NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

MEASUREMENTS IN FLIGHT OF THE FLYING QUALITIES OF A CHANCE VOUGHT F4U-4 AIRPLANE (TED NO. NACA 2388)

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

The results of flight tests to determine the flying qualities of a Chance Vought F4U-4 airplane are presented and discussed herein. In addition to comprehensive measurements at low altitude (about 8000 ft), tests of limited scope were made at high altitude (about 25,000 ft).

The more important characteristics, based on a comparison of the test results and opinions of the pilots with the Navy requirements, can be summarized as follows:

1. The short-period control-free oscillations of the elevator angle and the normal acceleration were satisfactorily damped.

2. The most rearward center-of-gravity locations for satisfactory static longitudinal stability with power on, as determined by the control-force variations, were approximately 30 and 27 percent M.A.C. with flaps and gear up and down, respectively.

3. In maneuvering flight the conditions for which control-force gradients of satisfactory magnitude were obtained were seriously limited by sizable changes in the gradient with center-of-gravity location, airspeed, altitude, acceleration factor, and direction of turn.

4. The elevator and rudder controls were satisfactory for landings and take-offs.

5. The trim tabs were sufficiently effective for all controls.

6. The directional and lateral dynamic stability was positive, but the rudder oscillation did not damp within one cycle. The airplane oscillation damped sufficiently at low altitude but not

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at high altitude.

7. Both rudder-fixed and rudder-free static directional stability were positive over a sideslip range of $\pm 15^{\circ}$. However, the rudder force tended to reverse at high angles of right sideslip with flaps and gear up, power on, at low speeds.

8. The stick-fixed static lateral stability (dihedral effect) was positive in all conditions, but the stick-free dihedral effect was neutral at low speeds with flap and gear down, power on.

9. The yaw due to abrupt full aileron deflection at low speed was not excessive, and the rudder control was adequate to hold trim sideslip.

10. In abrupt rudder-fixed aileron rolls in the clean configuration the maximum $pb/2V$ for full aileron deflection at low and normal speeds was only 0.064.

11. The stalling characteristics were considered unsatisfactory in all configurations in both straight and turning flight due to inadequate stall warning. The motions in the stalls were not unduly severe, and recovery could be effected promptly by normal use of the controls.

INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, and the U. S. Army Air Forces, the National Advisory Committee for Aeronautics has been conducting flight tests for the past few years to determine the stability and control characteristics of a number of service-type airplanes. Specific requirements designed to insure satisfactory flying qualities have been formulated as a result of this investigation. These requirements are continually being revised and supplemented in accordance with new developments.

As a part of this general flying-qualities program, the Bureau of Aeronautics, Navy Department, requested that the Ames Aeronautical Laboratory conduct flight tests of a Chance Vought F4U-4 airplane. The flight-test procedure indicated in reference 1 was used as a general guide in planning the test program. In addition to comprehensive tests at low altitude (about 8000 ft), measurements of a limited scope were made at high altitude (about 25,000 ft). Supplementary tests considered desirable by the Navy and by Ames were also performed. The results of these flying-qualities tests are presented and discussed herein.

SYMBOLS

The symbols used in this report are defined as follows:

V_i correct indicated airspeed, miles per hour

V true airspeed, feet per second

W airplane gross weight, pounds

S wing area, square feet

A_Z normal acceleration factor, in gravitational units (32.2 ft/sec^2), positive when directed upward

q free-stream dynamic pressure, inches of mercury

C_L lift coefficient ($WA_Z/70.73\ qS$)[1]

δ_e elevator angle referred to stabilizer, degrees

F_e elevator control force, pounds

p rolling velocity, radians per second

r yawing velocity, radians per second

b wing span, feet

σ air density ratio

DESCRIPTION OF THE AIRPLANE

The Chance Vought F4U-4 is a single-place, single-engine, low-wing monoplane. It has an inverse gull wing and a conventional-type landing gear. Among the various features which distinguish it from earlier F4U models are the four-blade propeller and the noncircular engine cowl with an air duct in the lower lip. Figure 1 shows photographs of the airplane as instrumented for the flight tests, and figure 2 is a three-view drawing.

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[1]Neglects effect of inclination of airplane thrust line to the flight path.

The following general specifications and dimensions were derived chiefly from references 2, 3, and 4:

Airplane, general

Manufacturer	Chance Vought Aircraft Division, United Aircraft Corp.
Type	F4U-4
Navy number	97028
Normal gross weight, center-of-gravity location, and limit load factor	Vary over sizable ranges, depending on tactical function (See references 2 and 4.)

Wing

Airfoil section	
Root	NACA 23018
Tip	NACA 23009
Area	276.3 sq ft
Span	40.98 ft
Aspect ratio	6.08
Chord length	
Root	105.00 in.
Tip	71.38 in.
Mean aerodynamic	94.00 in.
Dihedral (outer panel)	8.5°
Incidence (at root)	2.0°
Sweepback (leading edge of outer panel)	4.2°

Wing flaps

Type	Slotted
Total area	36.4 sq ft
Travel	50°

Ailerons

Area (total for both aft of hinge)	18.1 sq ft
Span (each)	7.48 ft
Balance tab area (both)	0.56 sq ft
Trim-tab area (left only)	0.74 sq ft
Trim-tab travel	15° up, 15° down

Horizontal tail surfaces

Total area	55.9 sq ft
Span	16.5 ft
Stabilizer area	28.6 sq ft
Incidence	1.25°

Elevator

Area (total aft of hinge)	21.9 sq ft
Balance area (forward of hinge)	5.4 sq ft
Trim-tab area (both)	1.36 sq ft
Trim-tab travel	10° up, 20° down
Balance-tab area (both)	0.74 sq ft

Vertical tail surfaces

Total area	22.00 sq ft
Fin area	7.34 sq ft
Fin offset	2° left

[redacted]

Rudder

Area (total aft of hinge) . . . . 13.0 sq ft

Balance area (forward of hinge) . . . . 1.66 sq ft

Trim-tab area . . . . 0.85 sq ft

Trim-tab travel . . . . 18° right, 18° left

Engine

Type . . . . Twin-row, radial, air-cooled, 18 cylinder

Manufacturer . . . . Pratt & Whitney

Number R-2800-18W

Supercharger . . . . Two-stage, two-speed

Gear ratio 0.45:1

Power rating

Take-off and military (5 min) . . . . . 2100 bhp at 2800 rpm

Maximum continuous . . . . 1700 bhp at 2600 rpm

Combat power (with water injection) . . . 2800 bhp at 2800 rpm

Propeller

Type . . . . Four-blade, hydraulically controlled

Manufacturer . . . . Hamilton Standard

Blade number 6501A-0

Diameter . . . . 13.167 ft

INSTRUMENTATION

Values of the following variables were measured by use of standard NACA photographically recording instruments: indicated air-speed; elevator, aileron, and rudder deflection; elevator- and rudder-tab deflection; rolling, yawing, and pitching velocity; normal acceleration; pressure altitude; angle of bank; sideslip angle; and elevator, aileron, and rudder control force. All records were synchronized by means of a 1-second-interval timer. Free-air temperature was measured with a standard indicating instrument installed at the laboratory.

The control-position recorders on the elevator, ailerons, and rudder were attached either directly to the surface or to a push-pull rod near the surface, so that the effects of control-system elasticity were negligible. The elevator and rudder trim-tab position recorders were attached to the control cables near the control surfaces.

For recording of the stick forces (both elevator and aileron) the service stick was replaced by a standard mechanical-type NACA recording stick. The rudder-force recorders were also of the mechanical type.

The yaw vane and the swiveling airspeed head were mounted on booms, one on each side, which extended approximately one chord length ahead of the wing about midway between the fuselage and the tips. (See fig. 1.)

The airspeed-recording installation was calibrated for position error by flying in formation with another airplane having a known position error. In order to eliminate airspeed errors due to ground effect during landing tests, a pressure recorder was connected to the total-pressure tube of the swiveling head, and the airspeed was determined from the difference between the pressure thus measured and the true ground static (barometric) pressure.

All values of indicated airspeed given in this report have been corrected for position error and were computed from the formula used in the calibration of standard airspeed indicators (based on adiabatic flow under standard sea-level conditions).

TESTS, RESULTS, AND DISCUSSION

The flight test procedures used in this investigation were similar to those indicated by reference 1, upon which this report is based. The numbers in parenthesis following the titles and subtitles in this section refer to the pertinent paragraphs of reference 1.

In the following table various flight test configurations are described, and the names shown will be used in this report to identify these configurations:

Configuration	Flaps[1]	Gear	Canopy	Cowl flaps	Manifold pressure (in. hg)	Engine speed setting (rpm)	Approx. power (bhp)	Approx. indicated stalling speed (mph)
Glide	Up	Up	Closed	Closed	15	2150	---	105
Cruise	Up	Up	Closed	Closed	31.5	2150	1100	--
Power-on-clean	Up	Up	Closed	1/4 open	48	2600	1750	95
Dive	Up	Down	Closed	Closed	15	2150	---	--
Landing	Down	Down	Open	Closed	Throttled	2400	---	92
Approach	Down	Down	Open	Closed	27	2400	950	82
Wave-off	Down	Down	Open	1/2 open	48	2600	1750	80
Cruise at high altitude	Up	Up	Closed	Closed	37.5	2100	1050	--
Power-on-clean at high altitude	Up	Up	Closed	1/4 open	47.5	2600	1550	--

[1]Blow-up type.

