TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 460

FULL-SCALE WIND-TUNNEL RESEARCH ON

TAIL BUFFETING AND WING-FUSELAGE INTERFERENCE OF

A LOW-WING MONOPLANE

By Manley J. Hood and James A. White
Langley Memorial Aeronautical Laboratory

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SUMMARY

This report is a presentation of some preliminary re-
sults of an investigation conducted in the N.A.C.A. full-
scale wind tunnel to determine the best means of reducing
the tail buffeting and wing-fuselage interference of a
low-wing monoplane. Data indicating the effects of an
N.A.C.A. engine cowling, fillets, auxiliary airfoils of
short span, reflexed trailing edge, propeller slipstream,
and various combinations of these features are included.

The results of the tests showed that the N.A.C.A.
cowling reduced the interference and buffeting to magni-
tudes small enough to be considered unobjectionable at
angles of attack up to within 3° or 4° of the stall. The
fillets, either alone or in combination with the N.A.C.A.
cowling or a reflexed trailing edge, reduced the buffeting
and interference to unobjectionable magnitudes at angles
of attack up to the stall. A large fillet, when used
alone, reduced the buffeting oscillations to one seventh
their original amplitudes thus giving the greatest reduc-
tion obtained. The best all-round results were obtained
by the use of fillets together with the N.A.C.A. cowling.
This combination reduced the tail buffeting oscillations
to one fourth their original amplitudes, increased the
maximum lift 11 percent, decreased the minimum drag 9 per-
cent, and increased the maximum ratio of lift to drag 19
percent.

INTRODUCTION

The increasing use of low-wing monoplanes has empha-
sized the susceptibility of this type of airplane to det-
rimental wing-fuselage interference. This interference
was first indicated by inferior aerodynamic characteristics
of the low-wing as compared to the high-wing monoplane.

In addition to reducing the aerodynamic efficiency, this interference produces other highly objectionable conditions resulting from the eddying wake from the region of the wing-fuselage intersection flowing over the empennage. The position of the tail surfaces in this eddying wake sometimes makes difficult the attainment of satisfactory longitudinal control and stability. The buffeting action of the eddying wake often causes an irregular oscillation, or shaking, of the tail surfaces. Tail buffeting may become severe enough in some cases to result in structural failure. It has been charged by one group of investigators (references 1 and 2) with having been the cause of an accident to a low-wing monoplane which disintegrated in the air, although another group of investigators (references 3 and 4) did not concur in this opinion.

A number of devices for reducing the wing-fuselage interference have been proposed (references 5 to 9, inclusive). This note presents the effects of several of them, as determined by an investigation in the N.A.C.A. full-scale wind tunnel.

The primary result of the wing-fuselage interference appeared to be a premature breaking down of the air flow in the region of the intersection of the wing with the fuselage. For this reason, the devices for reducing the interference were designed to postpone the breaking down of the flow in this region to the angle of attack at which the entire wing stalled. The devices tested were: two different fillets at the wing-fuselage intersection; a reflexed trailing edge on the wing near the fuselage, both alone and in combination with a fillet; short-span auxiliary airfoils in three different positions; and an N.A.C.A. engine cowling, alone and in combination with each of the other devices except the auxiliary airfoils.

The value of these devices in reducing the interference was studied in several different ways: Visual observations of the air flow in the region of the wing-fuselage intersections were made with strings; the velocity and direction of the air flow in the region of the empennage were measured; the lift and drag characteristics were determined for all the conditions investigated; longitudinal control and stability were investigated by measuring the pitching moments with various elevator settings and with the empennage removed; and the amplitude and frequency of the vertical movements of the stabilizer tip were measured. The above characteristics were measured

both with and without the slipstream from the airplane's
propeller.

This is a preliminary report and covers only the ob-
servations of the air flow in the region of the wing-
fuselage intersection, the lift and drag characteristics,
and the tail vibrations. The complete results will be
presented in a later report.

APPARATUS

Wind tunnel.- The tests discussed in this report were
made in the N.A.C.A. full-scale wind tunnel described in
reference 10.

Airplane.- The McDonnell airplane, a low-wing type,
which was originally built for entry in the Daniel Guggen-
heim Safe Aircraft Competition in 1929, was used for the
tests described in this report. It was chosen for these
tests because it had been reported by pilots to be subject
to tail buffeting. Flight tests of the McDonnell airplane
are described in reference 11. The airplane, equipped
with the large fillet and mounted on the balance in the
full-scale wind tunnel, is shown in figure 1. A 3-view
drawing, giving its principal dimensions, is shown on fig-
ure 2. The airplane was equipped with a Warner "Scarab"
engine having a rating of 110 horsepower at 1,850 r.p.m.
The leading-edge slots and trailing-edge flaps with which
the airplane was equipped were not used in this series of
tests. The flaps were locked in the neutral position and
the slots were prevented from opening by covering the
slats and forward part of the wings with doped fabric.
After preliminary tests had been made, a walkway that
raised the top surface of the right wing five eighths of
an inch above the normal profile from 15 to 69 percent of
the chord and from the fuselage to 10 inches outboard was
removed, and the gaps (fig. 3) between the wings and fu-
selage were covered. The stabilizer was set at an inci-
dence of 0.6° with respect to the thrust axis for all the
tests.

N.A.C.A. engine cowling.- The N.A.C.A. engine cowling
consisted of a hood that was placed over the engine and
nose of the airplane without altering the original fuse-
lage lines. The hood was designed in accordance with the
information in reference 12 except that it consisted of
only one thickness of metal, and consequently its cross

section did not resemble an airfoil profile. Figure 4
shows the nose of the airplane in the original condition
and with the hood in place.

Fillets.- The wing-fuselage fillets (figs. 5 to 8,
inclusive) were designed to reduce the rate at which it
was necessary for the air in this region to diverge in
order to follow the surfaces. The radius was small at
the leading edge and a short distance back started increas-
ing smoothly to a maximum at the trailing edge, behind
which the fillet was faired into the fuselage. The prin-
cipal difference between the two fillets was their size;
hence, they will be referred to as the small fillet (figs.
5 and 7) and the large fillet (figs. 6 and 8). Another
difference was that the small fillet had a constant radius
from the leading edge back to 41 percent of the chord,
whereas the radius of the large fillet began to increase
at 6.6 percent of the chord behind the leading edge.

Reflexed trailing edge.- The modification of the wing
root, herein called a reflexed trailing edge (fig. 9), was
designed to decrease the incidence at the wing root. The
lower surface of the wing, which had an upward curvature
(N.A.C.A.-M6 profile), was extended to the rear and a new
upper surface was formed by straight elements from the new
trailing edge to the points of tangency with the upper
surface of the original wing. The fillet that was tested
in combination with this reflexed trailing edge (fig. 10)
was similar to the large one previously described.

Auxiliary airfoils.- The auxiliary airfoils used in
these tests were of the N.A.C.A 22 profile, had a 10-inch
chord (14.7 percent of the main wing chord), and extended
30 inches from the fuselage on each side. They were first
located in a position similar to that found to be the op-
timum in the investigation reported in reference 13, with
the trailing edge 15 percent of the main wing chord ahead
of and 8.2 percent above the leading edge of the main wing,
and the chord parallel to the main wing chord. In the
second position the trailing edge of the auxiliary was
6.5 percent directly above the leading edge of the main
wing, and the incidence of the auxiliary was -30° with re-
spect to the chord of the main wing. In the third posi-
tion the trailing edge was 5.2 percent behind and 7.5 per-
cent above the leading edge of the main wing, and the in-
cidence was -25.5°.

METHODS

Lift and drag measurements.- The power-off lift and
drag characteristics were determined with the propeller
removed. The power-on characteristics were determined
with the propeller running at such a speed that its thrust
just balanced the drag of the airplane (making due allow-
ance for jet-boundary effect), in order to simulate steady
flight conditions. These characteristics were all meas-
ured at an air speed of between 55 and 60 miles per hour,
except that at the higher angles of attack the speed was
reduced during the power-on tests in order to make the
drag of the airplane low enough to be balanced by the pro-
peller thrust.

Investigation of air flow.- The flow of air in the
region of the wing-fuselage intersection was studied by
making visual observations of its effect on light strings
held at various points in this region by observers in the
cockpits.

Records of tail buffeting.- The vertical movements of
the tip of the stabilizer were recorded on a moving film
by an N.A.C.A. control-position recorder (reference 14)
modified to give a 1-inch deflection of the image on the
film for a 1.65-inch vertical movement of the stabilizer
tip and from these records the amplitude and frequency
were determined. The instrument was mounted on a solid
base in the balance room and connected to the right sta-
bilizer tip with an 0.008-inch-diameter piano wire that,
except for about 2 inches at the top, was shielded from
the air stream by a tube. The natural vibration frequency
of the instrument and piano wire was about 34 vibrations
per second. As this is four times the frequency of the
fastest stabilizer oscillations recorded, it insures that
the instrument was capable of accurately following the
movements of the stabilizer. Play and friction in the
linkage of the instrument resulted in small errors in the
indicated amplitudes of stabilizer oscillations which
probably did not exceed one eighth inch. During most of
these tests the tail of the airplane was supported by a
rigid "A" frame fastened to the tailpost. In order to de-
termine the effect of this rigid support records were made
of the movements of the stabilizer tip and the rear end of
the fuselage while the tail of the airplane was free from
external support, and the airplane was prevented from
turning about the main supports at the landing-wheel axles

only by cables secured to the forward part of the fuselage.
Most of the measurements of stabilizer-tip movements were
made at an air speed of about 58 miles per hour but a few
were made at different air speeds between 35 and 60 miles
per hour to determine the effect of air speed on the buf-
feting.

                               RESULTS

     Lift and drag characteristics.- The power-off lift
and drag characteristics are presented as polars and lift
and drag curves in four groups. The first group (figs.
11 and 12) shows a comparison of the results obtained with
the various fillets, both alone and with the N.A.C.A. en-
gine cowling. The second group (figs. 13 and 14) shows
curves for the airplane with the reflexed trailing edge
alone and in combinations with engine cowling and fillet.
The third group (figs. 15 and 16) shows the effects of the
auxiliary airfoils in different positions. The fourth
group (figs. 17 and 18) is a summary of the first three
groups. Curves showing theoretical induced drag, comput-
ed on the basis of the geometrical aspect ratio (6.23) of
the wing, and the lift and drag characteristics for the
airplane in the original condition are shown with each
group. Three representative polars are shown with their
experimental points (figs. 19 to 21, inclusive).

     The power-on lift characteristics are shown plotted
against angle of attack for the airplane in the original
condition (fig. 22), and when equipped with the large fil-
let and N.A.C.A. engine cowling (fig. 23). These charac-
teristics for all other conditions tested were practically
identical to those shown in figure 23. The curves show
values of lift coefficient with the engine developing a
thrust equal to the drag, which is the same condition as
in steady flight. As it was not practicable to hold the
engine speed so as to give exactly zero drag, three read-
ings were taken at each angle of attack at approximately
the proper engine speed, and the lift at zero net drag
determined by plotting these three readings against net
drag. No means were available for determining the thrust
of the propeller; so it was not possible to determine ex-
actly either the effect of the slipstream on the drag
characteristics of the airplane or the part of the total
lift that was due to the vertical component of the pro-
peller thrust. An approximate correction, however, for
this vertical component of thrust was applied in order to

make the difference between the power-off and power-on lift curves more nearly represent the effect of the slipstream; and the lift curves are shown both with and without this correction. These approximate corrections were arrived at by computing, for each angle of attack, the vertical component of a thrust large enough to overcome the drag of the airplane without the slipstream.

All the results have been corrected for wind-tunnel effects to make them comparable to actual flight. All coefficients were based on the original wing area of 196.5 square feet.

Air flow.- The action of the strings that were used to study the air flow in the region of the wing-fuselage intersection indicated that, except when the airplane was equipped with some of the most effective devices, the breaking down of the air flow over the upper surface of the wing originated near its intersection with the fuselage and spread laterally as the angle of attack was increased. With the airplane in the original condition the turbulent flow extended approximately 3 feet outboard from the fuselage at 14° angle of attack. The approximate angles of attack at which the air flow over the root of the wing first broke down when the airplane was equipped with the various devices were as follows:

Original condition	5°
N.A.C.A. engine cowling	14°
Small fillet	12°
Large fillet	15°
Small fillet and N.A.C.A. engine cowling	17° (at stall)
Large fillet and N.A.C.A. engine cowling	17° (at stall)
Reflexed trailing edge	7°
Reflexed trailing edge and N.A.C.A. engine cowling	16° (at stall)

Reflexed trailing edge and
    fillet   Above stall

Reflexed trailing edge, fil-
    let, and N.A.C.A. engine
    cowling   Above stall

Auxiliary airfoil in first
    position 7°

Auxiliary airfoil in second
    position 7°

Auxiliary airfoil in third
    position 10°

     In cases when auxiliary airfoils were used, vortices
trailing from their tips were evident. When the N.A.C.A.
cowling was used, particularly when in combination with
any of the fillets and both with and without the slipstream,
the action of the strings indicated the presence of vorti-
ces which were approximately concentric with the fillets
and trailed to the rear. The vortex on the right side
turned counterclockwise and the one on the left clockwise
as viewed from the rear.

     <u>Tail buffeting</u>.- Typical records of stabilizer-tip
movements are shown on figure 24.

     Maximum amplitude of the movements of the stabilizer
tip under various conditions is shown plotted against an-
gle of attack in degrees above and below the angle of max-
imum lift (fig. 25). Amplitude in this figure represents
the total deflection of the tip from the maximum positive
to the maximum adjacent negative position, and is expressed
in inches of movement in the direction normal to the sta-
bilizer. The amplitude of stabilizer-tip movements with
the propeller operating is not included in figure 25 be-
cause it did not vary consistently enough to permit draw-
ing curves. All the maximum deflections measured with
power on fell between 0.1 and 0.4 inch for angles of at-
tack below the stall. The figure applies only to ampli-
tudes measured when the rear end of the fuselage was ex-
ternally supported. When it was free from external sup-
port the amplitude of stabilizer-tip movement was nearly
doubled, but corresponding movements of the rear end of
the fuselage were only about one fifth as great as those
of the stabilizer tip. Figure 26 shows the variation in

amplitude with changes of air speed between 35 and 60 miles per hour.

The natural vibration frequencies of the stabilizer were as follows:

    With rear end of fuselage
      rigidly supported   7.3 vibrations per second

    With rear end of fuselage
      free from external sup-
      port   8.5 vibrations per second

The predominant frequencies when buffeting were approximately the same as the natural frequencies.

The stiffness of the stabilizer and fuselage was such that, when the rear end of the fuselage was externally supported, the stabilizer tip was deflected 1 inch by a force of 60 pounds concentrated at the tip.

DISCUSSION

Lift and drag characteristics.- The shape of the polar for the airplane in the original condition (fig. 19), compared with the theoretical induced drag polars based on the geometrical aspect ratio of the entire wing (6.2) and that of the part on one side of the fuselage (2.9), and also the slope of the lift curve (fig. 12), indicate that the abnormal increase in drag and reduction in lift at the higher angles of attack was largely due to the fact that the lift normally given by the roots of the wings and the span across the fuselage had been destroyed by the breakdown of the flow near the wing-fuselage intersection so that the part of the wing outboard of the disturbed region on each side of the fuselage was acting independently as a separate wing of lower aspect ratio.

