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RÉSUMÉ OF NACA STABILITY AND CONTROL TESTS

OF THE BELL P-63 SERIES AIRPLANE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Forces

RÉSUMÉ OF NACA STABILITY AND CONTROL TESTS

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INTRODUCTION

A résumé report on stability and control tests of Bell P-63 series airplanes, which have been conducted at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics, has been prepared and is presented herein. The purpose of this report is to describe briefly and to summarize NACA wind-tunnel tests conducted on models of the P-63 airplane and NACA flight tests conducted with two P-63A-1 airplanes up to the present time. In general, tests having an insignificant bearing on the possible development of the airplane are entirely omitted. Details of testing technique are also either omitted or treated only briefly. In cases where comparable tests were made in the wind tunnel and in flight, only the flight results are discussed. This is done because the wind-tunnel stability and control tests were entirely of a qualitative nature; the models used were of low scale and the tunnel velocities were also low. Major emphasis is laid on conclusions that may be drawn from the tests and on the opinions of NACA personnel with regard to the merit of the airplane and the merit of possible changes which may increase the value of the airplane from the stability and control stand-point. The remainder of this section of the report is devoted to a brief chronological outline of the wind-tunnel and flight stability and control investigations which have thus far been conducted on P-63 series air-planes by the NACA. At the time of this writing flight tests are still in progress.

Wind-tunnel tests of P-63 series airplane models were started in 1941 when a section model of the

XP-63 horizontal tail was tested in the 4- by 6-foot
closed-throat vertical wind tunnel. Measurements were
made of horizontal tail plane, elevator and tab
effectiveness, drag, and elevator hinge moments.
Three different elevator nose shapes were tested and
of these the one giving the best over-all characteristics
was determined.

Spin tests were made with a $\frac{1}{15}$-scale model of the
XP-63 and P-63A-1 airplanes in the 20-foot free-spinning
tunnel in 1942. These tests were made to predict the
ability of the full-scale airplane to recover from fully
developed spins. The effects on spin recovery of sequence
of control motion, airplane loading, and exterior config-
uration were investigated. In January of 1944, further
predictions were made of the spin characteristics of
heavily loaded P-63 airplanes with gross weights ranging
from 8,600 to 12,600 pounds. Results of these predictions,
as well as the earlier results, will be discussed farther
on in this report since no full-scale flight tests were
made by the NACA to investigate the spin characteristics
of the airplane.

A qualitative determination of the general stability
and control characteristics of a $\frac{1}{10}$-scale powered dynamic
model of the XP-63 airplane was made in the Langley free-
flight tunnel in the early part of 1943. Because full-
scale flight tests of a quantitative nature have since
been made, covering all of the important items investigated
in the free-flight tunnel, the free-flight tunnel tests
will not be further discussed in this report.

Flight tests of P-63 series airplanes at the NACA
were begun in the latter part of 1943 when a determina-
tion of the longitudinal stability and control charac-
teristics of one of the first P-63A-1 airplanes built
(AAF No. 42-68861) was made. In conjunction with these
initial longitudinal-stability tests a few data on the
lateral control characteristics of the airplane were
obtained.

Beginning in the first part of 1944 and continuing
until the present time, an extensive flight program of
testing and development has been carried on with another
P-63A-1 airplane (AAF No. 42-6889) at the NACA. The
primary purpose of this program is to improve the

longitudinal stability and control characteristics but
some effort has also been directed toward improving the
directional stability and control characteristics of the
airplane. Up to the present time, tests in this program
have been conducted with four different sets of elevators,
two different horizontal stabilizers, and two different
vertical tail surfaces. Future tests are expected to be
made with another set of elevators, a dorsal fin, and a
ventral fin. The major part of this report is based on
the test work covered in this most recent flight test
program.

DESCRIPTION OF AIRPLANE

AND MODIFICATIONS

Dimensional characteristics of first-production
P-63A-1 airplanes and of the various horizontal- and
vertical-tail modifications tested in flight are given
in the appendix. The following figures contain
descriptive material which is often referred to in later
discussions of tests made with the airplane at the NACA.

Figure 1 contains five reproduced pictures of an
early model P-63A-1 airplane. Figure 2 is a three-view
drawing of the same airplane. Initial flight tests and
nearly all wind-tunnel model tests were conducted with
this version of the P-63 series airplane. Aileron
dimensional characteristics are graphically portrayed
in figure 3. The various horizontal-tail plan forms
covered in flight tests of longitudinal stability are
shown in figure 4. Figure 5 shows cross-sectional
outlines of the different elevators tested in flight.
Figure 6 describes the two different vertical tail
surfaces used in the flight work done to improve the
directional stability and control characteristics of
the airplane. Finally, figure 7 shows photographs of
the modified P-63A-1 airplane as it is presently being
tested. The airplane represented by figure 7 differs
from that shown by figure 1 in that it is equipped with
larger horizontal and vertical tail surfaces and has a
dorsal fin.

D I S C U S S I O N

SPIN CHARACTERISTICS

All spin tests were conducted with a $\frac{1}{15}$-scale dynamically similar model of the P-63 airplane in the Langley 20-foot free-spinning vertical tunnel.

At the outset of spinning tests it was decided that the spin characteristics of the airplane should be made satisfactory in terms of the average pilot. For this reason a criterion was established which provided that the spin-tunnel model should be able to recover from fully developed spins in two turns or less after the rudder had been moved two-thirds full deflection against the spin with the ailerons set either one-third with or one-third full deflection against the spin and with the elevator set two-thirds full-up.

The original XP-63 model, ballasted to represent the airplane with a gross weight of 7447 pounds, did not meet the recovery criterion. The model spun flat and recovery was too slow. Adding ventral fin and rudder area below the fuselage was beneficial but this modification was not adopted because the change in ground clearance angle accompanying it was deemed objectionable. Instead, the vertical tail was moved back 17 inches full scale and the fuselage was lengthened a corresponding amount. The recovery criterion was satisfied with this configuration for normal loading and the rearward shift in vertical-tail position was incorporated in the design of the full-scale airplane. After the vertical tail had been moved rearward the airplane configuration corresponded to that shown in figures 1 and 2. When the addition of wing guns and ammunition was simulated on the model (involving a weight increase of about 400 pounds full scale) recoveries were insufficiently rapid to satisfy the criterion if the ailerons were set one-third with the spin. Brief tests of antispin fillets - dorsal fins installed forward of the horizontal tail plane - indicated such a modification would aid recovery. As a result of these tests it was decided that the best all-round recovery technique would consist of holding the ailerons in neutral and completely reversing the rudder against the spin, followed by moving the elevator down.

Further spin-tunnel tests with the model reballasted
to gross weights simulating the P-63A-1 airplane gave
results similar to those described above. For a gross
weight of 7704 pounds, full scale, without wing guns,
recoveries were sufficiently rapid to meet the criterion.
With the weight increased to 8076 pounds by adding wing
guns the recoveries were unsatisfactory if the ailerons
were held even partially with the spin. Holding ailerons
against the spin expedited recovery. These tests
indicated that the spin-recovery technique should vary
according to the distribution of weight in a spanwise
direction along the wings. When wing machine guns are
installed and wing fuel tanks are full, deflecting the
ailerons against the spin appears to be most beneficial
to rapid recovery; when no wing guns are present and the
fuel is almost entirely used from wing tanks, deflecting
the ailerons with the spin appears conducive to quick
recovery.

Recently an analysis was made to predict the spin
characteristics of the P-63 in the interceptor and long-
range fighter conditions, conditions in which the full-
scale gross weights vary from 8,632 to 12,581 pounds.
The effects of minor modifications to the wing tips and
elevator, involving slight increases in area, were
considered. It was predicted that recovery could not
be made with sufficient ease to meet the criterion for
any of the high gross weight conditions. It was
predicted, however, that rapid recoveries could be made
in any of these conditions if ailerons were deflected
against the spin and the rudder was fully deflected
against the spin followed by downward movement of the
elevator.

Full-scale spin tests of P-63 airplanes made by
the contractor agreed very well with results indicated
by tests of P-63 models made at the NACA with the possible
exception that recoveries from full-scale spins with
wing guns installed appeared even more critical than the
model tests had indicated. In this connection the
contractor's flight tests showed that the exterior shape
of the wing-gun fairings had a pronounced effect on spin-
recovery characteristics. In contrast, model tests
indicated that the direct aerodynamic effect of the
exterior wing-gun installation on spin-recovery charac-
teristics was negligible and that the adverse effect of
installing wing guns was due to the increase in spanwise
weight distribution accompanying the installation. If

the model tests are correct in this regard, no improvement in spin characteristics would be realized by simply installing the wing guns inside the wings instead of slinging them beneath the wings.

Summing up the P-63 spin characteristics on the basis of dynamic model tests, it appears that satisfactory recoveries from spins should be easily obtained with airplane gross weights under about 7700 pounds without wing guns installed. For gross weights ranging between 7,700 and 12,600 pounds and/or with wing guns installed, a precise sequence of corrective control action is required to effect rapid recovery from the spinning condition. Spin recoveries should be made less critical by adding a ventral fin and/or rudder area below the fuselage. The addition of horizontal dorsal fins should be beneficial to more rapid recovery as should the use of a taller vertical tail such as is shown in figure 6. Before leaving the subject of spinning it should be remarked that NACA flight tests indicate the stall-warning characteristics of the P-63 airplane are excellent so that inadvertent spinning would not ordinarily be encountered with this airplane. As the stall is approached, elevator buffeting and mild rolling motions occur which warn the pilot of an impending stall in sufficient time so that he can apply corrective control action before spinning has a chance to develop.

LATERAL CONTROL CHARACTERISTICS

Brief flight tests were made to determine the aileron characteristics of a first-production P-63A-1 airplane (AAF No. 42-68861).

The geometric characteristics of the P-63 ailerons are shown in figure 5 and additional dimensions are listed in the appendix.

The aileron characteristics were evaluated on the basis of the maximum rolling velocity and the stick force obtained by abruptly deflecting the ailerons predetermined amounts at indicated airspeeds of 120, 210, and 315 miles per hour while holding the rudder fixed in its straight-flight trim position. Indicated airspeed, as used throughout this report, corresponds to

the reading of a standard U. S. Army Air Force airspeed
meter vented to correct impact and static pressures. As
such it accounts for the compressibility error at sea
level and hence expresses true airspeed at sea level
under standard atmospheric conditions.

Figure 8 shows the data obtained in the test
aileron rolls plotted as stick force and wing-tip helix
angle pb/2V against estimated true change in total
aileron angle. The parameter pb/2V is made up of
symbols having the following definitions:

p   rolling velocity, radians per second

b/2   wing semispan, feet

V   true airspeed, feet per second

Estimated true change in total aileron angle is used
because only the position of the stick was measured in
flight. The loss in aileron deflection due to the
flexibility of the control system was estimated by
measuring the amount of control-system stretch as a
function of aileron stick force on the ground. Fig-
ure 9 shows the estimated rolling performance of the
P-63 airplane as a function of indicated airspeed for
50 pounds aileron stick force.

On the basis of the brief flight tests to determine
the aileron characteristics of the P-63 airplane the
following conclusions are indicated:

The rolling performance of the P-63 airplane is
generally satisfactory. The maximum rate of roll
possible with full aileron deflection is exceeded by
but few other current airplanes for which comparable
data are available. Aileron effectiveness per unit area
and per degree deflection is exceptionally high. The
aileron stick forces are about normal for this type
airplane. Because the stick forces, as a function of
aileron deflection, are desirably linear and because only
±15° of aileron travel are presently used, however, it
appears that a further considerable increase in rolling
performance could be obtained by making minor modifica-
tions to increase the aerodynamic balance of the
ailerons and by increasing the permissible aileron
deflection a few more degrees each way. If such

modifications are made, the P-63 airplane should exhibit
exceptionally high rolling performance. In this connec-
tion, the question of the ability of the airplane to
withstand the large aileron and vertical-tail aero-
dynamic loads associated with large aileron deflections
at high speed should not be overlooked. Vertical-tail
loads due to aileron action are discussed later in this
report. Two other points appear to require attention in
an evaluation of the P-63 ailerons.

First, on the airplane used to determine aileron
characteristics (AAF No. 42-68861), the aileron control
system was excessively flexible. For instance, a ground
calibration indicated that only $16\frac{1}{2}$ out of a possible
30° change in total aileron angle could be obtained
with a stick force of 50 pounds. It is not known if
this is a general condition in all P-63 airplanes but
it is recommended that this condition be investigated
and corrected if it is general. Flexibility, of course,
needlessly penalizes the rolling ability of the airplane
in the low and intermediate speed ranges. Second, the
P-63 airplanes flight tested at the NACA were equipped
with a fixed aileron trim tab which could be adjusted
only on the ground. It is strongly recommended that an
aileron trim tab adjustable from the cockpit during
flight be provided if this is not already being done.
The relatively small aileron trim-force changes due to
unequal fuel consumption from the wing tanks and to
changing speed were considered objectionable by NACA pilots.

LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS

Complete longitudinal-stability determinations were
not made for any of the various elevator-stabilizer
combinations tested but items not investigated were those
having little importance in a general evaluation of the
airplane. Due to the interim nature of this report it
is impossible to include all of the flight results which
have been obtained since many of the results are not yet
plotted in suitable form. Where this applies, the data
obtained will be described without reference to illus-
trative figures. The various longitudinal-stability
tests are treated in the approximate chrononological
order in which the tests were made.

Original Horizontal Tail Surfaces

The original P-63A-1 horizontal tail surfaces had the plan form shown in figure 4(a). The elevator was fabric covered and its ribs were $8\frac{1}{2}$ inches apart on the average. The elevator section shape is shown in figure 5(a). It may be noted that the elevator surfaces in the trailing-edge region were flat and formed an acute angle of about 13°. The original stabilizer incidence was 2.7° nose up with respect to the airplane thrust axis.

Static longitudinal stability.- The static longitudinal stability of the original P-63A-1 airplane is shown in figures 10 and 11 for power on and power off, respectively. When the airplane was trimmed for zero elevator stick force at 300 miles per hour indicated airspeed, the variation of stick force with speed always went in the wrong direction at higher speeds. This characteristic was extremely undesirable. It was caused by aeroelastic distortion of the horizontal stabilizer and elevator due to the combination of a too high positive stabilizer incidence and a very flexible elevator covering. Further analysis of the elevator-angle variations with speed indicated that the center of gravity for which neutral stability would occur with stick fixed was at 32 percent of the mean aerodynamic chord with either power on or off at 10,000 feet altitude for speeds at which the airplane would be flown for protracted periods of time. The significance of this measurement is that it establishes an extreme rearward center-of-gravity limit beyond which the airplane should not be flown even if acceptable stick-force characteristics are present. As can be seen from figures 10 and 11, the stick-force characteristics of the original P-63A-1 airplane in straight flight were unsatisfactory at all center-of-gravity positions at high speed.

Maneuvering longitudinal stability.- The maneuvering stability of the original P-63 airplane was investigated by determining the average stick force required to produce a unit change in normal acceleration and the average change in elevator angle required per unit change in airplane normal-force coefficient in essentially steady turns up to 4g total acceleration and up to 300 miles per hour indicated airspeed for

two center-of-gravity positions.   Summary curves of the
results obtained are shown in figure 12.   These results
indicate the stick-force gradient would be zero if the
center of gravity were at 29.2 percent of the mean
aerodynamic chord and turns were made at 10,000 feet
altitude.   Actually, to have an acceptable minimum
stick-force gradient of about 3 pounds per g, the
permissible center-of-gravity location would have to be
kept forward of 26 percent mean aerodynamic chord.
Even this restriction would not insure desirable turning
stability at higher altitudes since it is usual for
longitudinal maneuvering stability to deteriorate with
decreasing air density (increasing altitude).

Incidence and Elevator Modifications with Original

Horizontal Stabilizer

As a result of the generally poor longitudinal-
stability characteristics of original production
P-63 airplanes, a conference was held between United
States Army Air Force, Materiel Command, Bell Aircraft
Corporation, and NACA representatives to discuss means
of improving the various unsatisfactory stability
characteristics.   As a result of this conference, plans
were made to investigate the effects of stabilizer-
incidence setting, elevator stiffness, and elevator
cross-sectional shape as a means of improving the stick-
free longitudinal-stability characteristics of the
airplane.   Definite objectives set up were the elimina-
tion of the stick-force reversal at high speed in
straight flight and the attainment of the elevator
balance characteristics necessary to give stick-force
gradients which would always be between 3 and 8 pounds
per g at any altitude up to 25,000 feet and for any
center-of-gravity position between 20 and 30 percent
of the mean aerodynamic chord.   The following discussion
describes the work done toward obtaining these objectives.

Effect of stabilizer incidence and elevator fabric
distortion on static longitudinal-stability charac-
teristics.- The P-63A-1 airplane (AAF No. 42-68889)
used in testing the modifications referred to above
was practically identical to the original P-63A-1
tested (AAF No. 42-68861) except that the elevator
plan form was changed by providing a cut-out as is shown
in figure 6(b).   This modification was made by the

Bell Aircraft Corporation to improve rudder effectiveness
in spin recoveries. The longitudinal-stability charac-
teristics were not notably changed from those of original
P-63A-1 airplanes.

It was generally believed that the stick-force
reversal in high-speed straight flight was caused by
an improper high stabilizer incidence and by resultant
objectionable changes in elevator cross-sectional shapes
due to fabric distortion. To cure this condition the
stabilizer incidence was reduced from 2.7° to 1.1°, and
the original elevator having unsupported spanwise fabric
bays of 8 inches (see fig. 13) was replaced by an
elevator of the same cross-sectional shape having twice
as many ribs, which cut down the fabric bay width to
$3\frac{3}{4}$ inches on the average. (See fig. 14.)

Figure 15 shows a comparison between static longi-
tudinal stability characteristics of the original and
modified stabilizer-incidence, elevator-stiffness
combinations. It may be noted that with the stabilizer
incidence at 1.1° the elevator is practically lined up
with the stabilizer at high speeds so that there is
practically no tendency for fabric bowing to warp the
elevator mean camber line and hence cause undesirable
stick-force variations. This is borne out by the stick-
force measurements shown in figure 15 since no force
reversal occurred with the lowered incidence, stiffer-
elevator combination.

In order to gain a more complete knowledge of the
effects of stabilizer incidence and fabric distortion,
pictures were taken in flight of the upper and lower
elevator surfaces for each of the two combinations
tested. Examples of such pictures taken in level flight
at an indicated airspeed of approximately 350 miles
per hour are shown in figure 16. From pictures such
as these the elevator section shapes at the middle of
representative fabric panels were determined at various
speeds in straight flight and at various normal
accelerations in turning flight at constant indicated
airspeeds. Results of these determinations covering
the case of changing speed in straight flight are shown
in figures 17 and 18 for the original elevator and the
double-ribbed elevator, respectively. The section
shapes for changing acceleration are omitted because it
was found that the amount of fabric distortion was
sensibly independent of normal acceleration at a constant

indicated airspeed. An examination of figures 17
and 18 indicates that by doubling the number of elevator
ribs the maximum fabric distortion at the center of an
elevator panel was cut to about one-fifth its original
amount at a given speed. This agrees well with theory
which indicates the maximum fabric distortion for
essentially constant pressure differentials should be
in proportion to the square of the unsupported panel
gap distance.

Summarizing the results of the investigation to
correct stick-force reversal at high speeds, the following
points may well be reemphasized:

The stabilizer-incidence setting of $1.1°$ nose up
from the thrust axis is satisfactory since no stick-
force reversal with increasing speed exists with this
incidence setting. This lowered stabilizer incidence
has been adopted for production P-63 airplanes. If any
further incidence changes are made they should be in a
downward direction since this should tend to increase
further stick-free stability at high speeds. It is
felt that on an airplane capable of speeds often encoun-
tered by the P-63 airplane, the elevator rib spacing
should not exceed about 4 or 5 inches if fabric is to
be used for covering since the extreme fabric distor-
tion occurring with greater rib spacings raises doubt of
structural integrity regardless of stabilizer-incidence
setting. Although a metal-covered elevator would be
desirable to reduce distortion effects, the use of
fabric-covered elevators is not necessarily undesirable
so long as enough ribs are used to back up the flexible
fabric covering.

Effect of elevator cross-sectional shape on stick-
force characteristics.- The second objective of the
flight-test program was, as stated previously, to develop
an elevator giving stick-force gradients in steady
accelerated flight always between 3 and 8 pounds per g
at either 5,000 or 25,000 feet altitudes at any
center-of-gravity position between 20 and 30 percent
of the mean aerodynamic chord. To define the starting
point of the problem more clearly, tests were first
carried out with original-contour elevators to establish
definitely their characteristics in steady accelerated
flight at 5,000 and 25,000 feet altitudes. The cross-
sectional shape of original-contour elevators is shown
in figure 5(a) and the horizontal-tail plan form was that

shown in figure 4(b). The rib spacing on the elevators averaged $4\frac{1}{4}$ inches between center lines.

Testing technique consisted in making steady turns at various steady accelerations with different constant indicated airspeeds at 5,000 and 25,000 feet altitudes. The data were plotted as stick-force and elevator angle required to trim against normal acceleration in multiples of the acceleration of gravity. An example of such a plot is shown in figure 19. From plots of this form the stick-force gradient was found by dividing the average stick-force increment between 1g and 5g by 4. Then, to determine the stick-free maneuver point (center-of-gravity position at which stick-force gradient would be zero) the stick-force gradients at different center-of-gravity positions were plotted as a function of center-of-gravity position, as is shown in figure 20, and straight lines were drawn through the test points. The pertinent points brought out by the data for original-contour half rib-spaced short-chord elevators, shown in figure 20, were the following:

In the critical 25,000-foot-altitude condition, the most aft center-of-gravity position at which a stick-force gradient of 3 pounds per g could be obtained was about 24 percent mean aerodynamic chord. Furthermore, the rate of change of stick-force gradient with center-of-gravity position was such that the force gradient limits of 3 to 8 pounds per g could be met over only 5 percent mean aerodynamic chord instead of the desired 10-percent range, excluding consideration of the loss in stick-force gradient with increasing altitude. It was therefore concluded that the elevator balance was insufficient to meet the desired objective.

Two new elevators were designed and built which incorporated increased trailing-edge angles as a means of increasing the aerodynamic balance. Cross sections of these elevators are shown in figures 5(b) and 5(c), respectively. One of these elevators (fig. 5(b)) was fabric covered with a rib spacing of $4\frac{1}{4}$ inches and its average trailing-edge angle was 21.3°.[4] Preliminary tests indicated these elevators were too highly balanced, so the balance was then reduced to obtain the desired amount by adding 9-inch long strips of $\frac{1}{8}$-inch diameter wire on the upper and lower surfaces, at the elevator

trailing edge, on each side of the airplane at elevator
midspan. The other elevator (fig. 5(c)) was metal
covered and had an average trailing-edge angle of 17.0°.
These elevators had about a $\frac{1}{2}$-inch greater chord than
either the original contour or the fabric-covered
bulged elevators. No extra balance modifications were
necessary with the bulged metal-covered elevators.

Summaries of the stick-force characteristics of the
airplane with the bulged elevators installed are shown
in figures 20 and 21. It may be noted that the variations
of stick-force gradient with center-of-gravity position
were almost small enough to meet the objective but that
the stick-force gradients were too low at rearward
center-of-gravity positions. This was corrected by
installing a 2.3-pound bobweight in the elevator control
system in the case of the fabric-covered bulged elevators
and a $3\frac{1}{4}$ pound bobweight in the case of the metal-covered
bulged elevators. A bobweight is simply weight unbalance
in the elevator control system which adds stick force
in proportion to the normal acceleration on the airplane.
In level, or 1g, flight the stick-force increment due to
the bobweight is trimmed out with the elevator trim tab.
The actual variations of stick force with acceleration
were very satisfactory with the bulged elevators as can
be seen from the typical plot shown in figure 22.
Besides supplying the desired stick-force characteristics
in steady accelerated flight, the bulged elevators gave
excellent static stability characteristics, an example
of which is shown in figure 23. Also, the elevator-free
short-period oscillation characteristics were satisfactory.
In spite of all these good points, however, some bad
control-feel characteristics were inherent in the use of
these highly balanced elevators.

First, the stick was unusually easy to deflect
when rapid longitudinal maneuvers were made. In most
airplanes larger stick forces are required to reach
a given maximum normal acceleration in fast maneuvers
than in slow maneuvers. With very highly balanced
elevators the reverse is true. The bulged elevators,
then, tended to make proper control difficult in abrupt
maneuvers when the center of gravity was rearward and
only small stick movements were necessary to produce
large normal accelerations.

Second, the control feel was objectionable when
flying in rough air. Whenever the airplane hit a gust
the stick would immediately tend to move in a direction
to return the airplane to its trim condition. The
stick forces accompanying these self-induced restoring
tendencies were objectionable to the pilot, who described
the action as "stick bouncing." A part of this trouble
was undoubtedly due to the bobweight installation and
a part was attributed to the tendencies of these highly
balanced elevators to float against the relative wind
whenever a change in angle of attack occurred.

Summing up this portion of the investigation, it
appears that the satisfactory control-feel characteristics
associated with the small aerodynamically balanced
original-contour elevators can be obtained only at the
expense of having a restricted center-of-gravity range
where steady flight stick-force characteristics are
altogether desirable. On the other hand, desirable
steady flight stick-force characteristics can be obtained
over a large center-of-gravity range if certain poor
control-feel characteristics can be accepted. This
analysis overlooks the possibility that some type of
artificial dampener might be developed to improve control-
feel characteristics of highly balanced elevators. In
connection with the poor control-feel characteristics
explained above, it was noted by the pilot that the
undesirable characteristics tended to become less
noticeable as familiarity with them increased.

The longitudinal characteristics with an enlarged
horizontal tail are discussed in a subsequent part of
this report.

Ability to raise nose wheel on take-off.- In the
course of running longitudinal-stability tests, measure-
ments were made of the elevator effectiveness available
to raise the nose wheel from the ground in take-off runs
on a concrete runway and of the ability of the elevator
to hold the airplane off the ground until minimum air-
speed had been reached on landing. All tests were made
with the horizontal tail plan form shown in figure 4(b)
and with the elevators represented by figures 5(a),
5(b), and 5(c).

The test procedure in take-off was to hold the
elevator up until the nose wheel came off the ground at
which time the airspeed was recorded. Various up-
elevator deflections were used in these runs up to nearly
full-up elevator angle. The results are plotted in
figure 24 showing airspeed at which the nose wheel
raised as a function of center-of-gravity position.
A dash line has been faired to indicate the estimated
variation of minimum speed to raise the nose wheel,
using full-up elevator deflection, with center-of-
gravity position.

It may be concluded that the P-63A-1 airplane has
sufficiently great elevator power in take-off with any
of the elevators tested since the nose wheel could
easily be raised from the ground before 0.8 of the normal
take-off speed had been reached with the center of
gravity at its most forward limit (20 percent mean
aerodynamic chord).

Elevator control in landing.- Testing technique to
find if sufficient elevator effectiveness were available
for making minimum speed landings consisted in making
power-off landings with flaps full down in which the
pilot attempted to hold the airplane off the ground
until the stall occurred. Landings were made with
various center-of-gravity positions. The maximum
recorded up-elevator angles required to perform such
landings are shown in figure 25.

Figure 25 indicates the available elevator power
is slightly deficient to make minimum-speed landings
with center-of-gravity positions forward of 22 percent
of the mean aerodynamic chord. Since this deficiency
is only marginal and since the power-off landing test
condition is the severest possible, it may be concluded
that the P-63A-1 airplane has sufficient elevator power
to make minimum-speed landings in any condition it is
likely to be used in service.

