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# RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

FLIGHT MEASUREMENTS OF FLYING QUALITIES OF A P-47D-30 AIRPLANE  
(AAF NO 43-3441) TO DETERMINE LONGITUDINAL STABILITY  
AND CONTROL AND STALLING CHARACTERISTICS

By

Christopher C. Kraft, Jr., R. Fabian Goranson, and John P. Reeder

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FLIGHT MEASUREMENTS OF FLYING QUALITIES OF A P-47D-30 AIRPLANE

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S U M M A R Y

Flight tests have been made to determine the longitudinal stability and control and stalling characteristics of the P-47D-30 airplane. The test results show the airplane to be unstable stick free in any power-on condition even at the most forward center-of-gravity position tested. At the rearward center-of-gravity position tested the airplane also had neutral to negative stick-fixed stability with power on. The characteristics in accelerated flight were acceptable at the forward center-of-gravity position at low and high altitudes except at high speed where the control-force variations with acceleration were high. At the rearward center-of-gravity position, elevator-force reversals were experienced in turns at low speeds, and the force per g was low at all the other speeds. Ample stall warning was afforded in all the conditions tested and the stalling characteristics were very satisfactory except in the approach and wave-off conditions.

I N T R O D U C T I O N

At the request of the Air Materiel Command, Army Air Forces, flight tests have been made to determine the flying qualities of a P-47D-30 airplane (AAF No. 43-3441). The results of the tests of longitudinal stability and control and stalling characteristics are presented herein. Data on the lateral and directional stability and control have been presented in a previous report (reference 1).

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## DESCRIPTION OF AIRPLANE AND TESTS

The P-47D-30 is a low-wing fighter-type airplane. This model incorporates an R-2800-59 engine, a dorsal fin, dive-recovery flaps, round-nose ailerons, and a bubble canopy. A three-view drawing of the airplane is shown in figure 1 and additional data describing the airplane are presented in table I. Photographs of the test airplane are shown in figures 2 to 4. The airplane was flown at two center-of-gravity positions. The forward center-of-gravity position of 26.4 percent mean aerodynamic chord (landing gear down) with the gross weight varying from 12,810 pounds at take-off to 11,870 pounds was obtained by attaching 200 pounds of lead to the propeller reduction gear box and flying the airplane with the auxiliary tank empty. A photograph of this ballast installation is shown in figure 5. This lead ballast was more than sufficient to balance the moment rearward of the center of gravity brought about by the installation of instruments in the baggage compartment. The instrument installation caused a rearward center-of-gravity shift of approximately 0.2 percent mean aerodynamic chord and the lead installation caused a forward center-of-gravity shift of approximately 1 percent. The airplane manual gives the service center-of-gravity range as between 24.75 and 31.0 percent mean aerodynamic chord with landing gear down. The forward center-of-gravity position of 24.75 percent of the mean aerodynamic chord could not be obtained on the test airplane with any normal loadings. A rearward center-of-gravity position of 29.1-percent mean aerodynamic chord with gross weight ranging from 13,200 pounds to 12,400 pounds was obtained by using the same configuration as above and flying the airplane with the auxiliary tank filled. Raising the landing gear caused a 0.4-percent shift forward in the center-of-gravity position. Tests were run at low altitude in the conditions as shown in the following table:

Condition	Power	Flaps	Landing gear	Canopy
Approach	21 in. Hg at 2550 rpm	Down	Down	Open
Glide	Off	Up	Up	Closed
Landing	Off	Down	Down	Open
Power-on clean	42.5 in. Hg at 2550 rpm	Up	Up	Closed
Wave-off	42.5 in. Hg at 2550 rpm	Down	Down	Open
Dive	15 in. Hg at 2550 rpm	Up	Up	Closed

Tests were also run at high altitude in the power-on clean, glide, and dive conditions. The data were obtained by both the steady and continuous record methods. In the steady method, the pilot either dived

or climbed the airplane to some certain speed and when the airplane reached a steady condition, a record was taken of the required values. In the continuous method the airplane was flown through the speed range with gradually changing speed and the required values were recorded throughout the entire period. The continuous records are indicated by flagged symbols.

## I N S T R U M E N T A T I O N

Standard NACA photographic recording instruments were used to obtain the data. A description of this instrumentation is given in reference 1.

## C O N T R O L F R I C T I O N A N D T R A V E L

Plots of the friction and travel of the elevator, ailerons, and rudder are shown in figures 6 to 9. The amount of friction in all of the controls except the rudder was small and well within the requirements of reference 2.

## D I S C U S S I O N A N D R E S U L T S

### L O N G I T U D I N A L S T A B I L I T Y A N D C O N T R O L C H A R A C T E R I S T I C S

#### D y n a m i c L o n g i t u d i n a l S t a b i l i t y

The short-period dynamic oscillation of normal acceleration and elevator angle was investigated in the power-on clean, glide, and landing conditions by abruptly deflecting and releasing the elevator at various speeds throughout the speed range. There was no oscillation of the elevator, but the airplane diverged longitudinally, sometimes violently, at low speeds in the power-on clean condition. (See fig. 11.) This unstable condition is in all probability due to the static longitudinal instability of the airplane. Typical time histories of these attempted oscillations are shown in figures 10 and 11.

#### S t a t i c L o n g i t u d i n a l S t a b i l i t y

The static longitudinal stability was measured at two center-of-gravity positions of approximately 26 and 29 percent of the mean aerodynamic chord throughout the speed range for the configurations shown in the preceding table. The curves of elevator force and elevator angle plotted against speed are presented in figures 12 to 20 and show the static longitudinal stability characteristics. The elevator tab angle  $\delta_{etab}$  was also measured and is given for each test made.

The evaluation of the stick-free and stick-fixed neutral points is shown in figures 21 to 26. The variation of the elevator angle  $\delta_e$  and elevator force divided by dynamic pressure  $F_e/q$  with airplane normal-force coefficient  $C_N$  are plotted and the stick-fixed and stick-free neutral points are determined from the slopes of these curves. For a given normal-force coefficient the neutral points are at the center-of-gravity positions at which the slopes  $\frac{d\delta_e}{dC_N}$  and  $\frac{d(F_e/q)}{dC_N}$  are zero. The neutral points as determined by the above procedure for each flight condition are shown in figure 27.

The following discussion of the static longitudinal stability characteristics is based on the requirements of reference 2.

Power-on clean condition (figs. 12 and 13).— The curves of elevator angle and elevator force against speed show characteristics which do not meet the requirements of reference 2. The data show the airplane to be unstable stick free at both center-of-gravity positions and to have neutral to negative stability stick fixed. The same conditions existed at low and high altitude.

Diving condition (figs. 14 and 15).— The airplane failed to meet the requirements in this condition. The data show the airplane to be unstable stick free at speeds above approximately 260 miles per hour and neutral to unstable stick fixed above approximately 300 miles per hour. The same conditions existed at low and high altitude.

Glide condition (figs. 16 and 17).— The airplane was stable stick fixed and stick free at both center-of-gravity positions except at high speeds at the rearward center-of-gravity position where the airplane became slightly unstable stick free. At high altitude the airplane was neutrally stable stick free at the rearward center-of-gravity position. The airplane did not meet the requirements in this condition.

Approach condition (fig. 18).— The curve of elevator force against speed had a stable slope at the forward center-of-gravity position but became unstable above approximately 125 miles per hour at the rearward center-of-gravity position. The stick-fixed stability was neutral at the rearward center of gravity at speeds above approximately 130 miles per hour. The requirement of reference 2 was not satisfied. It should be noted that the flaps on the P-47D-30 are of the blow-up type; that is, the flap deflection varies with decreasing airspeed until a speed is reached where the flaps remain full down. The variation of the flap deflection with airspeed is shown in figure 18.

Landing condition (fig. 19).— The requirement was satisfied as the airplane was stable both stick fixed and stick free throughout the permissible speed range at both the center-of-gravity positions tested.

Wave-off condition (fig. 20).— The airplane was unstable stick fixed and stick free in this condition and the requirement of reference 2 was not satisfied.

Neutral points (figs. 21 to 27).— The data shown in figures 21 to 26 illustrate the method used in obtaining the neutral points shown in figure 27. Since only two center-of-gravity positions were tested, the actual numerical values of the neutral points may not be entirely accurate, but they do give a general picture of the stick-fixed and stick-free stability. In the power-on clean condition, the stability parameter  $\frac{d(F_e/q)}{dC_N}$  is always negative, indicating that the center-of-gravity position required to make the airplane stable is so far forward that it would be impossible to make the airplane stable with any normal loading of the airplane. These data also indicate that it would be useless to test the airplane at any more rearward center-of-gravity position since it is already known that the airplane will be unstable. The same condition existed in the wave-off condition. In the approach condition data were obtained both forward and rearward of the neutral points which gave a very good indication of the position of the neutral points. In the glide and landing conditions the airplane was stable throughout the speed range except at low lift coefficients in the glide condition where the stick-free neutral points were slightly forward of the rearmost center-of-gravity position tested. The determination of the neutral points would have been better defined had a more rearward center-of-gravity position been tested in these two conditions but the significance of these data did not warrant the tests.

It can be seen from the above discussion that the application of power had a definite destabilizing effect in both stick-fixed and stick-free conditions. Also the adverse effect of rearward center-of-gravity position is markedly shown. It should be noted that center-of-gravity positions rearward of the rearmost test center-of-gravity position may be obtained with normal loadings of the airplanes.

#### Longitudinal Control

Longitudinal control in accelerated flight.— The longitudinal stability characteristics in accelerated flight were investigated by making steady turns at constant speed and acceleration at both high and low altitude and at the two center-of-gravity positions. The changes in elevator control force and elevator angle with change in acceleration at the different speeds tested are shown in figures 28 to 32. In figures 33 to 36 the variations of elevator angle with normal-force coefficient in the aforementioned turns are plotted.

In order to evaluate the stick-fixed and stick-free maneuver points at the different speeds (figs. 37 to 40), curves of change in elevator stick force divided by change in acceleration  $\frac{\Delta F_e}{\Delta n}$  and variation of

elevator angle with normal-force coefficient,  $\frac{\Delta\delta_e}{\Delta C_N}$  were plotted as a function of the center-of-gravity position. The neutral points are the center-of-gravity positions at which the slopes  $\frac{dF_e}{dn}$  and  $\frac{d\delta_e}{dC_N}$  are zero.

At the forward center-of-gravity position of 26 percent and low altitude the elevator-control-force increment per unit acceleration in left turns was 7.5 pounds per g at 200 miles per hour and 11.0 pounds per g at 350 miles per hour. This value was approximately 1 or 2 pounds per g higher in right turns. The effect of altitude was to decrease the force per g at the lower speeds. However, at a Mach number of approximately 0.6 the force per g reached a value of 14.2 pounds per g in right turns, indicating that some form of breakdown of flow was taking place. (See fig. 40.) A plot of the force per g against Mach number is shown in figure 42 which indicates the effect of increasing speed and Mach number on the force per g characteristics. As the Mach number increases, the force per g increases until at a Mach number of 0.6 the curve reaches a peak and begins to fall off as shown in the high-altitude tests.

At the rearward center-of-gravity position tested, 29 percent of the mean aerodynamic chord, the stick-force gradient varied from 2 to 7 pounds per g (fig. 30). At 200 miles per hour, elevator-force reversal occurred in both left and right turns. At high altitude, push forces were required with increasing acceleration at 200 miles per hour in both left and right turns and in left turns at 250 miles per hour. At the higher speeds at high altitude, the curves of force against acceleration show that pull forces were required but that these forces were dangerously low.

In figure 41 the data at 200 miles per hour are plotted as a graph showing the center-of-gravity range and altitude at which desirable stick forces, according to the requirements of reference 2, can be obtained. The center-of-gravity range for desirable stick forces shown in figure 41 is only approximate because the stick-force variation with acceleration at 200 miles per hour was nonlinear. The tests at 200 miles per hour were used because this condition was the most critical one tested, indicating the smallest center-of-gravity range for desirable stick forces. All of the data mentioned above in regard to steady turns in accelerated flight are designated either left or right because of the difference in airplane characteristics in left and right turns.

From the above discussion, it can be seen that the airplane did not completely satisfy the requirements of reference 2. The values of force per g at the forward center-of-gravity position were as a whole within the required limits of 3 to 8 pounds per g. At the rearward center-of-gravity position, the force reversals experienced at low speeds, especially at high altitude, are unsatisfactory.

The most forward stick-fixed maneuver point was found to be 29.7 percent mean aerodynamic chord at 300 miles per hour at high altitude, and most forward stick-free maneuver point at 27.4 percent mean aerodynamic

chord at 200 miles per hour at high altitude. In all the data obtained, the airplane, in general, had higher stick force per g characteristics in right turns. Part of this difference was probably due to the gyroscopic moment of the propeller, but the results are not consistent and the gyroscopic moment does not account for the entire difference.

Longitudinal control in landing.— The elevator deflection used in landing is shown as a function of speed in figure 43. These data show the elevator deflection to be adequate at all the speeds tested and at both center-of-gravity positions. The elevator angles shown were not necessarily the minimum elevator angles required to land. The elevator force required during landing did not exceed the 35-pound limit of the requirements of reference 2. (See time histories of stall approaches in the approach and landing conditions in figs. 53 and 55.) The pilot disliked the characteristics of the airplane in landing with power off because of the very high rate of descent, approximately 50 feet per second. (This value was obtained from the pilot's readings of the instruments in the cockpit.) The application of a small amount of power corrected this undesirable characteristic but brought about another. As pointed out in the preceding discussion on static longitudinal stability, the airplane was unstable in the approach condition at the lower normal-force coefficients tested and the pilot disliked this instability in landing the airplane. After the airplane reached the ground, the pilot considered the airplane to be easy to handle.

Tests were made to determine the change in trim caused by the lowering of the landing flaps. The tests were made with the controls held fixed and repeated with the controls used to correct the ensuing motion. Typical time histories are shown in figures 44 and 45. The results showed that the two flaps did not lower at the same rate, the left leading the right, resulting in a slight rolling tendency which had to be corrected by use of small deflections of the ailerons and rudder.

Longitudinal control in take-off.— With the center-of-gravity in the most rearward position tested, it was possible to hold the tail of the airplane off the ground at any attitude up to thrust axis level by use of the elevator at approximately 80 miles per hour. (This speed was obtained from the pilot's readings of the instruments in the cockpit.) The pilot considered the airplane satisfactory under all conditions during take-off.

Longitudinal trimming control.— It was possible to trim the airplane to zero elevator force by use of the elevator trim tab in all conditions and at all the speeds between the stall and the maximum speed tested. This satisfies the requirement of reference 2. This fact was obtained from the pilot's observations.

Trim changes due to flaps and power.— The trim changes due to flaps and power are shown in tables II and III. The tests were made according to the specifications of the requirements in reference 2. The elevator force required to trim the airplane due to flaps or power change was



usually small, 0 to 5 pounds, and well below the limits set by the requirements. The change in rudder force required when the power was changed was large as was discussed in reference 1.

### Dive-Recovery-Flap Investigation

The dive-recovery flaps of the P-47D-30 were tested at both center-of-gravity positions at high and low altitude. The airplane was trimmed for zero control forces at the various speeds tested, and with the controls free the dive flaps were deflected. The variation of the change in normal acceleration with speed and Mach number is plotted in figure 46 to show the dive-flap effectiveness.

The data obtained are in fair accordance with those predicted from wind-tunnel tests in reference 3. Peaks in effectiveness were reached at approximately 3g at the forward center-of-gravity position at high altitude and at approximately 3.5g at high altitude at the rearward center-of-gravity position. However, at low altitude at both the rearward and forward center-of-gravity positions, a peak in effectiveness was not reached. Accelerations as high as 4.6g at a Mach number of 0.665 were obtained, but there was no evidence of a change in slope at this point.

The dive flaps were considered effective at all speeds and altitudes tested and the dive recovery was considered satisfactory.

### STALLING CHARACTERISTICS

The stalling characteristics of the airplane were investigated in all the various configurations by making stall approaches, starting a few miles an hour above the stall up to and into the stall region. These stalls were performed in two ways: first, by using all the controls to overcome the motions of the airplane brought about by the stall and, secondly, by holding all but the elevator control fixed and allowing the airplane to roll off. Time histories of typical stalls performed by both of these methods are shown in figures 47 to 59. The stalling characteristics may be summarized as follows:

(a) In the power-on clean condition (figs. 47, 48, and 51) stall warning was afforded by mild buffeting about 4 miles per hour above the stall. As the stall was reached, an initial tendency to roll to the right was experienced followed by a roll to the left. This rolling tendency could be controlled by normal use of the controls but with a little difficulty. During the actual stall a strong buffeting occurred. The stall warning and characteristics during the stall were considered satisfactory.

(b) In the glide condition (figs. 49 to 51) ample warning of the stall was provided in the form of buffeting about 5 miles per hour above

the stall. At the stall there was a mild roll to the left which could be easily controlled by normal use of the controls. The stalling characteristics in this condition were considered very satisfactory.

(c) In the approach condition (figs. 52 and 53) the stall was preceded by mild buffeting about 3 miles per hour above the stall. The aileron and rudder forces required to hold the airplane level were slightly high and irregular, and maximum rudder deflection was reached before the stall. Although there was a buffet warning, the stalling characteristics were considered unsatisfactory. In runs in which the airplane was pulled further into the stall than those shown in the time histories, there was a rapid roll which could not be controlled by either the ailerons or rudder, or both.

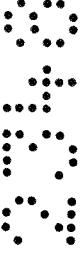
(d) In the landing condition (figs. 54 and 55) no buffeting preceded the stall, but the positive stability in this condition affords ample stall warning because of stick force and position. At the stall the airplane rolled generally to the left but occasionally to the right. The roll could be easily controlled by normal use of the controls. The stalling characteristics in this condition were considered satisfactory.

(e) In the wave-off condition (figs. 56 and 57) the airplane was not carried to the complete stall because of the instability in this condition. Rudder control was lost before the stall and almost complete aileron deflection had to be used. The nose-high attitude of the airplane was also uncomfortable to the pilot. Mild buffeting preceded the stall and there appeared to be a tendency to roll right. The stalling characteristics were considered unsatisfactory because the airplane was unstable in this condition.

(f) The stall in accelerated flight (power-on clean) (figs. 58 and 59) was preceded by buffeting. At the stall mild lateral instability existed which could be easily controlled with the ailerons. The stalling characteristics for this condition were considered very satisfactory.

## CONCLUSIONS

1. Abruptly deflecting and releasing the elevator produced no oscillation of the elevator, but the airplane itself diverged in the low-speed, power-on clean condition, sometimes violently.
2. The airplane did not satisfy the Army handling-qualities requirements for stick-free stability at either center-of-gravity position for any power-on condition with flaps and landing gear up or down. With the center of gravity at 26 percent mean aerodynamic chord the airplane had satisfactory stick-fixed stability except in the wave-off condition. At a center-of-gravity position of approximately 29 percent, however, the airplane was unstable stick fixed for any power-on condition with flaps and landing gear up or down.



3. At the forward center-of-gravity position of 26 percent mean aerodynamic chord, the increment of elevator control force per unit acceleration was within the required limits of reference 1 except at 350 miles per hour at low altitude. At the rearward center-of-gravity position of approximately 29 percent mean aerodynamic chord and at low altitude, the force per g was low and force reversal occurred at the low speeds. At high altitude force reversal occurred at speeds below 250 miles per hour and the force per g above these speeds was dangerously low. Over the speed range and altitudes tested the force per g was higher in right turns than in left turns. The most forward stick-free maneuver point was at 27.4 percent mean aerodynamic chord.

4. The elevator control for landing met the requirements of reference 1, but, because of the longitudinal instability in this condition, with the small amount of power applied the pilot disliked the landing approach. On the ground during take-off and landing the airplane had satisfactory handling qualities.

5. The power of the elevator trimming tab was sufficient to trim the control forces to zero throughout the speed range at both the center-of-gravity positions tested.

6. The elevator-trim-force changes due to power and flaps were small and very satisfactory.

7. The performance of the dive-recovery flaps was satisfactory throughout the speed range and altitudes tested.

8. The stalling characteristics of the P-47D-30 airplane were considered satisfactory except in the approach and wave-off conditions. In all cases there was sufficient stall warning several miles per hour above

the stall in the form of mild buffeting, increased stick forces, or by rearward movement of the stick.

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2. Anon.: Stability and Control Characteristics of Airplanes. AAF Specification No. R-1815-A, April 7, 1945.
3. Hamilton, William T., and Boddy, Lee E.: High-Speed Wind-Tunnel Tests of Dive-Recovery Flaps on a 0.3-Scale Model of the P-47D Airplane. NACA ACR No. 5D19, 1945.

TABLE I

## PERTINENT DIMENSIONS OF THE P-47D-30 AIRPLANE

Engine . . . . .	Pratt & Whitney R-2800-59
Propeller . . . . .	(four blades) Curtiss Dwg. No. SPA-5
Total wing area, sq ft . . . . .	300
Total aileron area, sq ft . . . . .	25.7
Aileron trim tab area (left aileron), sq ft . . . . .	0.89
Stabilizer area, sq ft . . . . .	33.0
Elevator area, sq ft . . . . .	22.0
Elevator trim tab area, sq ft . . . . .	0.94
Fin area, sq ft . . . . .	13.9
Rudder area, sq ft . . . . .	11.9
Rudder trim tab area, sq ft . . . . .	0.87



TABLE II

TRIM CHANGES P-47D-30

[Center of gravity, 0.291 M.A.C.; gear retracted]

V <sub>1</sub> (mph)	Power	Flaps	Gear	Control force (lb)			Change in Sideslip (deg)
				Elevator pull	Rudder	Aileron	
164	50 percent	Up	Up	0	0	0	0
164	50 percent	Up	Down	5.4	1 left	0	.1 left
164	50 percent	Down	Down	.8	9 left	.6 right	.5 right
166	Off	Down	Down	5.4	33 left	0	.2 right
139	50 percent	Down	Down	0	0	0	0
139	Off	Down	Down	3.9	62 left	.6 right	2.7 right
162	Off	Up	Up	0	0	0	0
163	Off	Up	Down	3.9	1 left	.6 left	0
165	Off	Down	Down	1.1	7 left	1.0 left	1.1 left
139	Off	Down	Down	0	0	0	0
138	Normal rated	Down	Down	-8.5	98 right	0	2.2 left
139	Normal rated	Down	Down	0	2 right	0	2.5 left
138	Normal rated	Down	Up	-3.8	14 right	.6 left	3.1 left
138	Normal rated	Up	Up	-3.8	3 right	.6 left	4.7 left
117	Normal rated	Up	Down	0	0	0	0
117	<b>Normal rated</b>	Up	Up	-3.8	19 right	0	.1 left

TABLE III

## TRIM CHANGES P-47D-30

[Center of gravity, 0.263 M.A.C.; gear retracted]

V <sub>1</sub> (mph)	Power	Flaps	Gear	Control force (lb)			Change in Sideslip (deg)
				Elevator pull	Rudder	Aileron	
164	50 percent	Up	Up	0	0	0	0
165	50 percent	Up	Down	4.6	14 left	.8 right	.5 right
165	50 percent	Down	Down	1.5	18 left	.8 right	.7 right
163	Off	Down	Down	4.6	44 left	.8 right	1.2 right
137	50 percent	Down	Down	0	0	0	0
138	Off	Down	Down	6.3	30 left	0	2.0 right
164	Off	Up	Up	0	0	0	0
165	Off	Up	Down	5.3	2 left	4.8 left	.1 left
164	Off	Down	Down	3.1	27 left	6.0 left	.2 right
138	Off	Down	Down	0	0	0	0
140	Normal rated	Down	Down	-18.5	96 right	0	2.9 left
139	Normal rated	Down	Down	0	0	0	0
138	Normal rated	Down	Up	-3.8	1 right	0	.2 right
137	Normal rated	Up	Up	-4.7	3 left	0	1.2 left
120	Normal rated	Up	Down	0	0	0	0
118	Normal rated	Up	Up	-4.7	5 right	0	.7 left



FIGURE LEGENDS

- Figure 1.- Three-view layout of the P-47D-30 airplane.
- Figure 2.- Three-quarter front view of P-47D-30 test airplane.
- Figure 3.- Side view of P-47D-30 test airplane.
- Figure 4.- Three-quarter rear view of P-47D-30 test airplane.
- Figure 5.- Photographs of ballast installed on P-47D-30 test airplane.  
(a) Front view of engine showing lead ballast ring mounted on gear box.  
(b) Details of lead ring mounted on reduction gear housing.
- Figure 6.- Variation of aileron and elevator deflection with stick position. P-47D-30 airplane.
- Figure 7.- Aileron and elevator stick force due to friction as measured on the ground with no load on the ailerons or elevator. P-47D-30 airplane.
- Figure 8.- Variation of rudder angle with rudder-pedal position as measured on the ground with no rudder load.
- Figure 9.- Rudder pedal forces due to friction in the rudder control system as measured on the ground with no rudder load. Free-air temperature 70° F.
- Figure 10.- Time histories of short-period oscillations induced by a rapid deflection and release of the elevator; power-on clean condition; c.g. at 29.0 percent M.A.C.; gr. wt. 12,260 pounds.
- Figure 11.- Time histories of short-period oscillations induced by a rapid deflection and release of the elevator; power-on clean condition; c.g. at 29.0 percent M.A.C.; gr. wt. 13,310 pounds.
- Figure 12.- Longitudinal stability characteristics of the P-47D-30 airplane in the power-on clean condition, approximately 5000 feet altitude.
- Figure 13.- Longitudinal stability characteristics of the P-47D-30 airplane in the power-on clean condition at approximately 25,000 feet altitude.
- Figure 14.- Longitudinal stability characteristics of the P-47D-30 airplane in the dive condition at approximately 5000 feet altitude.
- Figure 15.- Longitudinal stability characteristics of the P-47D-30 airplane in the dive condition at approximately 25,000 feet altitude.
- Figure 16.- Longitudinal stability characteristics of the P-47D-30 airplane in the glide condition at approximately 7000 feet altitude.

## FIGURE LEGENDS - Continued

Figure 17.- Longitudinal stability characteristics of the P-47D-30 airplane in the glide condition at approximately 22,000 feet altitude.

Figure 18.- Longitudinal stability characteristics of the P-47D-30 airplane in the approach condition at approximately 5000 feet.

Figure 19.- Longitudinal stability characteristics of the P-47D-30 airplane in the landing condition at approximately 5000 feet altitude.

Figure 20.- Longitudinal stability characteristics of the P-47D-30 airplane in the wave-off condition at approximately 5000 feet altitude.

Figure 21.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the power-on clean and glide condition at two center-of-gravity positions and low altitude, P-47D-30 airplane.

Figure 22.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the power-on clean and glide condition at two center-of-gravity positions and high altitude, P-47D-30 airplane.

Figure 23.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the approach and wave-off condition at two center-of-gravity positions, P-47D-30 airplane.

Figure 24.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the landing condition at two center-of-gravity positions, P-47D-30 airplane.

Figure 25.- Determination of neutral points for the various conditions at low altitude, P-47D-30 airplane.

Figure 26.- Determination of neutral points for the power-on clean and glide condition at high altitude, P-47D-30 airplane.

Figure 27.- Variation of neutral points with airplane normal-force coefficient and approximate indicated airspeed for all conditions at low altitude and for the power-on clean and glide conditions at high altitude, P-47D-30 airplane.

- (a) Stick-free neutral points.
- (b) Stick-fixed neutral points.

Figure 28.- Turning characteristics of the P-47D-30 airplane in the power-on clean condition at low altitude. Forward center-of-gravity position.

## FIGURE LEGENDS - Continued

- Figure 29.- Turning characteristics of the P-47D-30 airplane in the power-on clean condition at high altitude. Forward center-of-gravity position.
- Figure 30.- Turning characteristics of the P-47D-30 airplane in the power-on clean condition at low altitude. Rearward center-of-gravity position.
- Figure 31.- Turning characteristics fo the P-47D-30 airplane in the power-on clean condition at high altitude. Rearward center-of-gravity position.
- Figure 32.- Turning characteristics of the P-47D-30 airplane in the landing condition: landing flaps and gear down, canopy closed, power for level flight at 170 miles per hour.
- Figure 33.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at low altitude and at the forward center-of-gravity position, P-47D-30 airplane.
- Figure 34.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at high altitude and at the forward center-of-gravity position, P-47D-30 airplane.
- Figure 35.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at low altitude and at the rearward center-of-gravity position, P-47D-30 airplane.
- Figure 36.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at high altitude and at the rearward center-of-gravity position, P-47D-30 airplane.
- Figure 37.- Determination of the stick-fixed maneuver points at low altitude, P-47D-30 airplane.
- Figure 38.- Determination of the stick-fixed maneuver points at high altitude, P-47D-30 airplane.
- Figure 39.- Determination of the stick-free maneuver points at low altitude, P-47D-30 airplane.
- Figure 40.- Determination of the stick-free maneuver points at high altitude, P-47D-30 airplane.
- Figure 41.- Variation with altitude of the center-of-gravity range for desirable stick force per g in left and right turns at 200 miles per hour. P-47D-30 airplane.

## FIGURE LEGENDS - Continued

- Figure 42.- Variation of force per g with Mach number at low and high altitude at the forward center-of-gravity position. P-47D-30 airplane.
- Figure 43.- Variation of elevator angle required to land with airspeed, P-47D-30 airplane.
- Figure 44.- Time history showing results of deflecting landing flaps and holding controls fixed; c.g. at 29.1 percent M.A.C.; gr. wt. 13,280 pounds; 5000 feet altitude.
- Figure 45.- Time history showing result of deflecting landing flaps and holding wings level by use of controls; c.g. at 29.1 percent M.A.C.; gr. wt. 13,280 pounds; 5000 feet altitude.
- Figure 46.- Variation of the change in normal acceleration with Mach number and airspeed as the dive-recovery flaps were deflected. P-47D-30 airplane. (Two sets of points for same condition indicate data from two flights.)
- Figure 47.- Time history of a stall approach in the power-on clean condition using elevator alone. Pilot attempted to hold other controls fixed; c.g. at 26.4 percent M.A.C.; gr. wt. 12,660 pounds; 5000 feet altitude.
- Figure 48.- Time history of a stall approach in the power-on clean condition. All controls used to hold wings level after initial stall; c.g. at 26.4 percent M.A.C.; gr. wt. 12,570 pounds, 5000 feet altitude.
- Figure 49.- Time history of a stall approach in the glide condition using elevator alone. Pilot attempted to hold other controls fixed; c.g. at 26.3 percent M.A.C.; gr. wt. 12,400 pounds, 5000 feet altitude.
- Figure 50.- Time history of a stall approach in the glide condition. All controls used to hold wings level after initial stall; c.g. at 26.3 percent M.A.C.; gr. wt. 12,400 pounds; 5000 feet altitude.
- Figure 51.- Time histories of stall approaches, using all controls to hold wings level after initial stall.
- (a) Glide condition at 24,000 feet average altitude. Center of gravity 0.264 M.A.C. at 12,770 pounds gross weight.
  - (b) Power-on clean condition at 26,500 feet average altitude. Center of gravity 0.264 M.A.C. at 12,570 pounds gross weight.
- Figure 52.- Time history of a stall approach in the approach condition using elevator alone. Pilot attempted to hold other controls fixed after initial stall; c.g. at 28.9 percent M.A.C.; gr. wt. 12,860 pounds; 5000 feet altitude.

## FIGURE LEGENDS - Concluded

- Figure 53.- Time history of a stall approach in the approach condition. All controls used to hold wings level after initial stall; c.g. at 28.9 percent M.A.C.; gr. wt. 12,860 pounds; 5000 feet altitude.
- Figure 54.- Time history of a stall approach in the landing condition using elevator alone. Pilot attempted to hold other controls fixed after initial stall; c.g. at 29.0 percent M.A.C.; gr. wt. 13,170 pounds, 5000 feet altitude.
- Figure 55.- Time history of a stall approach in the landing condition. All controls used to hold wings level after initial stall; c.g. at 29.0 percent M.A.C.; gr. wt. 13,170 pounds; 5000 feet altitude.
- Figure 56.- Time history of a stall approach in the wave-off condition using elevator alone. Pilot attempted to hold other controls fixed. Complete stall was not reached because of insufficient rudder control; c.g. at 28.8 percent M.A.C.; gr. wt. 13,210 pounds, 5000 feet altitude.
- Figure 57.- Time history of a stall approach in the wave-off condition. All controls used to hold wings level after initial stall. Complete stall was not reached because of insufficient rudder control, c.g. at 28.8 percent M.A.C.; gr. wt. 13,219 pounds, 5000 feet altitude.
- Figure 58.- Time history of a stall approach in a low-speed left turn using elevator alone. Pilot attempts to hold other controls fixed; c.g. at 26.3 percent M.A.C.; gr. wt. 12,690 pounds; 5000 feet altitude.
- Figure 59.- Time history of a stall approach in a wind-up left turn in the landing condition using elevator alone to produce stall. Pilot attempted to hold other controls fixed; c.g. at 26.4 percent M.A.C.; gr. wt. 12,680 pounds, 5000 feet altitude.

