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FLIGHT MEASUREMENTS OF THE FLYING QUALITIES OF AN F6F-3 AIRPLANE (BUAER NO. 04776)

I - LONGITUDINAL STABILITY AND CONTROL

By Walter C. Williams and John P. Reeder

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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NACA

WASHINGTON

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

FLIGHT MEASUREMENTS OF THE FLYING QUALITIES OF AN F6F-3 AIRPLANE (BUAER NO. 04776)

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INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, flight measurements were made of the handling qualities of an F6F-3 airplane. Thirty flights were made covering the period from February 1 to May 15, 1944. This test program was conducted at the Langley Field laboratory of the NACA. The present paper gives results of tests made to determine the longitudinal stability and control of the subject airplane. The remaining portion of the investigation, which includes the lateral and directional stability and control and the stalling characteristics, will be covered in two later reports.

AIRPLANE

The F6F-3 is a single-engine, single-place, low-wing fighter-type monoplane. Figures 1, 2, and 3 are general views of the subject airplane. A three-view drawing is given in figure 4. Pertinent details and dimensions of the F6F-3 airplane are as follows:

Name and type	Grumman F6F-3
Engine	Pratt & Whitney R-2800-10
Rating:	
Take-off, hp	2000
Maximum continuous, hp	1675
Military	1650 hp at 25,000 ft

Supercharger (two-speed, two-stage):	
Main stage blower ratio	7.8:1
Low blower ratio	6.46:1
High blower ratio	7.93:1
Propeller	Hamilton Standard Hydomatic
Diameter	13 ft 1 in.
Number of blades	3
Gear ratio	2:1
Fuel capacity, gal	250
Oil capacity, gal	19
Weights as flown for tests:	
c.g. at 24.4 percent (wheels up), lb	10,600 (at take-off)
c.g. at 28.5 percent (wheels up), lb	11,300 (at take-off)
c.g. at 31.2 percent (wheels up), lb	11,500 (at take-off)
Service loading:	
Normal fighter, c.g. at 25 percent M.A.C. (wheels up), lb	11,364
Overload fighter, c.g. at 26.1 percent M.A.C. (wheels up), lb	12,153
Wing:	
Span, ft	42.833
Area (including ailerons and section through fuselage) sq ft	334
Airfoil section root	NACA 23015.6 (modified)
Airfoil section tip	NACA 23009
Aspect ratio	5.5
M.A.C., in.	97.4
L.E. M.A.C. aft L.E. station 75, in.	3.7
Taper ratio	2:1
Dihedral (from station 75 to tip), deg	$7\frac{1}{2}$
Incidence from thrust axis, deg	3
Wing flaps (NACA slotted):	
Area, sq ft	39.8
Span, ft	12.17
Deflection, under no load, deg	50
(For deflection under aerodynamic loads see following description)	
Ailerons:	
Span, ft	6.375
Area (aft hinge line), each, sq ft	7.84
Area (forward hinge line), each, sq ft	2.72
Aileron chord, percent wing chord	20
Inboard end of aileron from ℄ of airplane, percent semispan	64

Horizontal tail:	
Span, ft	18.5
Area, sq ft	77.84
Incidence from thrust axis, L.E. up, deg	3
Stabilizer area, sq ft	43.74
Elevator area (aft hinge line including tab), sq ft	25.78
Elevator balance area, sq ft	8.32
Elevator trim-tab area, each, sq ft	1.0
Vertical tail	
Area, sq ft	23.4
Offset from thrust axis, deg	0
Fin area, sq ft	12.5
Rudder area (aft hinge line including tab), sq ft	9.0
Rudder horn-balance area, sq ft	0.676
Rudder trim-tab area, sq ft	0.62

The flaps on the subject airplane are of particular interest. The flaps are in four segments, as shown in figure 4. These flap segments are not interconnected. Figure 5 shows the position of the flaps when deflected under no load. The flaps are spring-loaded, however, and under aerodynamic loads each segment rotates independently about the hinge axis as shown in figure 5.

During the present tests, no machine guns were installed and the gun ports were closed by means of metal plates as can be seen in figure 2.

The relation between elevator deflection and stick position is shown in figure 6. The elevator angles as used in this report are in degrees from the thrust axis. The stabilizer incidence relative to the thrust axis is 3°. Elevator trim-tab angles are given in degrees from the elevator. A section of the elevator at a station 60 inches from the airplane center line is shown in figure 7. The elevator was fabric-covered and the bevel at the trailing edge was caused by the trailing-edge strip not fairing with the fabric. The bevel was not consistent along the trailing edge. The product of the span and chord squared, on which elevator hinge-moment coefficients presented herein are based, is 39.31 feet^3. The friction in the elevator system was approximately $\pm 1\frac{1}{2}$ pound measured at the stick with the control near neutral.

INSTRUMENTATION

Standard NACA photographically recording instruments were used to measure the various quantities necessary to determine the flying qualities of the subject airplane. The records were synchronized by means of a timer. The instruments used and the quantities measured follow.

Recording instrument	Quantity measured
Airspeed recorder	Indicated airspeed
Three-component accelerometer	Normal, longitudinal, and transverse acceleration
Roll turn meter	Rolling velocity
Pitch turn meter	Pitching velocity
Yaw turn meter	Yawing velocity
Inclinometer	Angle of bank
Yaw-angle recorder	Sideslip angle
Stick-force recorder	Aileron and elevator stick force
Pedal-force recorder	Rudder pedal force
Control-position recorder	Aileron, elevator, rudder and landing flap position (measured at the surface)
Timer	Time

The yaw vane used with the yaw-angle recorder was mounted one chord length ahead of the right wing tip. Indicated airspeed was measured with a swiveling static head and a shielded total head mounted one chord length ahead of the left wing tip. The airspeed used throughout this report, called service indicated airspeed, is the reading of a standard Army-Navy airspeed meter connected to a pitot static head that is free from position error and is defined by the formula:

$$V_{i_s} = 45.08\ f_c\sqrt{q_c}$$

where

V_{i_s} service indicated airspeed, miles per hour

f_o standard sea-level compressibility correction factor

q_c measured difference between total and static pressures with the static pressure corrected for position error, inches of water

The position error of the static head was determined at low speeds by flying in formation with an airplane which had the airspeed measuring system calibrated with a trailing bomb. The position error at high speeds was determined in a fly-by calibration as described in reference 1.

TESTS

The airplane was flown at center-of-gravity positions ranging from 24.4 to 31.2 percent mean aerodynamic chord, wheels up, and 21.8 to 28.75 percent mean aerodynamic chord, wheels down. The gross weight at take-off ranged from 10,600 to 11,500 pounds.

The flight conditions used in the tests are defined below.

Condition	Flaps	Landing gear	Canopy	Cowl flaps	Oil and intercooler shutters	RPM	Manifold pressure (in. Hg)
Gliding	Up	Up	Closed	Closed	Closed	Engine idling	
Climbing	Up	Up	Closed	Closed	Closed	2550	43
Landing	Down	Down	Open	Closed	Closed	Engine idling	
Approach	Down	Down	Open	Closed	Closed	2550	23
Wave-off	Down	Down	Open	Open	Open	2550	43

RESULTS AND DISCUSSION

The results are presented and analyzed in the order given in reference 2 with mention made of the specific requirements of reference 3.

I. Longitudinal Stability and Control

I-A. Characteristics of uncontrolled longitudinal motion

The characteristics of the uncontrolled longitudinal motion were investigated at various speeds in the climbing and gliding conditions with the center of gravity at 31.2 percent mean aerodynamic chord. In these tests the pilot trimmed the airplane at a given speed and abruptly deflected and released the elevator control. In the present case, all short-period oscillations damped completely within one cycle. Typical time histories of this maneuver are given in figure 8 for the gliding condition and figure 9 for the climbing condition.

I-B. Characteristics of elevator control in steady flight

The characteristics of elevator control in steady flight were obtained by measuring the elevator angle and force required to trim at various speeds through the speed range at three center-of-gravity positions in each of the various flight conditions. The table below lists the flight conditions, center-of-gravity positions, and figures in which the experimental data are presented.

Condition	Center-of-gravity position (percent M.A.C.)	Figure no.
Gliding	24.4, 28.5, and 31.2	10
Climbing	24.4, 28.5, and 31.2	10
Landing	21.8, 26.5, and 28.75	11(a)
Approach	21.8, 26.5, and 28.75	11(b)
Wave-off	21.8, 26.5, and 28.75	11(c)

At a later date, tests were made to determine the blow-up characteristics of the landing flaps with speed. As mentioned heretofore, the landing flaps were spring-loaded so that the deflection varied with speed. This system is probably used on the F6F-3 to avoid inadvertent excessive loading of the flaps as speed is increased with the flaps down. The blow-up characteristics were obtained in tests similar to those described above and the results are shown in figures 12 and 13 as the variation of the deflection of the four flap segments with service indicated airspeed. Figure 12 gives data obtained in the landing condition and data for the wave-off condition are shown in figure 13.

The data presented in figures 10 and 11 were evaluated to determine the stick-fixed and stick-free neutral points in the various flight configurations by the following methods. Plots were made of the variation of elevator angle and of elevator stick force divided by impact pressure (F/q_c) with C_L. Lift coefficient as used herein is defined by the expression $C_L = \frac{Wa_n}{Sq}$ and is actually normal-force coefficient. The difference between normal-force coefficient and lift coefficient, however, is small. A typical plot is shown in figure 11 which applies to the gliding condition. The slopes of these curves were taken at representative values of lift coefficient and were plotted as a function of center-of-gravity position, as shown in figure 15 for the gliding condition. The stick-fixed and stick-free neutral points are the center-of-gravity positions at which $\frac{d\delta_e}{dC_L}$ and $\frac{d(F/q_c)}{dC_L}$, respectively, are zero. This procedure was followed for the other flight conditions. The values of neutral points thus obtained are plotted as a function of airplane lift coefficient in figure 16 for the climbing and gliding conditions and in figure 17 for the landing, approach, and wave-off conditions.

The following facts regarding the static longitudinal stability of the F6F-3 airplane are shown by figures 10 to 17.

(a) The stick-fixed neutral point in the gliding condition varied from 36 percent mean aerodynamic chord at a lift coefficient of 0.2 to 39 percent mean aerodynamic chord at a lift coefficient of 1.0. Application of rated power (climbing condition) had a destabilizing effect above a lift coefficient of 0.4 which increased with increases in lift coefficient. At lift coefficients below 0.4, application of power had a small but stabilizing effect on the airplane.

(b) The stick-fixed neutral point in the landing condition varied from 35 percent mean aerodynamic chord at a lift coefficient of 0.8 to 37 percent mean aerodynamic chord at a lift coefficient of 1.4. Application of power with flaps down, as with flaps up at the higher values of lift coefficient, had an appreciable destabilizing effect. The wave-off condition was the least stable condition tested.

(c) Requirement D-6 of reference 3 specifies that the stick-fixed stability should be such that, in the gliding and landing conditions, the movement of the top of the control stick shall not be less than 4 inches in trimming from the maximum level-flight speed to stalling speed. The present data show that the F6F-3 airplane will meet this requirement when the center of gravity is located forward of 31 percent mean aerodynamic chord in the gliding condition and forward of 26 percent mean aerodynamic chord in the landing condition. The values of maximum speed used were 275 miles per hour and 150 miles per hour for the gliding and landing condition, respectively. Requirement D-6 (reference 3) also specifies that there shall not be less than 1-inch stick motion in going from the speed for minimum power to the stall in either the landing or gliding condition. This latter requirement will be met by the F6F-3 within the center-of-gravity range tested.

(d) The stability with stick free was less than with stick fixed. The difference between stick-fixed and stick-free neutral points increased with increase in lift coefficient.

(e) The elevator control was such that it was possible to maintain steady flight at the minimum and maximum speeds required of the airplane.

(f) The blow-up of the flaps did not cause any adverse effects on the longitudinal control of the airplane and was not apparent to the pilot.

I-C. Characteristics of the elevator control in accelerated flight

The characteristics of the elevator control in accelerated flight were obtained by measuring elevator angle, elevator stick force, normal acceleration, and airspeed in turns during which the pilot held a constant value of acceleration, allowing the airspeed to decrease until the airplane stalled. Right and left turns were made at approximately 1 g, 2g, 3g, and 4 g increments. Typical time histories of these turns are shown in figures 18 and 19. Measurements were made at three center-of-gravity positions (24.4, 28.5, and 31.2 percent mean aerodynamic chord) at 8000 feet pressure altitude and in addition, with the center of gravity at 24.4 percent mean aerodynamic chord, measurements were made at 3000, 15,000, and 20,000 feet pressure altitude. In evaluating the data obtained in these turns, measurements from right and left turns were plotted up separately. Figure 20 gives the change in elevator stick force as a function of change in normal acceleration for the three center-of-gravity positions tested at constant pressure altitude (8000 feet). Most of the data cover the speed range from 170 to 230 miles per hour and incremental accelerations up to 3 g. As mentioned above, some turns were made to higher accelerations at higher speeds, but these turns were rather rough and yielded only a few test points as can be seen in figure 20. The variation of elevator angle with airplane lift coefficient at various values of normal acceleration is shown in figure 21 for the three center-of-gravity positions tested. Figures 22 and 23 present the data obtained in turns made at several altitudes with the center of gravity at 24.4 percent mean aerodynamic chord. From these data the stability criterions, stick force per unit acceleration and change in elevator angle with lift coefficient were determined. Values of dF_e/da_n were determined for a 3 g increment in normal acceleration or a 4 g turn. The same range of acceleration increment was used in obtaining $d\delta_e/dC_L$. In determining $d\delta_e/dC_L$, values of lift coefficient equivalent to 200 miles per hour were determined at each value of acceleration and points thus obtained were connected with a straight line. These lines of constant speed are indicated in figures 21 and 23. The slopes of these lines were taken as the values of $d\delta_e/dC_L$. The values of these stability criterions, dF_e/da_n and $d\delta_e/dC_L$, were plotted as functions of center-of-gravity position in figure 24 in order to determine the stick-fixed and stick-free maneuver point. The effects of altitude are shown in figure 25 where the stability criterions are plotted as a function of pressure altitude. From the curves of figures 24 and 25, figure 26 was prepared which gives the variation with altitude of the range of center-of-gravity positions which give satisfactory values of stick force per g, 3 to 8 pounds per g (references 2 and 3). Data are shown on this figure for right and left turns, and the double cross-hatched area gives the ranges over which the control forces will be satisfactory in both left and right turns. From the data presented in figures 18 to 26, the following conclusions can be made regarding the elevator control of the F6F-3 airplane in accelerated flight.

(a) By use of the elevator control alone, it was possible to develop the maximum lift coefficient of the airplane in maneuvers. No attempt was made to develop the allowable load factor.

(b) The variation of elevator angle with lift coefficient was a smooth curve having a stable slope for all center-of-gravity positions and altitudes tested.

(c) The values of $d\delta_e/dC_L$ and dF_e/da_n were higher in right turns than left turns. The stick-free and stick-fixed maneuver point, however, seemed to be approximately the same in right turns and left turns. The difference between left and right turns would be expected to be caused by the gyroscopic moment of the propeller. The effect of the gyroscopic moment of the propeller, however, should be independent of the center-of-gravity position.

(d) The F6F-3 will satisfy the requirement of reference 2 that the slope of the elevator-angle curve should be such that not less than 4 inches of rearward stick movement is required to change the angle of attack from C_L of 0.2 to $C_{L_{max}}$ in accelerated flight when the center of gravity is ahead of 28.1 percent mean aerodynamic chord at 3000 feet or ahead of 24.6 percent mean aerodynamic chord at 20,000 feet.

(e) The F6F-3 airplane will have the desired stick force per g (3 to 8 pounds per g requirement D-4, reference 3) in right and left turns at 3000 feet pressure altitude when the center of gravity is between 29.9 and 33.2 percent mean aerodynamic chord. The desirable center-of-gravity range at 20,000 feet altitude lies between 26.6 and 30.5 percent mean aerodynamic chord (see fig. 26).

From the data presented above, it was possible to determine the elevator hinge-moment coefficients, Ch_{α} and Ch_{δ}, of the F6F-3 airplane. The values were -0.0011 and -0.0036, respectively. These values are based on free-stream dynamic pressure. These elevator hinge-moment coefficients compare favorably with those of the well-balanced elevators that have been tested on other airplanes. It is interesting to note that, even though the variation of stick force per g with center-of-gravity position in steady turns was rather low (approximately 1 pound per g per percent), the stick-force characteristics in abrupt maneuvers were completely satisfactory (see figs. 8 and 9).

I-D. Characteristics of the elevator control in landing

The characteristics of the elevator control in landing were determined by measuring the elevator deflection required to produce three-point contact in landings made at three center-of-gravity positions with the engine idling and flaps full down. The results of these tests are given in figure 27 where the elevator deflections required to land are plotted as a function of center-of-gravity positions. Figure 28 gives a time history of a typical three-point landing. The rudder pedal forces shown in this figure, as well as in the time history of a take-off presented below, are actually the forces used to obtain the rudder deflections shown as the pilot did not use the brake during the take-off or landing runs. From the data obtained in the landing tests, the following can be concluded:

(a) The elevator of the F6F-3 airplane was sufficiently powerful to perform a three-point landing at the most forward center-of-gravity position tested. This center-of-gravity position

(21.8 percent mean aerodynamic chord), however, is approximately the forward limit in getting the tail down for three-point contacts.