The N.A.C.A. engine cowling, either fillet, or the combined reflexed trailing edge and fillet eliminated most of the adverse interference, as is indicated by the straightness of the lift curves and parallelism of the polars to the induced drag polar (figs. 11, 12, 17, and 18). All these devices increased the angle of attack at which the flow over the wing roots became unstable to within 3° or 4° of the angle of attack of maximum lift, and the com-

bined reflexed trailing edge and fillet postponed the break-
down to well beyond the angle at which the main part of the
wing stalled. The minimum drag coefficient was slightly
increased by the combined reflexed trailing edge and fil-
let, not affected by the small fillet, and reduced from
0.0637 to 0.0625 by the large fillet and to 0.0590 by the
N.A.C.A. engine cowling.

The magnitude of the improvement obtained by the use
of the cowling alone indicated that, as might be expected,
conditions which disturb the air flow ahead of the region
of the wing-fuselage intersection may have important ef-
fects on the degree of interference.

It was found that when fillets were used alone the
large one was slightly superior (figs. 11 and 12). When
they were used in combination with the N.A.C.A. cowling,
however, the small fillet gave results (not shown in this
report) almost identical with those obtained with the
large fillet and cowling.

An unstable flow in the region of maximum lift when
the airplane was equipped with either the N.A.C.A. cowling
or the fillet was evidenced by the double lift curves and
polars (figs. 17, 18, and 20). The use of the cowling and
fillet in combination eliminated this unstable condition
(fig. 21). The combination reduced the minimum drag by an
amount practically equal to the sum of the reductions given
by the two devices when used alone.

The reflexed trailing edge, when used alone, had a
negligible effect on the lift and drag characteristics.

The auxiliary airfoils gave their best results when
in the third position, but even then the improvement over
the original condition was only about one half that ob-
tained with the fillets or cowling. It is probable, how-
ever, that the optimum position was not found, because
only three were tested.

The effect of the slipstream was sufficient to pre-
vent a premature breakdown of the flow near the wing-
fuselage intersection in all except the original condi-
tion, and in this condition it postponed the breakdown
from about 5° to 12° angle of attack. It is not practica-
ble, however, to depend on the slipstream for maintaining
the smooth flow, especially during landing.

Preliminary tests showed that the presence of the raised walkway had no appreciable effect on the character- istics of the airplane when equipped with the small fillet and that when the airplane was not equipped with any of the special devices removing the walkway and covering the gaps between the wing and fuselage had a negligible effect.

The maximum lift coefficient of the airplane in its original condition, as determined by these tests, was con- siderably higher than the highest lift coefficient (with slots closed and flaps neutral) measured in flight. This apparent discrepancy was due to the fact that the airplane did not have sufficient longitudinal control to permit flying at angles of attack above 16°. (See reference 11.)

The best lift and drag characteristics were obtained when fillets and N.A.C.A. cowling were used together. The use of this combination eliminated most of the wing-fuse- lage interference, increased the maximum lift 11 percent above its original value, decreased the minimum drag 9 percent, and increased the maximum ratio of lift to drag 19 percent.

Air flow.- The observations made of the air flow with strings agreed well with the lift curves and polars in showing the angles of attack at which the air flow first broke down over the wing roots, and indicating the rela- tive effectiveness of the different devices in reducing the wing-fuselage interference.

Tail buffeting.- The effectiveness of the various de- vices in reducing tail buffeting is best visualized by reference to figure 25. The buffeting oscillations were reduced to amplitudes small enough to be considered unob- jectionable throughout the range of normal flight atti- tudes by the use of the fillets, either alone or in any combination with the N.A.C.A. engine cowling or reflexed trailing edge. The use of the large fillet alone reduced the oscillations to one seventh their original amplitudes and the use of the same fillet with the N.A.C.A. cowling, the combination which gave the best lift and drag charac- teristics, reduced the oscillations to one fourth their original amplitudes.

In general, the devices which gave the greatest im- provement in lift and drag characteristics also gave the greatest reduction in tail buffeting. The N.A.C.A. cowl- ing was an exception to this rule. When it was used ei- ther alone or in combination with other devices, the ampli-

tudes of the buffeting oscillations were slightly greater than would be expected from the improvement in lift and drag.

The slipstream was shown to be practically as effective as the fillets in reducing buffeting with the airplane in the original condition, but had only a small effect when the airplane was equipped with fillets or cowling.

In all cases the stabilizer vibrated at a predominant frequency that was practically the same as the natural frequency of the surface and the amplitude varied irregularly in a manner similar to that shown on the typical records (fig. 24).

The vibrations of the stabilizer obtained under the conditions of these tests do not necessarily correspond exactly to those that would be obtained in flight, because of the way in which the airplane was supported, but they do afford good comparisons between the degrees of buffeting existing under the various conditions tested. The special tests made with the rear end of the fuselage free from external support indicate that the amplitude of stabilizer vibrations which would exist in flight would be considerably greater than those shown on figure 25. The frequency is apparently dependent upon the natural frequency of the tail structure.

The severity of buffeting was shown to increase rapidly with increase in air speed between 35 and 60 miles per hour (fig. 26). It cannot be assumed, however, that this increase would continue at velocities above those investigated, because the relations may be affected by resonance between the natural frequency of the tail and the frequency of the buffeting eddies. An investigation of the frequencies of eddies trailing from the wing roots of different airplanes would yield information which would be very useful in tail surface design.

CONCLUSIONS

1. Fillets reduced the wing-fuselage interference and tail buffeting to unobjectionable magnitudes throughout the range of normal flight attitudes.

2. N.A.C.A. engine cowling reduced the wing-fuselage

interference and tail buffeting to unobjectionable magnitudes at angles of attack up to within $3°$ of the stall.

3.   The reflexed trailing edge slightly increased the amplitude of tail oscillations due to buffeting.

4.   The auxiliary airfoils, in the positions tested, reduced the interference and buffeting but were considerably inferior to the fillets.

5.   Buffeting was least when the large fillet was used alone. This fillet reduced the amplitude of stabilizer-tip oscillations at an angle of attack $2°$ below the stall from the 1.37 inches obtained with the airplane in the original condition to 0.18 inch.

6.   The combination of fillets and N.A.C.A. engine cowling gave the best all-round results. This combination reduced the total amplitude of stabilizer-tip oscillations at an angle of attack $2°$ below maximum lift from the original 1.37 inches to 0.32 inch, increased the maximum lift 11 percent, decreased the minimum drag 9 percent, and increased the maximum lift/drag ratio 19 percent.

Langley Memorial Aeronautical Laboratory,
      National Advisory Committee for Aeronautics,
          Langley Field, Va., April 18, 1933.

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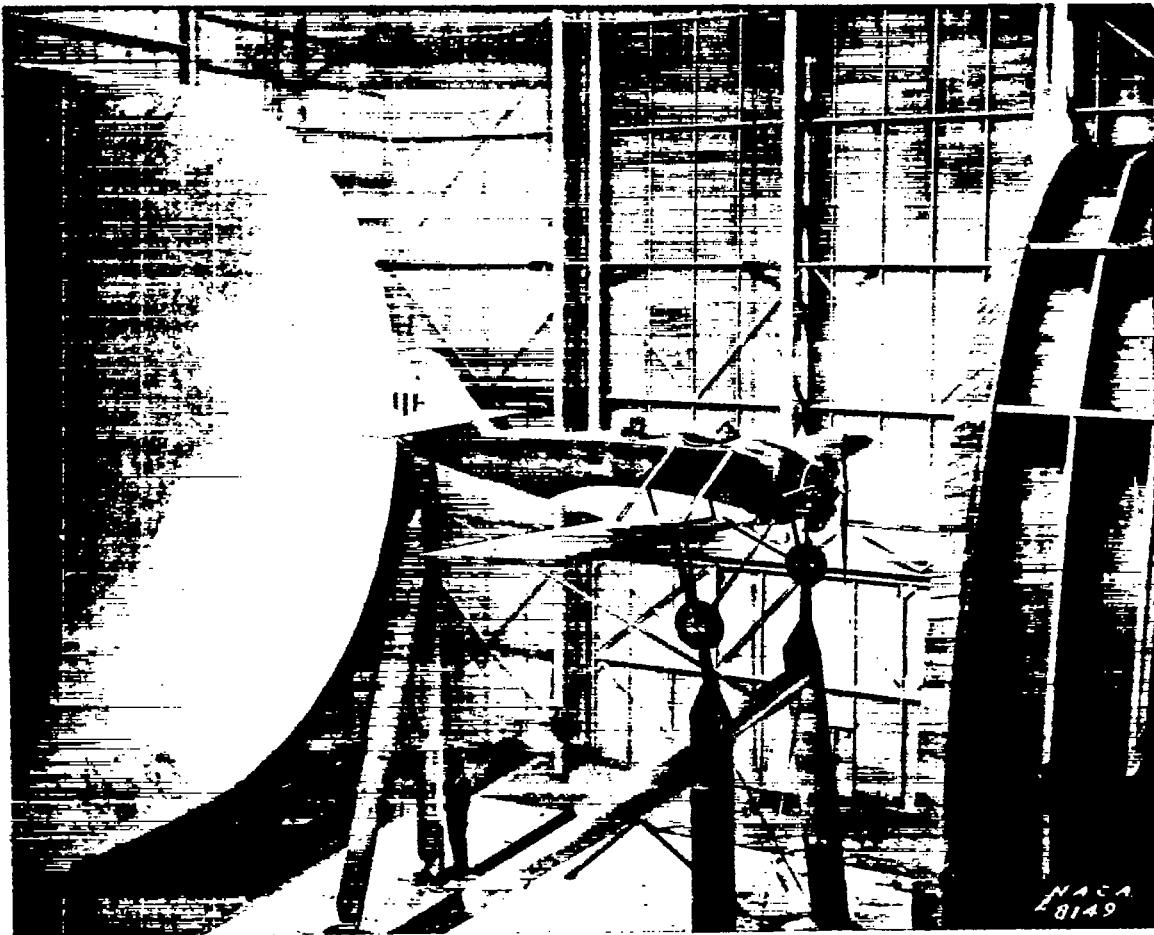
Figure 1.- McDonnell airplane
with large fillet
in full- scale wind tunnel
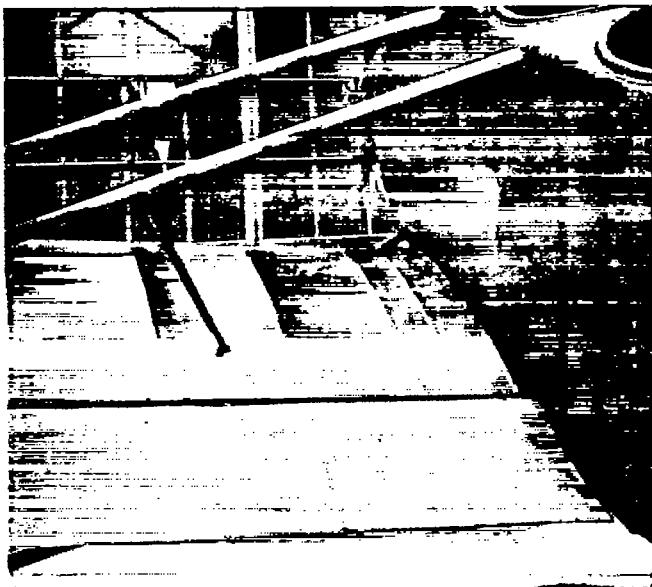
Figure 3.- Wing- fuselage
intersection
of McDonnell airplane

Fig.2

35'0"

Track 12'4½"

4½°

11'0"

68"

12'0."

21½"   38"

16½"

21' 4"

40"

8'1"