Enlarged Horizontal Tail Surfaces

Because of the difficulty in acquiring sufficient
longitudinal stability at rearward center-of-gravity
positions, the Bell Aircraft Corporation recently put
into production an enlarged horizontal tail having an
increased aspect ratio. The dimensional characteristics

of this horizontal tail are given in the appendix and
the plan form is shown in figure 4(c). This larger
tail provided a rearward shift in the center-of-gravity
position for neutral stick-fixed stability of about
2 percent mean aerodynamic chord. The stick-free
stability for a given elevator shape should, of course,
be affected in a similar manner. Present production
P-63 airplanes are being fitted with original contour
elevators having the cross section shown in figure 5(a).
Even with the gain in stability provided by using the
larger horizontal tail, however, the problem of supplying
adequate stick-force gradients at rearward center-of-
gravity positions and high altitudes appears critical.
At the request of the United States Army Air Forces,
Materiel Command, the NACA designed and is testing another
set of bulged fabric-covered elevators in an effort to
determine the best type of elevator for use with the
enlarged horizontal tail. In the present test program
the attainment of desirable stick-force characteristics
at rearward center-of-gravity positions is being sought
without resort to the use of a bobweight.

Characteristics with modified elevators.- A cross
section of the NACA designed bulged elevators is shown
in figure 5(d). These elevators have been tested only
at 5000 feet altitude to date. Two configurations have
so far been tested; first, with the elevator-stabilizer
gap open between 1/8 and 1/4 inch along its entire
length, and second, with a positive curtain seal across
the gap along the entire length of the elevators except
at the hinges.

Without the seal installed, the stick-force charac-
teristics were unsatisfactory because the aerodynamic
balance was too great. In straight flight the variation
of stick force with speed was almost negligible as can
be seen in figure 26. In turning flight the stick-
force gradients were insufficiently high at all except
forward center-of-gravity positions. This is shown in
figure 27. Furthermore, the stick forces required to
make abrupt maneuvers were much too low.

With the curtain seal installed the aerodynamic
balance characteristics were improved. The variation
of stick force with speed in straight flight was
satisfactory as can be seen from figure 28. The stick-
force gradients in steady turning flight were increased
somewhat for forward center-of-gravity positions but

were apparently reduced at far rearward center-of-
gravity positions. (See fig. 29.) The control feel
in abrupt maneuvers was improved.

Further modifications may be attempted with this
set of bulged elevators in the near future.

Predicted characteristics with present production
elevators.- Although no flight tests have been made at
the NACA to determine the longitudinal-stability charac-
teristics of present-production P-63 airplanes with
original-contour flat-sided elevators on the enlarged
horizontal tail, it is felt that a fairly accurate
prediction can be made of the over-all steady turning
stability characteristics of the airplane on the basis
of the accumulated test data gathered in previous tests
of P-63 airplanes at the NACA. Such a prediction has
been made and is presented in figure 30.

From figure 30 it may be concluded that the stick-
force gradients will be very low for rearward center-
of-gravity positions at high altitudes and quite high
at forward center-of-gravity positions at low altitude.
Control-feel characteristics in rapid maneuvers should be
satisfactory with this configuration.

DIRECTIONAL STABILITY AND CONTROL CHARACTERISTICS

During the course of the longitudinal-stability
flight test programs, it was found that the directional
stability of the P-63A-1 airplane was inadequate. In
turn entries, small inadvertent motions of the rudder
caused large amounts of skidding. Also, in certain
steady flight conditions, an undamped directional
oscillation existed even when the pilot attempted to
hold all the controls absolutely fixed. A time history
of such an oscillation is shown in figure 31. Due to
the apparent weak directional stability of the airplane,
measurements of its directional characteristics in typical
maneuvers were made and then the same tests were repeated
after an enlarged vertical tail had been installed to
make the directional stability more satisfactory.
Outlines of both the original and enlarged vertical
tails tested are shown in figure 6. Dimensional charac-
teristics of both vertical tails are given in the appendix.
Figure 7 contains reproduced views of the airplane with

the modified vertical tail installed. The dorsal fin
shown in figure 7 is a recent addition which has not
yet been formally tested.

Directional Characteristics in Sideslips

The results of all the sideslip tests made with each
vertical tail installed on the airplane are shown in
figures 32 to 38, inclusive. The following table is a
key showing the airplane conditions corresponding to
each set of sideslip data:

Figure no.	Service indicated airspeed (mph)	Power conditions	Altitude (ft)
32	150	Engine idling	5,000
33	150	Normal rated (2600 rpm, 43 in. Hg.)	5,000
34	250	---------do.---------	5,000
35	300	---------do.---------	5,000
36	400	---------do.---------	5,000
37	150	Power on (2600 rpm, 38 in. Hg.)	22,000
38	250	Power on (2600 rpm, 39 in. Hg.)	25,000

An examination of these data shows that, in general,
about twice as much rudder force and rudder deflection is
required to produce a given change in sideslip angle with
the enlarged vertical tail as with the original. Further-
more, the rudder-force reversal, which occurs in low-speed
high-power conditions (figs. 33 and 37), occurs at much
higher sideslip angles with the enlarged vertical-tail
installation. In this connection, the dorsal fin shown
in figure 7 was built for the express purpose of
eliminating the rudder-force reversal altogether.
Preliminary tests with this dorsal fin installed indicate
that it does accomplish complete elimination of the
rudder-force reversal.

Pilots noted the directional stability of the airplane was much more satisfactory after installation of the enlarged vertical tail. Inadvertent skidding during abrupt maneuvering was greatly reduced. There was no tendency for the airplane to perform self-induced oscillations in a directional sense. The steadiness of the airplane as a gun platform was improved. It may be pointed out here that the desired amount of directional stability can very likely be obtained by installing a ventral fin beneath the fuselage in addition to increasing the height of the original vertical tail by the amount done in NACA tests. Such an addition would be advantageous from directional stability, spin recovery, and vertical-tail-load considerations. One possible disadvantage of installing a ventral fin would be the change in ground clearance angle accompanying its installation. Tests at the NACA indicate nearly the entire original ground clearance angle is needed to effect minimum-speed landings. If a very deep ventral fin is added some minor difficulty may be encountered due to hitting the tail on the ground when making minimum-speed landings.

Directional Trim Characteristics

The variation in rudder force with speed to maintain wings-level straight flight with a constant rudder tab setting and the accompanying rudder-angle variation with speed for the original vertical tail on the airplane are shown in figure 39. Similar data obtained with the enlarged vertical tail on the airplane are shown in figure 40. A comparison of these figures shows that no noticeable change in directional trim characteristics was brought about by enlarging the vertical tail.

The directional trim characteristics of the P-63 airplane are excellent. The relatively small change in rudder force with speed indicates very little use of the rudder trim tab need be made in normal flight conditions. Since only about 20° of rudder deflection out of a possible 30° are necessary to maintain straight, laterally level flight at stalling speed with high power, the rudder effectiveness is entirely adequate in flight.

Yaw Due to Aileron Action

The ability of the vertical tail to balance out yawing moments due to aileron deflection and rolling is a very important factor in a consideration of directional stability, particularly in the case of highly maneuverable fighter airplanes. One series of directional stability tests made with the P-63A-1 airplane consisted in determining what maximum sideslip angles were reached when the ailerons were abruptly deflected various amounts at various indicated airspeeds and under various amounts of normal acceleration attained by pulling out of dives. In these tests the rudder was held fixed in its trim position until after the maximum sideslip angle due to aileron action had been reached.

Theory indicates the yawing moment due to aileron deflection and rolling is a direct function of airplane normal-force coefficient. For this reason the results of all abrupt rolling maneuvers were plotted as the maximum change in sideslip angle divided by the airplane normal-force coefficient against total aileron deflection from trim. The resulting test points form a single curve, which is significant because its slope is inversely proportional to the directional stability of the airplane. Data obtained and evaluated in this manner for the P-63 airplane are shown in figures 41 and 42. Figure 41 covers rolls made over a range of normal accelerations at constant indicated airspeed while figure 42 covers rolls made over a range of speeds at constant normal acceleration.

This series of tests showed that the airplane would sideslip only 63 percent as much with the enlarged vertical tail as it would with the original vertical tail installed for a given yawing moment caused by aileron deflection and rolling.

Vertical-Tail Loads Due to Aileron Action

By using the data given in figures 41 and 42 the vertical-tail dimensional characteristics given in the appendix and the aileron-characteristics data of figure 9, estimates were made of the maximum vertical-tail

loads which would be expected due to the application
of 50 pounds of aileron stick force during accelerated
flight. These estimates are portrayed graphically in
figure 43.

It will be seen that the vertical-tail loads likely
to be produced due to aileron action would exceed the
design strength of the vertical tail for the gust
condition if fast rolls were made above about 3g normal
acceleration. This indicates an immediate need for
increasing the vertical-tail strength and also, very
likely, for increasing the torsional strength of the
fuselage. Under given aileron-deflection conditions
the vertical-tail load appears to be somewhat lower for
the enlarged vertical tail. This is due to the large
directional-stability increase which restricts the
maximum sideslip angles caused by rolling to much smaller
values. When the sideslip angles are restricted the
unstable fuselage and propeller yawing moments are
reduced and, hence, the vertical-tail loads are also
reduced.

In case the aileron-control characteristics are
further improved, attention should immediately be
given to the question of further increases in vertical-
tail and fuselage-torsional strength. The pertinency
of these load considerations have already been
demonstrated by the loss of some P-63 airplanes due
to vertical-tail-fuselage failures in fast rolling
maneuvers.

CONCLUSIONS

On the basis of stability and control tests conducted by the NACA on models and airplanes of the P-63 type, the following summary evaluation of the airplane is indicated.

Spin Characteristics

Spin tests of a $\frac{1}{15}$-scale dynamic model indicated that recoveries from fully-developed spins of the full-scale airplane should be effected in two turns or less if the rudder is fully reversed against the spin and the elevator is then put down. For small airplane gross weights and without wing guns installed, the position of the ailerons during spin recovery is not critical between the deflection ranges of one-third of full aileron deflection either with or against the spin. For high gross weights and/or with wing guns installed, it is necessary to put ailerons against the spin for rapid recovery. Spin recoveries will probably be improved if any one or a combination of the following modifications are made to the original P-63A-1 airplane:

  (a) Adding a ventral fin and/or rudder area beneath the fuselage

  (b) Increasing the height of the original vertical tail

  (c) Installing horizontal dorsal fins ahead of the stabilizer

Flight tests of P-63 airplanes showed that the stall-warning characteristics of the airplane are excellent, so that little trouble is anticipated due to inadvertent spinning.

Lateral Control Characteristics

Flight tests showed that the aileron characteristics of the P-63 airplane compare favorably with those of other contemporary fighter airplanes. The ailerons are exceptionally effective per unit area and per unit deflection. Since the deflection range is now only ±15° and since the hinge-moment variations with deflection are desirably linear, it appears that minor modifications

involving slight increases in the aerodynamic balance
and the total deflection range of the ailerons can easily
be effected to make the aileron characteristics outstand-
ingly good, particularly at high speeds. Such modifica-
tions, if made, will probably necessitate increasing the
strength of the ailerons and will certainly require an
increase in vertical-tail strength along with some prob-
able necessary increase in fuselage torsional strength.
The aileron control system in the airplane tested at the
NACA was excessively flexible. If this is a general con-
dition in production airplanes, steps should immediately
be taken to increase the rigidity of the aileron control
system since excessive flexibility needlessly penalizes
the rolling performance of the airplane at low and
intermediate indicated air speeds. The provision of an
aileron trim tab, adjustable from the cockpit in flight,
is strongly recommended.

Longitudinal Stability and

Control Characteristics

Because of an incorrect high stabilizer incidence
and an unusually flexible elevator covering for such a
high-speed airplane, original   P-63A-1 airplanes possessed
extremely undesirable stick-force variations with speed
in the high-speed range. These characteristics, consist-
ing of stick-force reversals with increasing airspeed,
were eliminated by reducing the stabilizer incidence
from 2.7° to 1.1°. Due to very great elevator fabric
distortion at high speed it is recommended that the eleva-
tor rib spacing for the P-63 airplane should not exceed
4 or 5 inches for fabric-covered elevators. Metal-
covered elevators are desirable although a resort to
them does not appear necessary if sufficient ribs are
used to back up a fabric covering.

The stick-fixed stability characteristics of original
P-63A-1 airplanes in both straight and turning flight were
generally satisfactory. The present production enlarged
horizontal tail surfaces tend to improve further stick-
fixed longitudinal stability in both straight and turning
flight. The stick-free longitudinal-stability character-
istics of original P-63A-1 airplanes in straight and
turning flight were satisfactory in the forward to middle
range of useable center-of-gravity positions. At most
rearward useable center-of-gravity positions, the stick-
free stability was marginal to negative, particularly at

high altitudes. The present production enlarged horizontal
tail surfaces should improve the stick-free stability
characteristics at all useable center-of-gravity positions
but will tend to make stick forces in turning flight
undesirably high at most forward useable center-of-gravity
positions, particularly at low altitudes. A small bob-
weight (elevator weight unbalance) may be used to adjust
the stick-force gradients of airplanes with production
contour elevators without great adverse effects on control-
feel characteristics. To gain a much more nearly constant
stick-force gradient over the entire useable center-of-
gravity range at all altitudes, an elevator incorporating
greater aerodynamic balance could be used. Such an
elevator, however, would possess somewhat poor control-
feel characteristics in normal flying and especially in
rapid longitudinal maneuvers, as a result of the increased
aerodynamic balance.

     The elevator power available to raise the nose wheel
from the ground in take-off runs is sufficiently great.
The nose wheel can be raised from a concrete runway long
before 80 percent of the take-off speed is reached even
with the most forward permissible center-of-gravity posi-
tion.

     The elevator power available to make minimum speed
landings with flaps full down is sufficiently great,
although marginal with extreme forward center-of-gravity
positions.

          Directional Stability and Control Characteristics

     The directional stability of original P-63A-1 airplanes
is inadequate. Excessive inadvertent yawing occurs in
abrupt rolling maneuvers and the airplane tends to oscil-
late directionally even with controls fixed in certain
steady flight conditions. The directional stability can
be made nearly satisfactory and the value of the airplane
as a gun platform can be greatly increased by increasing
the height of the original vertical tail about 16 inches,
involving a vertical-tail area increase of less than
3 square feet. The use of a relatively small dorsal fin
in combination with this taller vertical tail improves
the behavior of the airplane at large angles of sideslip
in low-speed steady sideslips using high engine powers.
Besides increasing the vertical-tail height, a further
increase in directional stability appears desirable and

can be accomplished by adding a ventral fin to the taller
vertical-tail modification. Such an addition would also
be desirable from a spin-recovery standpoint and from
vertical-tail aerodynamic-loads considerations. One
possible disadvantage of a ventral fin would be that it
might change the ground clearance angle enough so that
minimum-speed landings could no longer be made without
hitting the tail on the ground. In spite of this possible
objection, it is recommended that a taller vertical tail
and a ventral fin be incorporated in the P-63 airplane
to increase its directional stability and, consequently,
its value as a gun platform. If the directional stability
of the original P-63 airplane is not improved and a
larger propeller is installed to take care of possible
engine power increases, serious directional-stability
difficulties are anticipated. The directional trim char-
acteristics of the P-63 airplane are excellent; rudder-
force trim changes due to changing speed are desirably
low and the rudder effectiveness is easily adequate to
maintain straight, laterally level flight at the stalling
speed with high engine powers.

        Estimates of the vertical-tail loads which are ex-
pected to occur on P-63 airplanes as a result of aileron
action during accelerated flight indicate the original
vertical tail is insufficiently strong. This probably
also applies to the fuselage from a torsional strength
standpoint. In connection with vertical-tail loads
resulting from rolling, increasing the directional
stability of the airplane should bring about a slight
reduction in total vertical-tail load for a rolling
maneuver of given rapidity. If any improvement is made
in the rolling performance of the airplane, further
increases in vertical tail and fuselage torsional strength
over what now appears necessary should be considered.

Langley Memorial Aeronautical Laboratory
    National Advisory Committee for Aeronautics
            Langley Field, Va., October 19, 1944

APPENDIX

GENERAL SPECIFICATIONS AND DIMENSIONS OF AIRPLANE

Name and type . . . . Bell P-63A-1 Pursuit - Interceptor

Engine . . . . Allison V-1710-93
  Rating:
    Take-off . . . . 1325 hp at 3000 rpm, 54 in. Hg at S.L.
    Normal rated . . . . . . 1050 hp at 2600 rpm, 43 in. Hg at 10,000 ft
    Military rated . . . . . 1180 hp at 3000 rpm, 52 in. Hg at 21,500 ft
  Supercharger gear ratio 6.85:1

Propeller (special aeroproducts type)
  Diameter . . . . 11 ft 1 in.
  Number of blades 4
  Engine-propeller gear ratio 2.23:1

Fuel capacity (without belly tank), gal. 136

Weight empty, lb 5910

Normal gross weight, lb 7650

Wing loading (normal gross wt.), lb/sq ft 30.85

Power loading (normal gross wt., 1050 hp), lb/hp 7.29

Over-all height (taxying position) . . . . 11 ft 4 in.

Over-all length . . . . 32 ft $8\frac{3}{8}$ in.

Wing:
  Span, ft 38.33
  Area (including section through fuselage) sq ft 248
  Airfoil section, root . . . . NACA 66,2x-116
  Airfoil section, tip . . . . NACA 66,2x-216
  Mean aerodynamic chord, in. 82.54
    Leading edge M.A.C., in. aft L.E. root chord 6.11
  Aspect ratio 5.92:1
  Taper ratio 2:1
  Dihedral (35-percent chord, upper surface), deg. 3.67
  Root incidence, deg. 1.30
  Tip incidence, deg. . . . . -0.45

Wing flaps (Plain sealed type):
   Total area, sq ft 12.9
   Span (along hinge line, each), in. 62.38
   Travel, deg. 45

Ailerons:
   Span (along hinge line, each), in. 120.75
   Area aft of hinge center line, each, sq ft 8.143
   Fixed balance area, each, sq ft 4.826
   Location of inboard end of aileron, percent semispan 44.2
   Location of outboard end of aileron, percent semispan 96.7
   Travel, deg. . . . . ±15

Horizontal tail (letters refer to plan forms shown in fig. 4):

	A	B	C
Span, in.	159	159	175
Total area, sq ft	45.15	44.11	46.92
Stabilizer area, sq ft	31.80	30.44	34.15
Total elevator area, sq ft	13.35	13.67	12.77
Elevator area aft of hinge center line, including tab, sq ft	10.38	10.59	9.85
Elevator area forward of hinge center line, sq ft	2.97	3.08	2.92
Elevator trim tab area, sq ft	0.92	0.92	0.92
Distance elevator hinge center line to L.E. of M.A.C., in.	226.28	226.28	226.28
Elevator travel from stabilizer, deg down . . .	15	15	15
Elevator travel from stabilizer, deg up	35	35	35

Vertical tail (plan forms shown in fig. 6):

	Original	Enlarged
Height along hinge center line, in.	78.87	94.62
Total area, sq ft	23.73	26.58
Fin area, sq ft	13.47	15.96
Total rudder area, sq ft	10.26	10.62
Rudder area aft of hinge center line, sq ft	8.30	8.65
Rudder area forward of hinge center line, sq ft . . .	1.96	1.97
Rudder trim tab area, sq ft	0.84	0.84
Distance rudder hinge center line to L.E. of M.A.C., in.	248.40	248.40
Fin offset from thrust axis, deg.	0	0
Rudder travel, deg.	±30	±30
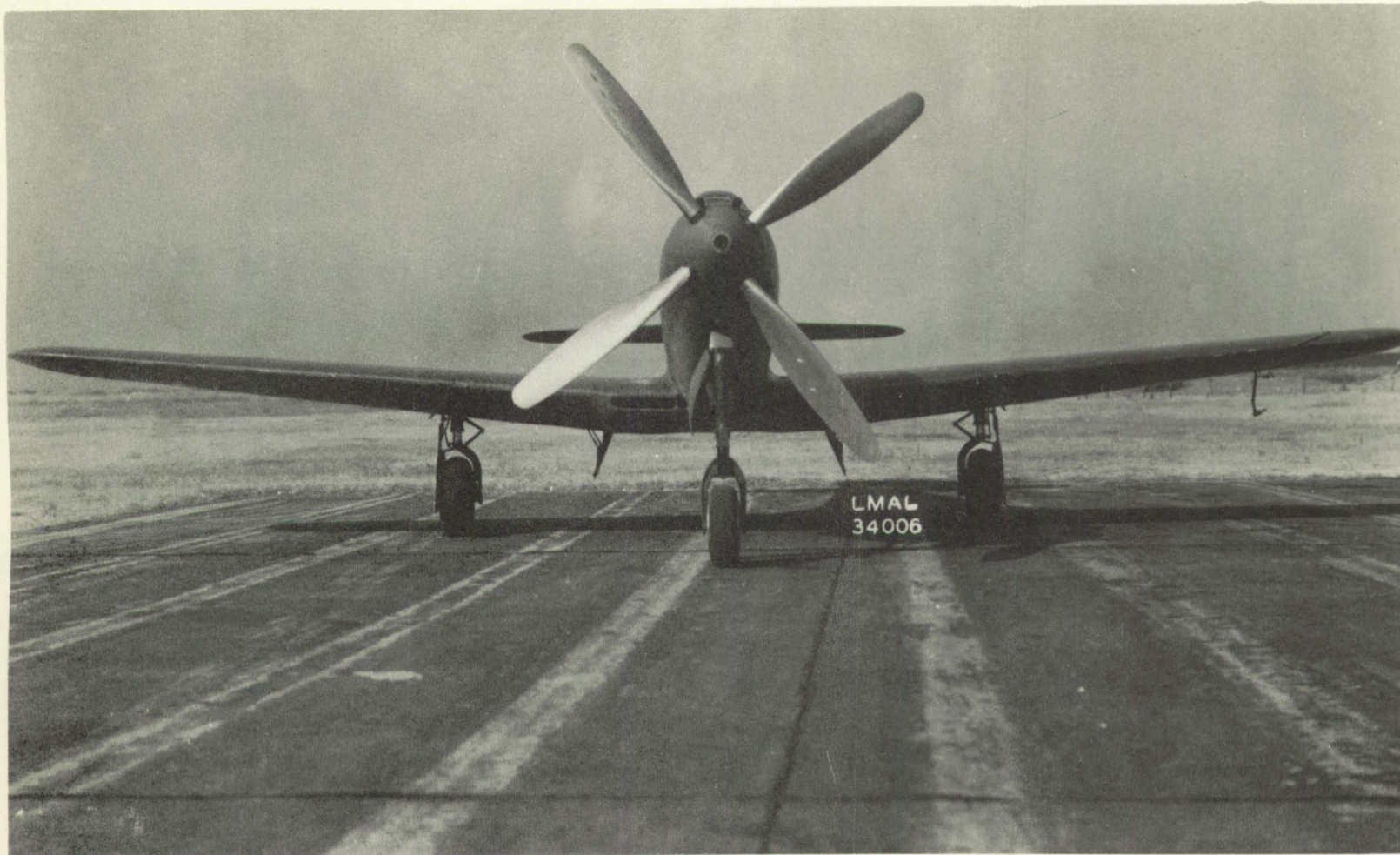
(a) Front view.

Figure 1.- Photographs of original Bell P-63A-1 airplane (AAF No. 42-68861).
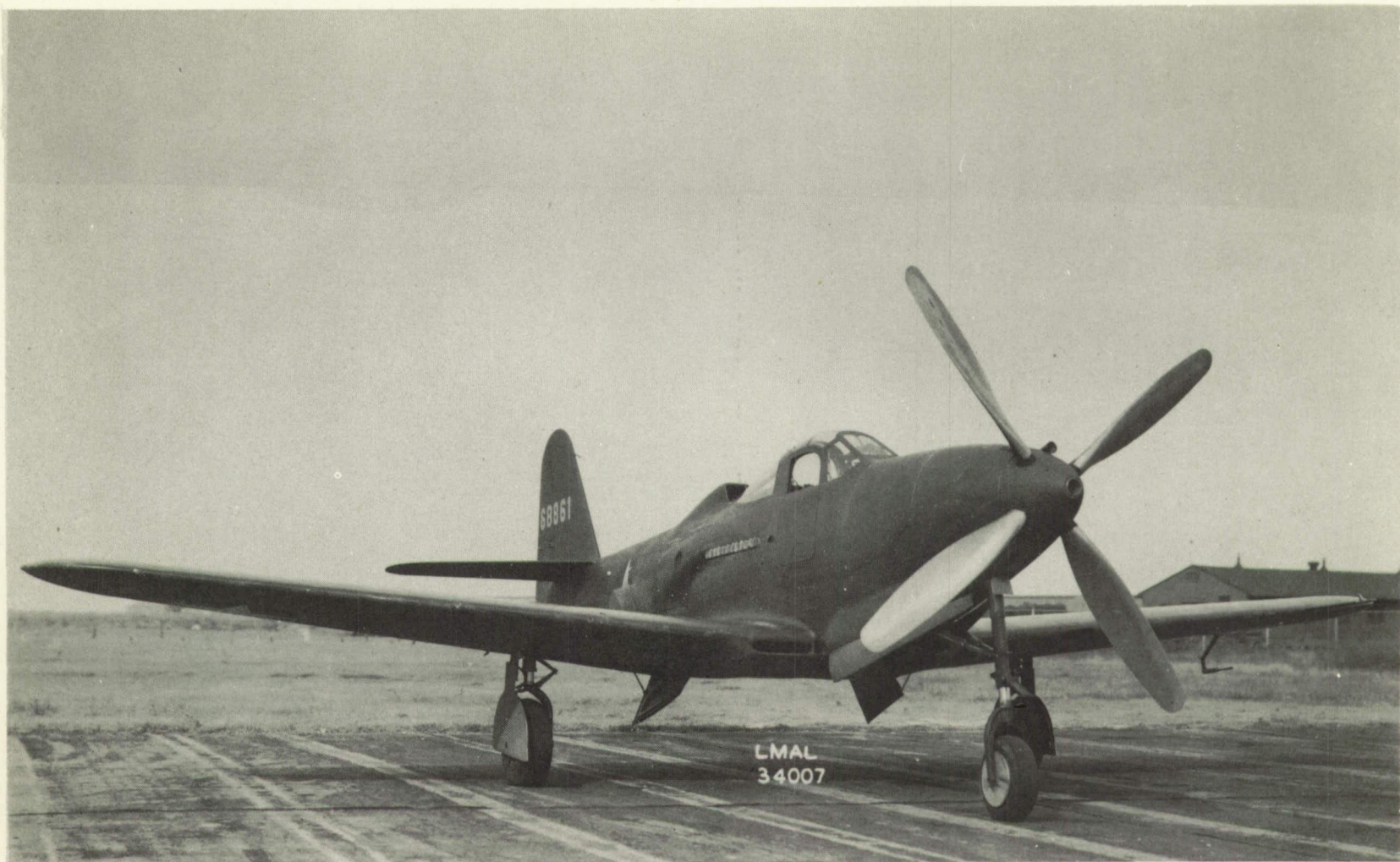
(b) Three-quarter front view.

Figure 1.- Continued.

(c) Side view.

Figure 1.- Continued.

(d) Three-quarter rear view.