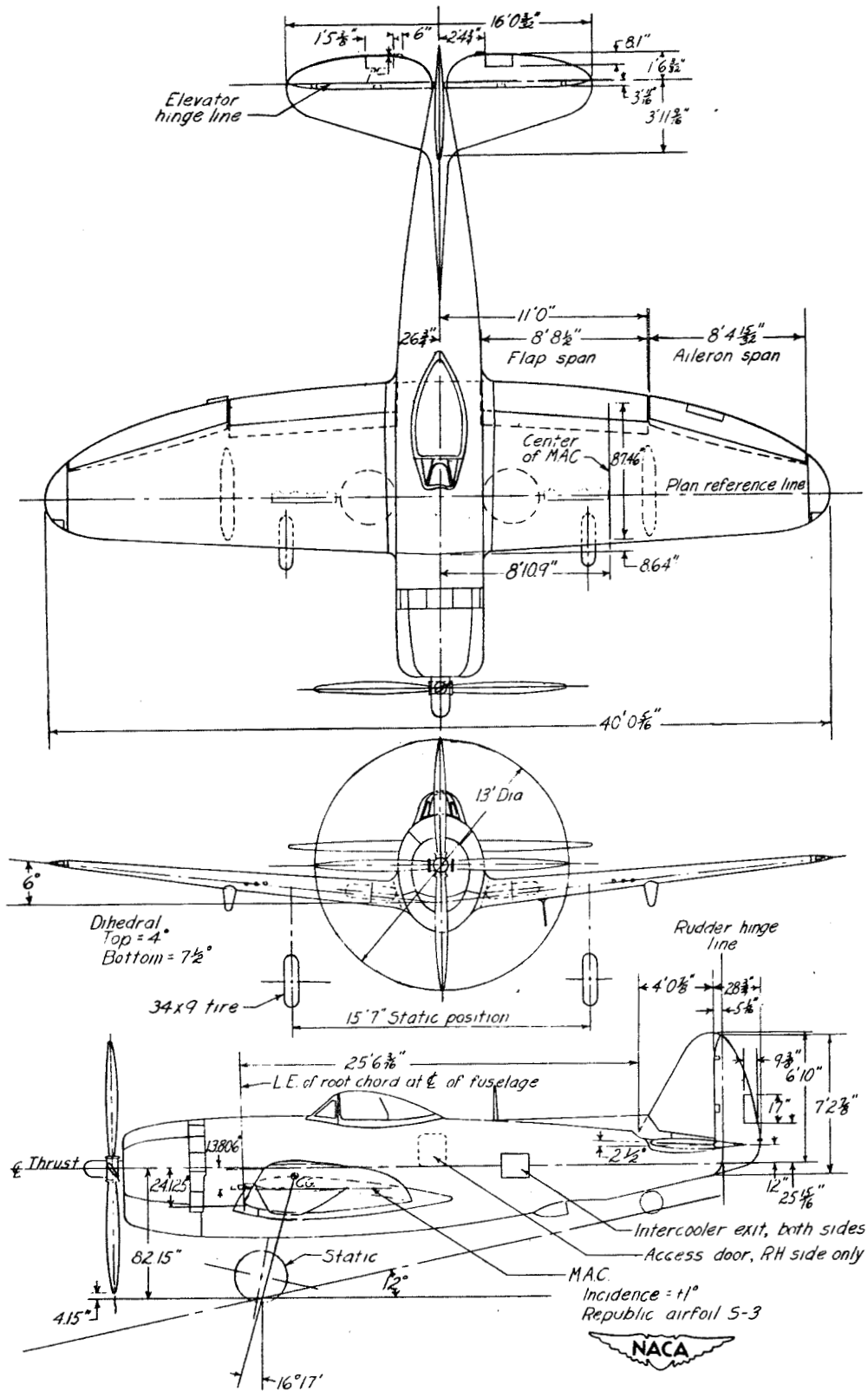


Figure 1.- Three-view layout of the P-47D-30 airplane.

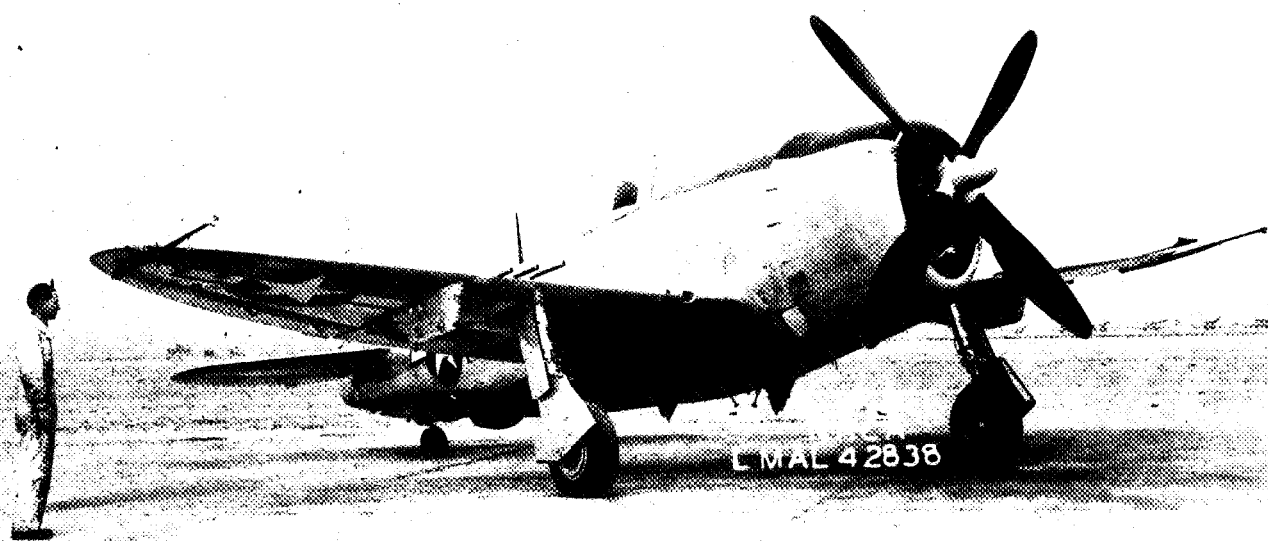


Figure 2.- Three-quarter front view of P-47D-30 test airplane.



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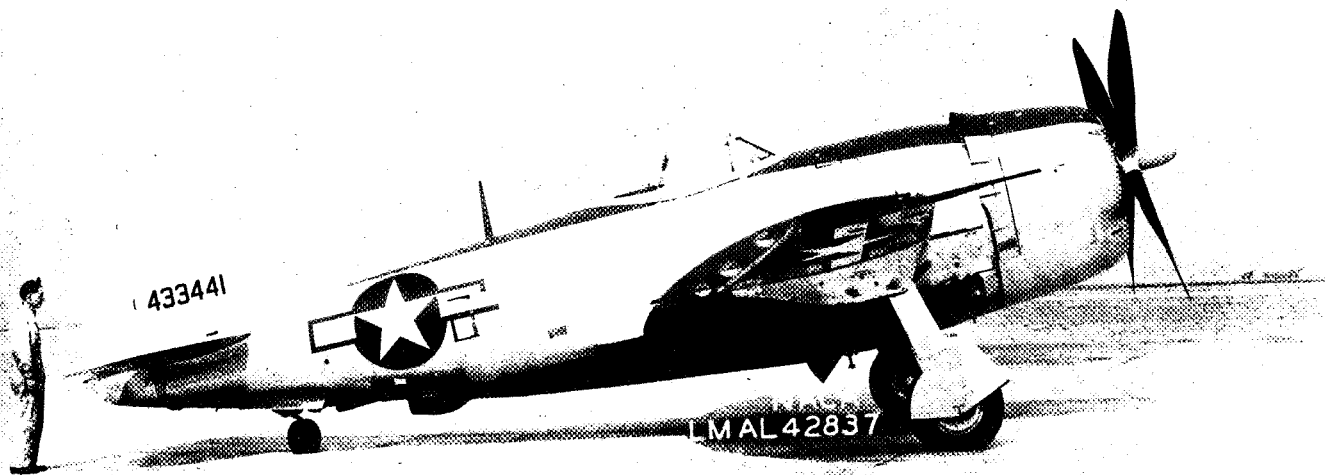


Figure 3.- Side view of P-47D-30 test airplane.





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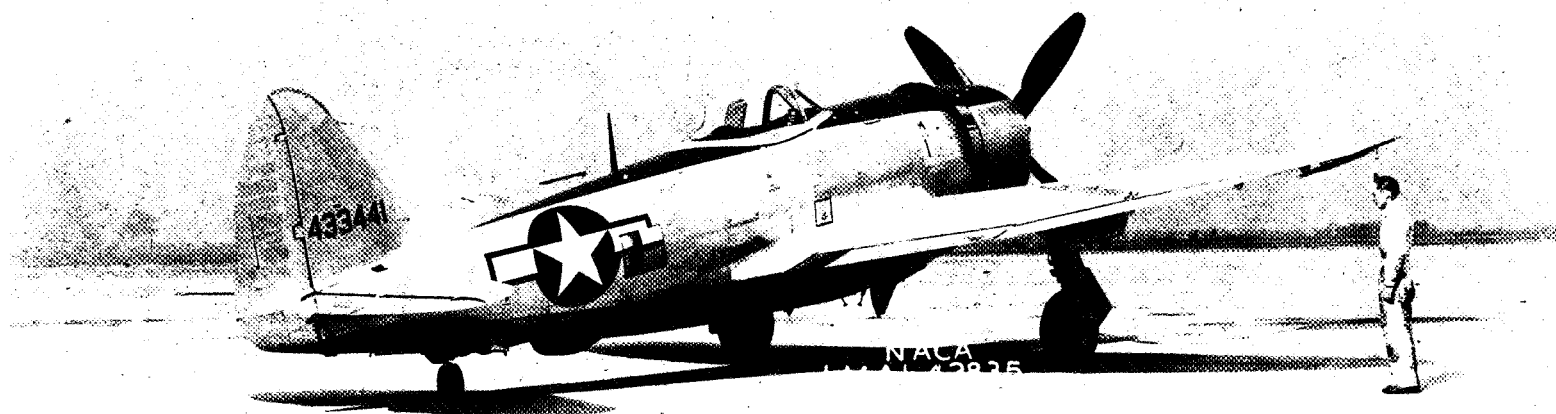
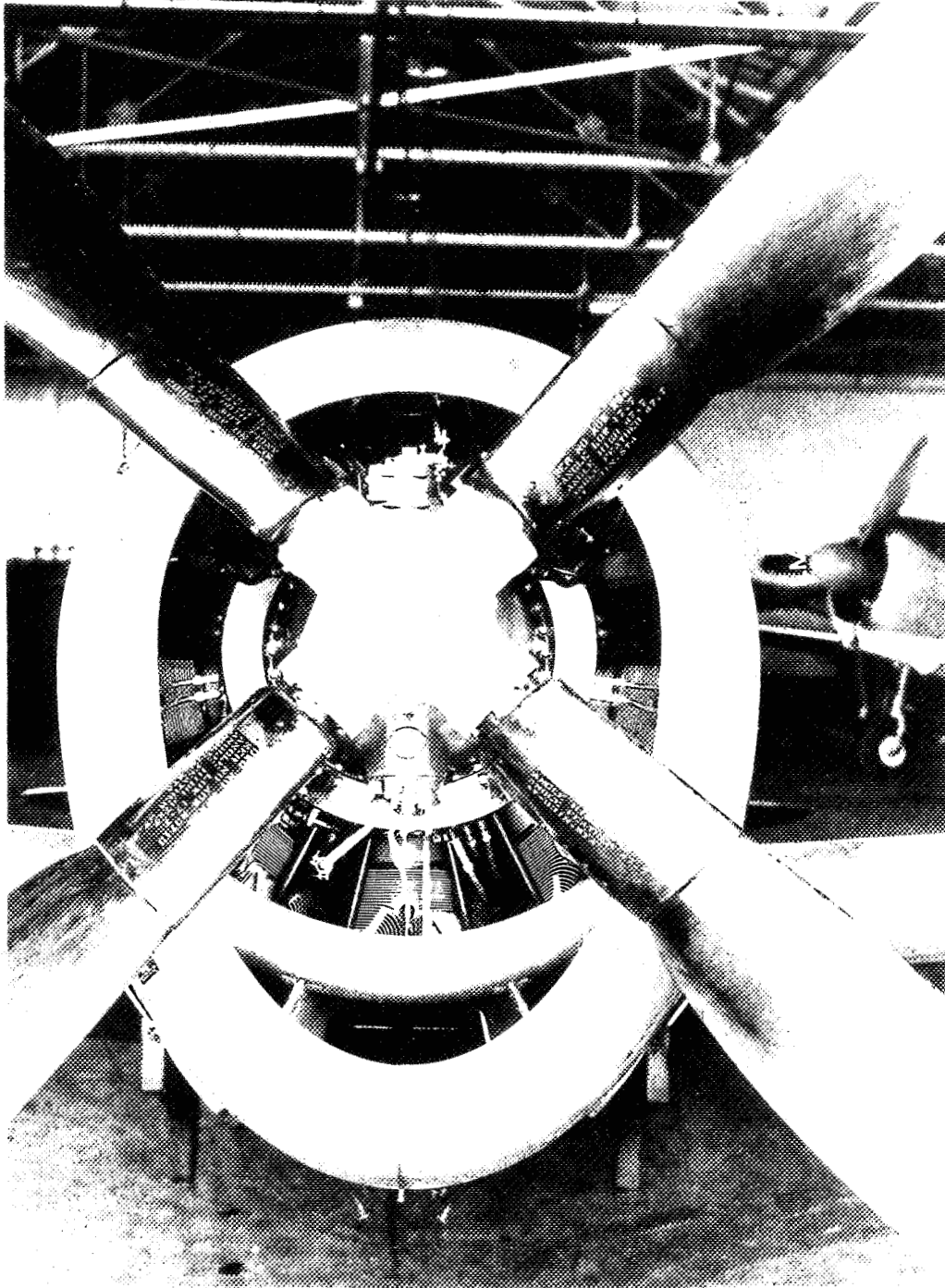


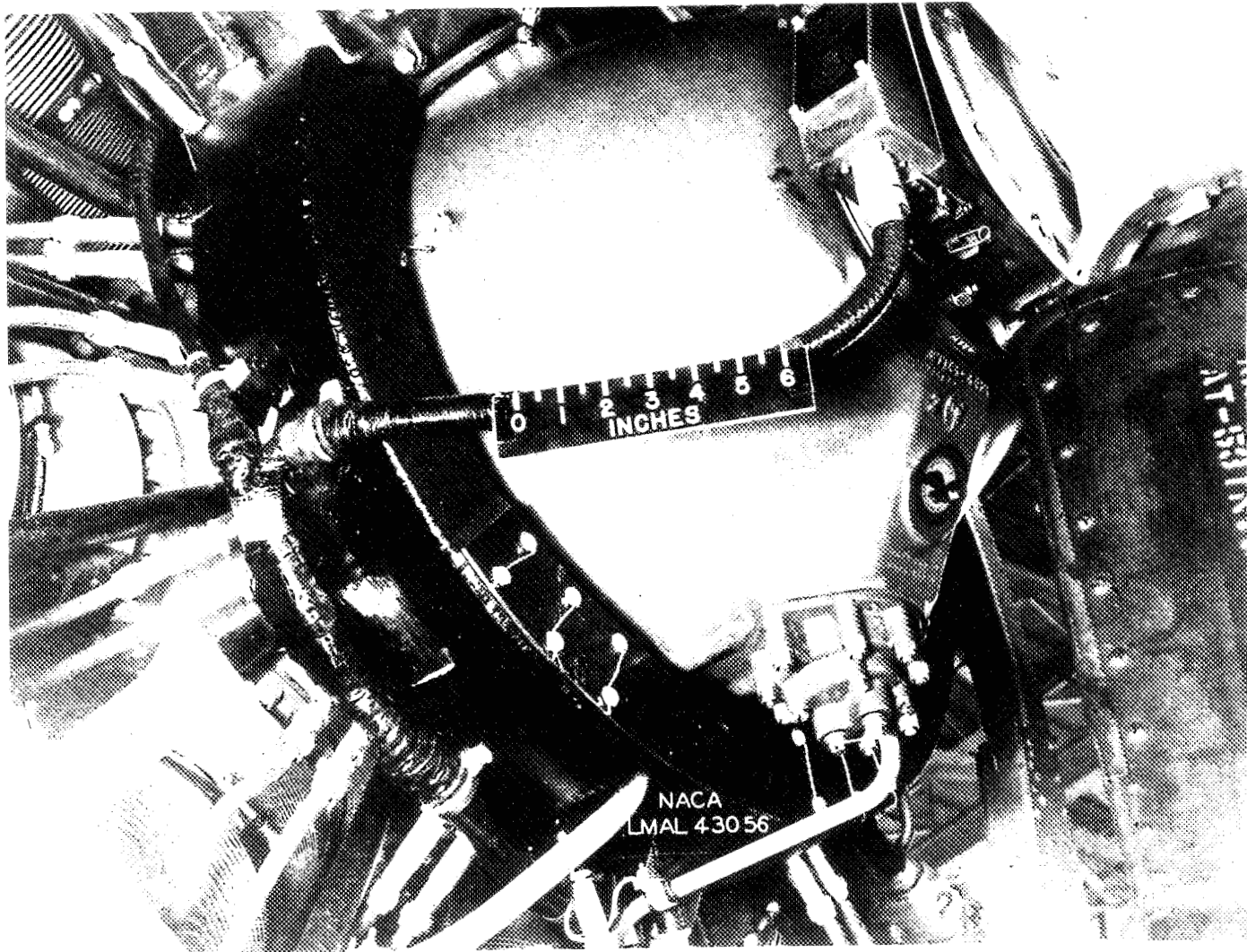
Figure 4.- Three-quarter rear view of P-47D-30 test airplane.





(a) Front view of engine showing lead ballast ring mounted on gear box.

Figure 5.- Photographs of ballast installed on P-47D-30 test airplane.



(b) Details of lead ring mounted on reduction gear housing.

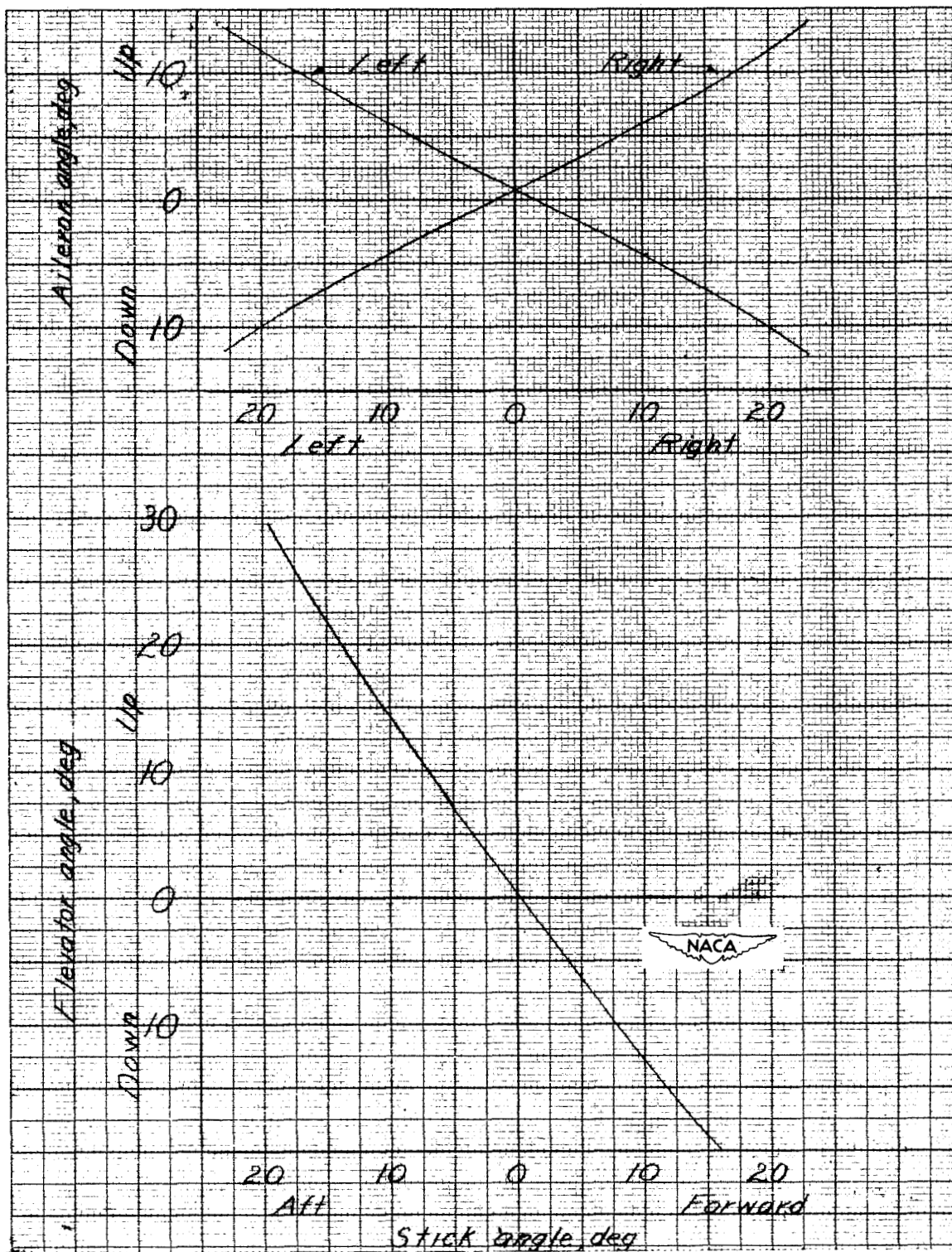


Figure 6.- Variation of aileron and elevator deflection with stick position. P-47D-30 airplane.

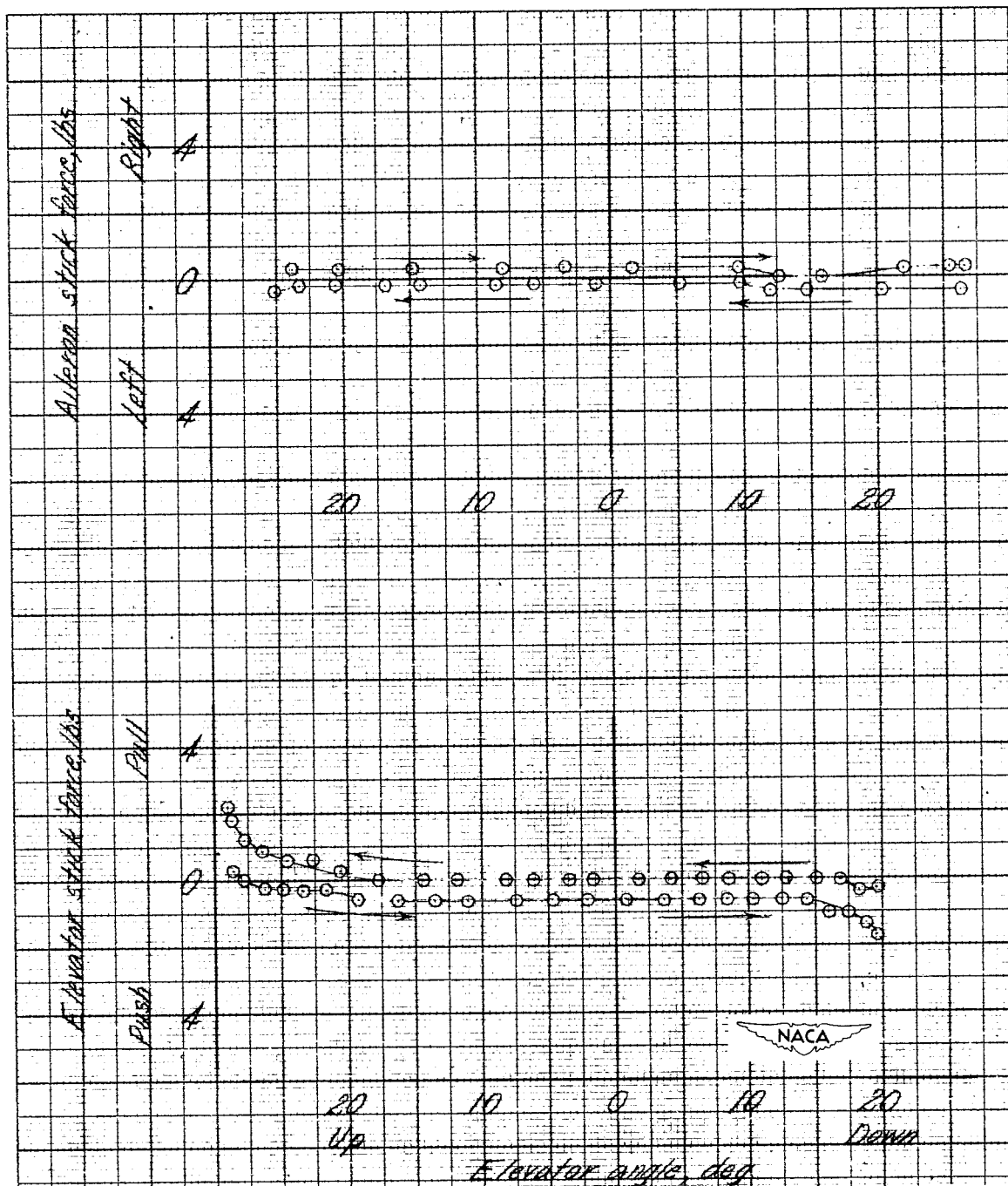


Figure 7.- Aileron and elevator stick force due to friction as measured on the ground with no load on the ailerons or elevator. P-47D-30 airplane.

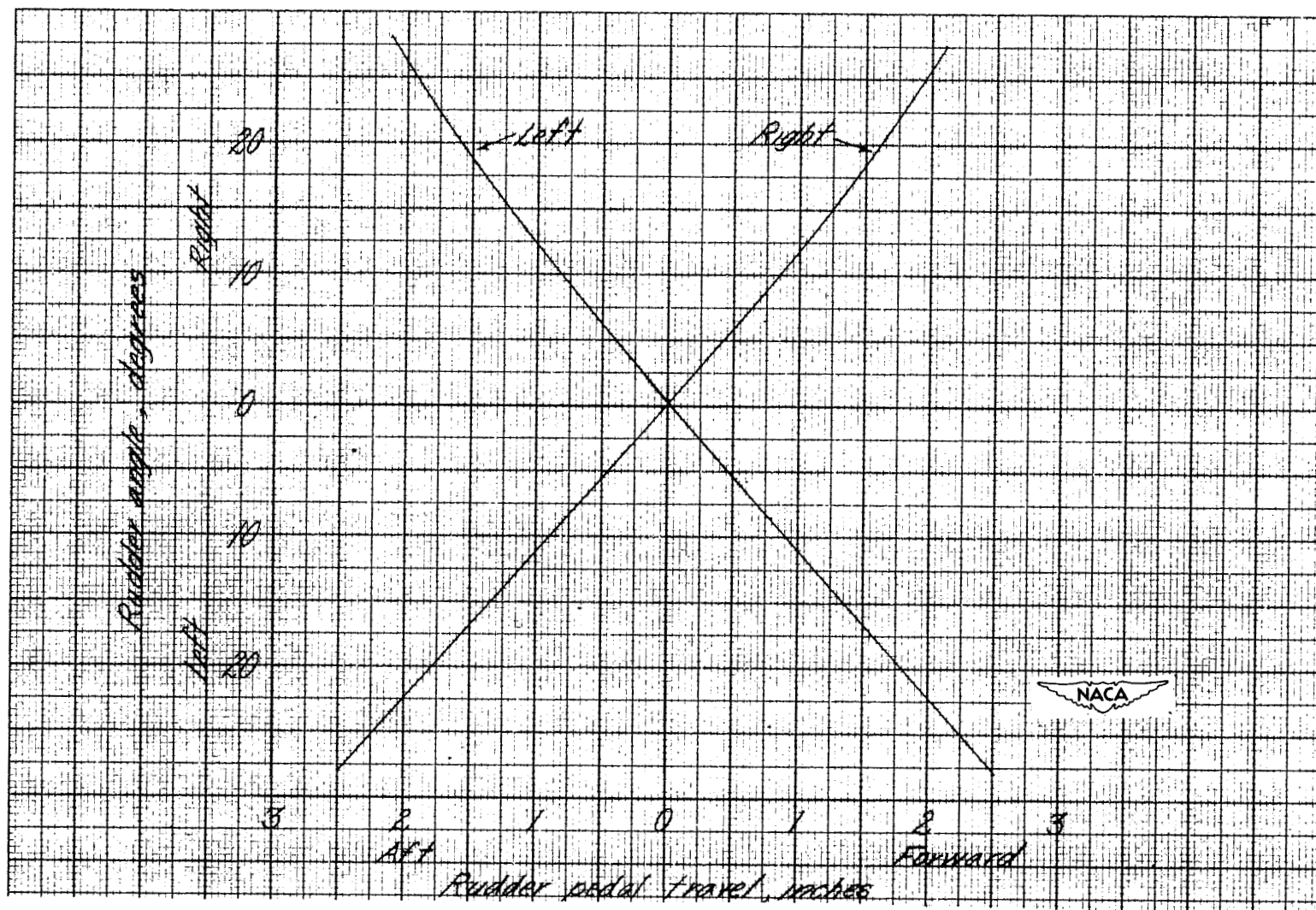
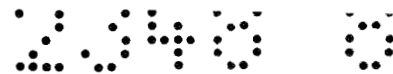


Figure 8.- Variation of rudder angle with rudder-pedal position as measured on the ground with no rudder load.

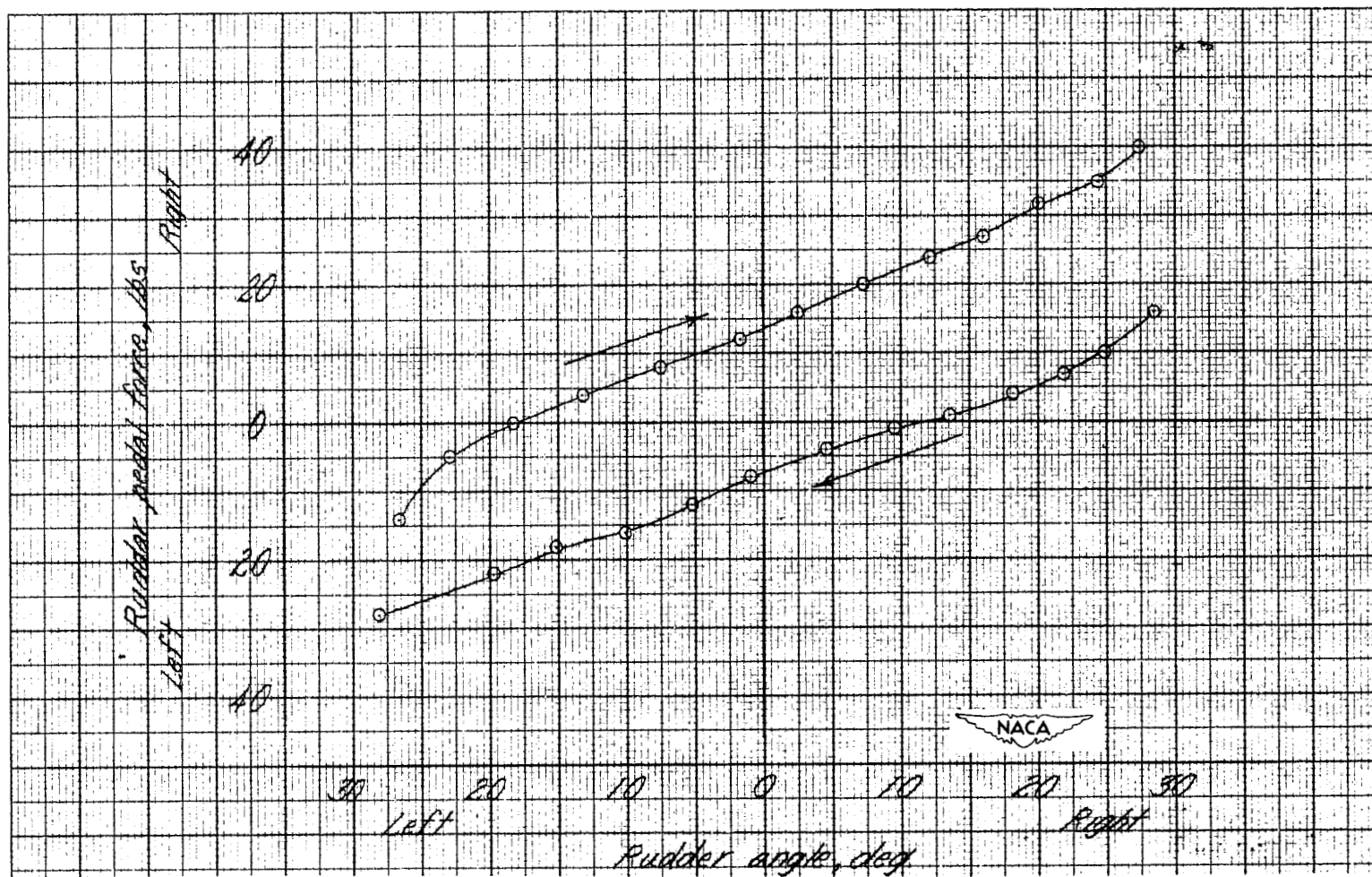
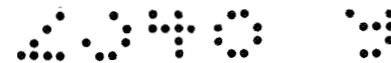


Figure 9.- Rudder pedal forces due to friction in the rudder control system as measured on the ground with no rudder load. Free-air temperature 70° F.