M6

3.5° incidence

14½"
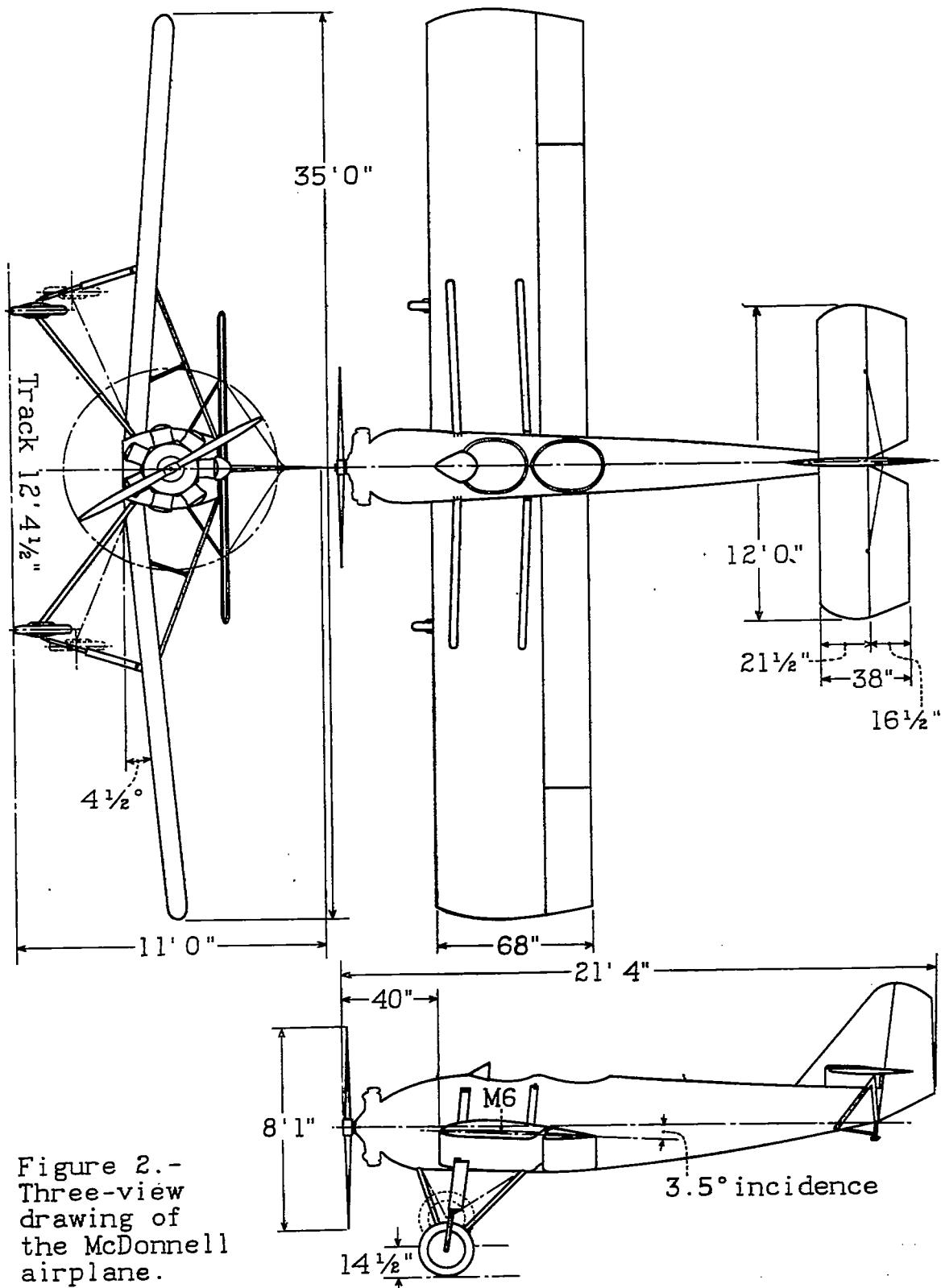
Figure 2.-
Three-view
drawing of
the McDonnell
airplane.
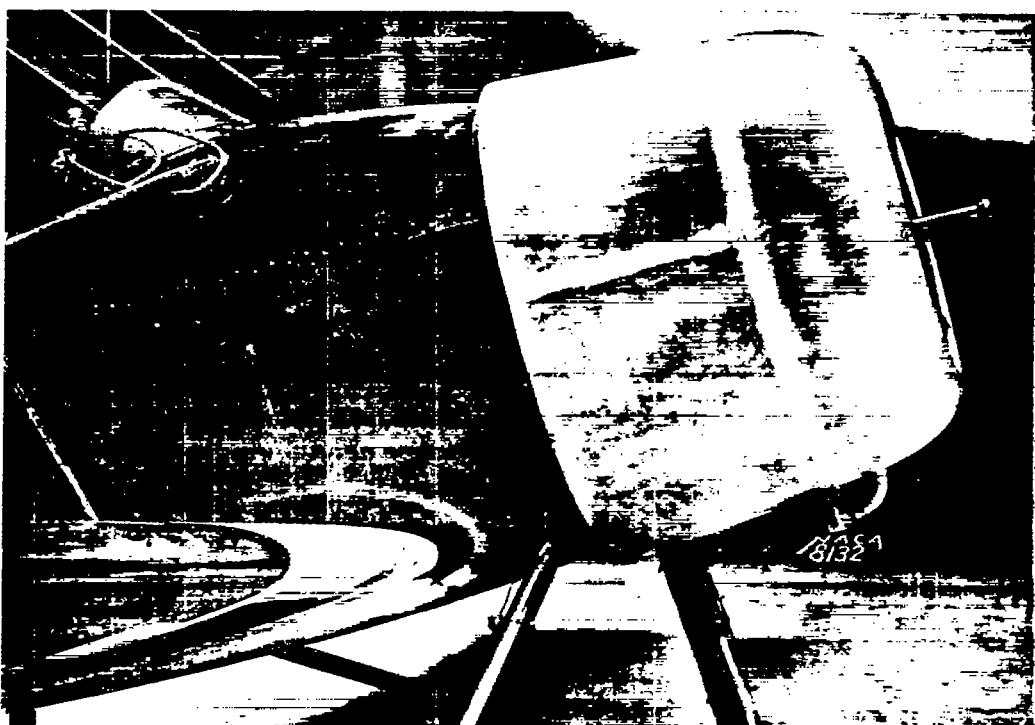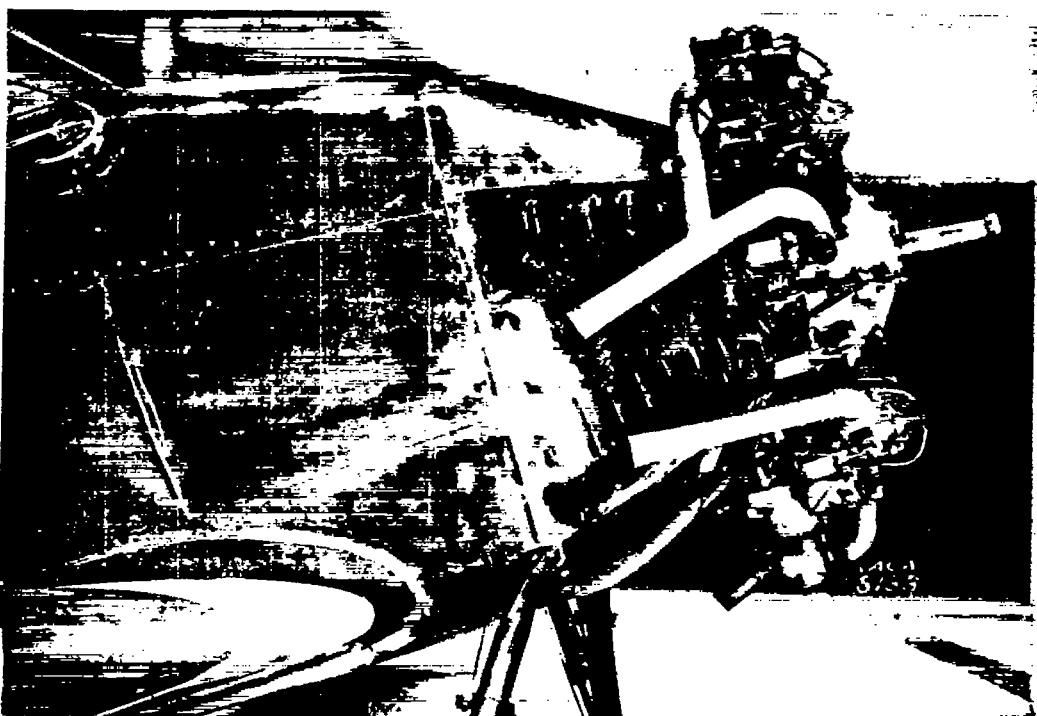
Figure 4. – Nose of McDonnell airplane in original condition
and with N.A.C.A. engine cowling.
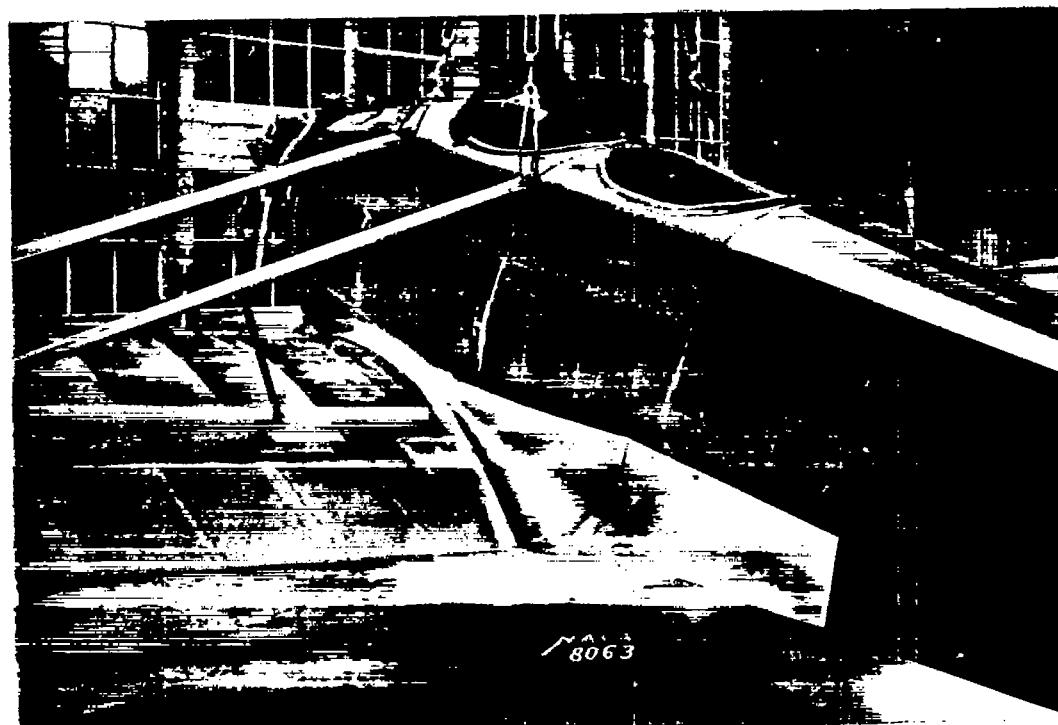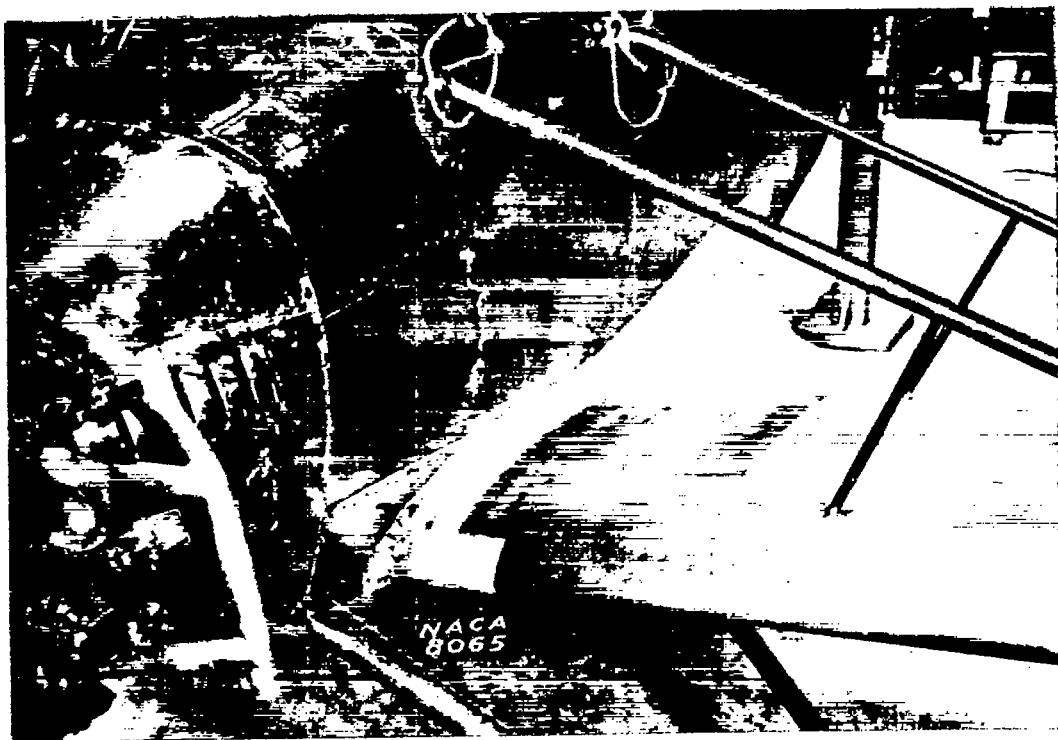
Figure 5.— Small fillet on McDonnell airplane
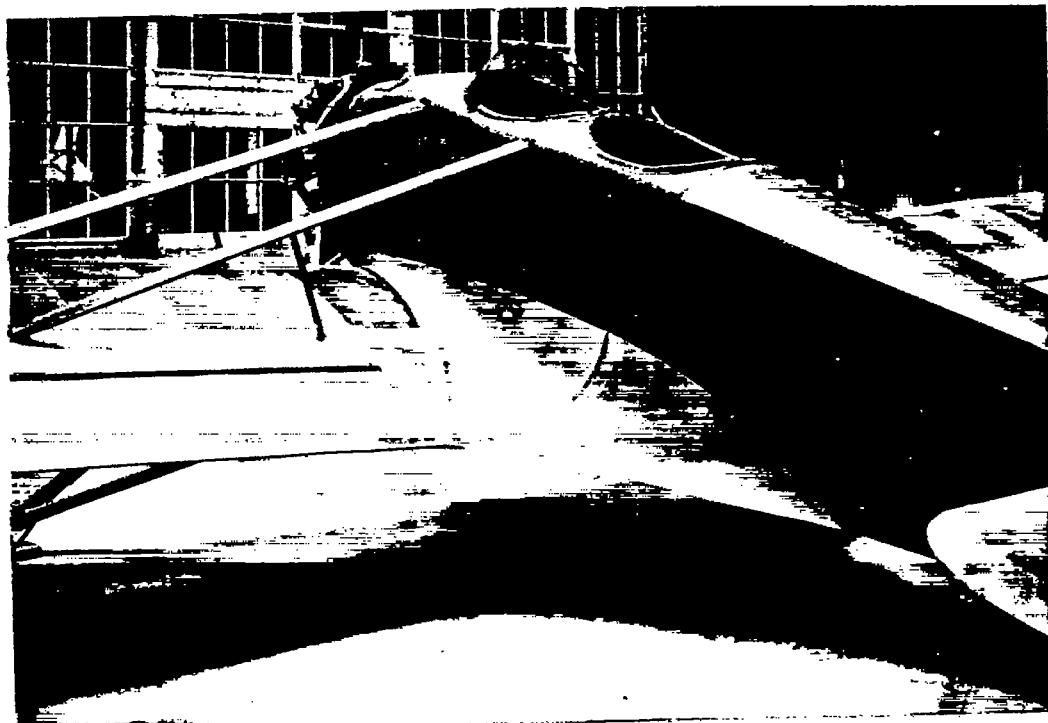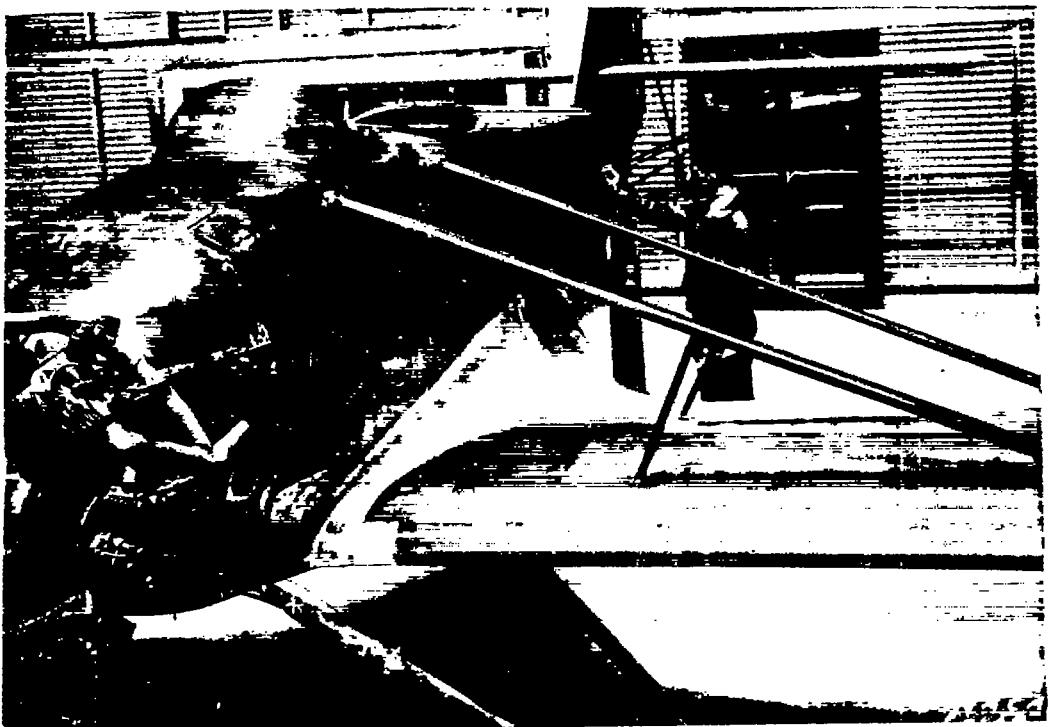
Figure 6.— Large fillet on McDonnell airplane

F, Intersection of fillet and fuselage   Lower edge
W,   "   "   "   " wing   of fuselage

Station, % chord	Radius, % chord
140	
130	
120	
110	
100	17.6
90	14.2
80	10.8
70	7.4
60	4.5
50	2.5
40	1.5
30	1.5
20	1.5
10	1.5
0	0

