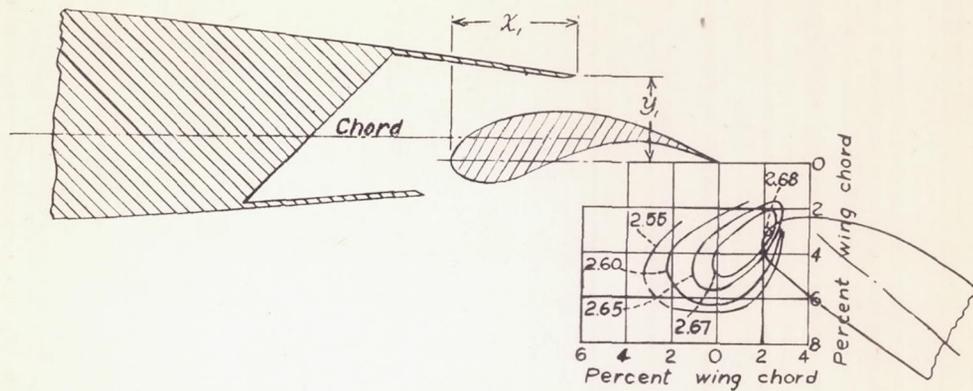
(d) $\delta_{f_2} = 40°$.
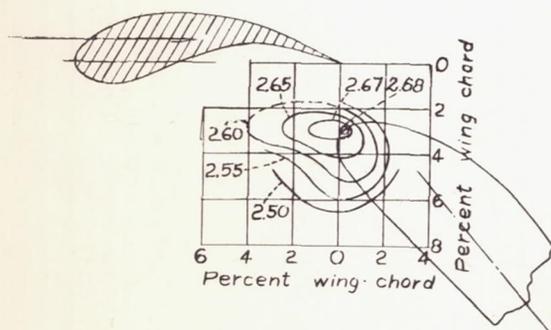
(e) $\delta_{f_2} = 50°$.
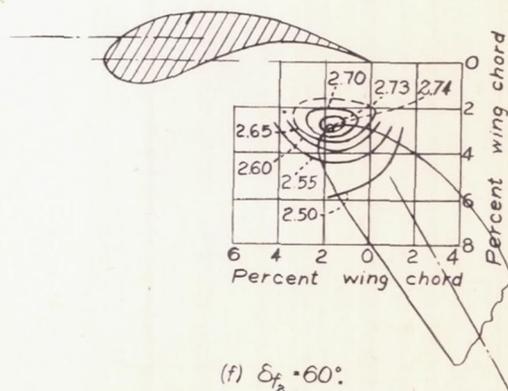
(f) $\delta_{f_2} \cdot 60°$.

Figure 4.- Concluded.

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(a) $\delta_{f_2}=30°$

(b) $\delta_{f_2}=40°$.

(c) $\delta_{f_2}=50°$.

(d) $\delta_{f_2}=60°$.
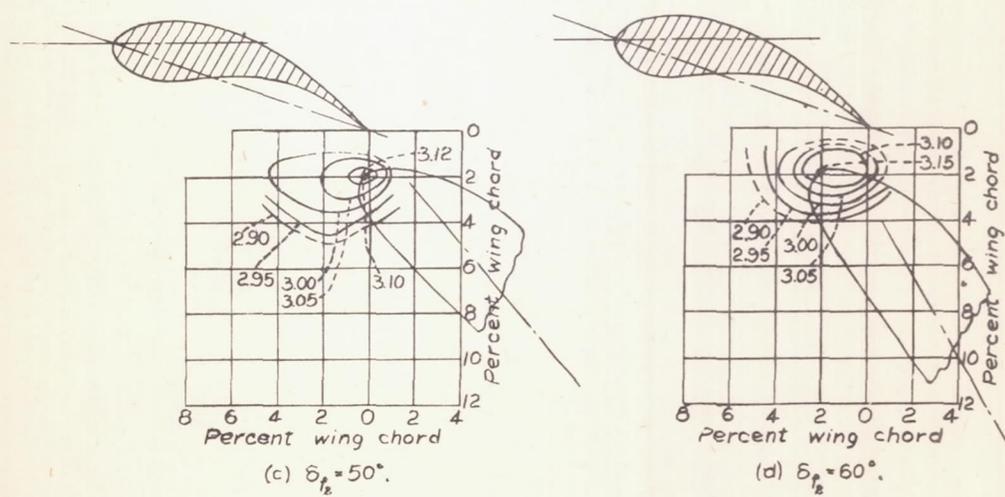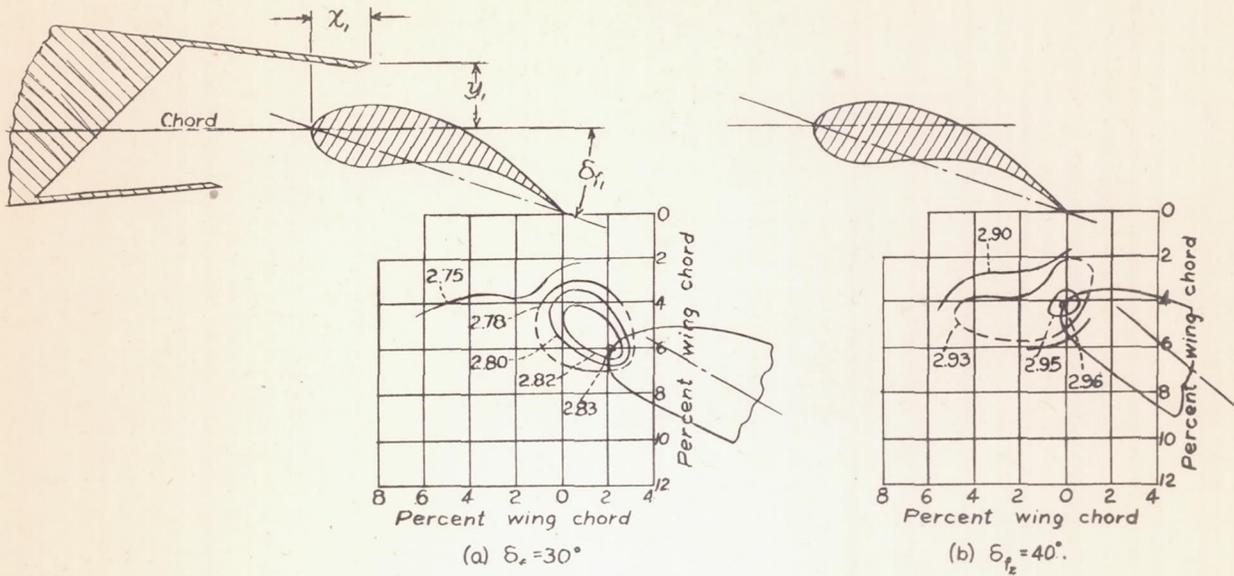
Figure 5.- Contours of rear-flap position for c_{2max}. Fore flap A, position 2; $\delta_{f_1}=20°$; $x_1=2.59$; $y_1=2.72$. (Values of x_1, y_1 are given in percent airfoil chord.)
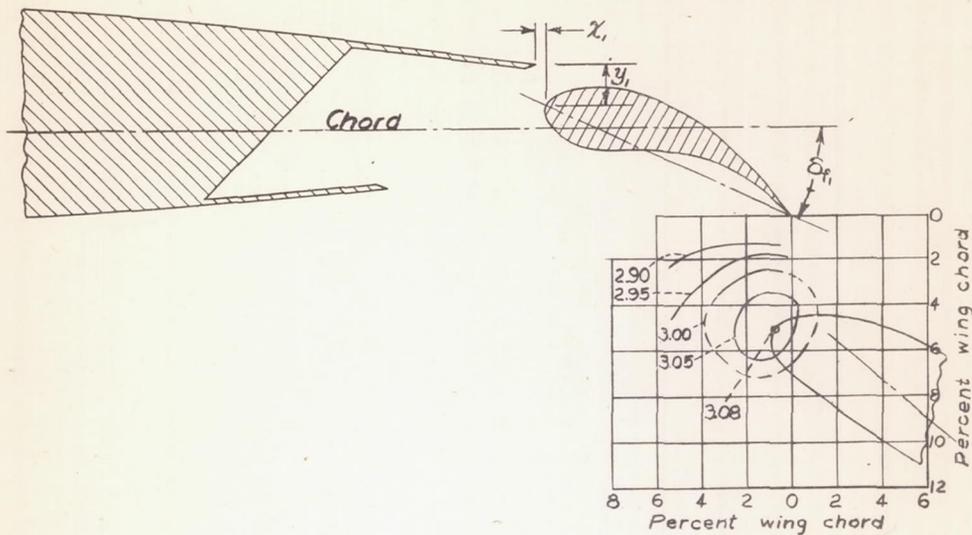
(a) $\delta_{f_2} = 40°$.
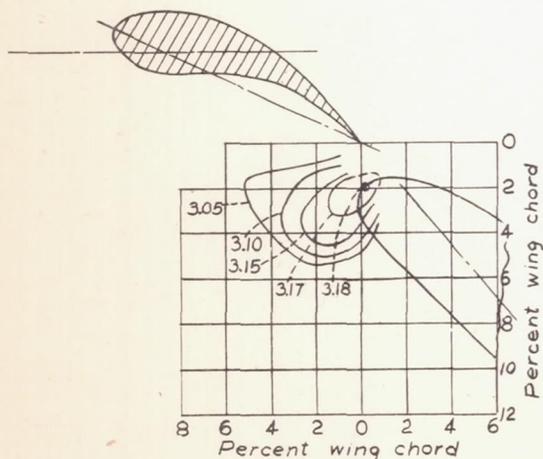
(b) $\delta_{f_2} = 50°$.
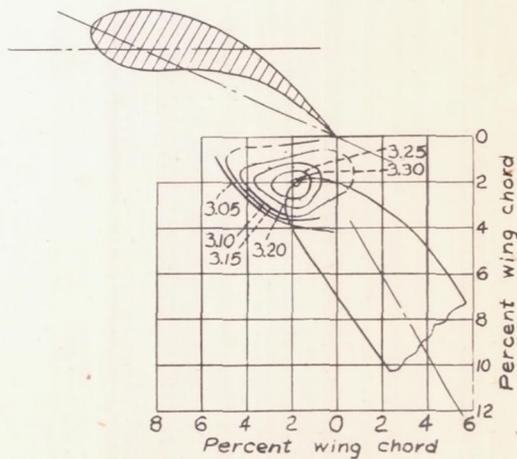
(c) $\delta_{f_2} = 60°$.