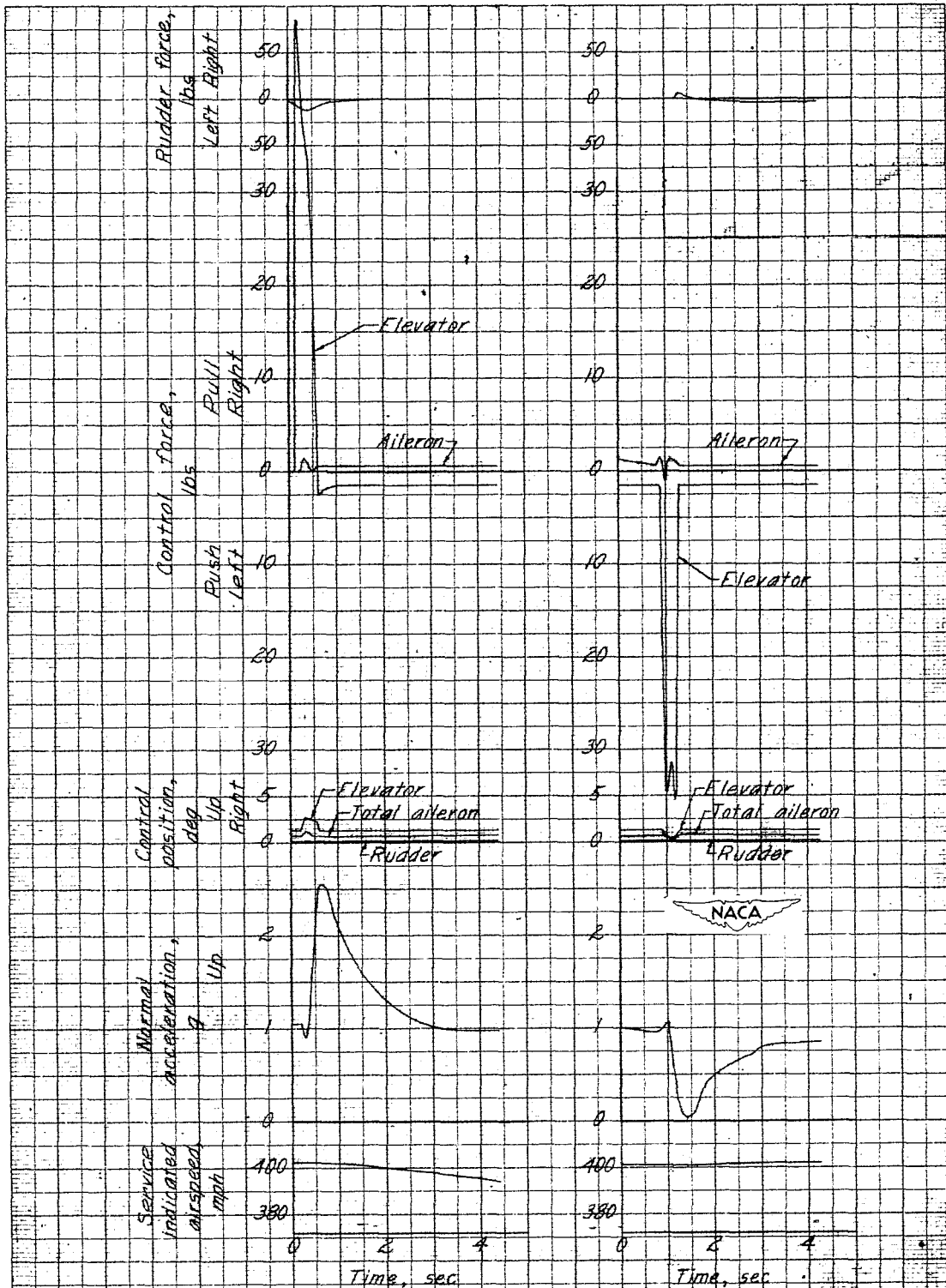


Figure 10.- Time histories of short-period oscillations induced by a rapid deflection and release of the elevator; power-on clean condition; c.g. at 29.0 percent M.A.C.; gr. wt. 12,260 pounds.



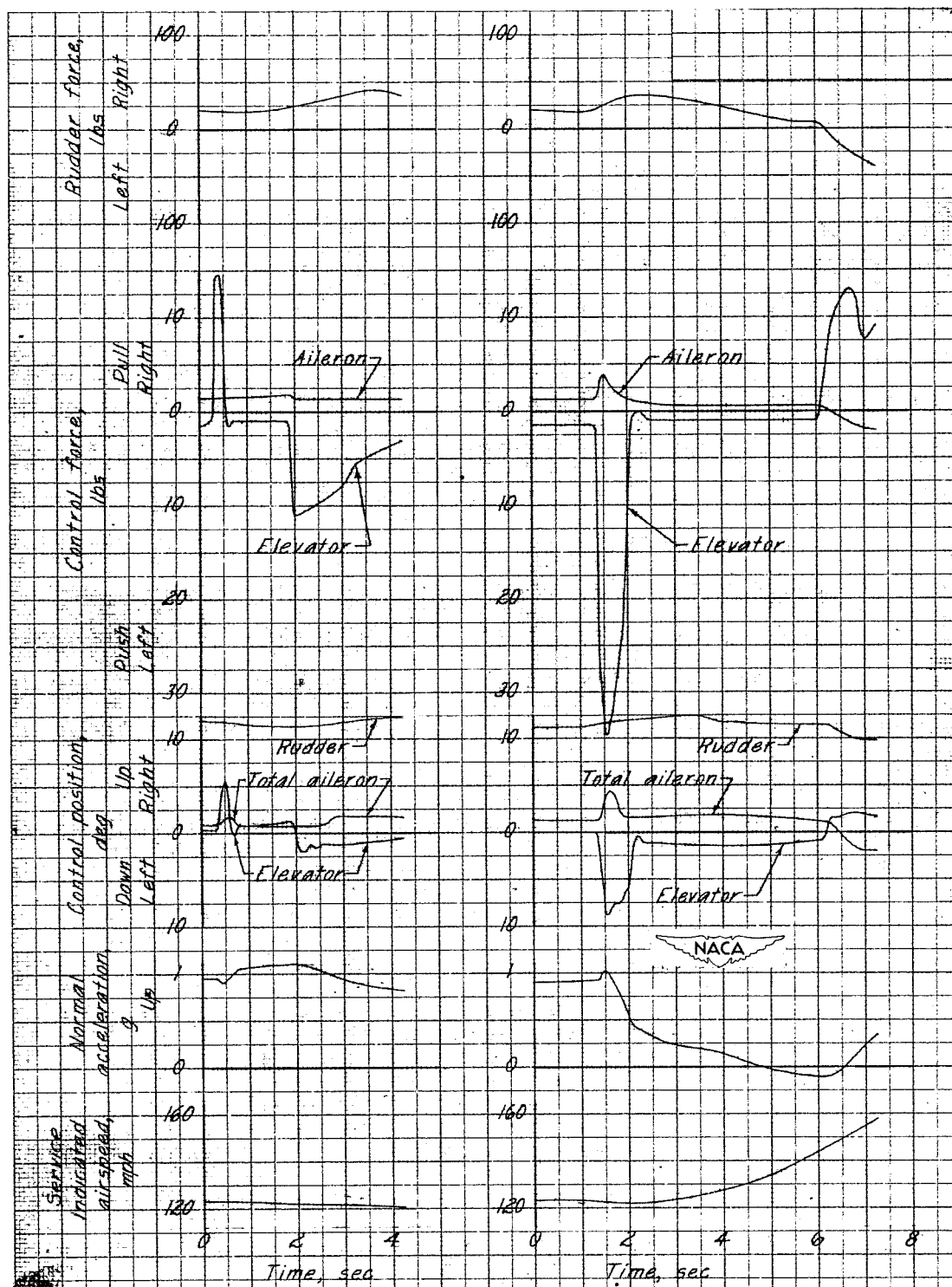


Figure 11.- Time histories of short-period oscillations induced by a rapid deflection and release of the elevator; power-on clean condition; c.g. at 29.0 percent M.A.C.; gr. wt. 13,310 pounds.

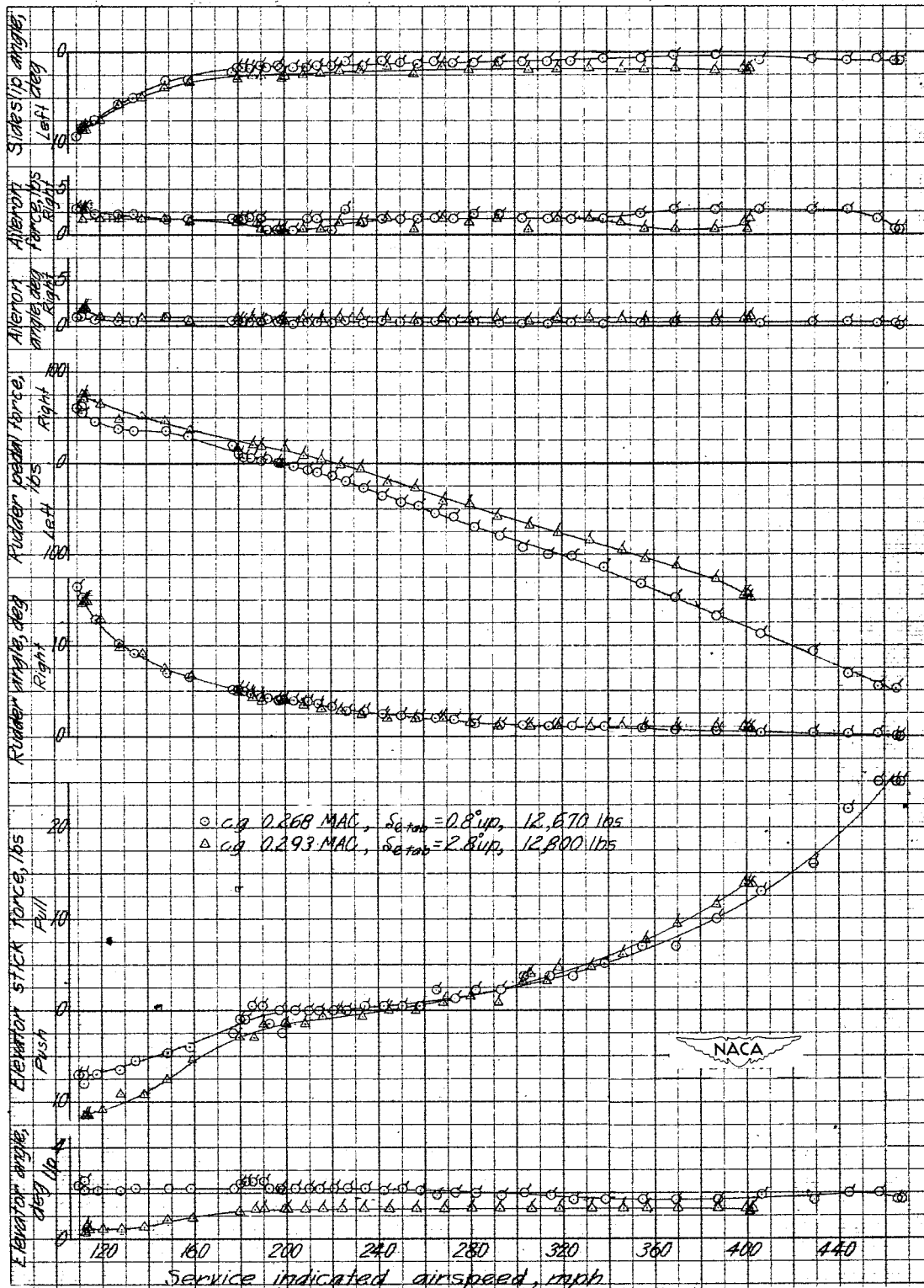


Figure 12.- Longitudinal stability characteristics of the P-47D-30 airplane in the power-on clean condition, approximately 5000 feet altitude.

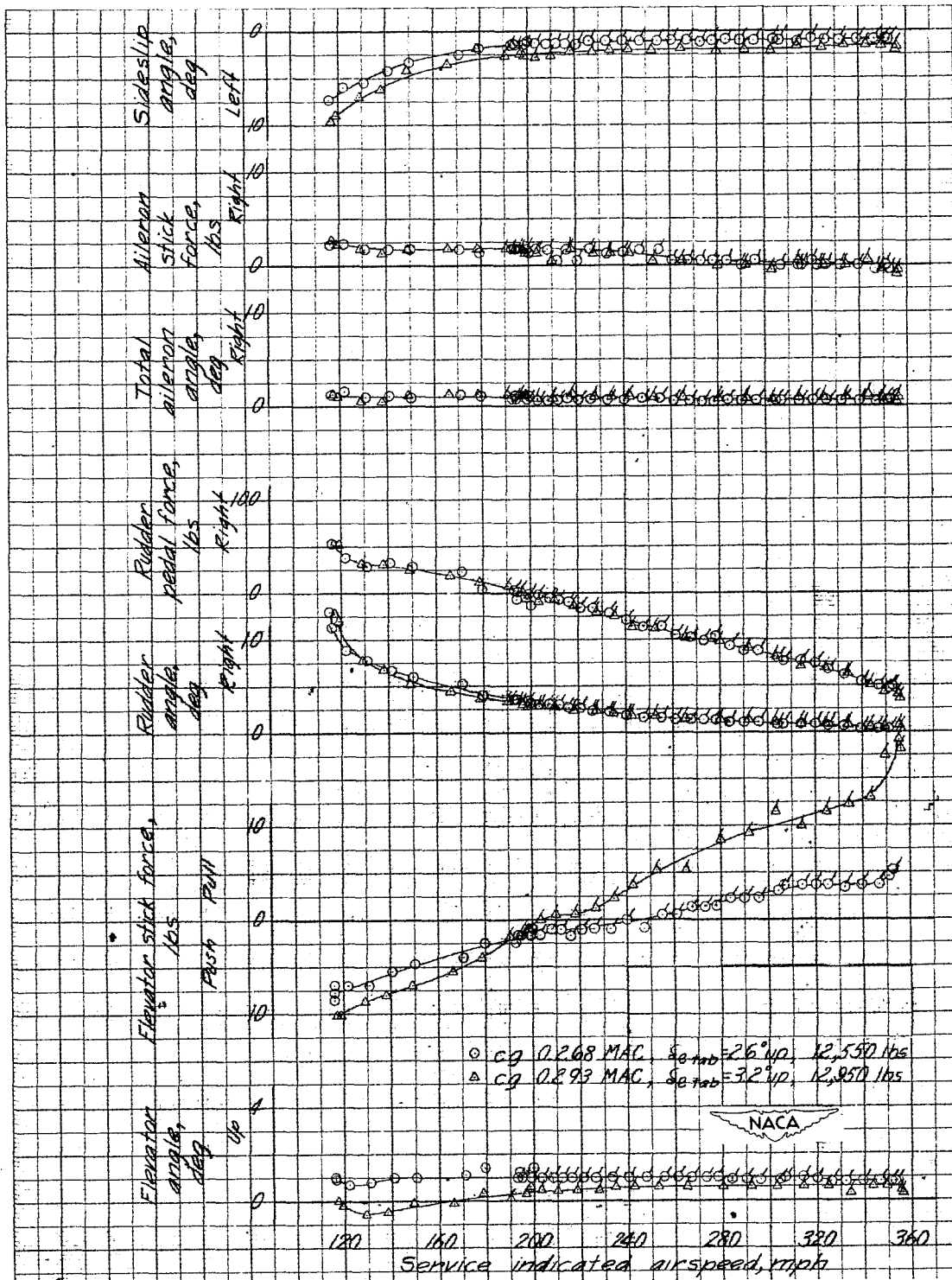


Figure 13.- Longitudinal stability characteristics of the P-47D-30 airplane in the power-on clean condition at approximately 25,000 feet altitude.

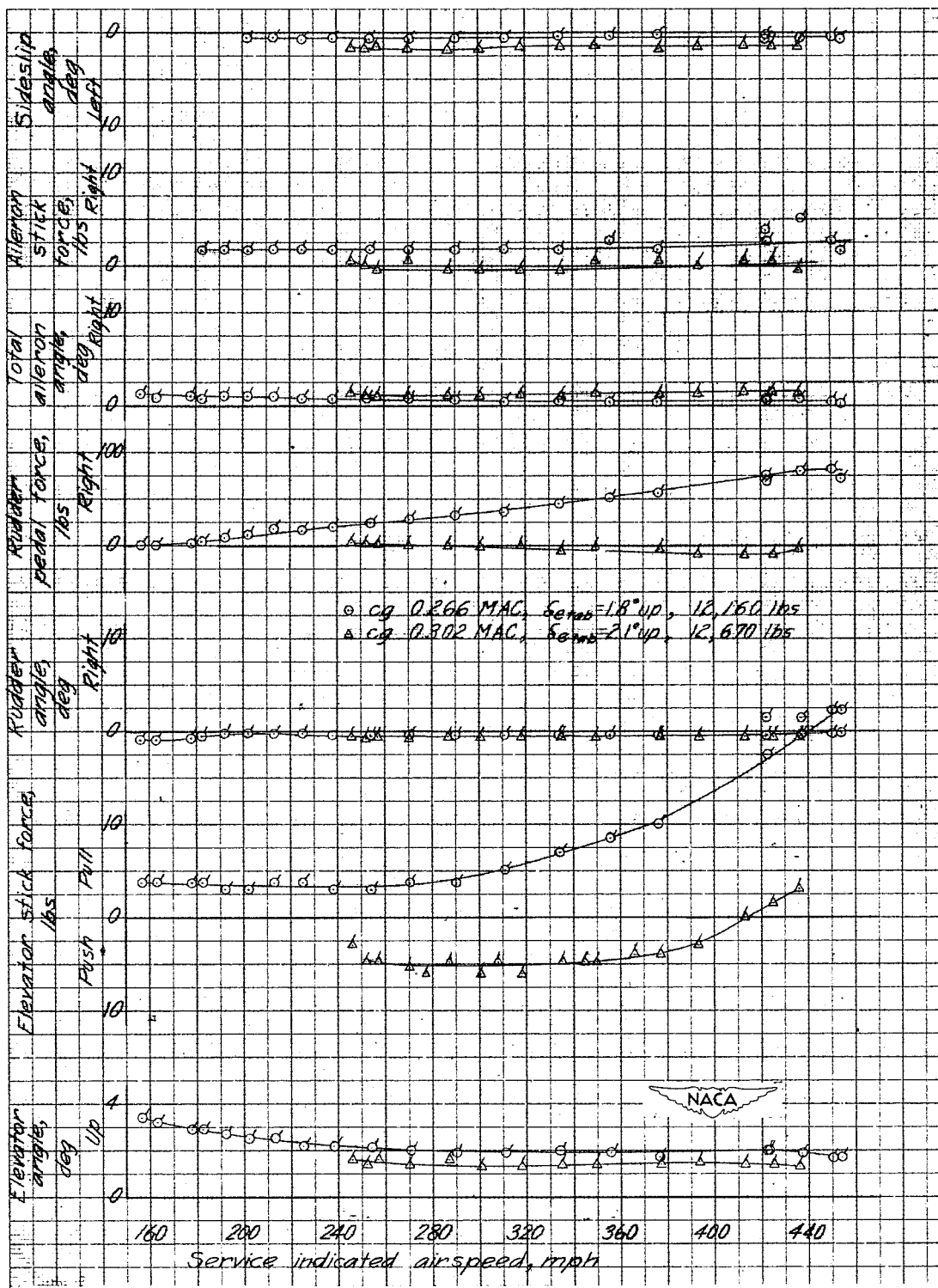


Figure 14.- Longitudinal stability characteristics of the P-47D-30 airplane in the dive condition at approximately 5000 feet altitude.

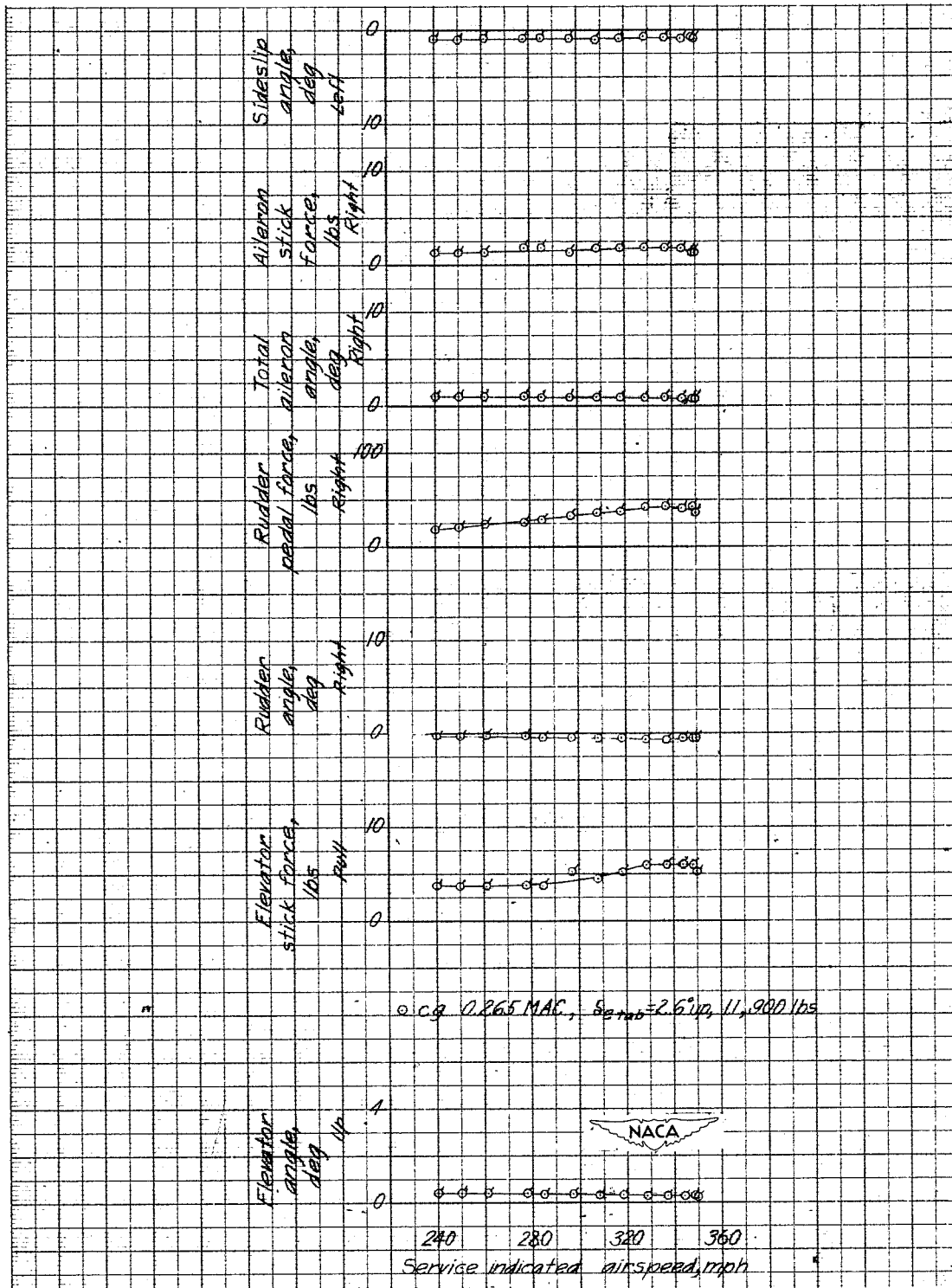


Figure 15.- Longitudinal stability characteristics of the P-47D-30 airplane in the dive condition at approximately 25,000 feet altitude.

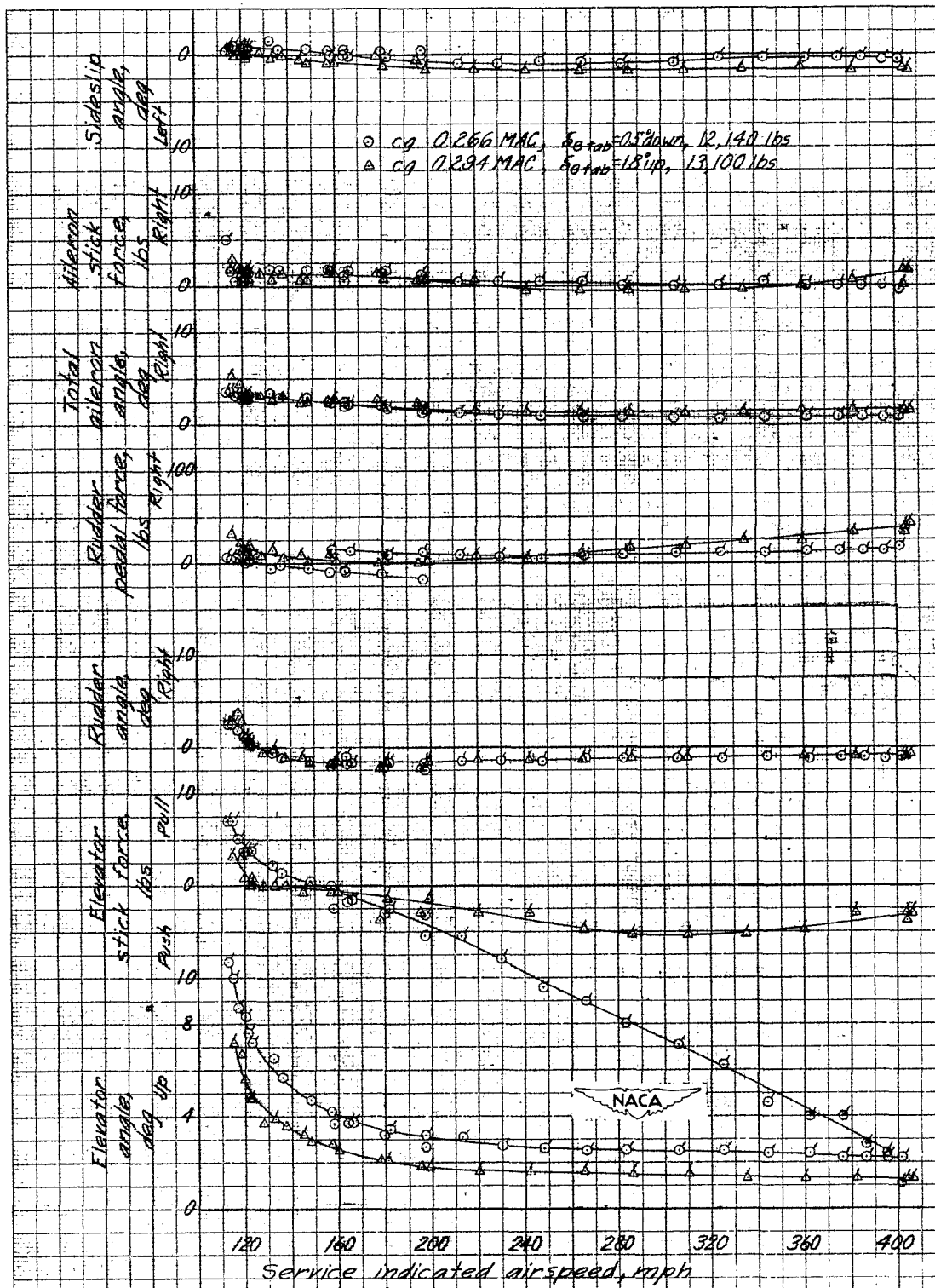


Figure 16.- Longitudinal stability characteristics of the P-47D-30 airplane in the glide condition at approximately 7000 feet altitude.

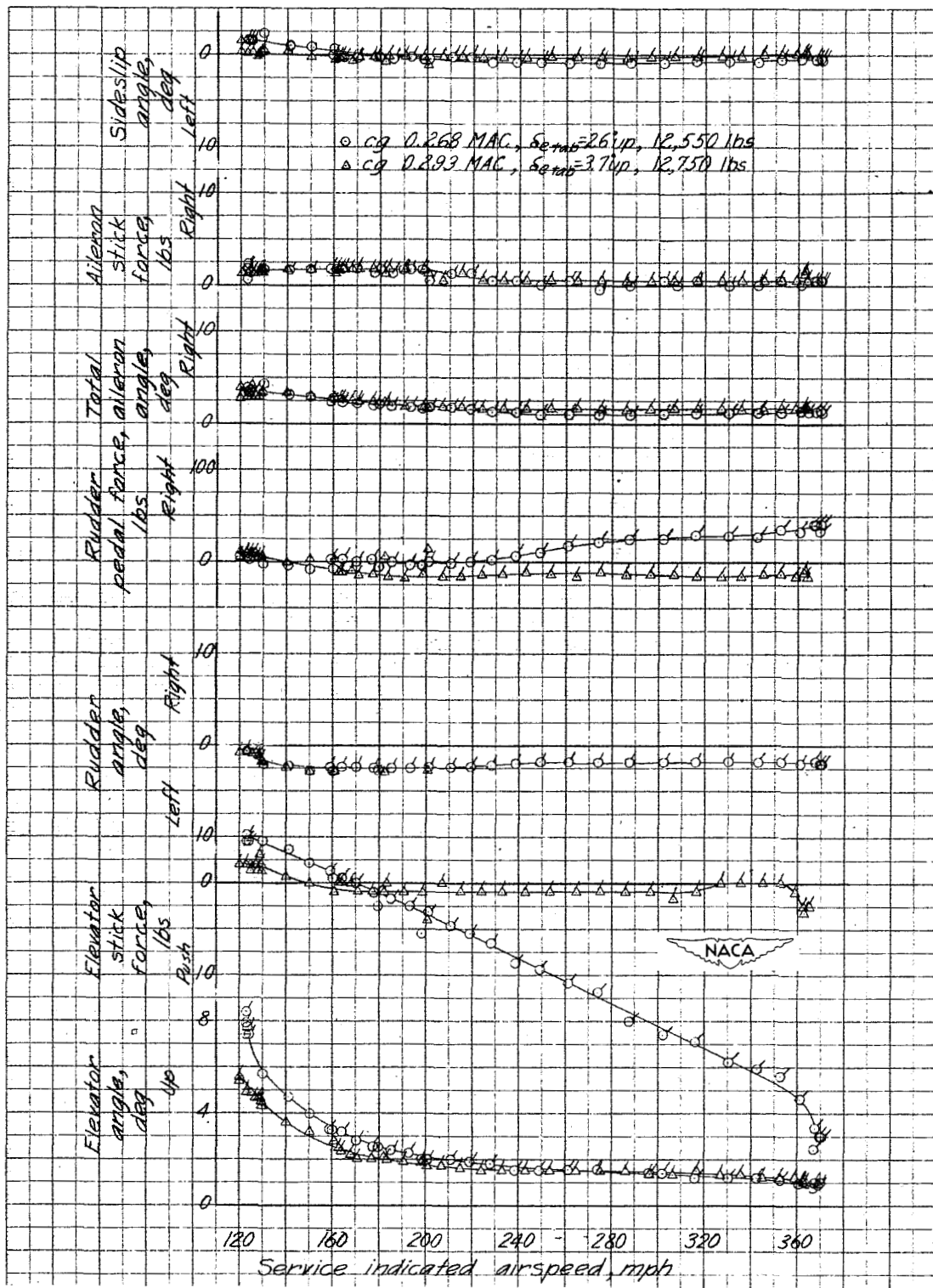


Figure 17.- Longitudinal stability characteristics of the P-47D-30 airplane in the glide condition at approximately 22,000 feet altitude.