Figure 1.- Continued.
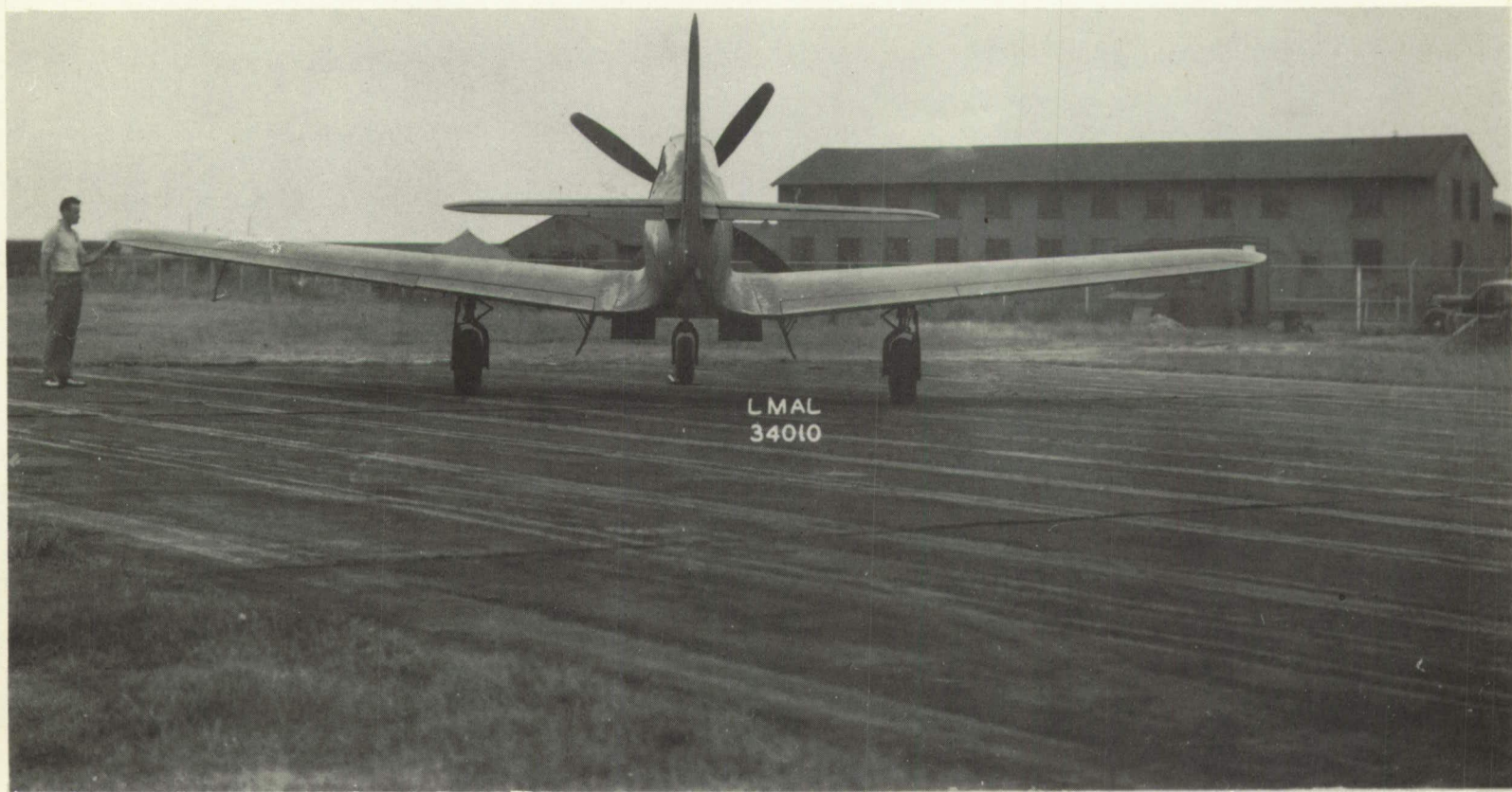
(e) Rear view.

Figure 1.- Concluded.

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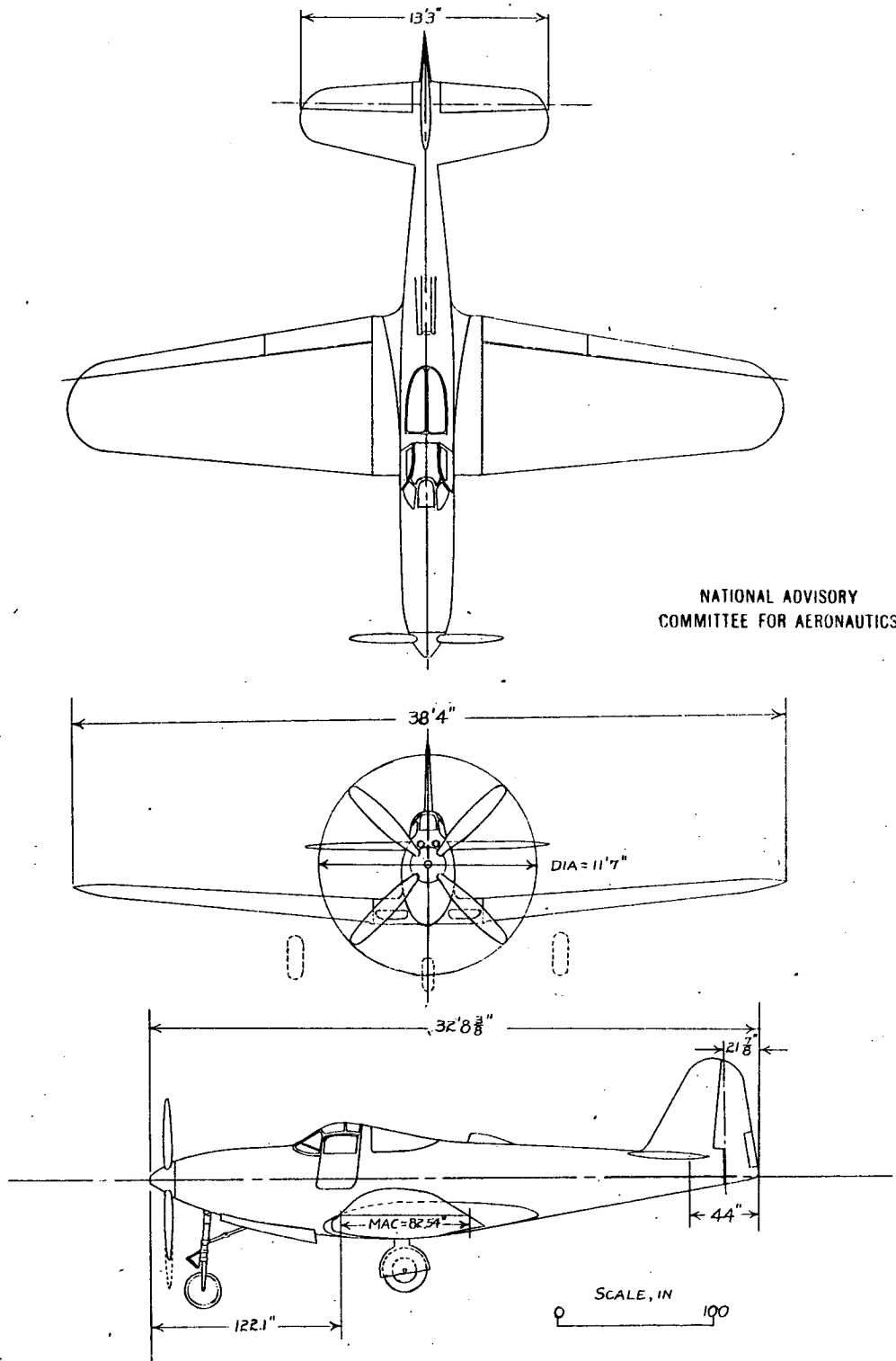
Figure 2.- Three-view drawing of original Bell P-63A-1 airplane.
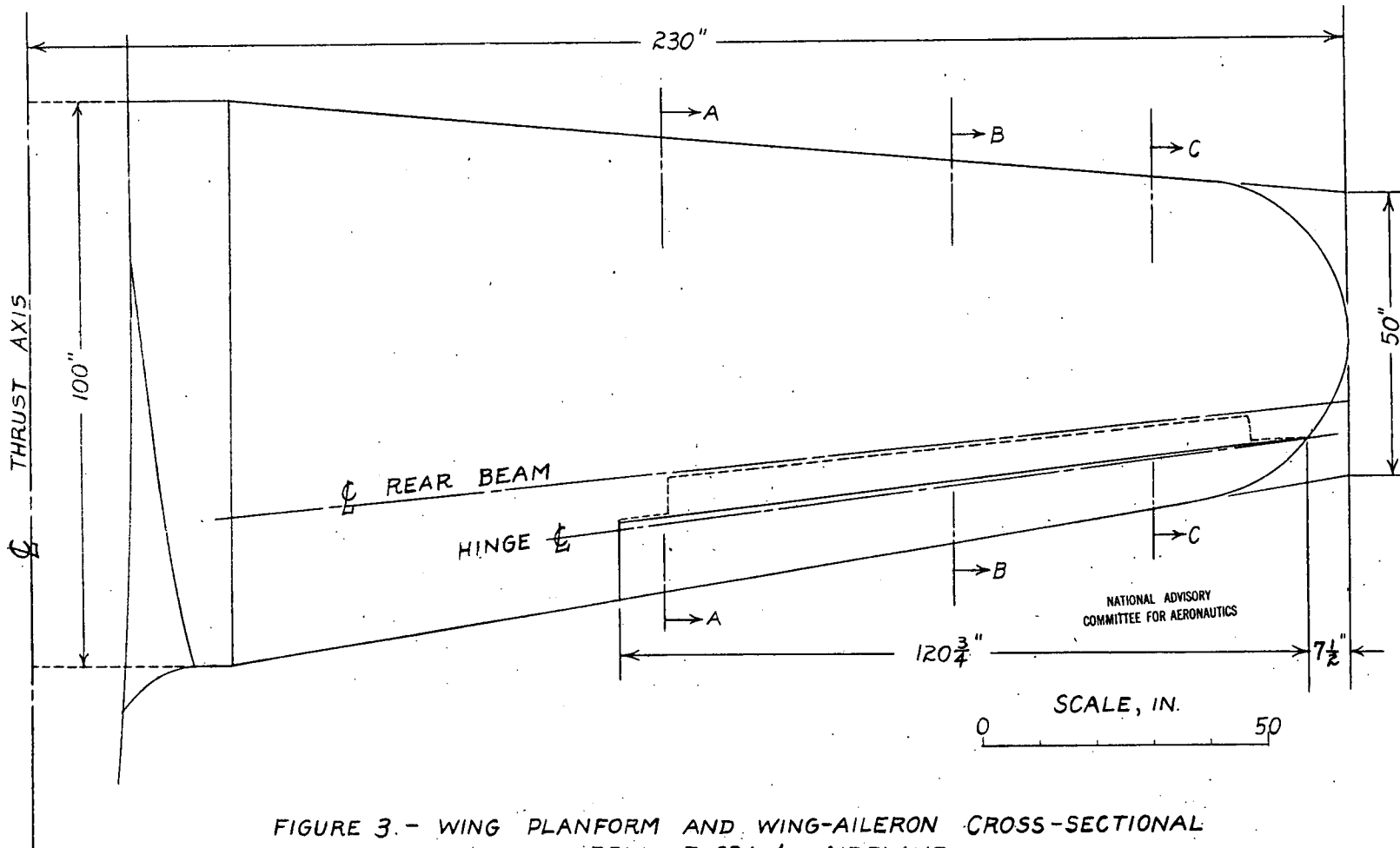
FIGURE 3.- WING PLANFORM AND WING-AILERON CROSS-SECTIONAL
OUTLINES OF BELL P-63A-1 AIRPLANE.

(A.) WING PLANFORM.

SECTION C-C

₵ REAR BEAM

₵ HINGE

SECTION B-B

ROOT CHORD LINE OF CENTER SECTION

SECTION A-A

SCALE, IN.

0   10   20
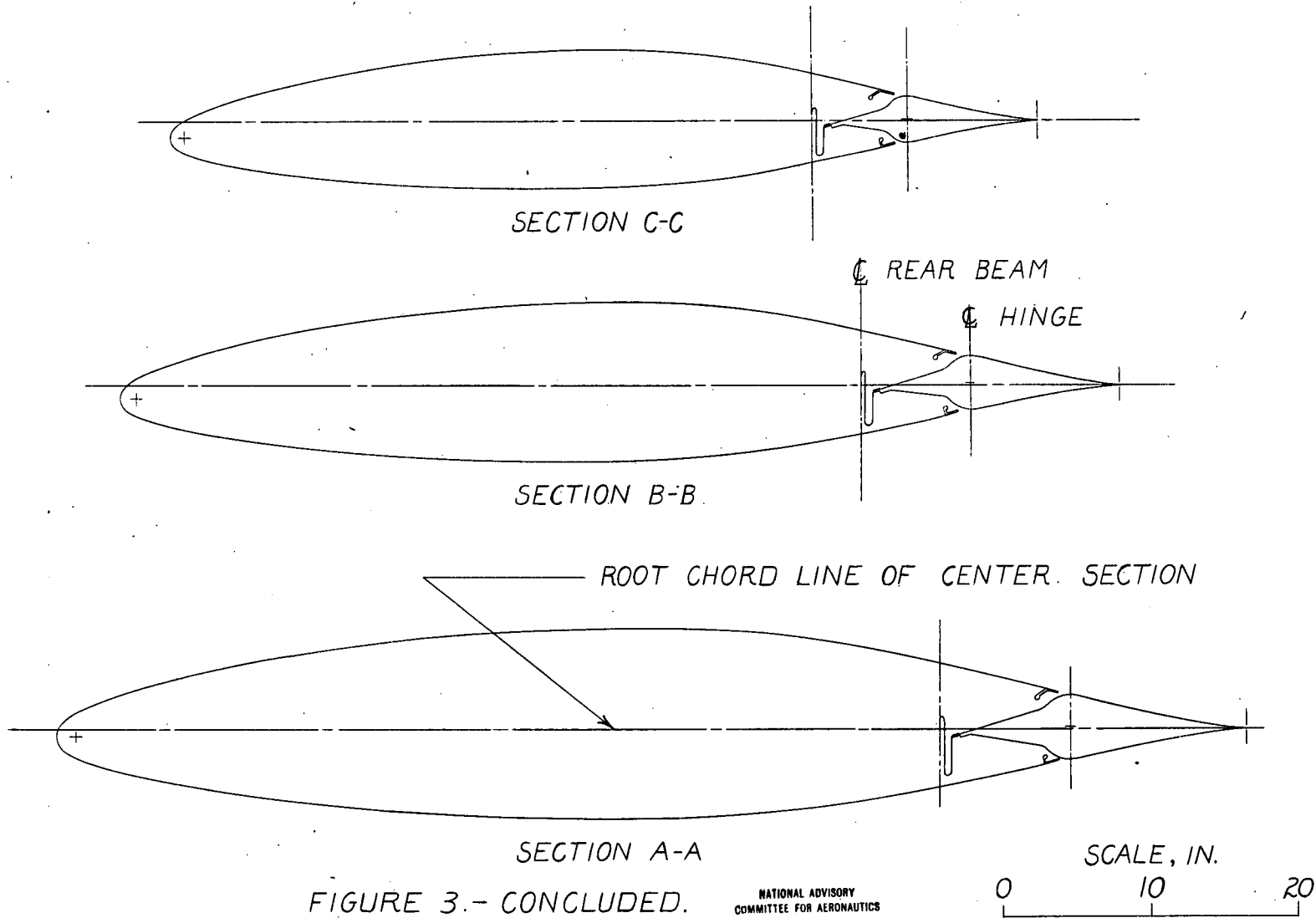
FIGURE 3.- CONCLUDED.

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(B.) WING-AILERON CROSS-SECTIONAL OUTLINES.

$79\frac{1}{2}"$

—A—

$79\frac{1}{2}"$

—B—

$87\frac{1}{2}"$

— C —
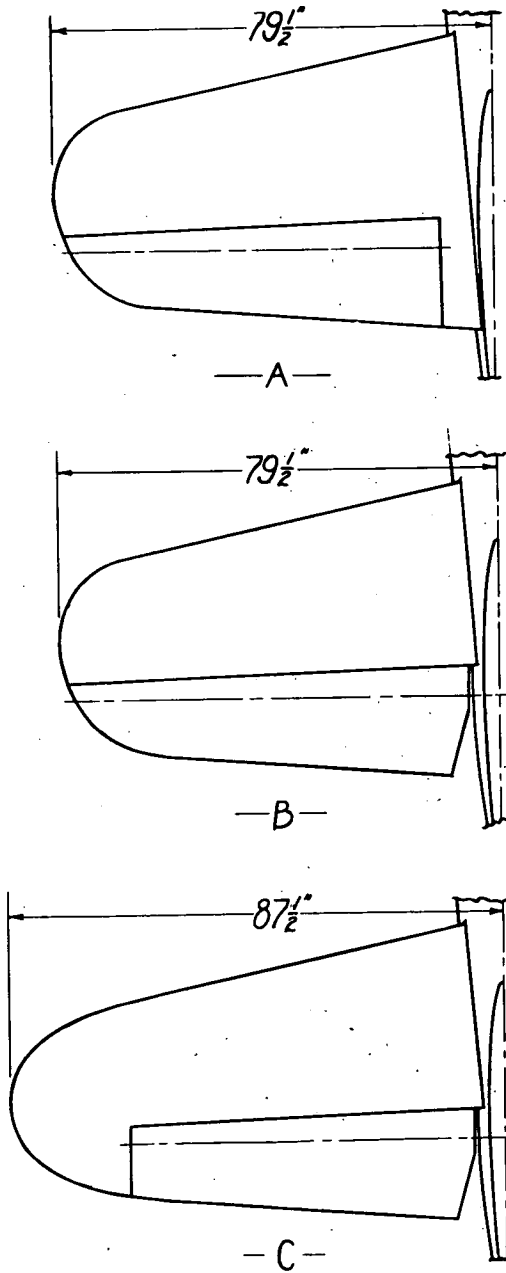
Figure 4. - Planforms of horizontal tails
tested on the P-63A-1-BE airplane

0   3
Scale, ft.

13°

A

TRANSITION FROM
FLAT TO CURVED SURFACE

21.3°

B

17°

C

18.5°

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D

Scale in inches
0   2   4
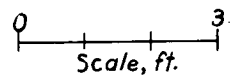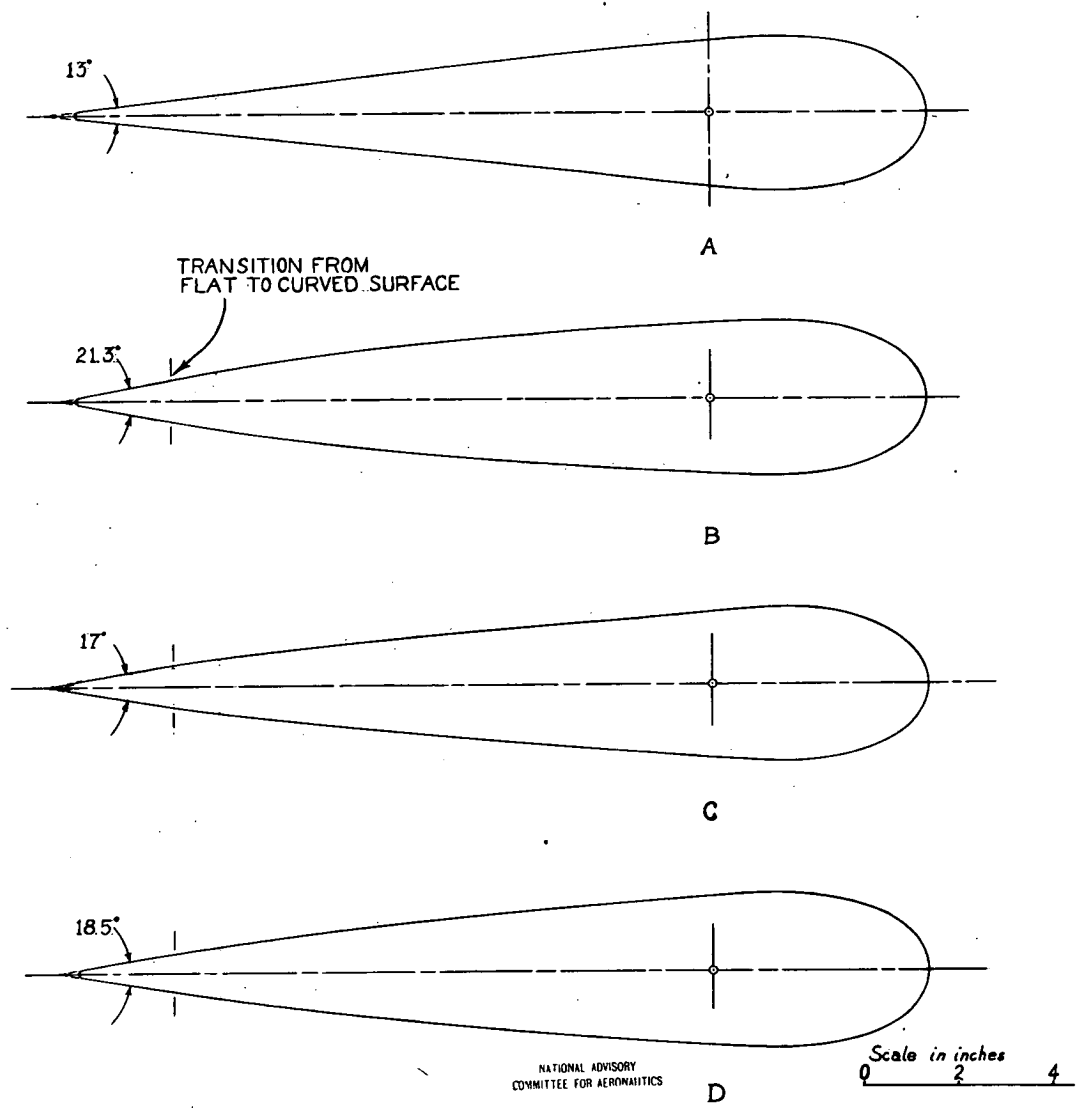
FIGURE 5.-CROSS-SECTIONAL OUTLINES OF THE VARIOUS ELEVATORS TESTED ON
THE P-63A-I AIRPLANE. SECTIONS ARE FOR SPANWISE STATIONS 15 INCHES
FROM AIRPLANE CENTERLINE.

ADDITIONAL AREA 2.85 SQ. FT.

ORIGINAL AREA 23.73 SQ. FT.

SCALE, IN

STABILIZER

THRUST AXIS
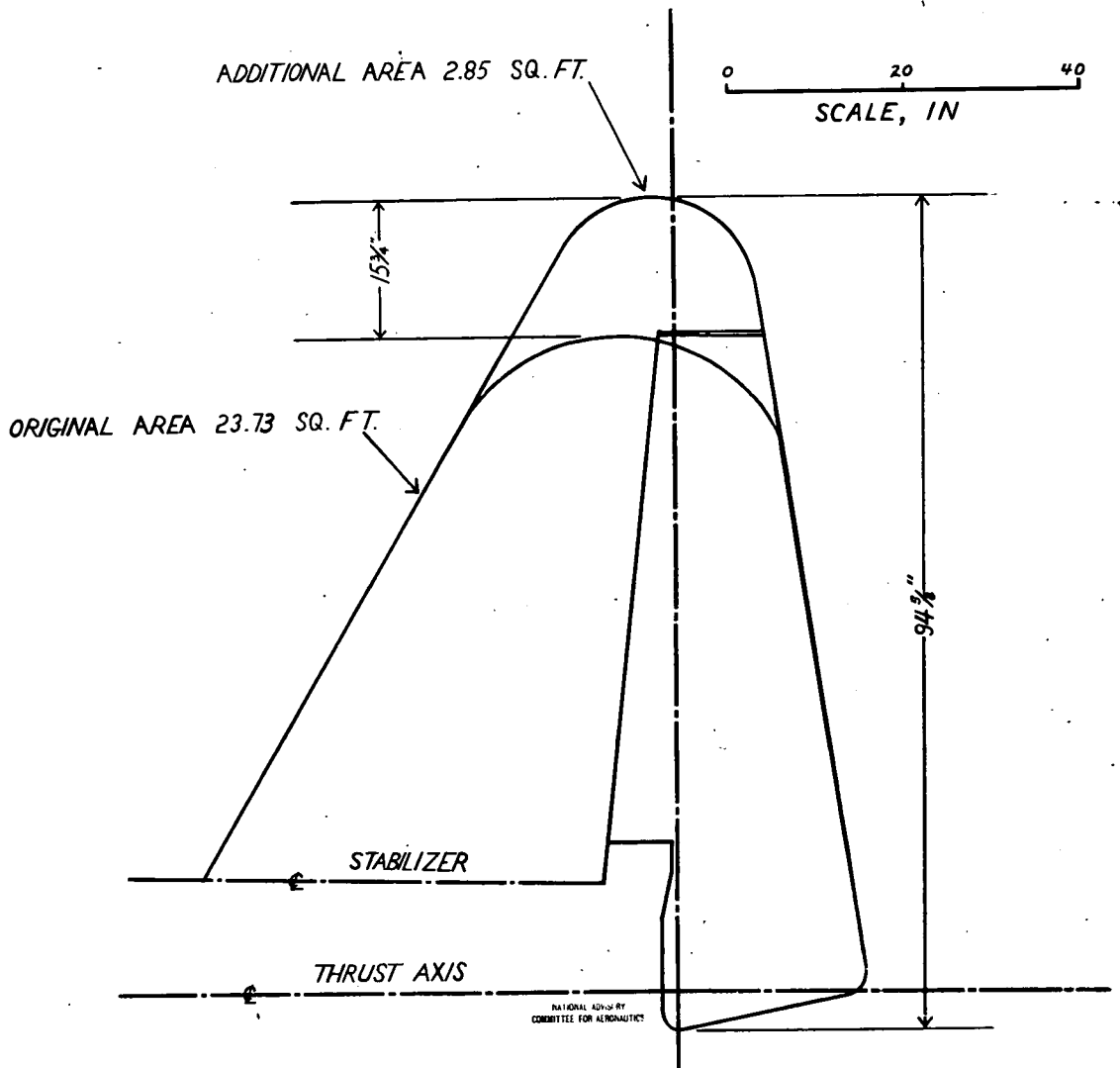
FIGURE 6. - ORIGINAL AND ENLARGED VERTICAL
TAIL SURFACES TESTED ON P-63A-1 AIRPLANE

(a) Three-quarter front view.

Figure 7.- Three-view photographs of modified P-63A-1-BE airplane presently being tested at the NACA.

(b) Side view.

Figure 7.- Continued.

(c) Three-quarter rear view.