The take-off gross weight was about 12,600 pounds for all test loading conditions. Unless otherwise noted, a test weight of 12,100 pounds and an average pressure altitude of 8000 feet may be assumed. Center-of-gravity positions given herein have been corrected for the effect of fuel consumption during flight.

Mechanical Characteristics of Control Systems (C)

Kinematics of control systems (C-1).- The relation between cockpit control position and control-surface deflection, as measured on the ground with no load on the surfaces, is given in figures 3, 4, and 5. The term "total aileron angle" used in figure 5 refers to the algebraic sum of the two aileron angles, and is referred to as "left" when the left aileron is up. The actions of the elevator and aileron balance tabs are indicated in figures 6 and 7.

Control system friction (C-2).- The control force required for slow motion of the controls with no load on the surfaces is shown in figure 8 as a function of control-surface position. It is seen that the forces thus required are affected, in the cases of the elevator and ailerons, by small weight moments in the systems. In the following table the friction forces, as measured by one-half the algebraic difference between the force required for movement in one direction and that required for movement in the other direction, are compared with the requirements of reference 1:

Control	F4U-4 friction	Limit of reference 1
Elevator	±2.5	±3
Rudder	±6.5	±7
Aileron	±1.0	±2

Longitudinal Stability and Control (D)

Dynamic longitudinal stability (D-1).- Short-period, control-free, longitudinal oscillations, initiated by abrupt deflection and release of the elevator control, were performed at pressure altitudes of about 7000 feet and 25,400 feet while the airplane was trimmed at various airspeeds in the power-on-clean configuration. Time histories of typical maneuvers are shown in figure 9. The oscillations of the elevator and the airplane damped completely within one cycle, as required by reference 1.

Static longitudinal stability (D-2).- The static longitudinal-stability characteristics were measured at low altitude in various configurations and at high altitude in the power-on clean configuration. Short records were taken in steady, straight, unbanked flight at various airspeeds for each configuration and test center-of-gravity location. The variations of elevator angle and elevator control force with airspeed obtained in this manner are given in figure 10.

For the determination of the neutral-point locations, the values of elevator angle δ_e and elevator control force divided by the dynamic pressure F_e/q were plotted against lift coefficient C_L. The slopes $d\delta_e/dC_L$ and $d(F_e/q)/dC_L$ of the resulting curves were then plotted against center-of-gravity location. The center-of-gravity location at which $d\delta_e/dC_L = 0$ was taken as the stick-fixed neutral point, and the location at which $d(F_e/q)/dC_L = 0$ was taken as the stick-free neutral point. Results of this analysis appear in figure 11.

On the basis of stick-free stability characteristics for the speed ranges specified in reference 1, an examination of figures 10 and 11(b) indicates that the most rearward desirable center-of-gravity locations are about 30 percent M.A.C. for the power-on-clean configuration, 33 percent M.A.C. for the glide configuration, and 27 percent M.A.C. for the approach configuration. However, the data of figure 10 show that, for the most rearward test center-of-gravity locations and the test trim speeds, the unstable forces which do occur are not excessive. The effect of altitude on the static longitudinal stability appeared to be negligible.

In addition to the tests described above, the static longitudinal-stability characteristics of the airplane with a spring installed in the elevator control system were measured for one center-of-gravity location and various airplane configurations. This spring was furnished by the manufacturer and was installed at Ames. It was of such strength as to necessitate an additional pull force of approximately 5 pounds at the stick. Figure 12 presents the results of these tests and shows a comparison between the elevator control forces with spring and those without spring (derived from fig. 10). Some improvement in the elevator-force characteristics at low speeds was gained by use of the spring, but excessive push forces were experienced at high speed when the test trim-tab setting was retained throughout the speed range (figs. 12(d) and 12 (e)).

Elevator control power and control forces (D-3, D-4, D-5).-

Elevator control power in steady flight (D-3.1).- As indicated by figure 10, the elevator control was sufficiently powerful to permit steady straight flight over the test speed range in all configurations for all practicable center-of-gravity locations.

Elevator control power and control forces in maneuvering flight (D-3.2, D-4.1, D-4.2, D-4.5).- The longitudinal-control characteristics in maneuvering flight were measured in steady turns in the power-on-clean configuration at low and high altitudes. Short records were obtained during steady turns at various speeds and accelerations. Three center-of-gravity locations were investigated at the low altitude, and two at high altitude.

The variations of elevator angle δ_e and control force F_e with normal acceleration factor A_Z for the various test loading conditions and airspeeds are presented in figures 13 and 14 for average pressure altitudes of 8500 feet and 25,000 feet, respectively.

The elevator control was sufficiently powerful to stall the airplane at all test center-of-gravity locations and airspeeds.

The control-force values shown in figures 13 and 14 vary smoothly with acceleration factor. However, the decrease in force-curve slope with increasing acceleration factor in some cases was considered objectionable by the pilots – especially in those cases where complete control-force reversals were experienced.

The variations of elevator control-force gradient $\Delta F_e/\Delta A_Z$ with center-of-gravity location, as derived from figures 13 and 14, are given in figure 15. In the term $\Delta F_e/\Delta A_Z$, ΔF_e represents the change in control force from the steady straight flight value, and $\Delta A_Z = A_Z - 1$. Due to the nonlinear variations of elevator control force with acceleration factor, gradient computations were made for several values of acceleration factor. As seen from figure 15, the variations of $\Delta F_e/\Delta A_Z$ with acceleration factor, center-of-gravity location, altitude, airspeed, and direction of turn seriously limited the conditions under which the gradient was of desirable magnitude (3 to 8 lb/g). In fact, there was no center-of-gravity location for which the gradient was always within these limits for all test values of the other variables. The optimum location appeared to be approximately 30.5 percent M.A.C. for which the gradient ranged from 2 to 14 pounds per g.

Abrupt pull-ups were made at one airspeed and one center-of-gravity location in order to investigate the elevator-control characteristics in rapid maneuvers. The method of data analysis set forth in reference 5 was followed. Figure 16 presents these data and shows a comparison of $\Delta F_e/\Delta A_Z$ in abrupt pull-ups with that in steady turns. The steady-turn value shown is an average of those obtained under conditions most nearly approximating the speed, altitude, and center-of-gravity location used for the pull-ups. It is seen that, as is desired, the gradients obtained in the pull-ups were well above those experienced during steady turns.

Elevator control power in take-offs (D-3.5).– Although no specific tests were conducted, the pilots reported that the elevator control power was adequate at low speeds during take-offs with the center-of-gravity at the most rearward test location.

Elevator control power and control forces in landings (D-3.3, D-4.6).– Landings were made at different contact speeds over a safe and feasible range for two center-of-gravity locations. These tests were performed in the landing configuration used in stability tests. The throttle was cut back early in the approach in all cases. The elevator-tab setting used during the tests was that required for zero force at about 100 miles per hour in the approach configuration. The variation of elevator angle and elevator control force with airspeed (all read at the instant of ground contact) is shown in figure 17. It is seen that there was sufficient elevator control for stall-type landings with the most forward test center of gravity, and that the forces required were not excessive.

Elevator control forces in high-speed dives (D-5.2).- Although no comprehensive high Mach number tests were made in this program, an indication of the high-speed control characteristics at subcritical Mach numbers can be derived from the available data. Figure 18 gives an estimate of the variations with the airspeed of the elevator control force in a dive. Due to the nonlinearity of the curves F_e against A_Z and the lack of turn data at the high speeds considered, it is not possible to predict with any degree of accuracy the normal acceleration which would be produced by release of the stick under the conditions illustrated by figure 18. However, comparison of the data of figure 13 with that of figure 18 indicates that excessive acceleration probably would result with a rearward center of gravity, especially with the spring installed.

Longitudinal trim changes (D-6).- The changes in elevator control force and elevator angle required to maintain steady straight flight following changes in flap, gear, and power settings are given in table I for various typical conditions. These results show that the changes were well below the specified maximum of 35 pounds. Although there is no pertinent requirement, the pilots noted that the pitching effects due to sideslip were disagreeably large in maneuvers such as rudder kicks and lateral oscillations. The changes in pitching moment due to sideslip, as indicated by the variation of elevator angle and elevator control force with steady sideslip angle, are given in figure 19. It is seen that sizable changes in the elevator angle and control force were required with changes in sideslip angle, especially with right sideslip.

Longitudinal trimming device (D-7).- The elevator trim tab maintained a given setting indefinitely unless changed manually.

Measurements of the effect of the trim tab in producing elevator control-force changes were made at several speeds with the airplane in various configurations. The over-all results of these measurements are presented in figure 20 in the form of the variation with lift coefficient of an effectiveness parameter $d(F_e/q)/d\delta_{t_o}$. Analysis based on the data of figure 20 and figure 10 indicates that the elevator trim-tab power was sufficient to meet easily the requirements of reference 1 over the feasible center-of-gravity range.

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Directional Stability and Control (E)

Dynamic directional stability (E-1).- Records were taken of directional and lateral oscillations which were initiated by two methods: (1) abruptly deflecting the rudder and quickly releasing it, and (2) releasing all controls in steady sideslips. The oscillations were performed at both high and low altitude.

Time histories of typical oscillations are shown in figure 21. Although the pitching motion of the airplane necessitated recovery from some of the maneuvers before the lateral and directional oscillations were completely damped, the oscillations did tend to damp as required by reference 1. The oscillation of the rudder itself did not disappear within the specified one cycle but continued with low damping for several cycles with the same frequency as the airplane oscillations. No flutter of the rudder or control-fixed or -free snaking of the airplane was experienced during the flight tests. Further discussion of the lateral and directional oscillations appears in the section on lateral dynamic stability.