(b) The elevator forces of the F6F-3 airplane in landing did not exceed the allowable force of 35 pounds (reference 3) at the center-of-gravity positions tested.

The pilots considered the F6F-3 airplane very easy to land. The rate of descent and glide-path angle in power-off approaches were reasonable. Visibility was such during the approach that the pilots had no difficulty in lining up on the runway. Once on the ground, the airplane was easily controllable.

I-E. Characteristics of the elevator control in take-off

No quantitative measurements were made of the elevator control in take-off. The pilots reported, however, that the elevator power at even the rearmost center of gravity tested was such that the tail could be raised almost as soon as the airplane started rolling. A time history of a typical tail-high take-off is shown in figure 29. As mentioned before, the pilot did not use the brakes, but was able to keep the airplane straight using the rudder alone.

I-F. Trim changes due to power and flaps

The trim changes caused by changes in flight configuration were measured at a speed of approximately 107 miles per hour with the center of gravity at 24.4 percent mean aerodynamic chord wheels up or 21.8 percent mean aerodynamic chord wheels down. For these tests the pilot used a given trim-tab setting as the flight configuration was changed and measurements were made of the control forces required to maintain constant speed. The results of these tests are given in table I. The full tail-heavy trim-tab setting given in this table corresponds to trim for landing. As can be seen by inspection of the table, all changes in trim forces were within the specified limit of 35 pounds as stated in references 2 and 3.

I-G. Characteristics of the longitudinal trimming device

The power of the elevator trim tabs was measured at various speeds in the gliding and climbing condition. In these tests, the elevator force required to trim at various speeds was measured with two trim-tab settings. The data obtained are presented in figure 30. These data were used to determine the change in elevator stick force per degree trim-tab deflection. This factor is plotted as a function of speed in figure 31. The change in elevator hinge-moment coefficient per degree trim tab is shown as a function of indicated airspeed in figure 32.

From the data obtained, the following conclusions may be drawn.

(a) The elevator trim tab was adequate to reduce the elevator force to zero throughout the speed range in the climbing and gliding condition.

(b) The elevator stick forces could not be trimmed to zero in the landing condition below 120 miles per hour at the most forward center of gravity used in the tests (see fig. 12(a)).

(c) The propeller slipstream had considerable effect on the effectiveness of the trim tab as can be seen by comparing the change in hinge-moment coefficients for the gliding and climbing condition shown in figure 32.

CONCLUSIONS

In general, the pilots were favorably impressed with the longitudinal stability and control of the F6F-3 airplane. They considered it an easy airplane to fly. The control forces in abrupt and steady maneuvers were satisfactory. Also, the airplane was very easy to land. The results of the tests described herein showed the following details concerning the longitudinal stability and control of the F6F-3 airplane.

1. The short-period longitudinal oscillations of the F6F-3 airplane were completely damped within one cycle.

2. The neutral point (stick fixed) in the gliding condition varied from 36 percent mean aerodynamic chord at a lift coefficient of 0.2 to 39 percent mean aerodynamic chord at a lift coefficient of 1.0. Application of rated power (climbing condition) had a destabilizing effect above a lift coefficient of 0.4 which increased with increase in lift coefficient. In this condition the neutral point was located at 31.5 percent mean aerodynamic chord at a C_L of 1.0. At lift coefficients below 0.4, application of power appeared to have a small stabilizing effect.

3. The use of flaps had a destabilizing effect. The stick-fixed neutral point in the landing condition varied from 35 percent mean aerodynamic chord at a C_L of 0.8 to 37 percent mean aerodynamic chord at a C_L of 1.4. The effects of power and flaps combined to make the wave-off the least stable condition tested.

4. The stability with stick free was less than stick fixed. The difference between stick-free and stick-fixed stability increased with increase in lift coefficient.

5. The stick force per g in maneuvers was satisfactory (3 to 8 pounds per g) at 3000 feet altitude for a center-of-gravity range between 29.9 and 33.2 percent mean aerodynamic chord. The desirable center-of-gravity range at 20,000 feet altitude lies between 26.6 and 30.5 percent mean aerodynamic chord.

6. The elevator provided adequate control in take-off at the most rearward center of gravity tested.

7. The elevator power in landing was sufficient to effect three-point contact with the center of gravity aft of 21.5 percent mean aerodynamic chord.

8. The longitudinal trim changes due to power and flaps were within the specified limits.

9. The elevator trim tab was sufficiently powerful to trim the airplane as desired throughout the speed

range in all flight conditions except below 120 miles per hour in the landing condition.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., February 13, 1945

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2. Gilruth, R. R.: Requirements for Satisfactory Flying Qualities of Airplanes. NACA Rep. No. 755, 1943.

3. Anon.: Specification for Stability and Control Characteristics of Airplanes. SR-119, Bur. Aero., Oct. 1, 1942.

TABLE I

Flight condition	Elevator force	
	Trim tab 14° (full tail heavy)	Trim tab 0°
Landing	3.7 pull	18.0 pull
Approach	8.8 push	13.4 pull
Wave-off	21.5 push	11.8 pull
Gliding	6.3 push	8.0 pull
Climbing	27.2 push	4.3 pull

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Figure 1.- Side view of the F6F-3 airplane.

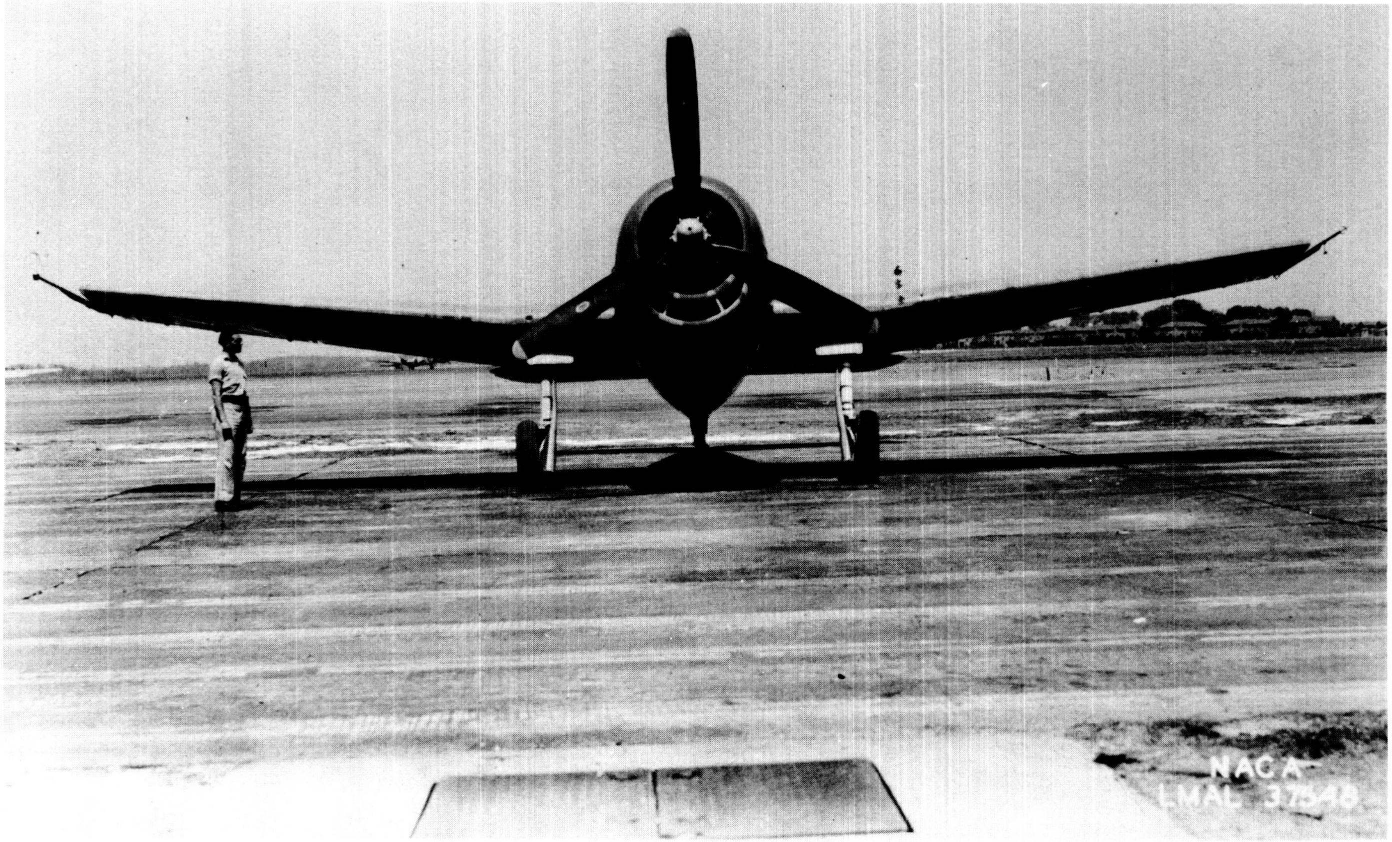

Figure 2.- Front view of the F6F-3 airplane.

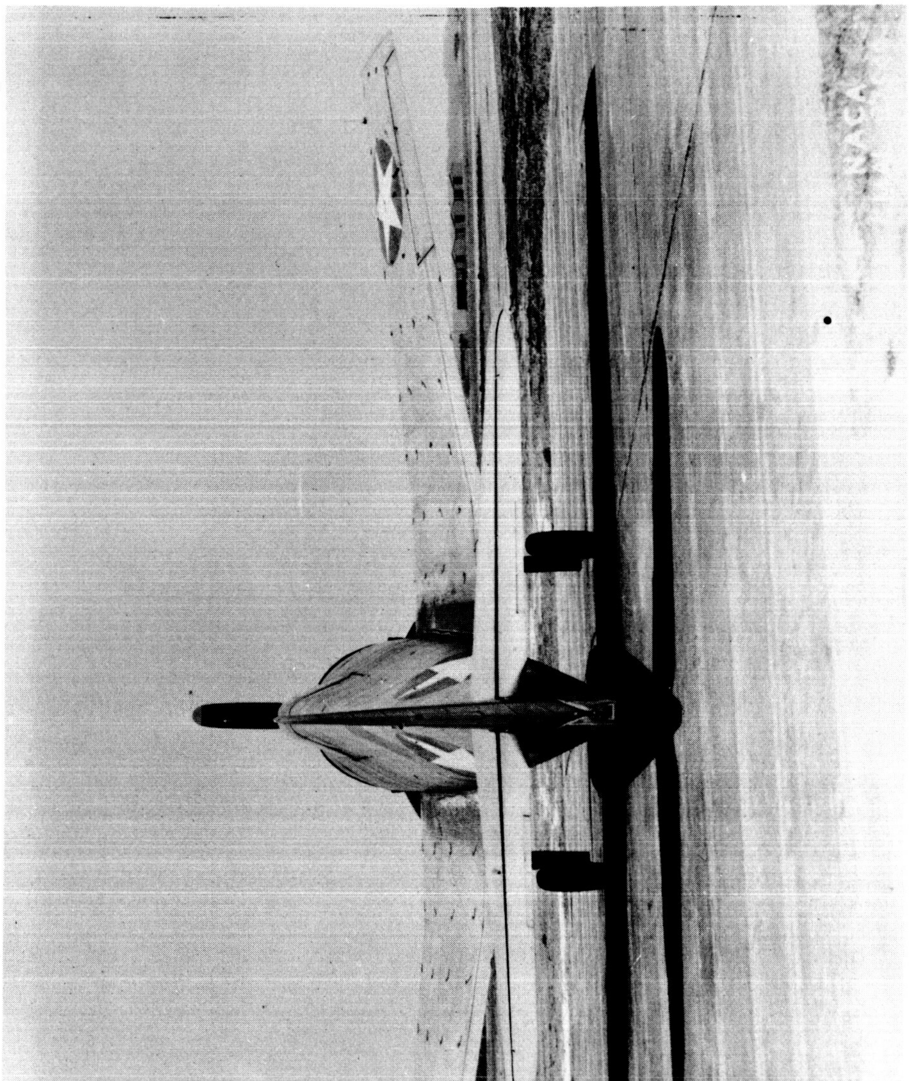

Figure 3.- Rear view of the F6F-3 airplane.

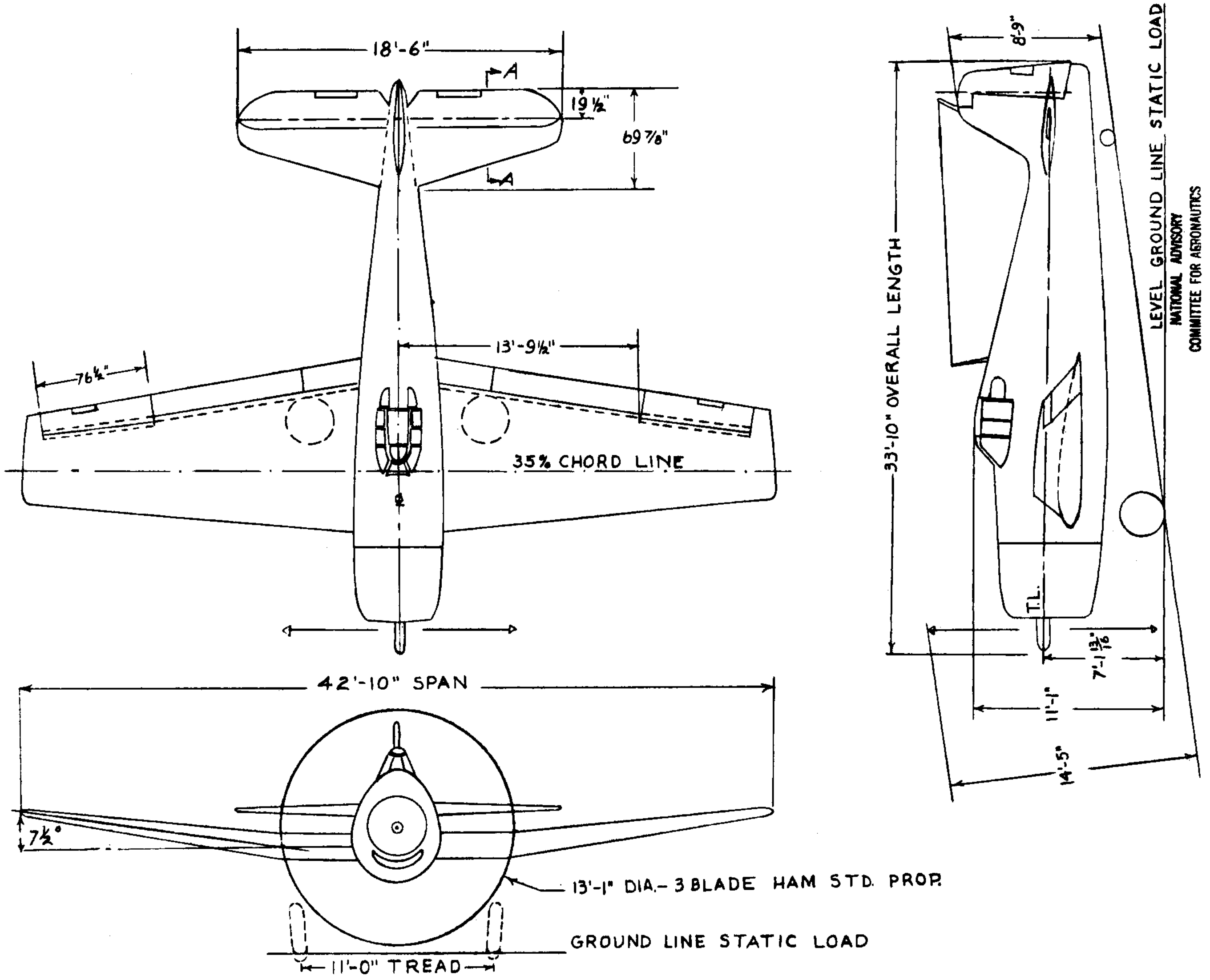

Figure 4. - Three-view layout of the F6F-3 airplane.

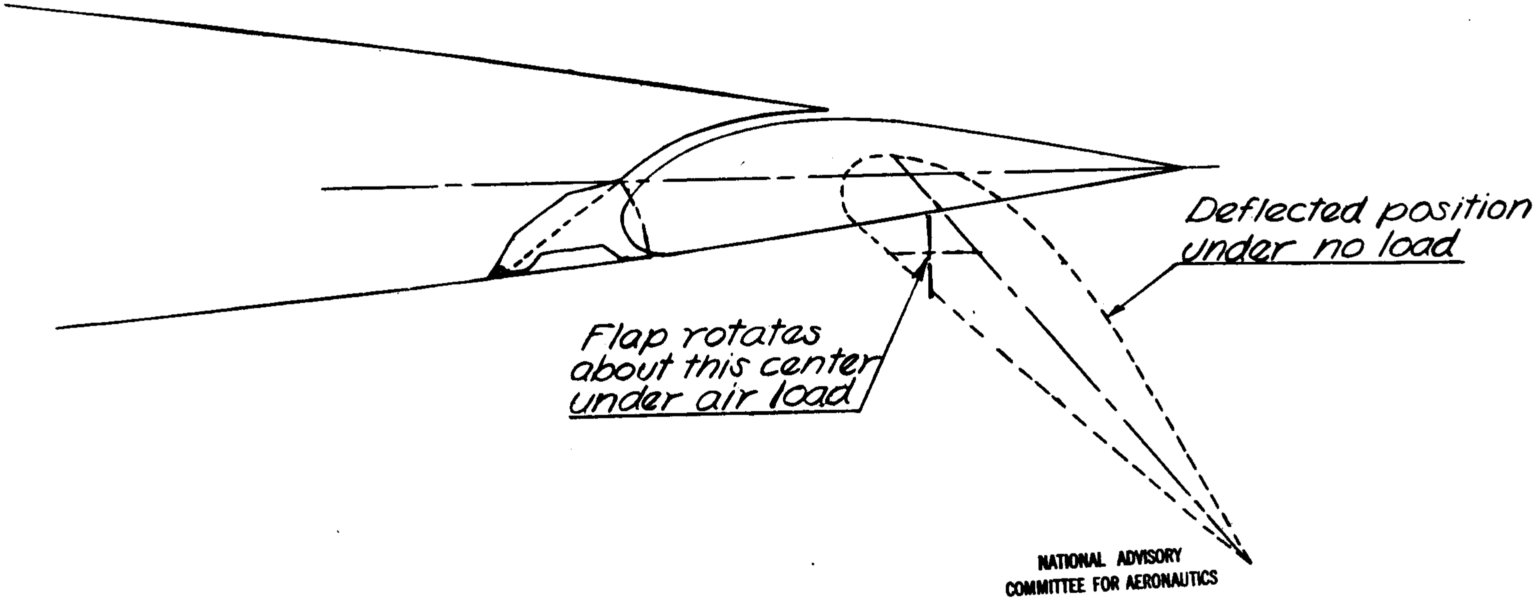

Figure 5. - Schematic sketch of landing flap arrangement, F6F-3 airplane.