Figure 7.- Concluded.
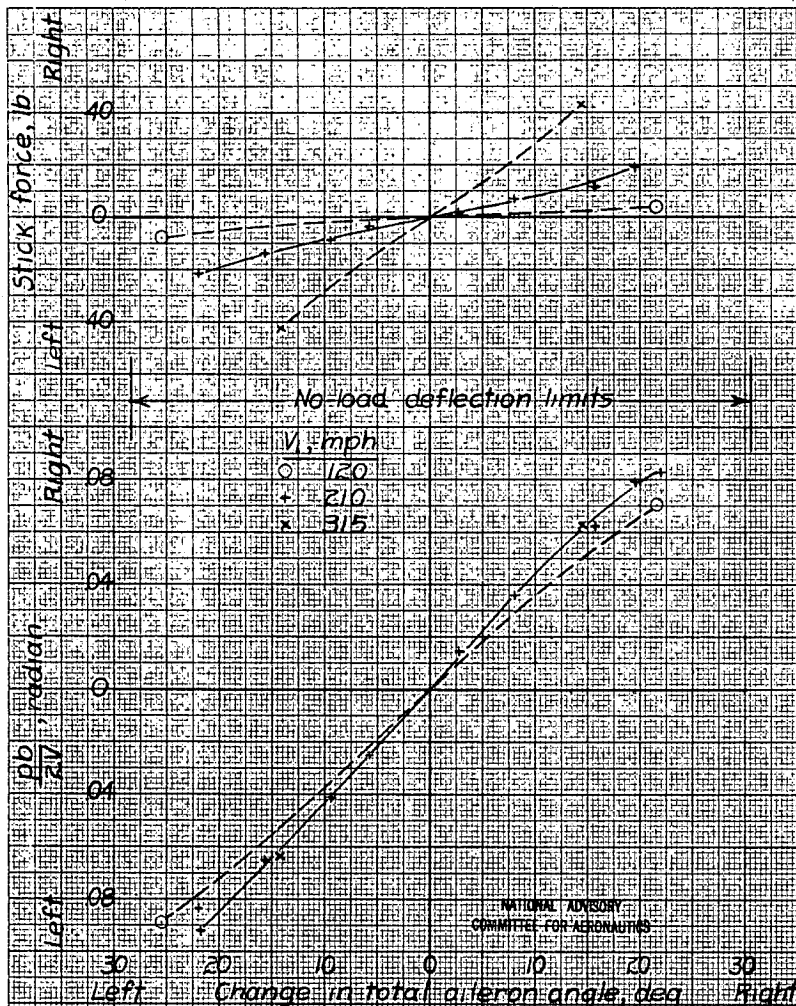
Figure 8.- Aileron stick forces and wing-tip helix angles plotted against estimated true change in total aileron angle. Bell P-63A-1 airplane, power for level flight, clean condition.
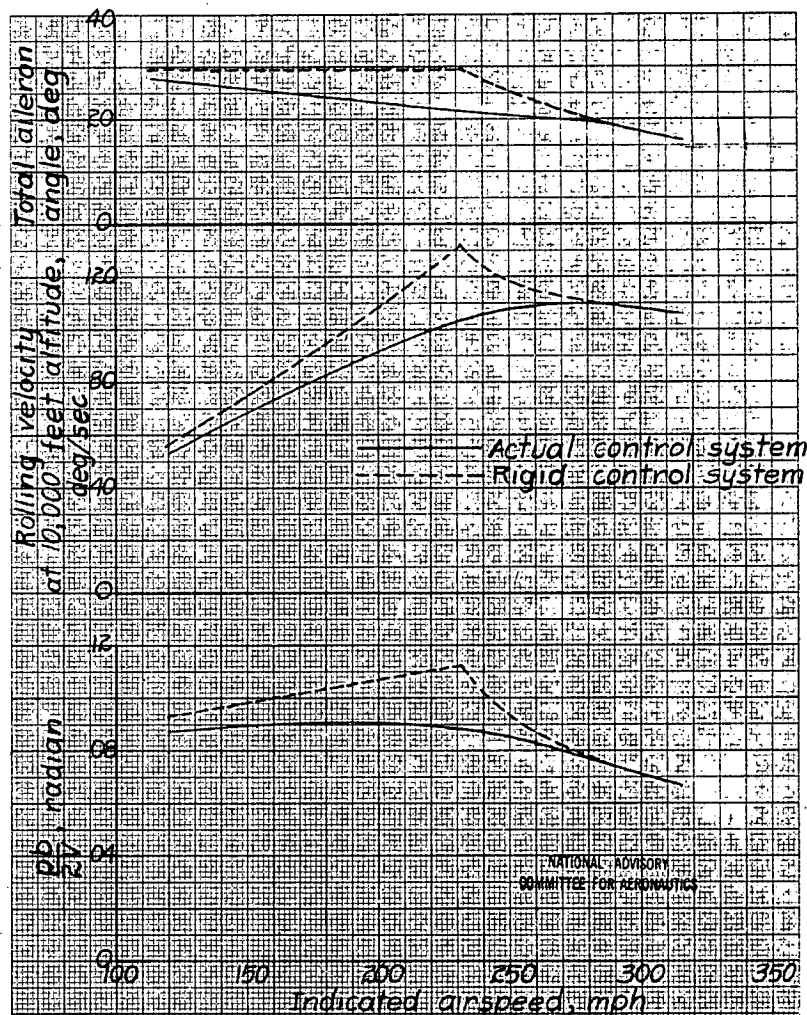
Figure 9.- Estimated average rolling performance of Bell P-63A-1 airplane with 50 pound stick force.
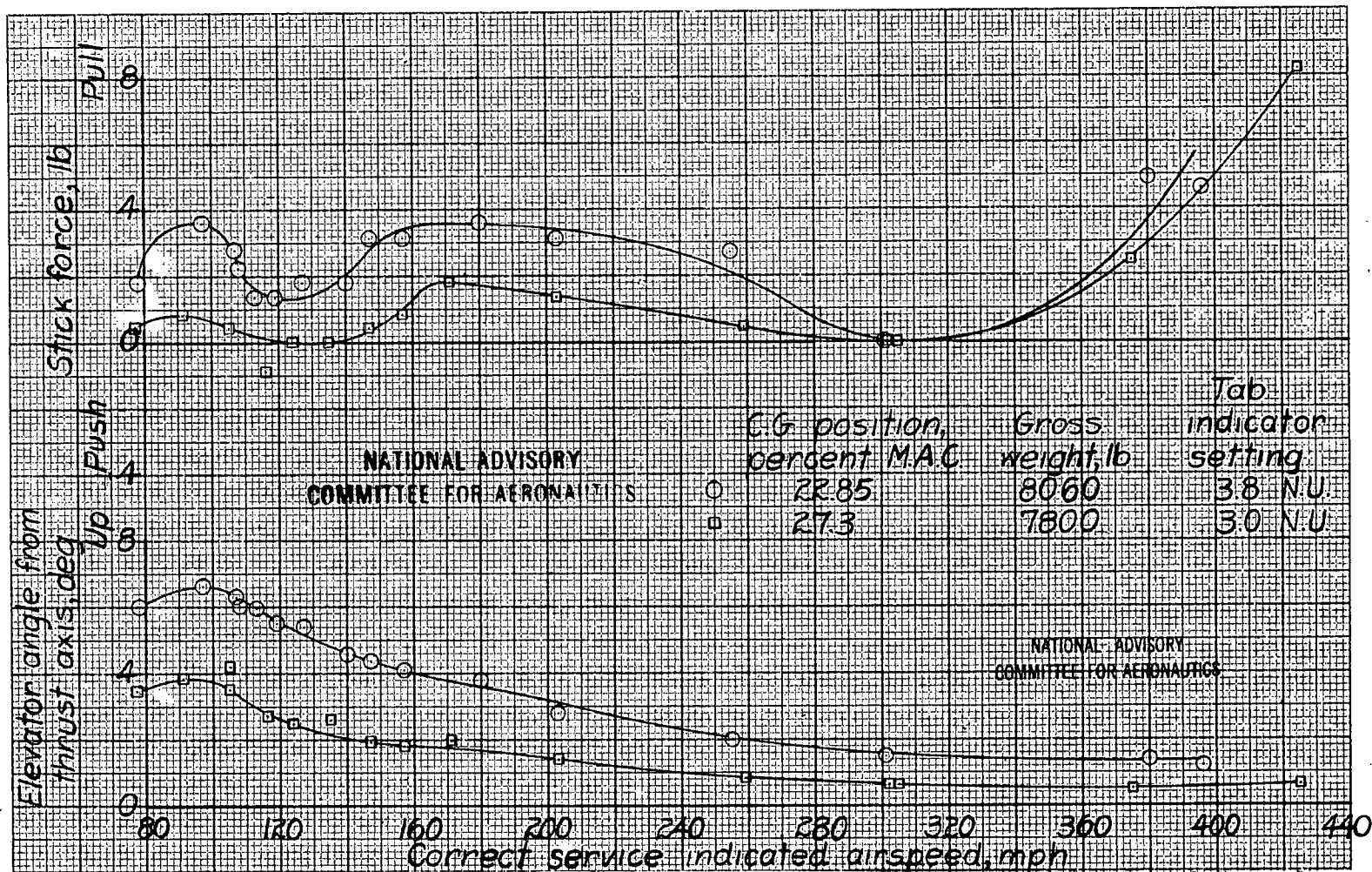
Figure 10.- Variation of stick force and elevator angle required to trim the Bell P-63A-1 airplane in straight flight plotted as a function of indicated airspeed for two center-of-gravity positions. Normal rated power at 10,000 feet (2600 RPM, 43 in. Hg), all cooling shutters locked in closed position, flaps and gear retracted.
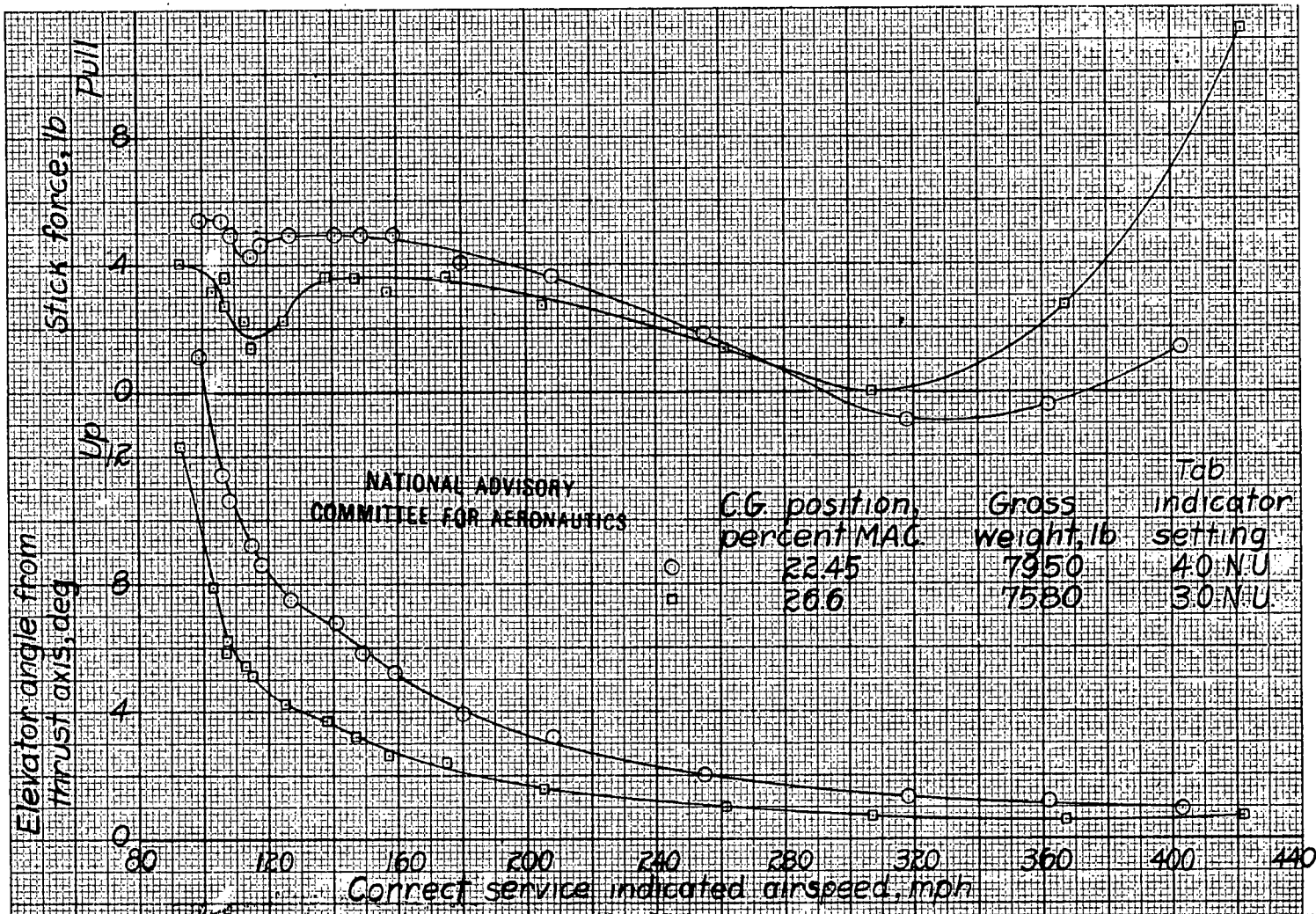
Figure 11.- Variation of stick force and elevator angle required to trim the Bell
P-63A-1 airplane in straight flight plotted as a function of indicated airspeed
for two center-of-gravity positions. Engine idling, all cooling shutters locked
in closed position, flaps and gear retracted.
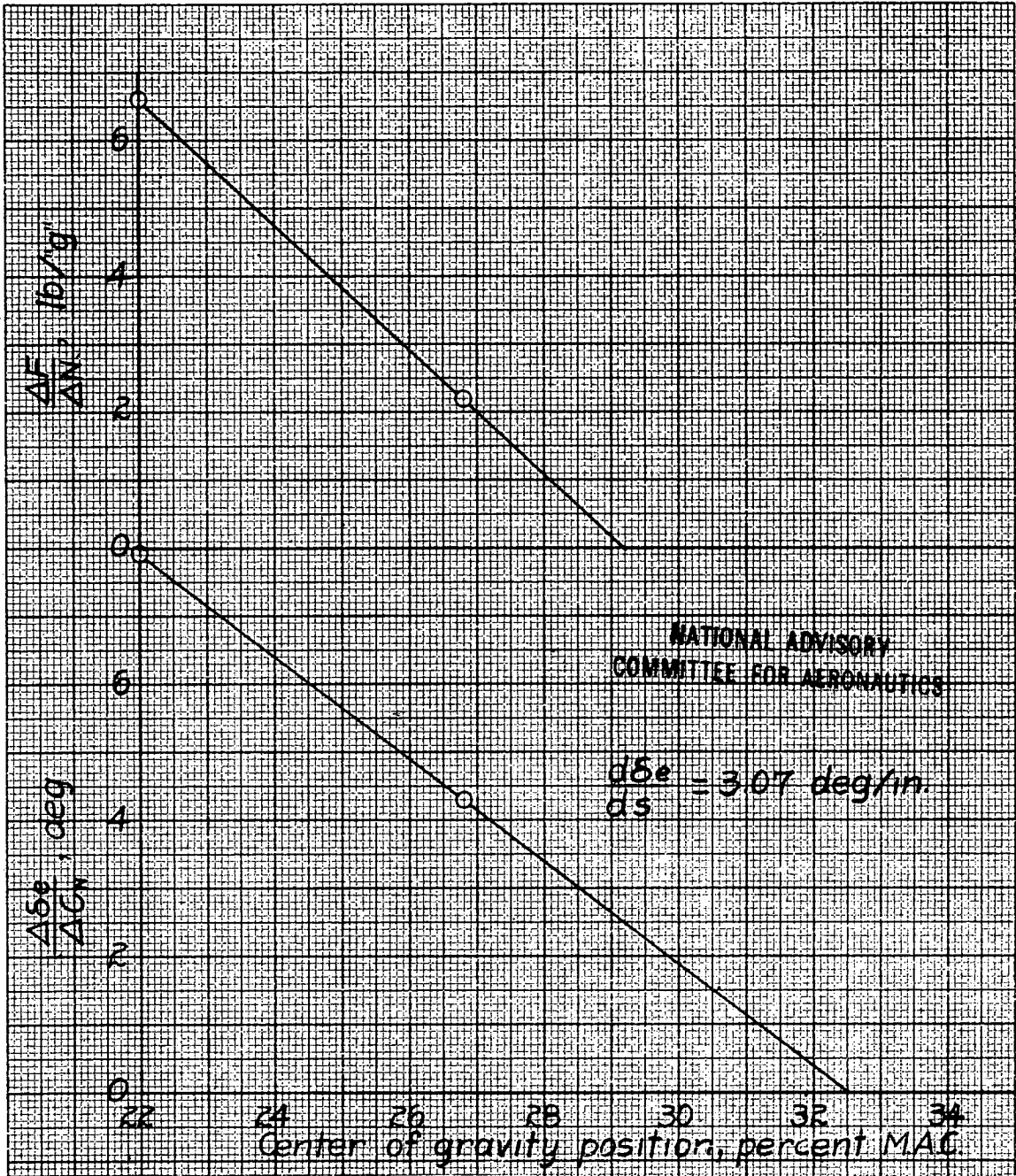
Figure 12.- Summary of the longitudinal stability and control
characteristics of an original P-63A-1 airplane (AAF No.
42-68861) in steady turning flight with normal rated power
at 10,000 feet altitude (2600 RPM, 43 in. Hg). Clean con-
dition, all cooling shutters locked in closed position.

Section for which measurements are given

1   2   3   4   5   6   7

Scale, in inches

0   10   20
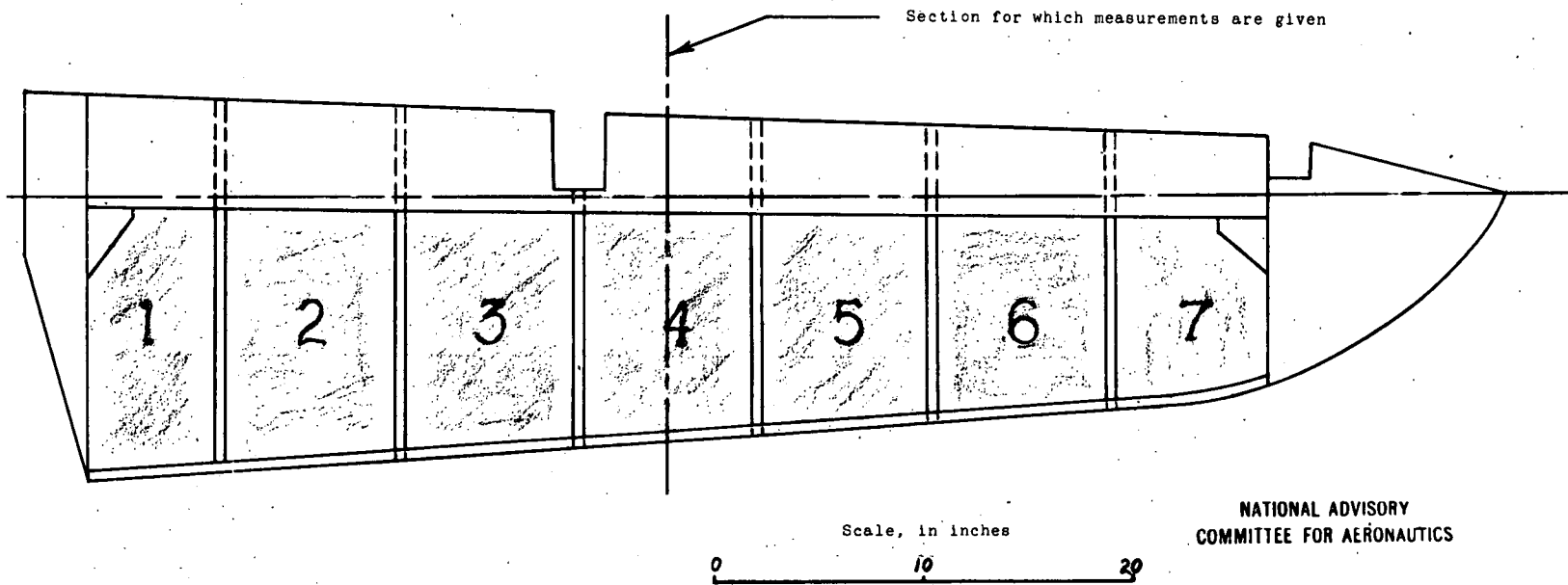
Figure 13.- Planform of P-63A-1 normal short-chord elevator showing rib locations and extent
of unsupported fabric panels.

SCALE, INCHES

0   10   20

SECTION FOR WHICH MEASUREMENTS ARE GIVEN

1   2   3   4   5   6   7   8   9   10   11   12   13

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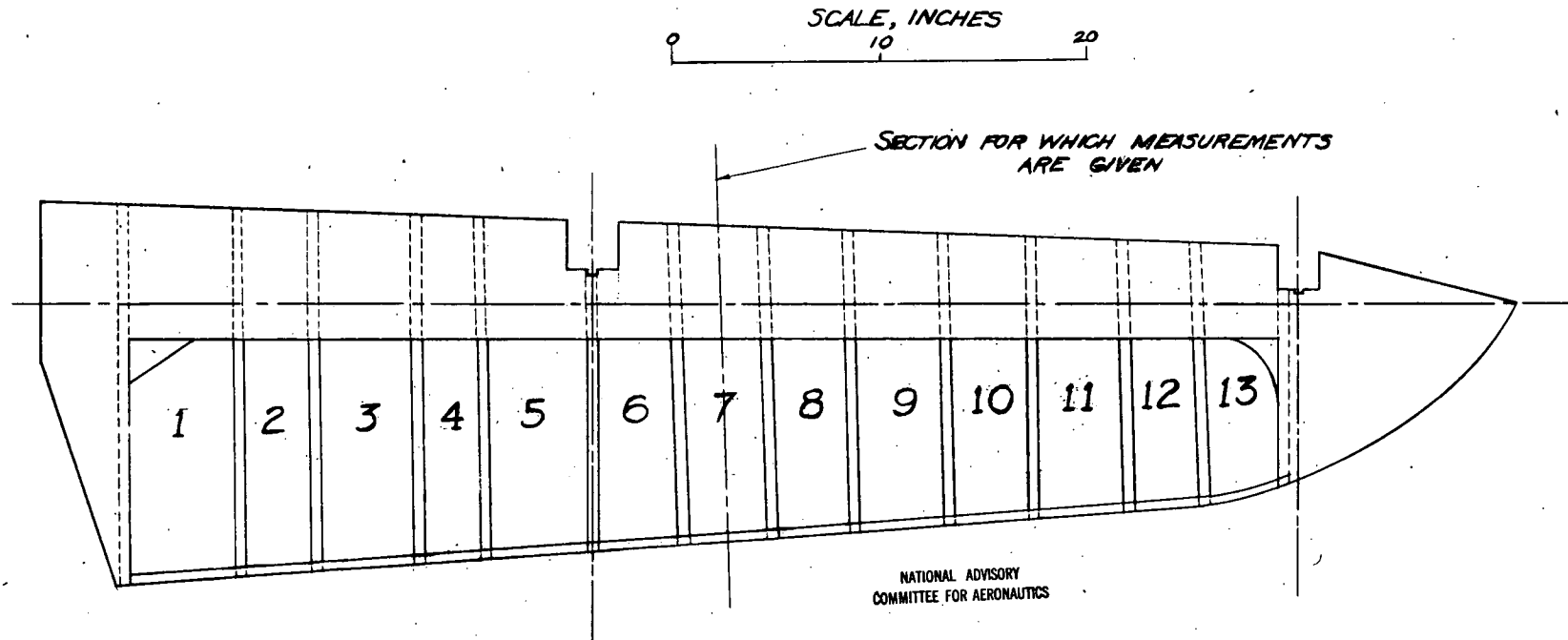
FIGURE 14.-PLANFORM OF P-63A-1 NORMAL SHORT-CHORD HALF RIB-SPACED ELEVATOR SHOWING RIB LOCATIONS AND POSITIONS OF UNSUPPORTED FABRIC PANELS.
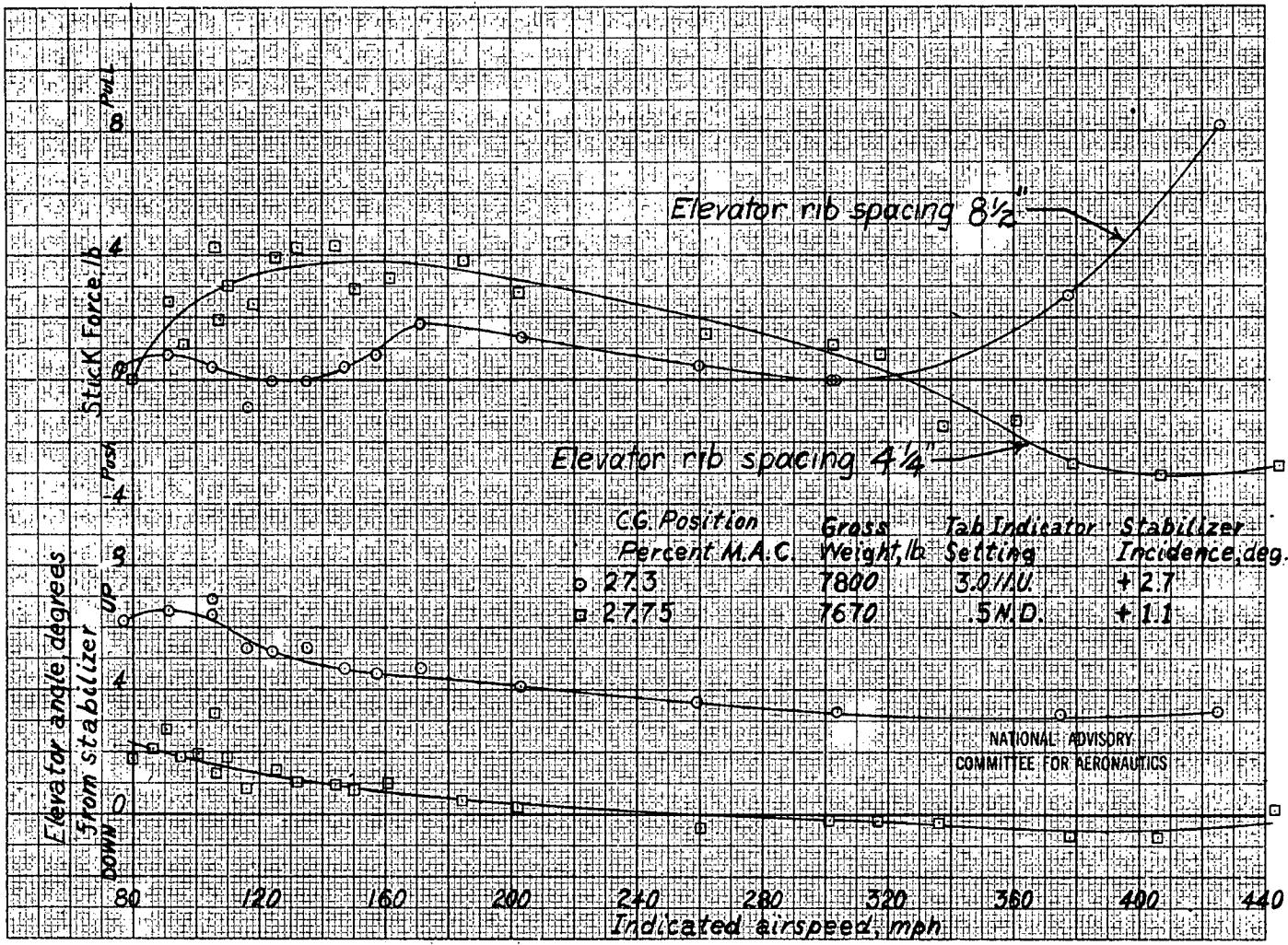
Figure 15.- Data showing the effect of stabilizer incidence setting and stiffness of elevator fabric covering on the static longitudinal stability characteristics of a P-63A-1 airplane (AAF No. 42-68889). Clean condition, normal rated power (2600 RPM, 43 in. Hg), altitude range 5-10,000 feet.
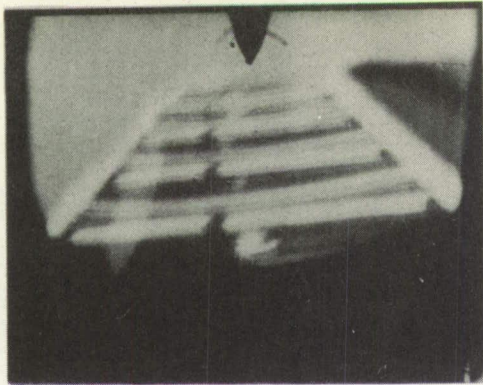
(a)   Upper Surface
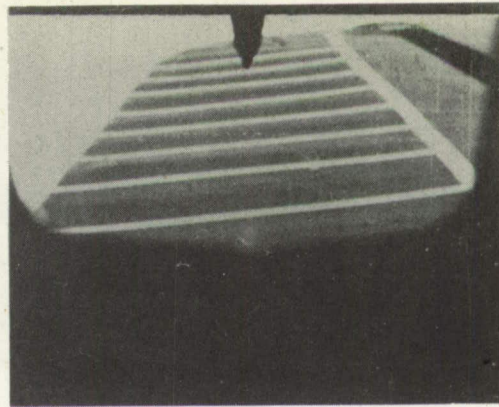
(b)   Upper Surface
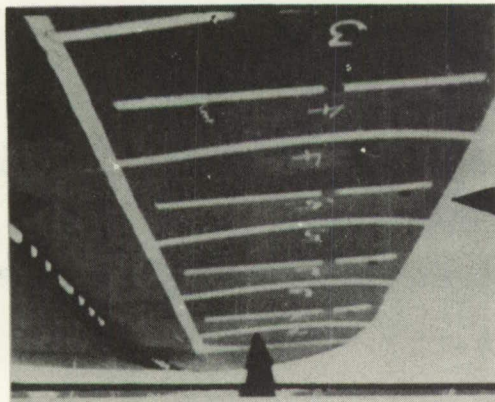
(a)   Lower Surface
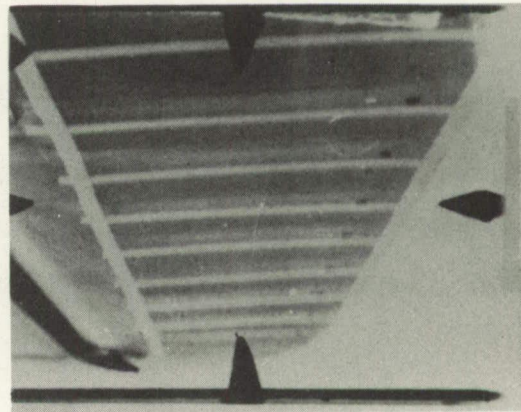
(b)   Lower Surface

Figure 16.- Examples of photographs taken to investigate the effects of elevator fabric distortion.
(a) Original P-63A-1 elevator in straight flight at V_i = 350 MPH. Elevator rib spacing
    $8\frac{1}{2}$ inches.
(b) Stiffened P-63A-1 elevator in straight flight at V_i = 350 MPH. Elevator rib spacing
    $4\frac{1}{4}$ inches.