Static directional stability (E-2).-

Rudder-fixed stability (E-2.1, 2.2).- The characteristics in steady sideslips were measured during short runs in steady straight flight at various angles of sideslip over the maximum feasible range. Sideslips were performed at low altitude for various airspeeds and airplane configurations. The variations with sideslip angle of rudder and aileron angles and control forces and angle of bank are given in figure 22. Additional tests were made at high altitude, but no significant effect of altitude was discernible, so only the low-altitude data are presented.

The variations of rudder angle with sideslip angle show positive rudder-fixed directional stability over the obtainable sideslip range for all test conditions. As is required by reference 1, the angle of steady sideslip was substantially proportional to the change in rudder deflection over a range of $\pm 15^\circ$ from trim. For angles of sideslip greater than $\pm 15^\circ$, increases in rudder angle produced increases in steady sideslip up to full or maximum feasible rudder deflection.

Data obtained during abrupt, rudder-fixed, aileron rolls showed the change in sideslip angle per 5 percent of full aileron deflection to vary with airspeed from 0.3° to 0.8°, well below the specified limit of 1.0° given in reference 1 for rolls out of 45° banked turns.

Rudder-free stability (E-2.3).- The rudder forces in steady sideslips (fig. 22) were in the correct direction at all times. However, at low speeds in the power-on-clean configuration (fig. 22(b)) the small and erratic force variation in left sideslips and the severe force-reversal tendency at large angles of right sideslip were objectionable. No doubt the force would have reversed had the right sideslip angle been increased slightly.

Rudder control power and control forces (E-3, E-4 and E-5).-

Rudder control power and control forces in steady straight flight (E-3.1 and E-5).- The rudder and aileron angles and control forces and the angle of sideslip required in steady, straight, unbanked flight were measured for various configurations during the static-longitudinal-stability tests and are plotted in figure 23 as a function of airspeed. It is seen that, as required by reference 1, the rudder control was sufficient for steady, straight, unbanked flight over the speed range in the specified configurations. Figures 22(e) and 22(f) indicate that there was sufficient rudder control to balance the airplane at the required angle of sideslip of 5° to either side of the wings-level value in the approach configuration at the specified speed.

It is estimated from the data of figure 23 that the rudder control force required at limit diving speed, with the tab set for zero force in level flight in the power-on-clean configuration, would be approximately 150 pounds, considerably above the maximum of 100 pounds specified in reference 1. The pilot considered the rudder forces in dives excessive.

Rudder control power and control forces in ground handling (E-3.2, E-3.3).- Although no extensive tests were made, the pilots reported that the rudder, in conjunction with other means of control, was adequately powerful in taxiing, take-offs, and landings. With suitable tab settings, the associated control forces were not excessive.

Rudder control power and control forces in abrupt exits from turns (E-3.5, E-4.1).- Abrupt exits were made from steady 45°-banked turns, left and right, at average indicated airspeeds of 140 mph and 120 mph for flap- and gear-up and flap- and gear-down configurations, respectively. In these maneuvers various amounts of rudder deflection were abruptly applied simultaneously with full aileron deflection. Figure 24 gives typical time histories of those maneuvers in which slightly favorable sideslip was obtained. The rudder control forces were generally high, especially in exits from left turns, but did not exceed substantially the specified value of 180 pounds, and the requirement of reference 1 essentially was satisfied.

Rudder control power and control forces in rudder kicks.– Although not required by reference 1, rudder kicks started from steady level flight were performed in the flap– and gear–up condition at average indicated airspeeds of 153 and 250 miles per hour. In these maneuvers the pilot abruptly deflected the rudder various amounts and attempted to hold the ailerons in the trim position. The results of these tests, showing the effectiveness of the rudder in producing roll and yaw, are given in figure 25. The dihedral effect at these test speeds was considered satisfactory by the pilots.

Directional trimming device (E-6).- The rudder trim tab maintained a given setting indefinitely unless changed manually.

Analysis of the data of figures 22 and 23 indicates that the rudder trim tab was sufficiently powerful to reduce the rudder force to zero in straight, steady, unbanked flight in the power–on–clean and glide configurations over the speed ranges specified in reference 1. It is estimated that the maximum tab angles required to meet the requirement are 14.5° left and 3.0° left for the power–on–clean and glide configurations, respectively.

Lateral Stability and Control (F)

Dynamic lateral stability (F–1).– No aileron overbalance or flutter was noted during the flight test program.

The data of figure 21, which were discussed previously in the section on dynamic directional stability, show that, on the basis of cycles to damp to one–half amplitude, the requirements of reference 1 on lateral–dynamic stability were met at low altitude but were not met at high altitude. Oscillations were also made in which the pilot attempted to hold the rudder fixed after the initial disturbance; only a slight improvement in damping resulted from this procedure. The pilots described the dynamic lateral and directional stability of the airplane as weak.

Static lateral stability (F–2).–

Lateral stability in steady sideslips (F–2.1, F–2.4).– The variations of aileron deflection with sideslip angle plotted in figure 22 show positive stick–fixed static lateral stability (dihedral effect) in all test conditions. The stick-free stability, indicated by the aileron–force data, is positive in all cases except in the approach and wave–off configurations at low speed (figs. 22(e) and 22(g)), in which cases the aileron control force did not change with sideslip angle, an indication of neutral stability. The pilots considered the lateral static stability satisfactory.

Side force in steady sideslips (F-2.3).- In figure 22 right angle of bank always accompanies right sideslip from trim and vice versa, and hence the variation of side force with angle of sideslip was in the proper direction.

Aileron control power and control forces (F-3, F-4, F-5).-

Aileron control power and control forces in aileron rolls (F-3.1, F-3.2, F-3.3, F-3.4, F-3.5, F-4.1, F-4.2).- Abrupt, rudder-fixed, aileron rolls were made with the flap and gear both up and down at various airspeeds. While the airplane was trimmed in steady, straight, unbanked flight, the control stick was abruptly deflected laterally and held until maximum rolling velocity was attained. For the flap- and gear-up tests the power was varied to maintain level flight (normal rated power for the high-speed runs), and for the flap- and gear-down runs the engine was throttled. Several left and right stick deflections were used at each speed.

The variations with change in total aileron angle of maximum $pb/2V$ and change in aileron control force are shown in figures 26 and 27. As is required, the $pb/2V$ curves and the force curves are smooth and nearly linear. No aileron shaking or force-reversal tendency was noted at any time during the test program.

Values of maximum $pb/2V$ obtainable with full stick deflection or a 30-pound control force, derived from figures 26 and 27, are presented in figure 28. For the flap- and gear-up condition, figure 28(a) shows an average (of left and right) $pb/2V$ of 0.064 for full aileron deflection in the low and normal speed range, compared with the specified value of 0.09. At higher speeds the maximum values of $pb/2V$ were seriously limited by high control forces; however, the extrapolation shown in figure 28(a) indicates that the required value of 0.015 at 423 miles per hour (95 percent of the limit diving speed at 10,000 ft, as given in reference 2) would probably be obtained. For the flap- and gear-down condition, figure 28(b) shows values of $pb/2V$ ranging from 0.06 to 0.076 as compared with the specified value of 0.07. The product of $p \times b$ (for full control throw) at 105 miles per hour was approximately 20 feet per second, well over the specified minimum of 10 feet per second.

Aileron control forces in high speed dives (F-5). The data of figure 23 show desirably small changes in aileron control force with speed in steady, straight, unbanked flight in all conditions. Figure 23(b) indicates that the force change in going from maximum level-flight speed (approx. 290 mph) to limit diving speed (445 mph at 10,000 ft) probably would not exceed to any appreciable degree the specified maximum of 10 pounds.

Lateral trimming devices (F-6).- The aileron trim tab maintained a given setting unless changed manually.

The aileron control force could be reduced to zero over the required speed range in the required configurations.

Stalling Characteristics (G)

Stalls from straight flight.- Time histories of stalls entered slowly from straight flight in various configurations are presented in figure 29. The stall warning was considered unsatisfactory in all configurations. There was no warning in the form of marked increase in rate of rearward stick travel near the stall. There was slight buffeting and control-surface tugging in some of the stall entries, but these were not definite enough and did not occur soon enough to be considered satisfactory stall warning. The most nearly satisfactory warning occurred in the power-on-clean configuration (fig. 29(b)) in which tail buffeting combined with small amplitude pitching and rolling motions to produce a warning which was termed "fair" by the pilot. The airplane tended to pitch down and roll simultaneously at the stall. The pitch-down was reinforced by a forward recovery motion of the stick. In the power-off configurations the roll-off was mild and inconsistent in direction. With power-on the roll-off was to the left and was termed "abrupt" with flap and gear down (figs. 29(d) and 29(c)). The motions of the airplane in the stall were not considered unduly severe, and recovery was readily accomplished by normal control manipulation.

Stalls from turning flight.- In figure 30 are presented time histories of stalls entered from left turns in various configurations. The stall warning was deficient in all configurations. The pilot reported a "flapping" sound on the canopy in the glide configuration but did not consider this a satisfactory warning, and reported virtually no stall warning in the other configurations. As was the case in straight flight, the airplane tended to nose down and roll simultaneously at the stall. In the power-on configurations there was a sharp left roll (into the turn for the test turns). The stalling characteristics in the approach and wave-off configurations (figs. 30(c) and 30(d)) were considered particularly undesirable. Normal use of the controls always resulted in satisfactory recovery.