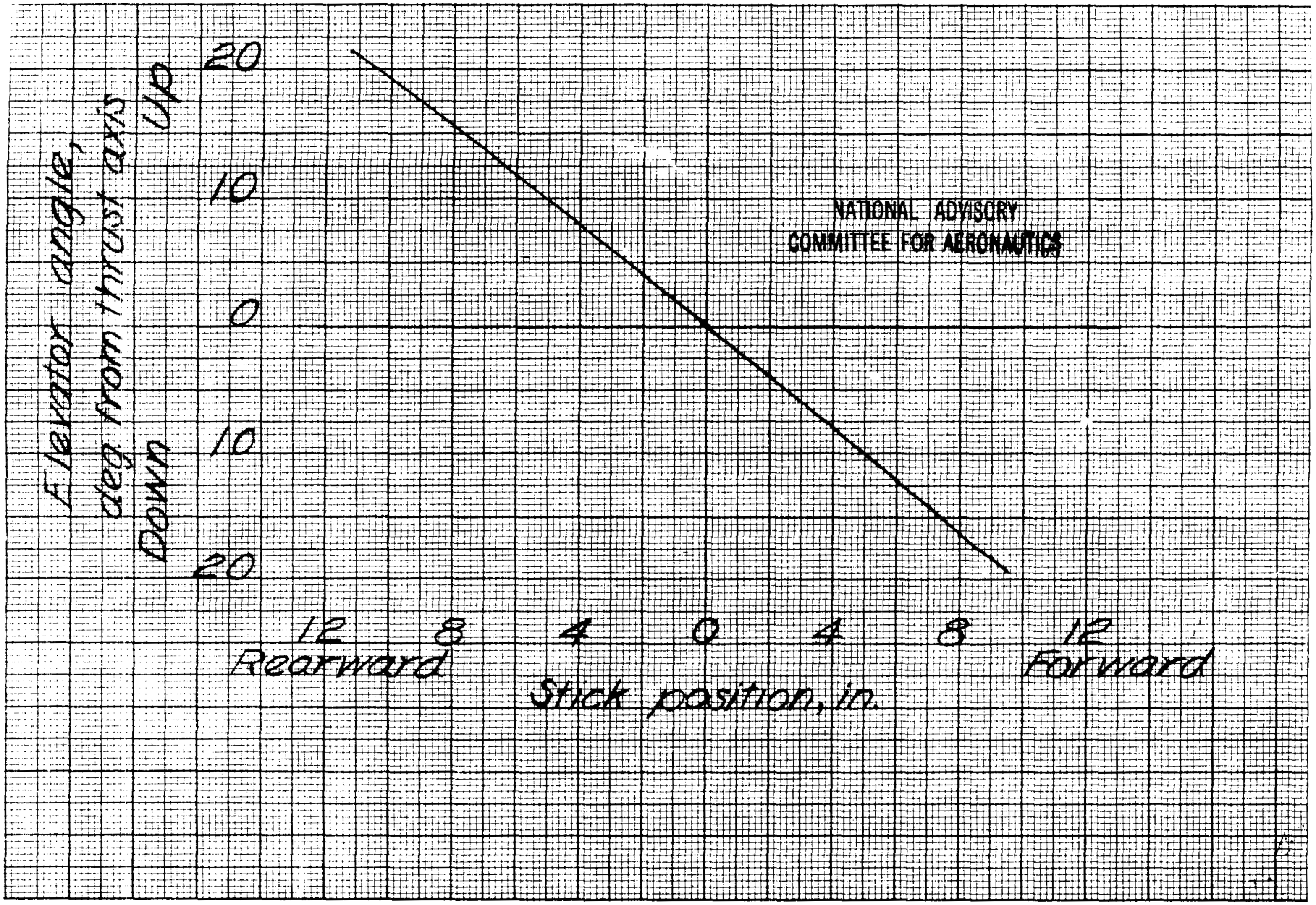

Figure 6. - Relation of elevator deflection and stick position, F6F-3 airplane.

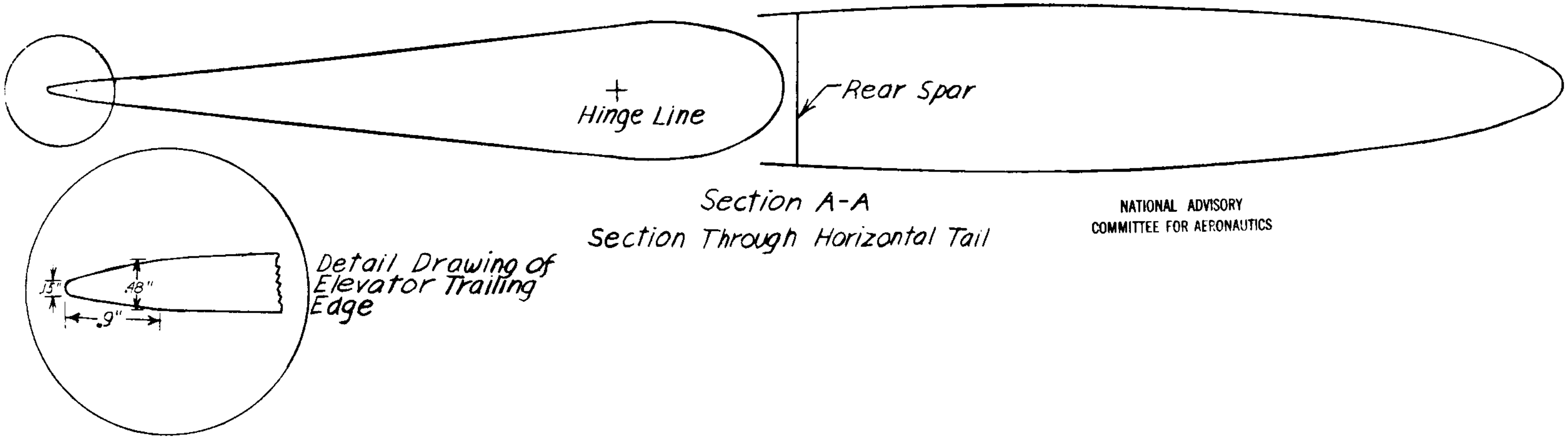

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Figure 7. - Section of horizontal tail at a station 60 inches from the airplane center line, F6F-3 airplane.

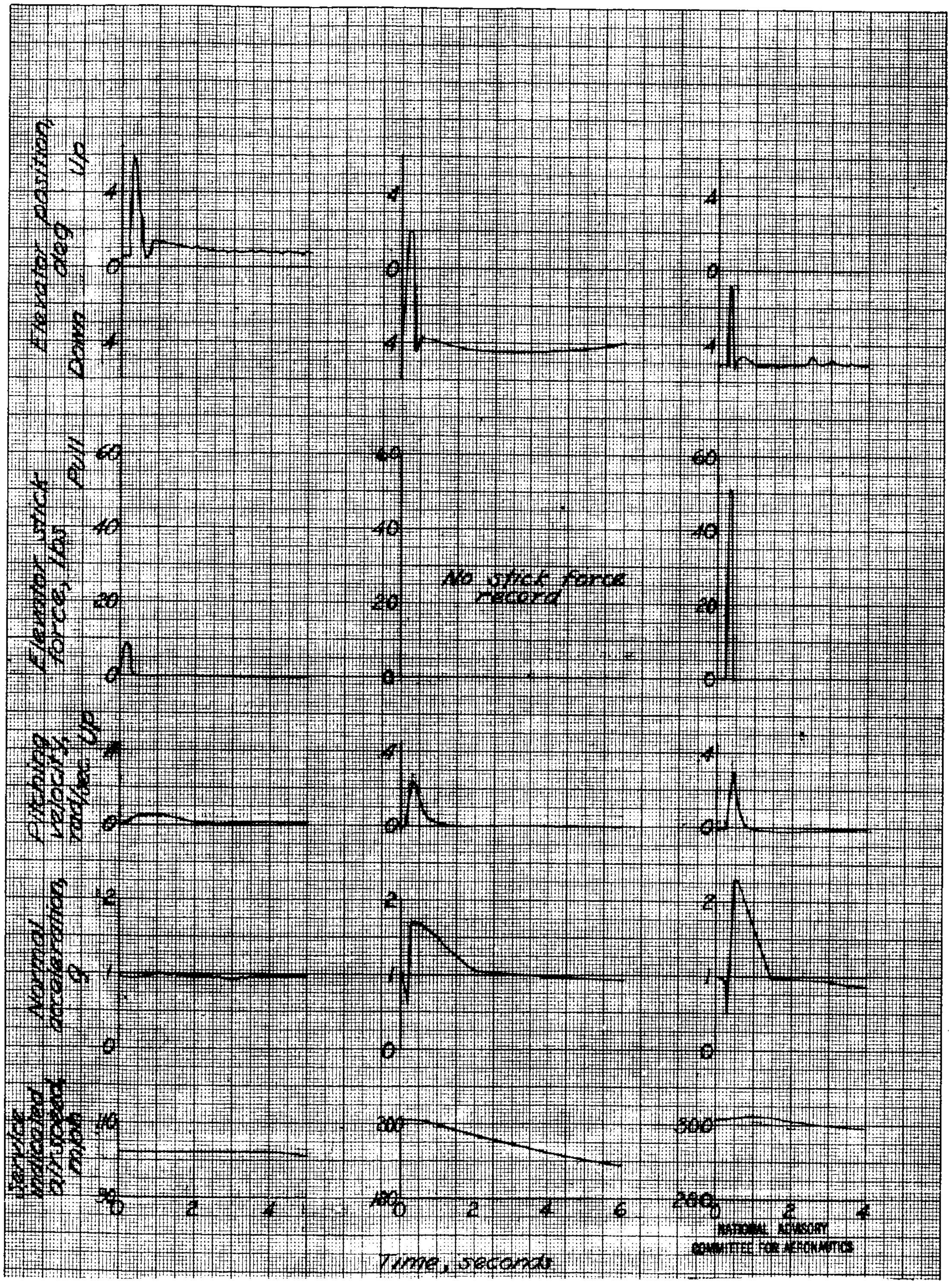

Figure 8. - Typical time histories of uncontrolled longitudinal motions following an abrupt elevator deflection in the gliding condition, center of gravity 31.2 percent M.A.C.

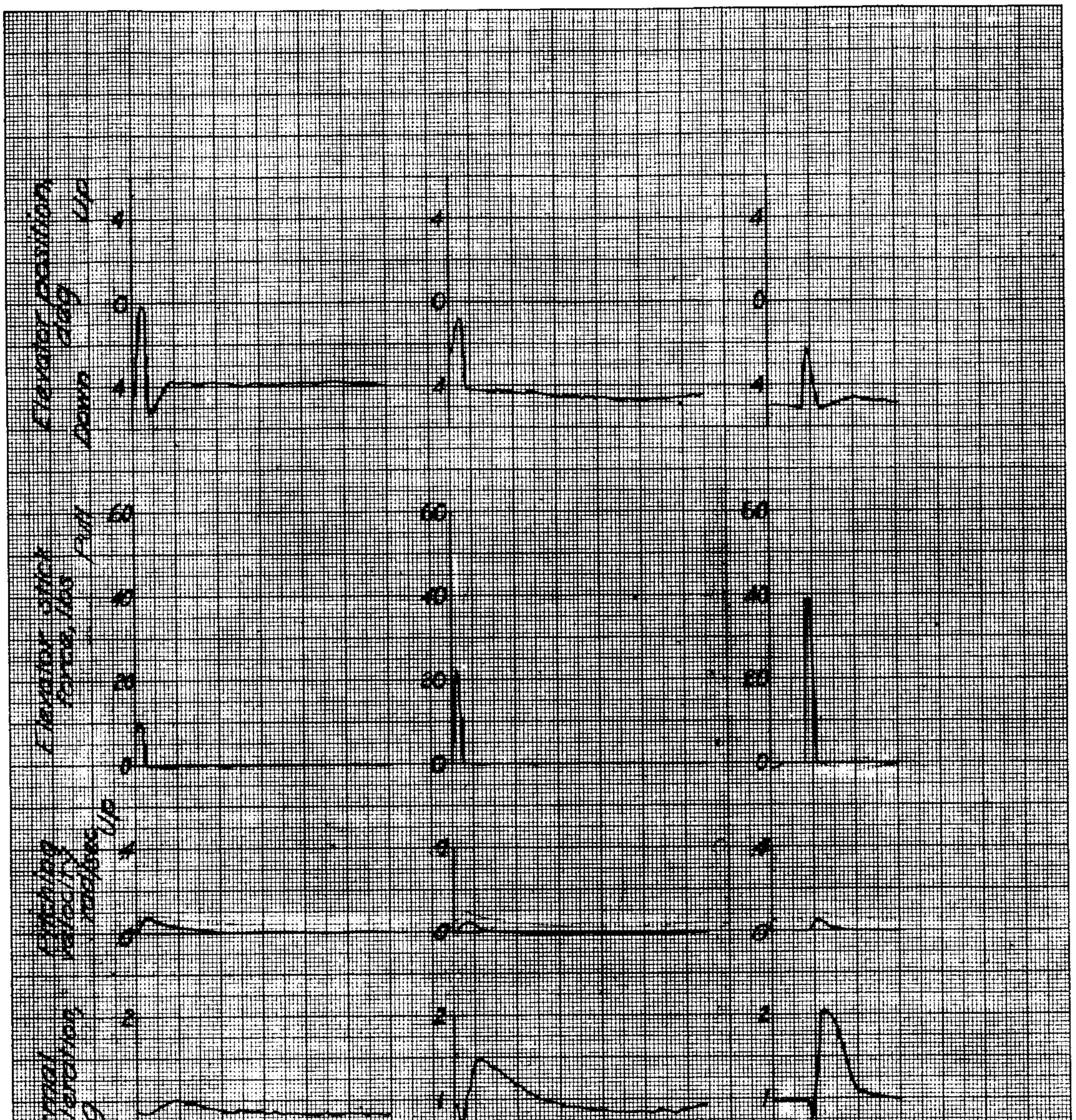

Figure 9. - Typical time histories of uncontrolled longitudinal motions following an abrupt elevator deflection in the climbing condition, center of gravity 31.2 percent M.A.C. F6F-3 airplane.