SCALE INCHES

0   5   10

←LIMITS OF UNSUPPORTED FABRIC→

MEAN CAMBER LINE

INDICATED AIR SPEED = 150 M.P.H.
ELEVATOR ANGLE = 5.4°

V_{is} = 200 MPH
δe = 4.8°

V_{is} = 250 MPH
δe = 3.6°

V_{is} = 300 MPH
δe = 3.6°

V_{is} = 360 MPH
δe = 3.6°

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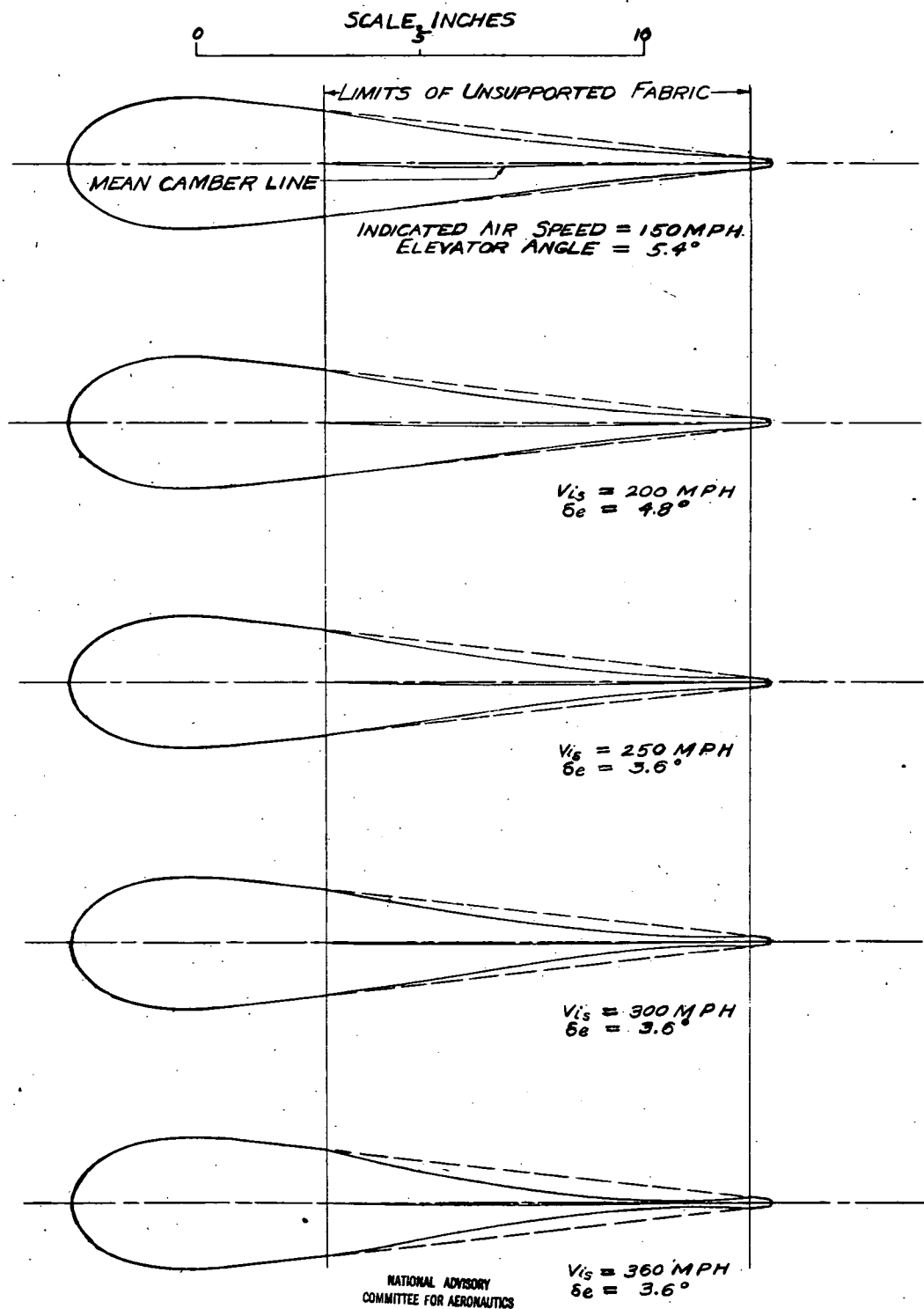
FIGURE 17. – ELEVATOR SECTIONS AT CENTER OF PANEL NUMBER 4 (FIGURE 13)
SHOWING THE VARIATION OF FABRIC DEFLECTION WITH INDICATED
AIRSPEED AT AN ACCELERATION OF 1g. ELEVATOR ANGLES ARE
GIVEN WITH RESPECT TO STABILIZER. (+ = UP); STABILIZER INCIDENCE 2.7°
ELEVATOR RIB SPACING 8½ INCHES.

SCALE, INCHES

0   5   10

←LIMITS OF UNSUPPORTED FABRIC→

INDICATED AIR SPEED = 110 M.P.H.
ELEVATOR ANGLE = 1.3° UP
$\Delta P_i / q_c$ = -.182

V_{is} = 150
δe = .7° UP
$\Delta P_i / q_c$ = -.173

V_{is} = 200
δe = .2° UP
$\Delta P_i / q_c$ = -.147

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V_{is} = 260
δe = .5° DOWN
$\Delta P_i / q_c$ = -.115

FIGURE 18.— ELEVATOR SECTIONS AT CENTER OF PANEL NUMBER 7 (FIGURE 14) SHOWING THE VARIATION OF FABRIC DEFLECTION WITH INDICATED AIRSPEED IN STRAIGHT FLIGHT. ELEVATOR ANGLES ARE GIVEN WITH RESPECT TO STABILIZER. STABILIZER INCIDENCE +1.1°. ELEVATOR INTERNAL PRESSURE MEASURED AT PANEL NUMBER 7 IS GIVEN AS FRACTION OF CORRECT IMPACT PRESSURE BELOW CORRECT STATIC PRESSURE. ELEVATOR RIB SPACING 4¼ INCHES.