Summary of Flying Qualities

A chart giving a summary of the flying qualities as determined in this investigation is presented in figure 31.

CONCLUSIONS

The following conclusions, based on the test results, pilots' opinion, and the requirements of reference 1, can be drawn with regard to the flying qualities of the F4U-4 airplane.

1. The short-period control-free oscillations of the elevator angle and the normal acceleration were satisfactorily damped.

2. The most rearward center-of-gravity locations for satisfactory static longitudinal stability, as determined by the control-force variations for the specified speed ranges and trim conditions, are approximately 33, 30, and 27 percent M.A.C. for the glide, power-on-clean, and approach configurations, respectively.

3. Use of a spring in the elevator control system gave some improvement in the stick-free static longitudinal-stability characteristics at low speed. However, excessive push elevator control forces were required when the elevator trim tab was left in the level-flight trim position during dives.

4. In steady turns the elevator control force varied smoothly with change in normal acceleration, but the force-curve slope decreased progressively with increased acceleration. The conditions for which control-force gradients of 3 to 8 pounds per g were obtained were seriously limited by sizable changes in the gradient with center-of-gravity location, airspeed, altitude, acceleration factor, and direction of turn.

5. The elevator control was adequate for take-offs with the center of gravity at its most rearward test location (0.325 M.A.C.) and for landings with the center of gravity at its most forward test location (0.265 M.A.C.). The associated control forces were not excessive.

6. The changes in elevator control force required to maintain steady straight flight after changes in flap, gear, and power settings were well under 35 pounds.

7. The elevator trim tab was sufficiently powerful.

8. The directional dynamic stability was positive, although the rudder did not damp within one cycle. The lateral oscillation was satisfactorily damped at low altitude but not at high altitude.

9. The changes from trim value of rudder angle and rudder control force varied smoothly with angle of sideslip over a $\pm 15^\circ$ sideslip range in all required conditions, an indication of positive rudder-fixed and rudder-free static directional stability. At low speed in the power-on-clean configuration, however, marked lightening of the rudder control force (which approached reversal) was experienced at high angles of right sideslip.

10. The yaw due to abrupt full aileron deflection at low speed was not excessive. There was adequate rudder control to hold trim sideslip with the specified control force of 180 pounds.

11. Both the rudder and aileron control were sufficiently powerful for steady, straight, unbanked flight over the speed range in all conditions. However, the changes in rudder control force with airspeed were excessive.

12. The rudder, in conjunction with other means of control, was adequately powerful in taxiing, take-offs, and landings. With suitable tab settings the associated control forces were not excessive.

13. The rudder and aileron trim tabs were sufficiently effective.

14. The stick-fixed static lateral stability (dihedral effect) was positive in all conditions, but the stick-free dihedral effect was neutral at low speeds with flaps and gear down, power on.

15. The variation of side force with angle of sideslip was of the proper sign.

16. In abrupt, rudder-fixed, aileron rolls the maximum $pb/2V$ and change in aileron control force varied smoothly with aileron deflection. The maximum $pb/2V$ for full aileron deflection at low and normal speeds in the clean configuration was only about 0.064.

17. The stalling characteristics in straight flight were considered fair in the clean configuration. Warning was inadequate, but the motions in the stall were not violent. With flaps and gear down in straight flight, and in all configurations in turning flight, there was insufficient stall warning. In all cases prompt recovery could be effected with normal use of the controls.

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1. Anon: Specifications for Stability and Control Characteristics of Airplanes. Spec. No. 119A, Bur. Aero. Navy Dept., Apr. 7, 1945.

2. Anon: Pilots Handbook of Flight Operating Instructions, Navy Model F4U-4 Airplane. Tech. Order No. AN-01-45HB-1, Bur. Aero. Navy Dept., Apr. 1, 1945.

3. Anon: Preliminary Handbook of Erection and Maintenance Instructions, Navy Model F4U-4 and FG-4 Airplanes. Tech. Order No. AN-01-45HB-2, Bur. Aero. Navy Dept., June 1, 1945.

4. Anon: Weight and Balance Data for Model F4U-4 Airplane. Tech. Order No. AN-01-1B-40, Bur. Aero., June 1, 1944 (May 29, 1945 for F4U-4).

5. Phillips, William, H.: An Investigation of Additional Requirements for Satisfactory Elevator Control Characteristics. NACA TN No. 1060, 1946.

TABLE I.- CHANGES IN ELEVATOR ANGLE AND ELEVATOR CONTROL FORCE DUE TO VARIATIONS IN FLAP, GEAR, AND POWER CONDITIONS. CHANCE VOUGHT F4U-4 AIRPLANE

Flap	Gear	Cowl flaps	Canopy	Manifold pressure (in.Hg)	Engine speed setting (rpm)	Elevator angle (deg)	Elevater tab setting (deg)	Indicated airspeed (mph)	Elevator control force change (lb)
up	up	closed	closed	27	2400	0.1 down	0.7 down	141	0
up	up	closed	open	27	2400	0.1 down			
up	up	closed	open	27	2400	0.2 down	0.9 down	141	6.5 pull
up	down	closed	open	27	2400	1.0 up			
up	down	closed	open	27	2400	1.2 up	3.4 down	140	0.5 push
full down	down	closed	open	27	2400	0.1 down			
full down	down	closed	open	27	2400	0.2 up	3.7 down	120	2.5 pull
full down	down	closed	open	15	2150	0.4 up			
full down	down	closed	open	15	2150	0.5 up	5.0 down	120	5.5 push
full down	down	closed	open	48	2600	0.4 up			
full down	down	closed	open	27	2400	0.2 up	2.3 down	97	2.0 push
full down	down	closed	open	48	2600	0.0			
full down	down	1/4 open	open	48	2600	0.3 up	2.7 down	120	2.0 push
full down	up	1/4 open	open	48	2600	0.6 down			
full down	up	1/4 open	open	48	2600	0.6 down	1.8 down	121	3.5 push
up	up	1/4 open	open	48	2600	0.0			
up	up	1/4 open	open	48	2600	0.0	0.4 down	123	0
up	up	1/4 open	closed	48	2600	0.1 up			
30° down	down	1/4 open	open	48	2600	0.5 up	1.7 down	101	5.5 push
30° down	up	1/4 open	open	48	2600	1.0 down			
30° down	up	1/4 open	open	48	2600	1.2 down	0.6 down	122	0
up	up	1/4 open	open	48	2600	0.1 down			
up	up	1/4 open	closed	48	2600	0.8 down	0.6 up	255	0.5 push
up	up	1/4 open	closed	15	2150	0.8 down			
up	up	closed	closed	15	2150	0.8 down	0.6 up	254	6.5 pull
up	down	closed	closed	15	2150	0.4 down			

FIGURE LEGENDS

Figure 1.– Chance Vought F4U-4 airplane as instrumented for flight tests. (a) Three-quarter front view.

Figure 1.– Concluded. (b) Three-quarter rear view.

Figure 2.– Three-view drawing of Chance Vought F4U-4 airplane.

Figure 3.– Variation of elevator angle with stick position. Measured on the ground with no load on the control surfaces. Chance Vought F4U-4 airplane.

Figure 4.– Variation of rudder angle with pedal position. Measured on the ground with no load on the surface. Chance Vought F4U-4 airplane.

Figure 5.– Variation of aileron angle with stick position. Measured on the ground with no load on the surfaces. Chance Vought F4U-4 airplane.

Figure 6.– Variation of elevator balance-tab angle with elevator angle. Chance Vought F4U-4 airplane.

Figure 7.– Variation of left aileron balance-tab angle with left aileron angle. Chance Vought F4U-4 airplane.

Figure 8.– Variation of control force with control surface position. Controls moved slowly with airplane at rest. Chance Vought F4U-4 airplane.

Figure 9.– Time histories of typical longitudinal oscillations. Power-on-clean configuration. Center of gravity at 0.318 M.A.C. Chance Vought F4U-4 airplane. (a) Average pressure altitude, 7000 feet.

Figure 9.– Concluded. (b) Average pressure altitude 25,400 feet.

Figure 10.– Variation of elevator angle and elevator control force with airspeed in steady straight unbanked flight. Chance Vought F4U-4 airplane. (a) Glide configuration.

Figure 10.– Continued. (b) Cruise configuration.

Figure 10.– Continued. (c) Power-on-clean configuration at low altitude (9000 ft av.).

Figure 10.– Continued. (d) Power-on-clean configuration at high altitude (25,000 ft av.).

Figure 10.– Continued. (e) Landing configuration.

Figure 10.– Continued. (f) Approach configuration.

Figure 10.– Concluded. (g) Wave-off configuration.

Figure 11.– Variation of neutral-point location with lift coefficient. Approximate altitude 9000 feet. Approximate weight 12,200 pounds. Chance Vought F4U-4 airplane (a) Stick fixed.

Figure 11. Concluded. (b) Stick free.

Figure 12.– Variation of elevator control force with airspeed in steady, straight, unbanked flight with and without spring installed. Chance Vought F4U-4 airplane. (a) Landing configuration, center of gravity 0.298 M.A.C. (b) Approach configuration, center of gravity 0.300 M.A.C. (c) Wave-off configuration, center of gravity 0.298 M.A.C.

Figure 12.- Continued. (d) Glide configuration, center of gravity 0.313 M.A.C.

Figure 12.– Concluded. (e) Power-on-clean configuration, center of gravity 0.313 M.A.C.