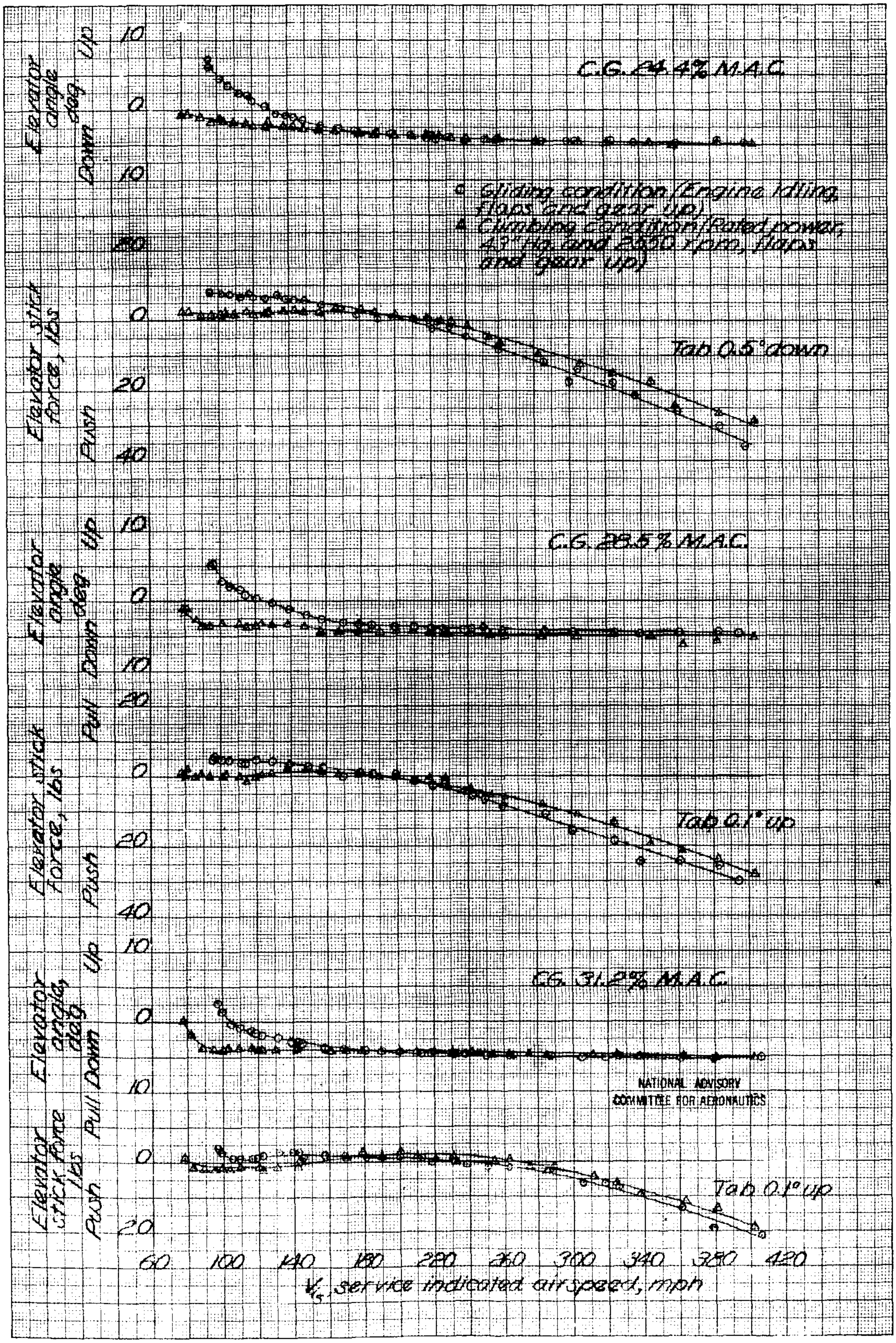

Figure 10. - Variation of elevator angle and elevator force with service indicated airspeed in the gliding and climbing condition, F6F-3 airplane.

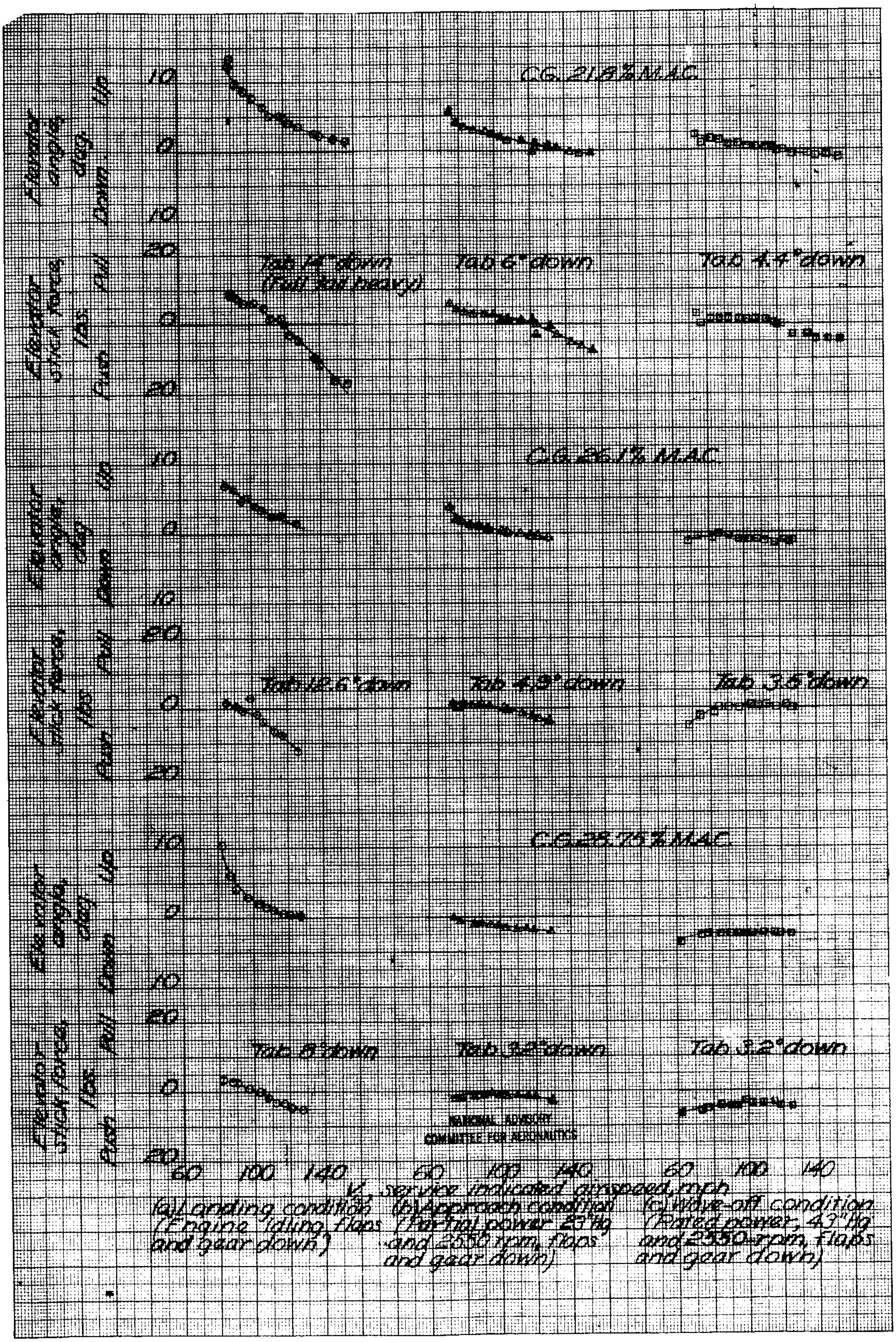

Figure 11. - Variation of elevator angle and elevator stick force with service indicated airspeed in the landing, approach and wave-off condition, F6F-3 airplane.

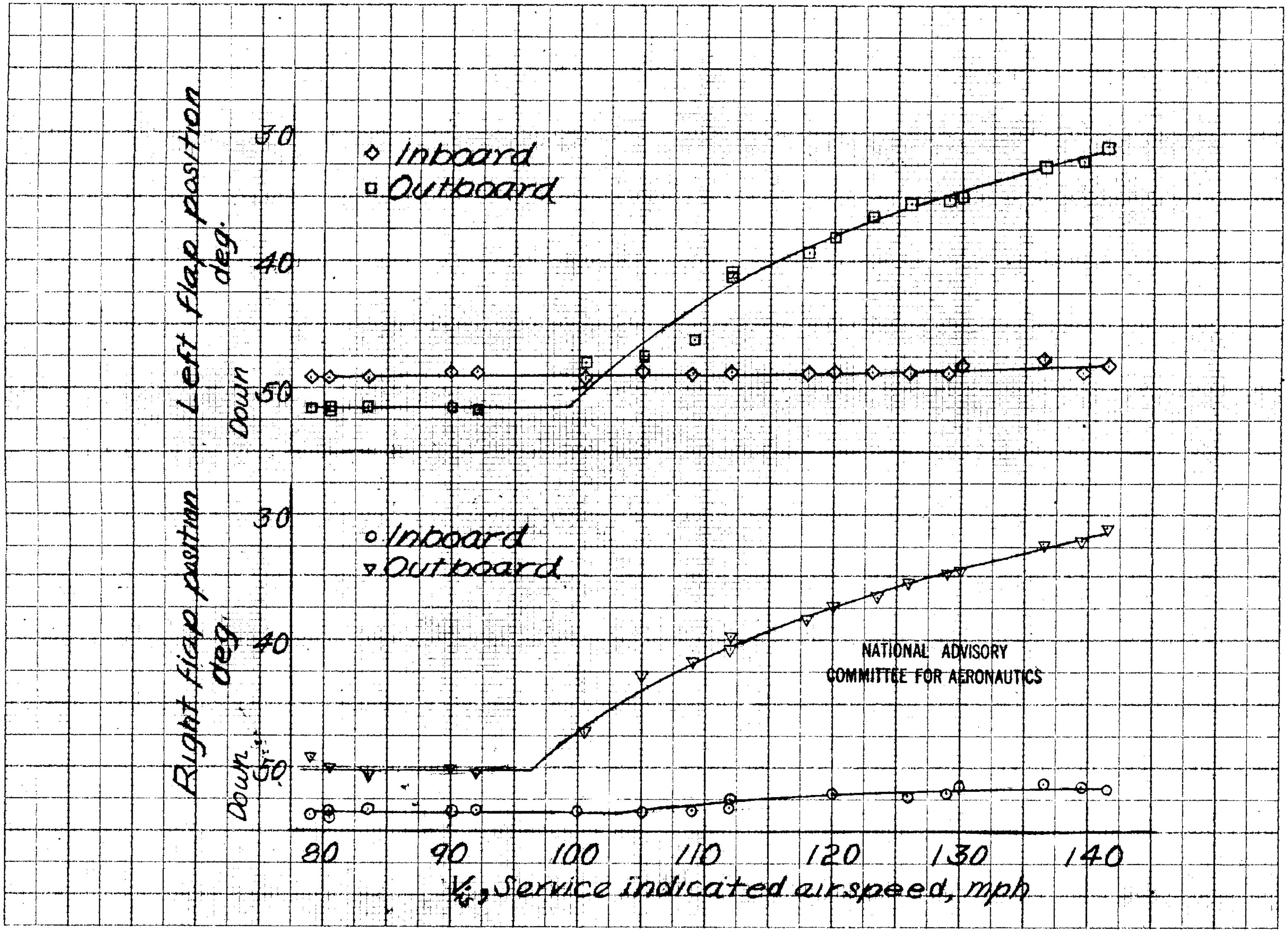

Figure 12. - Variation of flap position with indicated airspeed, landing condition, F6F-3 airplane.

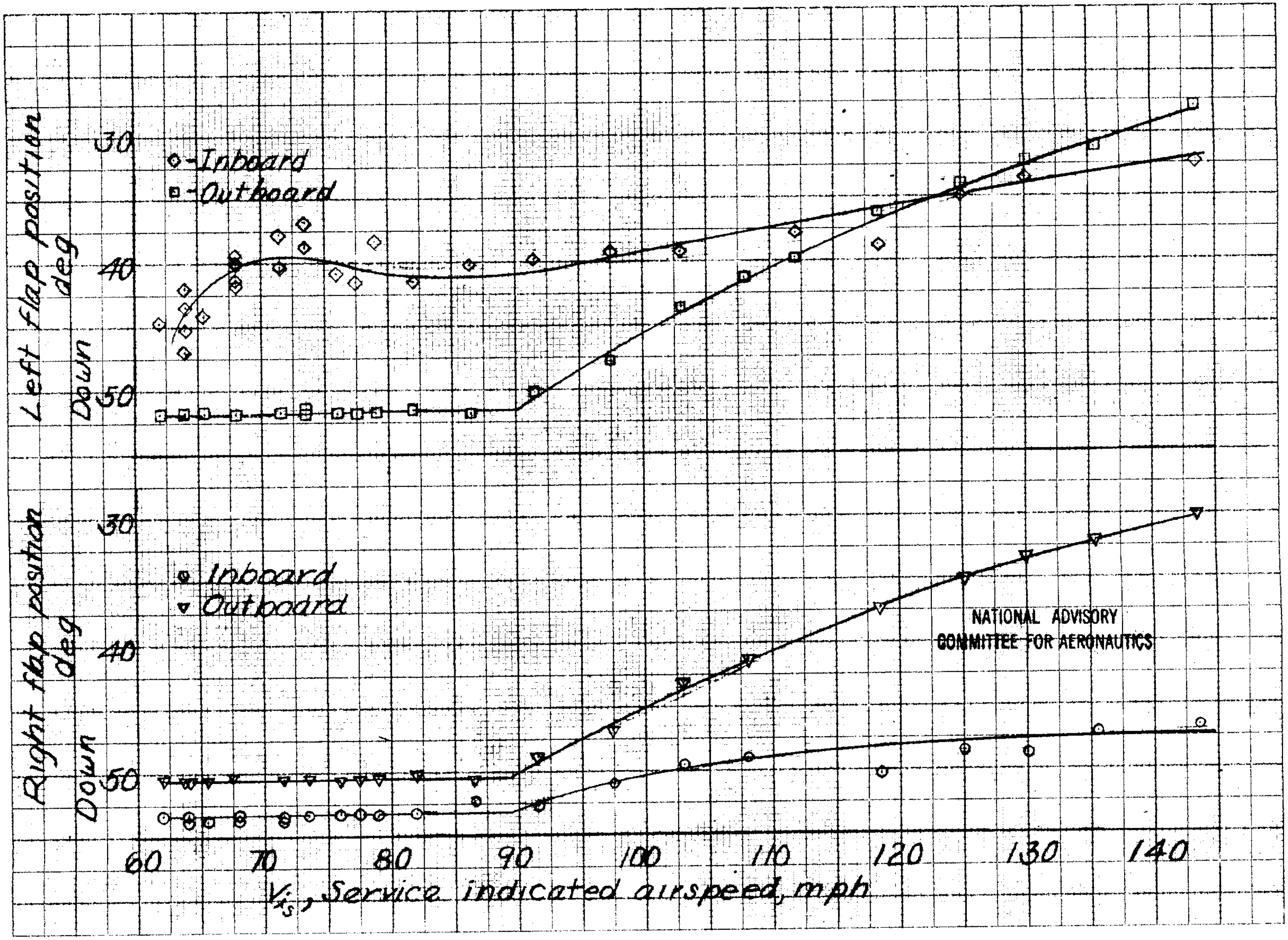

Figure 13. - Variation of flap position with indicated airspeed, wave-off condition, F6F-3 airplane.

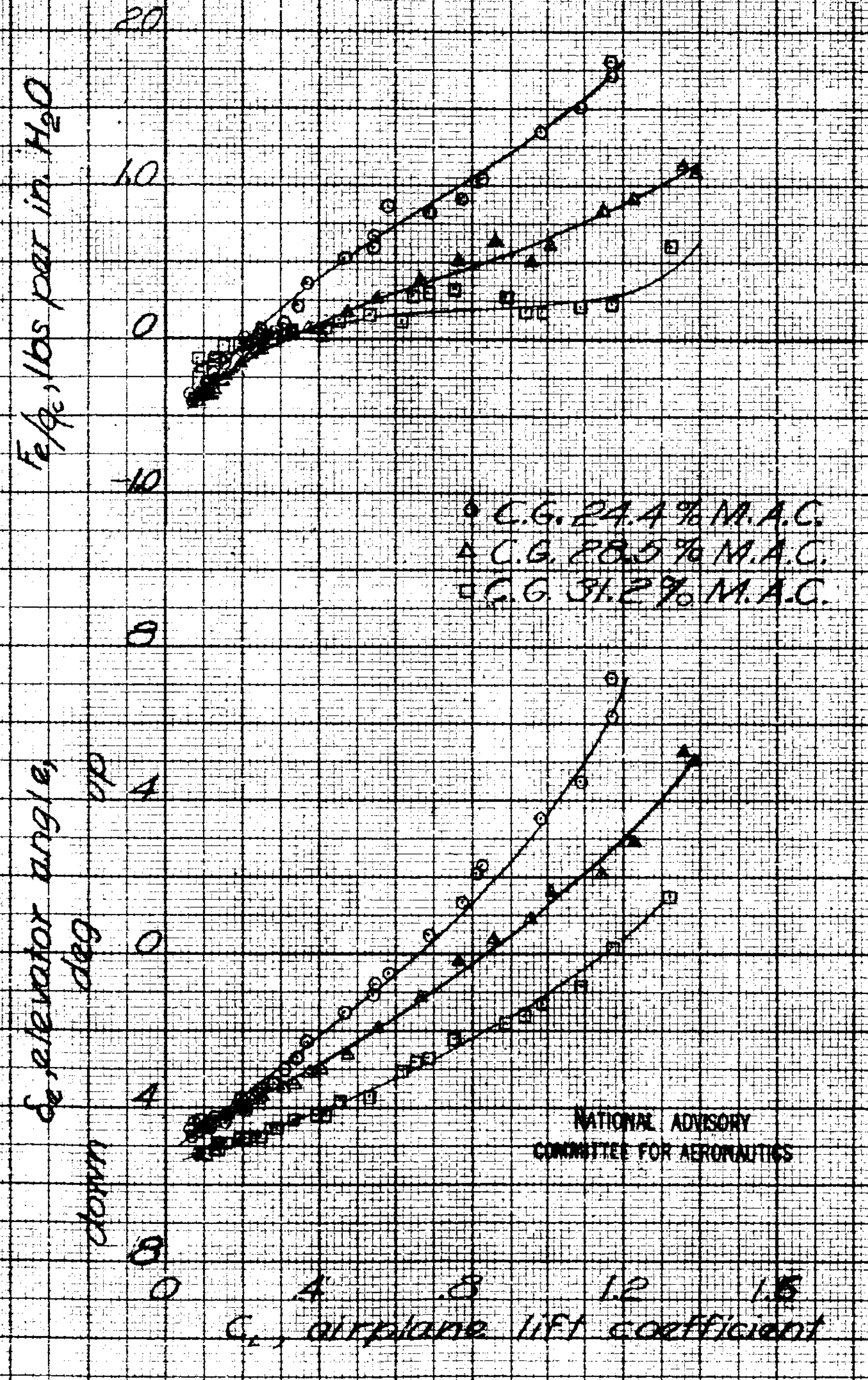

Figure 14. - Variation of elevator angle and F_e/q_c with airplane lift coefficient, gliding condition, F6F-3 airplane.