Figure 6.- Contours of rear-flap position for c_{2max}. Fore flap A, position 3; $\delta_{f_1} = 25°$; $x_1 = -0.41$; $y_1 = 1.72$. (Values of x_1, y_1 are given in percent airfoil chord.)

(a) $c_l = 1.0$; $\delta_{f_2} = 10°$

(b) $c_l = 1.0$; $\delta_{f_2} = 20°$.

(c) $c_l = 1.5$; $\delta_{f_2} = 20°$.

(d) $c_l = 1.5$; $\delta_{f_2} = 30°$.
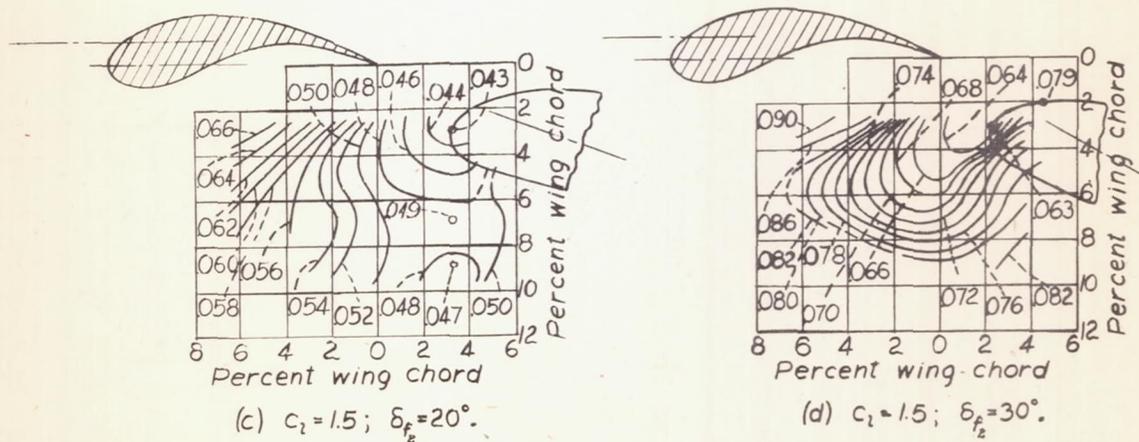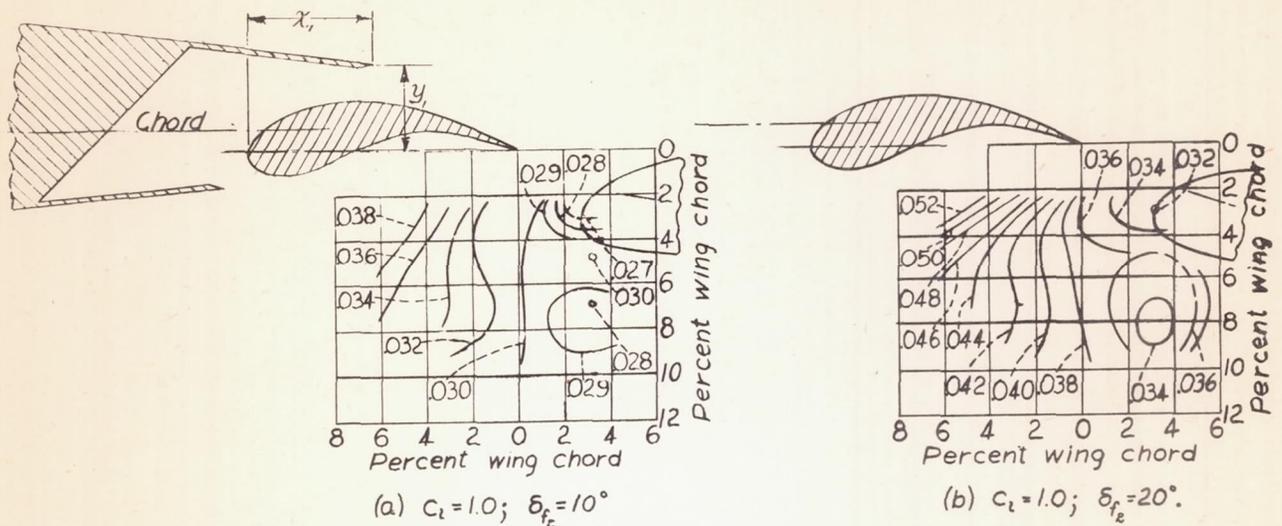
Figure 7.- Contours of rear-flap position for c_{d_0}. Fore flap A, position 1; $\delta_{f_1} = 0°$; $x_1 = 5.59$; $y_1 = 3.72$. (Values of x_1, y_1 are given in percent airfoil chord.)

(a) $c_l = 1.5$; $\delta_{f_2} = 30$.

(b) $c_l = 2.0$; $\delta_{f_2} = 30°$.

(c) $c_l = 2.0$; $\delta_{f_2} = 40°$.
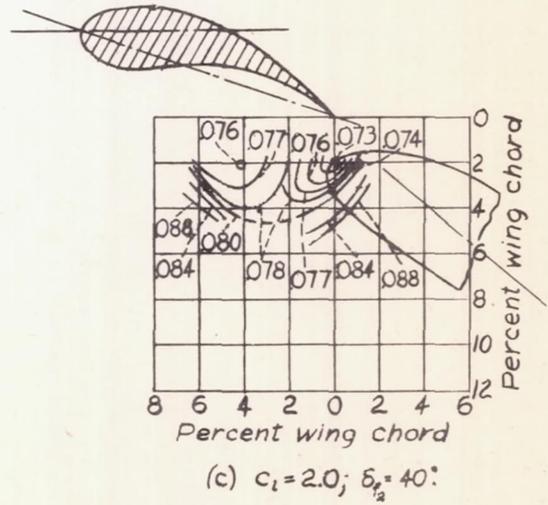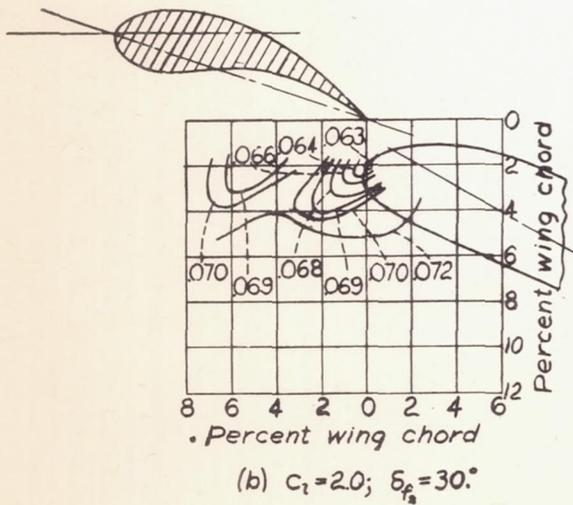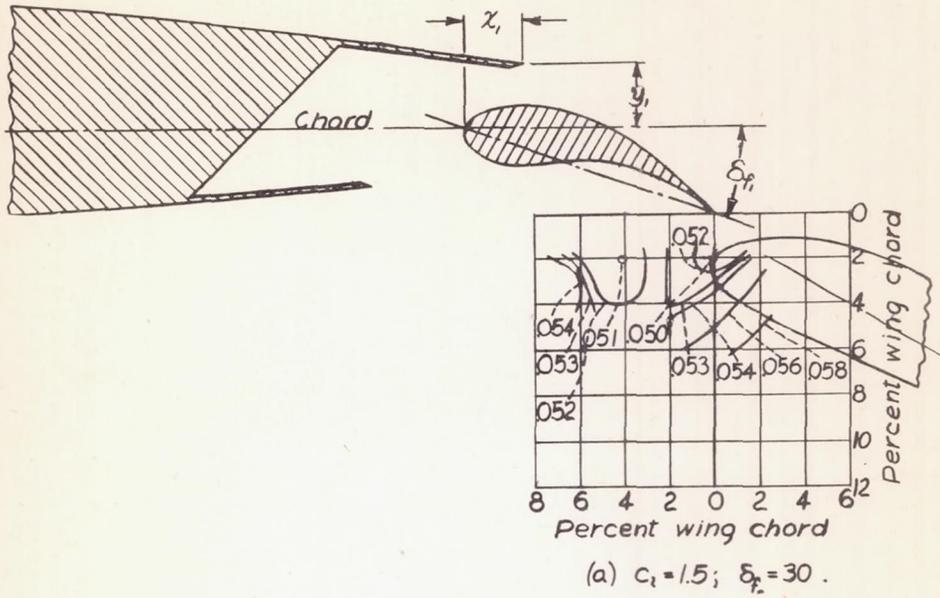
Figure 8.—Contours of rear-flap position for c_{d_0}. Fore flap A,
position 2; $\delta_{f_1} = 20°$; $x_1 = 2.59$; $y_1 = 2.72$. (Values of x_1, y_1 are
given in percent airfoil chord.)
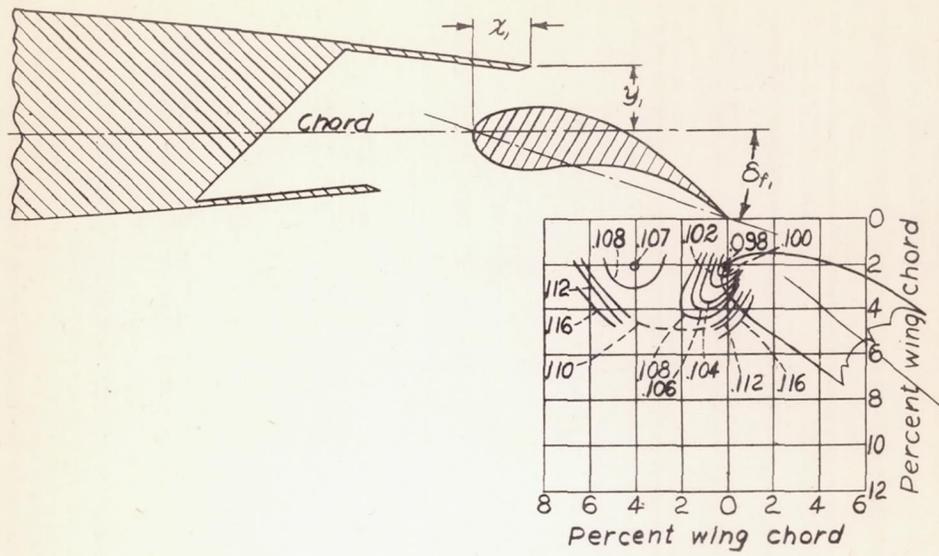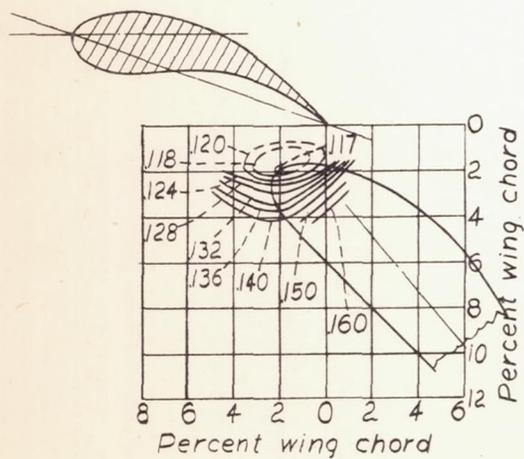
(d) $c_l = 2.5$; $\delta_{f_2} = 40°$
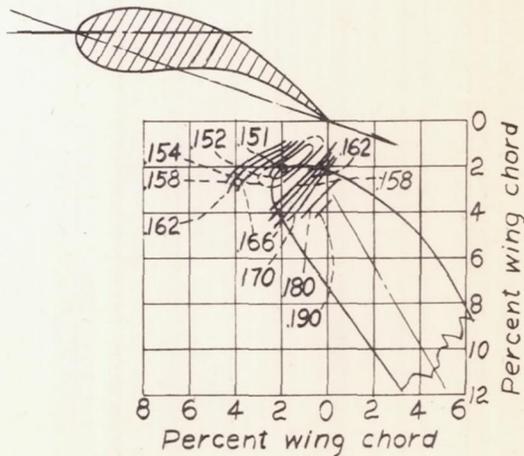
(e) $c_l = 2.5$; $\delta_{f_2} = 50°$.