Figure 13.– Variation of elevator angle and elevator control force with normal acceleration factor in steady turns. Power-on-clean configuration. Average pressure altitude 8500 feet. Chance Vought F4U-4 airplane. (a) Left turns.

Figure 13.- Concluded. (b) Right turns.

Figure 14.– Variation of elevator angle and elevator control force with normal acceleration factor in steady turns. Power-on-clean configuration. Average pressure altitude 25,000 feet. Chance Vought F4U-4 airplane. (a) Left turns.

Figure 14.– Concluded. (b) Right turns.

Figure 15.– Variation of elevator control force gradient with center-of-gravity location. Flaps and gear up, normal rated power. Chance Vought F4U-4 airplane. (a) Average pressure altitude 8500 feet. (b) Average pressure altitude 25,000 feet.

Figure 16.– Variation of elevator control-force gradient $\Delta F_e/\Delta A_Z$ in abrupt pull-ups with duration of maneuver. $V_i \approx 200$ mph. Center of gravity at 0.318 M.A.C. Altitude ≈ 8500 feet. Chance Vought F4U-4 airplane.

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Figure 17.– Variation with airspeed of elevator angle and elevator control force required for landing. Chance Vought F4U-4 airplane.

Figure 18.– Variation with airspeed of elevator control force in a dive, with and without spring installed. Trim speed 290 mph. Chance Vought F4U-4 airplane.

Figure 19.– Variation of elevator angle and elevator control force with angle of steady sideslip. Chance Vought F4U-4 airplane. (a) Power-on-clean configuration, $V_i \approx 142$ mph. (b) Power-on-clean configuration, $V_i \approx 350$ mph. (c) Approach configuration, $V_i \approx 95$ mph.

Figure 20.– Variation of elevator trim-tab effectiveness parameter with lift coefficient. Chance Vought F4U-4 airplane.

Figure 21.– Typical time history of rudder-free directional and lateral oscillations. Power-on-clean configuration. Chance Vought F4U-4 airplane. (a) Pressure altitude $\approx$ 5500 feet.

Figure 21.– Concluded. (b) Pressure altitude $\approx$ 25,5000 feet.

Figure 22.– Characteristics in steady sideslips. Chance Vought F4U-4 airplane. (a) Glide configuration, $V_i \approx 140$ mph.

Figure 22.– Continued. (b) Power-on-clean configuration, $V_i \approx 140$ mph.

Figure 22.– Continued. (c) Power-on-clean configuration, $V_i \approx 350$ mph.

Figure 22.– Continued. (d) Landing configuration, $V_i \approx 100$ mph.

Figure 22.– Continued. (e) Approach configuration, $V_i \approx 100$ mph.

Figure 22.– Continued. (f) Approach configuration, $V_i \approx 140$ mph.

Figure 22.– Concluded. (g) Wave-off configuration, $V_i \approx 100$ mph.

Figure 23.– Lateral and directional characteristics in steady, straight, unbanked flight. Chance Vought F4U-4 airplane. (a) Glide configuration.

Figure 23.– Continued. (b) Power-on-configuration.

Figure 23.– Continued. (c) Landing configuration.

Figure 23.– Continued. (d) Approach configuration.

Figure 23.– Concluded. (e) Wave-off configuration.

Figure 24.-- Time histories of aileron-rudder rolls out of turns of about 45° bank. Chance Vought F4U-4 airplane. (a) Clean, power for level flight, 140 mph.

Figure 24.— Concluded. (b) Approach configuration, 120 mph.

Figure 25.— Characteristics in aileron-fixed rudder rolls. Power-on-clean configuration. Chance Vought F4U-4 airplane. (a) $V_i \approx 200$ mph.

Figure 25.— Concluded. (b) $V_i \approx 302$ mph.

Figure 26.— Variation with change in total aileron angle of maximum $pb/2V$ and change in aileron control force in abrupt rudder-fixed rolls. Flaps and gear up, power on. Average altitude 8500 feet. Chance Vought F4U-4 airplane. (a) $V_i \approx 145$ mph.

Figure 26.— Continued. (b) $V_i \approx 197$ mph.

Figure 26.— Continued. (c) $V_i \approx 253$ mph.

Figure 26.— Continued. (d) $V_i \approx 305$ mph.

Figure 26.— Concluded. (e) $V_i \approx 354$ mph.

Figure 27.— Variation with change in total aileron angle of maximum $pb/2V$ and change in aileron control force in abrupt rudder-fixed rolls. Flaps and gear down, power off. Average altitude 8500 feet. Chance Vought F4U-4 airplane. (a) $V_i \approx 102$ mph.

Figure 27.— Continued. (b) $V_i \approx 117$ mph.

Figure 27.— Concluded. (c) $V_i \approx 137$ mph.

Figure 28.— Variation of maximum $pb/2V$ with indicated airspeed. Chance Vought F4U-4 airplane. (a) Flaps and gear up, power on.

Figure 28.— Concluded. (b) Flaps and gear down, power off.

Figure 29.— Time histories of stalls entered from steady, straight, unbanked flight. Chance Vought F4U-4 airplane. (a) Glide configuration.

Figure 29.— Continued. (b) Power-on-clean configuration.

Figure 29.— Continued. (c) Landing configuration.

Figure 29.— Continued. (d) Approach configuration.

Figure 29.— Concluded. (e) Wave-off configuration.

Figure 30.– Time histories of stalls entered from turning flight. Chance Vought F4U-4 airplane. (a) Glide configuration.

Figure 30.– Continued. (b) Power-on-clean configuration.

Figure 30.– Continued. (c) Approach configuration.

Figure 30.– Concluded. (d) Wave-off configuration.

Figure 31.– Summary of flying qualities of a Chance Vought F4U-4 airplane.

(a) Three-quarter front view.

Figure 1.- Chance-Vought F4U-4 airplane as instrumented for flight tests.

(b) Three-quarter rear view.

Figure 1.– Concluded.

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(b) Three-quarter rear view.

Figure 1.- Concluded.

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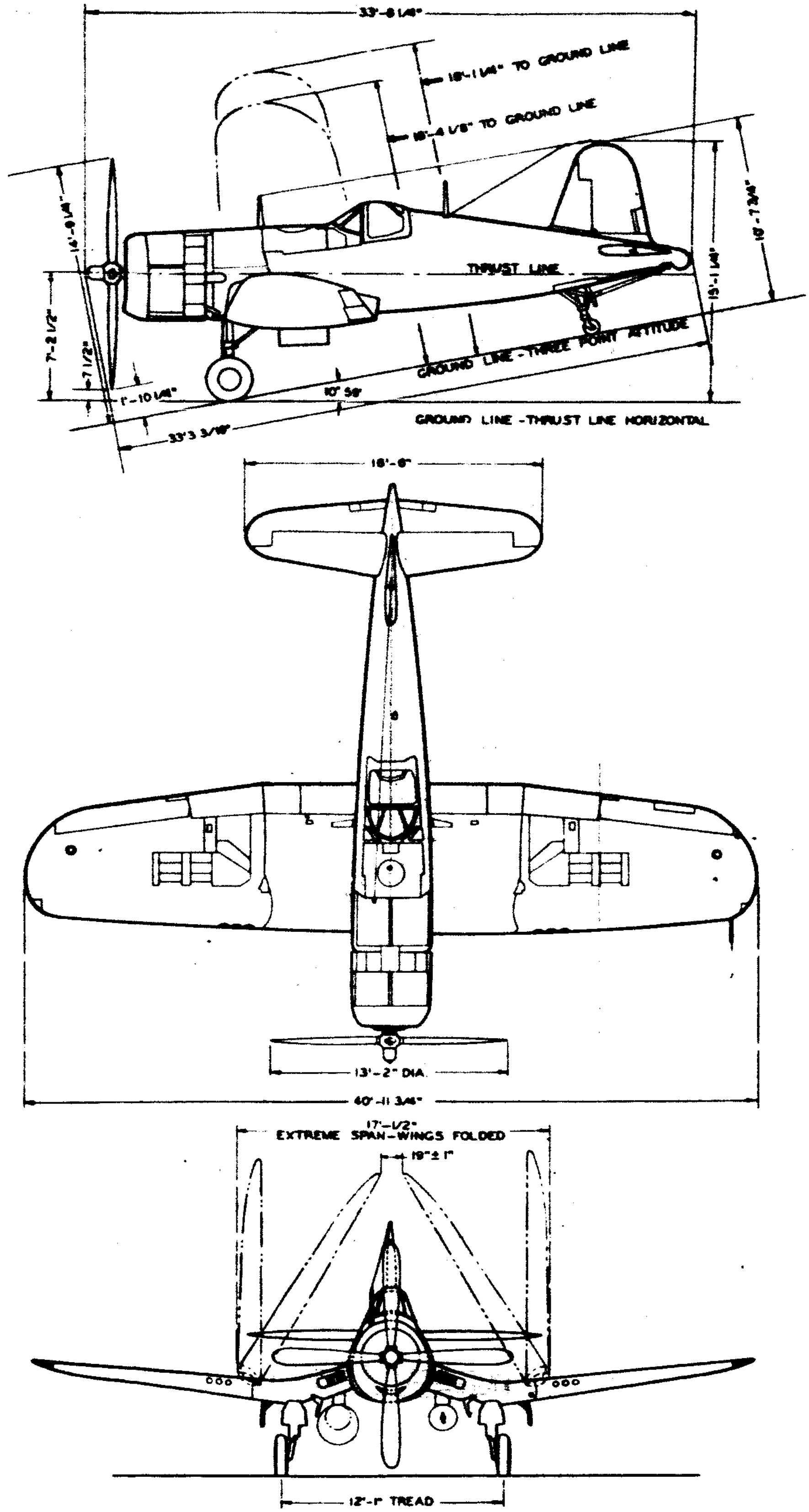