T, T.E.
of fillet

Plan view   Side view

% chord

Lower
edge
of
fuse-
lage

Front view   Rear view
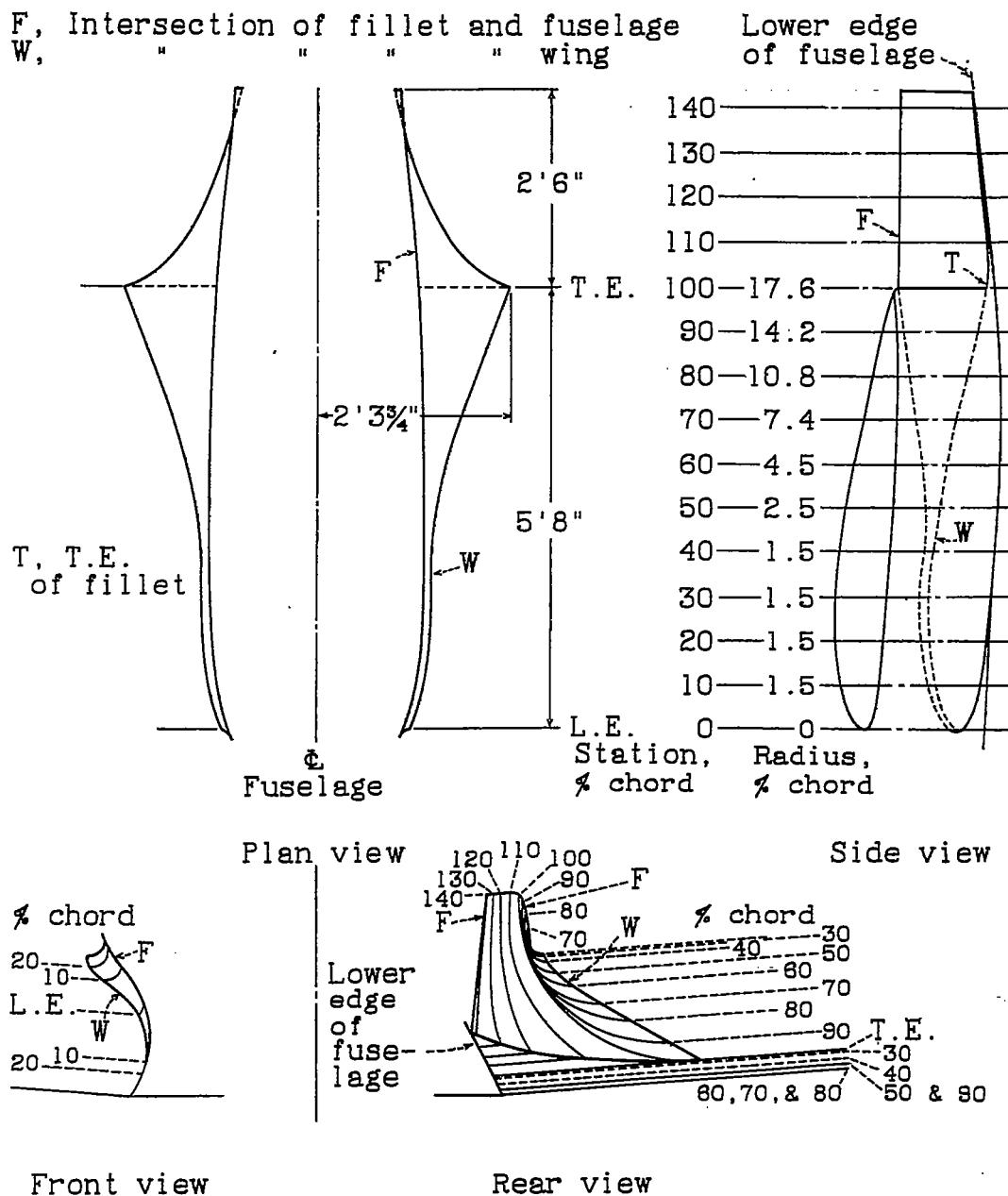
Note.-Front and rear views are to twice the scale
of the plan and side views

Figure 7-Drawing of the small fillet

F, Intersection of fillet and fuselage
W,   "   "   "   " wing

Lower edge
of fuselage

Plan view

Side view

Station,
% chord

Front view
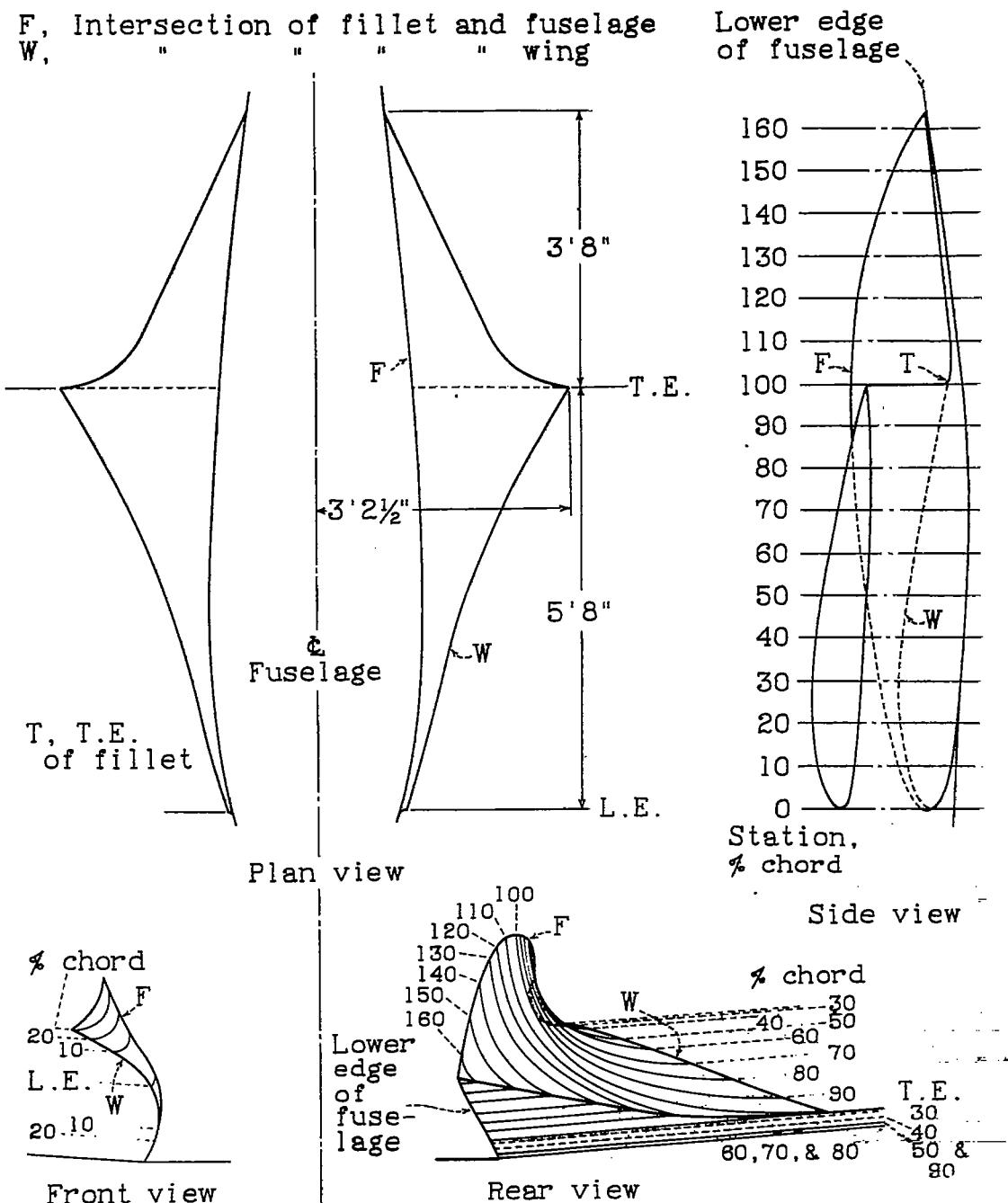
Rear view

Note.-Front and rear views are to twice the scale
of the plan and side views

Figure 8-Drawing of the large fillet

Plan view

Rib Nos.

Ⓛ of fuselage

10"

1
2
3
4
5
6
7

8' 7¾"

2' 1"

11"
11¾"
13"
13¾"
14"
14½"
14½"

Inter-
section
of new
upper
surface
and wing

←————5' 8"————→←——2' 7"——→
L.E.   T.E.

Station, % of chord
0   20   40   60   80   100   120   140

7 6 5 4 3 2 1
Rib Nos.

Profile of new surface 0' 10" inboard of No.1 rib

Wing profiles
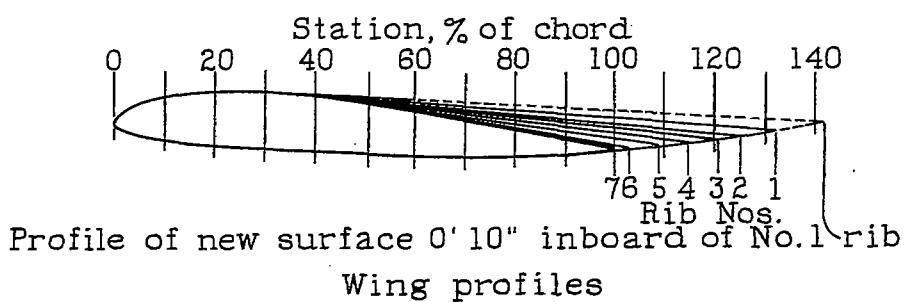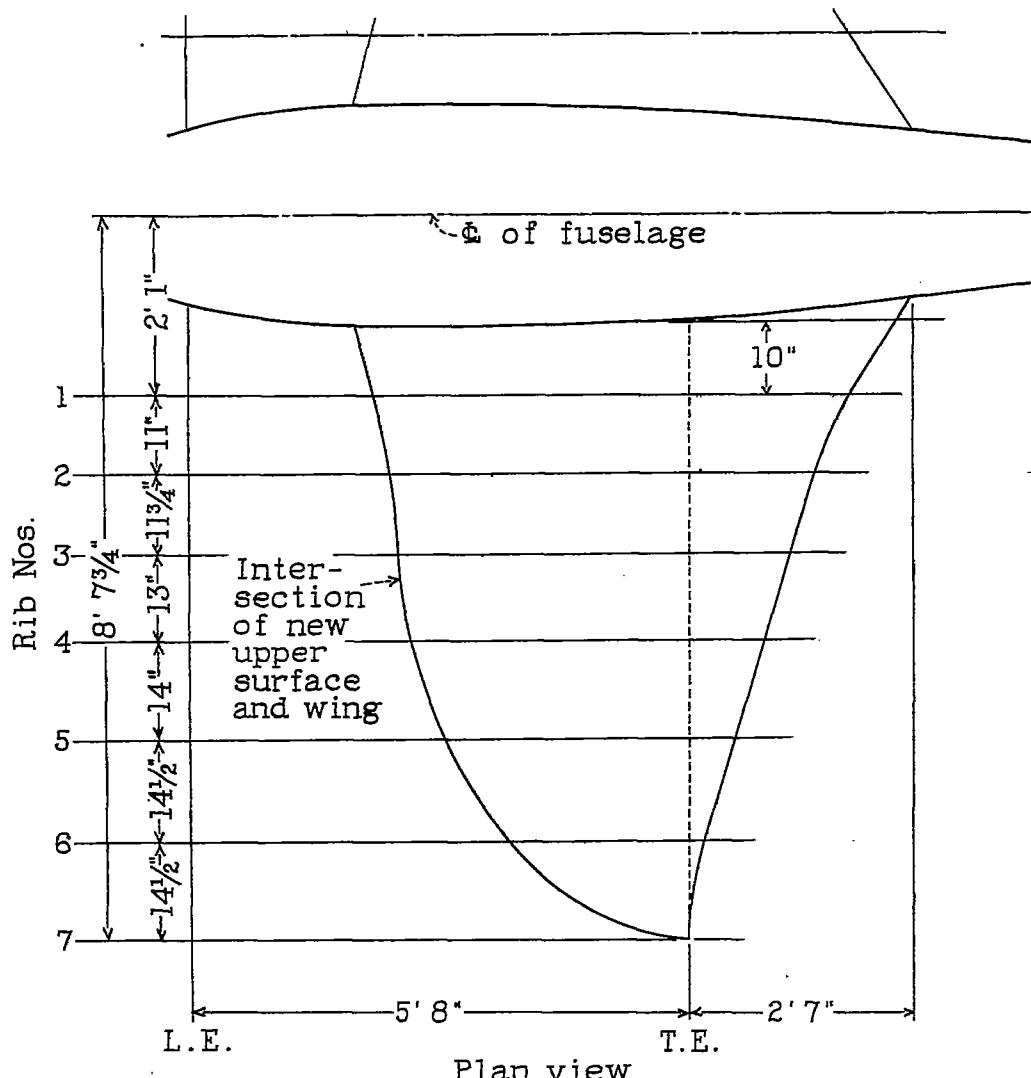
Figure 9-Drawing of the reflexed trailing edge
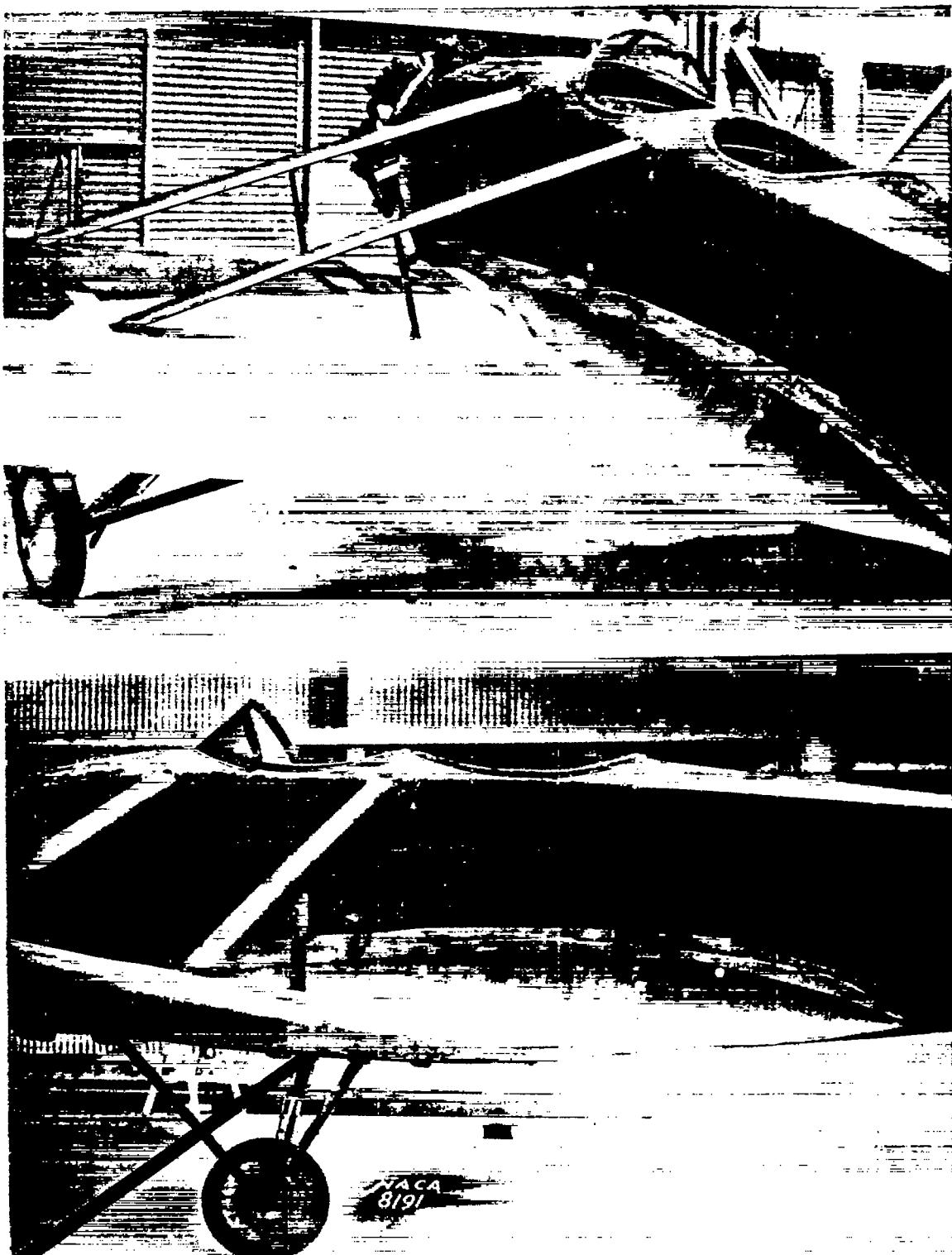
Figure 10.- Reflexed trailing edge with fillet on McDonnell airplane
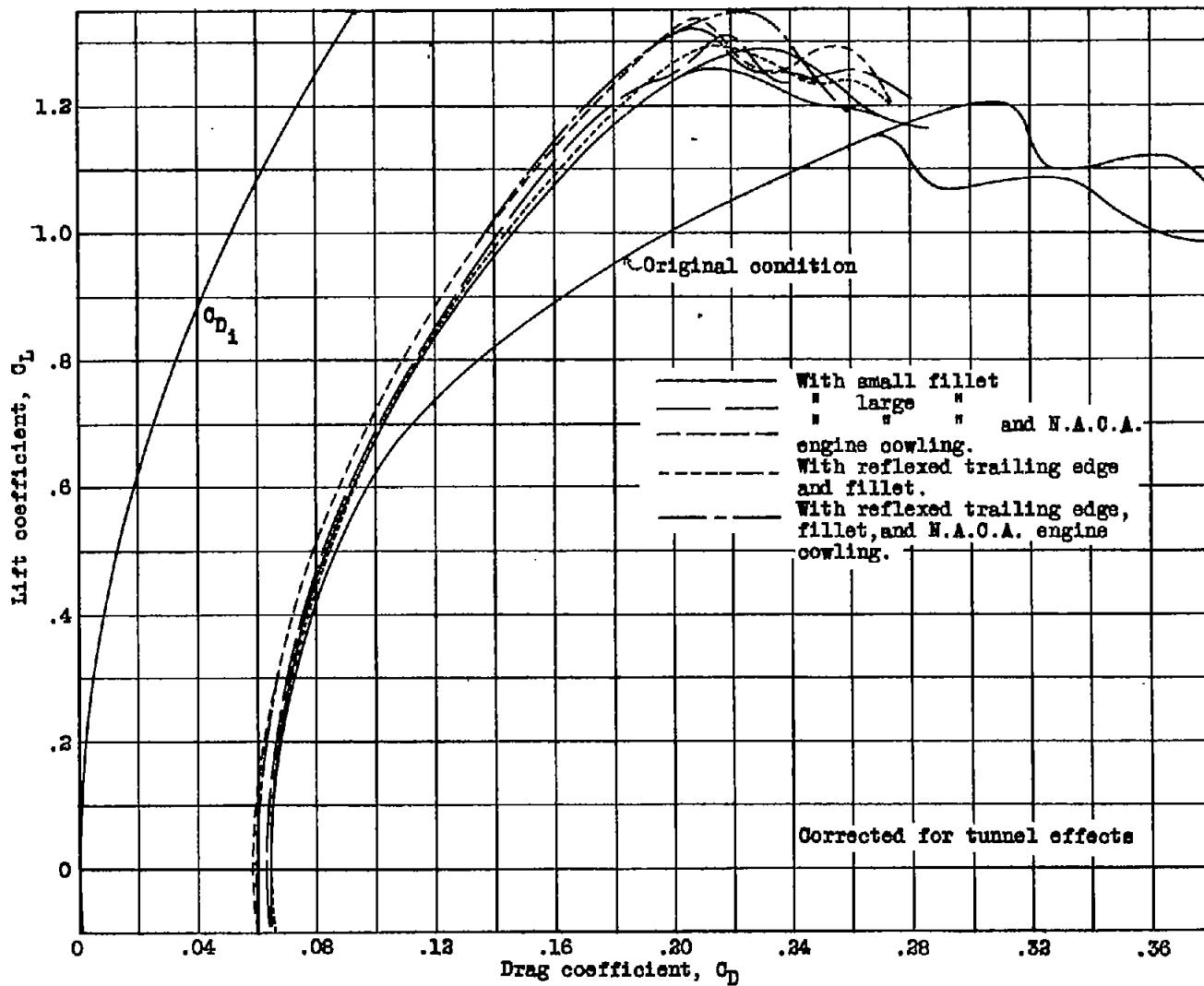
Figure 11.-Polars for McDonnell airplane with various fillets.