(f) $c_l = 2.5$; $\delta_{f_2} = 60°$.

Figure 8.- Concluded.

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(a) $c_l = 2.0$; $\delta_{f_a} = 40.°$

Percent wing chord

(b) $c_l = 2.5$; $\delta_{f_2} = 40.°$
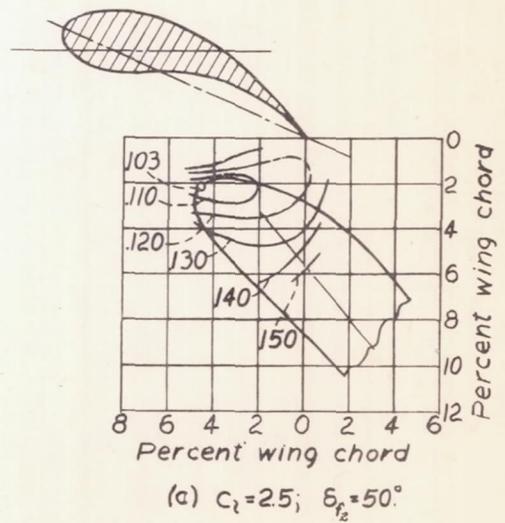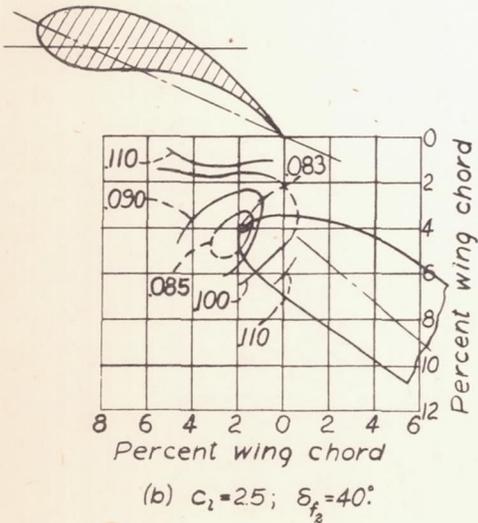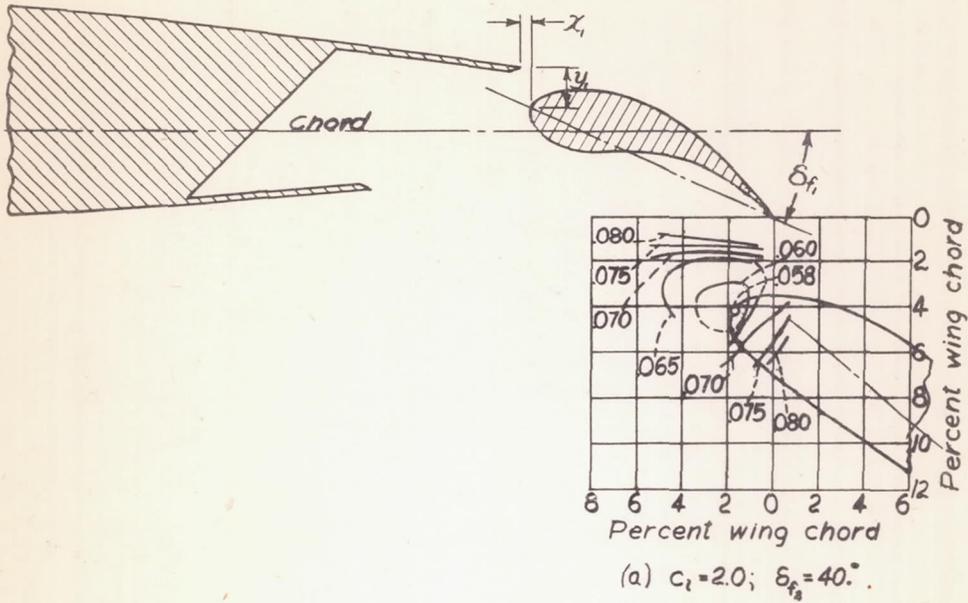
(a) $c_l = 2.5$; $\delta_{f_2} = 50.°$

Figure 9. - Contours of rear-flap position for c_{d_o}. Fore flap A, position 3; $\delta_{f_1} = 25°$; $x_1 = -0.41$; $y_1 = 1.72$. (Values of x_1, y_1 are given in percent airfoil chord.)
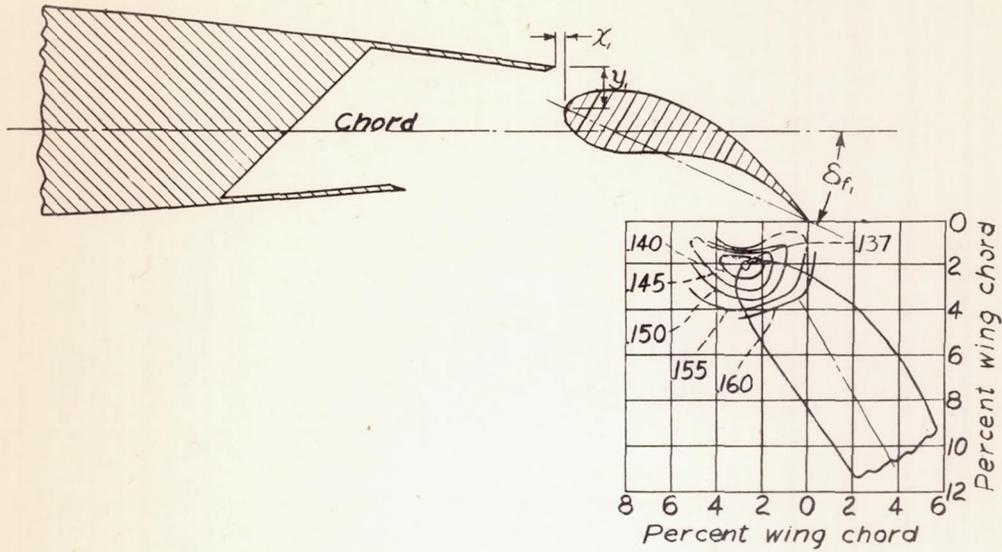
(d) $c_l = 2.5$; $\delta_{f_2} = 60°$.
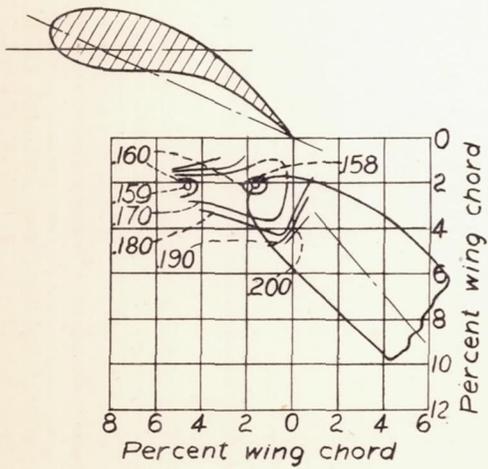
(e) $c_l = 3.0$; $\delta_{f_2} = 50°$.
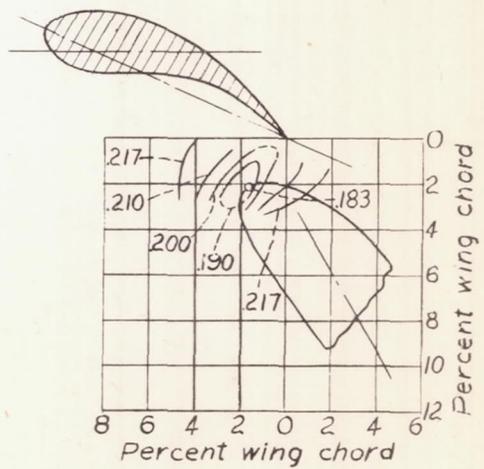
(f) $c_l = 3.0$; $\delta_{f_2} = 60°$.

Figure 9. - Concluded.

(a) $c_l = 1.0$; $\delta_{f_2} = 10°$.

(b) $c_l = 1.0$; $\delta_{f_2} = 20°$.

(c) $c_l = 1.5$; $\delta_{f_2} = 20°$.