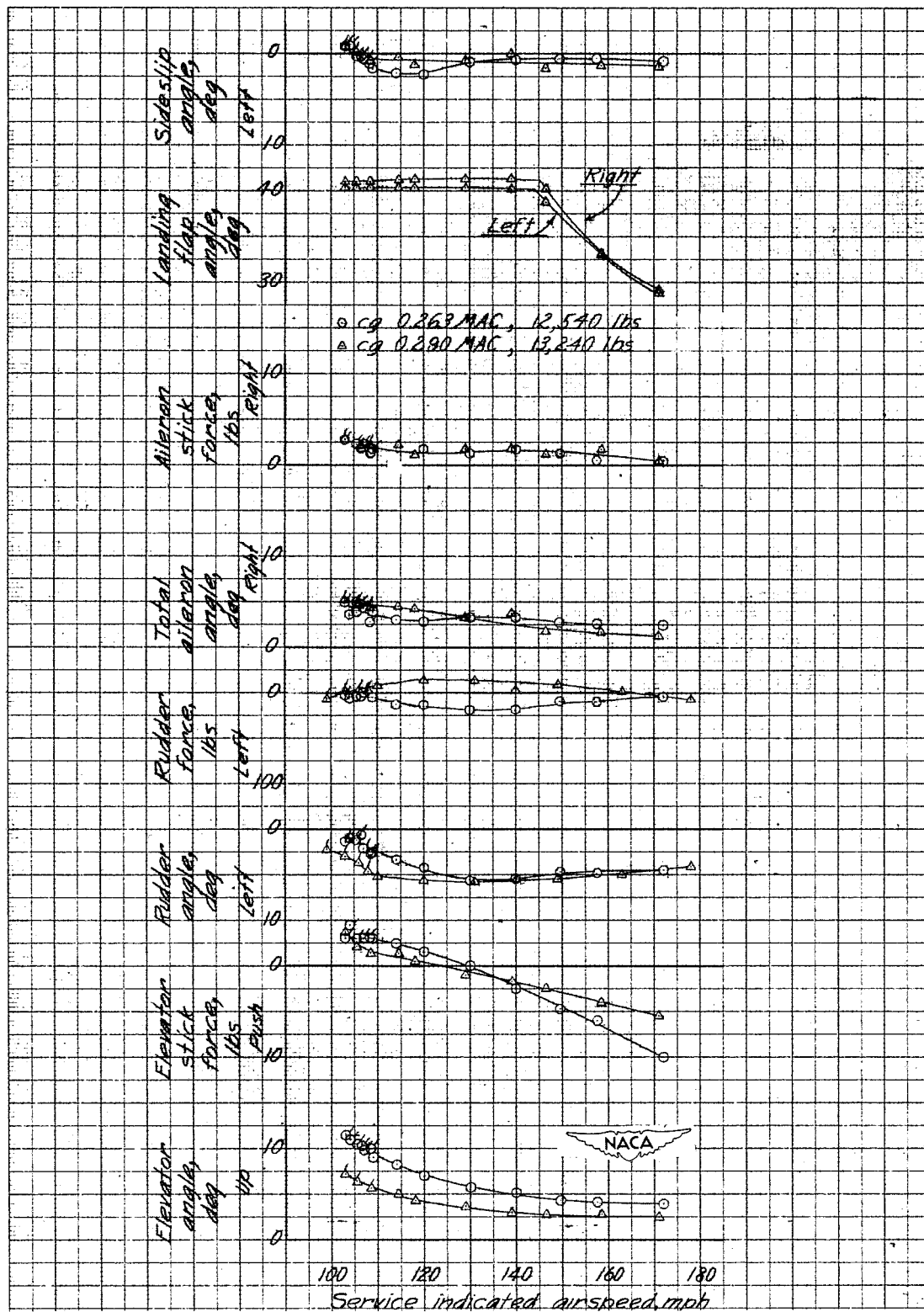


Figure 19.- Longitudinal stability characteristics of the P-47D-30 airplane in the landing condition at approximately 5000 feet altitude.

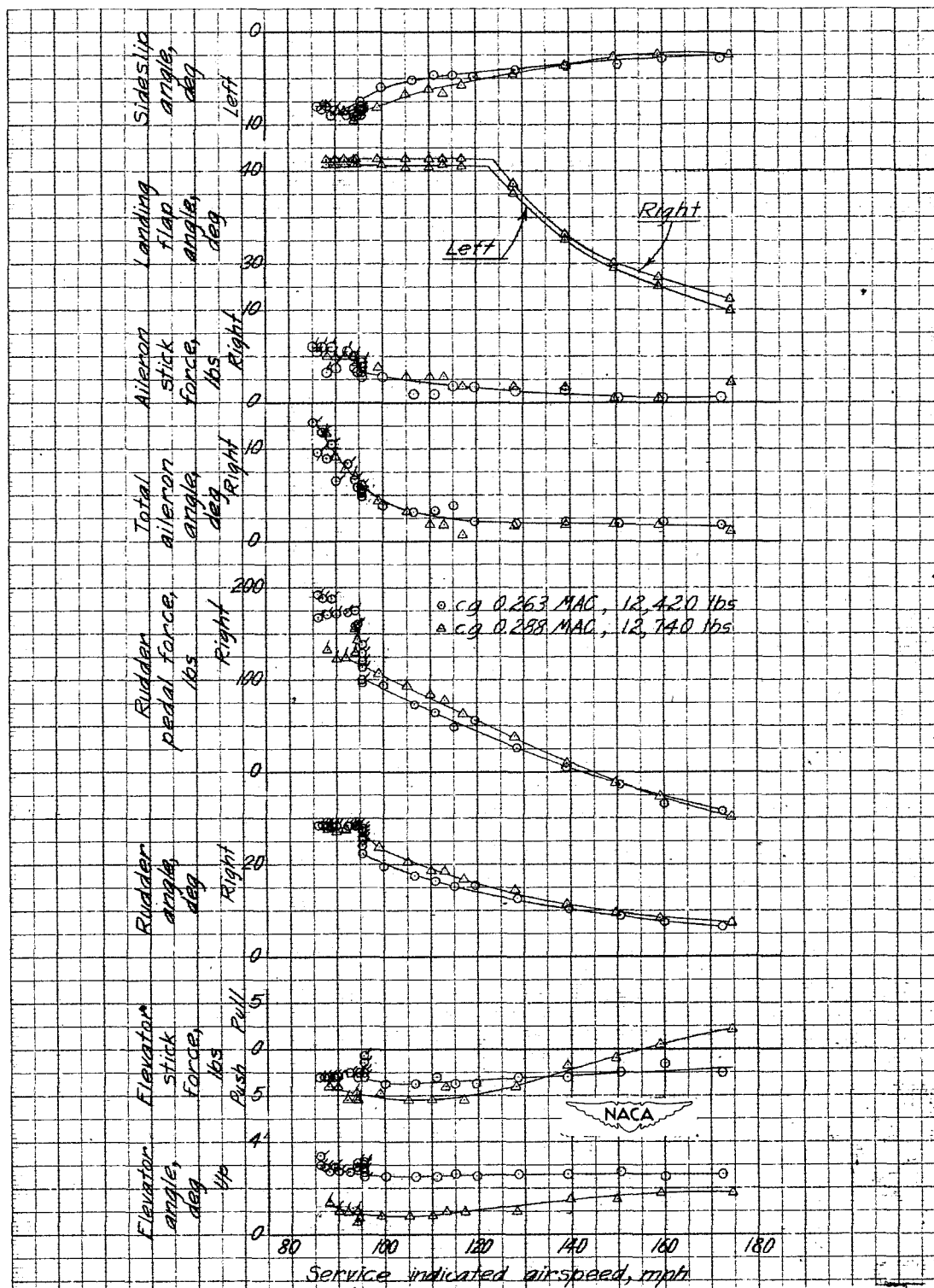


Figure 20.- Longitudinal stability characteristics of the P-47D-30 airplane in the wave-off condition at approximately 5000 feet altitude.

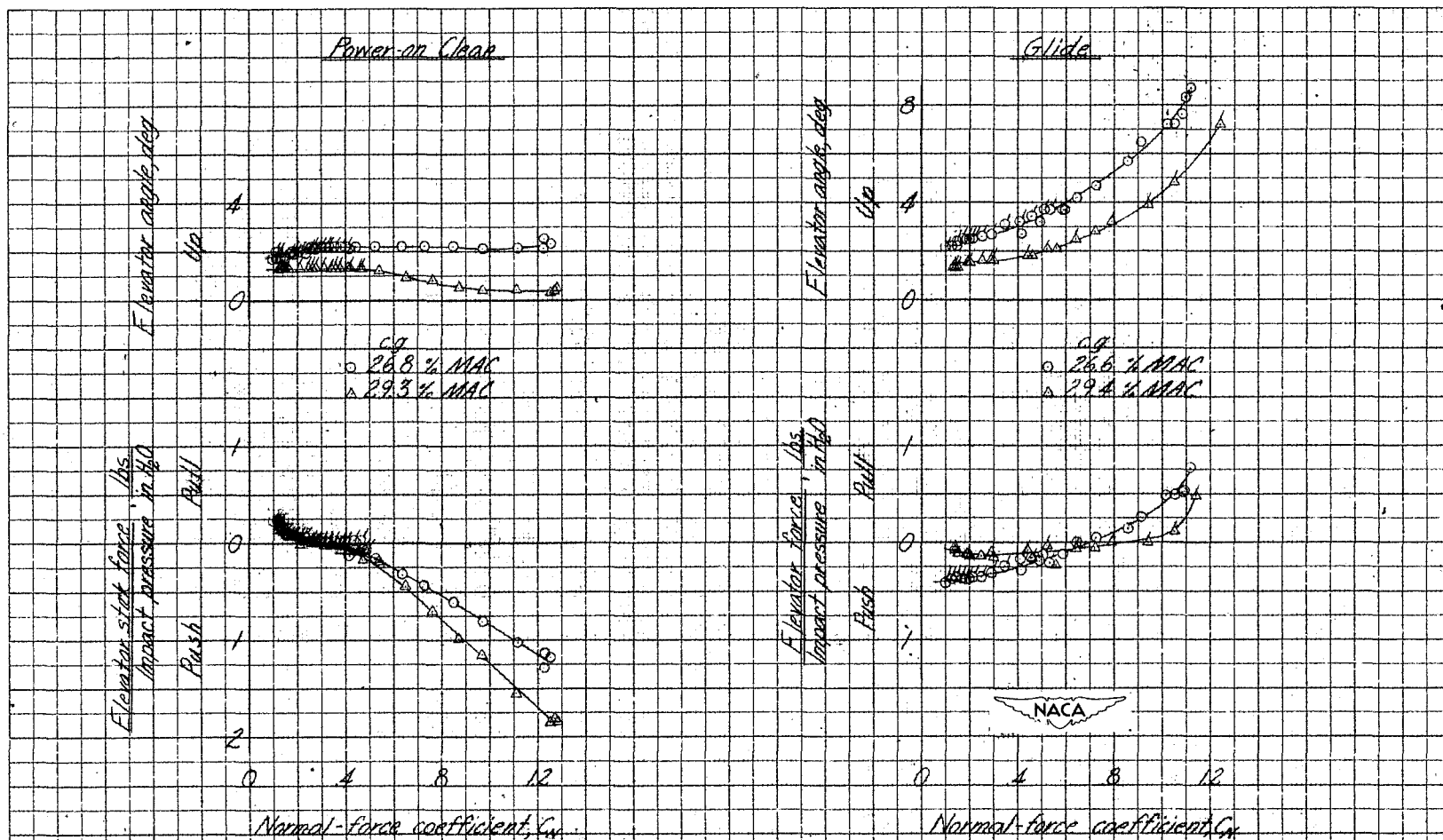


Figure 21.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the power-on clean and glide condition at two center-of-gravity positions and low altitude, P-47D-30 airplane.

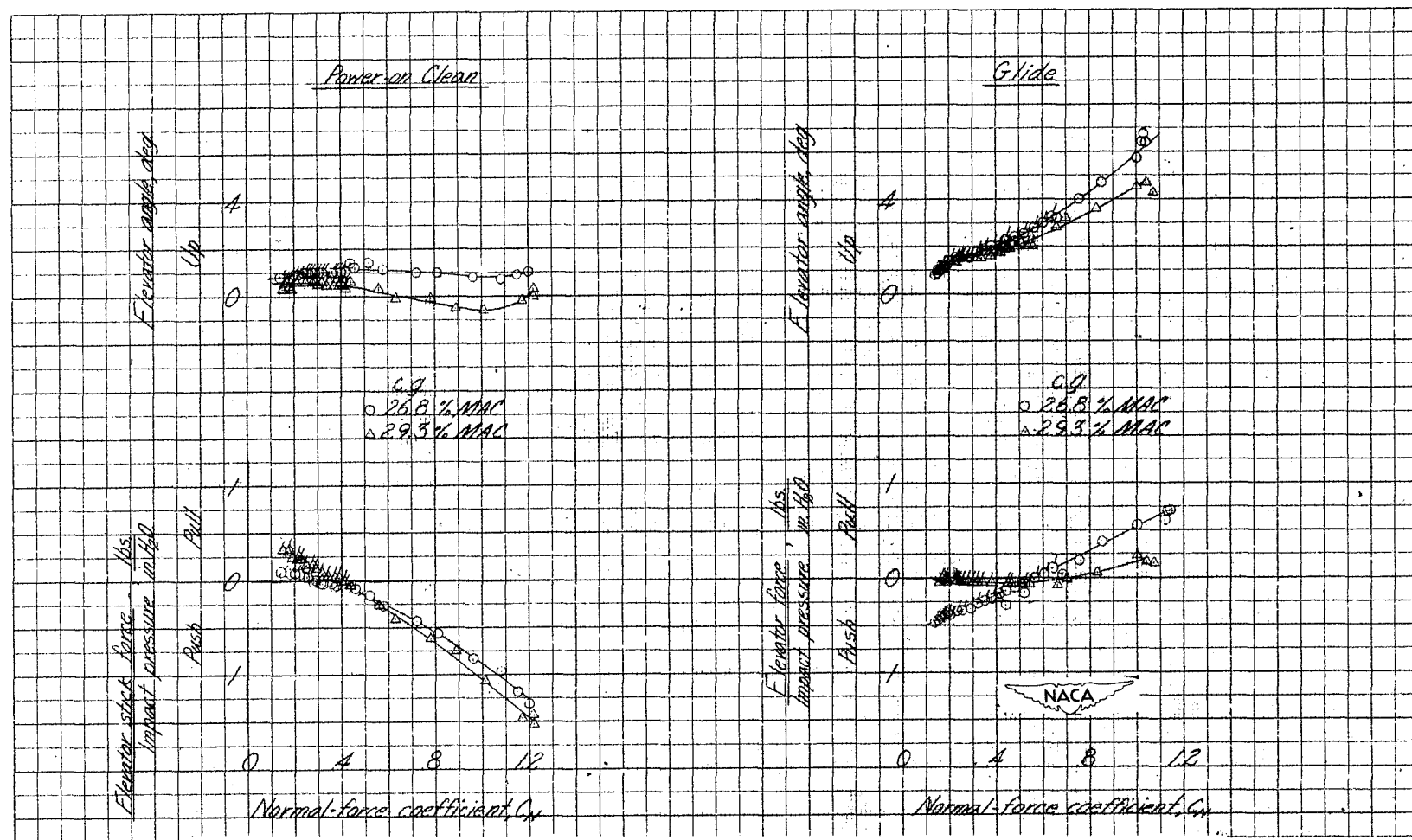


Figure 22.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the power-on clean and glide condition at two center-of-gravity positions and high altitude, P-47D-30 airplane.

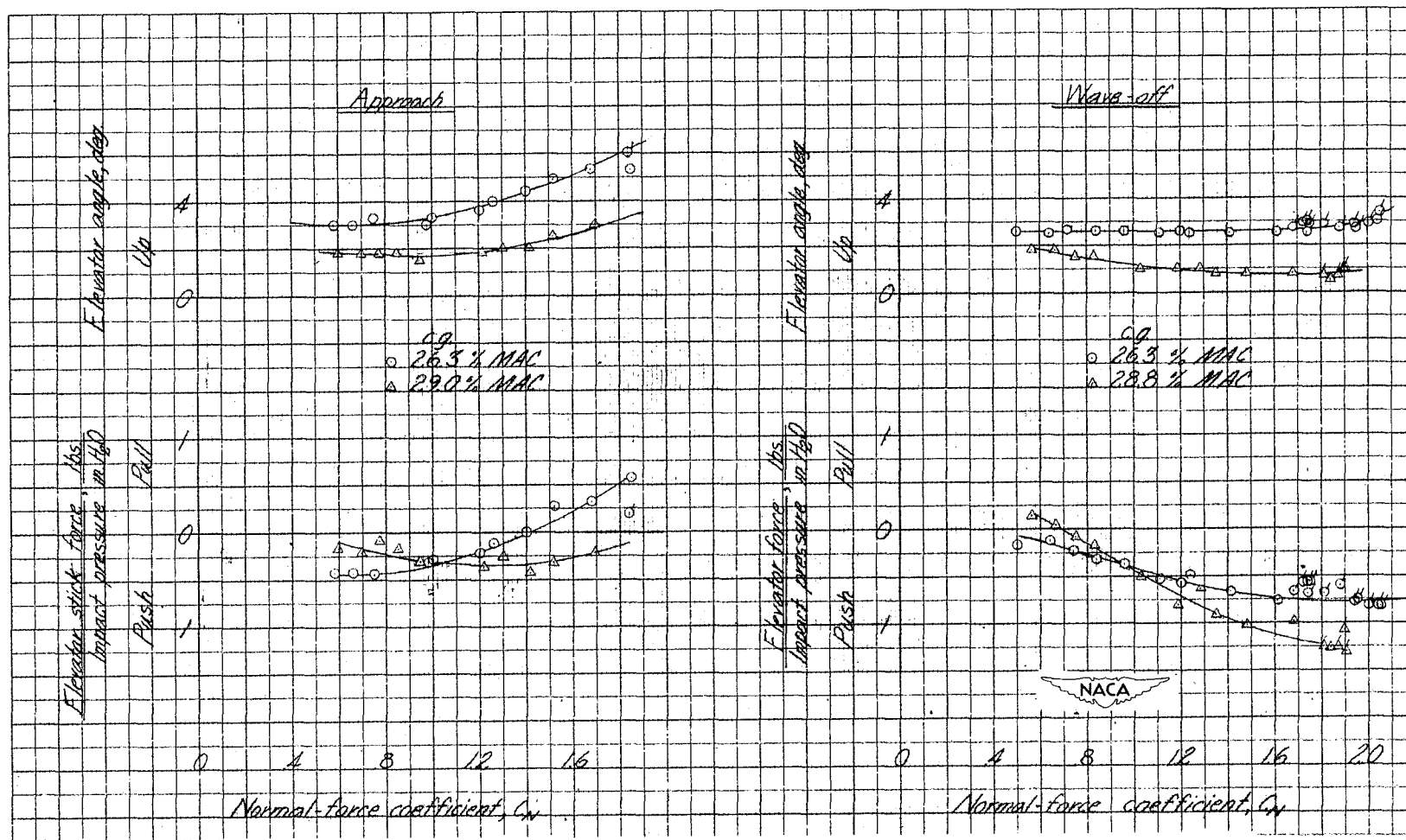


Figure 23.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the approach and wave-off condition at two center-of-gravity positions, P-47D-30 airplane.

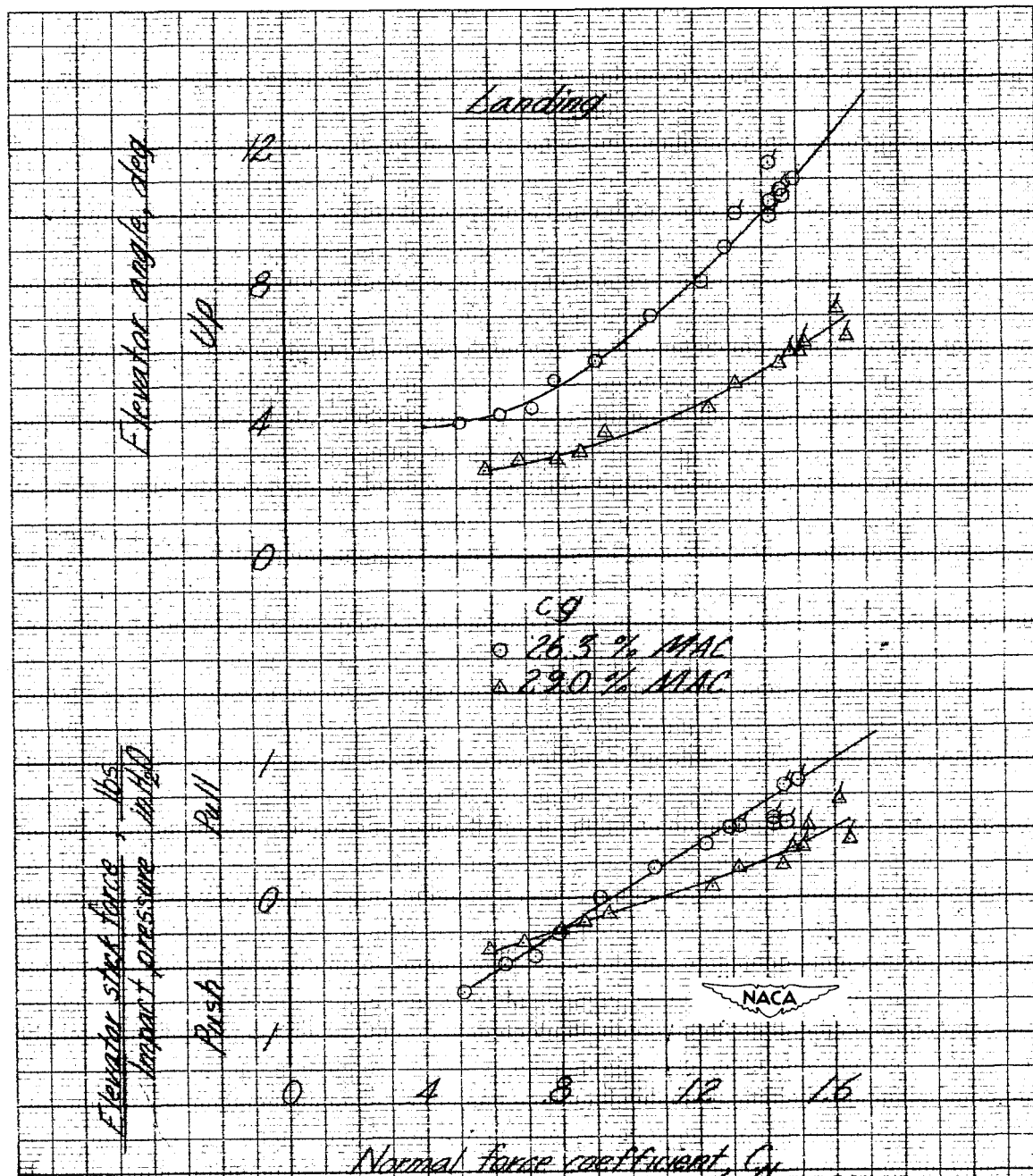


Figure 24.- Variation of elevator deflection and elevator force divided by  $q_c$  with airplane normal-force coefficient in the landing condition at two center-of-gravity positions, P-47D-30 airplane.

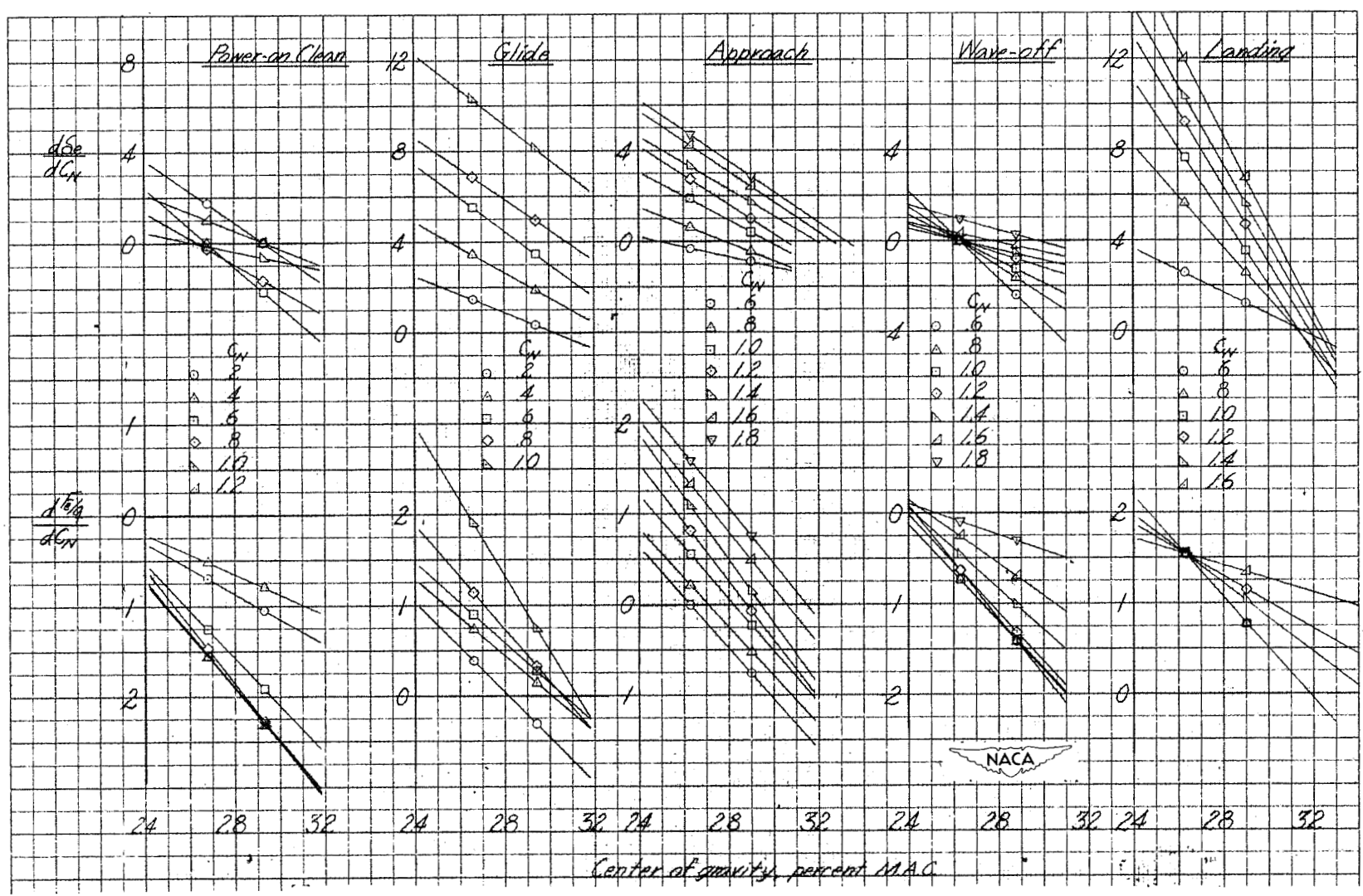
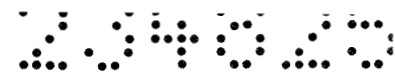


Figure 25.- Determination of neutral points for the various conditions at low altitude, P-47D-30 airplane.

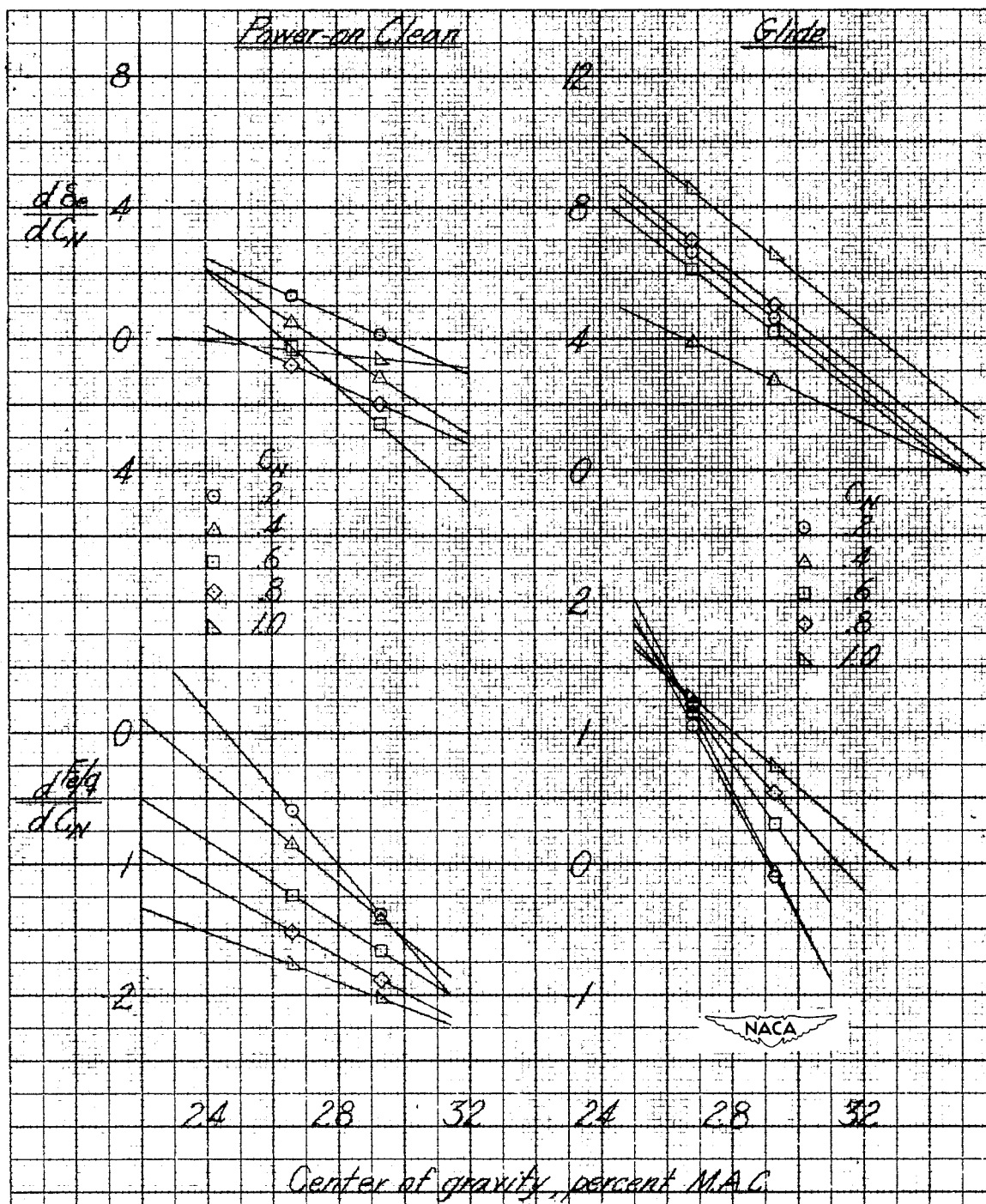
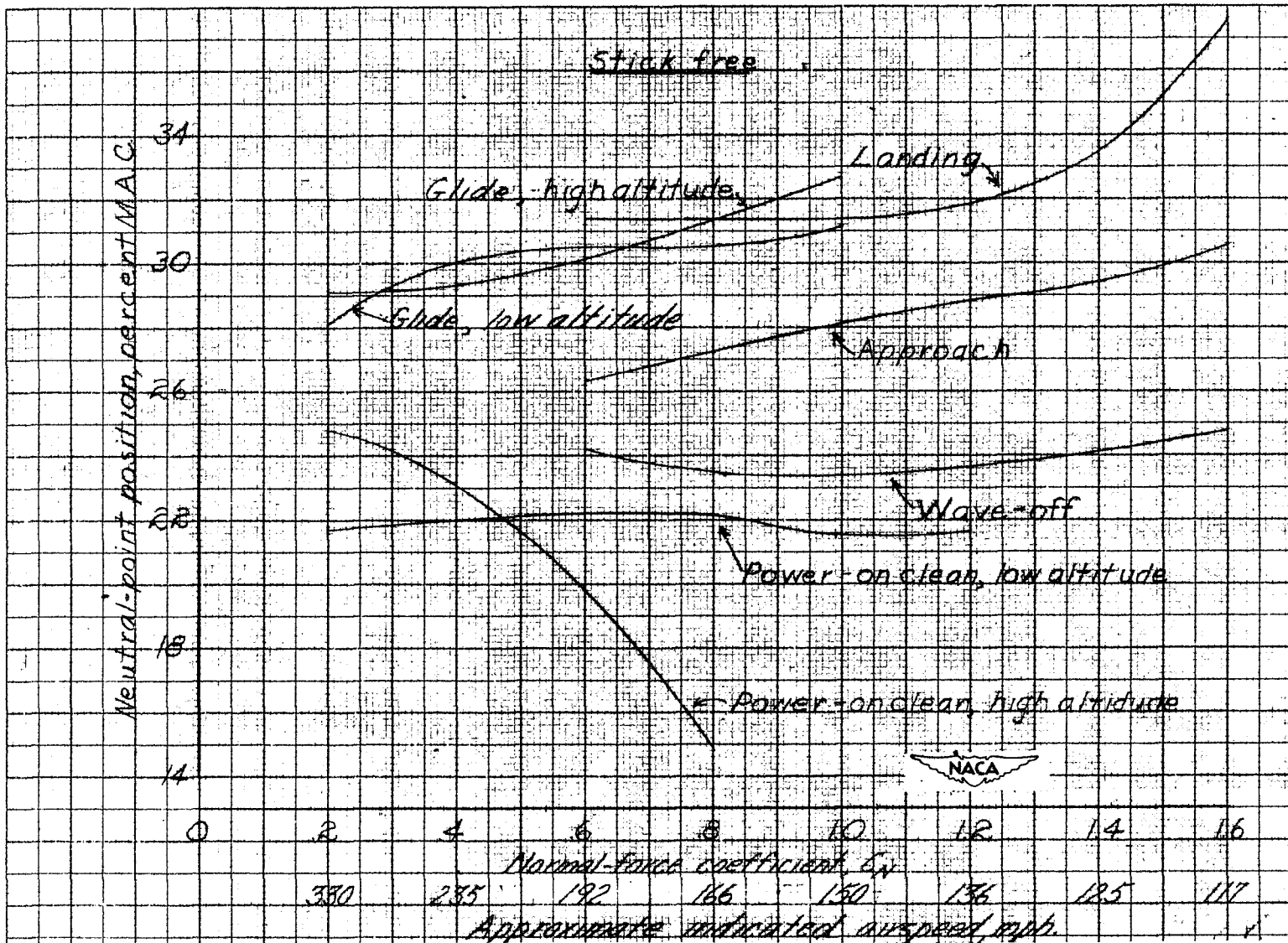