Fig.11
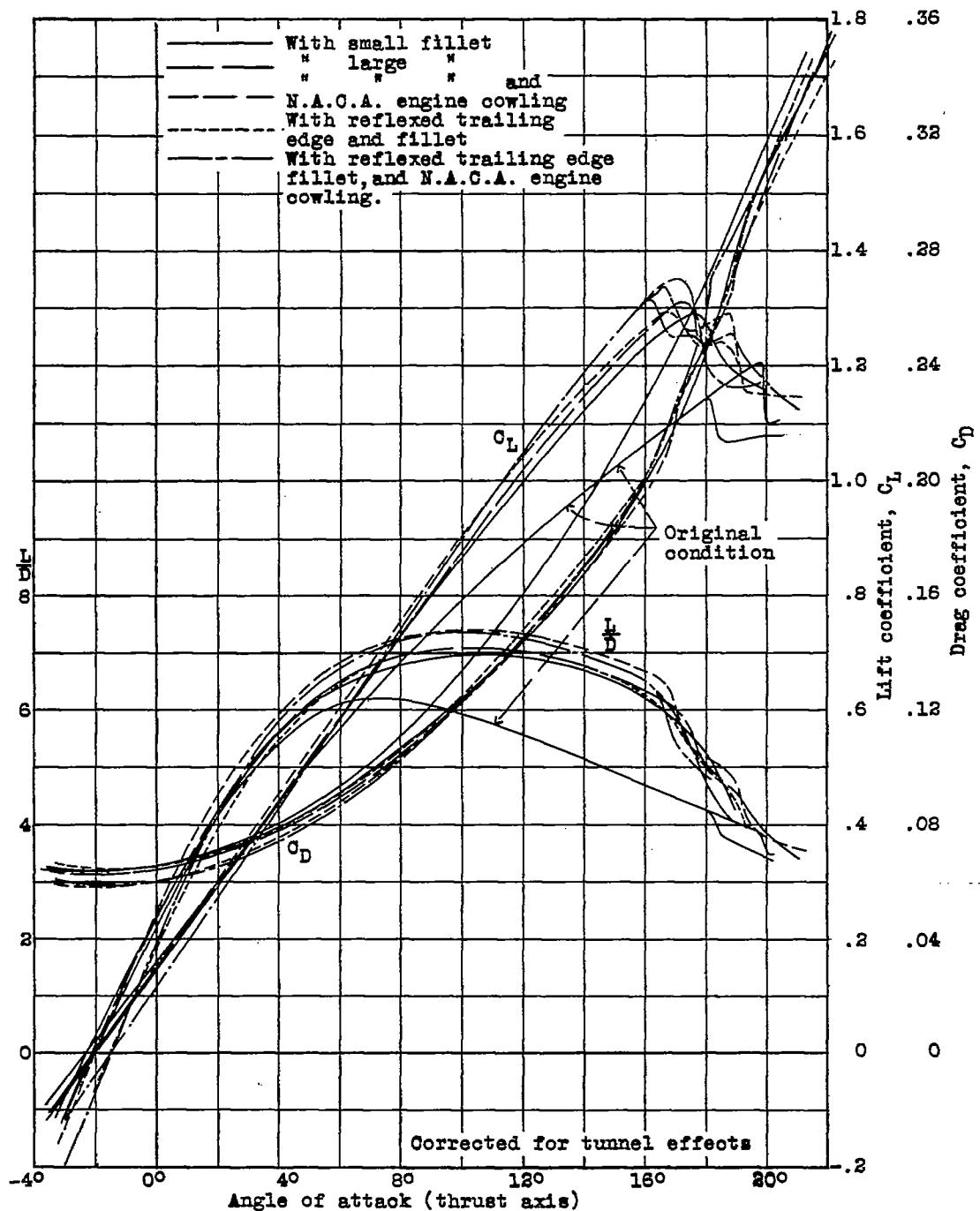
Figure 12.-Lift and drag of McDonnell airplane with various fillets.
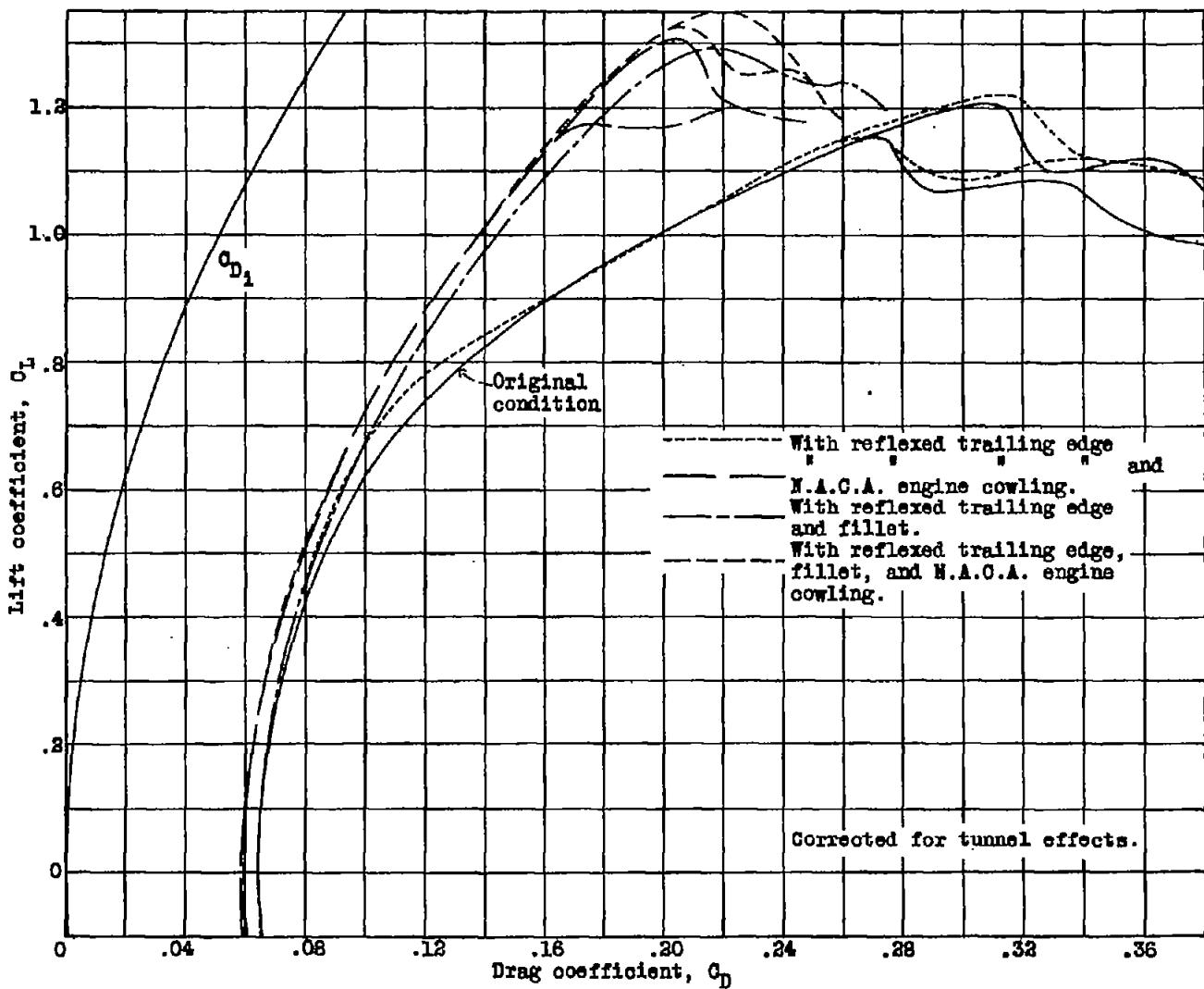
Figure 13.-Polars for McDonnel airplane with reflexed trailing edge.

With reflexed trailing edge
" " " " and
N.A.C.A. engine cowling.
With reflexed trailing edge
and fillet.
With reflexed trailing edge,
fillet, and N.A.C.A. engine
cowling.

Corrected for tunnel effects.