(d) $c_l = 1.5$; $\delta_{f_2} = 30°$.
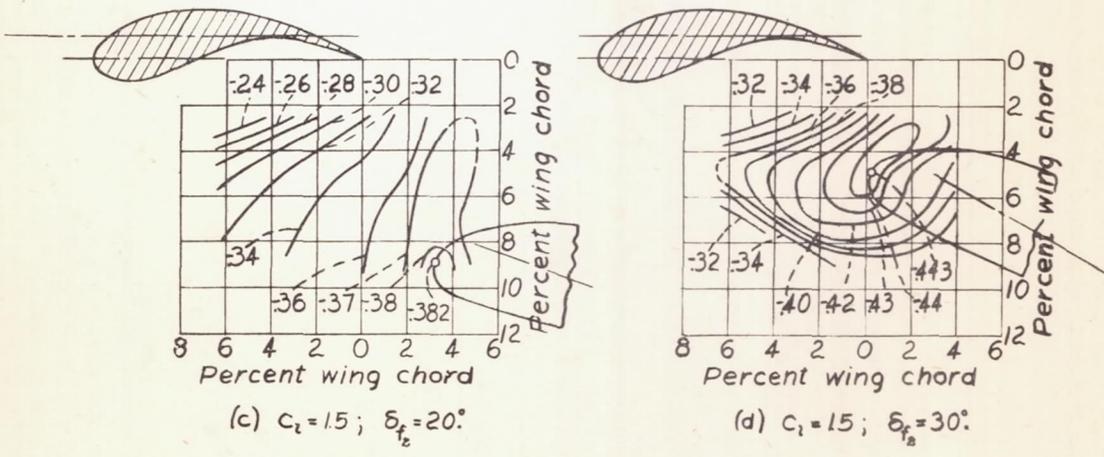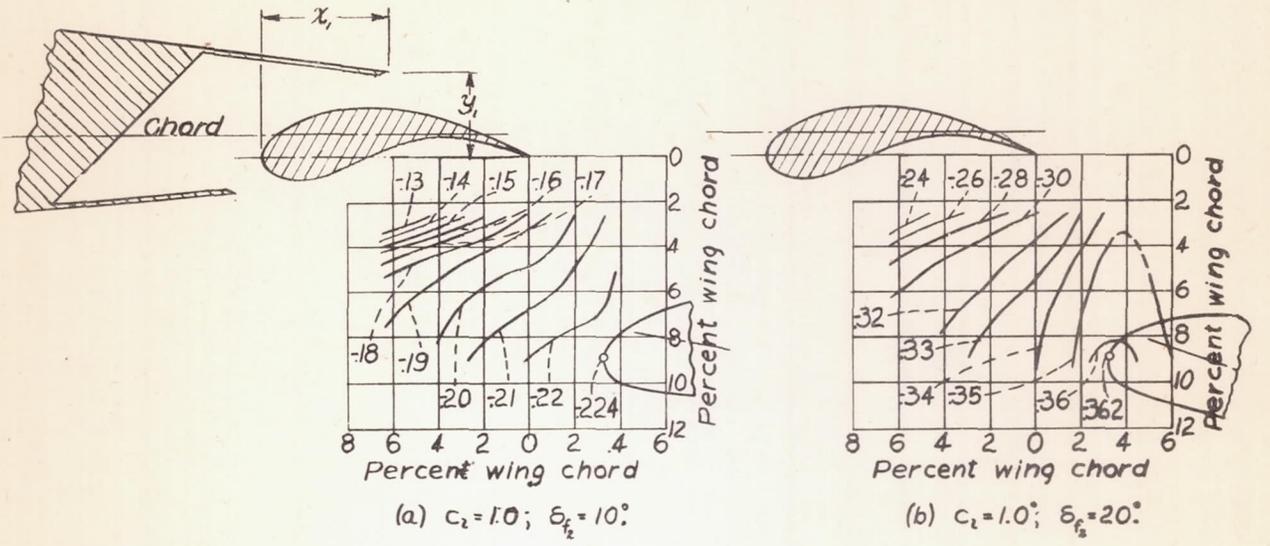
Figure 10.- Contours of rear-flap position for $c_{m(a.c.)_o}$. Fore flap A, position 1; $\delta_f = 0°$; $x_1 = 5.59$; $y_1 = 3.72$. (Values of x_1, y_1 are given in percent airfoil chord.)

(a) $c_l = 1.5$; $\delta_{f_2} = 30°$.

(b) $c_l = 2.0$; $\delta_{f_2} = 30°$.

(c) $c_l = 2.0$; $\delta_{f_2} = 40°$.
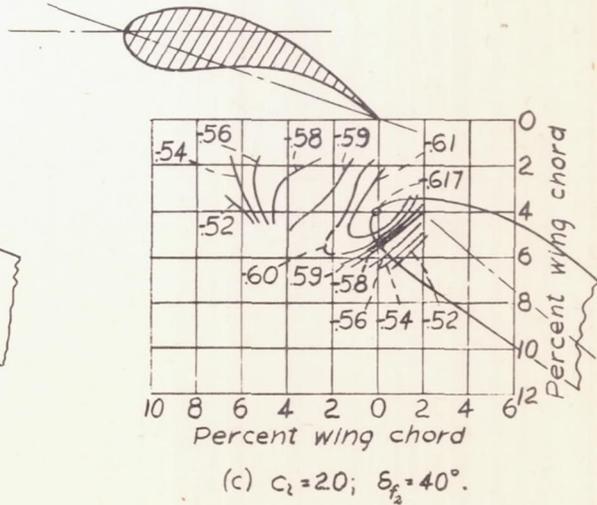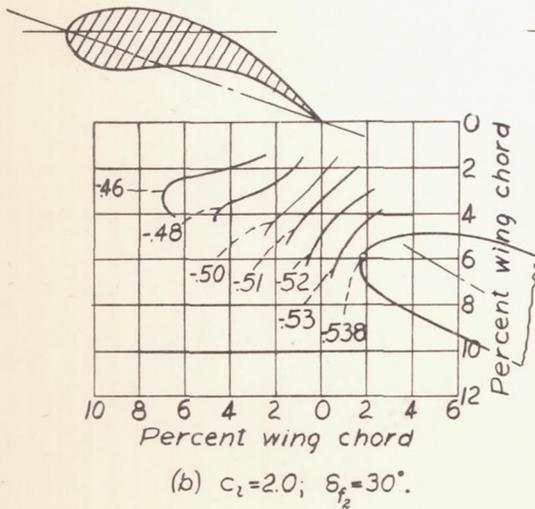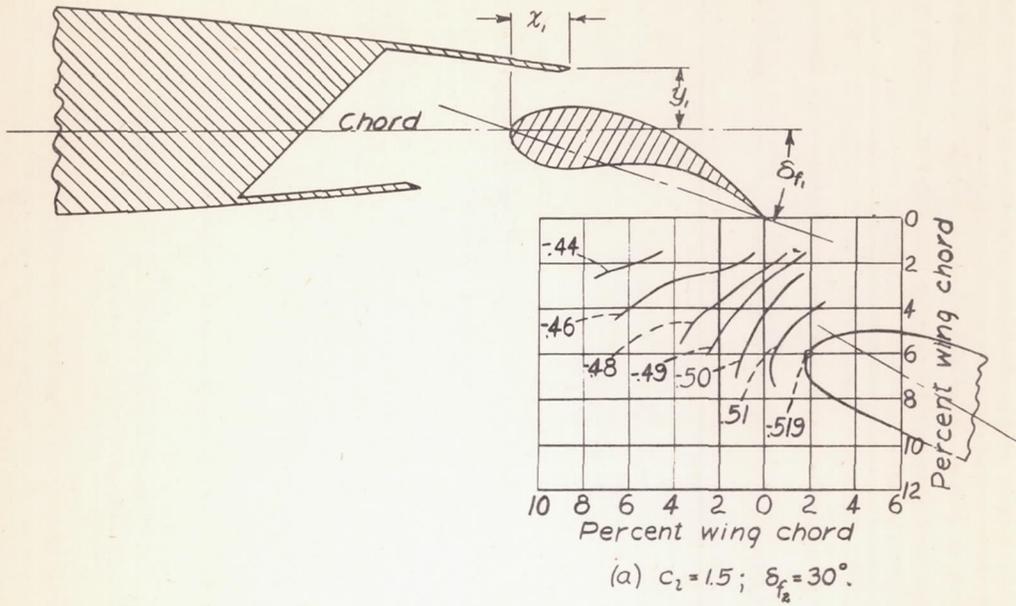
Figure 11.- Contours of rear-flap position for $c_{m(a.c.)}$. Fore flap A, position 2; $\delta_{f_1} = 20°$; $x_1 = 2.59$; $y_1 = 2.72$. (Values of x_1, y_1 are given in percent airfoil chord.)

(d) $c_l = 2.5$; $\delta_{f_2} = 40°$.

(e) $c_l = 2.5$; $\delta_{f_2} = 50°$.

(f) $c_l = 2.5$; $\delta_{f_2} = 60°$.

Figure 11.- Concluded

(a) $c_l = 2.0$; $\delta_{f_2} = 40°$.

(b) $c_l = 2.5$; $\delta_{f_2} = 40°$.