FIGURE 2.- THREE-VIEW DRAWING OF CHANCE VOUGHT F4U-4 AIRPLANE

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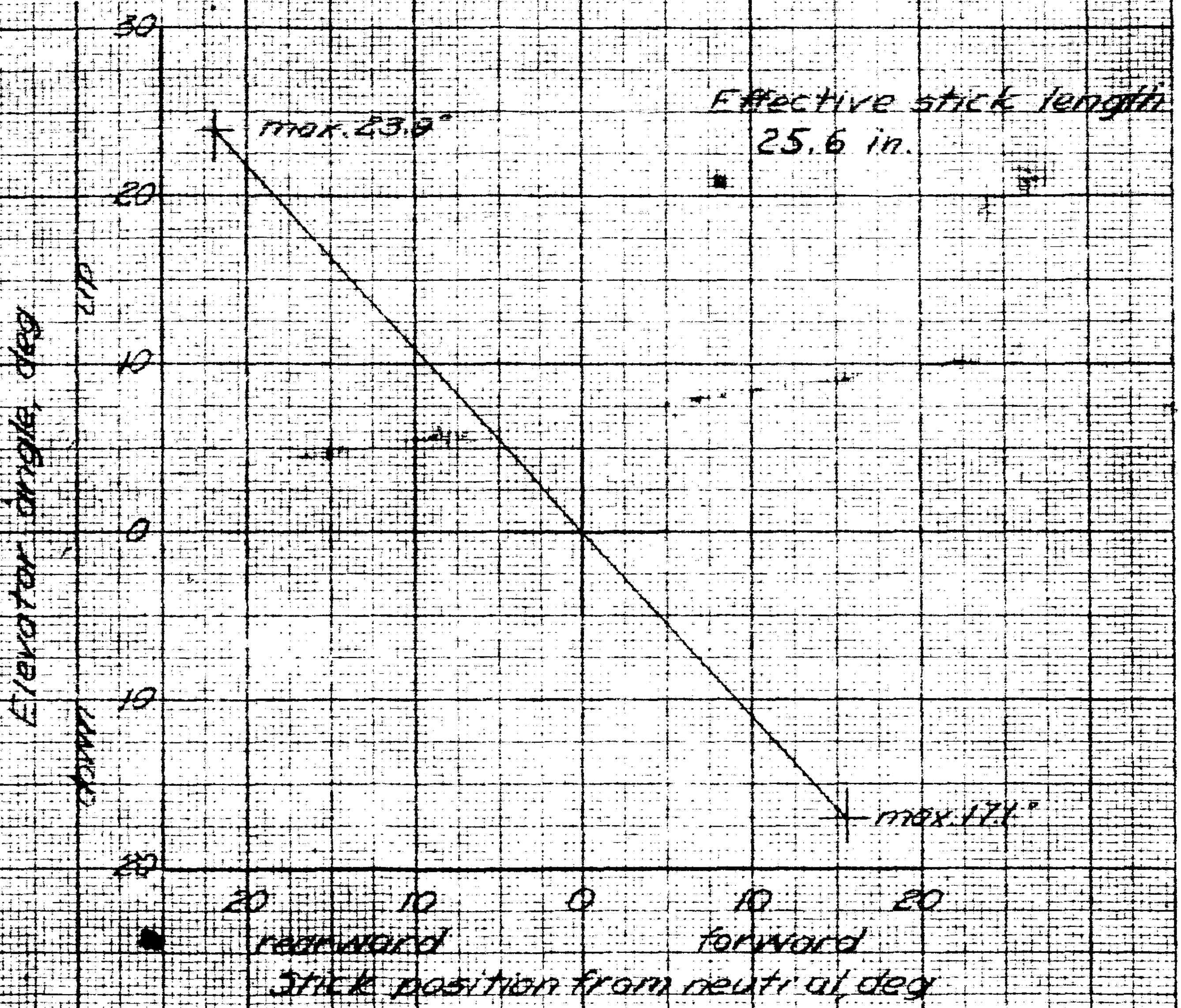

Figure 3. — Variation of elevator angle with stick position. Measured on the ground with no load on the control surfaces. Chance Vought F4U-4 airplane.

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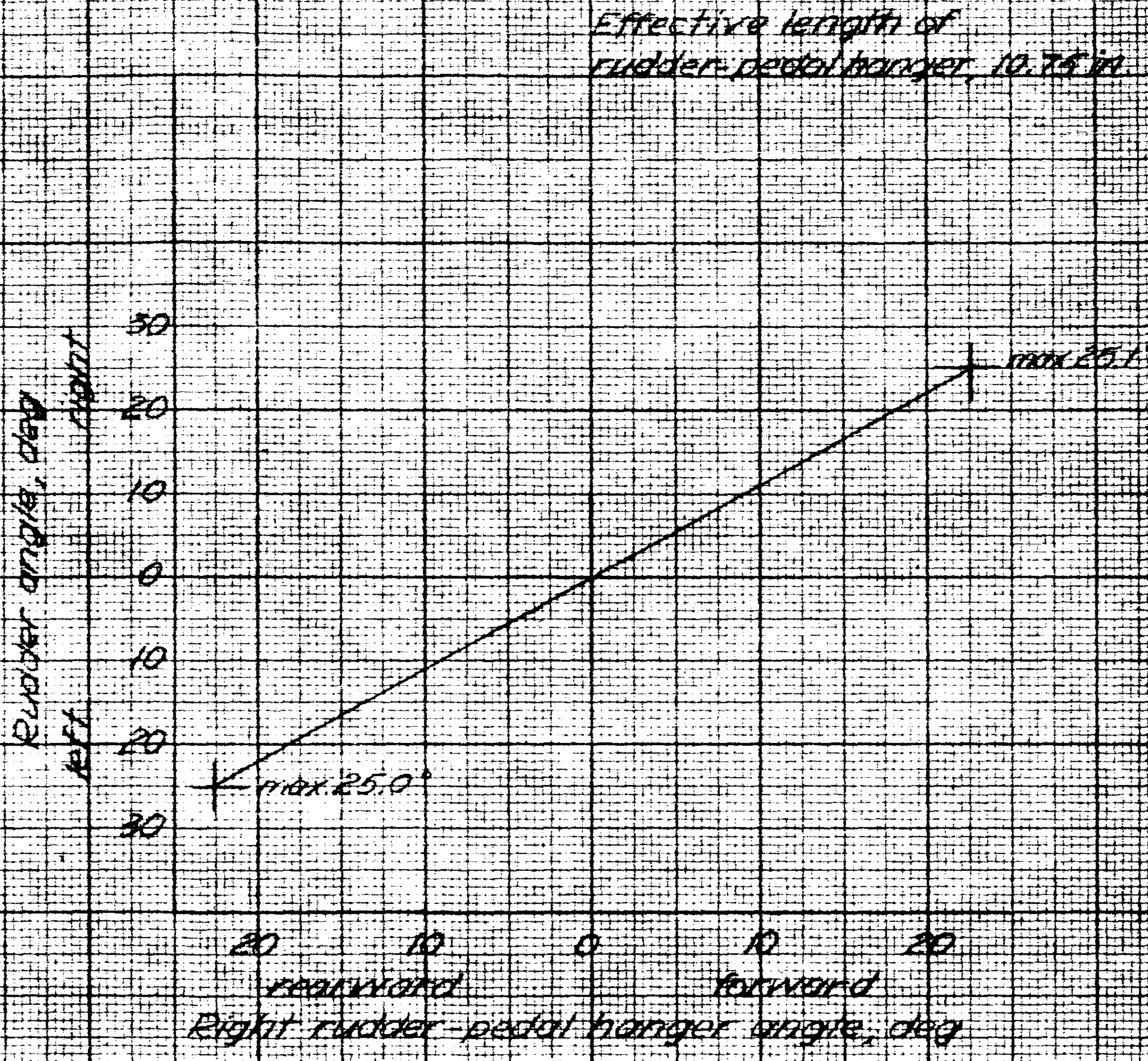

Figure 4. — Variation of rudder angle with pedal position. Measured on the ground with no load on the surface. Chance Vought F4U-4 airplane.