Original
condition

C_{D_1}

Lift coefficient, C_L

Drag coefficient, C_D

Fig.13
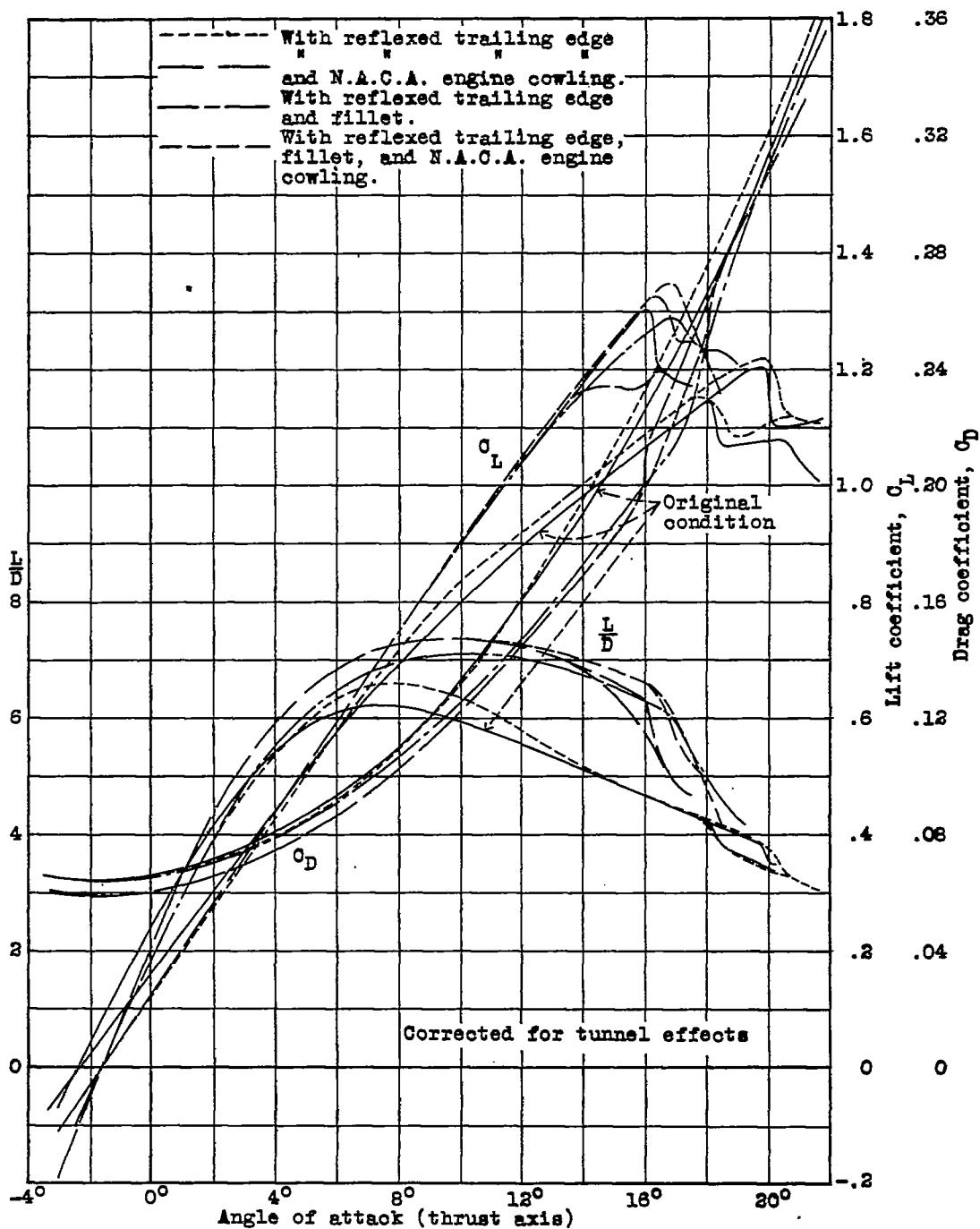
Figure 14.-Lift and drag of McDonnell airplane with reflexed trailing edge.
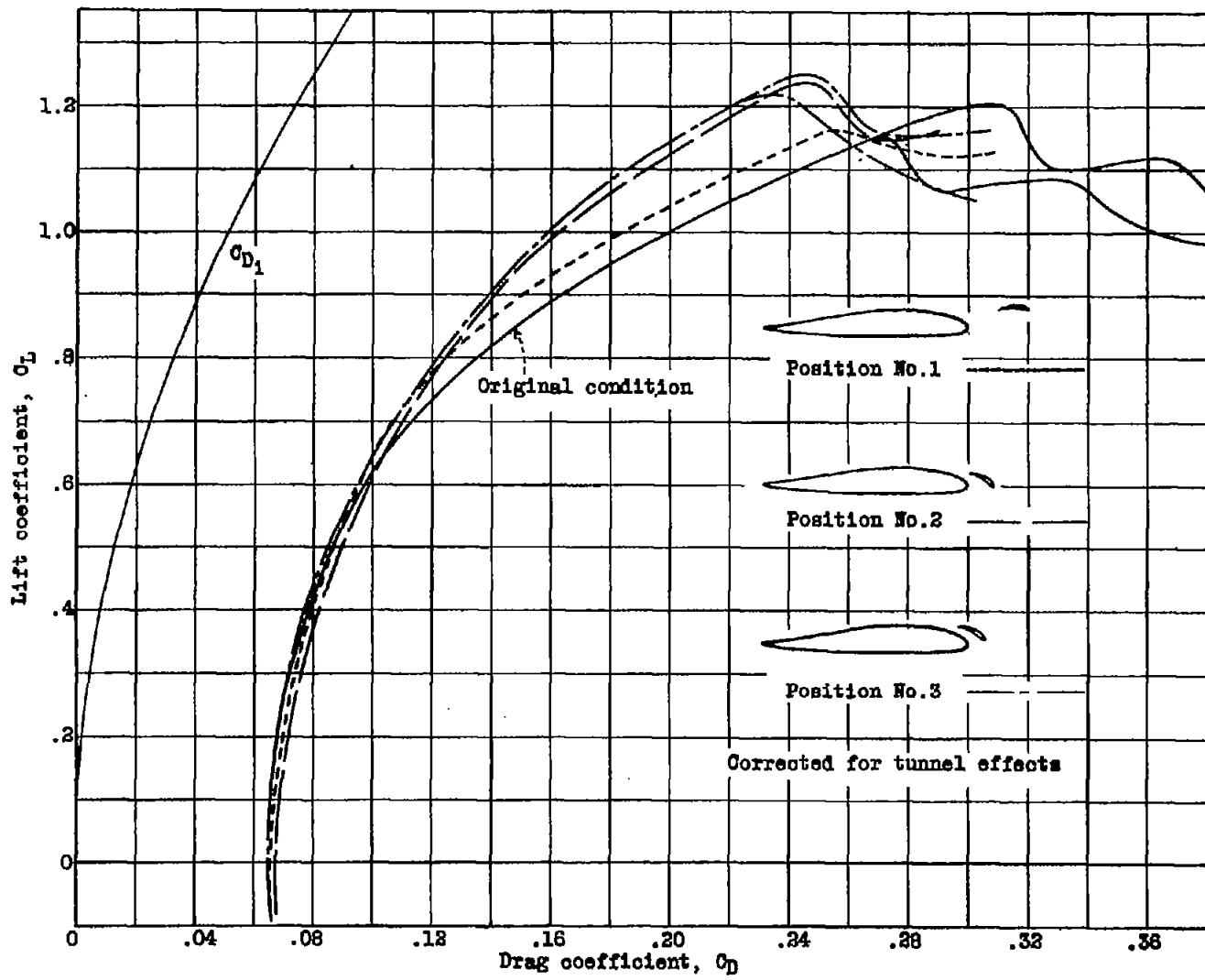
Figure 15.-Polars for McDonnell airplane with auxiliary airfoils.

Fig.15
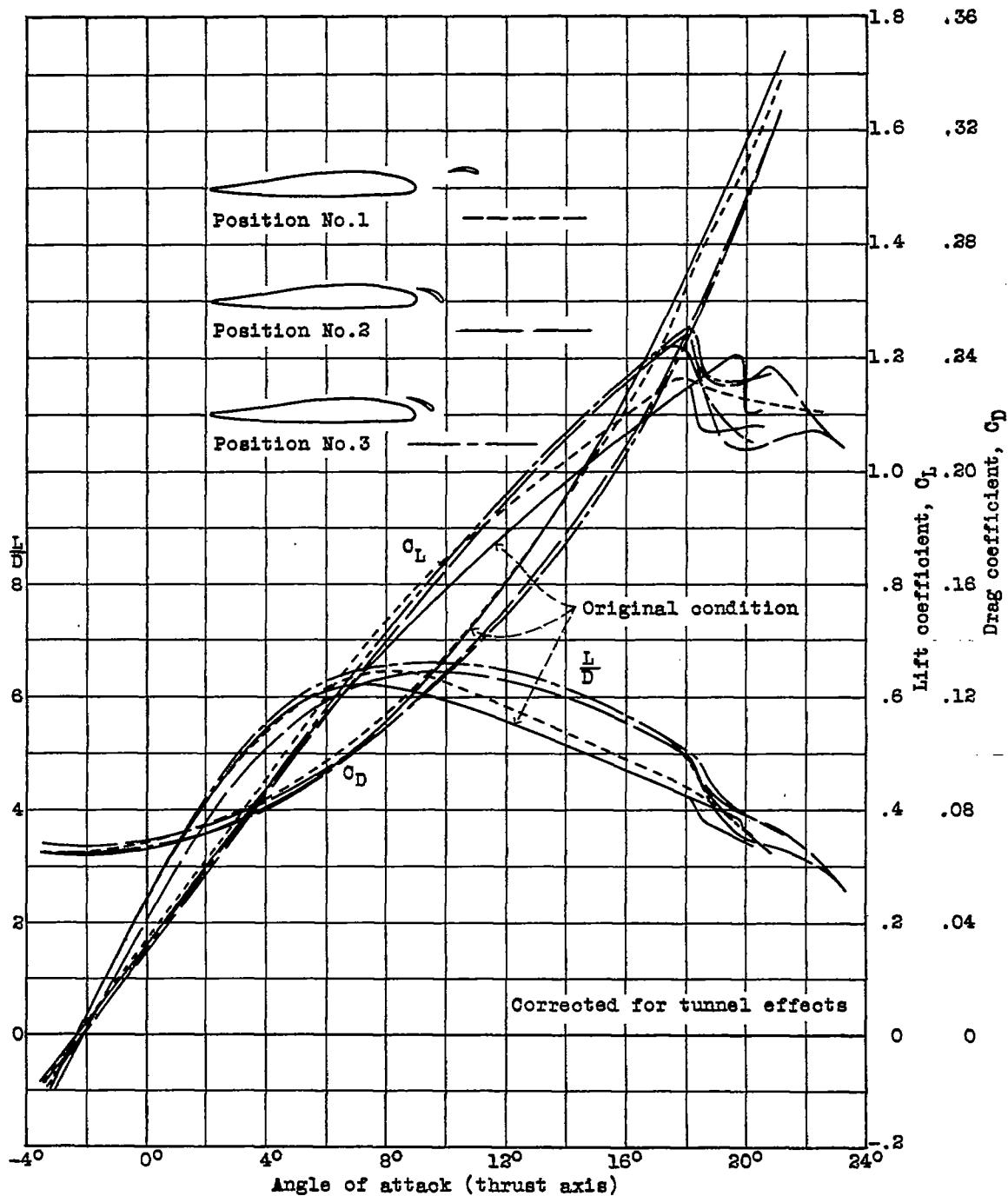
Figure 16.-Lift and drag of McDonnell airplane with auxiliary airfoils.

Fig. 17
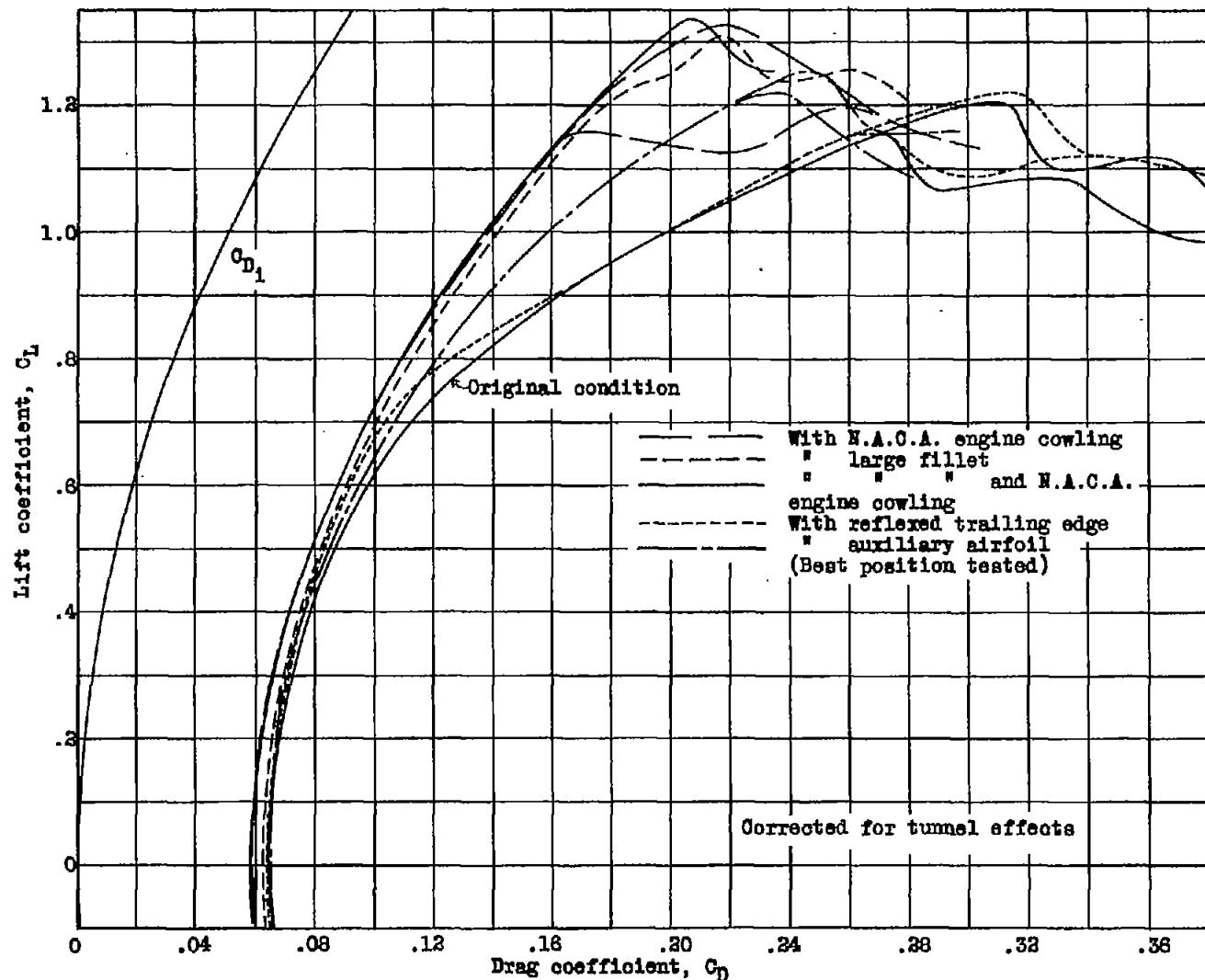
Figure 17.-Polars for McDonnell airplane comparing various devices.
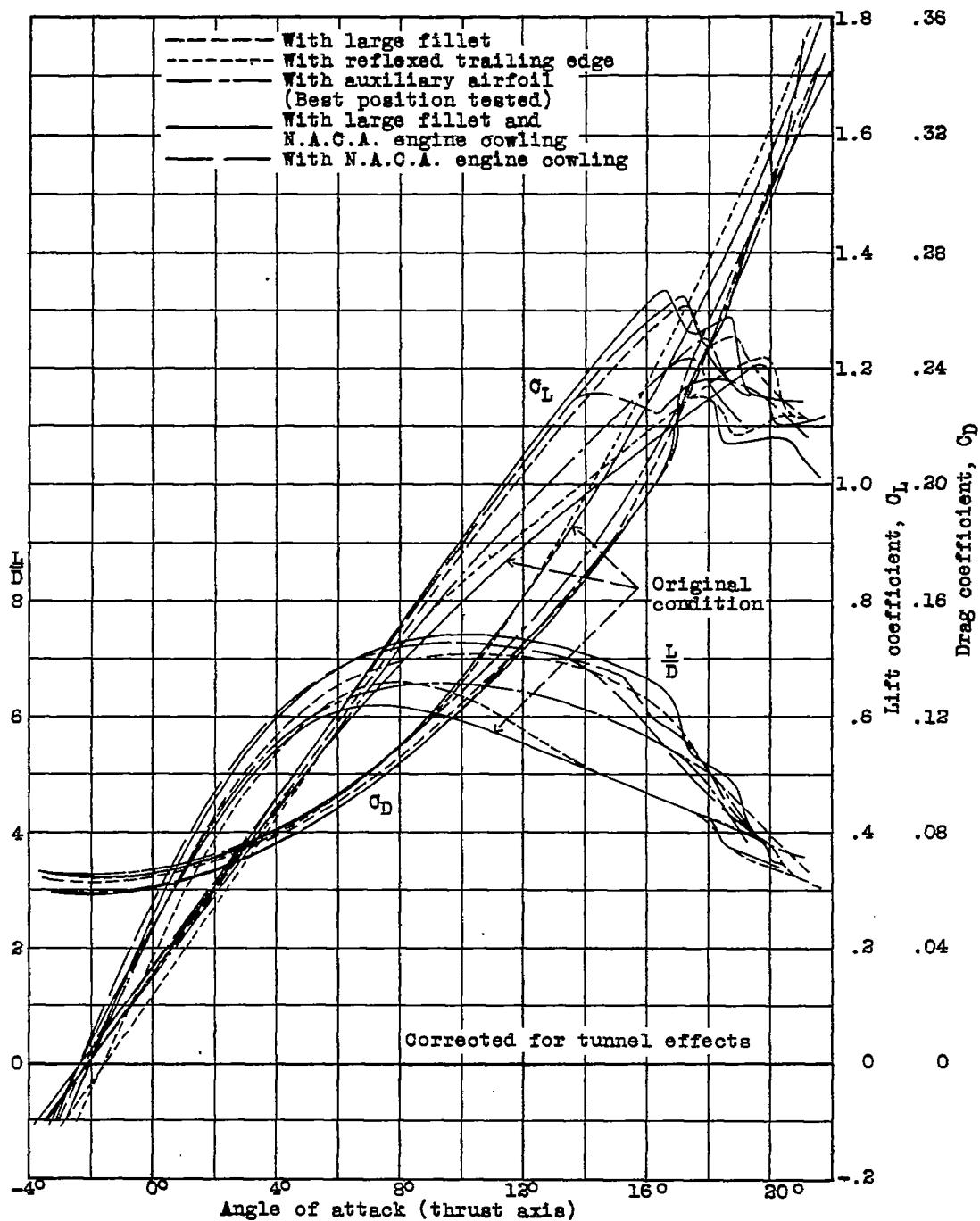
Figure 18.-Lift and drag of McDonnell airplane comparing various devices.
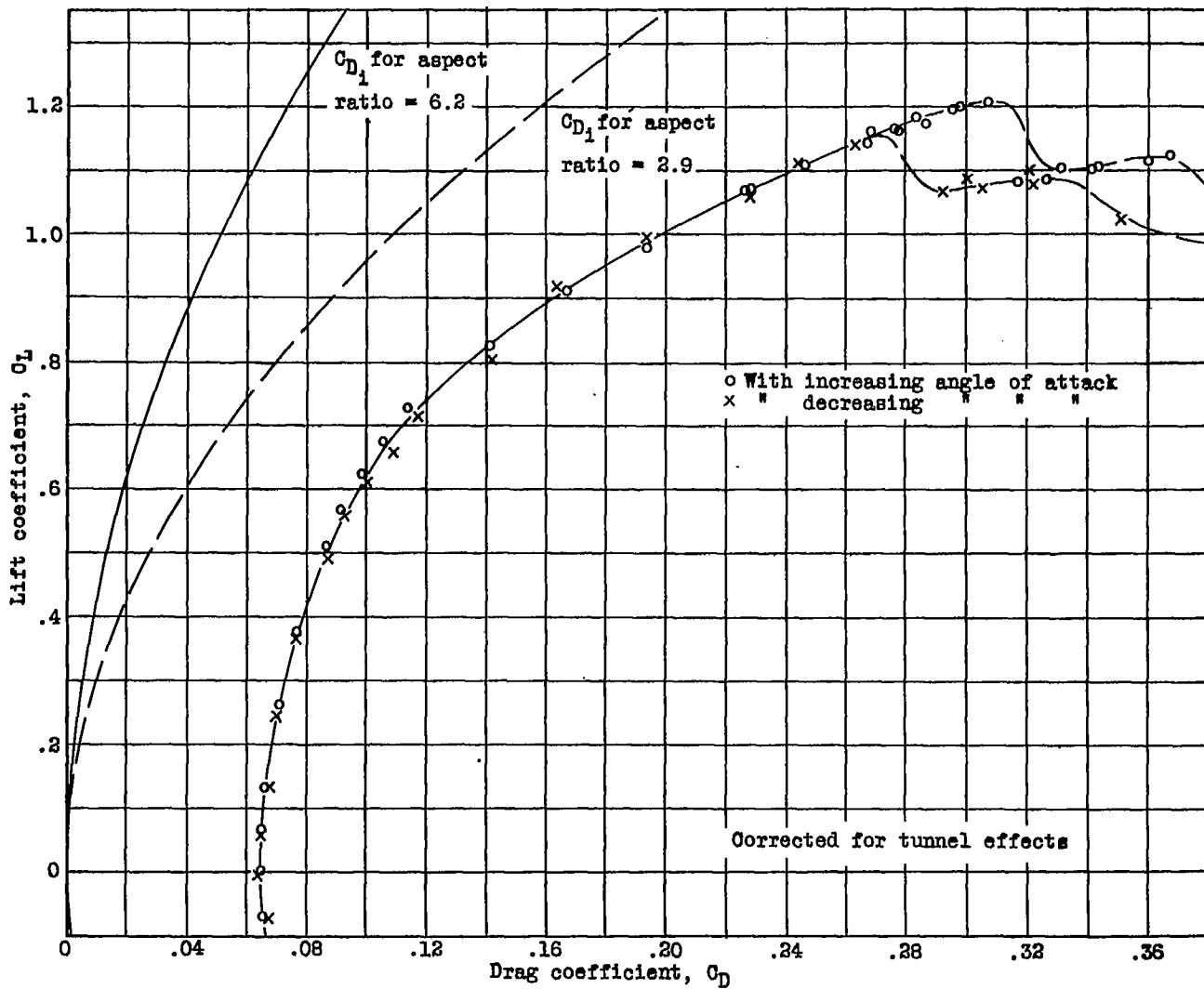
Figure 19.-Polar for McDonnell airplane in original condition.