(c) $c_l = 2.5$; $\delta_{f_2} = 50°$.
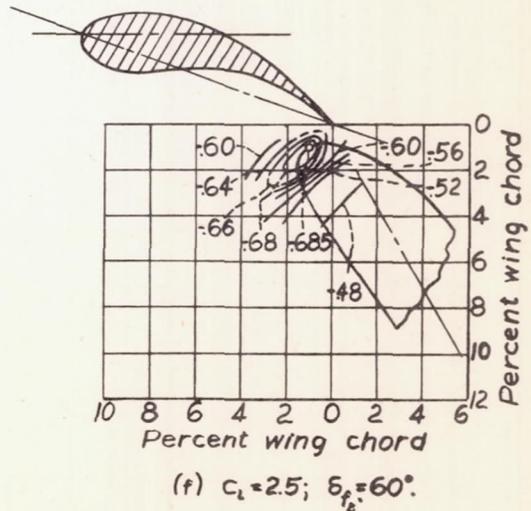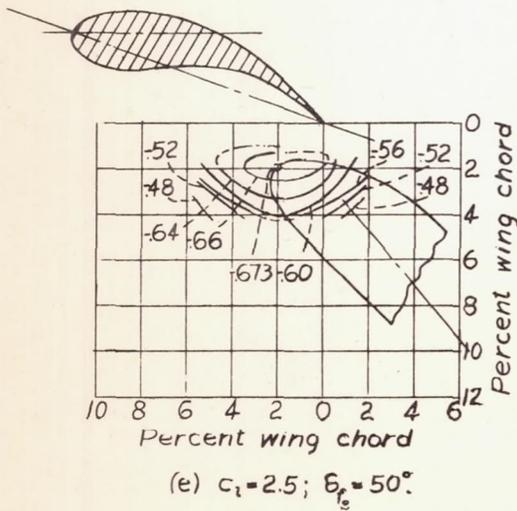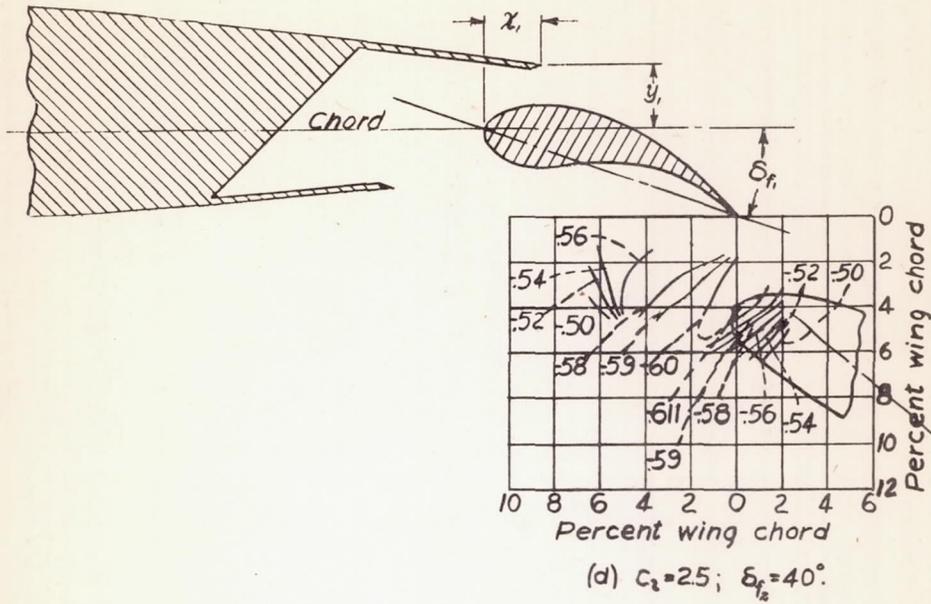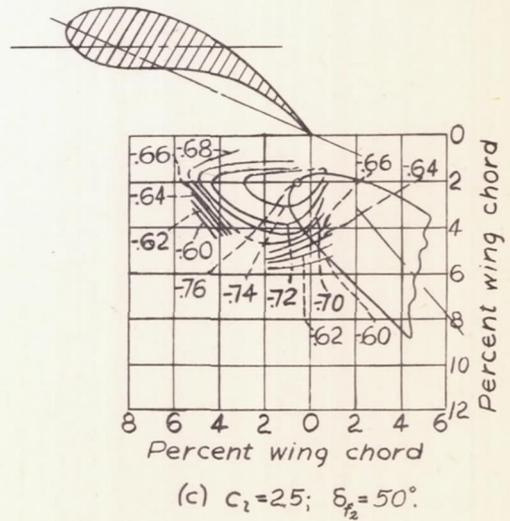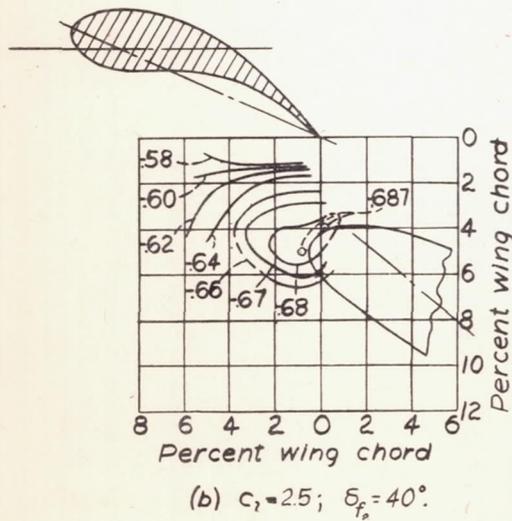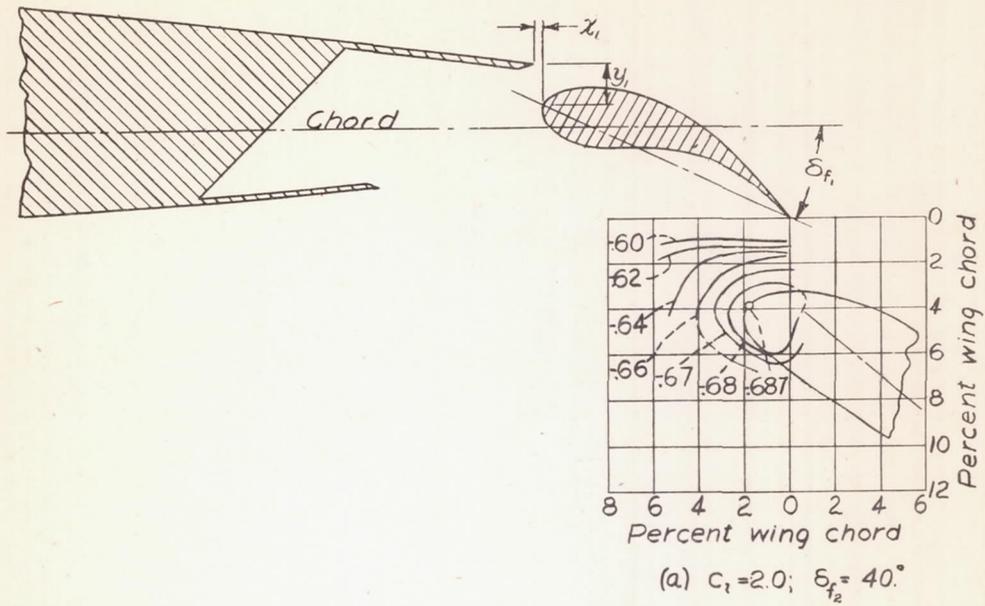
Figure 12.- Contours of rear-flap position for $c_{m(a.c.)_0}$. Fore flap A, position 3; $\delta_{f_1} = 25°$; $x_1 = -0.41$; $y_1 = 1.72$. (Values of x_1, y_1 are given in percent airfoil chord.)

(d) $c_l = 2.5$; $\delta_{f_2} = 60°$.

(e) $c_l = 3.0$; $\delta_{f_2} = 50°$.

(f) $c_l = 3.0$; $\delta_{f_2} = 60°$.

Figure 12. - Concluded.

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Chord

δ_{t_2}, deg | 10 | 20 | 30 | 40 | 50 | 60

x_2 | -3.30 | -3.30 | -2.30 | -2.30 | -0.30 | 1.70

y_2 | 9.00 | 5.00 | 4.00 | 3.00 | 3.00 | 3.00

(1 block = 10 divisions on 1/40 Eng. scale)

δ_{t_2}, deg

60
50
40
30
20
10

δ_{t_2}, deg

60
50
40
30
20
10

Section lift coefficient, c_l
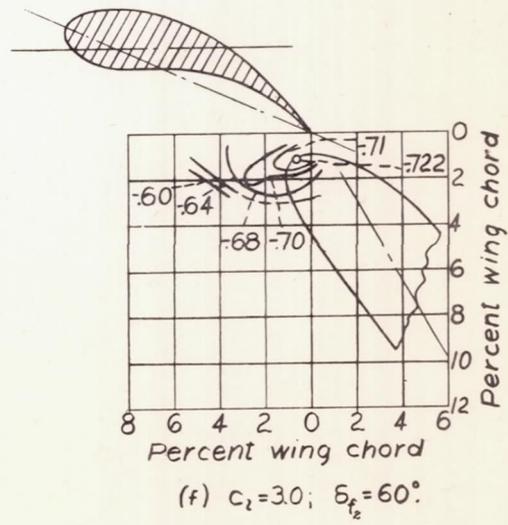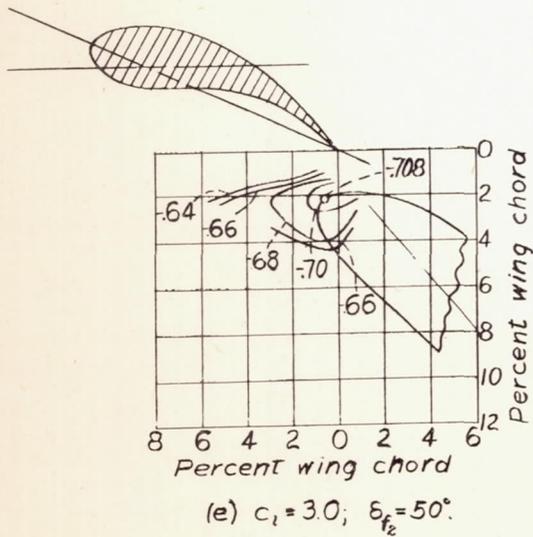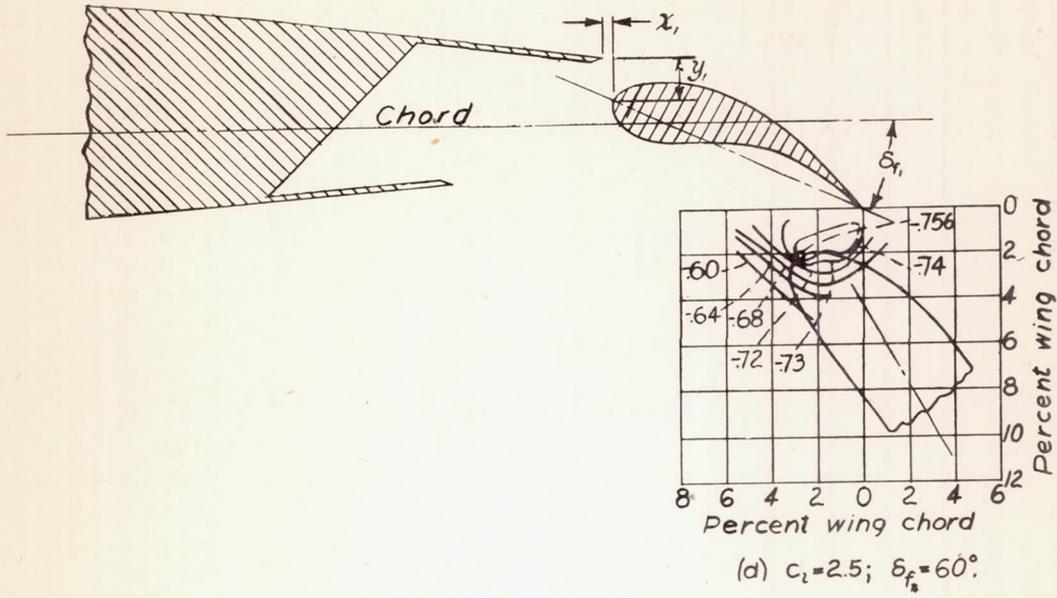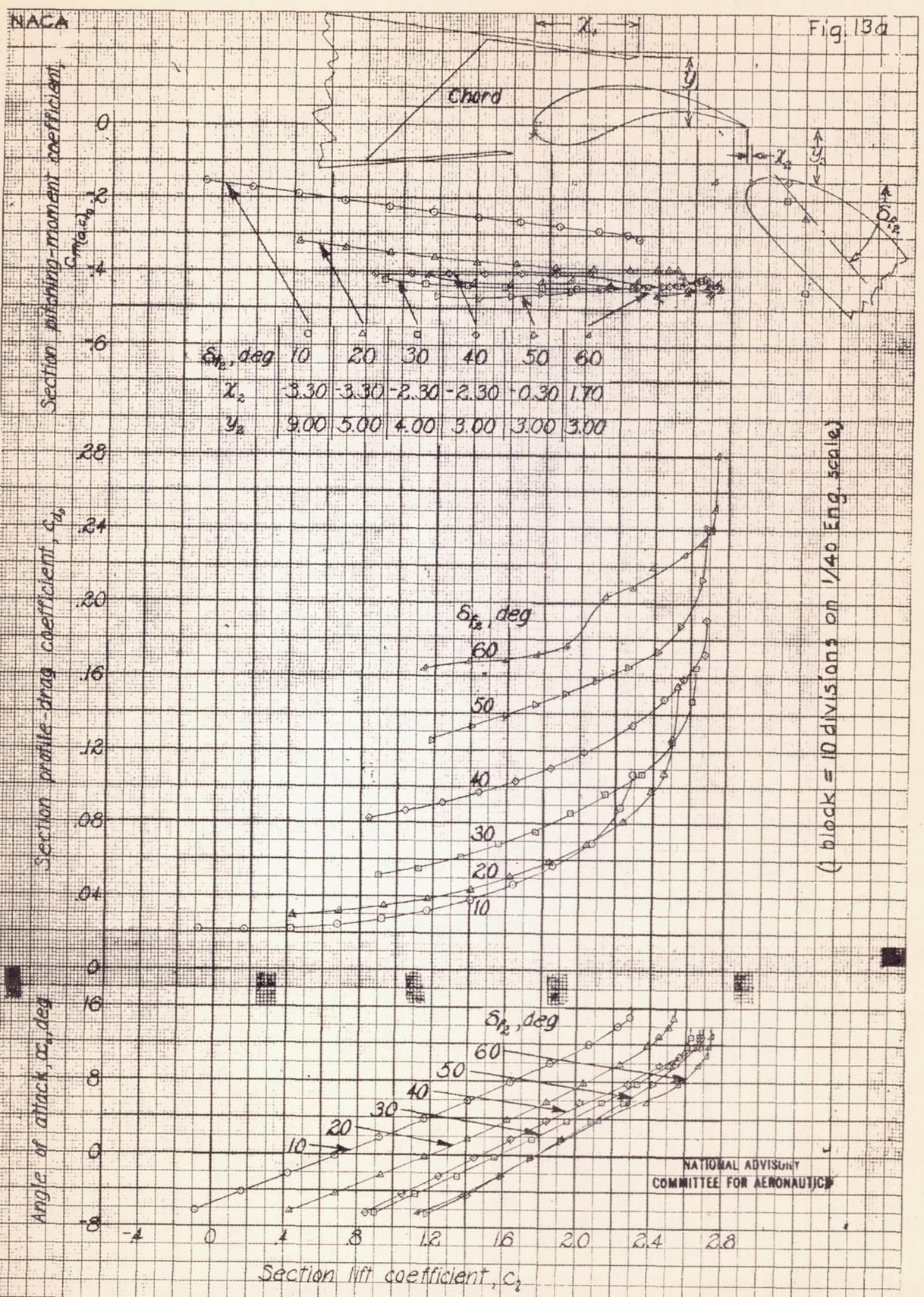
(a) Rear-flap positions for $c_{l max}$.