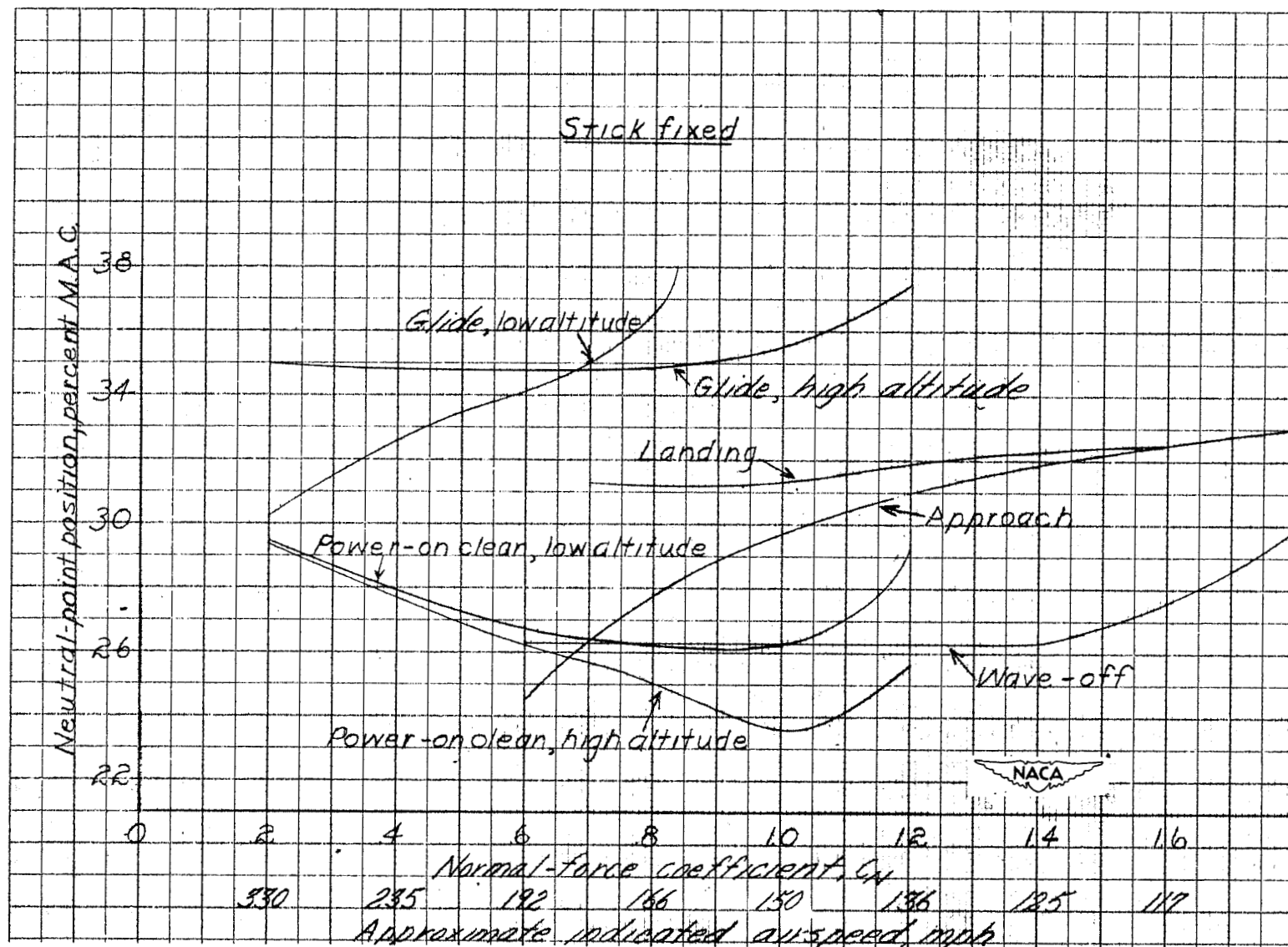
Figure 26.- Determination of neutral points for the power-on clean and glide condition at high altitude, P-47D-30 airplane.





(a) Stick-free neutral points.

Figure 27.- Variation of neutral points with airplane normal-force coefficient and approximate indicated airspeed for all conditions at low altitude and for the power-on clean and glide conditions at high altitude, P-47D-30 airplane.



(b) Stick-fixed neutral points.

Figure 27.- Concluded.

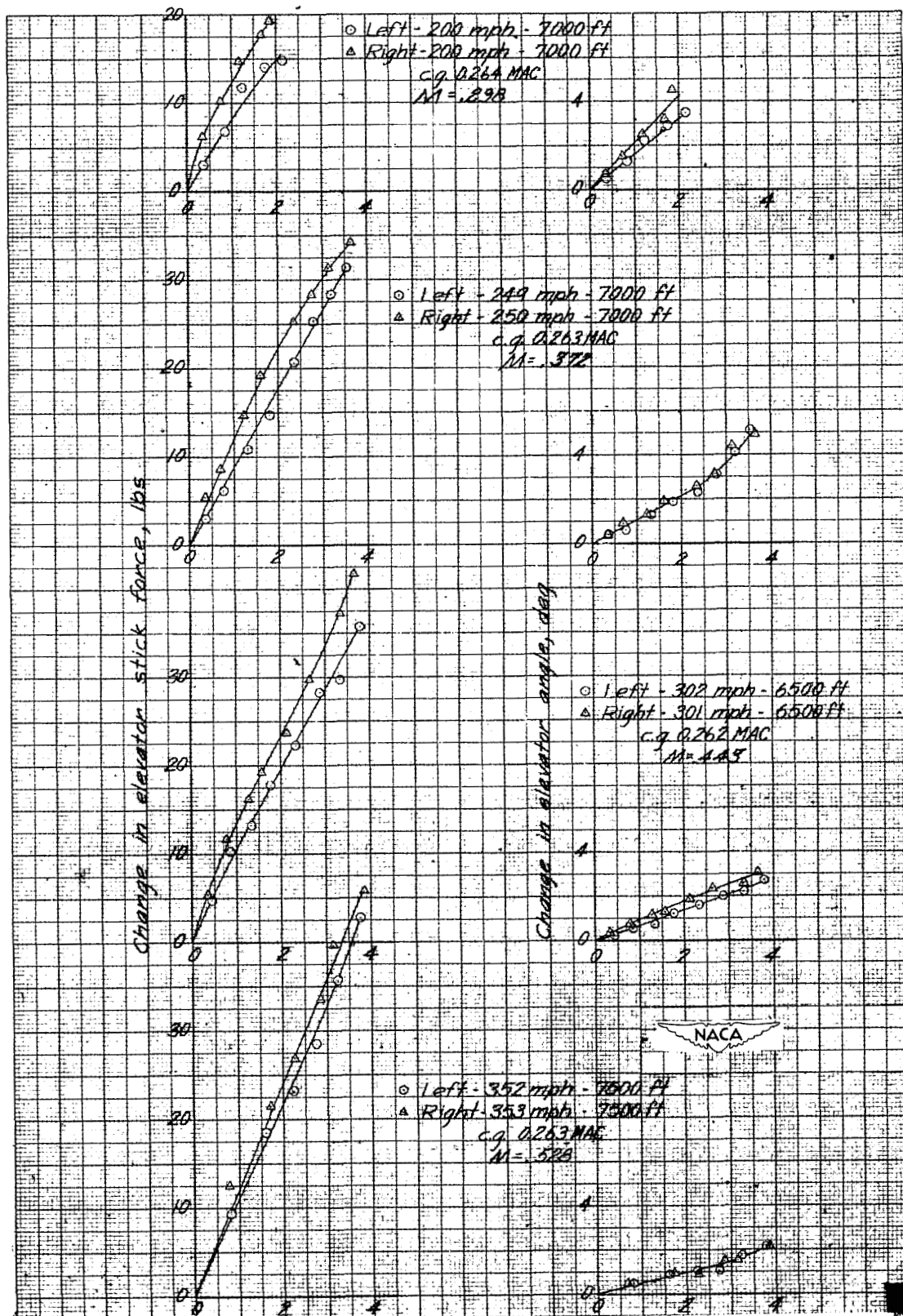


Figure 28.- Turning characteristics of the P-47D-30 airplane in the power-on clean condition at low altitude. Forward center-of-gravity position.

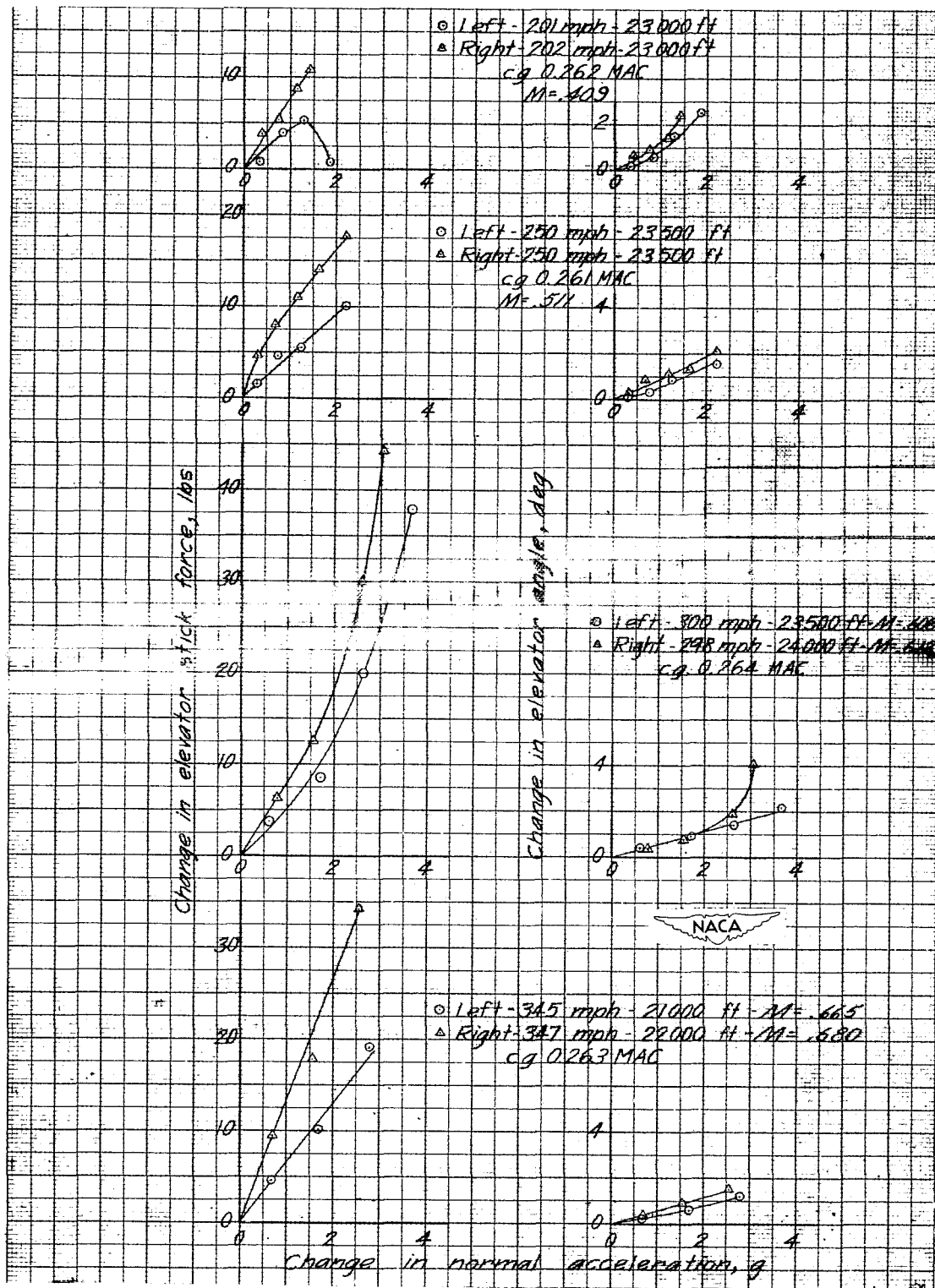


Figure 29.- Turning characteristics of the P-47D-30 airplane in the power-on clean condition at high altitude. Forward center-of-gravity position.

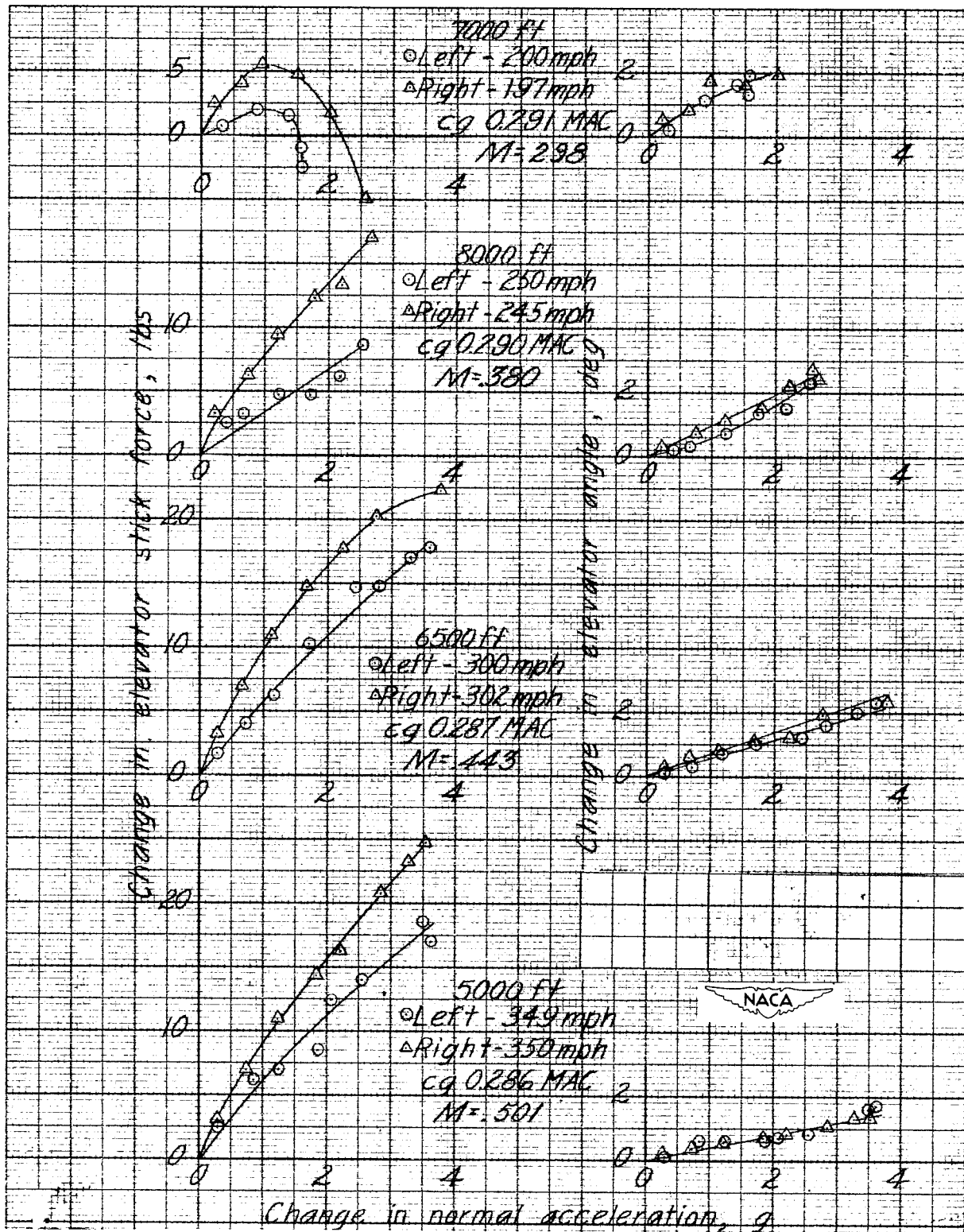


Figure 30.- Turning characteristics of the P-47D-30 airplane in the power-on clean condition at low altitude. Rearward center-of-gravity position.

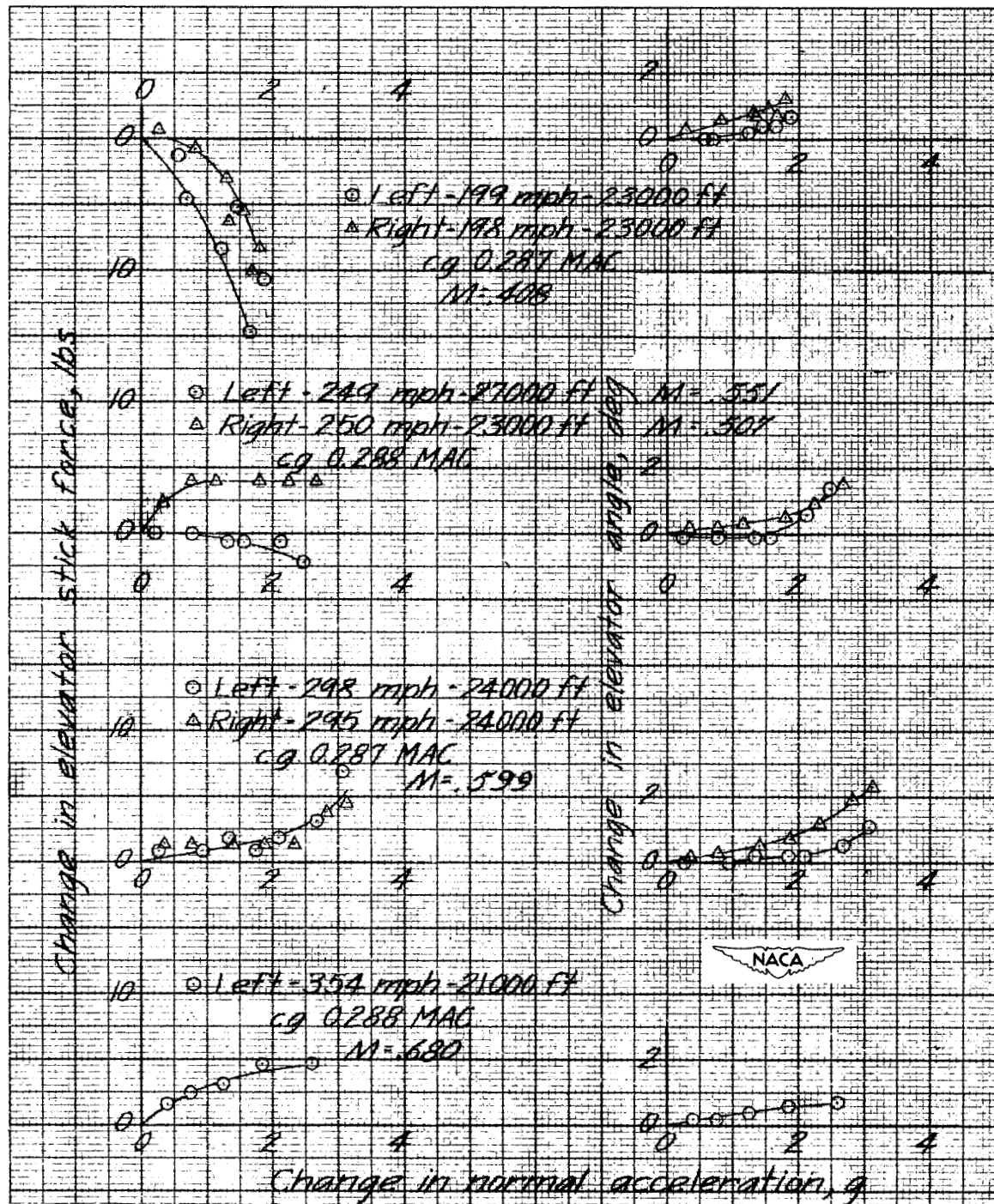


Figure 31.- Turning characteristics of the P-47D-30 airplane in the power-on clean condition at high altitude. Rearward center-of-gravity position.

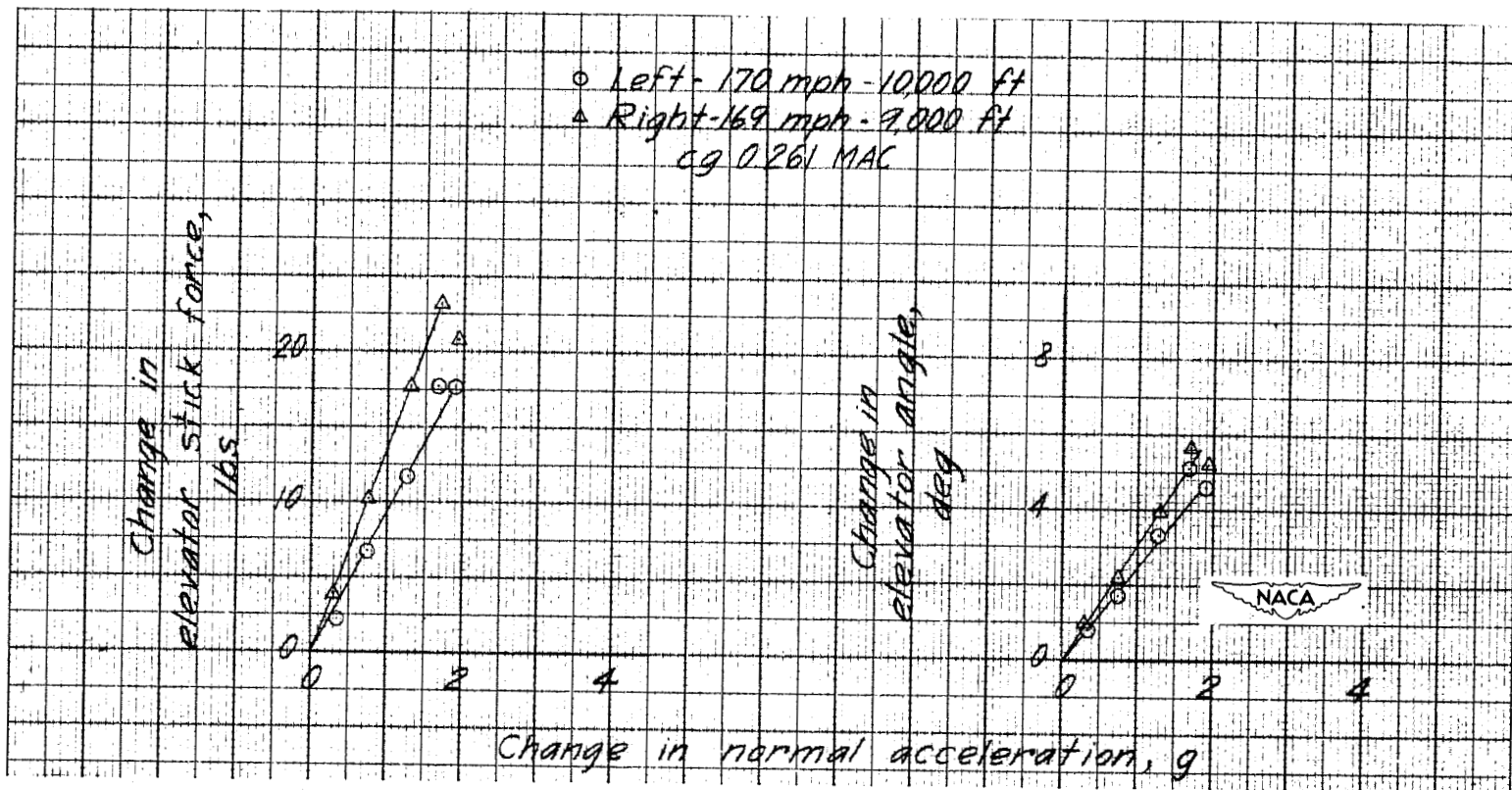


Figure 32.- Turning characteristics of the P-47D-30 airplane in the landing condition: landing flaps and gear down, canopy closed, power for level flight at 170 miles per hour.

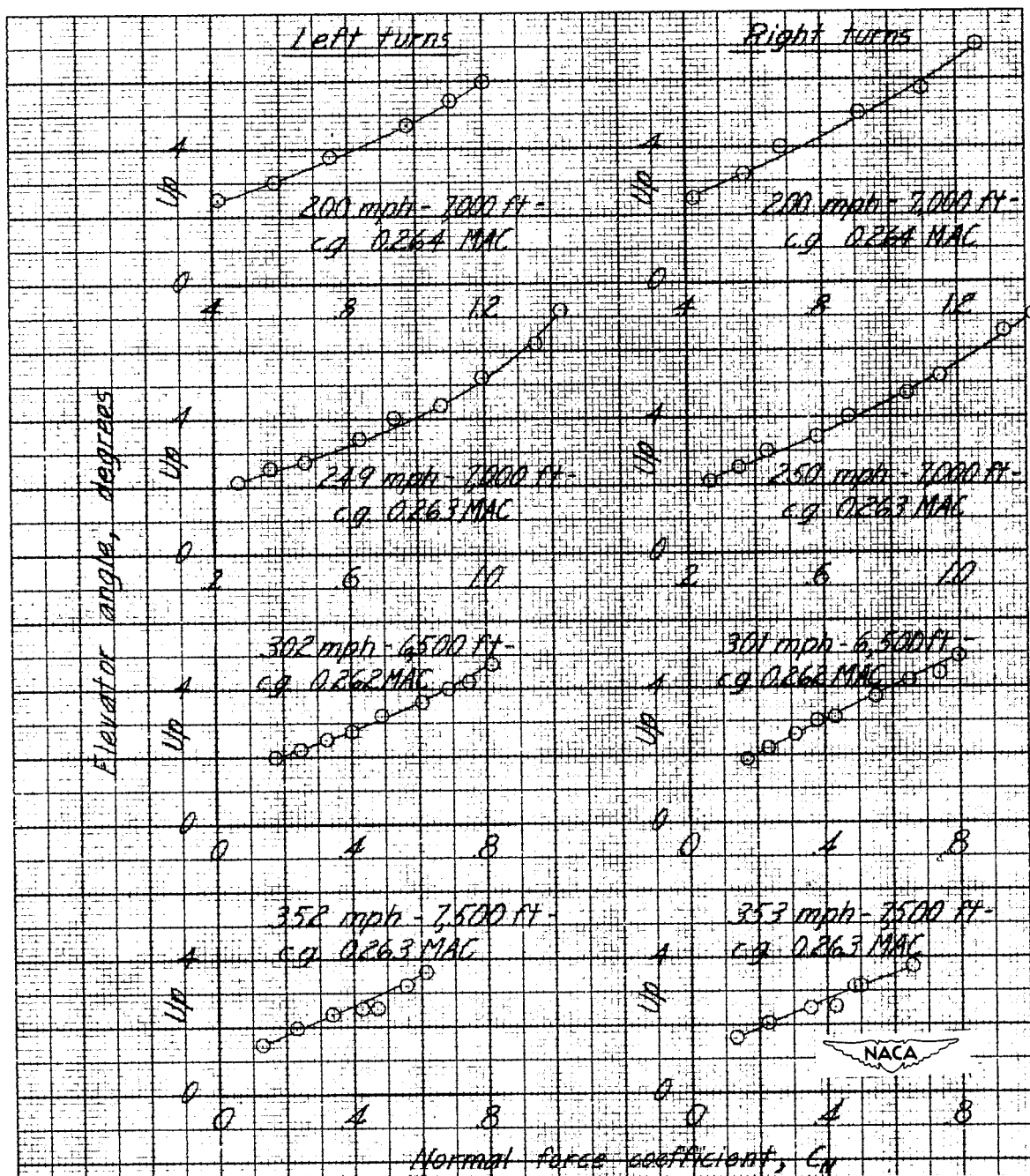


Figure 33.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at low altitude and at the forward center-of-gravity position, P-47D-30 airplane.



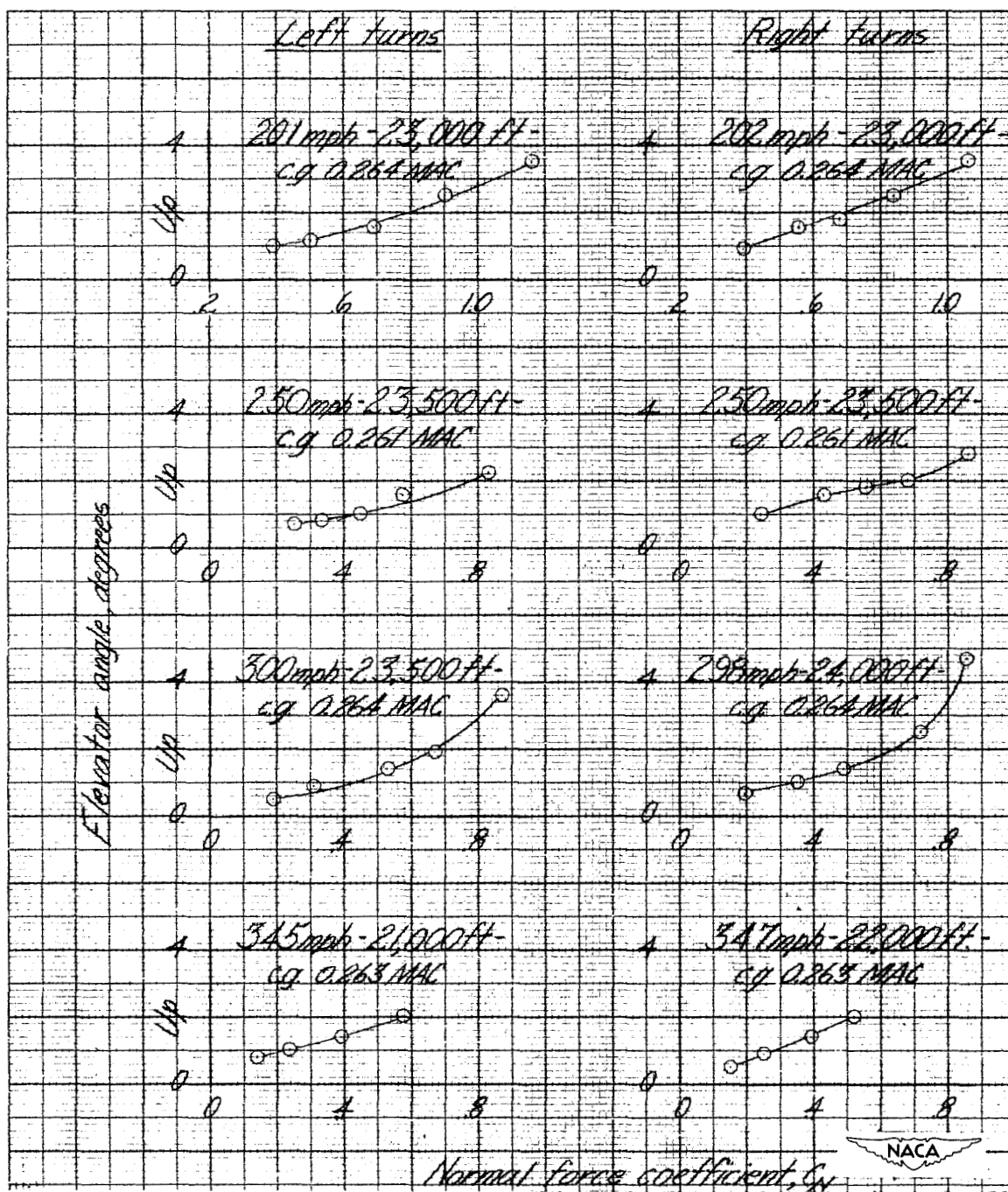


Figure 34.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at high altitude and at the forward center-of-gravity position, P-47D-30 airplane.