C_{D_1} for aspect ratio = 6.2

C_{D_1} for aspect ratio = 2.9

o With increasing angle of attack
x "   decreasing "   "   "

Corrected for tunnel effects

Lift coefficient, C_L

Drag coefficient, C_D

Fig.19
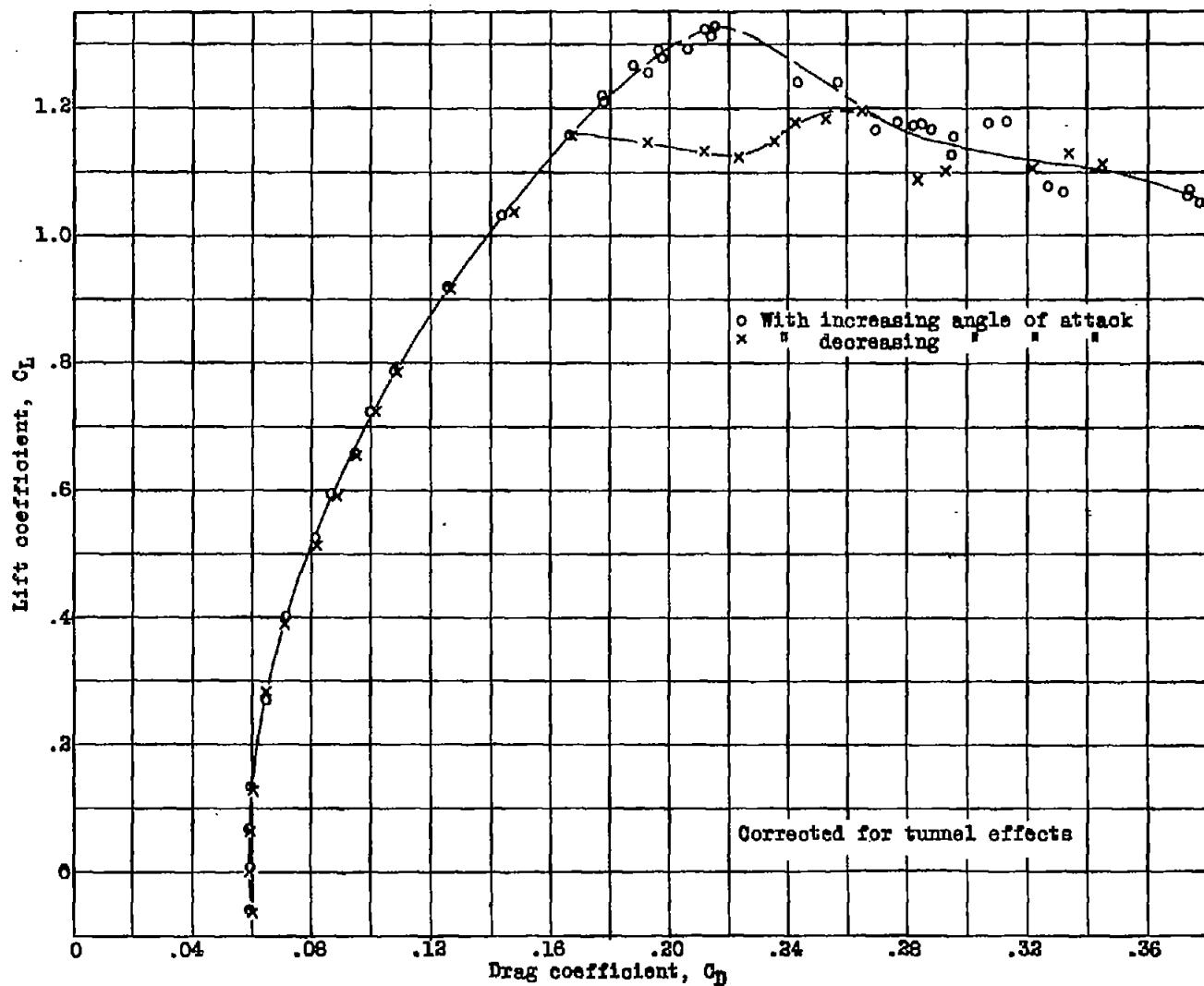
Figure 20.-Polar for McDonnell airplane with N.A.C.A. engine cowling.

Fig. 20
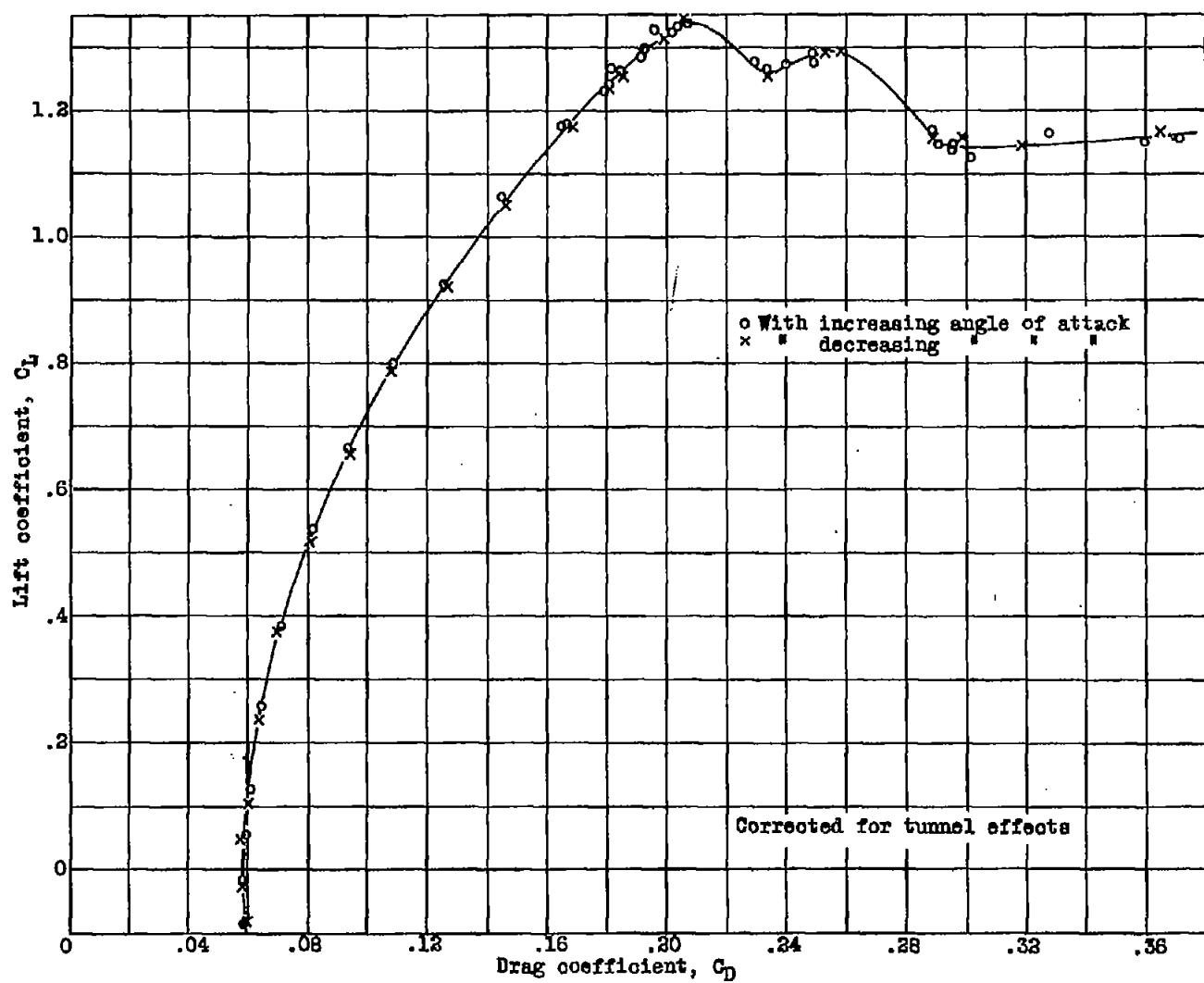
Figure 31.-Polar for McDonnell airplane with large fillet and N.A.C.A. engine cowling.