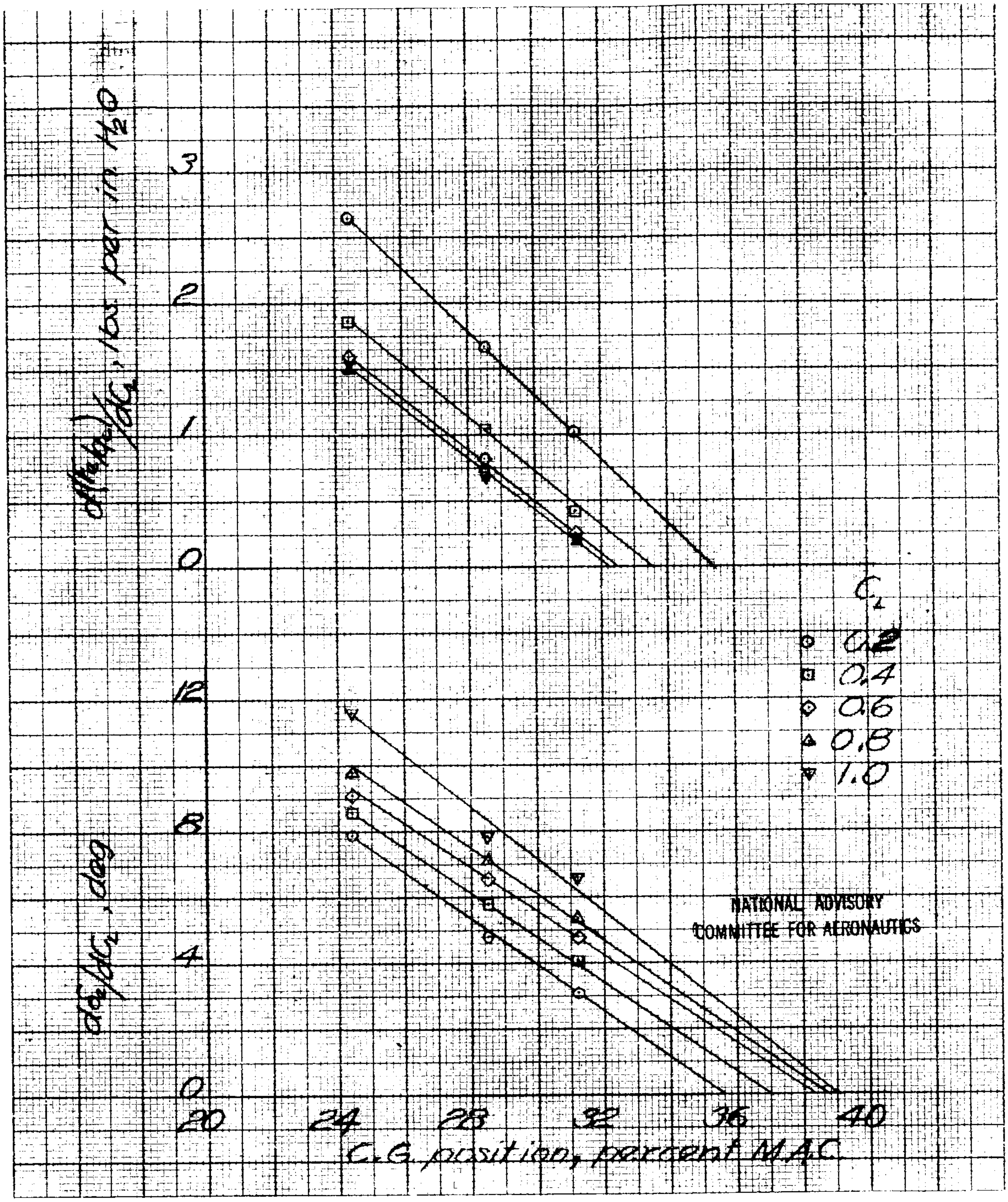

Figure 15. - Variation of $\frac{d\delta_e}{dC_L}$ and $d\left(\frac{F_e}{q_c}\right)\Big/dC_L$ with center of gravity position, gliding condition, F6F-3 airplane.

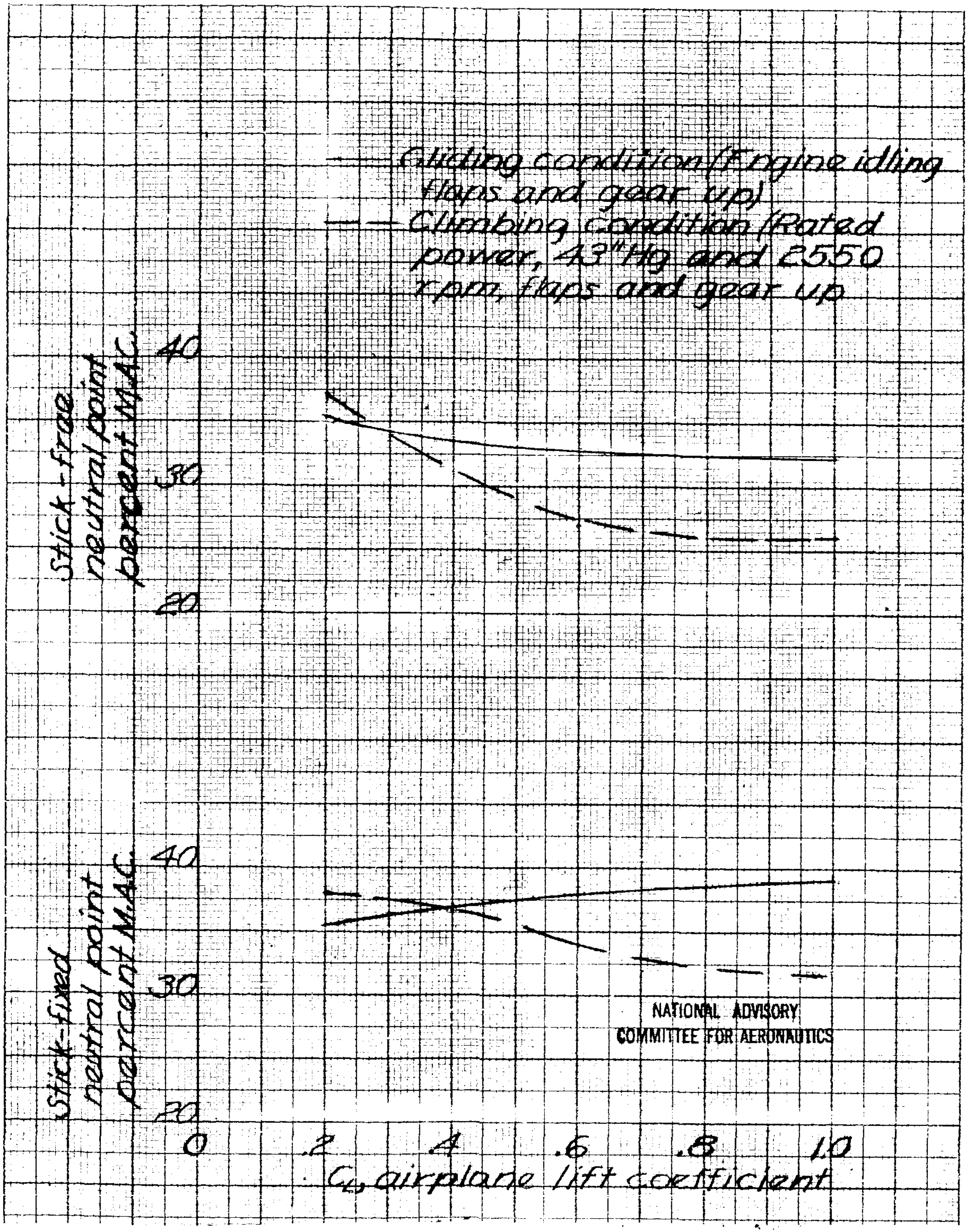

Figure 16. - Variation of stick-fixed and stick-free neutral points with airplane lift coefficient, gliding and climbing condition, F6F-3 airplane.

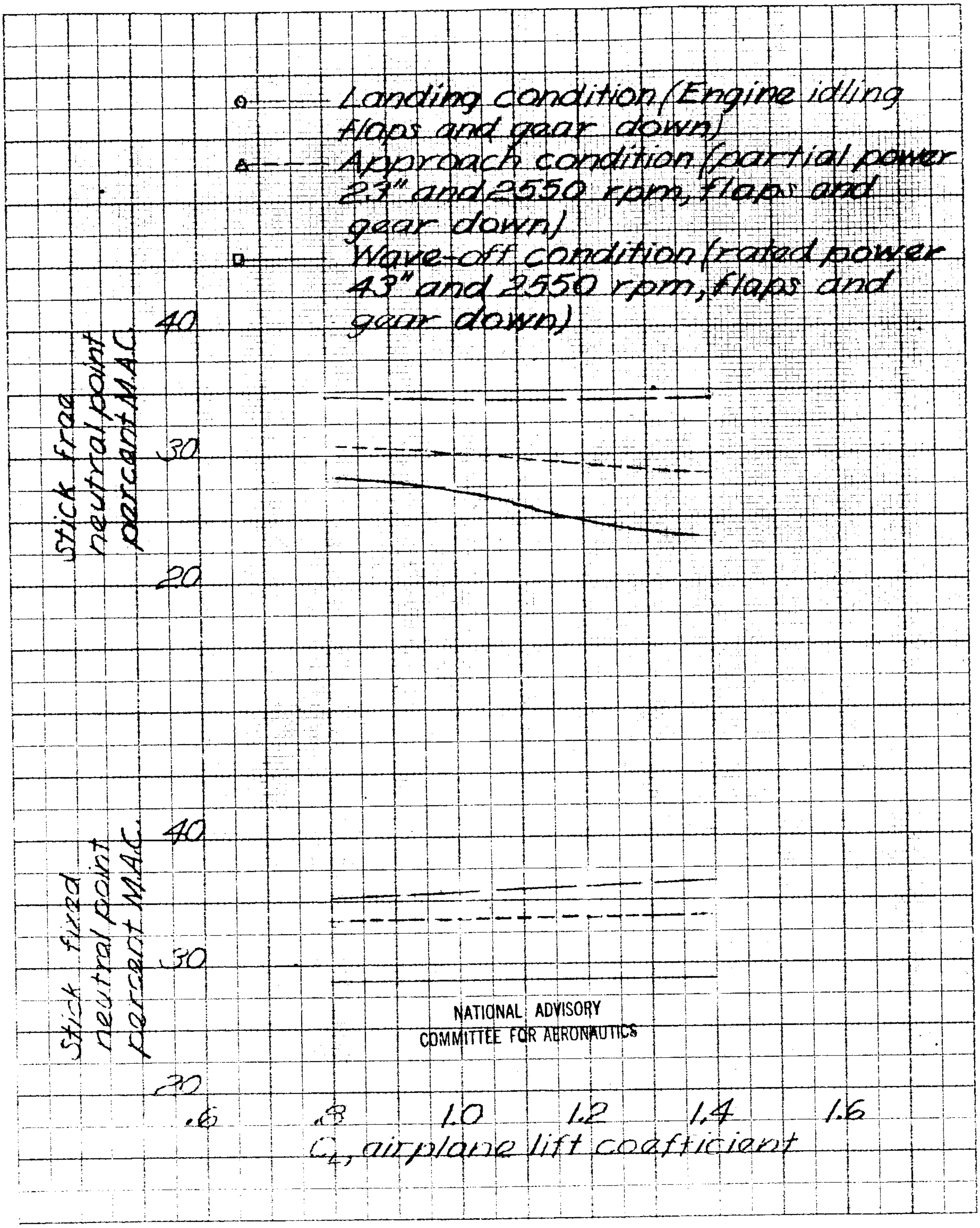

Figure 17. - Variation of the stick-fixed and stick-free neutral points with airplane lift coefficient, landing, approach, and wave-off condition, F6F-3 airplane.

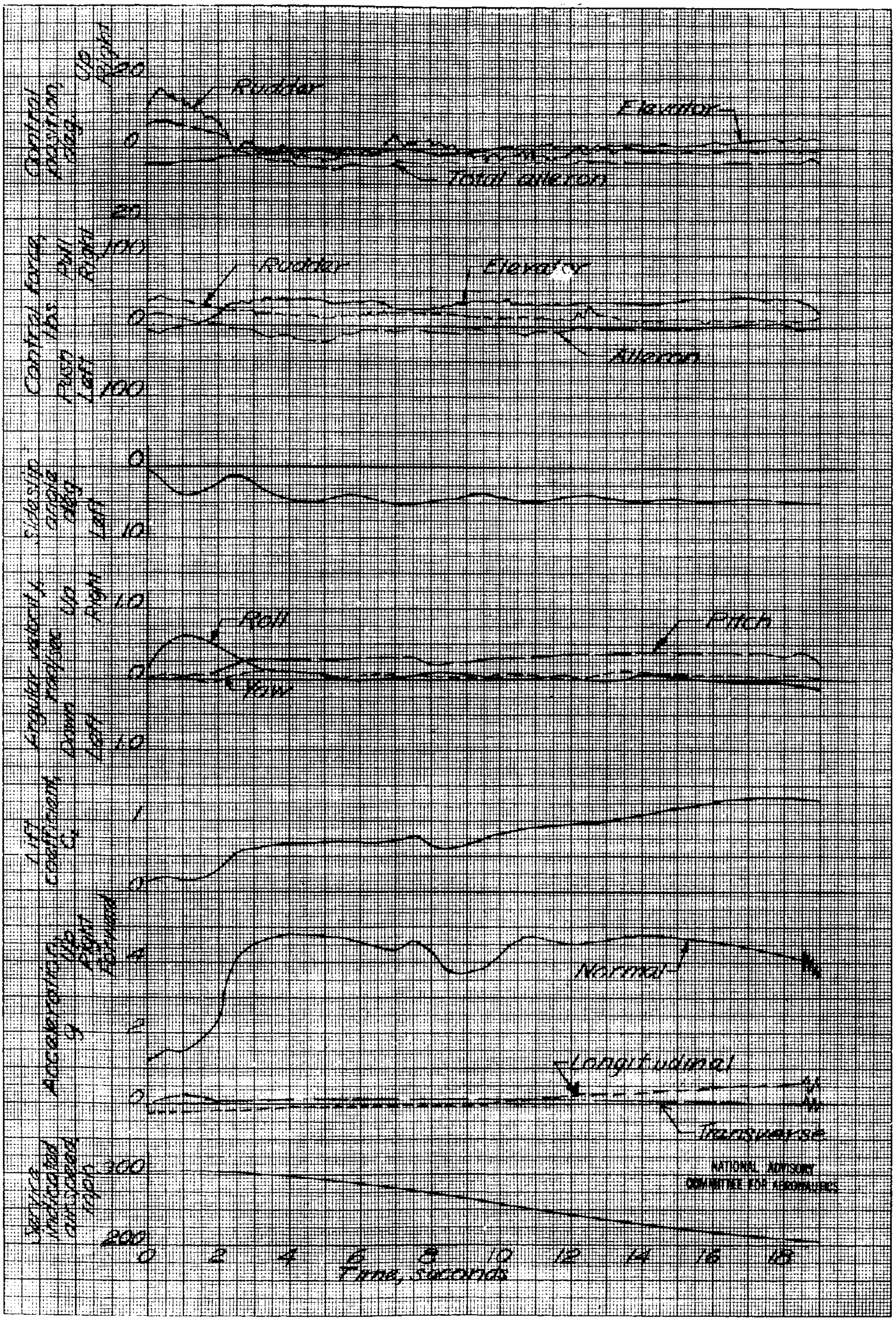

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Figure 18. - Time history of a typical wind-up turn to the right, center of gravity 28.5 percent M.A.C., climbing condition, F6F-3 airplane.