SCALE, INCHES

0   5   10

←—LIMITS OF UNSUPPORTED FABRIC —→

INDICATED AIR SPEED = 300 MPH
ELEVATOR ANGLE = .2° DOWN
$\Delta P_i / q_c$ = -.112

V_{is} = 360
δ_e = .3° DOWN
$\Delta P_i / q_c$ = -.109

V_{is} = 400
δ_e = .7° DOWN
$\Delta P_i / q_c$ = -.108

V_{is} = 460
δ_e = .1° DOWN
$\Delta P_i / q_c$ = -.114

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FIGURE 18.- CONCLUDED

Figure 19.- Variation of stick force and elevator angle required to trim in turning flight with normal acceleration for various service indicated airspeeds. Bell P-63A-1 airplane, normal short-chord half rib-spaced elevators, stabilizer incidence +1.1°. Clean condition, normal rated power (2600 rpm, 43 in. Hg), coolant shutters closed, altitude approximately 5000 feet.
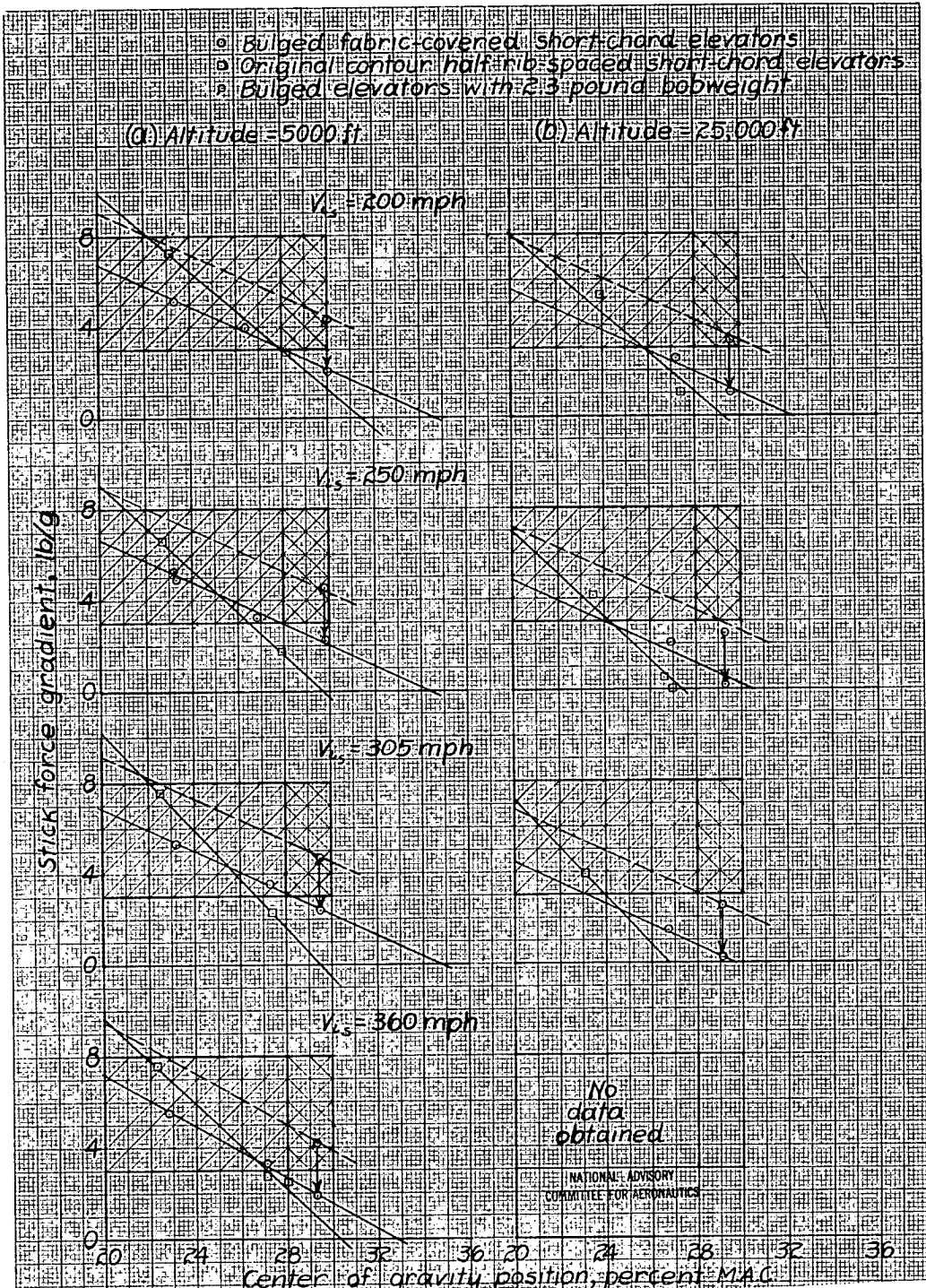
Figure 20.- Summary of the stick-free maneuvering characteristics of the P-63A-1 airplane with bulged fabric-covered short-chord elevators having 9 inches trailing edge strips, elevator-stabilizer gap = $\frac{1}{8}$ inch and with original contour half rib-spaced fabric-covered short-chord elevators for (a) 5000 feet altitude and, (b) 25,000 feet altitude. Clean condition, power on, stabilizer incidence +1.1°.
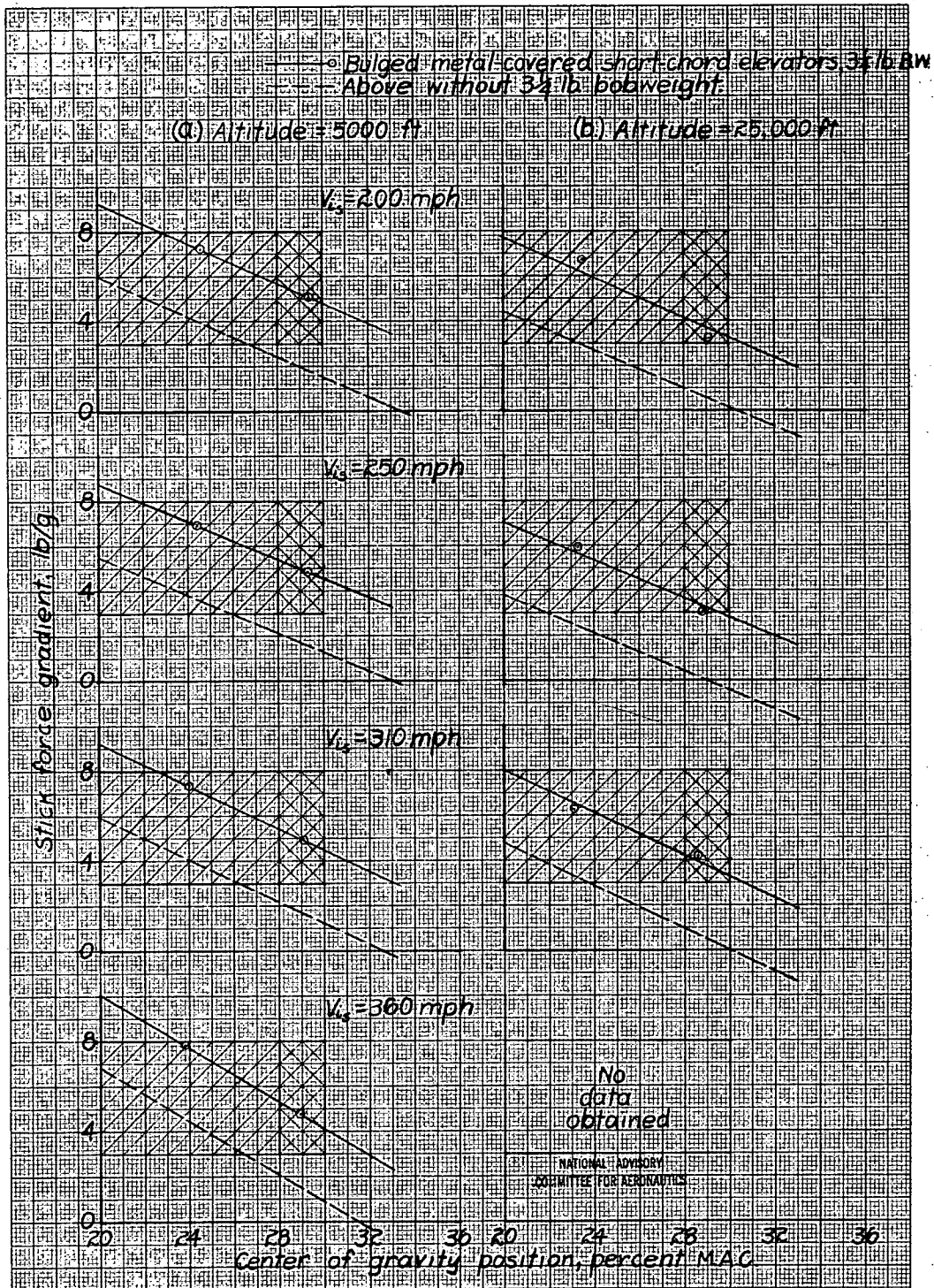
Figure 21.- Summary of the stick-free maneuvering characteristics of the
P-63A-1 airplane with bulged metal-covered short-chord elevators having
an average trailing edge angle of 17.0° and with the elevator-stabilizer
gap reduced to about $\frac{1}{8}$ inch for (a) 5000 feet altitude, and (b) 25,000 feet
altitude. Clean condition, power on, stabilizer incidence +1.1°.
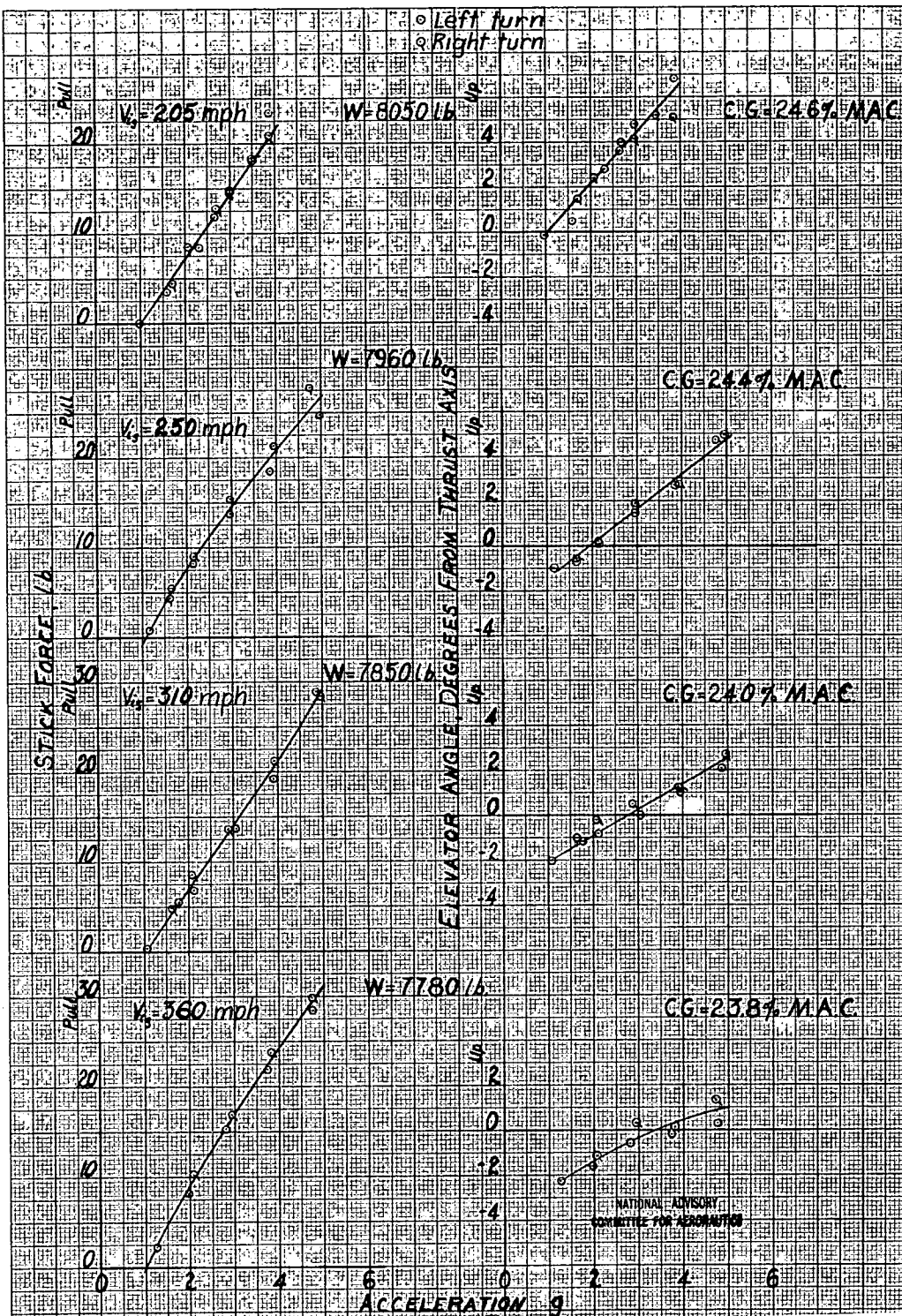
Figure 22.- Variation of stick force and elevator angle required to trim in turning flight with normal acceleration for various service indicated airspeeds. Bell P-63A-1 airplane, bulged metal-covered short-chord elevators with $3\frac{1}{4}$ pound bobweight, $\frac{1}{8}$ inch elevator-stabilizer gap, stabilizer incidence +1.1°. Clean condition, normal rated power (2600 RPM, 43 in. Hg), coolant shutters closed, altitude approximately 5000 feet.
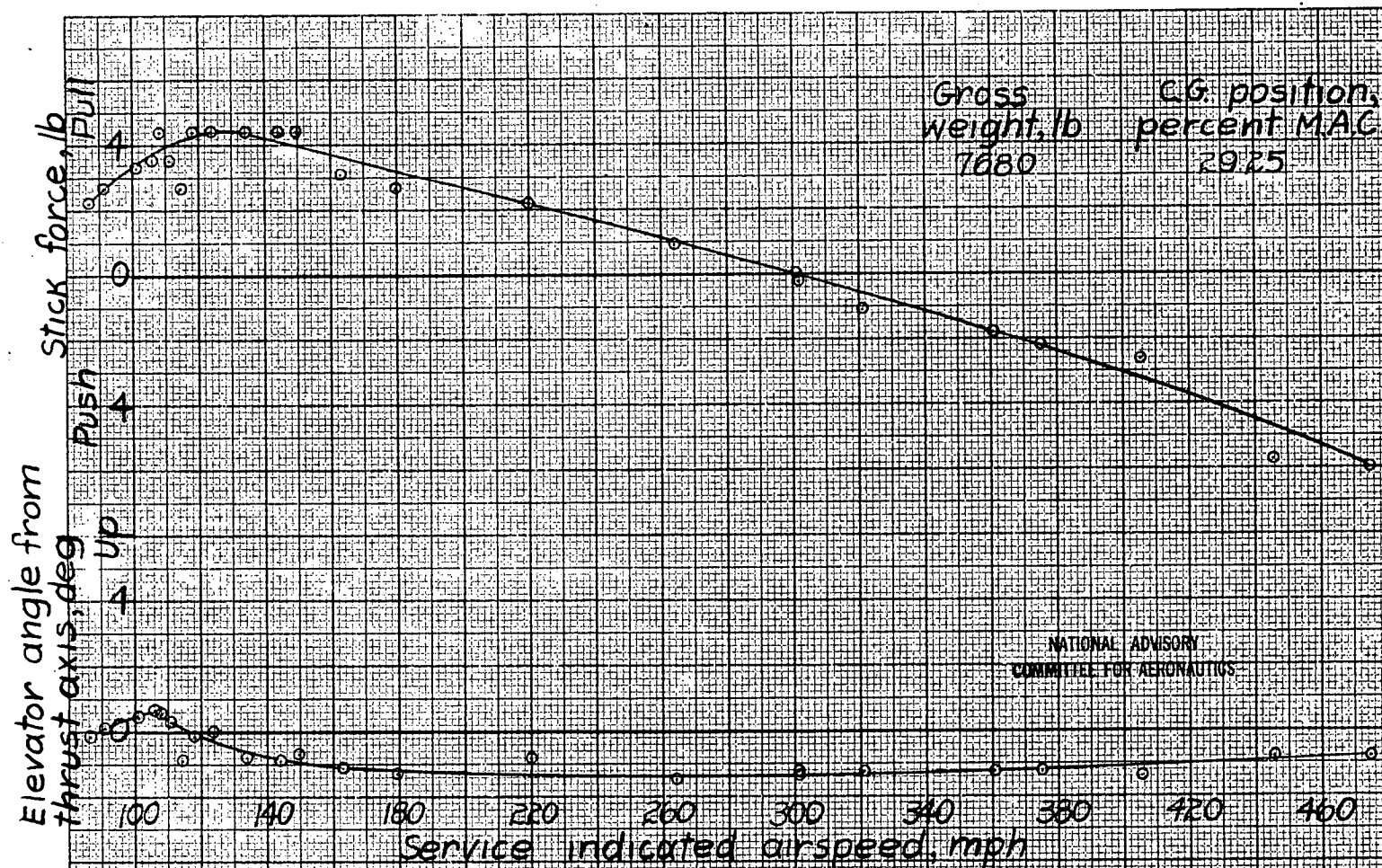
Figure 23.- Variation with service indicated airspeed of stick force and elevator angle required to trim in straight flight. Bell P-63A-1 airplane, bulged metal-covered short-chord elevators with $3\frac{1}{4}$ pound bobweight, $\frac{1}{8}$ inch elevator-stabilizer gap, stabilizer incidence +1.1°. Clean condition, normal rated power (2600 RPM, 43 in. Hg), coolant shutters closed, altitude approximately 5000 feet.
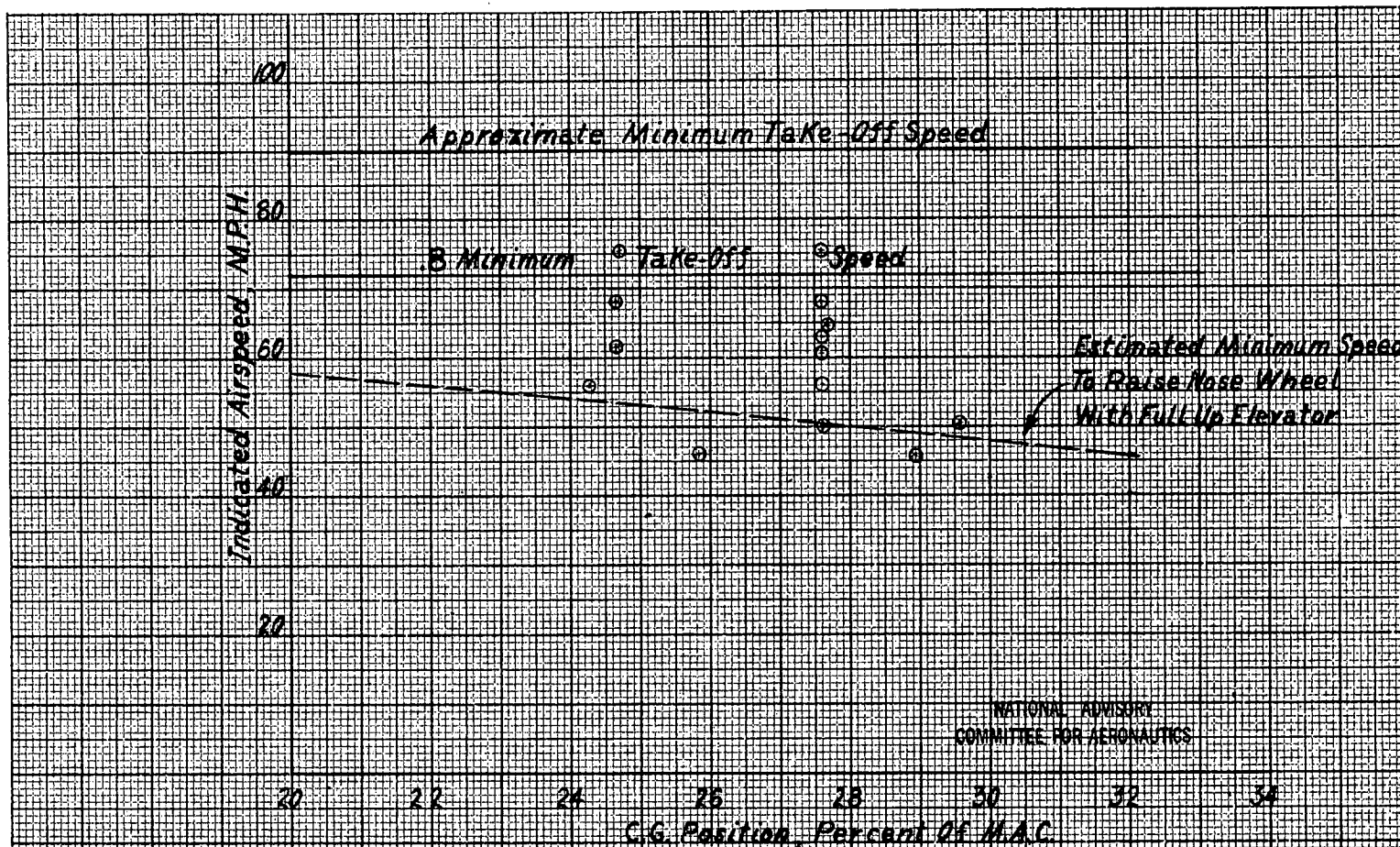
Figure 24.- Data showing speeds at which nose wheel was raised from concrete runway
during take-off using various amounts of up-elevator deflection. Faired curve is
estimated variation of minimum speed with full-up elevator deflection. Bell P-63A-1
airplane, horizontal tail planform shown in Figure 4B, various different elevators
installed.
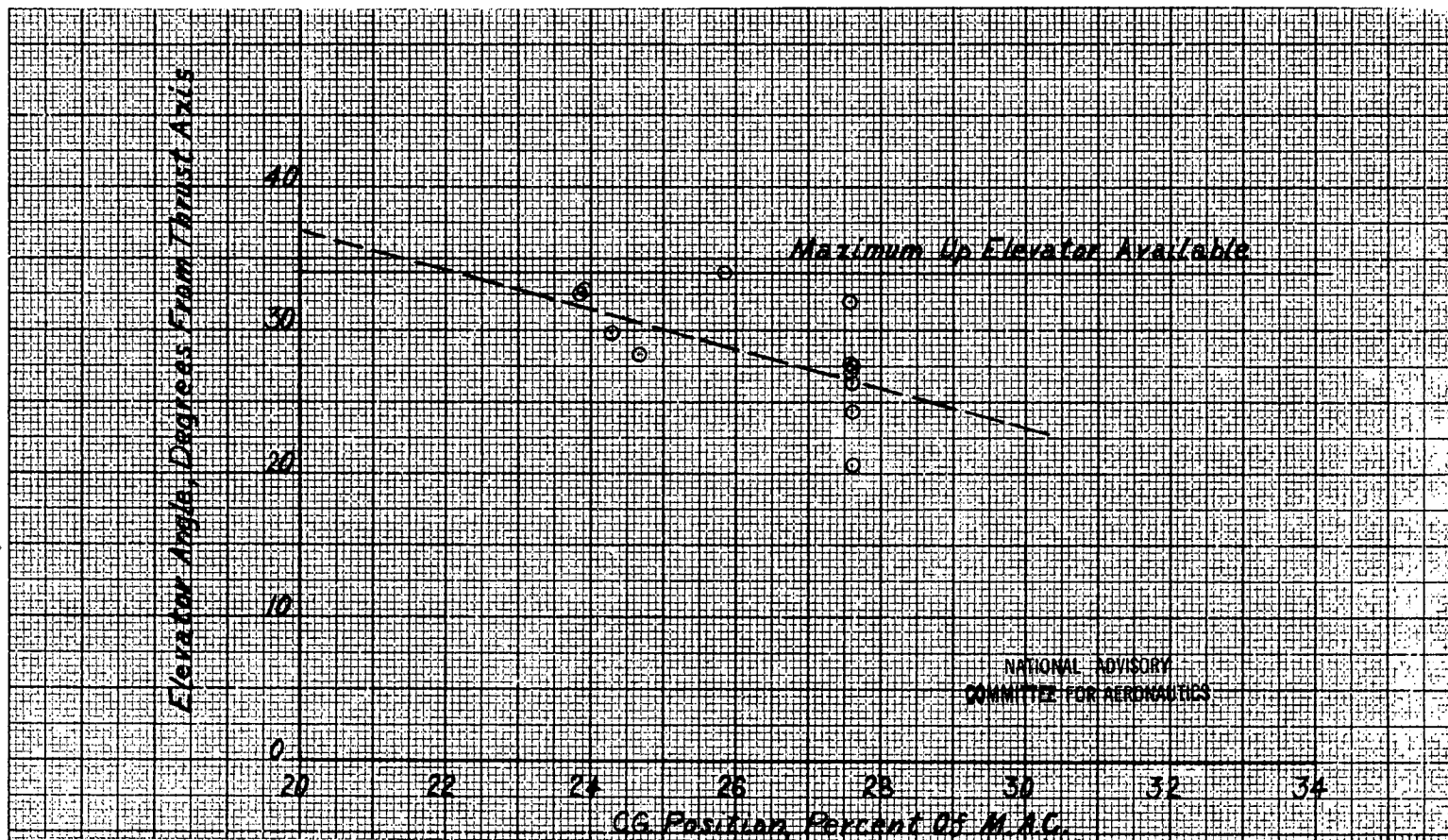
Figure 25.- Data showing the amount of elevator control necessary to make minimum speed landings with power off and landing flaps full down. Bell P-63A-1 airplane, horizontal tail planform shown in Figure 4B, various different elevators installed.
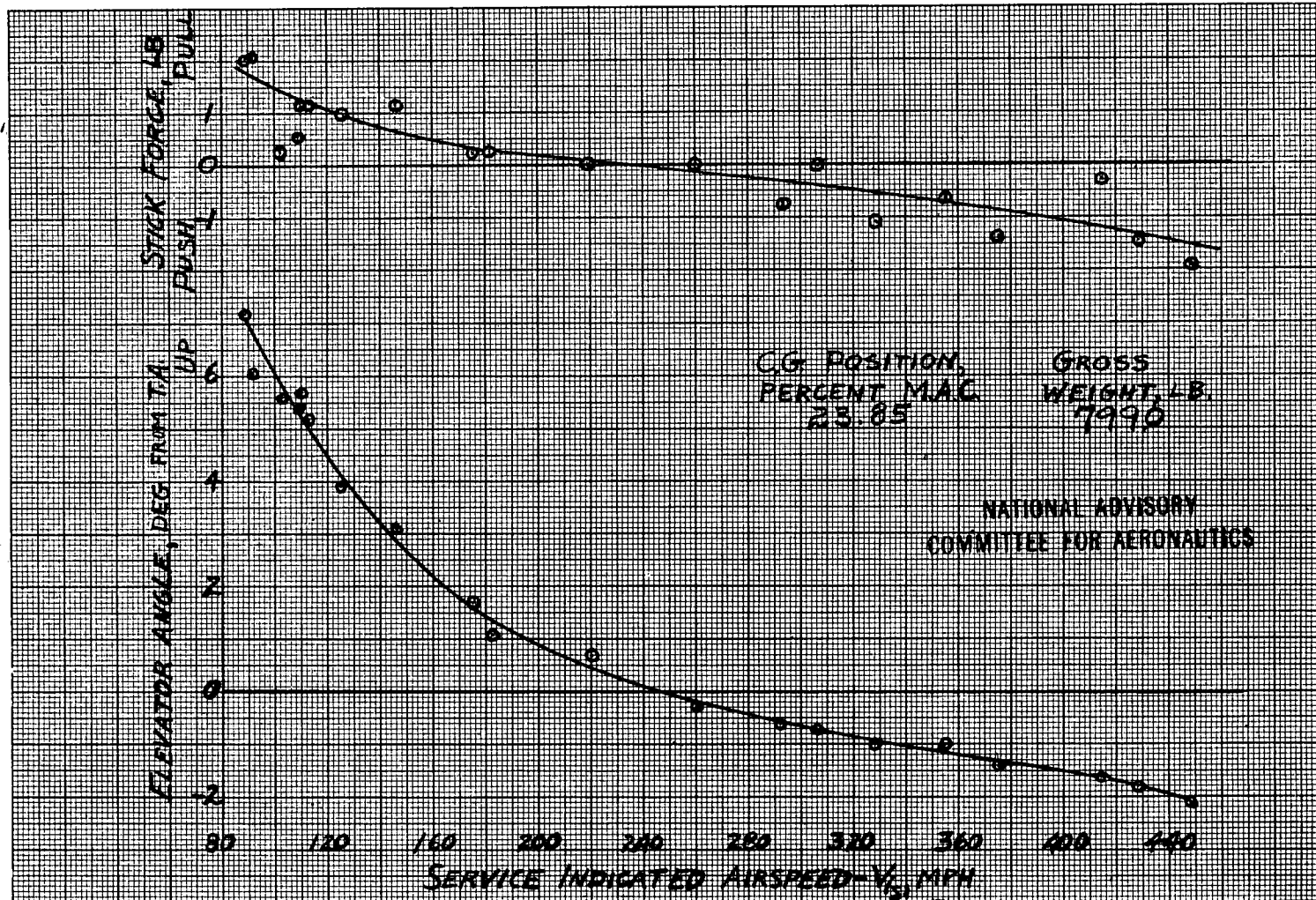
Figure 26.- Variation with indicated airspeed of stick force and elevator angle required to trim a Bell P-63A-1 airplane in straight flight. Horizontal tail shown in Figure 4C, bulged fabric-covered elevator shown in Figure 5D, elevator-stabilizer gap unsealed. Clean condition, normal rated power (2600 RPM, 43 in. Hg), altitude 5000 feet.
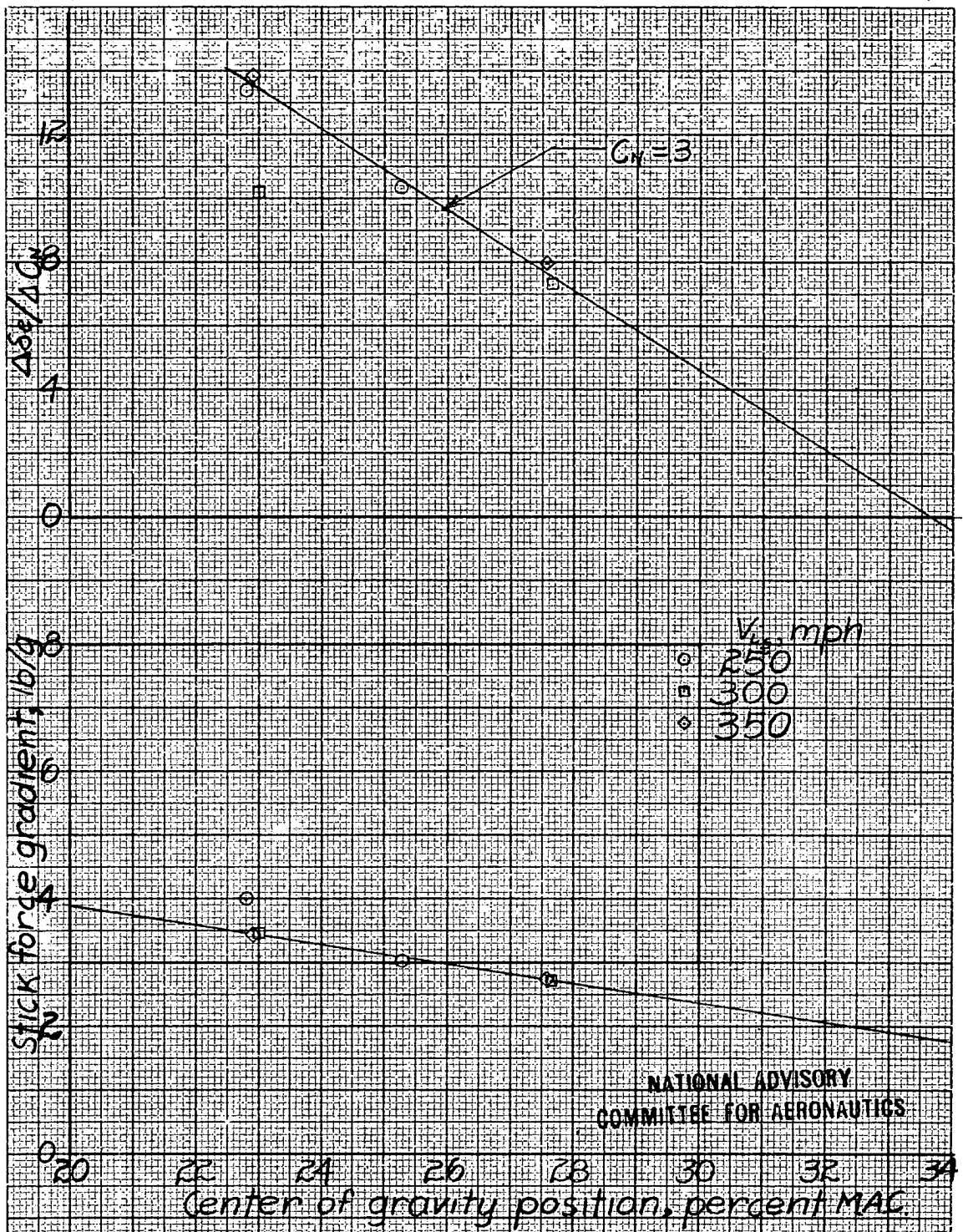
Figure 27.- Summary of the longitudinal stability characteristics
of the Bell P-63A-1 airplane in steady turning flight. Enlarged
horizontal tail shown in figure 4C, bulged fabric-covered elevators
shown in figure 5D, elevator stabilizer gap unsealed. Clean con-
dition, normal rated power (2600 RPM, 43 in. Hg), altitude 5000 feet.
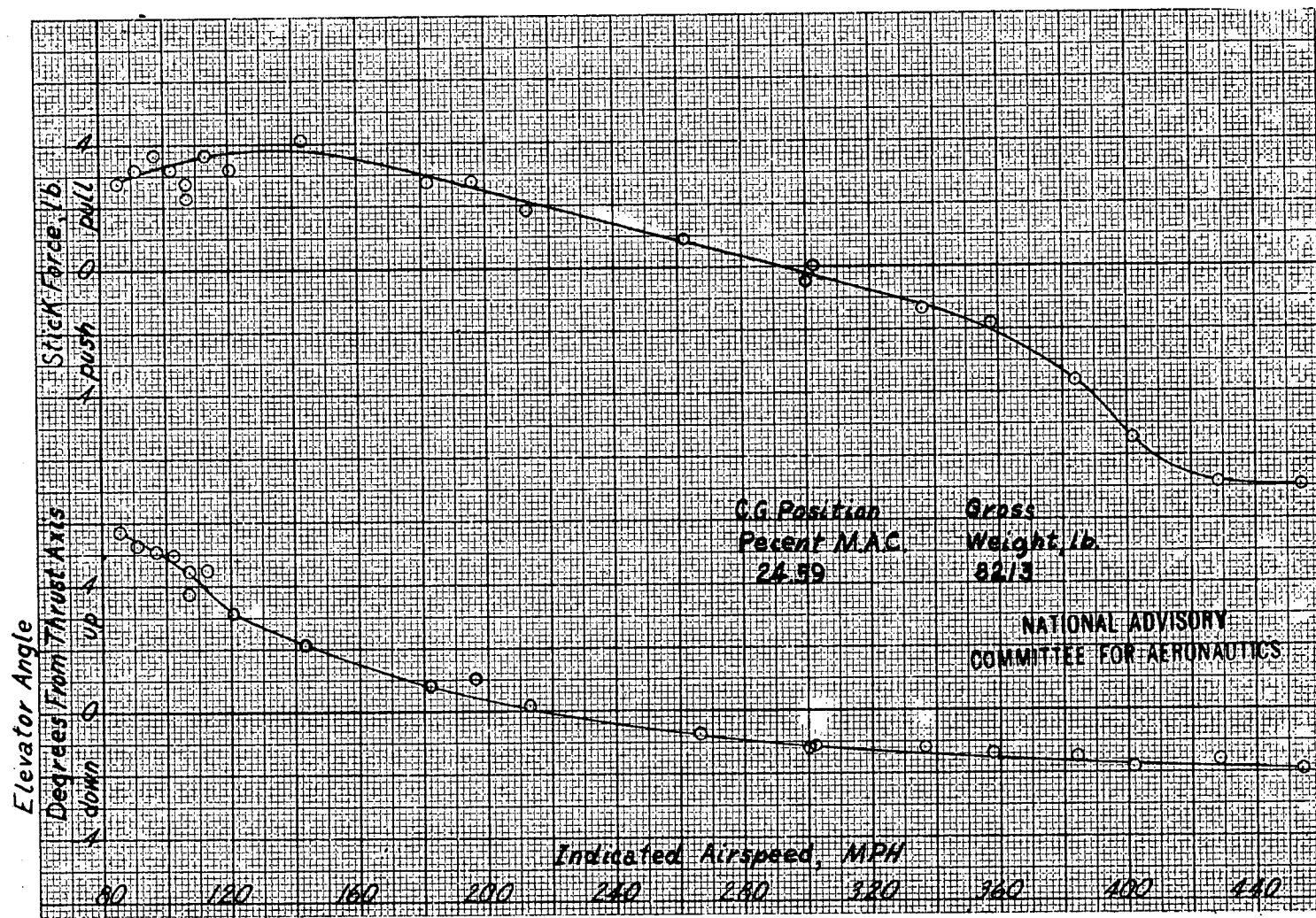
Figure 28.- Variation with indicated airspeed of stick force and elevator angle required to trim a Bell P-63A-1 airplane in straight flight. Horizontal tail shown in Figure 4C, bulged fabric-covered elevators shown in Figure 5D, elevator-stabilizer gap sealed. Clean condition, normal rated power (2600 RPM, 43 in. Hg), altitude 5000 feet.
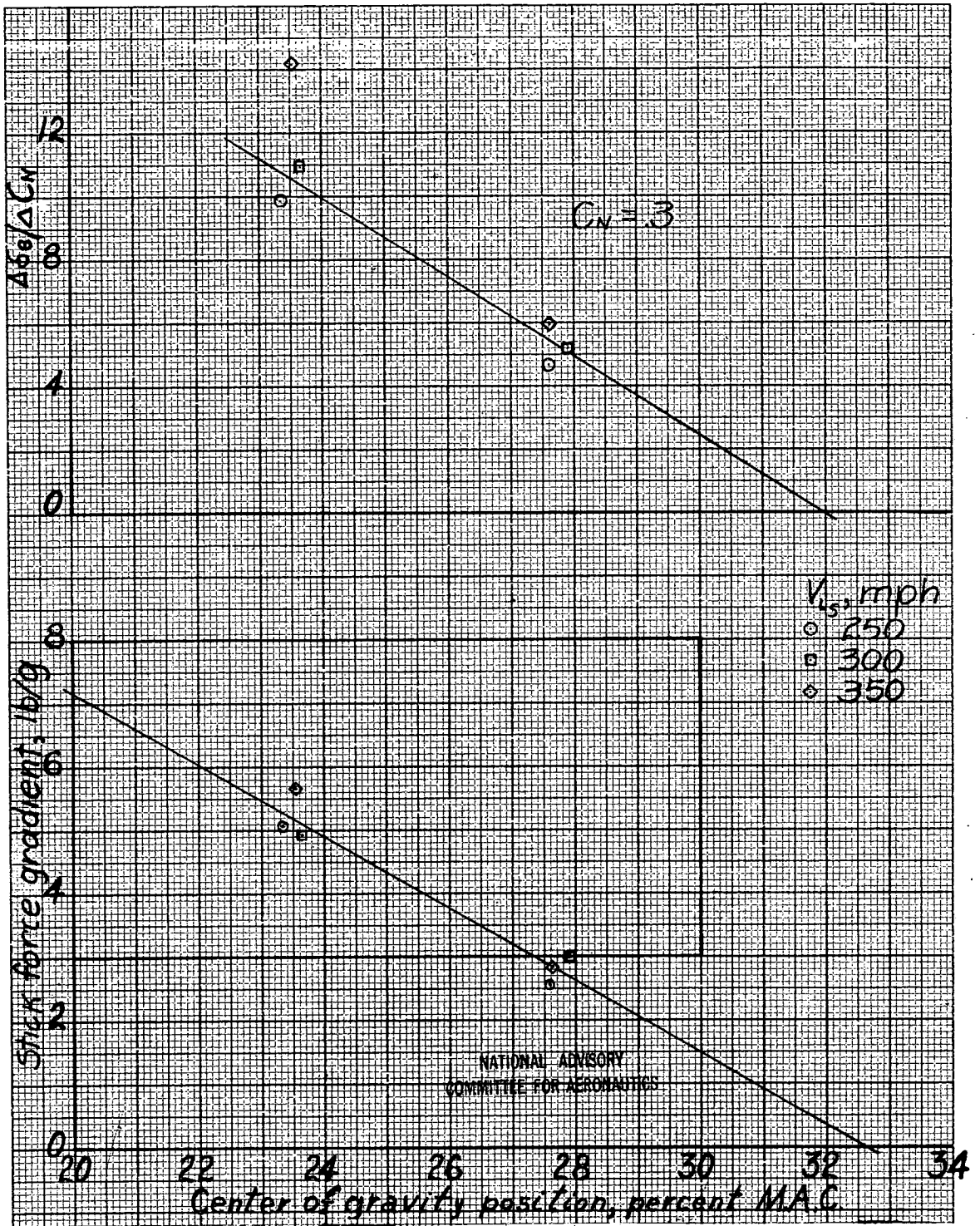
Figure 29.- Summary of the longitudinal stability characteristics
of the Bell P-63A-1 airplane in steady turning flight. Enlarged
horizontal tail shown in Figure 4C, bulged fabric-covered eleva-
tors shown in Figure 5D, elevator-stabilizer gap sealed. Clean
condition, normal rated power (2600 RPM, 43 in Hg), altitude
5000 feet.
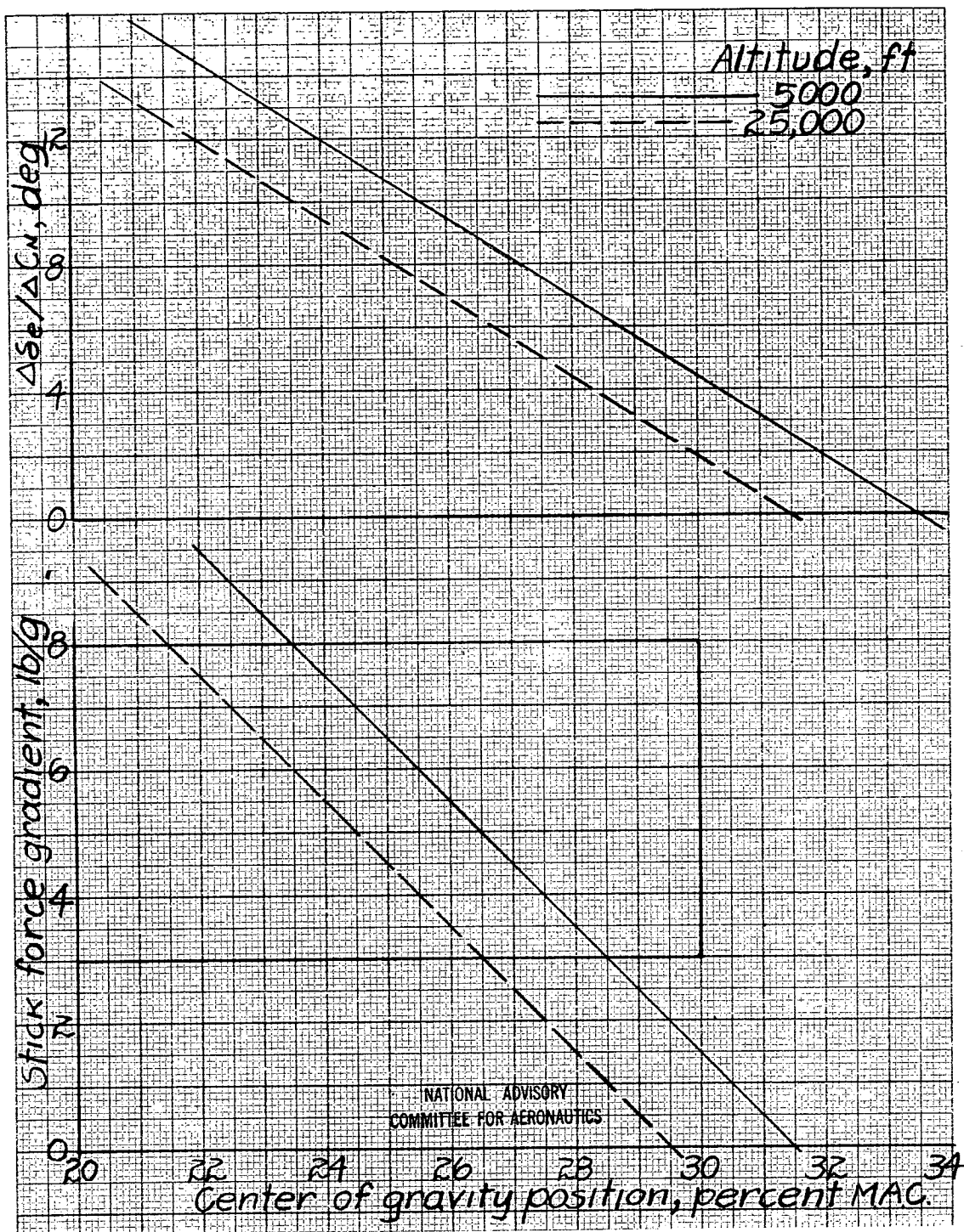
Figure 30.- Predicted longitudinal stability characteristics for steady turning flight. Bell P-63A-1 airplane with enlarged horizontal tail and original contour production elevators at V_i = 250-300 MPH. Clean condition, normal rated power, two different altitudes, no bob weight. No flight tests have yet been made at the NACA with this airplane configurations.
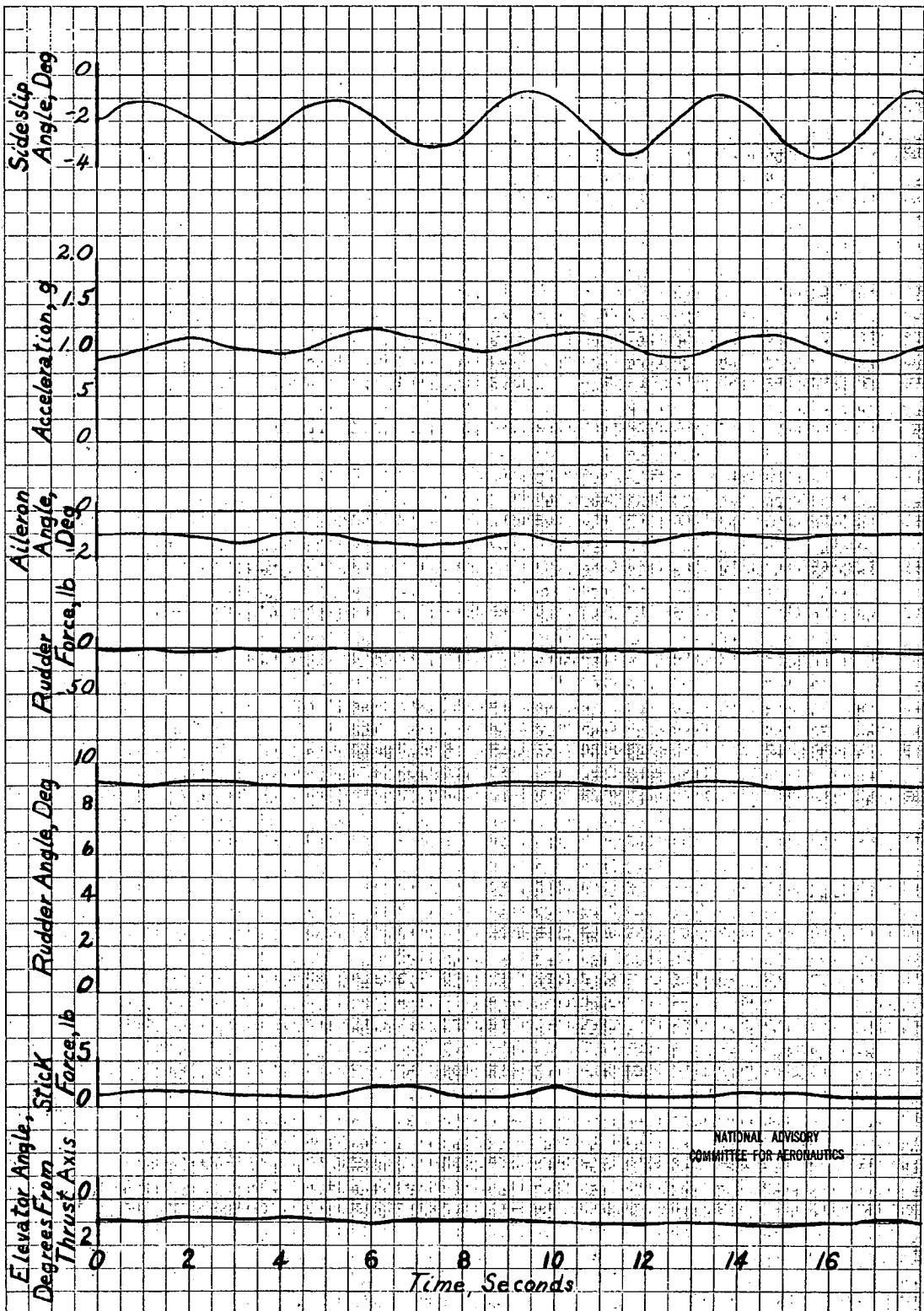
Figure 31.- Time history showing an undamped directional oscillation
which occurred with a P-63A-1 airplane with the original vertical
tail installed even though the pilot attempted to hold all controls
fixed. Climbing condition at 22,000 feet altitude. The occurrence
of such an oscillation indicates weak directional stability.
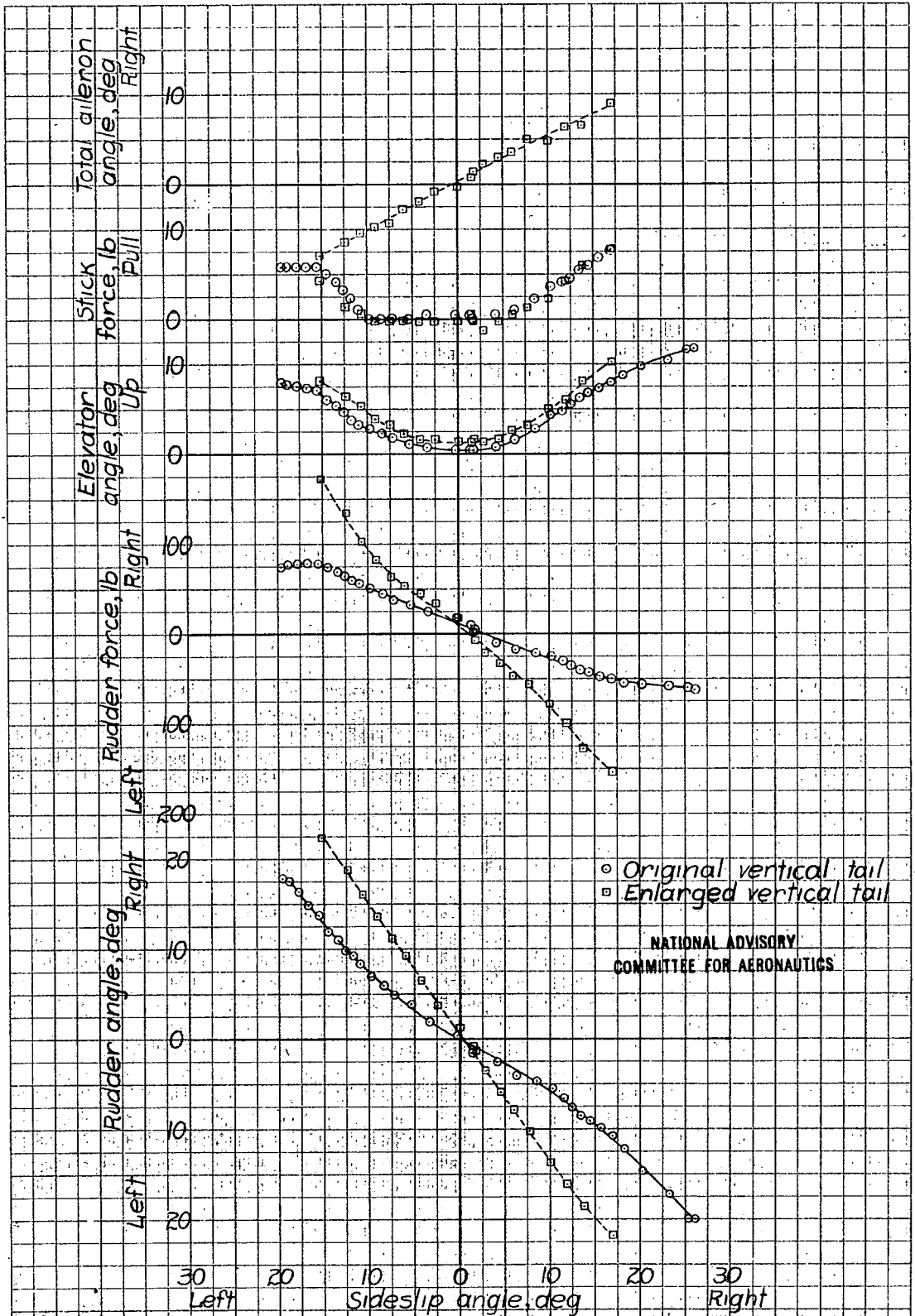
Figure 32.- Sideslip characteristics of P-63A-1 airplane with power off at V_{i_s} = 150 mph at 5000 feet altitude.
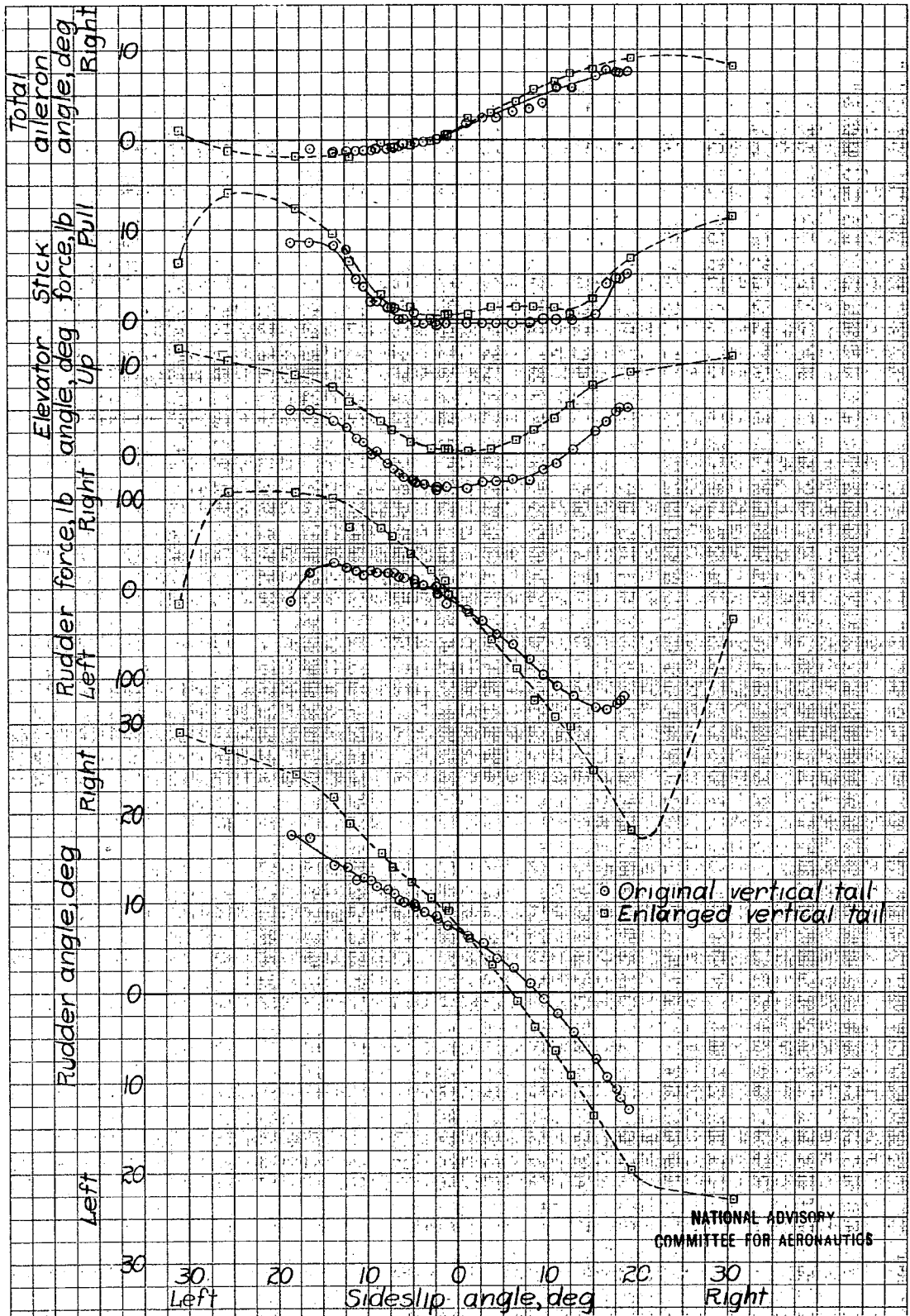
Figure 33.- Sideslip characteristics of P-63A-1 airplane with rated power (2600 RPM, 43 in. Hg.) at V_{i_s} = 150 mph at 5000 feet altitude.
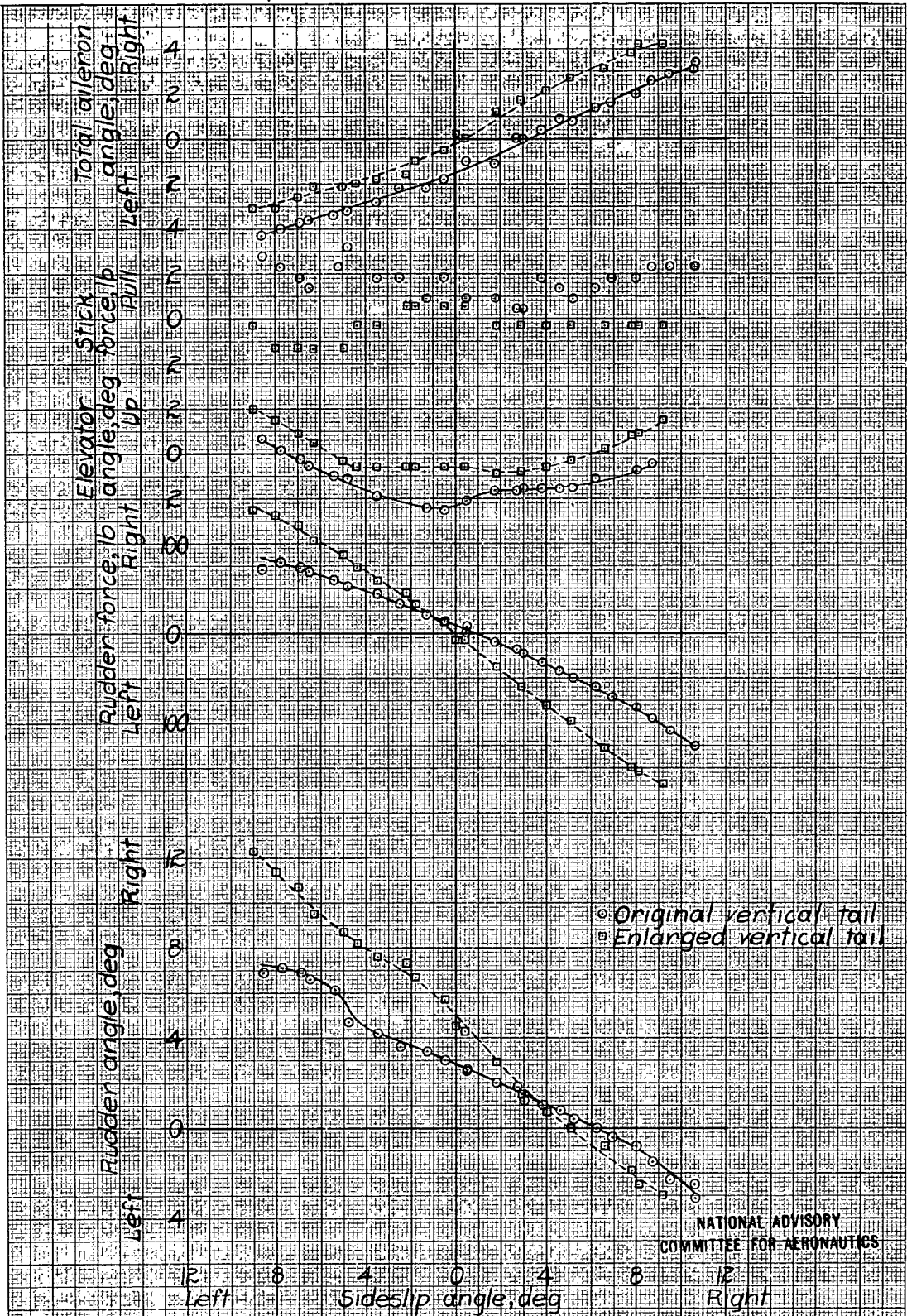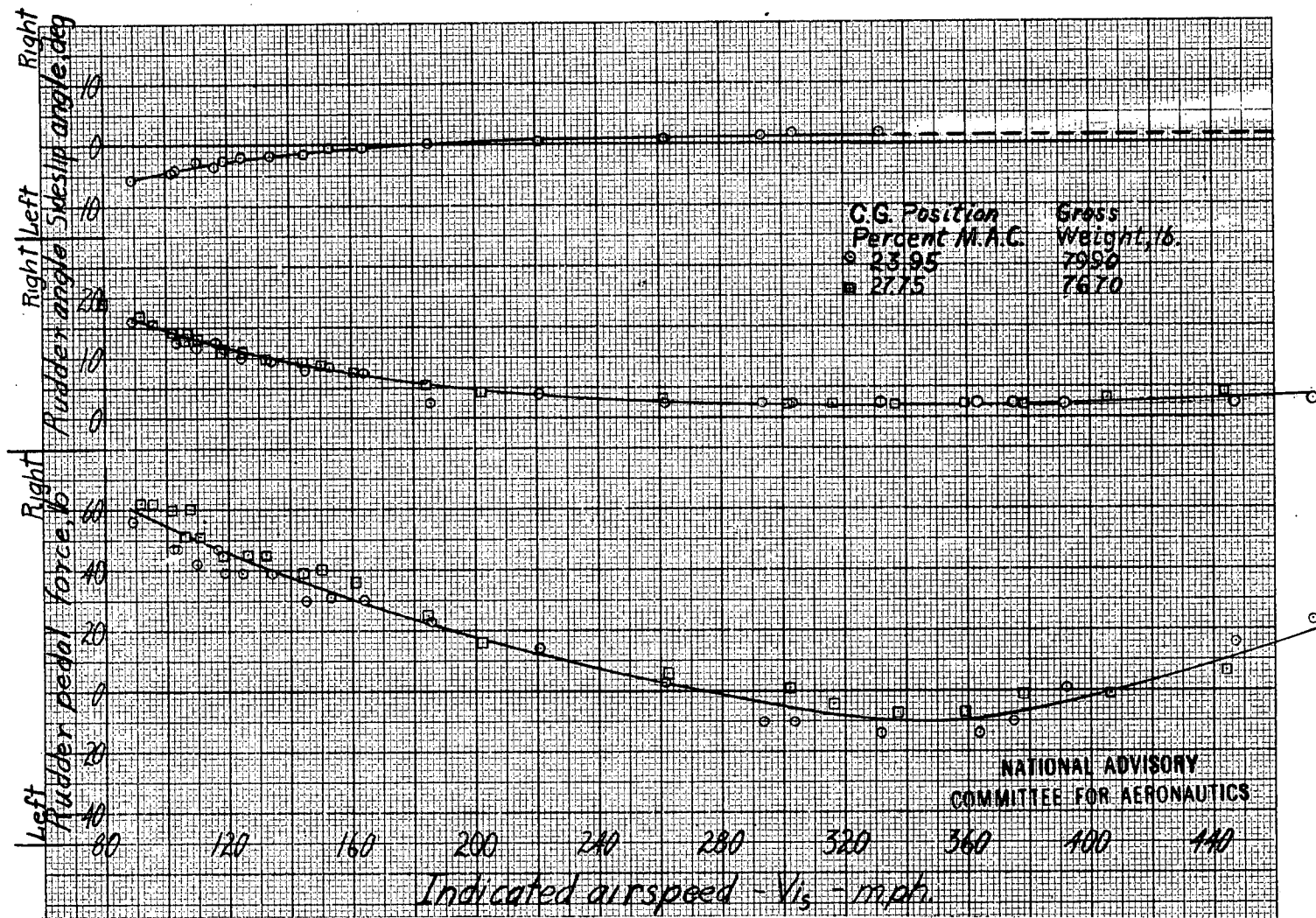
Figure 34.- Sideslip characteristics of P-63A-1 airplane with rated power (2600 RPM, 43 in Hg.) at V_{i_s} = 250 mph at 5000 feet altitude.
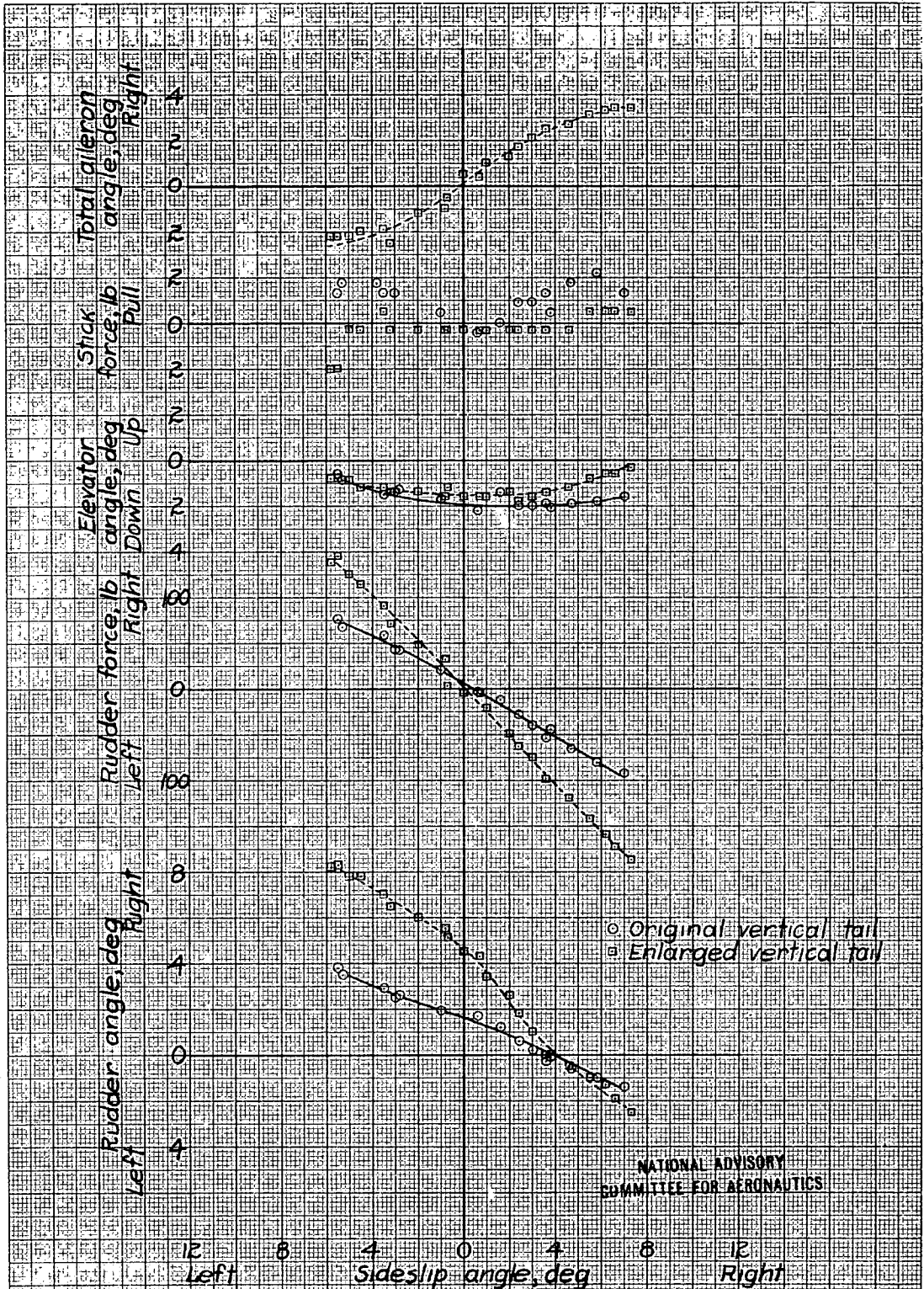
Figure 35.- Sideslip characteristics of P-63A-1 airplane with rated power (2600 RPM, 43 in. Hg.) at V_{i_s} = 300 mph at 5000 feet altitude.
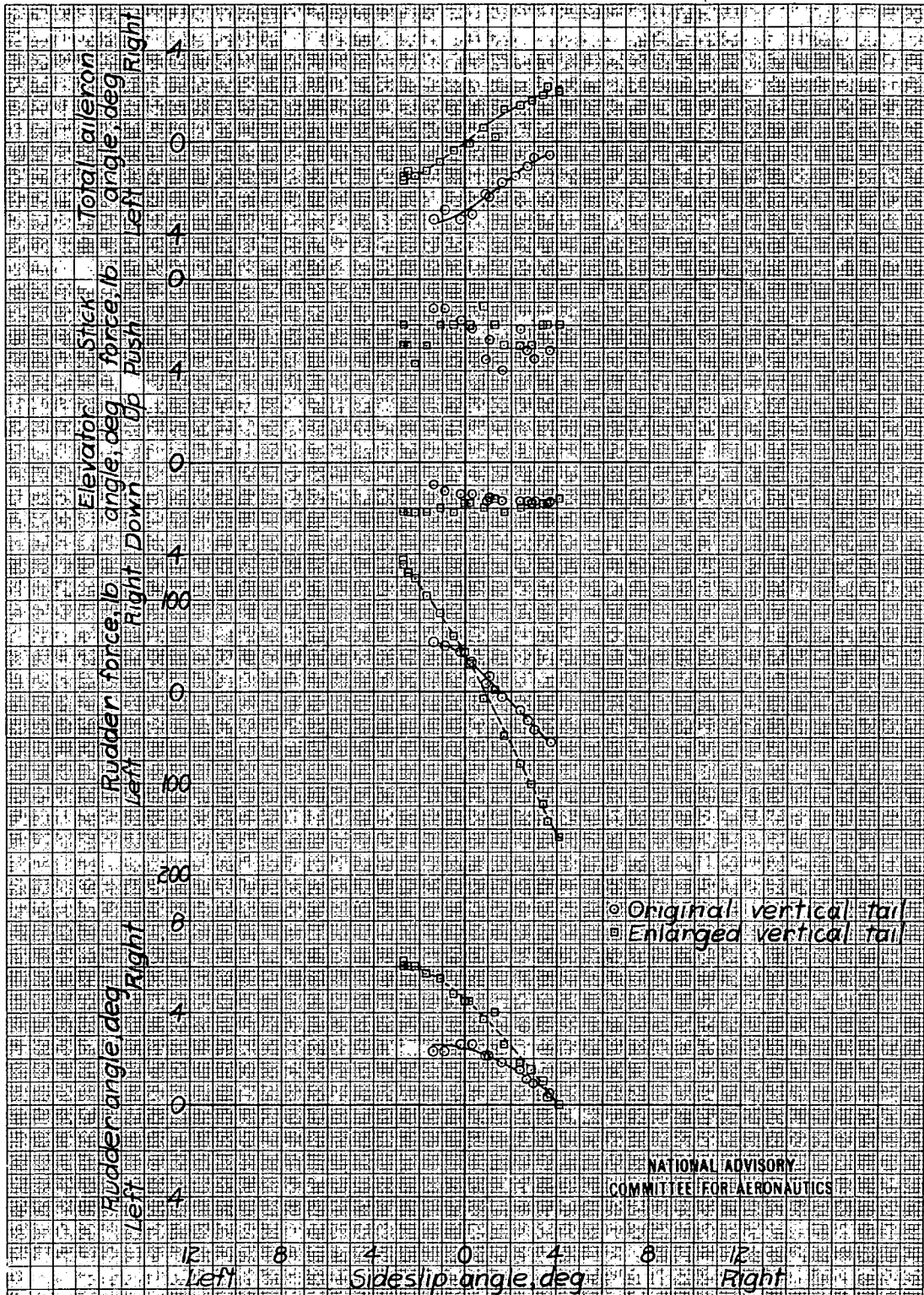
Figure 36.- Sideslip characteristics of P-63A-1 airplane with rated power (2600 RPM, 43 in. Hg.) at V_{i_s} = 400 mph at 5000 feet altitude.
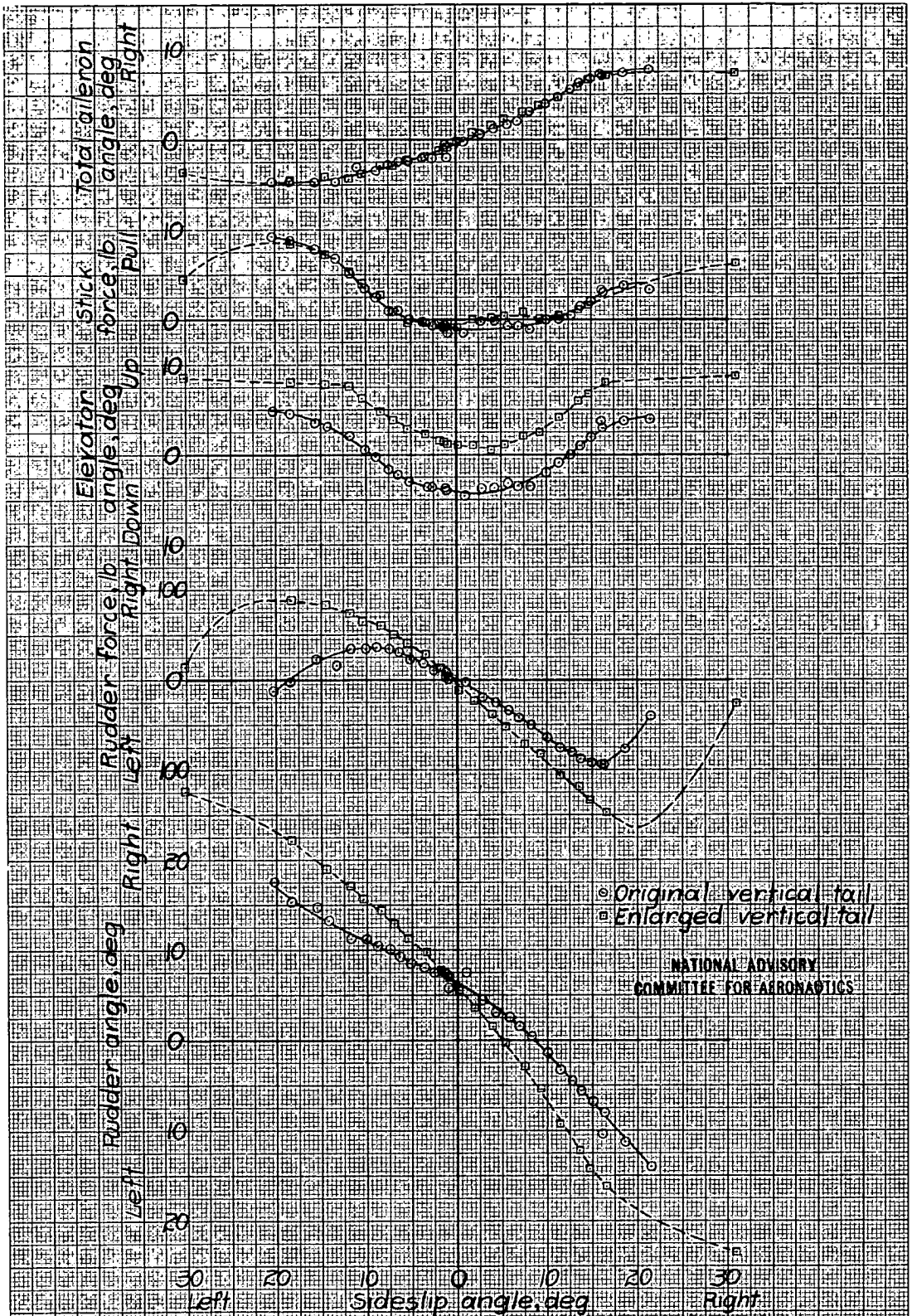
Figure 37.- Sideslip characteristics of P-63A-1 airplane with power on (2600 RPM, 38 in. Hg.) at V_{i_s} = 150 mph at 22,000 feet altitude.
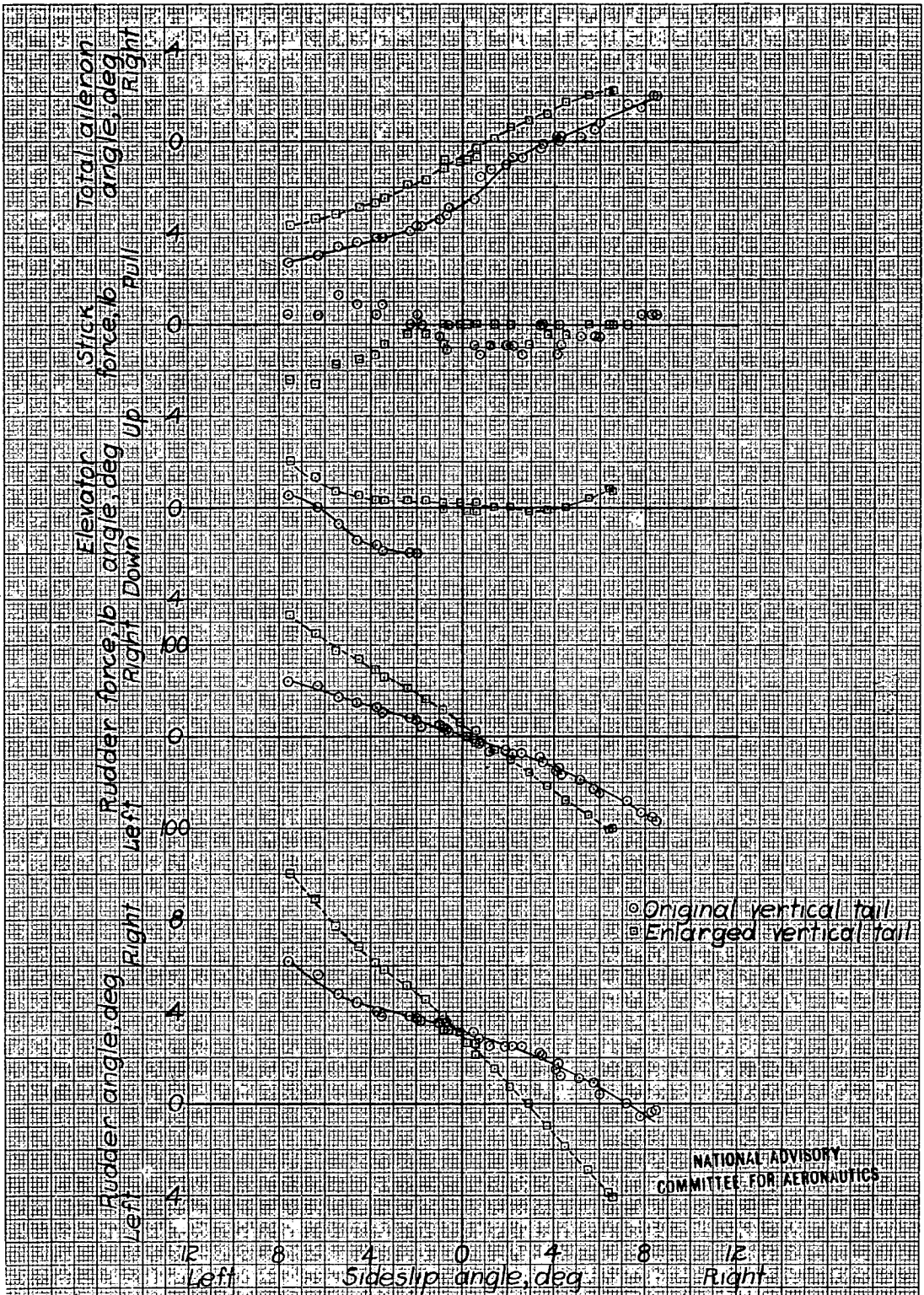
Figure 38.- Sideslip characteristics of P-63A-1 airplane with power on (2600 RPM, 39 in.Hg.) at $V_{i_a} = 250$ mph at 25,000 feet altitude.