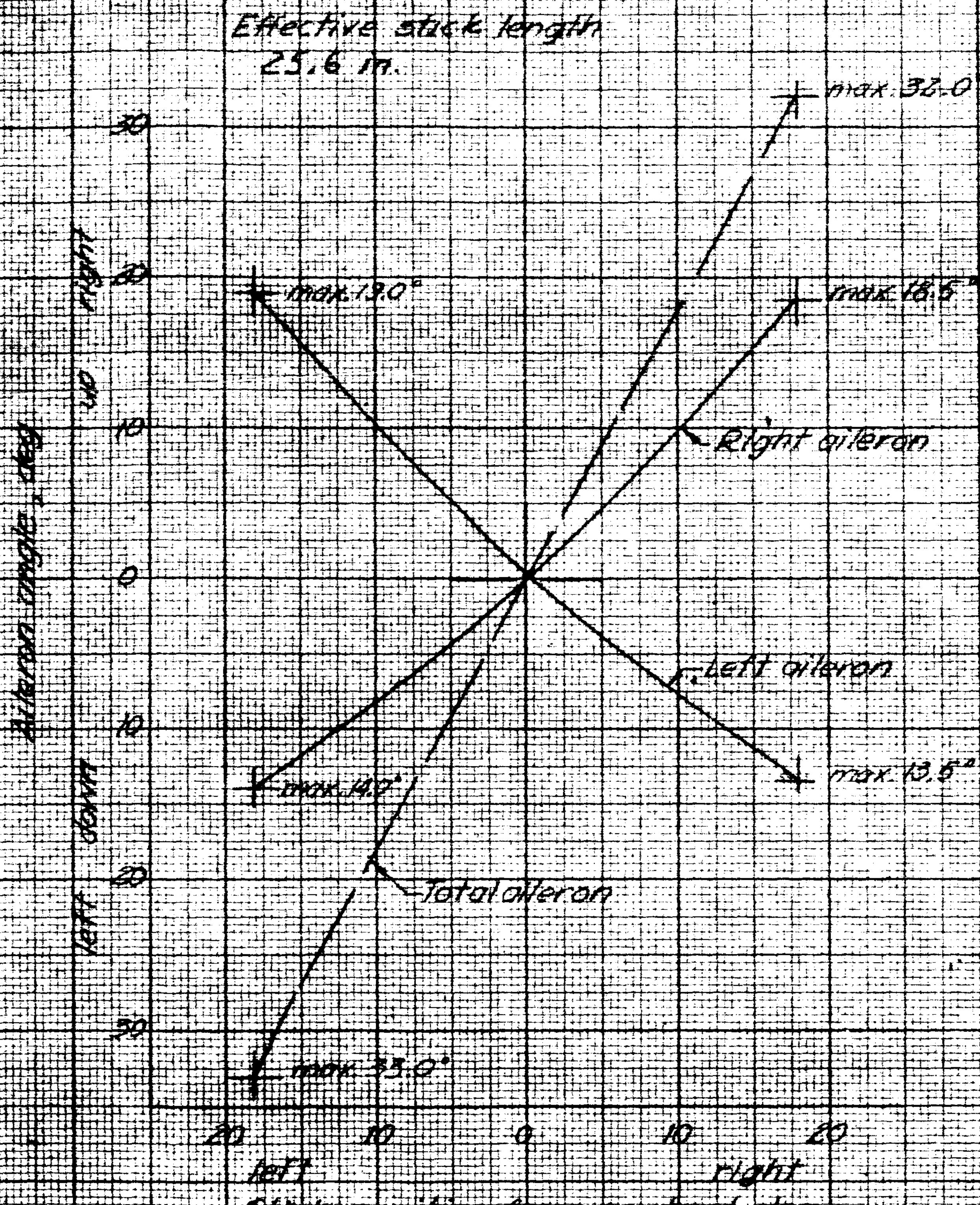

Figure 5. — Variation of aileron angle with stick position. Measured on the ground with no load on the surfaces. Chance Vought F4U-4 airplane

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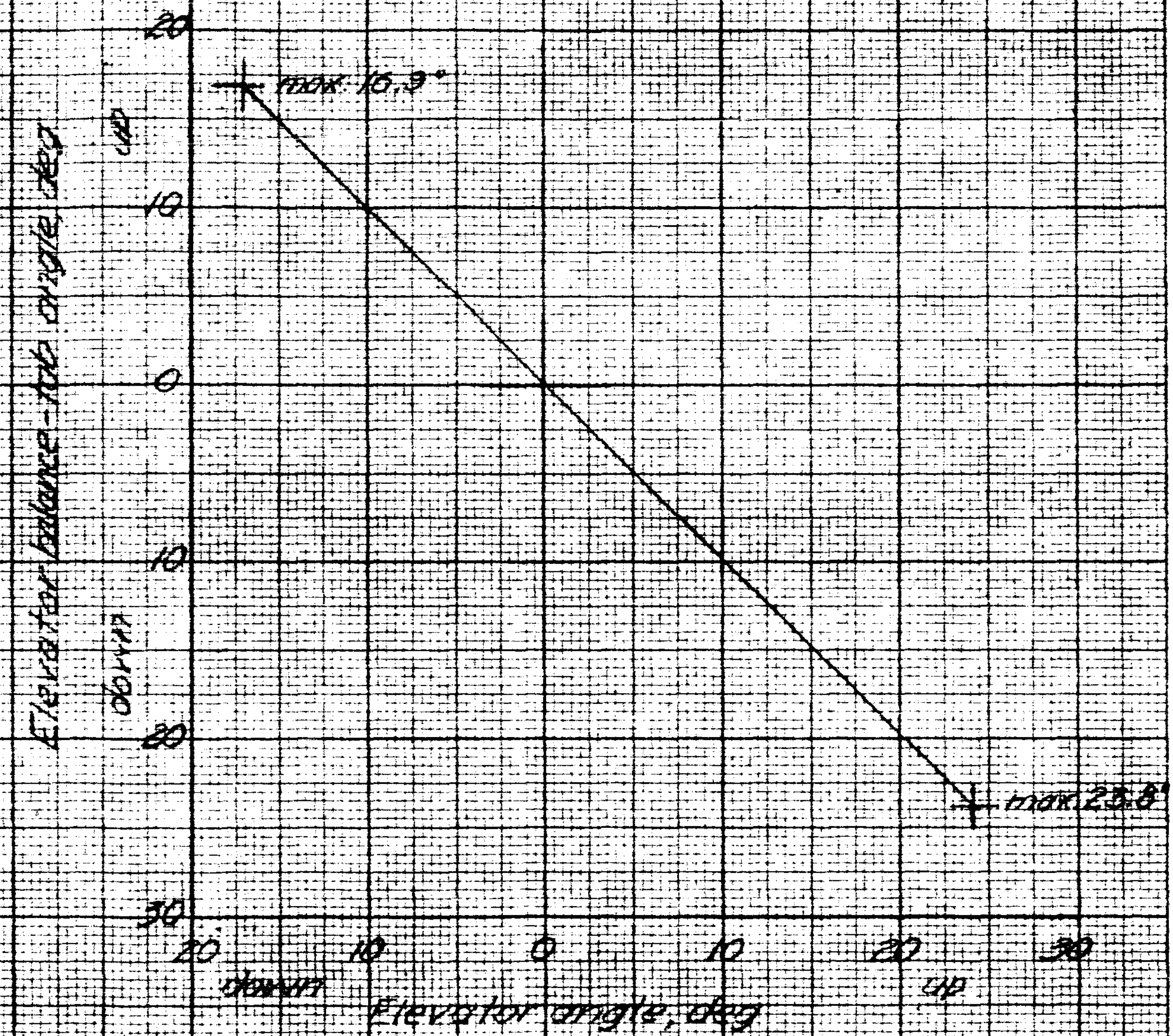

Figure 6. – Variation of elevator balance-tab angle with elevator angle. Chance Vought F4U-4 airplane.

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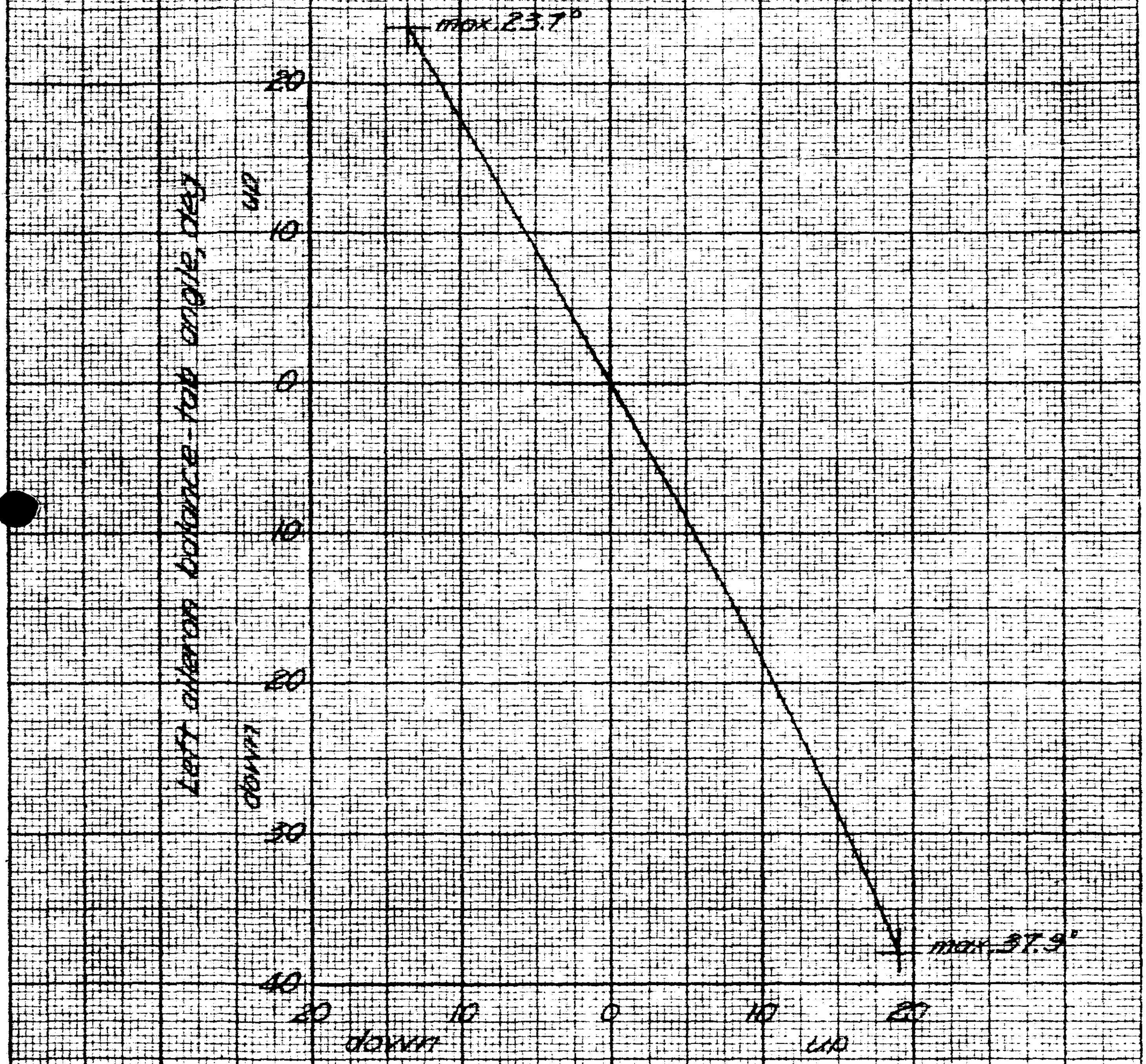

Figure 7. – Variation of left aileron balance-tab angle with left aileron angle. Chance Vought F4U-4 airplane.