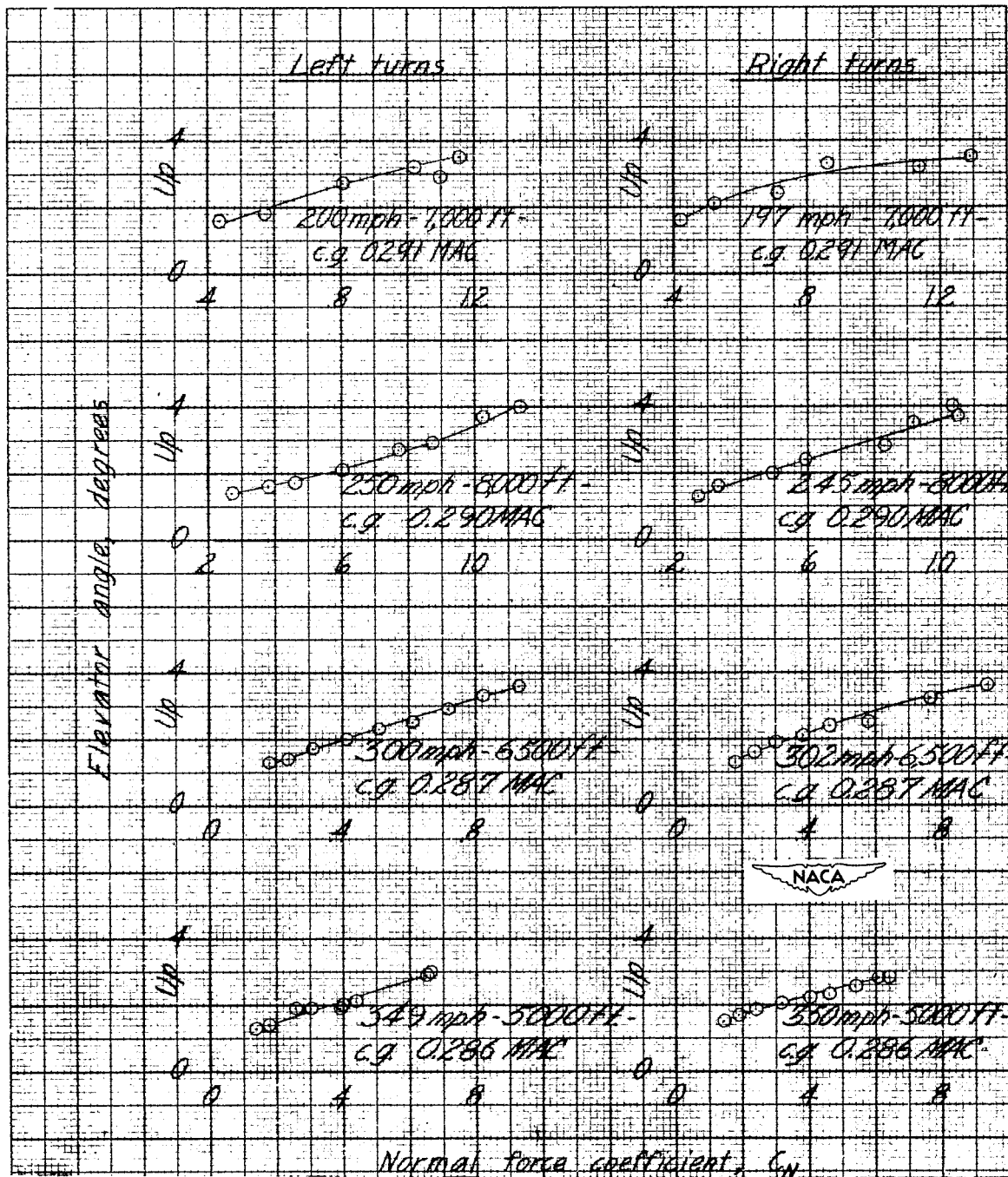


Figure 35.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at low altitude and at the rearward center-of-gravity position, P-47D-30 airplane.

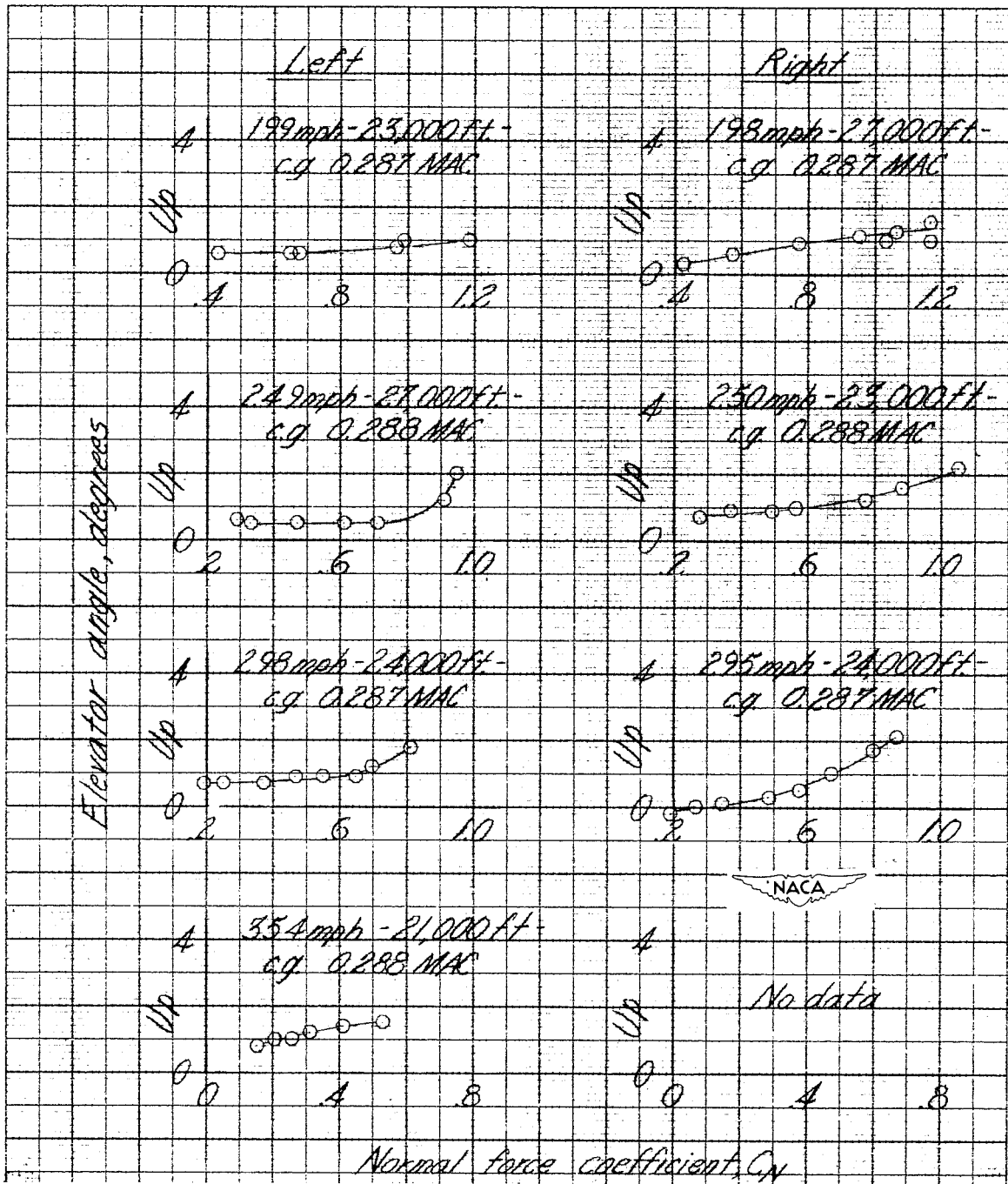


Figure 36.- Variation of elevator angle with airplane normal-force coefficient in turning flight, power-on clean condition at high altitude and at the rearward center-of-gravity position, P-47D-30 airplane.

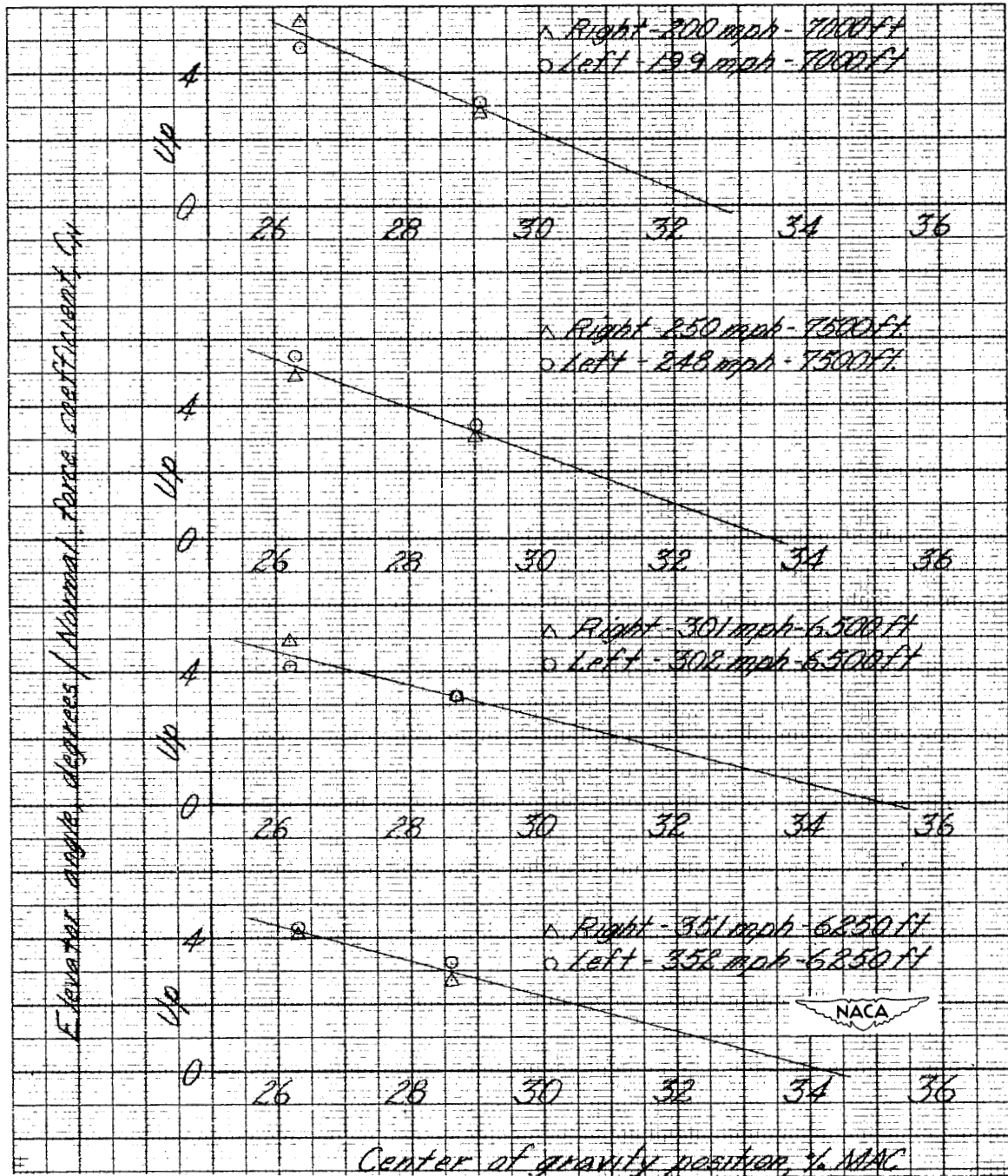


Figure 37.- Determination of the stick-fixed maneuver points at low altitude, P-47D-30 airplane.

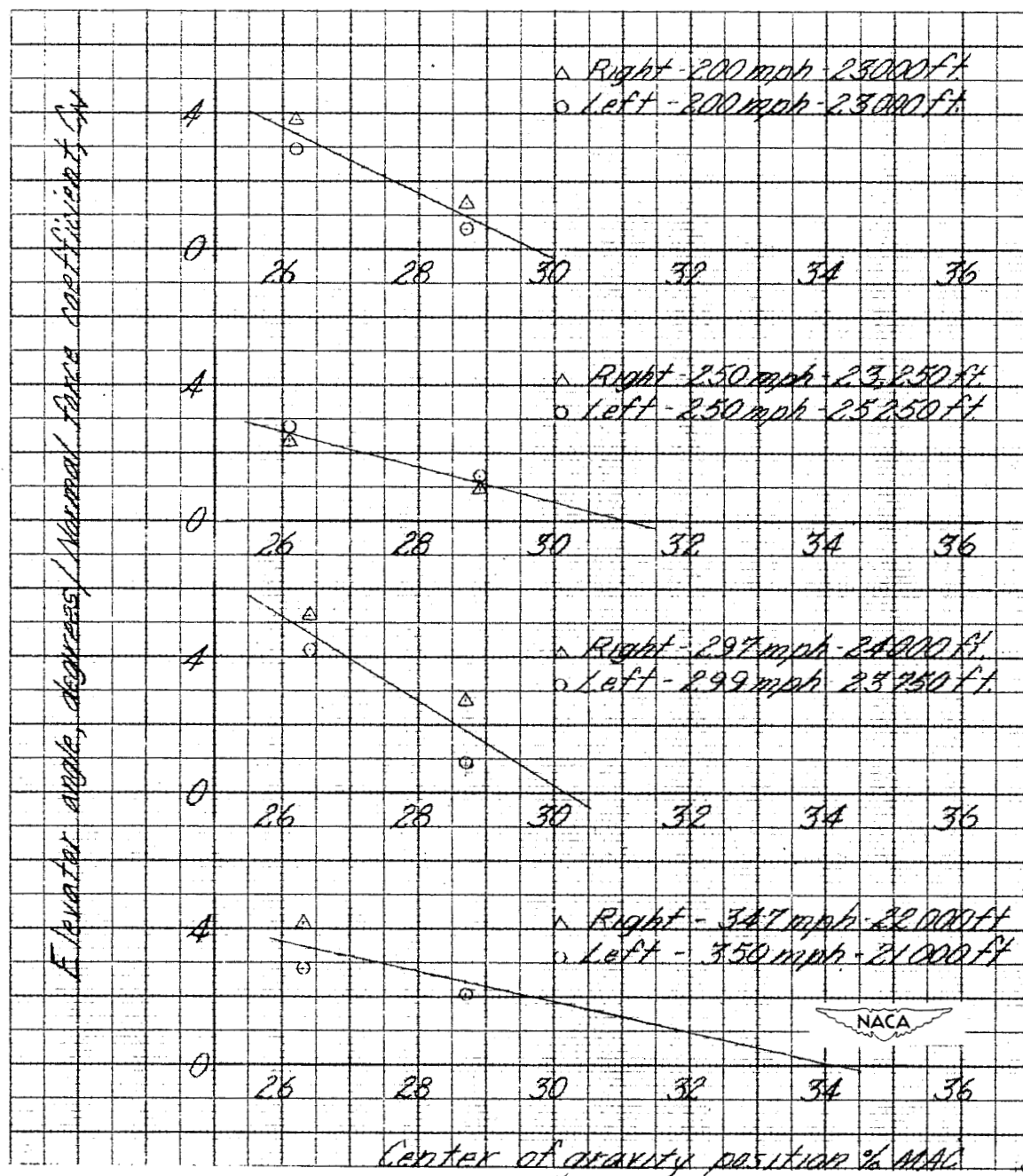


Figure 38.- Determination of the stick-fixed maneuver points at high altitude, P-47D-30 airplane.

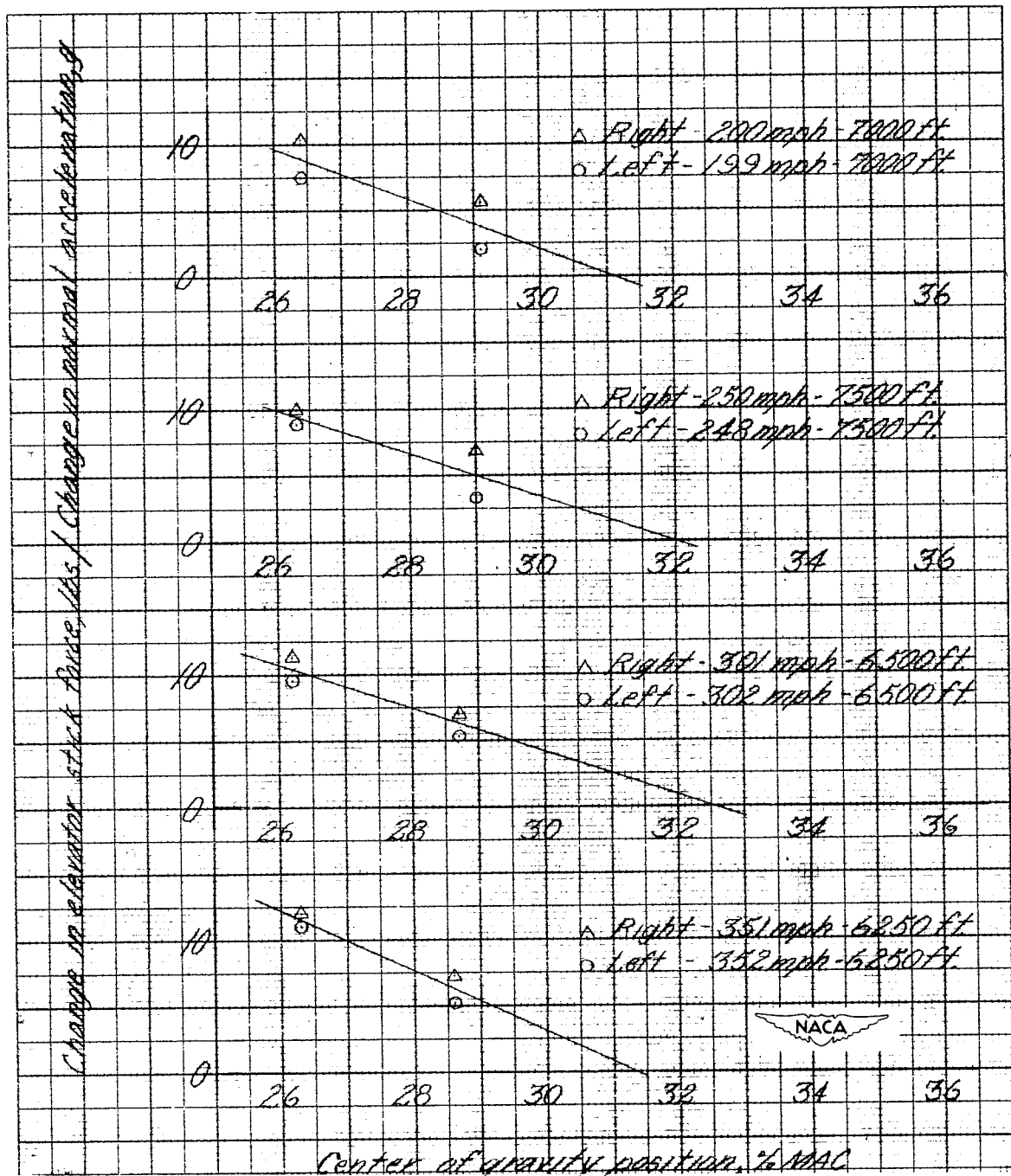


Figure 39.- Determination of the stick-free maneuver points at low altitude, P-47D-30 airplane.

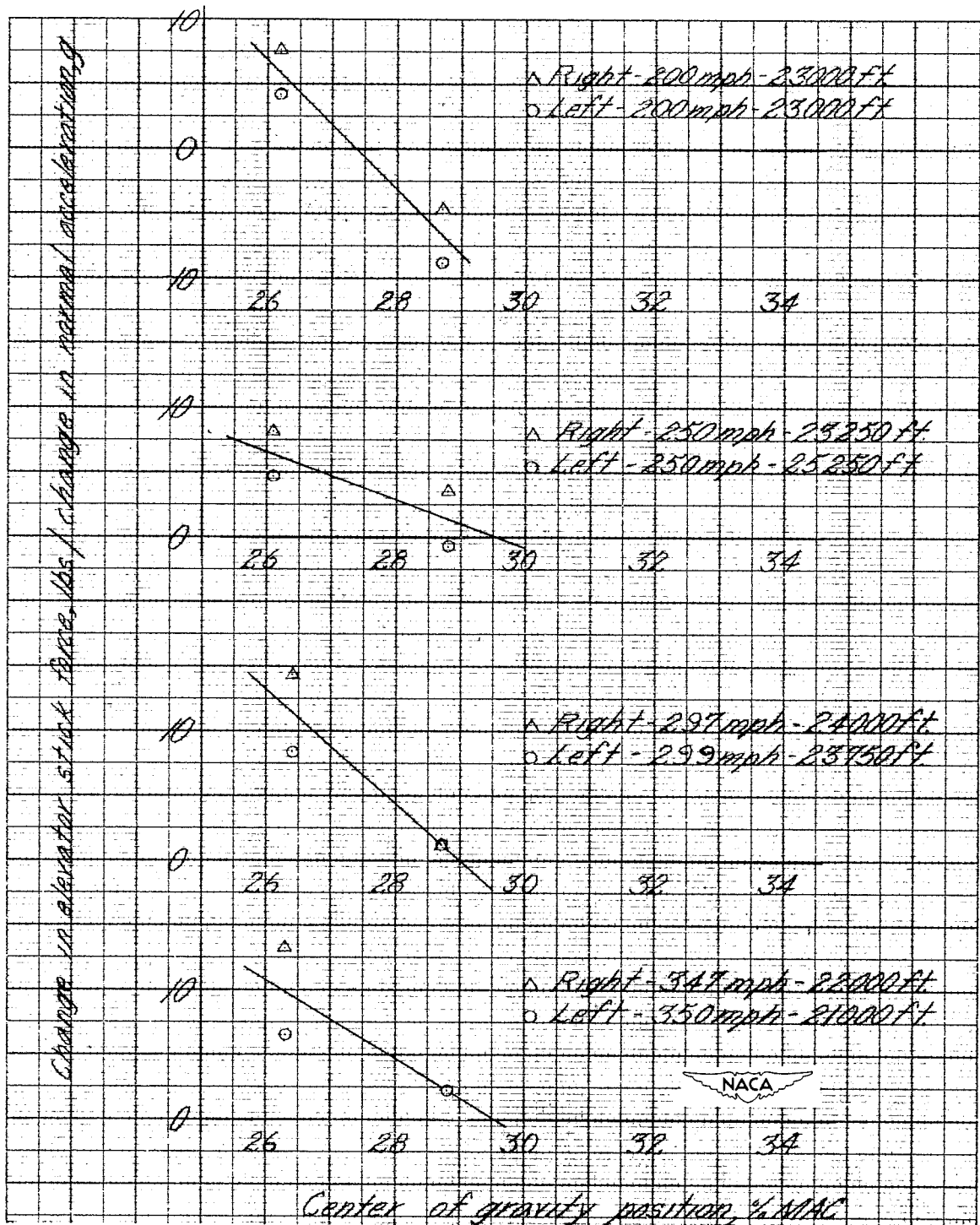


Figure 40.- Determination of the stick-free maneuver points at high altitude, P-47D-30 airplane.

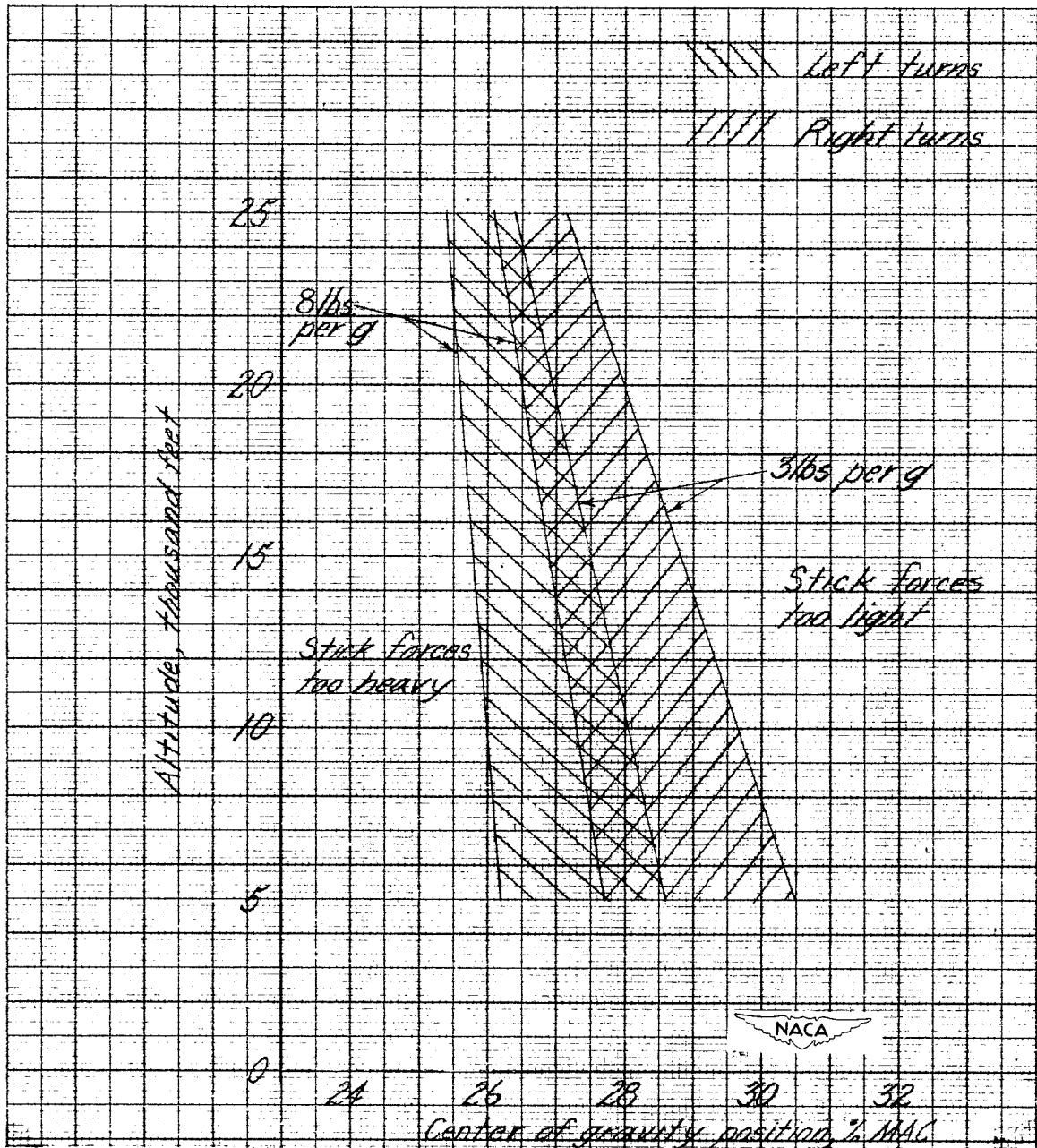


Figure 41.- Variation with altitude of the center-of-gravity range for desirable stick force per g in left and right turns at 200 miles per hour. P-47D-30 airplane.



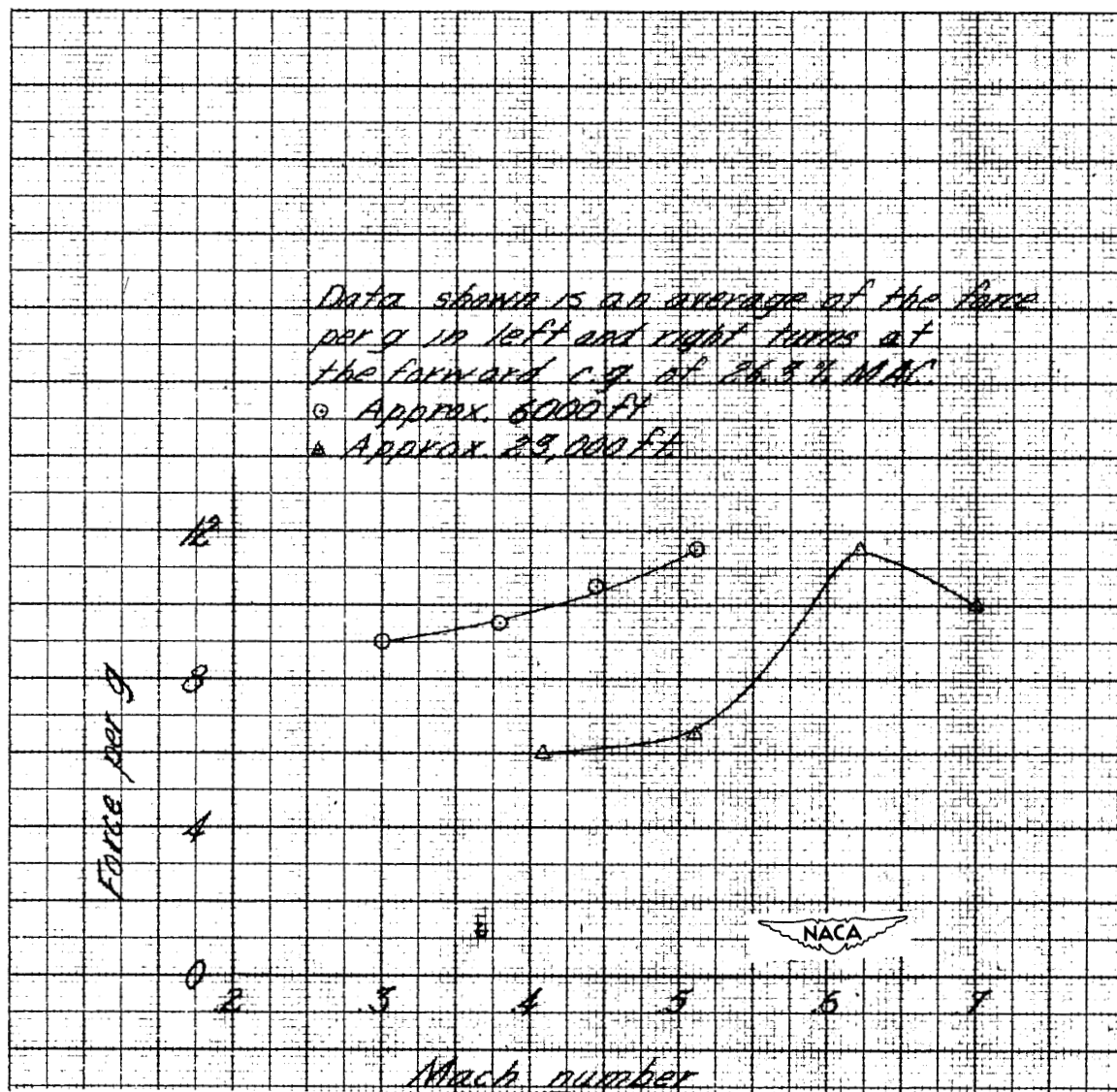


Figure 42.- Variation of force per g with Mach number at low and high altitude at the forward center-of-gravity position. P-47D-30 airplane.

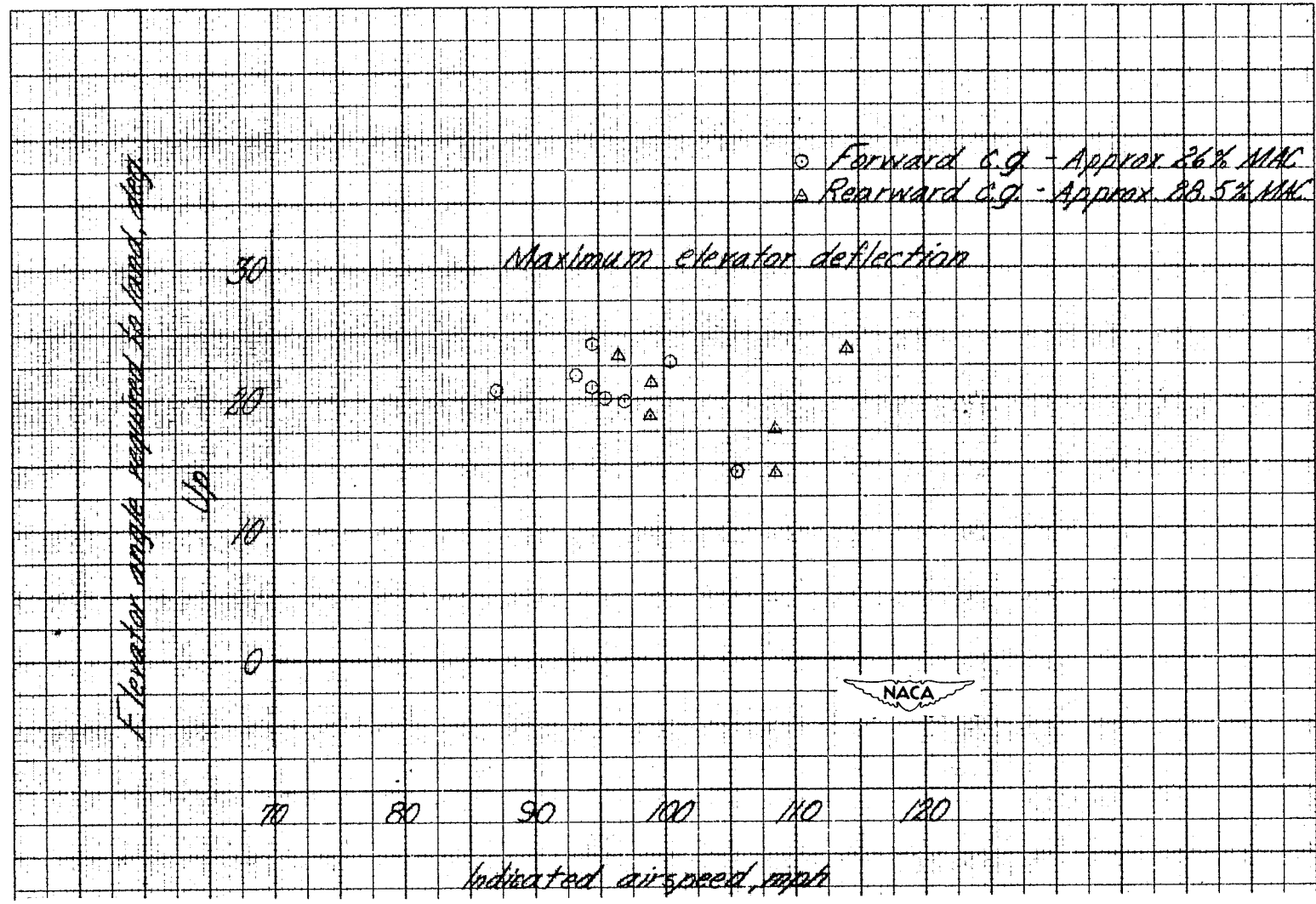
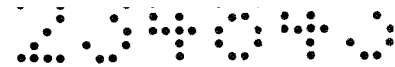


Figure 43.- Variation of elevator angle required to land with airspeed, P-47D-30 airplane.