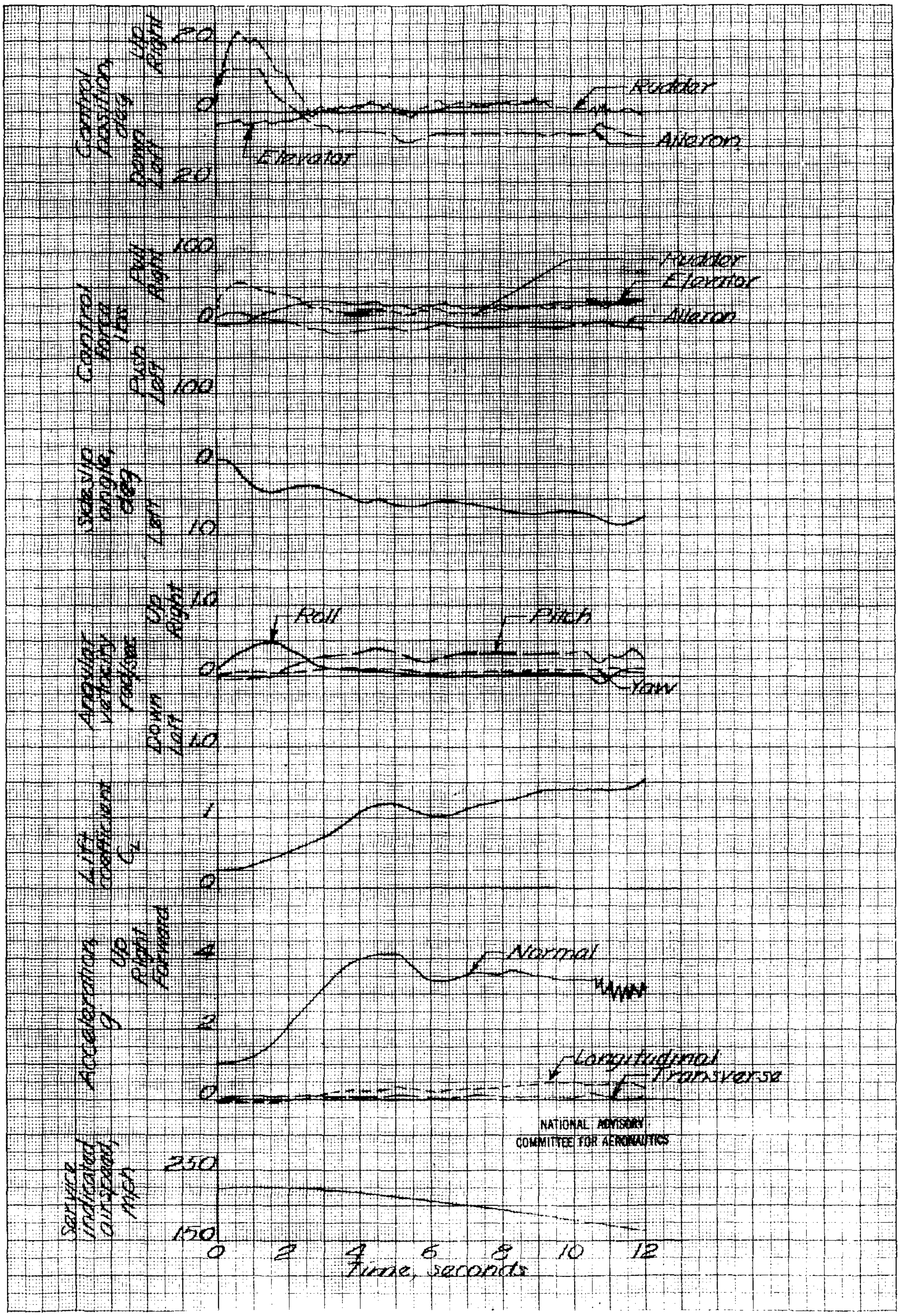

Figure 19. - Time history of a typical wind-up turn to the right, center of gravity 28.5 percent M.A.C. climbing condition, F6F-3 airplane.

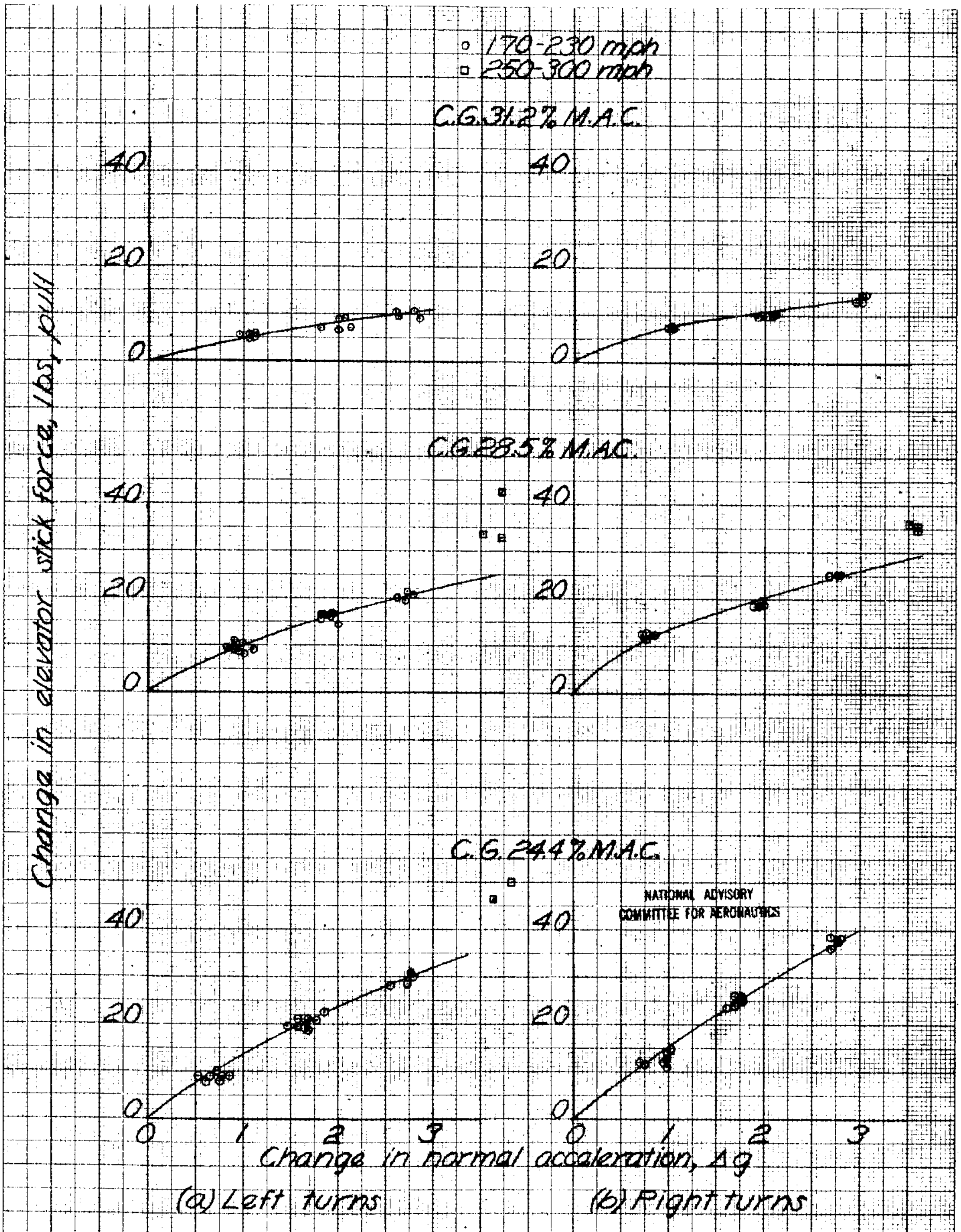

Figure 20. - Change in elevator stick force with change in normal acceleration in wind-up turns made at approximately 8,000 feet pressure altitude, climbing condition, F6F-3 airplane.

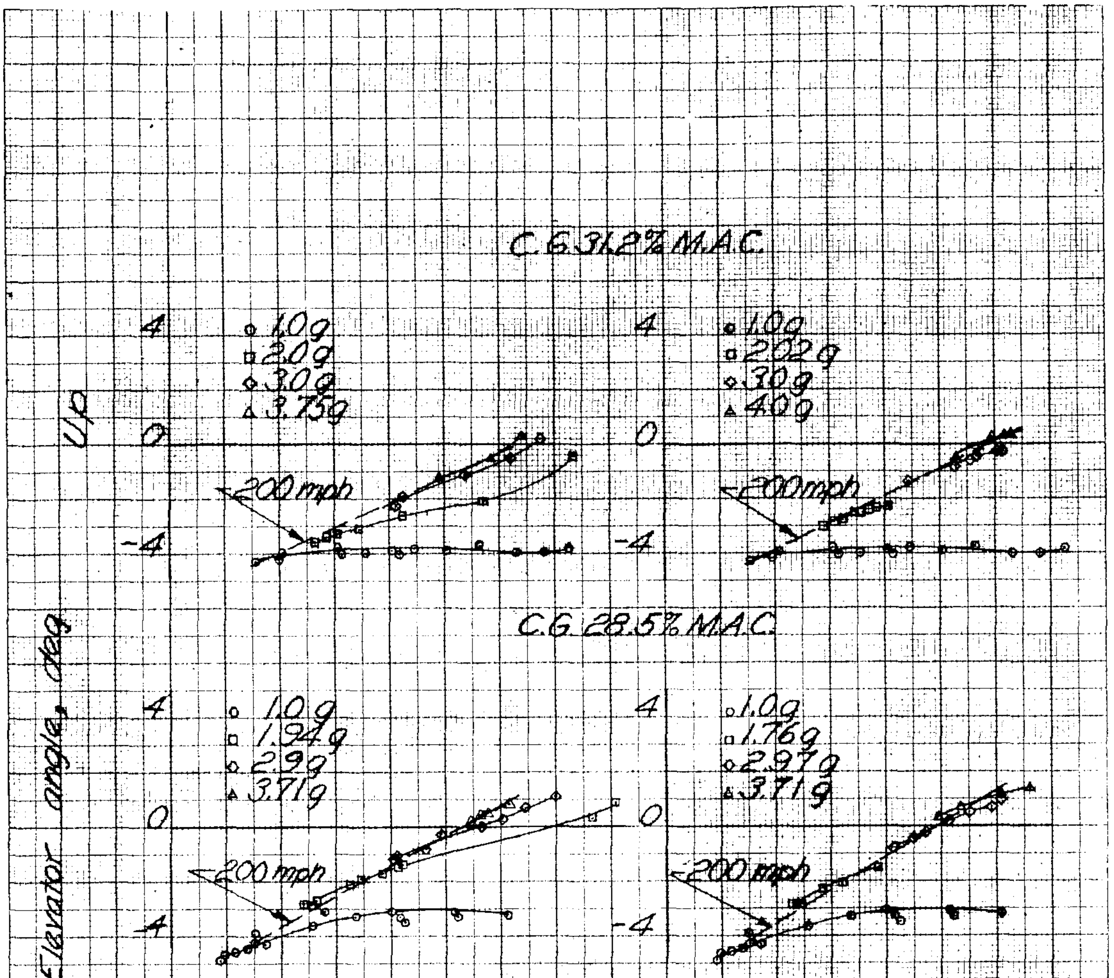

Figure 21. - Variation of elevator angle with change in airplane lift coefficient in wind-up turns made at approximately 8,000 feet pressure altitude, climbing condition, F6F-3 airplane.

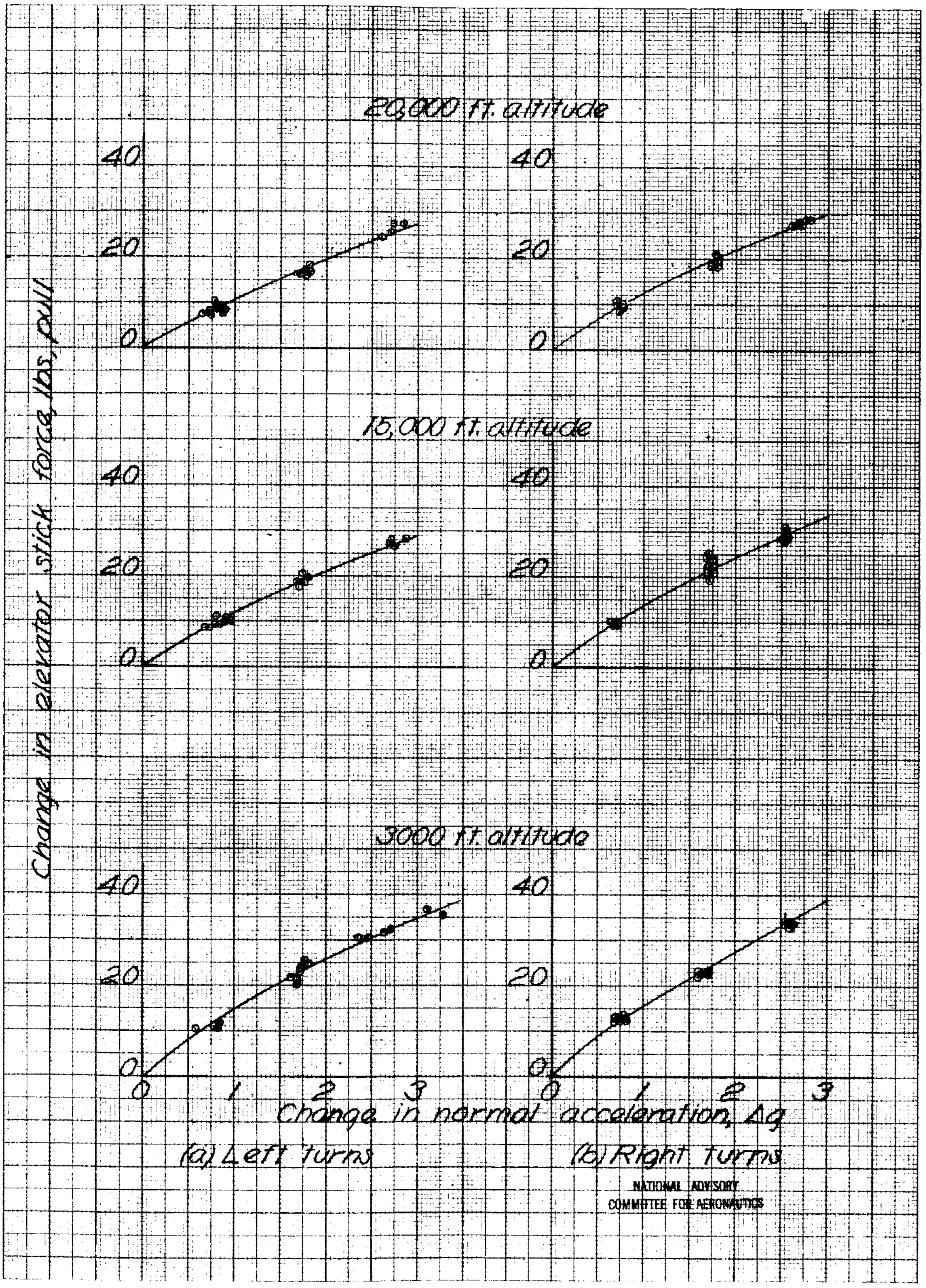

Figure 22. - Variation of change in elevator stick force with change in normal acceleration in wind-up turns made at various altitudes, center of gravity 24.4 percent M.A.C., climbing condition, F6F-3 airplane.

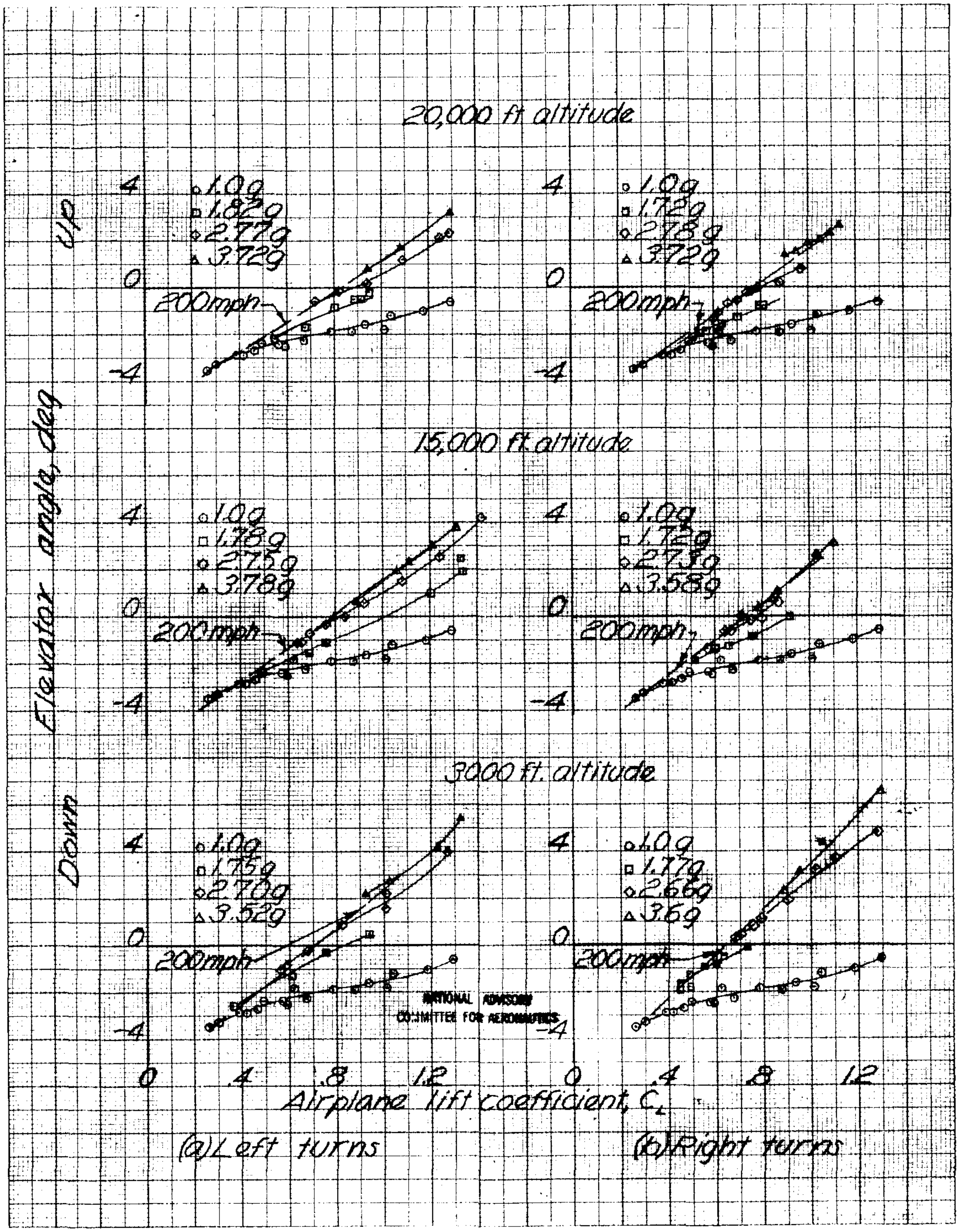

Figure 23. - Variation of elevator angle with change in airplane lift coefficient in wind-up turns made at various altitudes, center of gravity 24.4 percent M.A.C., climbing condition, F6F-3 airplane.