Fig. 31
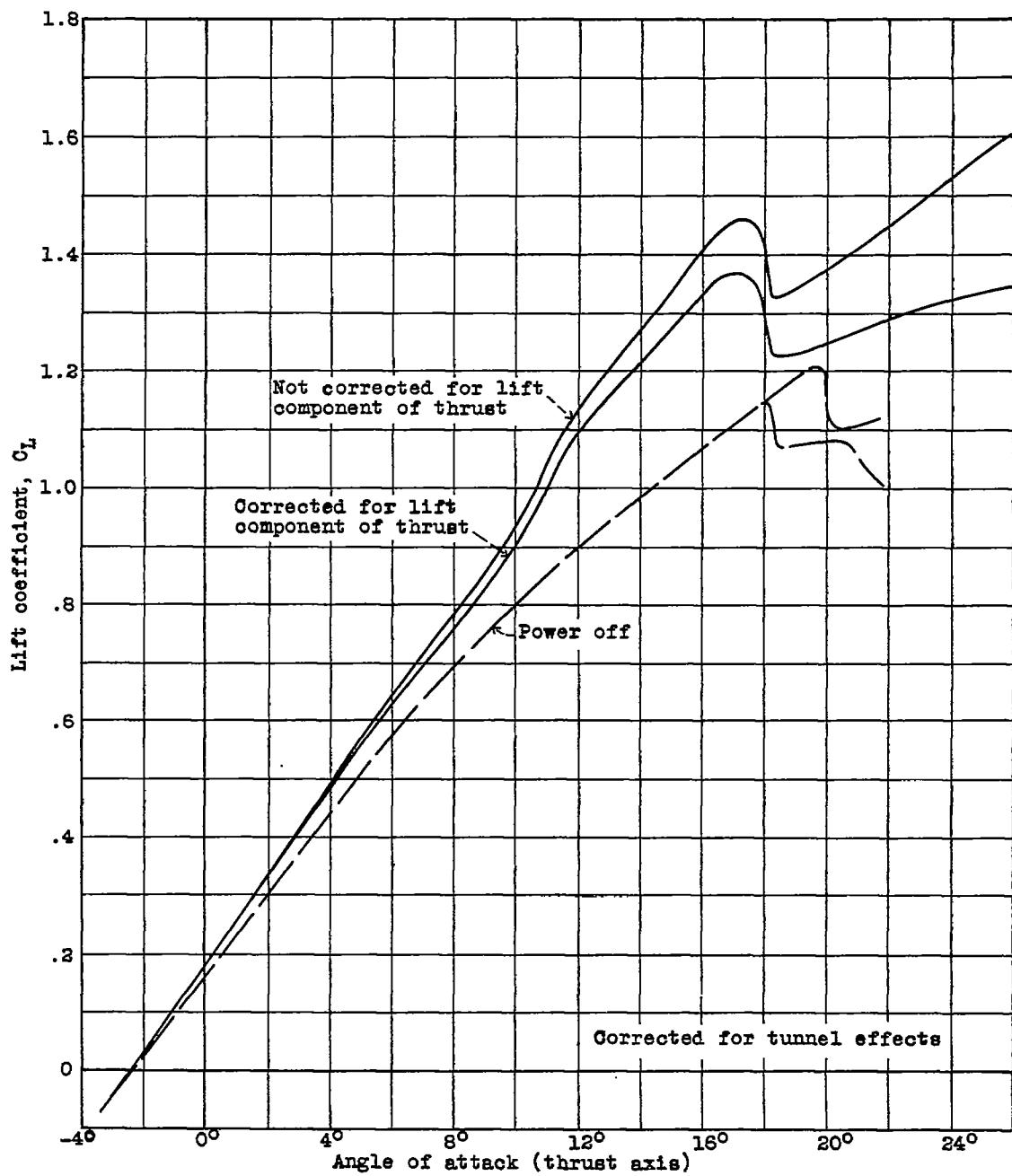
Figure 22.-Power-on lift of McDonnell airplane in original condition.
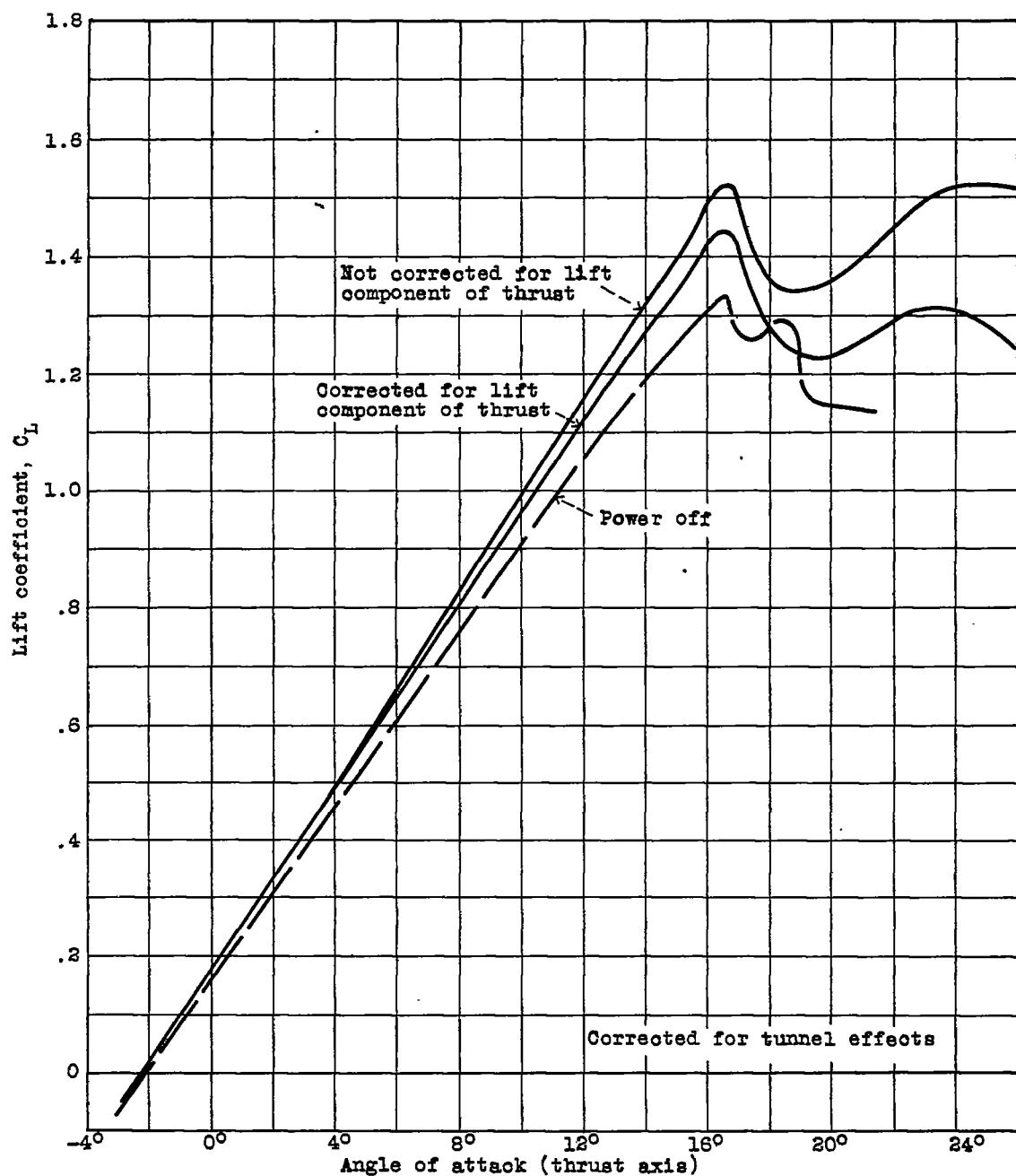
Figure 23.-Power-on lift of McDonnell airplane with large fillet and N.A.O.A.engine cowling.
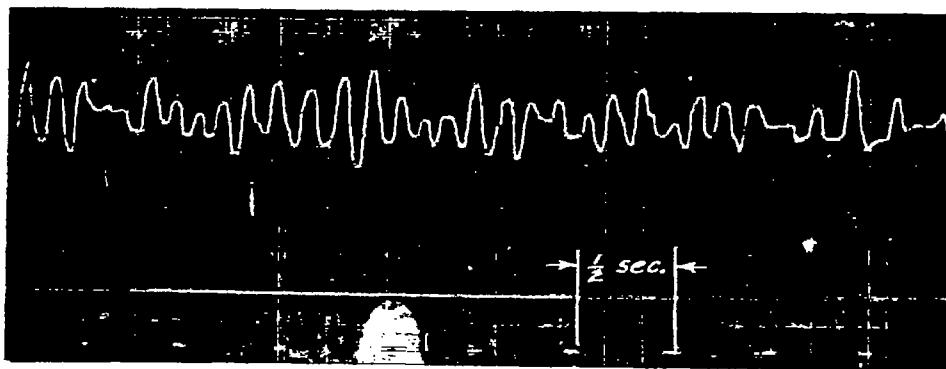
ORIGINAL CONDITION
Angle of attack = 14.1°, 5.6° Below $C_{L_{max}}$, C_L = 0.990
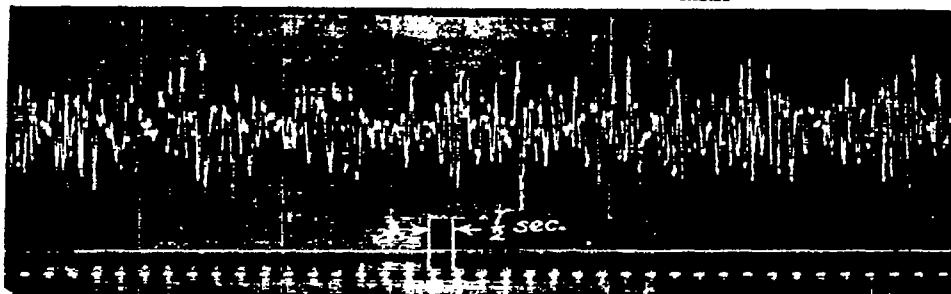
ORIGINAL CONDITION
Angle of attack = 17.8°, 1.9° Below $C_{L_{max}}$, C_L = 1.142
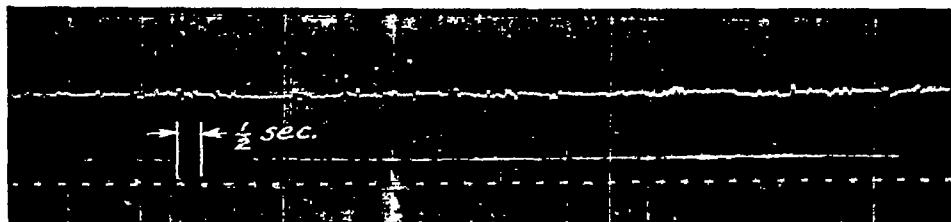
WITH LARGE FILLET
Angle of attack = 14.1°, 3.3° Below $C_{L_{max}}$, C_L = 1.145
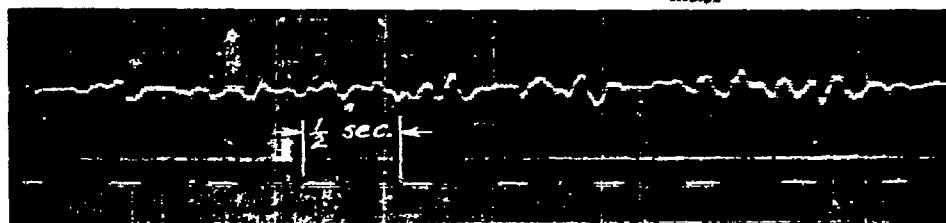
WITH LARGE FILLET
Angle of attack = 17.8°, 0.6° Above $C_{L_{max}}$, C_L = 1.250
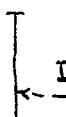
Deflection for 1- inch vertical
movement of stabilizer

Figure 24.-
Typical records of
stabilizer- tip movements
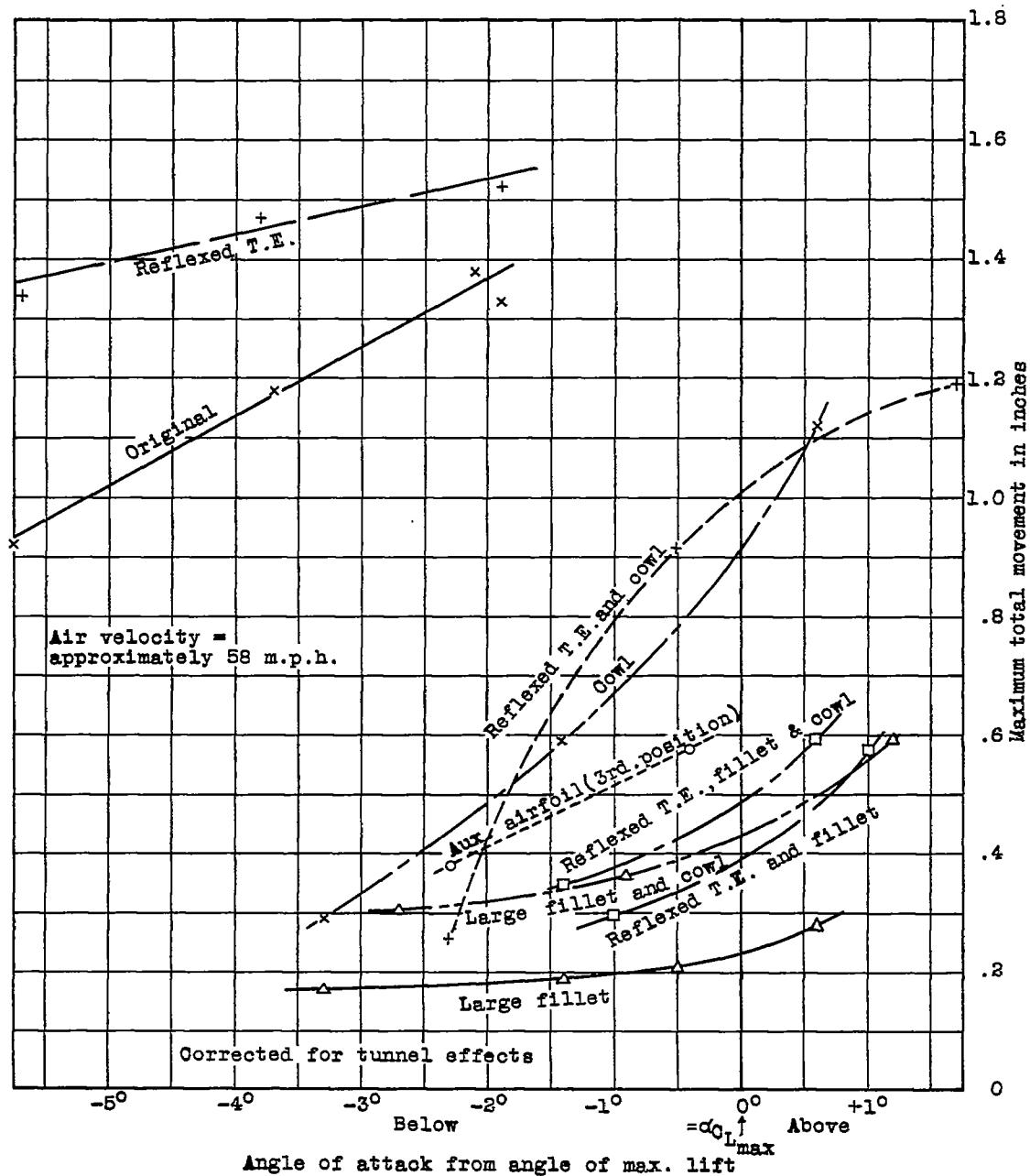
Figure 25.-Amplitude of stabilizer-tip movements under various conditions.
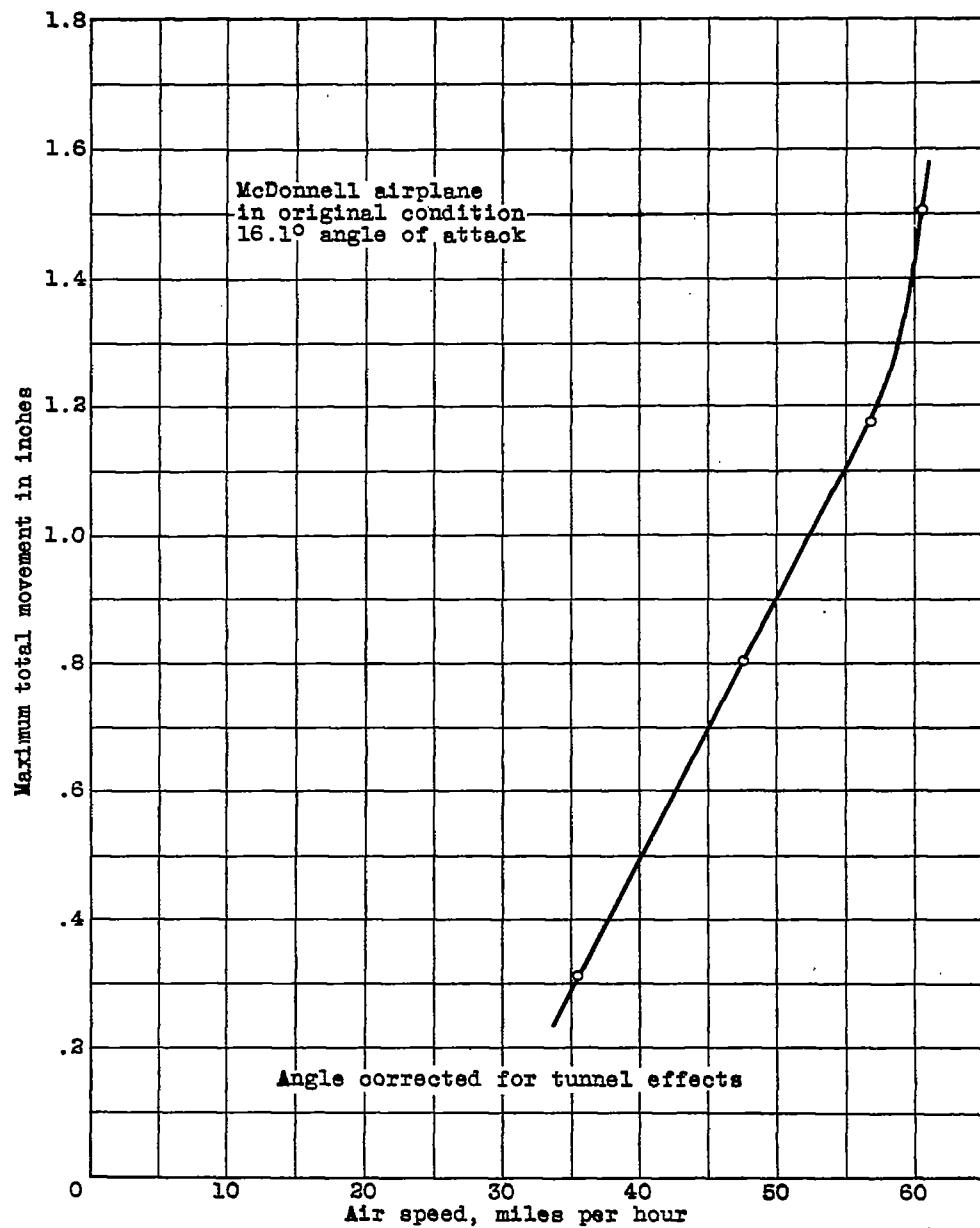
Figure 26.-Variation in stabilizer-tip movements with changes in air speed.