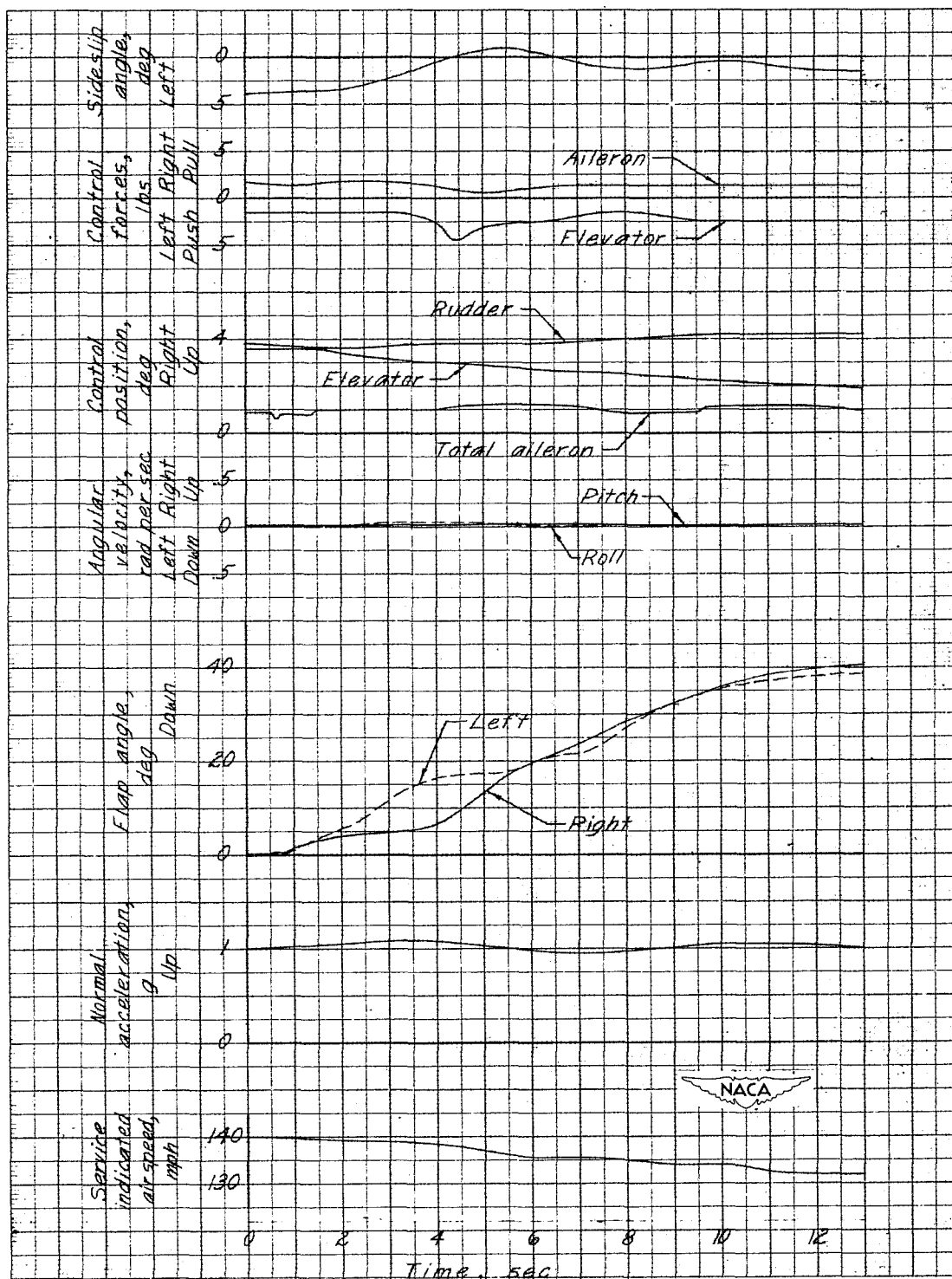


Figure 44.- Time history showing results of deflecting landing flaps and holding controls fixed; c.g. at 29.1 percent M.A.C.; gr. wt. 13,280 pounds; 5000 feet altitude.

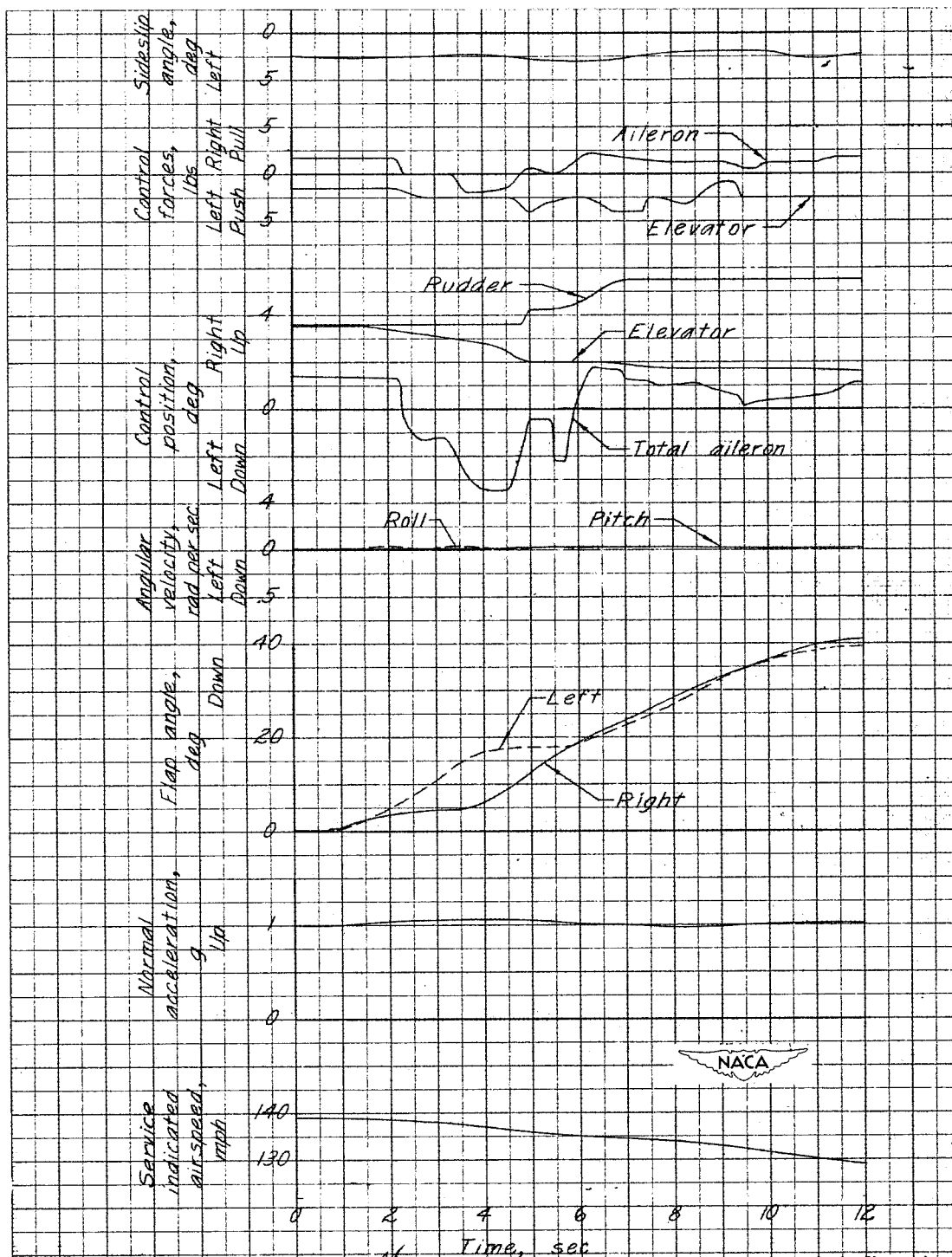


Figure 45.- Time history showing result of deflecting landing flaps and holding wings level by use of controls; c.g. at 29.1 percent M.A.C.; gr. wt. 13,280 pounds; 5000 feet altitude.

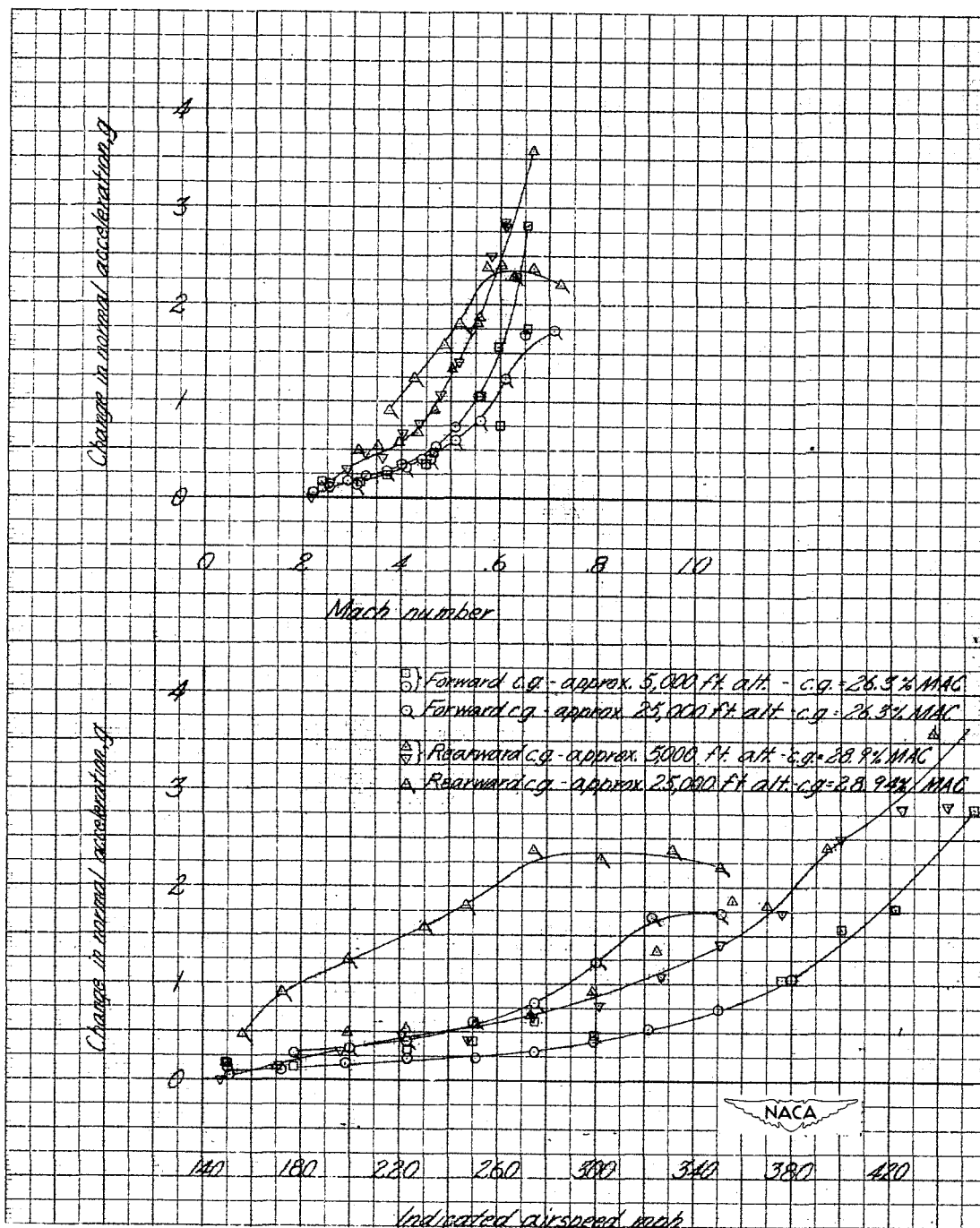


Figure 46.- Variation of the change in normal acceleration with Mach number and airspeed as the dive-recovery flaps were deflected. P-47D-30 airplane. (Two sets of points for same condition indicate data from two flights.)

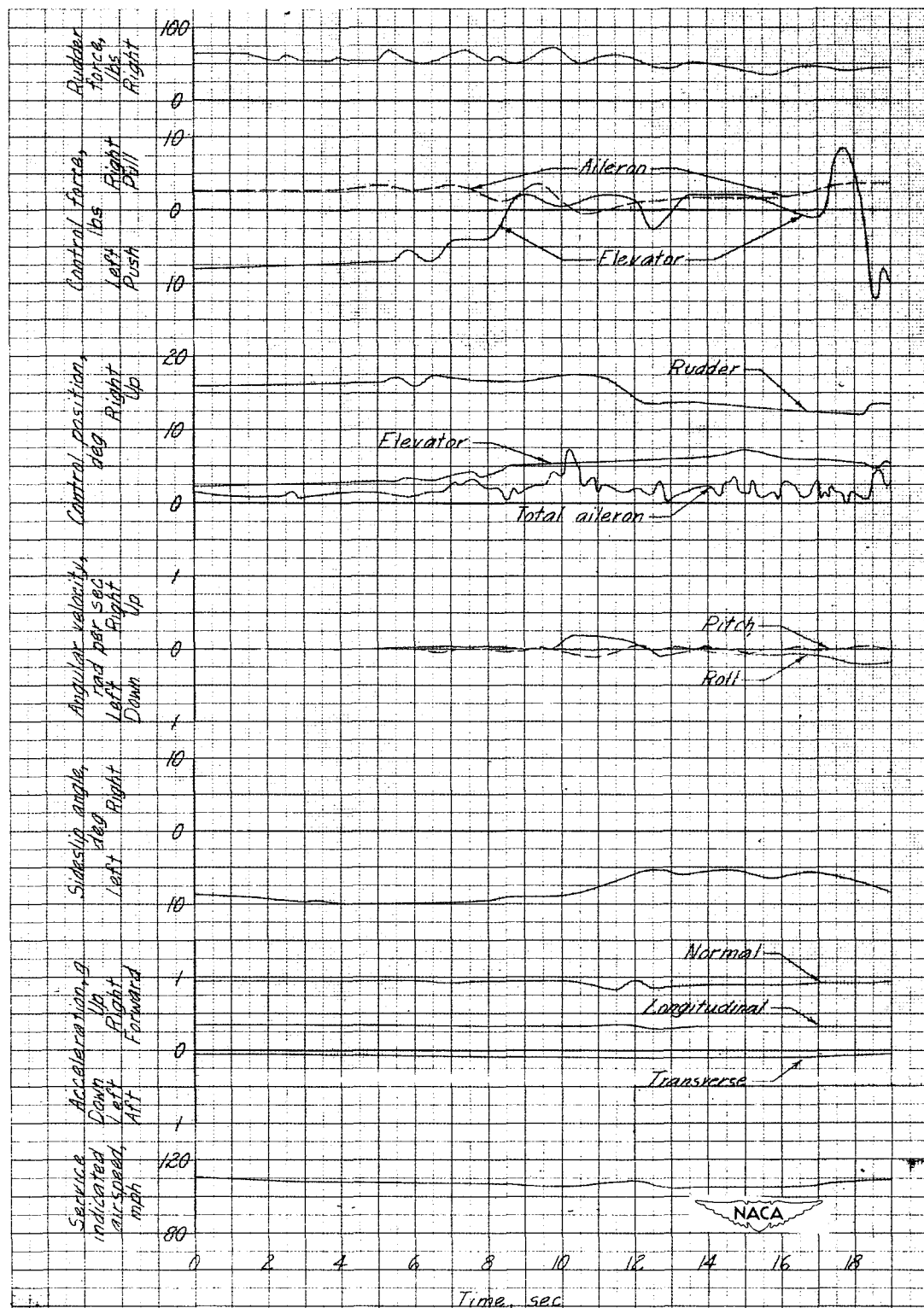


Figure 47.- Time history of a stall approach in the power-on clean condition using elevator alone. Pilot attempted to hold other controls fixed; c.g. at 26.4 percent M.A.C.; gr. wt. 12,660 pounds; 5000 feet altitude.

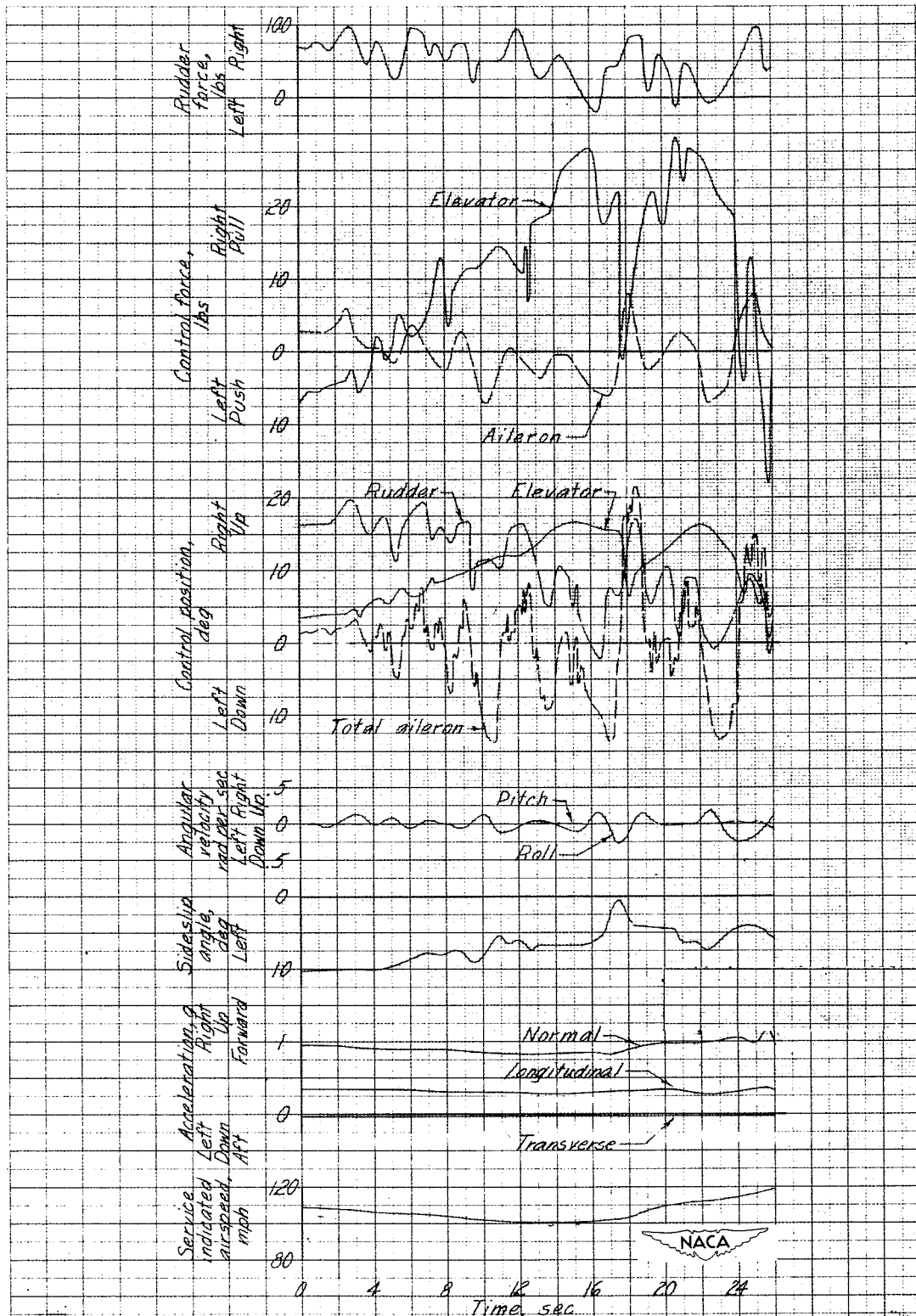


Figure 48.- Time history of a stall approach in the power-on clean condition. All controls used to hold wings level after initial stall; c.g. at 26.4 percent M.A.C.; gr. wt. 12,570 pounds, 5000 feet altitude.

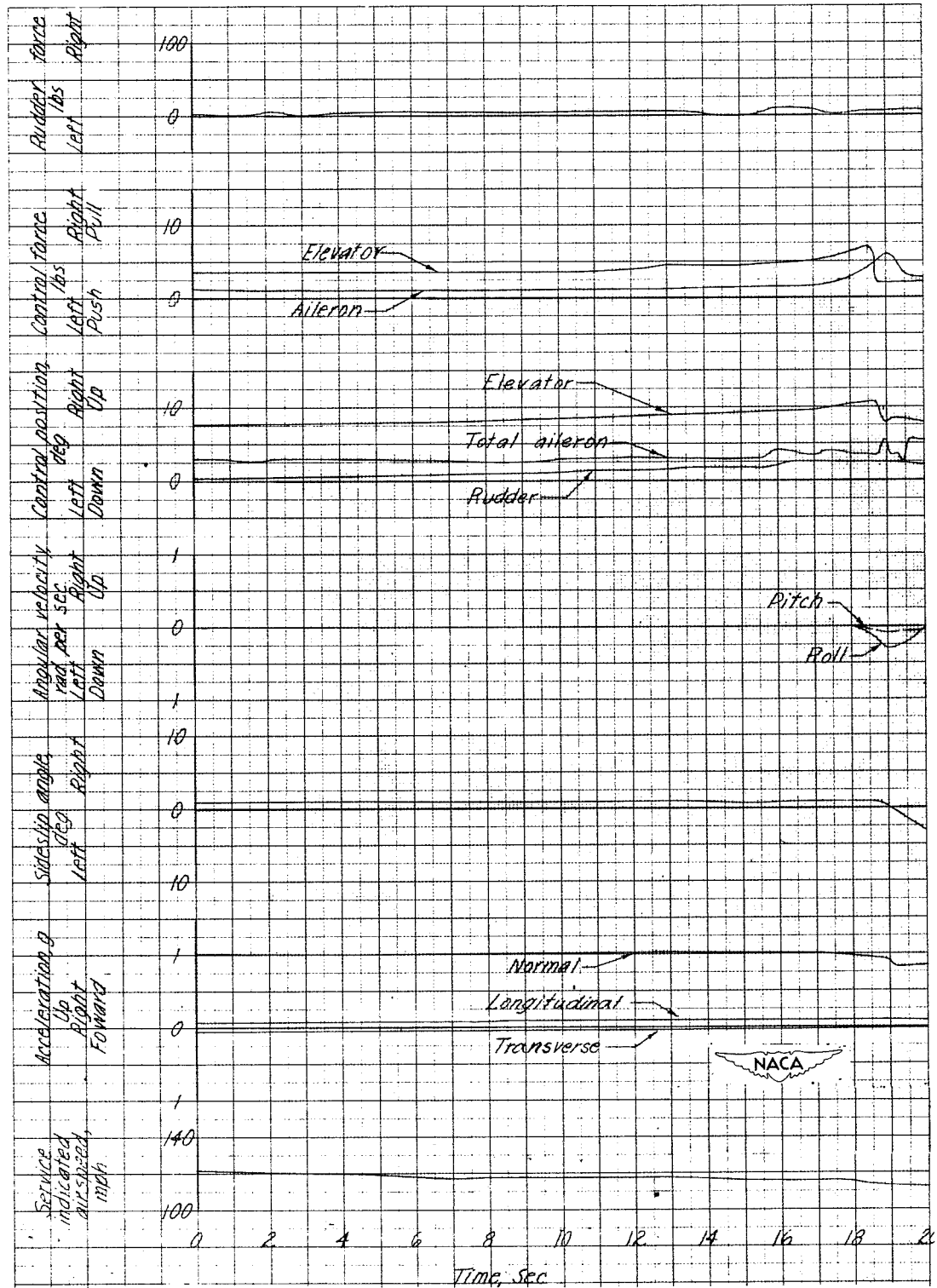


Figure 49.- Time history of a stall approach in the glide condition using elevator alone. Pilot attempted to hold other controls fixed; c.g. at 26.3 percent M.A.C.; gr. wt. 12,400 pounds, 5000 feet altitude.



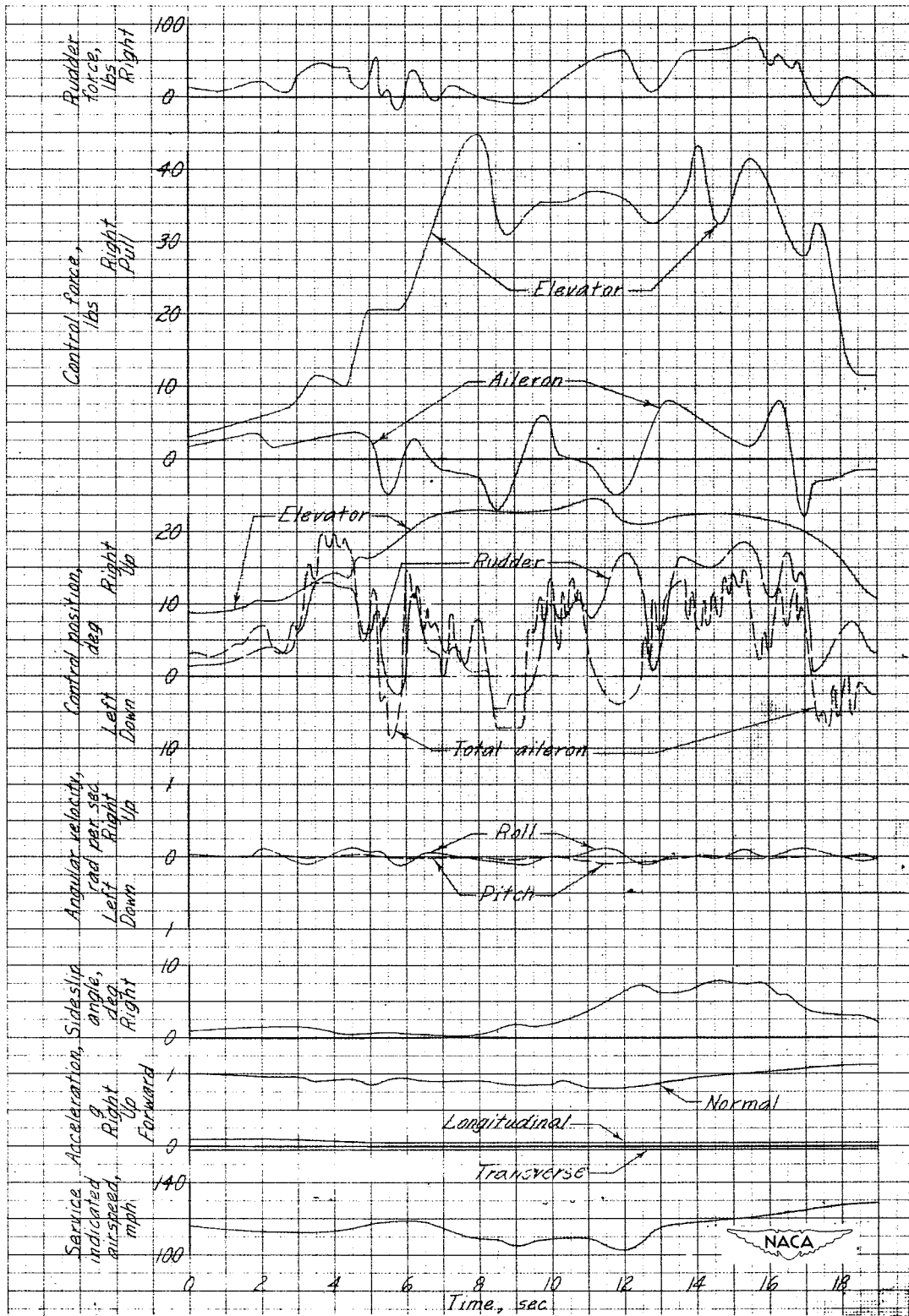
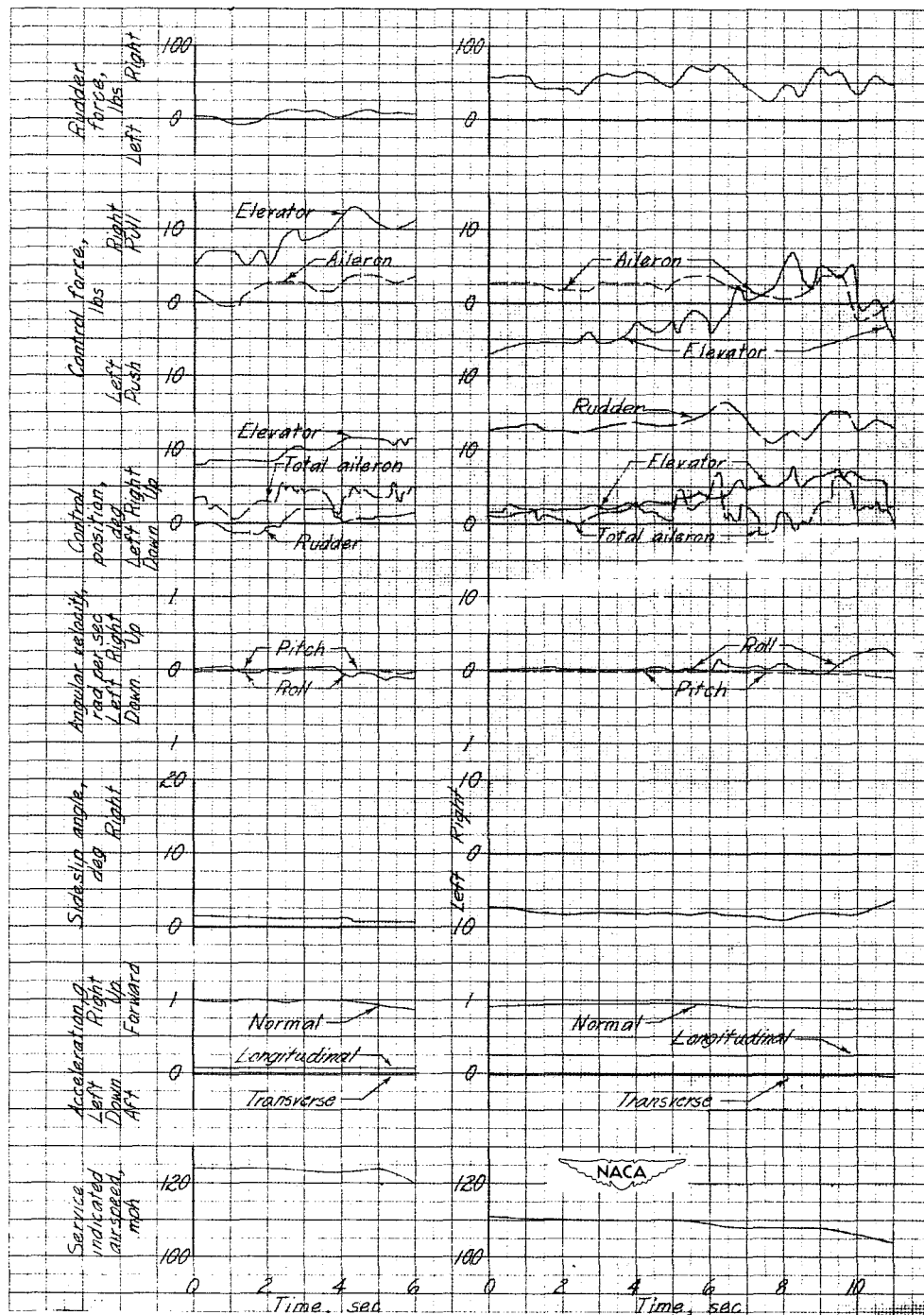


Figure 50.- Time history of a stall approach in the glide condition. All controls used to hold wings level after initial stall; c.g. at 26.3 percent M.A.C.; gr. wt 12,400 pounds; 5000 feet altitude.