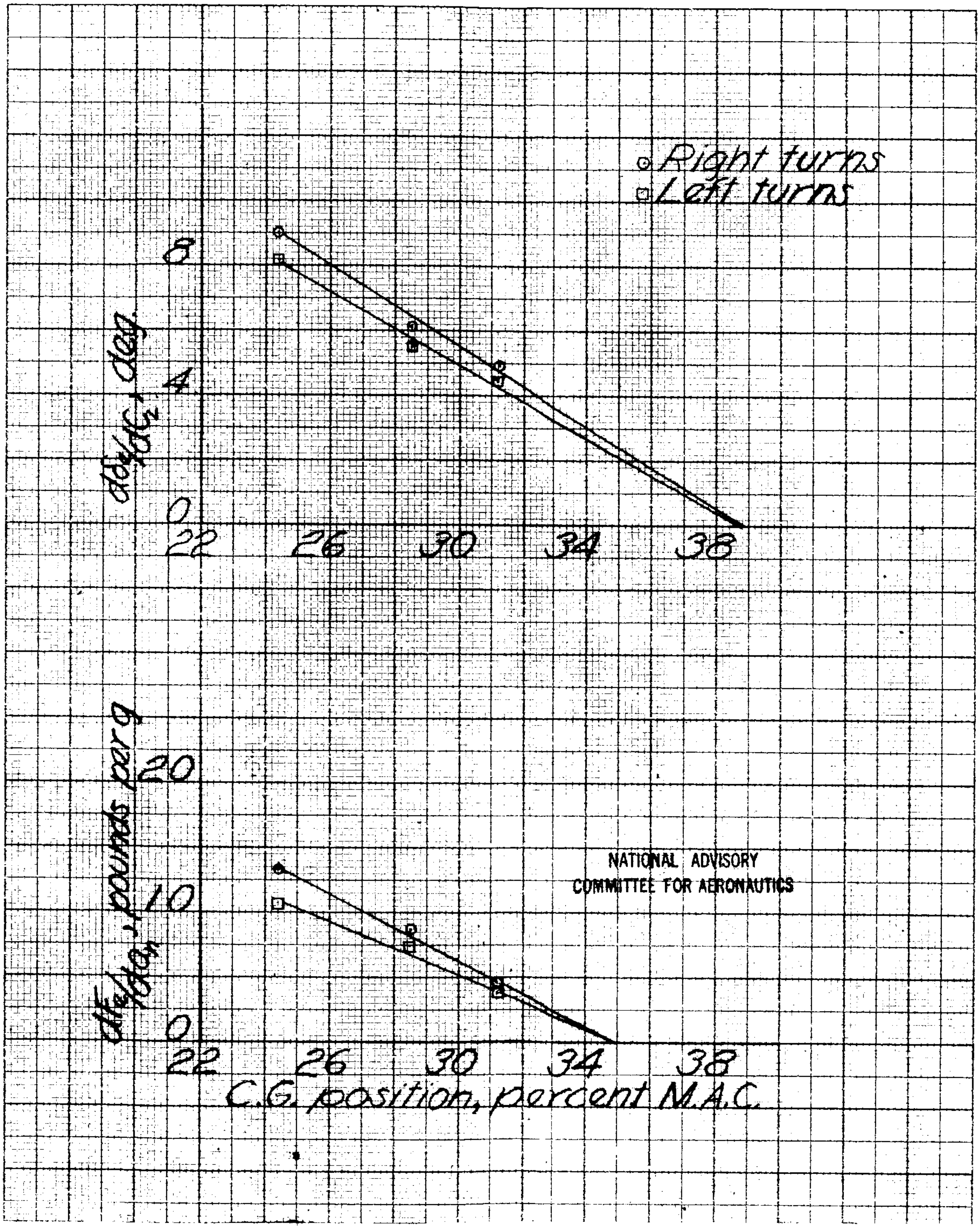

Figure 24. - Variation with center-of-gravity position of stick force per g and $d\delta_e/dC_L$ in turns made at 8,000 feet pressure altitude, F6F-3 airplane.

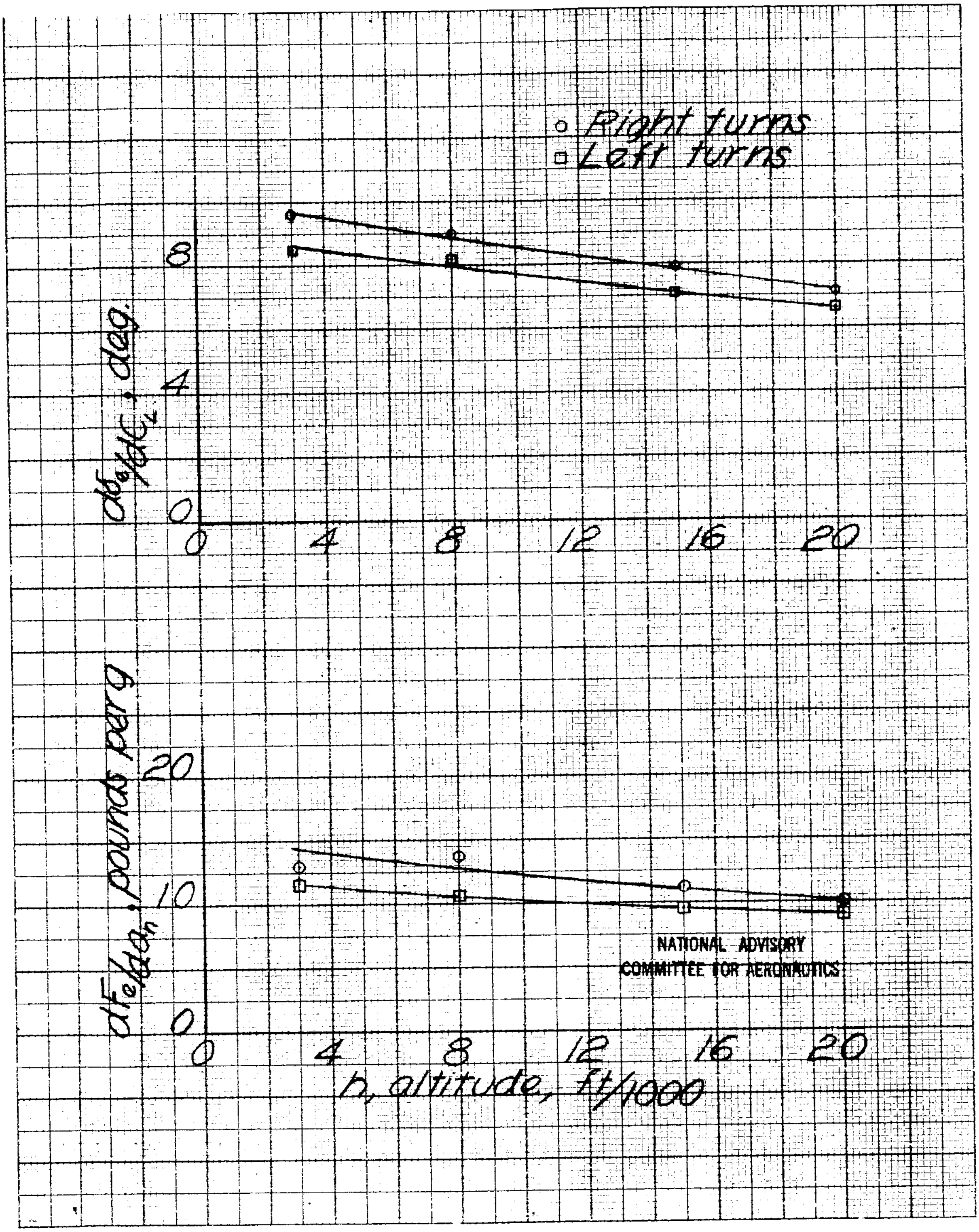

Figure 25. - Variation with altitude of $d\delta_e/dC_L$ and dF_e/da_n in wind-up turns, F6F-3 airplane.

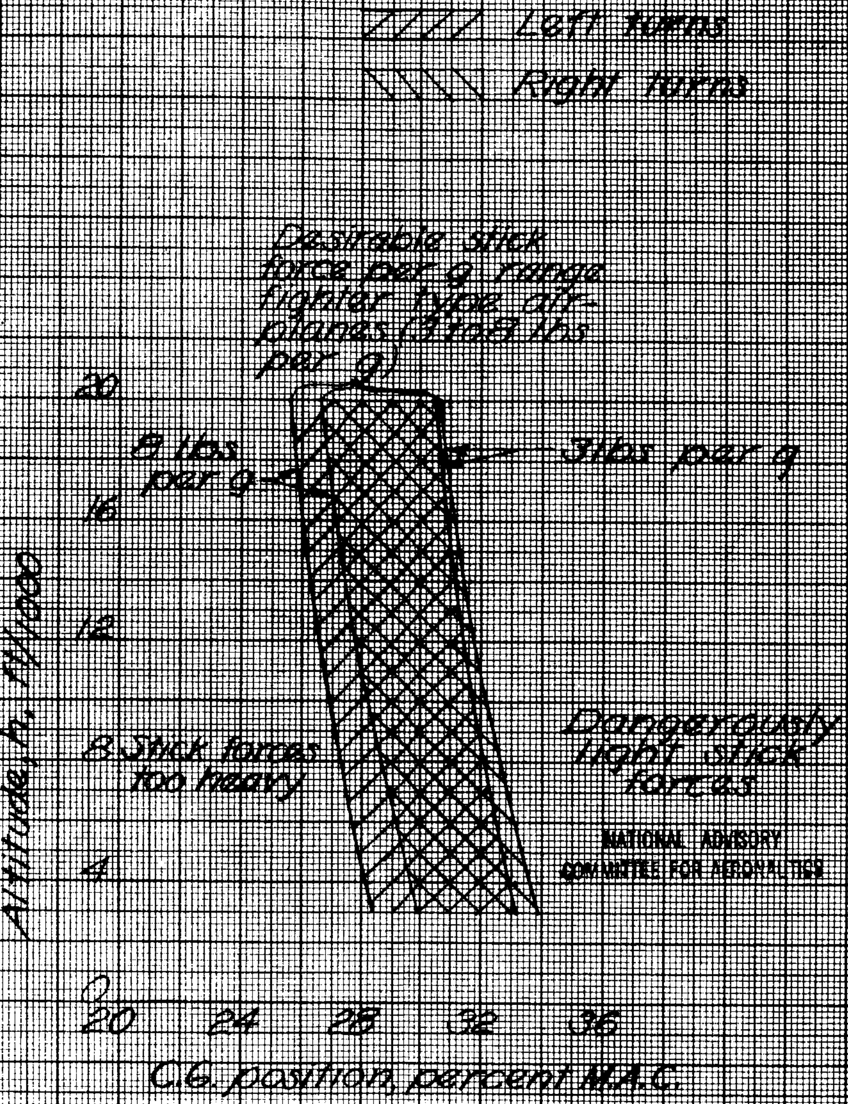

Figure 26. - Variation with altitude of the center-of- gravity range for desirable stick force per g, F6F-3 airplane.

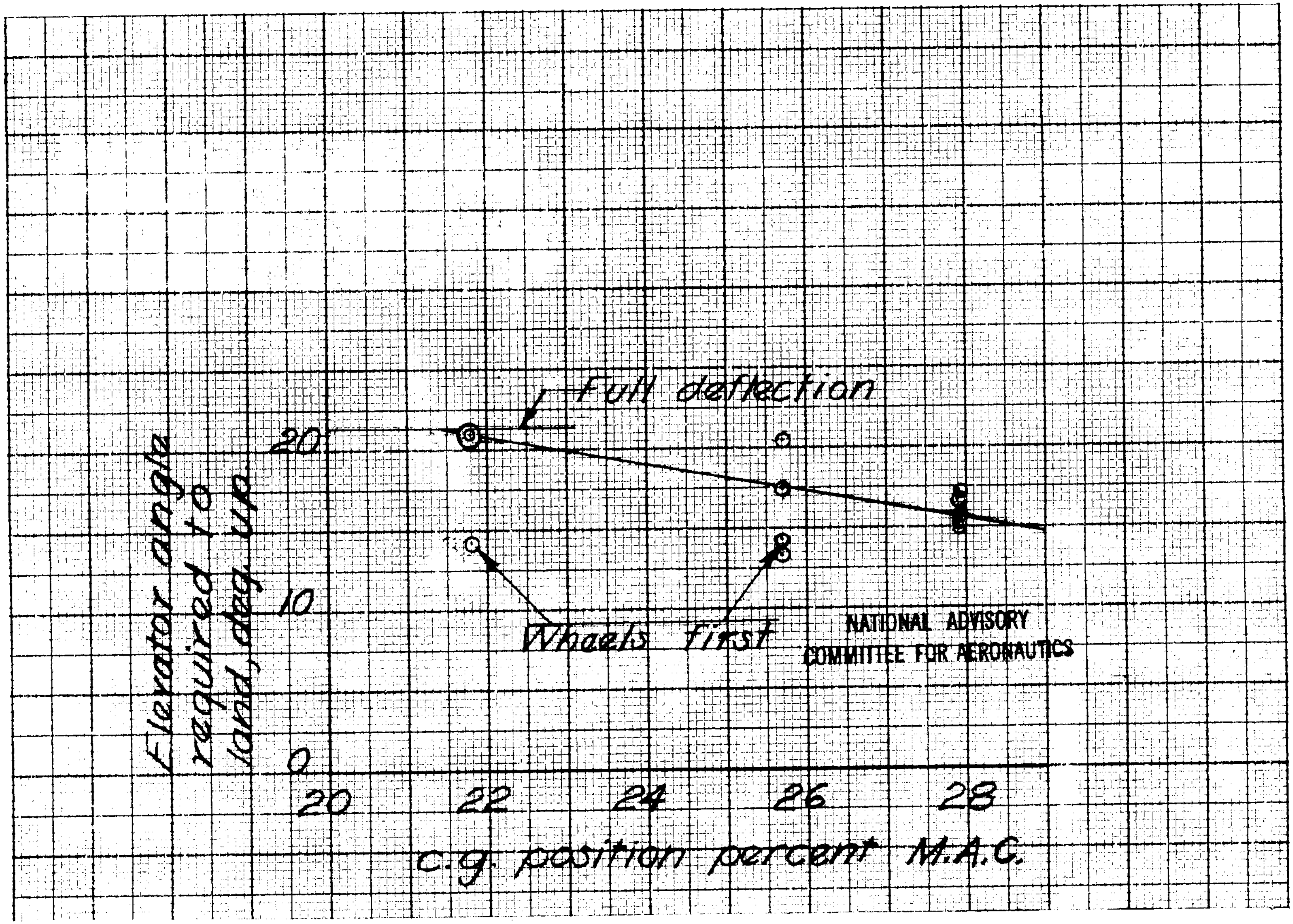

Figure 27. - Variation of elevator angle required to land with center-of-gravity position, F6F-3 airplane.

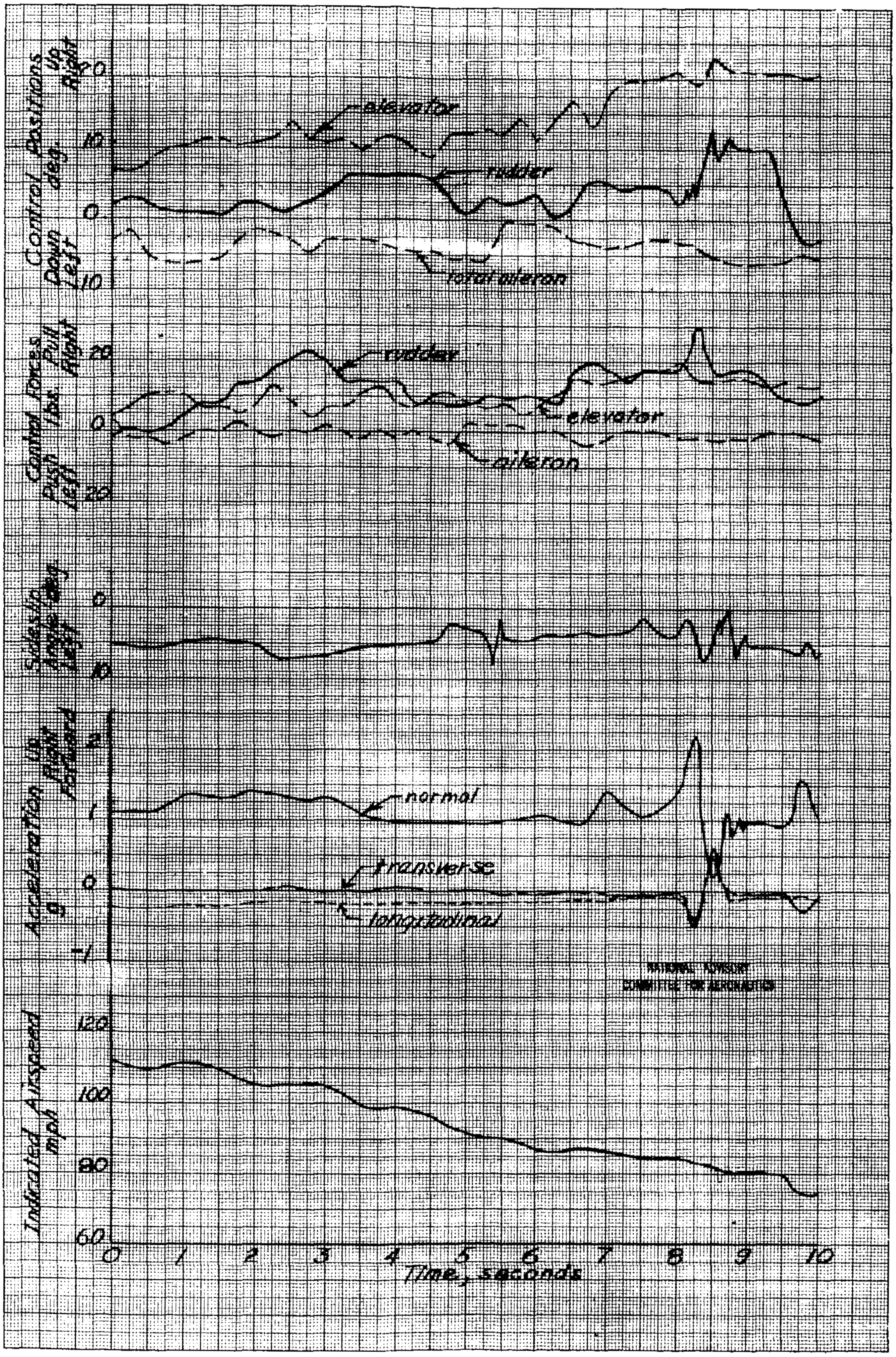

Figure 28. - Time history of a typical three-point landing, C.G. 21.8 percent M.A.C., F6F-3 airplane.