Figure 39.- Directional trim characteristics of P-63A-1 airplane with original vertical tail showing the variations in rudder force and angle with indicated airspeed to maintain straight, wings-level flight. Clean condition, normal rated power (2600 RPM, 43 in. Hg), altitude 5000 feet.
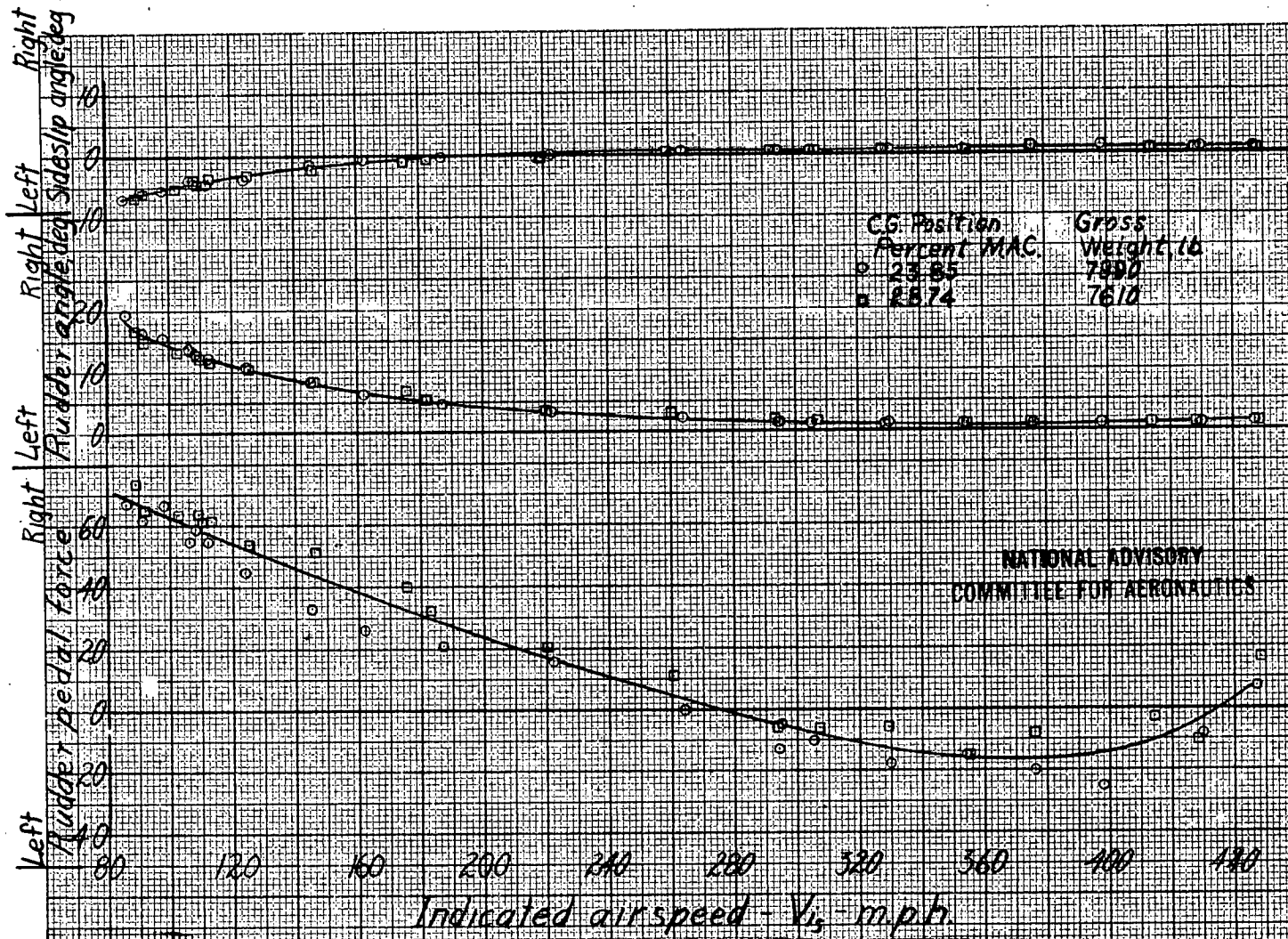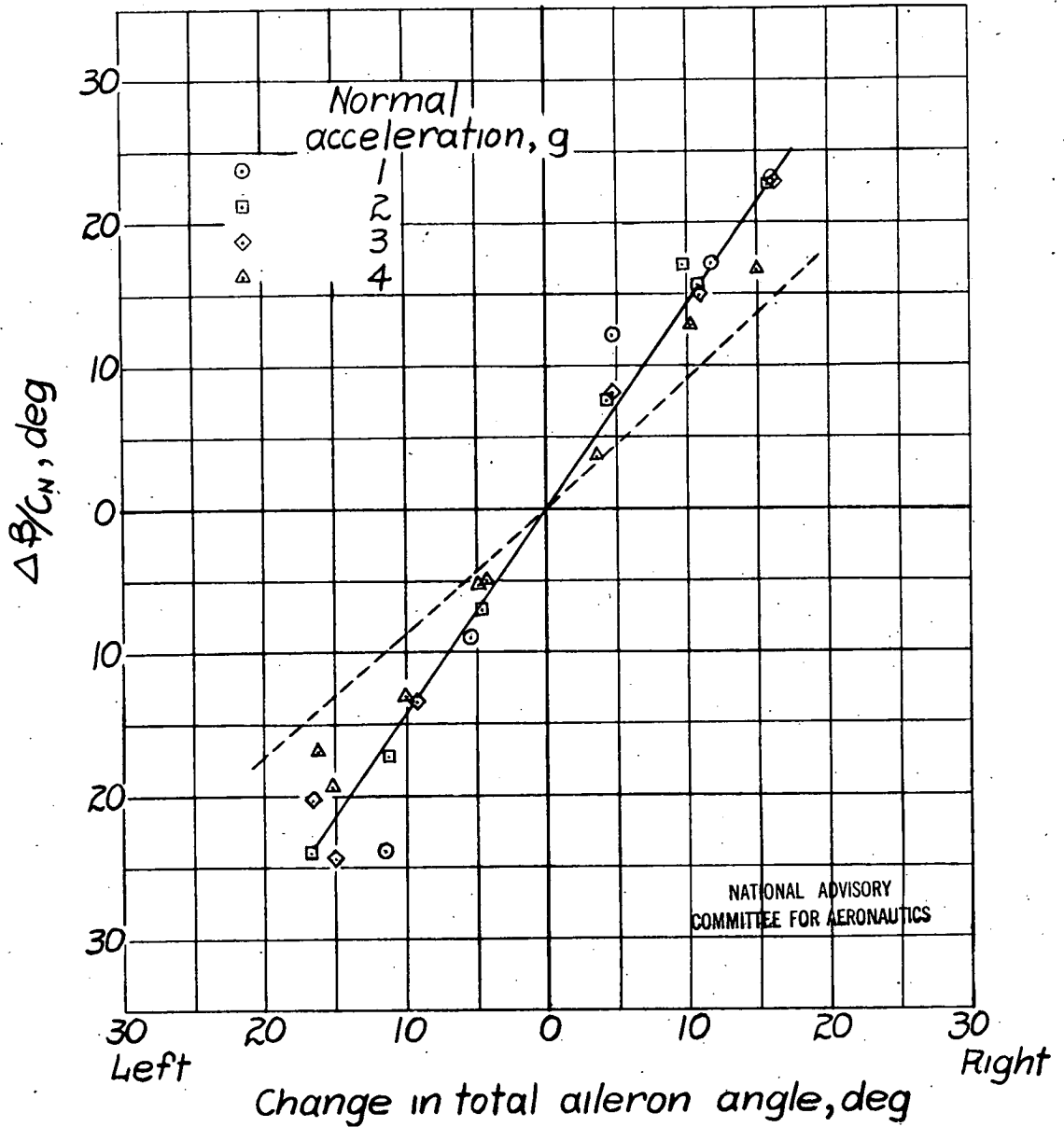
Figure 40.- Directional trim characteristics of P-63A-1 airplane with enlarged
vertical tail surfaces showing the variation in rudder force and angle with
indicated airspeed to maintain straight, wings-level flight. Clean condition,
normal rated power (2600 RPM, 43 in. Hg.), altitude 5000 feet.