Figure 13.- Aerodynamic section characteristics of NACA 23012 airfoil with a 0.30c double slotted flap. Fore flap A, position 1; $\delta_c = 0°$; $x_1 = -5.59$, $y_1 = 3.72$. (Values of x_1, y_1 and x_2, y_2 are given in percent airfoil chord.)

(b) Rear-flap positions for $c_{d_{0 min}}$.   Figure 13.- Concluded.

Figure 14.- Aerodynamic section characteristics of NACA 23012 airfoil with a 0.30c double slotted flap. Fore flap A, position 2; $\delta_f = 20°$; $x_1 = 2.59$, $y_1 = 2.72$. (Values of x, y, and x_2, y_2 are given in percent airfoil chord.)

(d) Rear flap positions for $c_{l\,max}$.

(b) Rear-flap positions for $c_{d_{0\,min}}$.   (Figure 14. - Concluded)

δ_{f_2}, deg	30	40	50	60
z_2	2.00	2.00	2.00	2.00
y_2	0	0	2.00	2.00

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Chord

χ_1, y_1

δ_{f_1}

χ_2 y_2

δ_{f_2}

Section pitching-moment coefficient, $c_{m(a.c.)_0}$

Section profile-drag coefficient, c_{d_0}

Angle of attack, α_0, deg

δ_{f_2}, deg	40	50	60	70
χ_2	0.60	-.40	1.60	1.60
y_2	5.05	2.05	2.05	1.05

δ_{f_2}, deg
70
60
50
40

(1 block = 10/40")

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δ_{f_2}, deg
40 50 60 70

Section lift coefficient, c_l

(a) Rear-flap positions for $c_{l_{max}}$.

Figure 15.- Aerodynamic section characteristics of the NACA 23012 airfoil with a 0.30c double slotted flap. Fore flap A, position 3; δ_{f_1}=25°; χ_1=0.41; y_1=1.72. (Values of χ_1, y_1, and χ_2, y_2 are given in percent airfoil chord.)

(b) Rear-flap positions for $c_{d_0 min}$.   Figure 15.- Concluded.

Figure 16.- Effect of rear-flap deflection on the increment of maximum section lift coefficient. The 0.30c double slotted flap on an NACA 23012 airfoil; fore flap A.
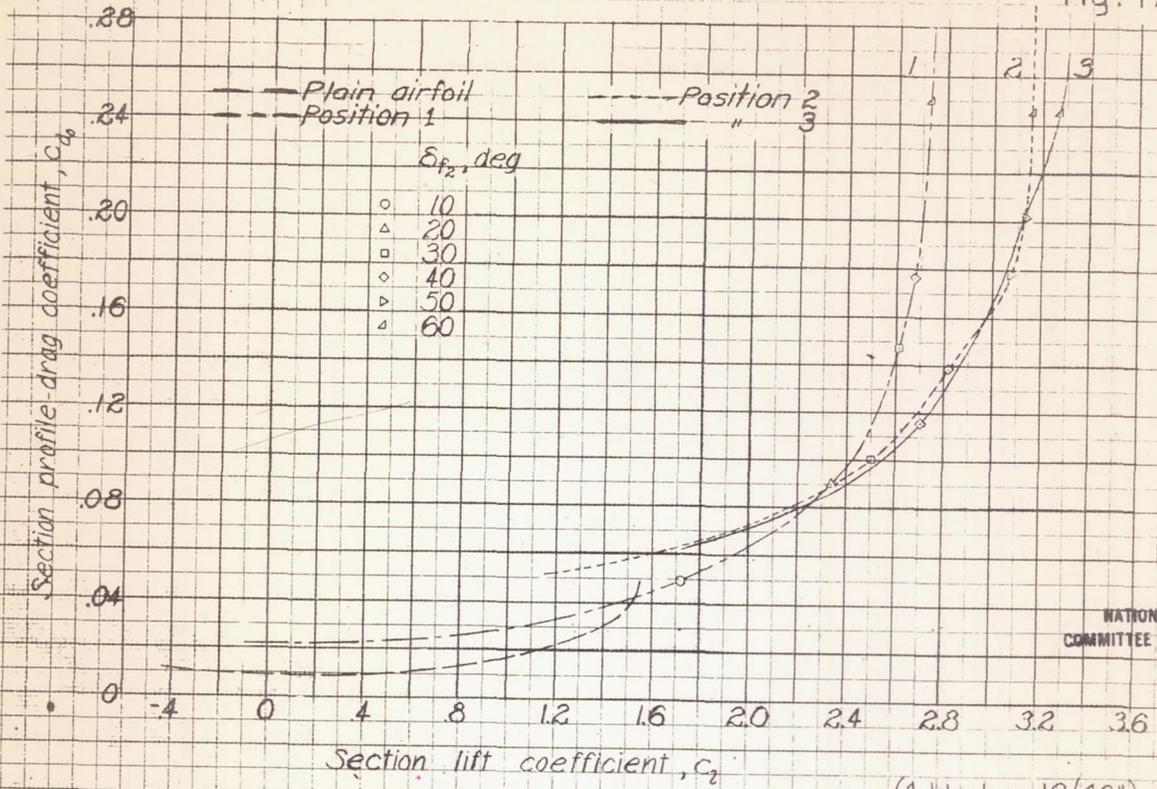
Fig. 16

(a) Rear-flap positions for $c_{l_{max}}$

(1 block = 10/40")