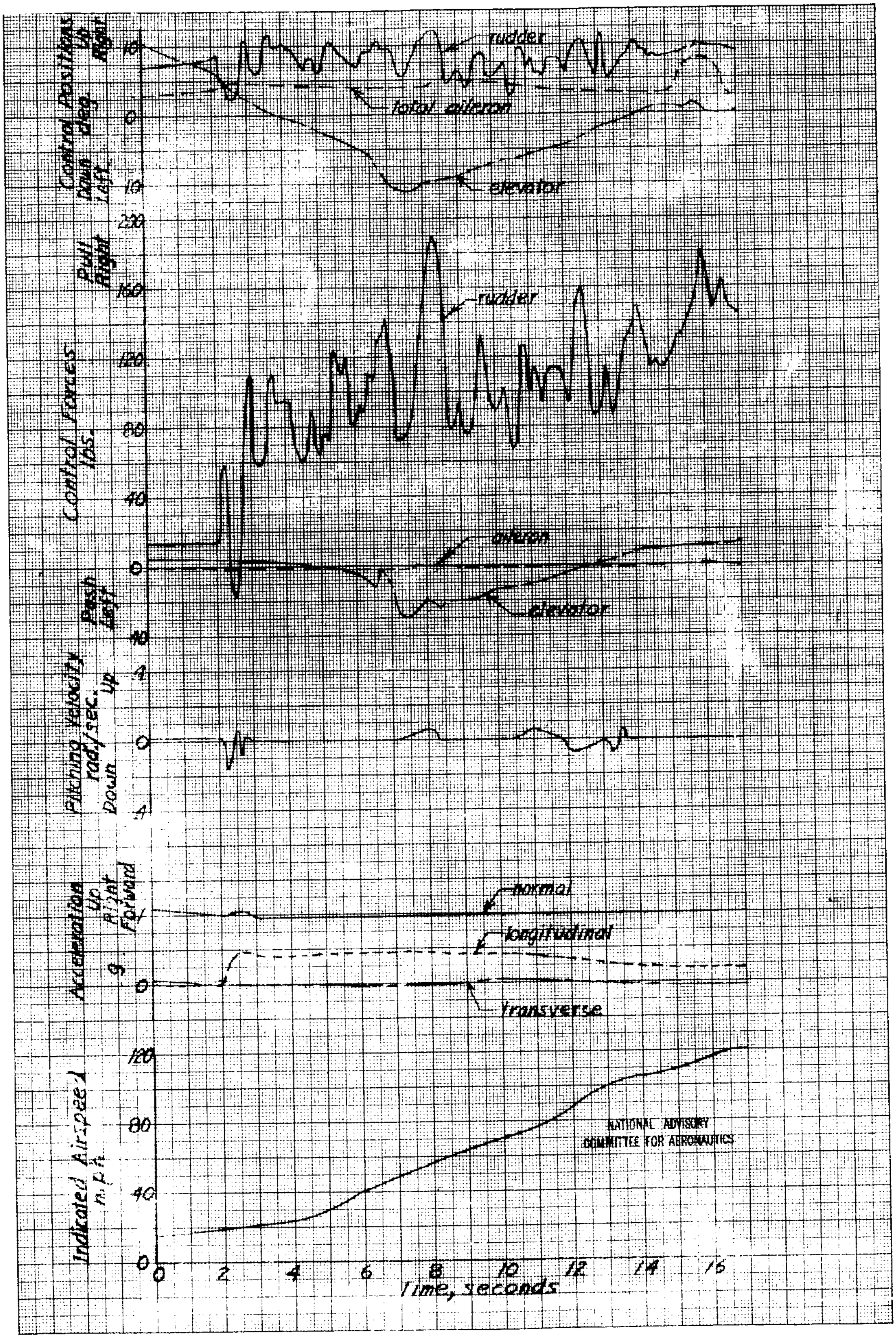

Figure 29. - Time history of a tail high take-off, F6F-3 airplane.

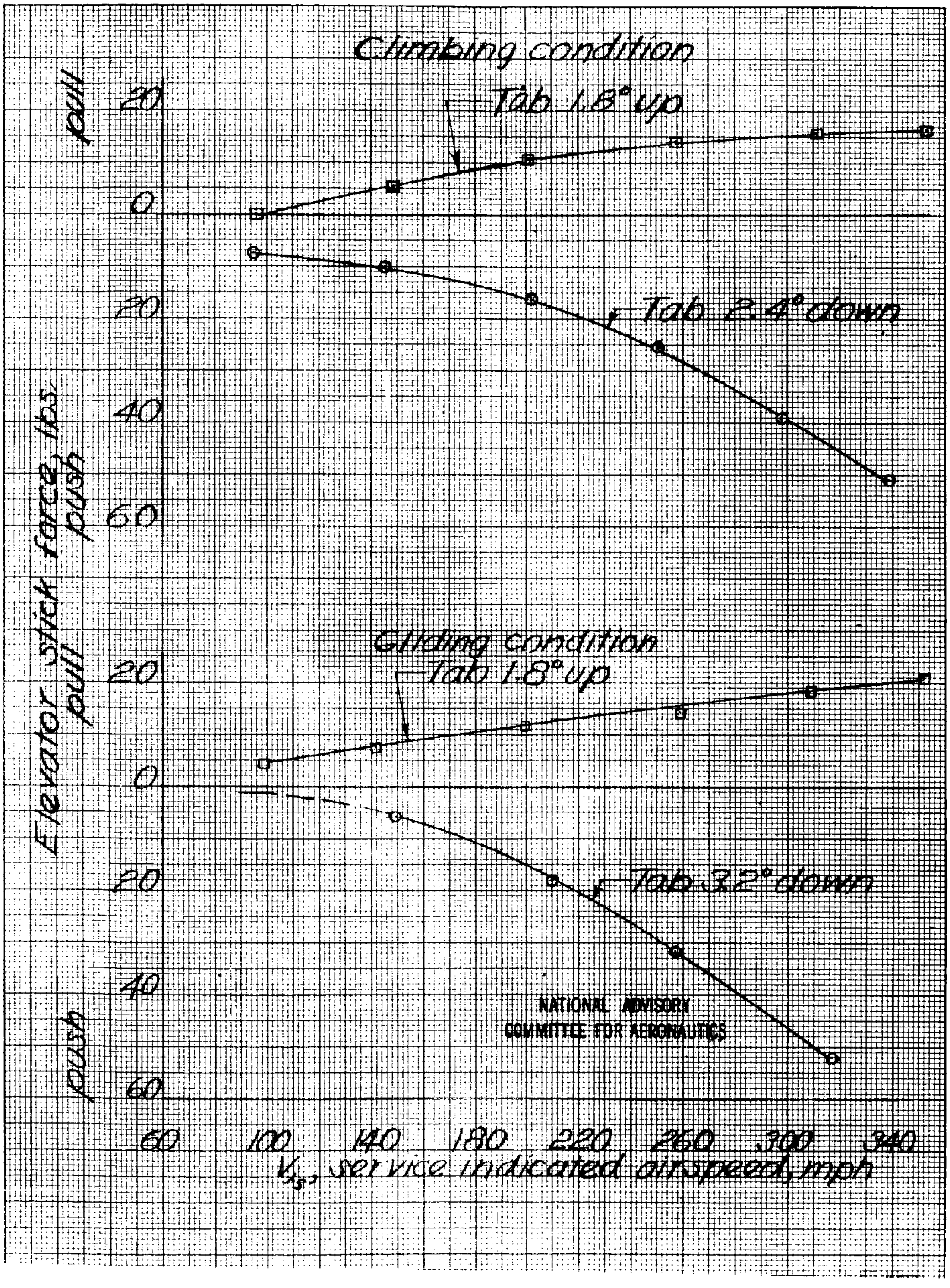

Figure 30. - Variation of elevator stick force with service indicated airspeed for two trim tab settings, gliding condition and climbing condition, F6F-3 airplane.

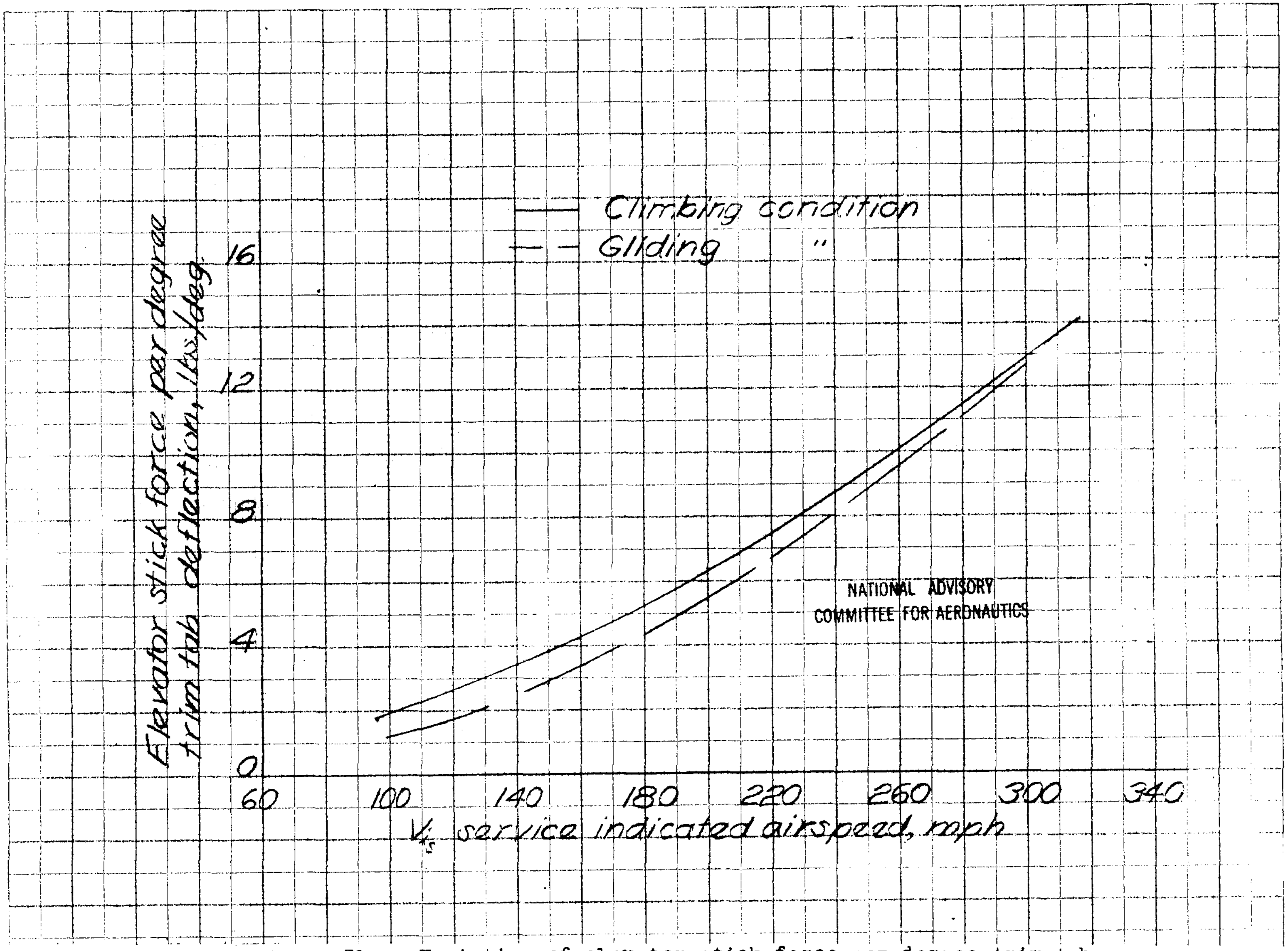

Figure 31. - Variation of elevator stick force per degree trim tab deflection with indicated airspeed, gliding condition and climbing condition, F6F-3 airplane.

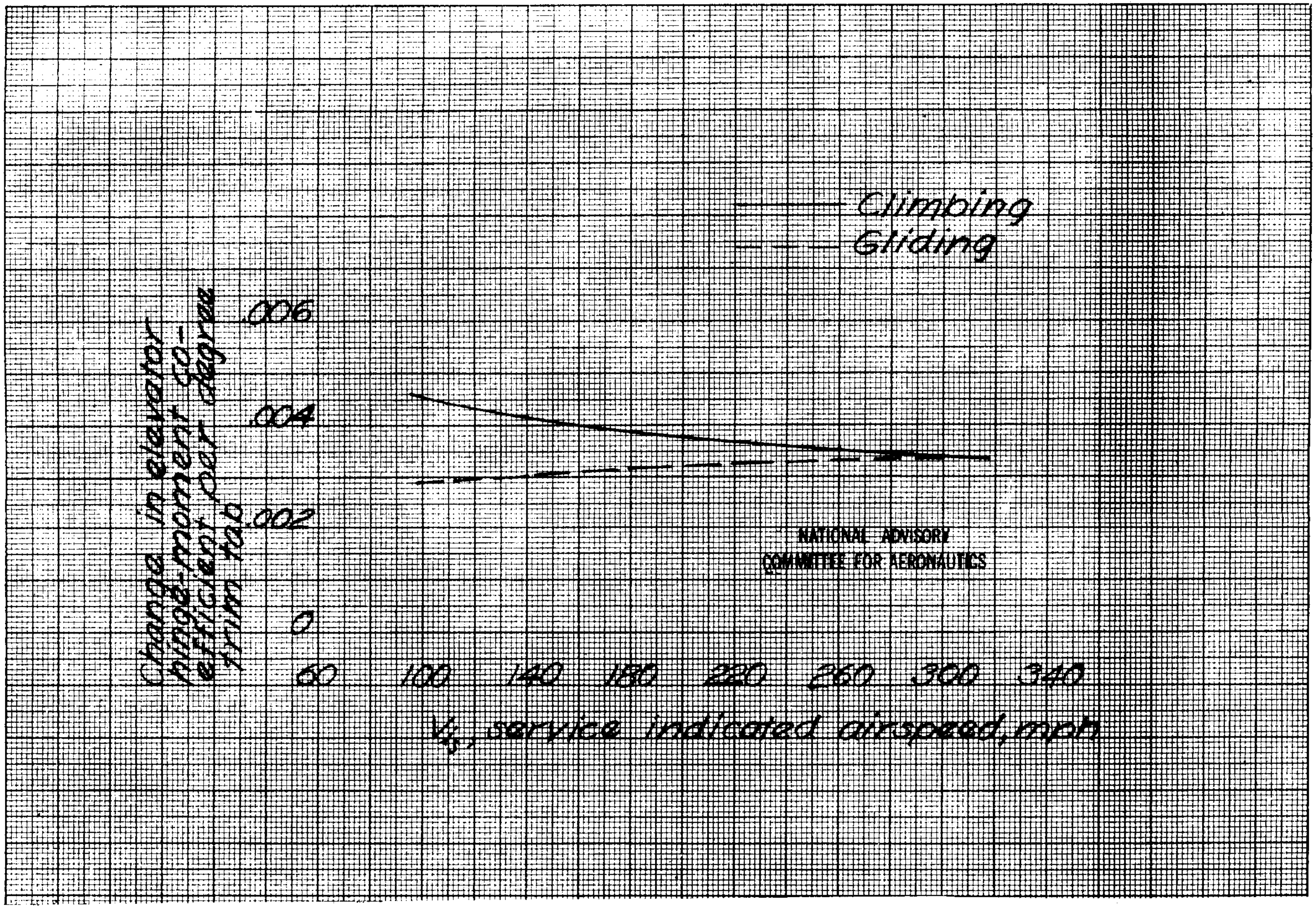

Figure 32. - Change in elevator hinge-moment coefficient per degree trim tab angle as a function of indicated airspeed, climbing and gliding condition, F6F-3 airplane.