Figure 41.- Results of rudder-fixed rolls out of pull-outs at
various normal accelerations at an indicated speed of
250 MPH at 5000 feet altitude using constant propeller blade
angle and thrust coefficient. Bell P-63A-1 airplane (AAF
No. 42-68889). (a) Original vertical tail. Dash line is
faired curve for enlarged vertical tail shown in figure 41b.
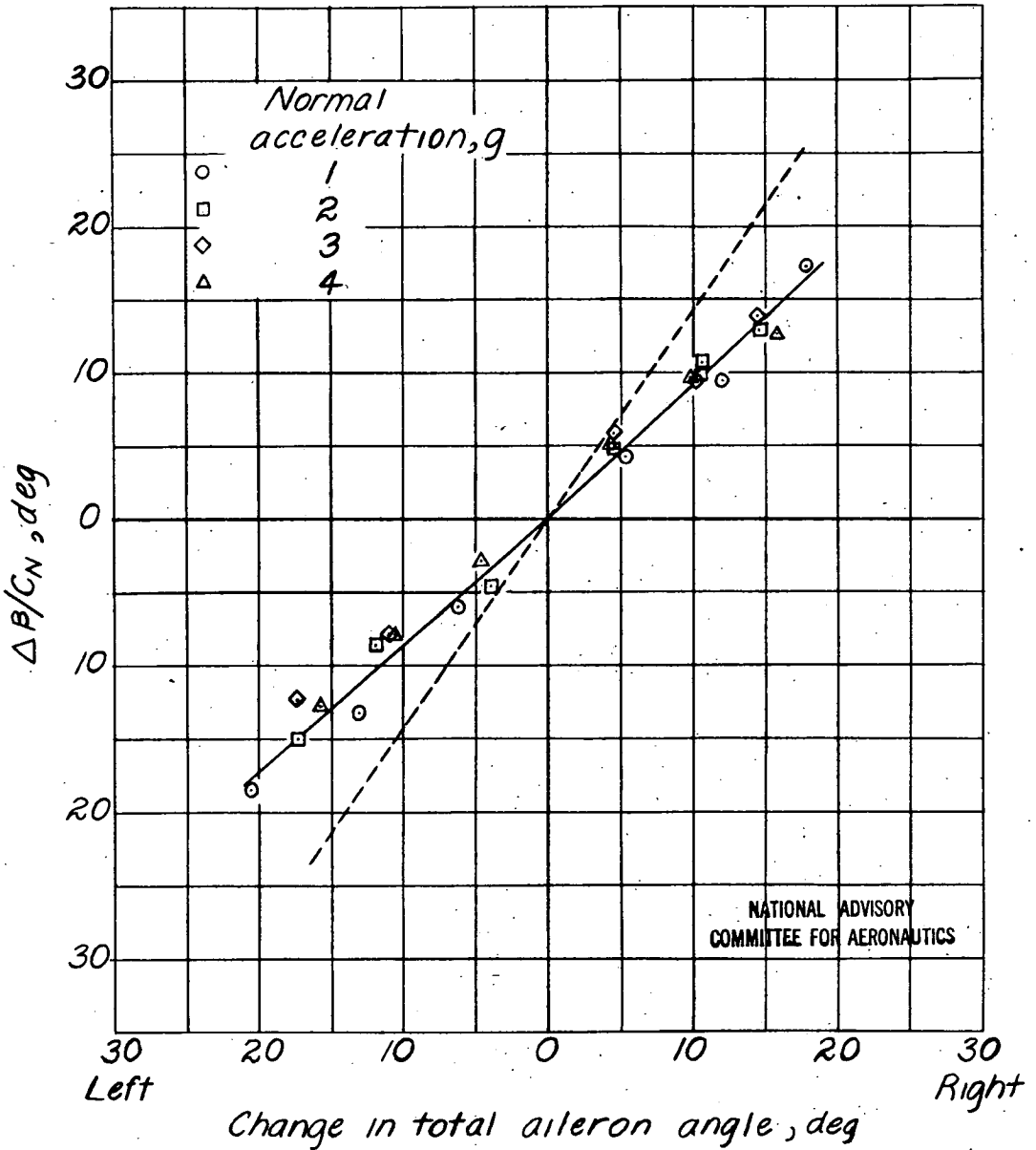
(b) Enlarged vertical tail. Dash line is faired curve for
original vertical tail shown in figure 41a.
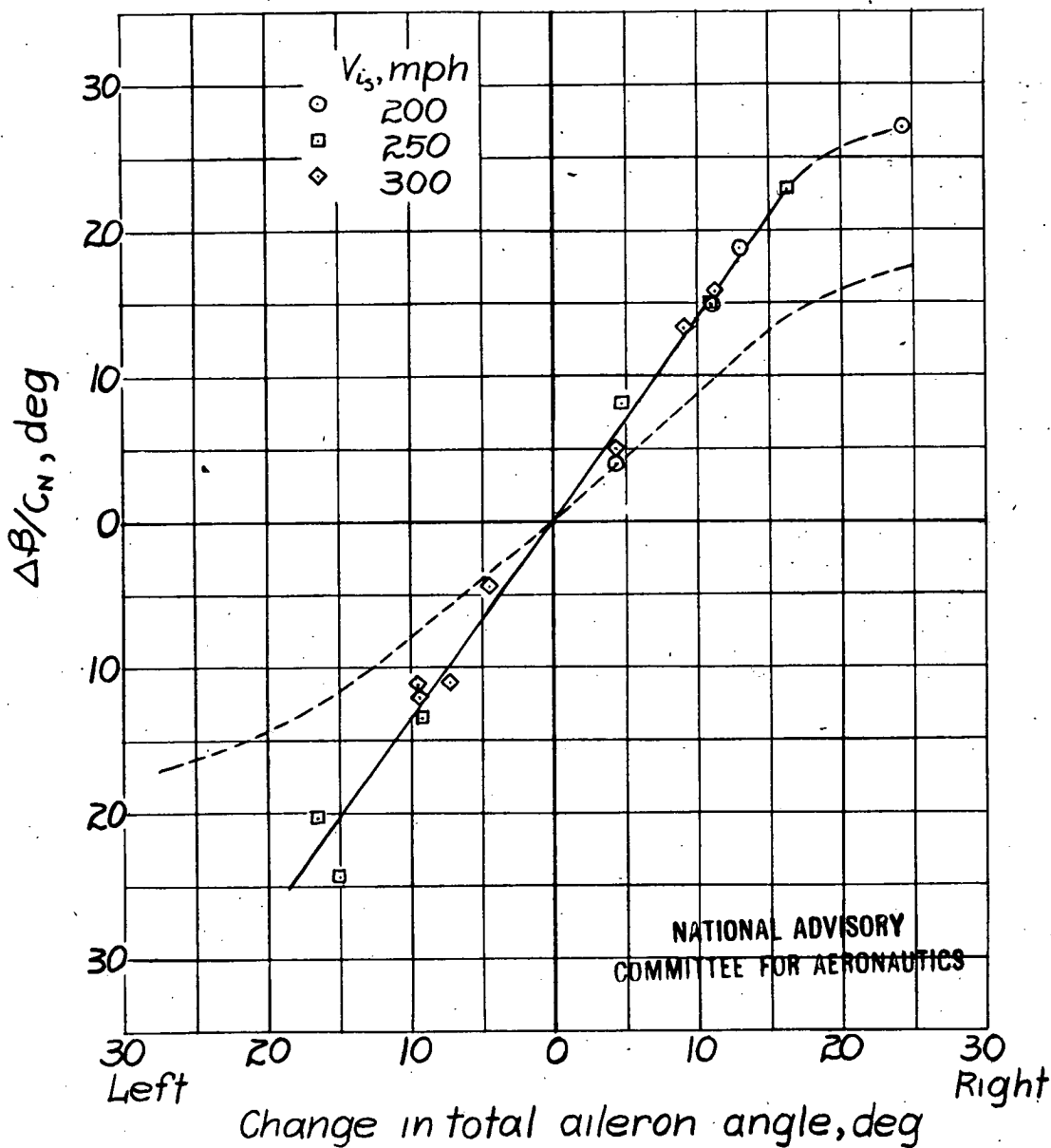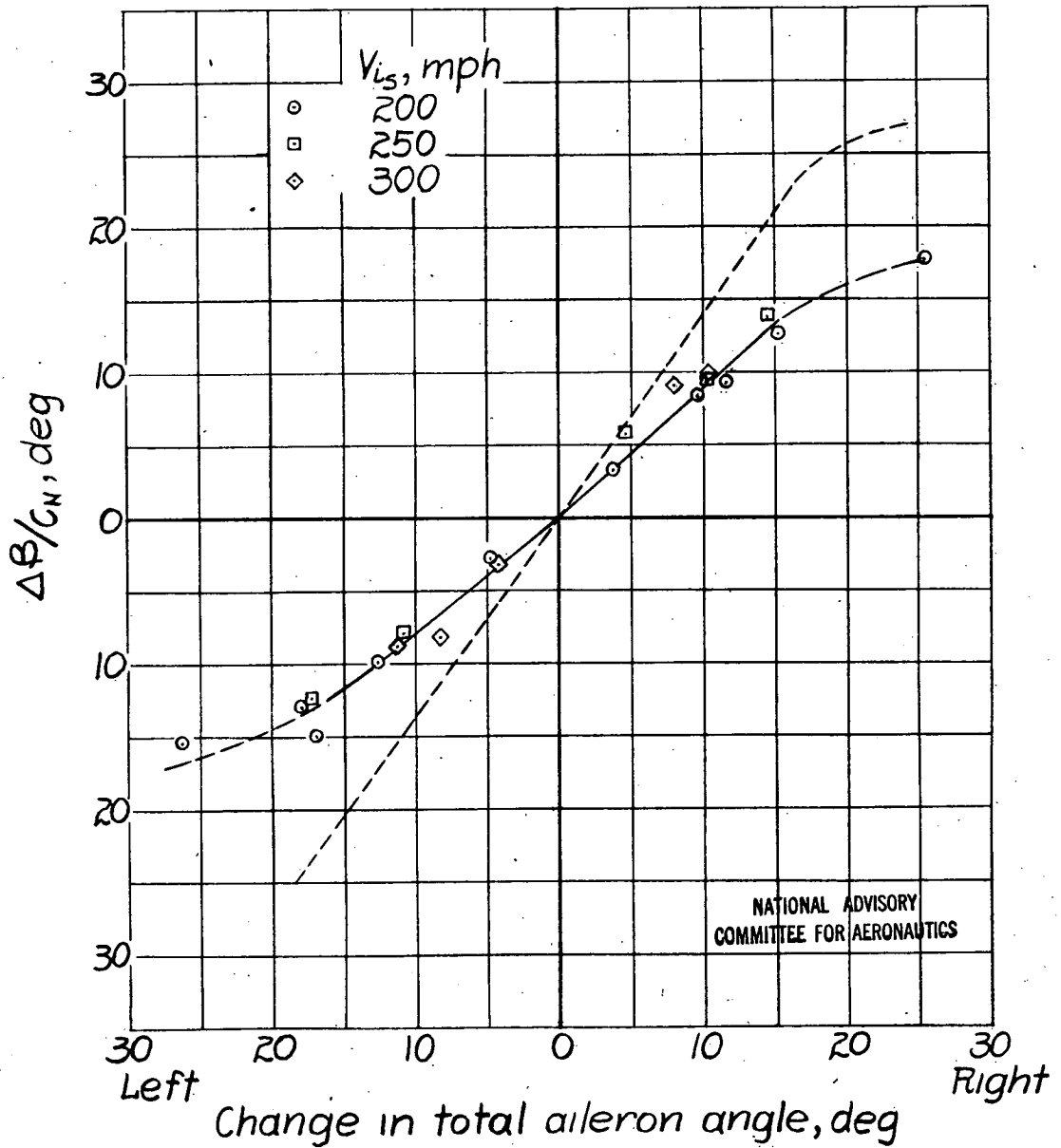
Figure 41.- Concluded.

Figure 42.- Results of rudder-fixed rolls out of 3 g pull-outs at
5000 feet altitude at various speeds using constant propeller
blade angle and thrust coefficient. Bell P-63A-1 airplane
(AAF No. 42-68889). (a) Original vertical tail. Dash line is
faired curve for enlarged vertical tail shown in figure 42b.

(b) Enlarged vertical tail. Dash line is faired curve for original
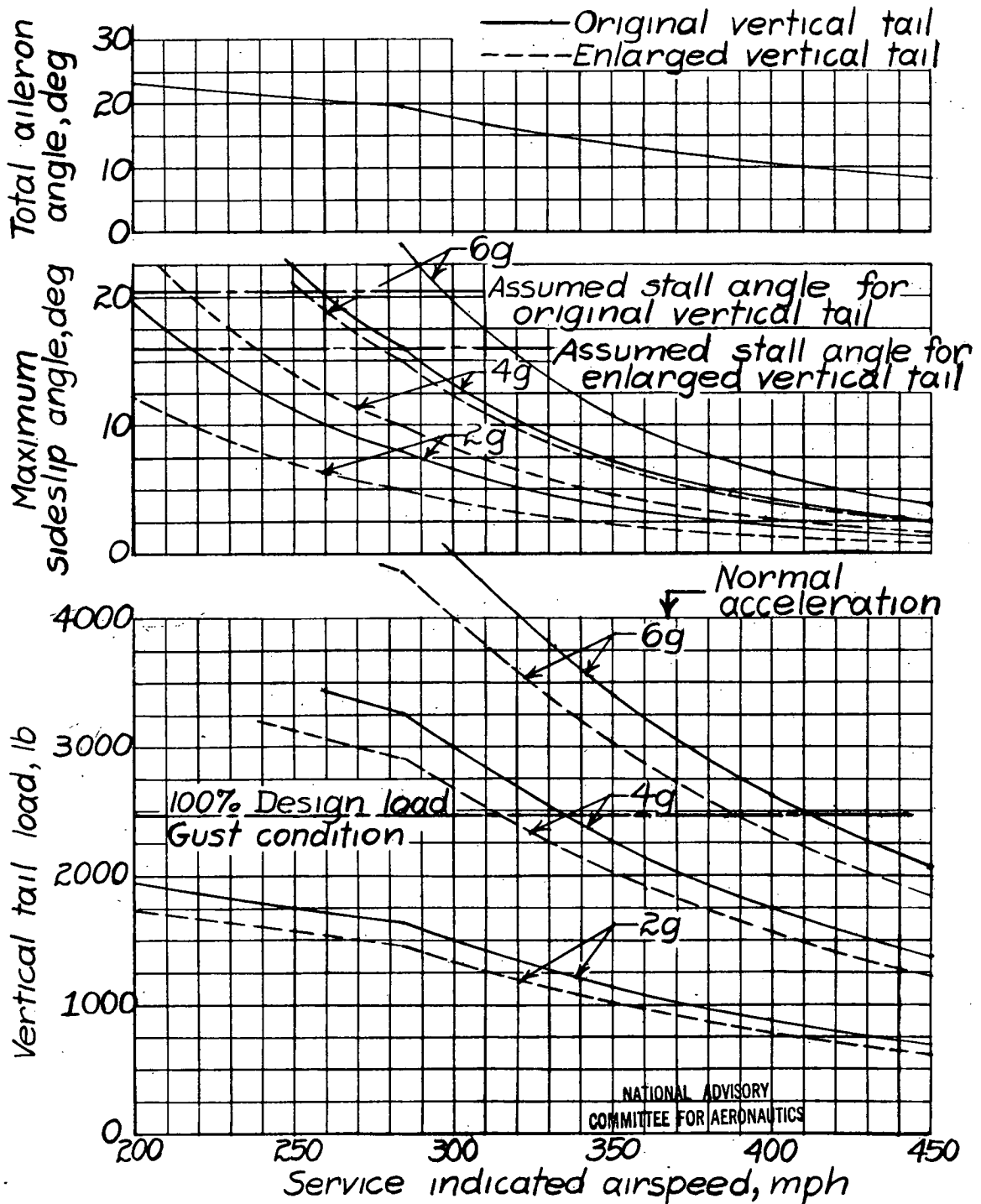vertical tail shown in figure 42a.

Figure 42.- Concluded.

Figure 43.- Estimated maximum vertical tail loads to be expected in rudder-fixed rolls during accelerated flight employing 50 pounds aileron stick force.