Figure 17.- Profile-drag envelope polar curves for the NACA 23012 airfoil with a 0.30 c double slotted flap. Fore flap A.
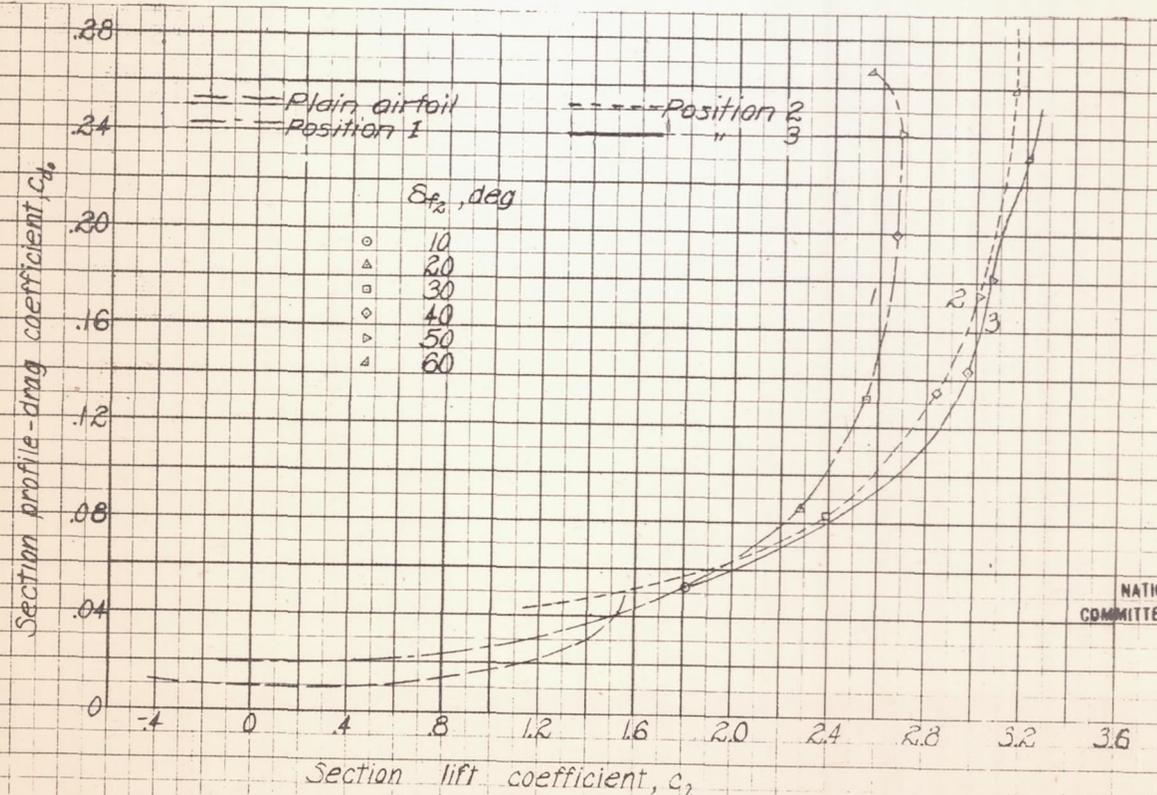
(b) Rear-flap positions for $c_{d_{o min}}$.   Figure 17.- Concluded.
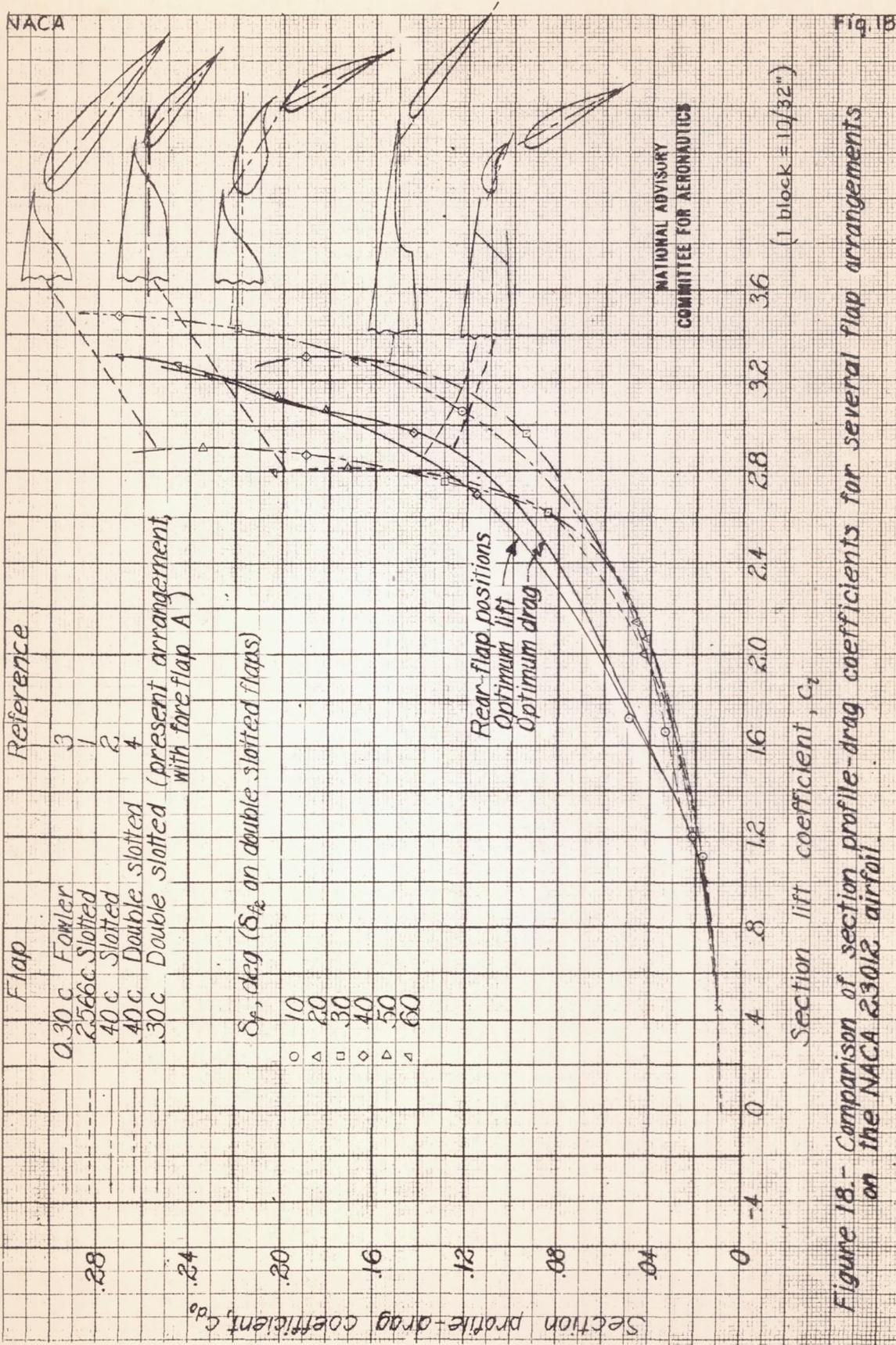
Figure 18.— Comparison of section profile-drag coefficients for several flap arrangements on the NACA 23012 airfoil.

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Flap   Ref.
◇ 0.30c Fowler flap   3
▽ 0.2566c Slotted flap (flap 3h)   1
△ 0.40c Slotted flap (flap 1b)   2
▽ 0.40c Double slotted flap   4
○ Fore A, position 1 } 0.30c double slotted
△ flap A, position 2 } flap (present
□ flap [A, position 3] arrangement)
                        (B
ᗡ flap [A, position 3] arrangement)
+ Plain airfoil

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(1 block = 10/32²)

Loss in $c_{q_{max}}$ in trimming
airplane with:
— Tail length, $l_t = 2c$
— Tail length, $l_t = 3c$
— Tail length, $l_t = 5c$

Maximum section lift coefficient, $c_{l_{max}}$

Section pitching-moment coefficient, $[c_{m(a.c.)}]_{l_{max}}$

Figure 19.- Section pitching-moment coefficient at the maximum section lift coefficient
for several flap arrangements on the NACA 23012 airfoil.

Figure 20.- Aerodynamic section characteristics of the NACA 23012 airfoil with a 0.30 c double slotted flap showing the effect of moving the two flaps as a unit perpendicular to airfoil chord. Fore flap A; $\delta_{f_1} = 25°$, $\delta_{f_2} = 60°$, $x_2 = 1.60$, $y_2 = 2.05$ (values of x_1, y_1 and x_2, y_2 are given in percent airfoil chord.)

Fig. 21
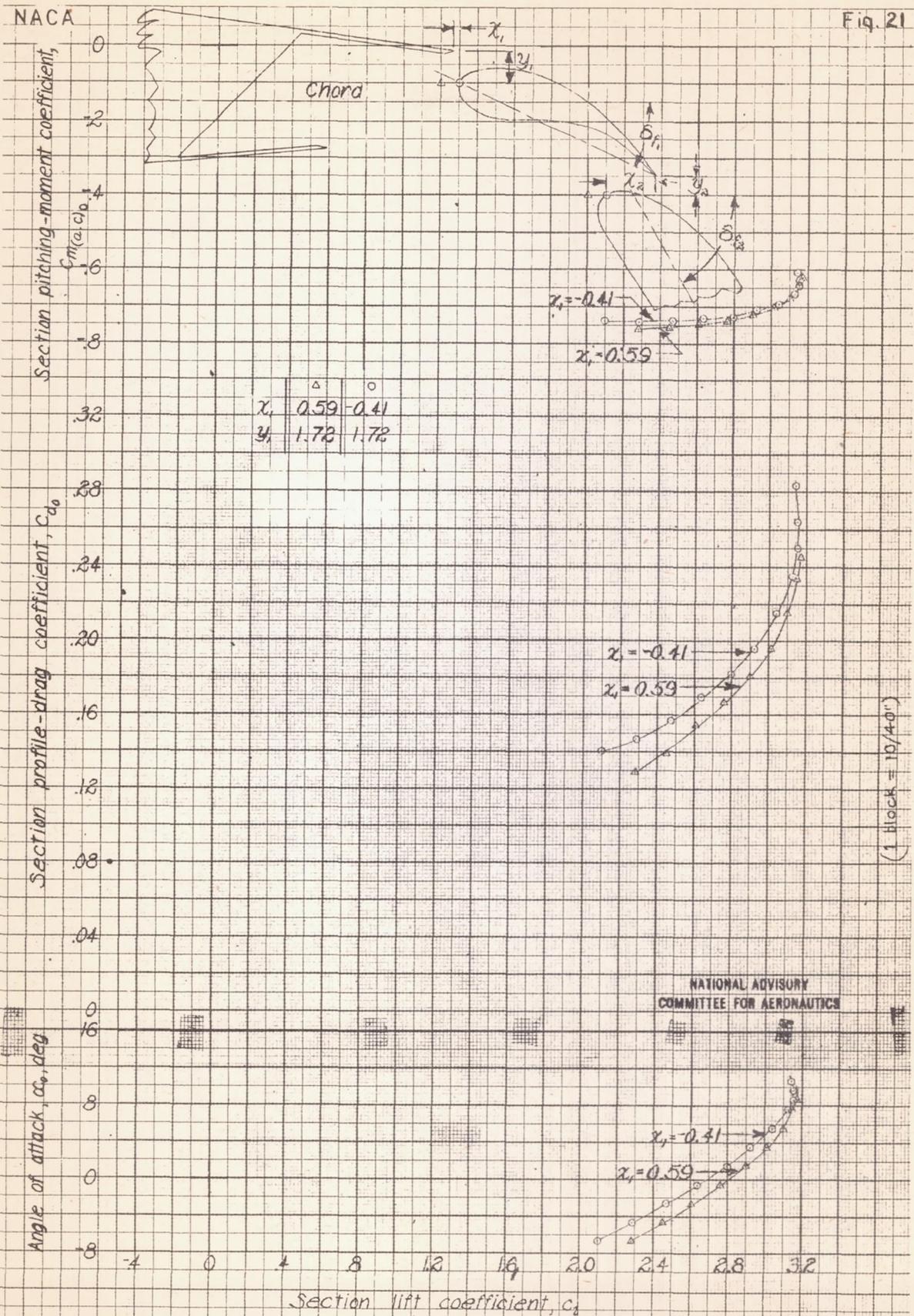
Figure 21.- Aerodynamic section characteristics of the NACA 23012 airfoil with a 0.30c double slotted flap showing the effect of moving the two flaps as a unit parallel to airfoil chord. Fore flap A; δ_{f_1}=25°, δ_{f_2}=60°, x_0=2.60; y_0=1.05 (Values of x_1, y_1 and x_2, y_2 are given in percent airfoil chord.)