(a) Glide condition at 24,000 feet average altitude. Center of gravity 0.264 M.A.C. at 12,770 pounds gross weight.

(b) Power-on clean condition at 26,500 feet average altitude. Center of gravity 0.264 M.A.C. at 12,570 pounds gross weight.

Figure 51.- Time histories of stall approaches, using all controls to hold wings level after initial stall.

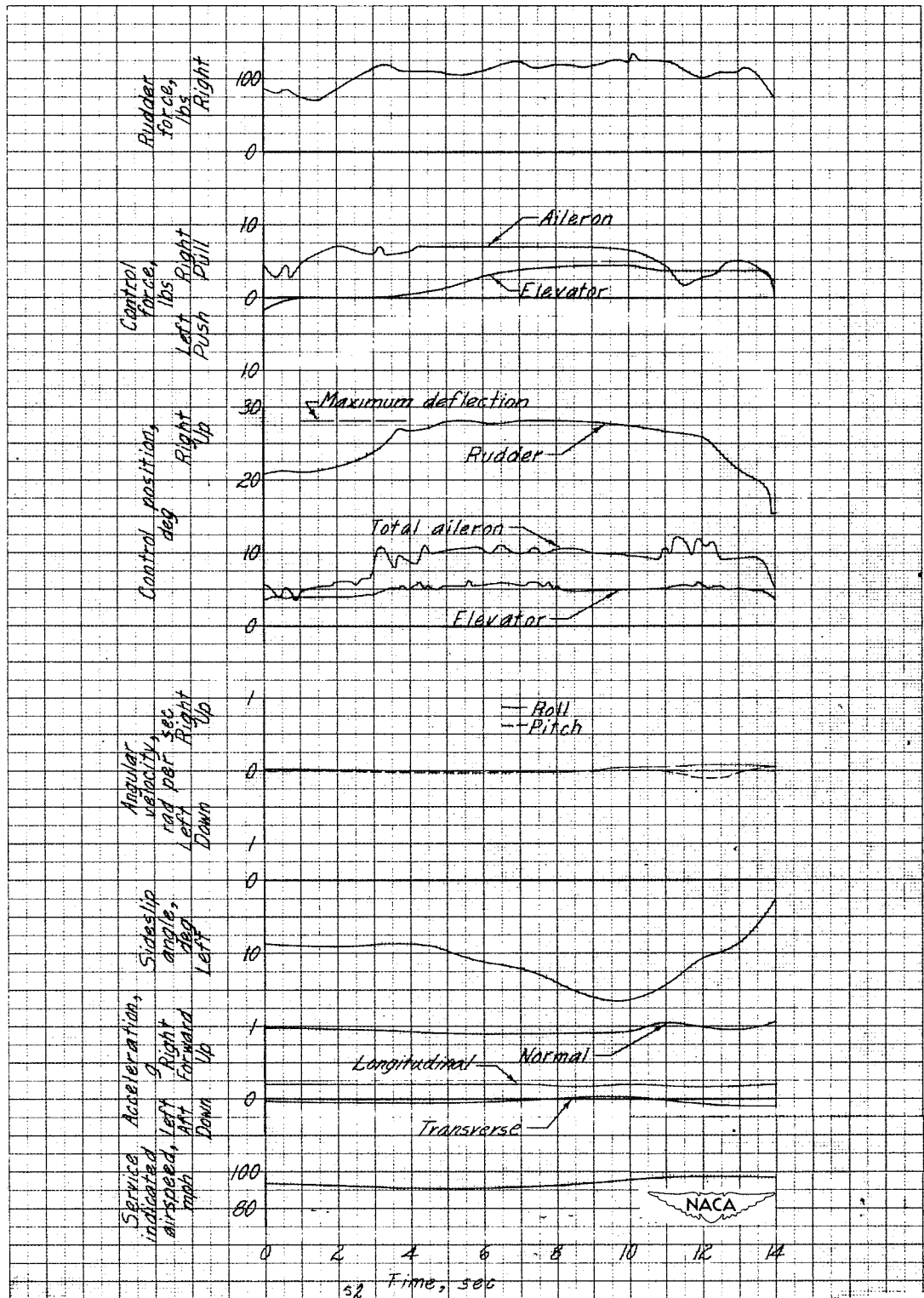


Figure 52.- Time history of a stall approach in the approach condition using elevator alone. Pilot attempted to hold other controls fixed after initial stall; c.g. at 28.9 percent M.A.C.; gr. wt. 12,860 pounds; 5000 feet altitude.

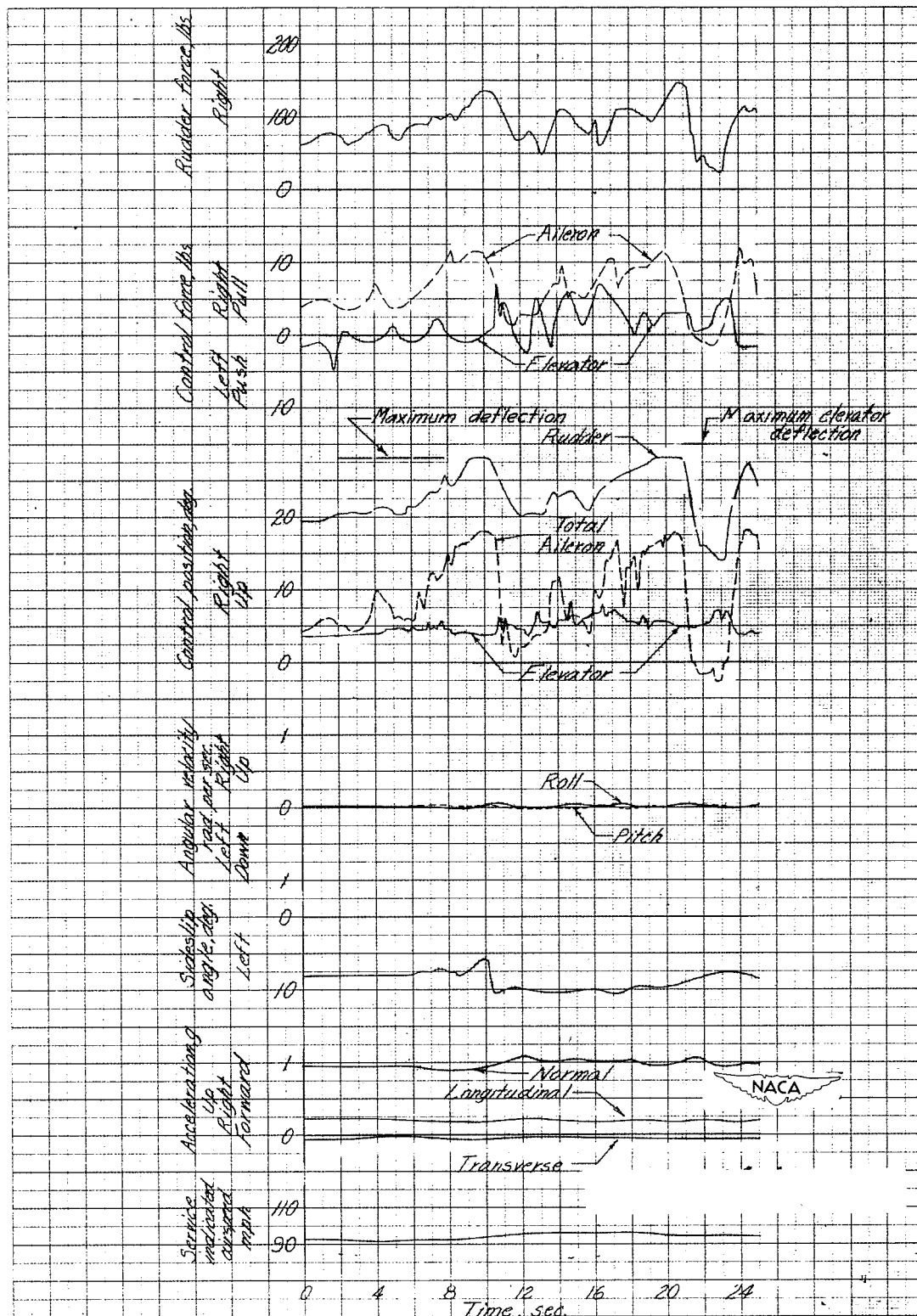


Figure 53.- Time history of a stall approach in the approach condition. All controls used to hold wings level after initial stall; c.g. at 28.9 percent M.A.C.; gr. wt. 12,860 pounds; 5000 feet altitude.

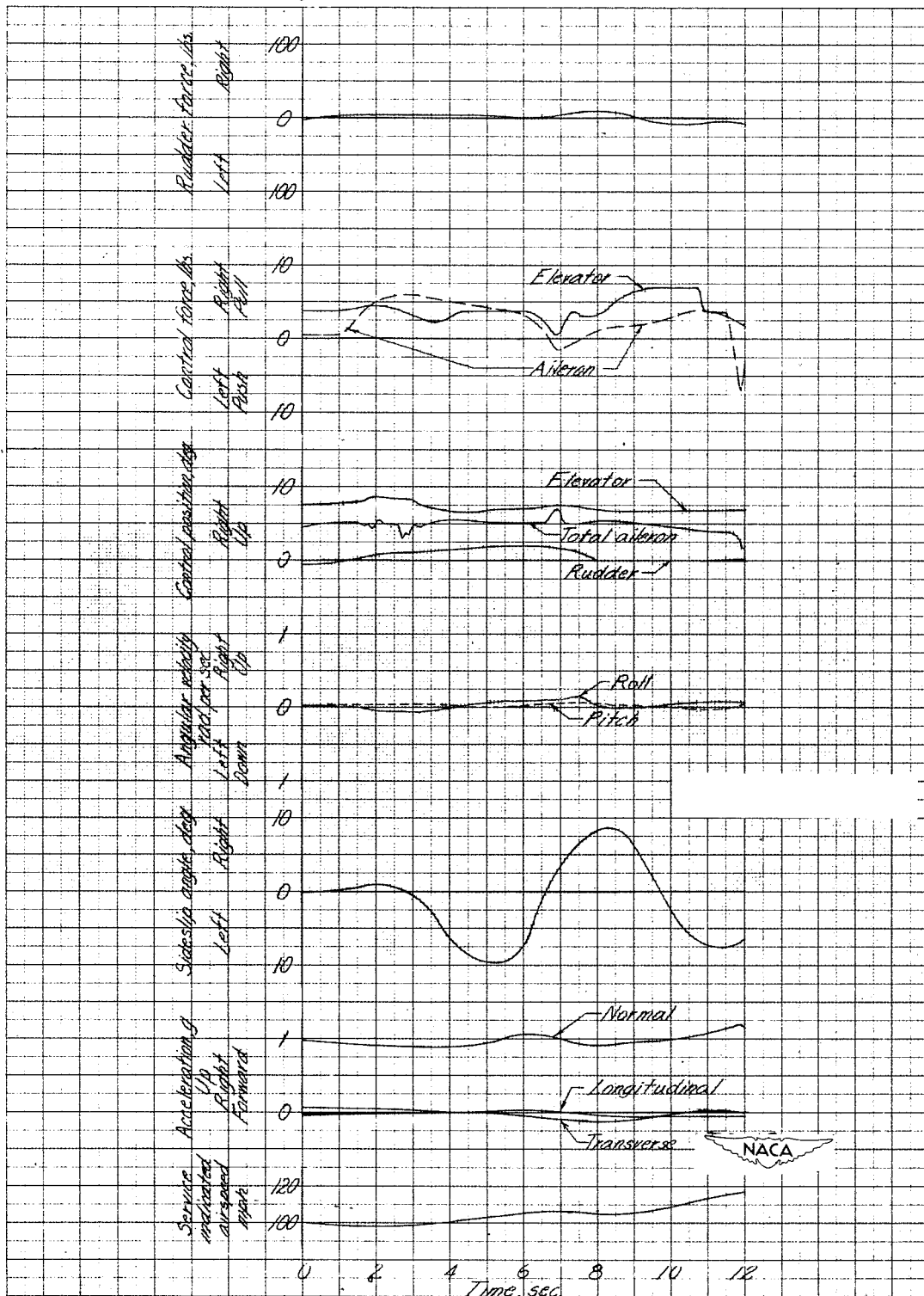


Figure 54.- Time history of a stall approach in the landing condition using elevator alone. Pilot attempted to hold other controls fixed after initial stall; c.g. at 29.0 percent M.A.C.; gr. wt. 13,170 pounds, 5000 feet altitude.

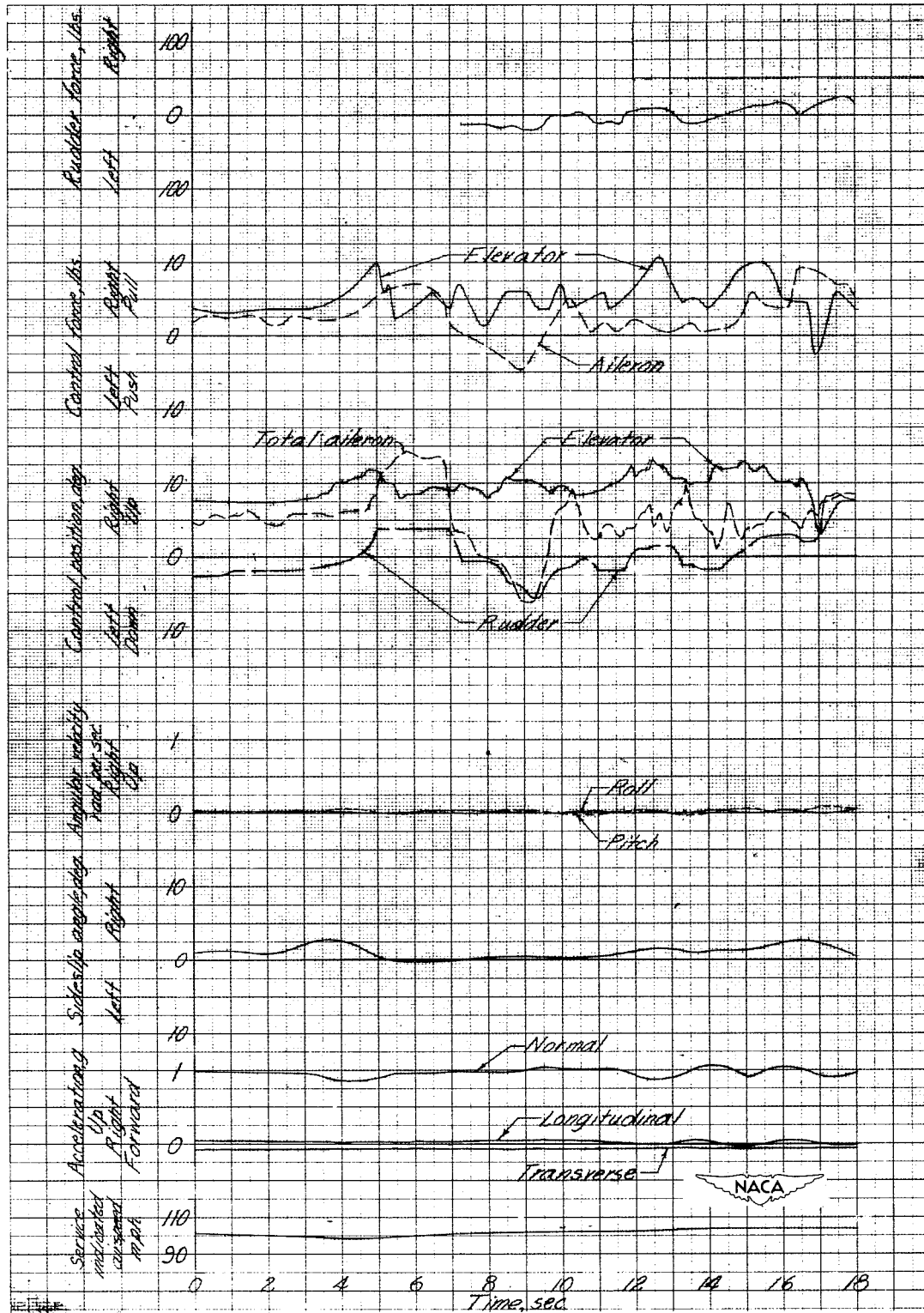


Figure 55.- Time history of a stall approach in the landing condition. All controls used to hold wings level after initial stall; c.g. at 29.0 percent M.A.C.; gr. wt. 13,170 pounds; 5000 feet altitude.

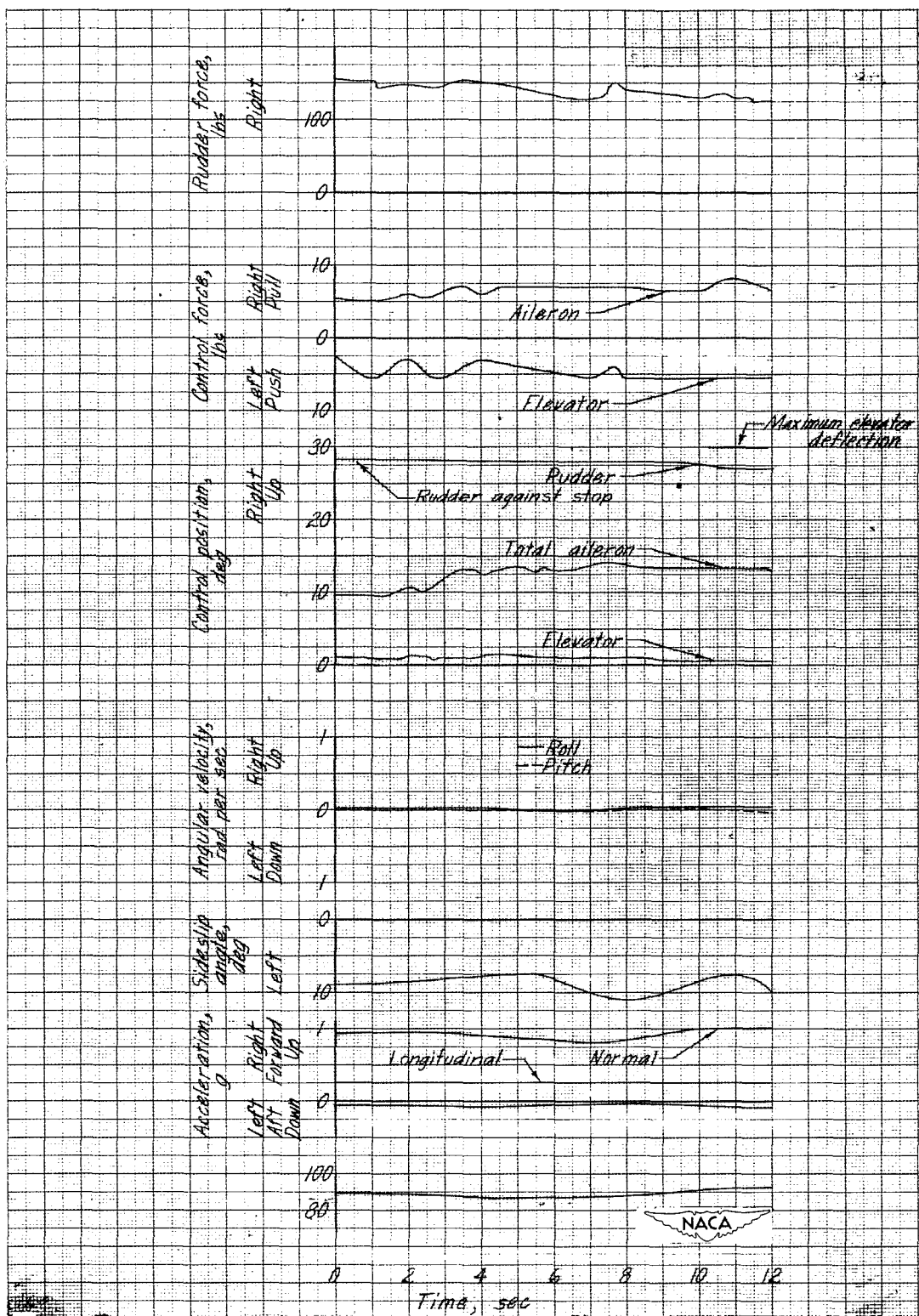


Figure 56.- Time history of a stall approach in the wave-off condition using elevator alone. Pilot attempted to hold other controls fixed. Complete stall was not reached because of insufficient rudder control; c.g. at 28.8 percent M.A.C., gr. wt. 13,210 pounds, 5000 feet altitude.

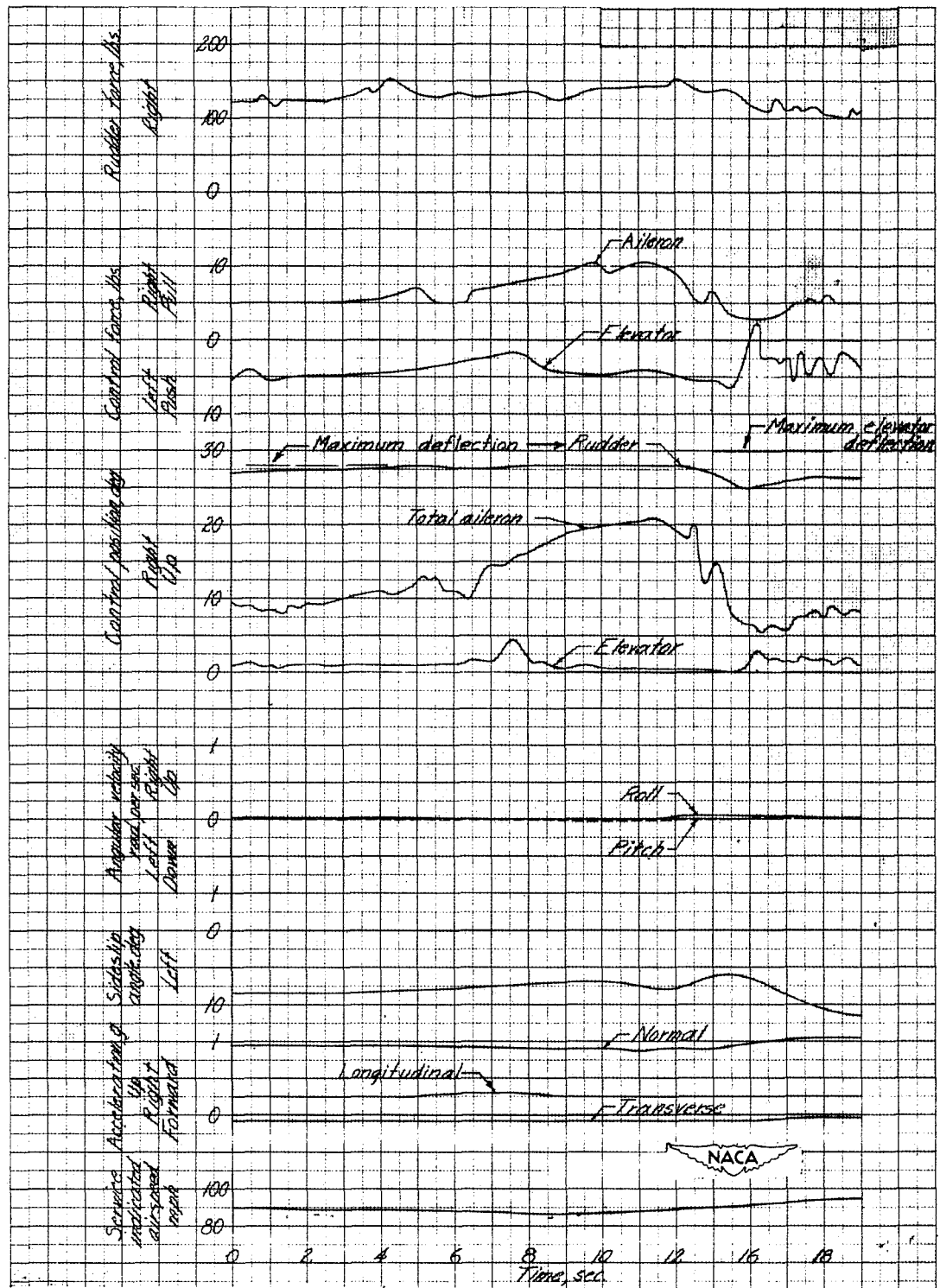


Figure 57.- Time history of a stall approach in the wave-off condition. All controls used to hold wings level after initial stall. Complete stall was not reached because of insufficient rudder control, c.g. at 28.8 percent M.A.C. gr. wt. 13,219 pounds, 5000 feet altitude.



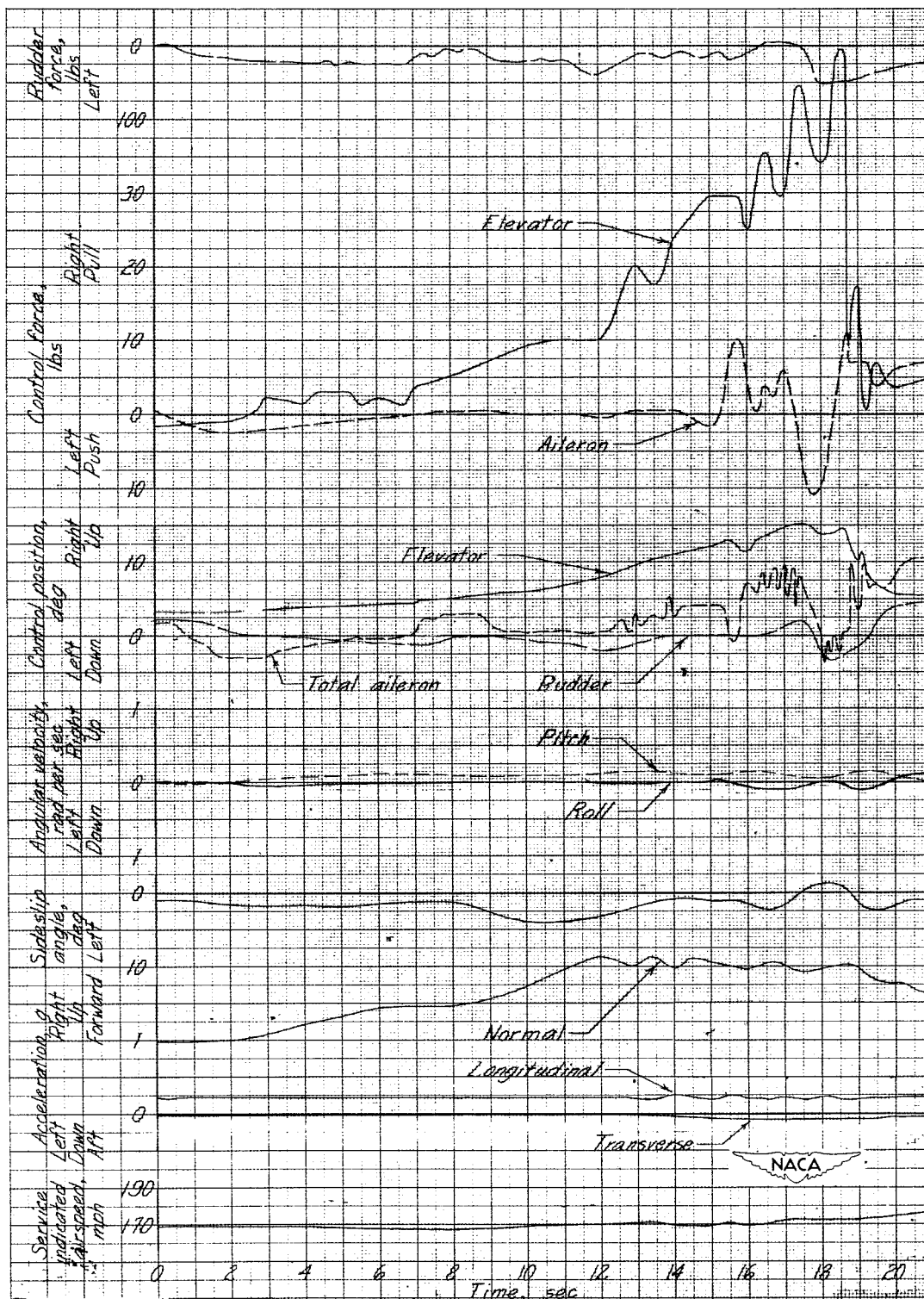


Figure 58.- Time history of a stall approach in a low-speed left turn using elevator alone. Pilot attempts to hold other controls fixed; c.g. at 26.3 percent M.A.C.; gr. wt 12,690 pounds; 5000 feet altitude.

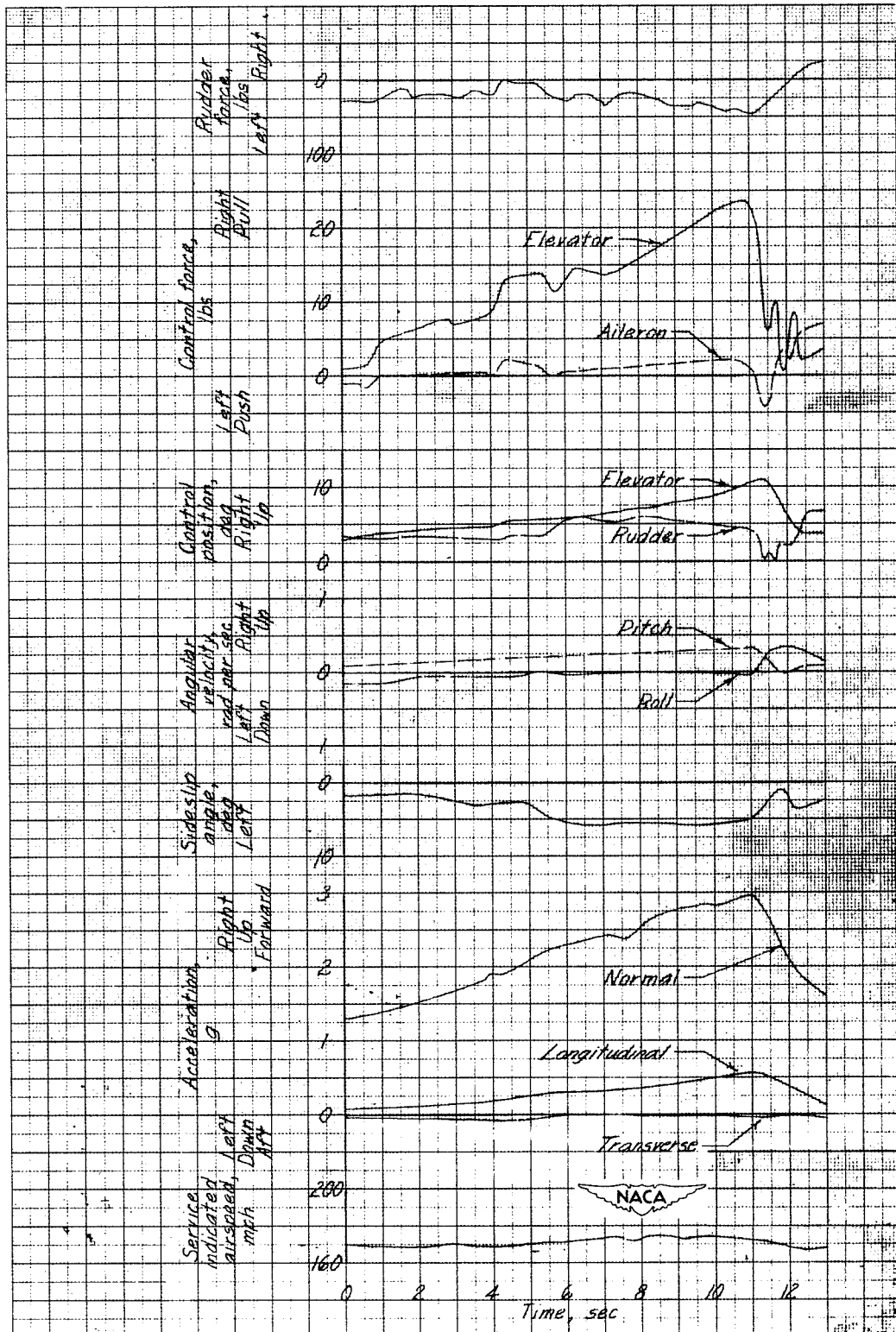


Figure 59.- Time history of a stall approach in a wind-up left turn in the landing condition using elevator alone to produce stall. Pilot attempted to hold other controls fixed; c.g. at 26.4 percent M.A.C.; gr. wt. 12,680 pounds, 5000 feet altitude.