Chord

Airfoil
lower lip

Section pitching-moment coefficient, $c_{m_{(a.c.)_0}}$

Section profile-drag coefficient, c_{d_0}

Angle of attack, α_0, deg

o On
△ Off
□ Deflected (13.5°)

On
Off
Deflected

Deflected
Off
On

Deflected
Off
On

(1 block = 10/40")

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Section lift coefficient, c_l

Figure 22. Aerodynamic section characteristics of the NACA 23012 airfoil with a 0.30c double slotted flap showing the effect of the airfoil lower lip. Fore flap A position 3; $\delta_f = 25°$; $x_1 = -0.41$; $y_1 = 1.72$; $\delta_{f_2} = 60°$; $z_2 = 1.60$; $y_2 = 2.05$. (Values of $x_1, y_1,$ and z_3, y_2 are given in percent airfoil chord.)

Fig. 23
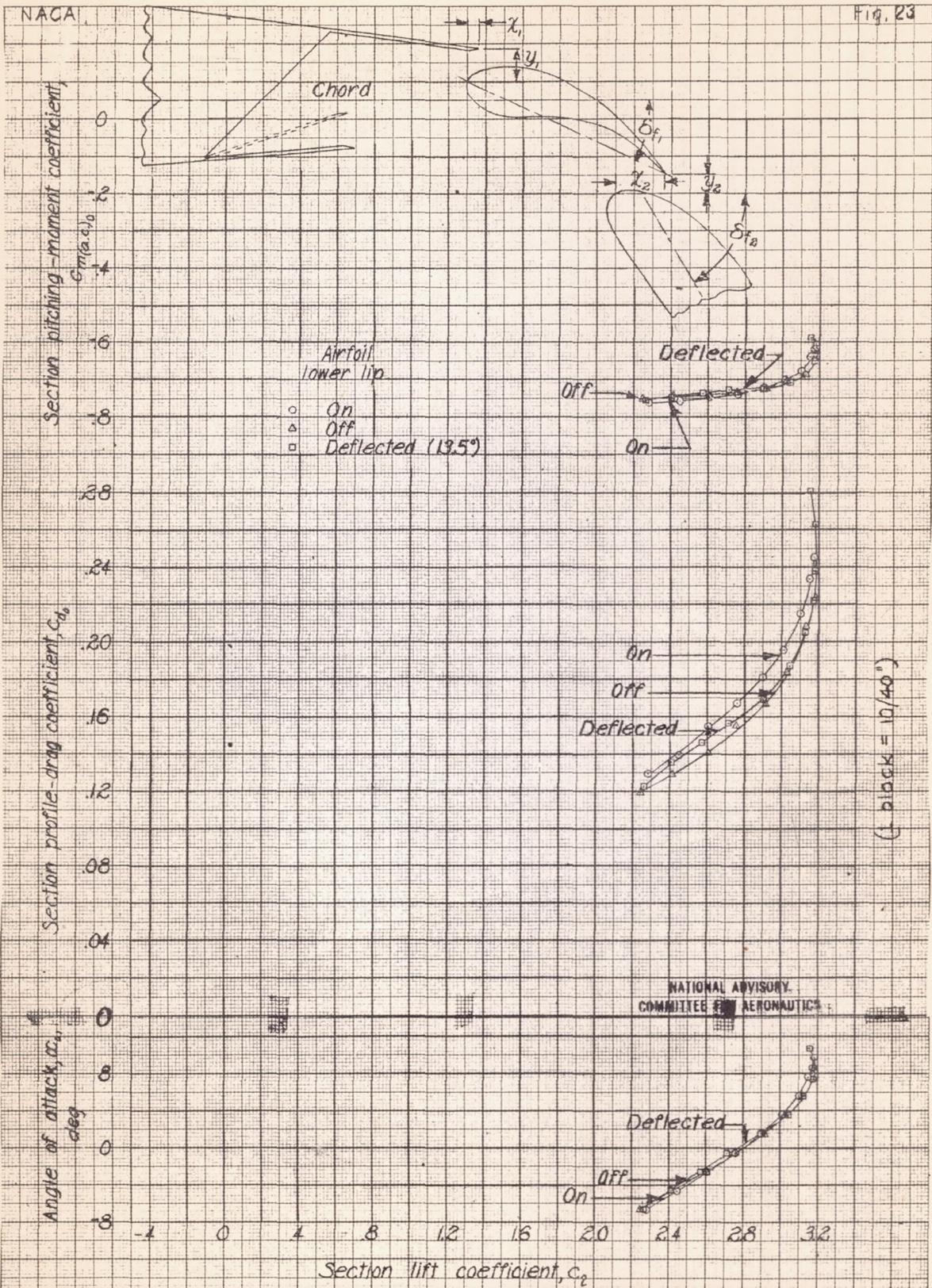
Figure 23.- Aerodynamic section characteristics of the NACA 23012 airfoil with a 0.30 c double slotted flap showing the effect of the airfoil lower lip Fore flap A; $\delta_{f_1} = 25°$; $x_1 = 0.59$; $y_1 = 1.72$. $\delta_{f_2} = 60°$; $x_2 = 2.60$; $y_2 = 1.05$. (Values of x_1, y_1 and x_2, y_2 are given in percent airfoil chord.)

Fig. 24

Section pitching-moment coefficient, $c_{m(a.c.)_0}$

Section profile-drag coefficient, c_{d_0}

Angle of attack, α_0, deg

Chord

Fore flap	A	A	B
δ_{f_1}, deg	30	25	35
x_1	0.59	-0.41	0.59
y_1	1.72	1.72	1.72
δ_{f_2}, deg	70	60	70
x_2	3.13	1.60	2.02
y_2	1.15	2.05	1.59

Best position for $c_{l_{max}}$

Approx. equal gaps

$A, 25°$
$A, 30°$
$B, 35°$

$B, 35°$
$A, 30°$
$A, 25°$

(1 block = 0.40")

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$B, 35°$
$A, 30°$
$A, 25°$

Section lift coefficient, c_l

-4   0   4   8   12   16   20   24   28   32   36

.28   .24   .20   .16   .12   .08   .04   0

8   0   8
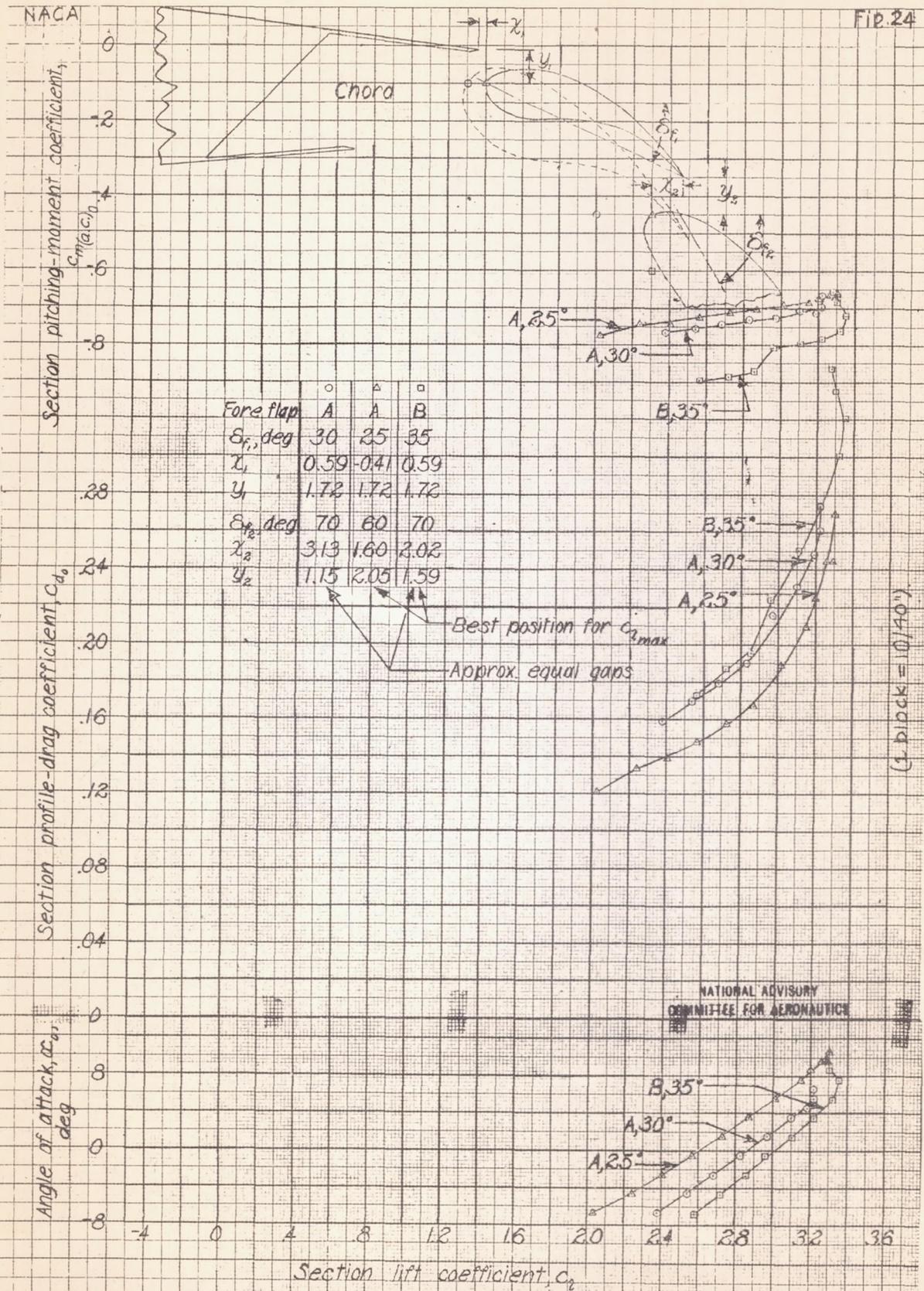
Figure 24.- Aerodynamic section characteristics of the NACA 23012 airfoil
with double slotted flaps showing the effect of fore-flap size.
(Values of x_1, y_1 and x_2, y_2 are given in percent airfoil chord.)