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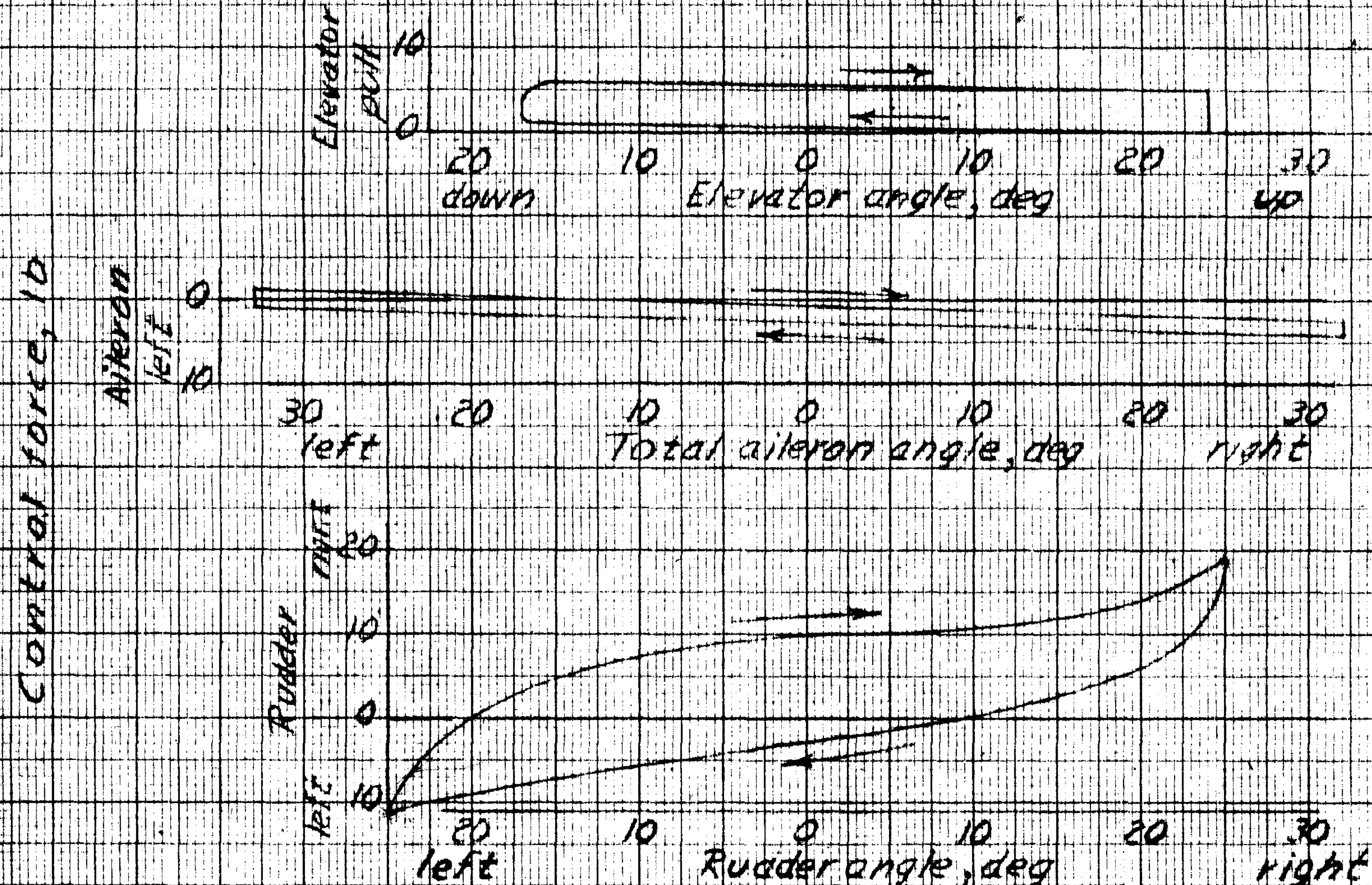

Figure 8. - Variation of control force with control surface position. Controls moved slowly with airplane at rest. Chance Vought F4U-4 airplane.

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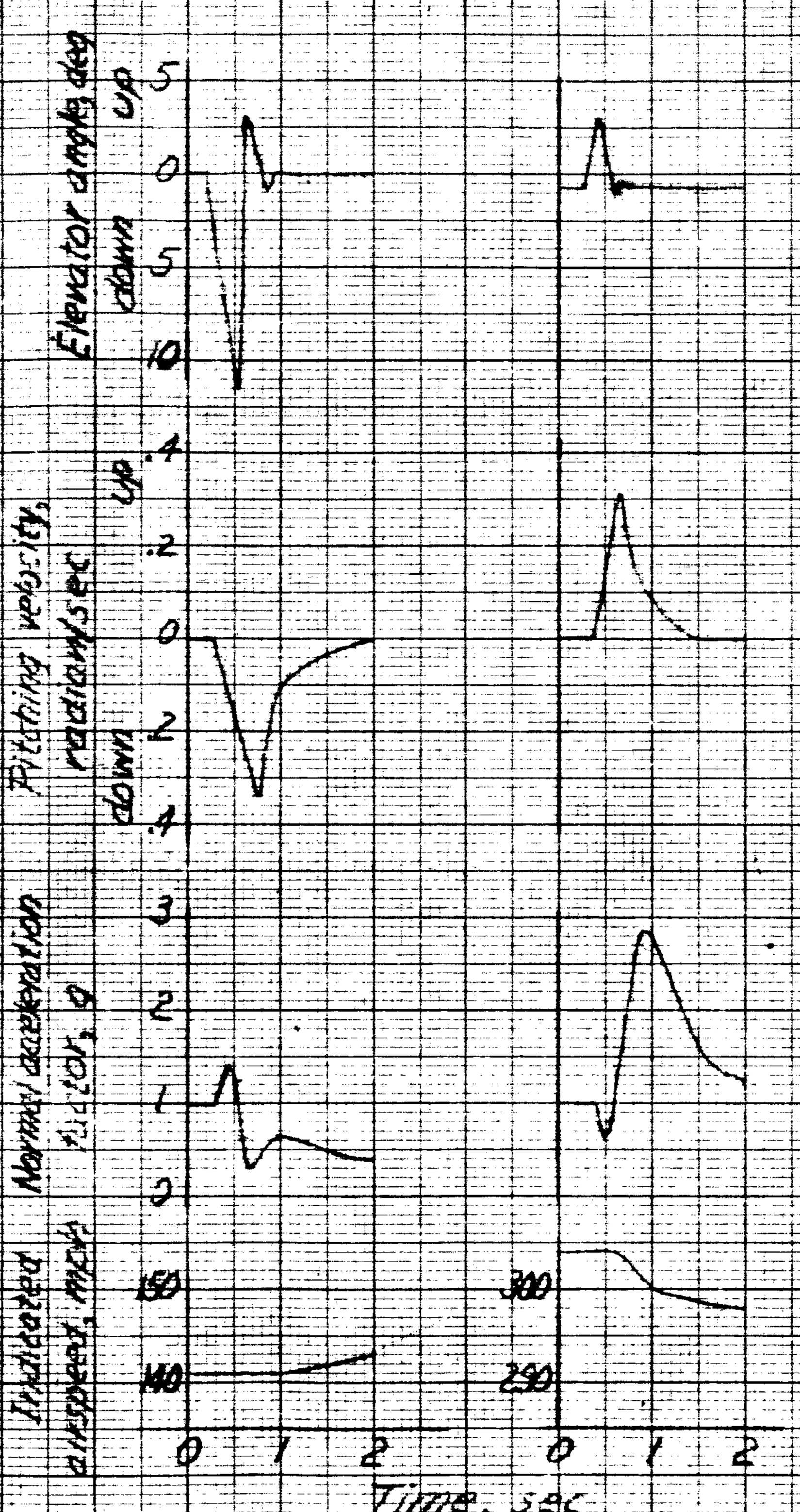

(a) Average pressure altitude, 7000 ft

Figure 9 .– Time histories of typical longitudinal oscillations. Power-on clean configuration. Center of gravity at 0.318 M.A.C. Chance Vought F4U-4 airplane.

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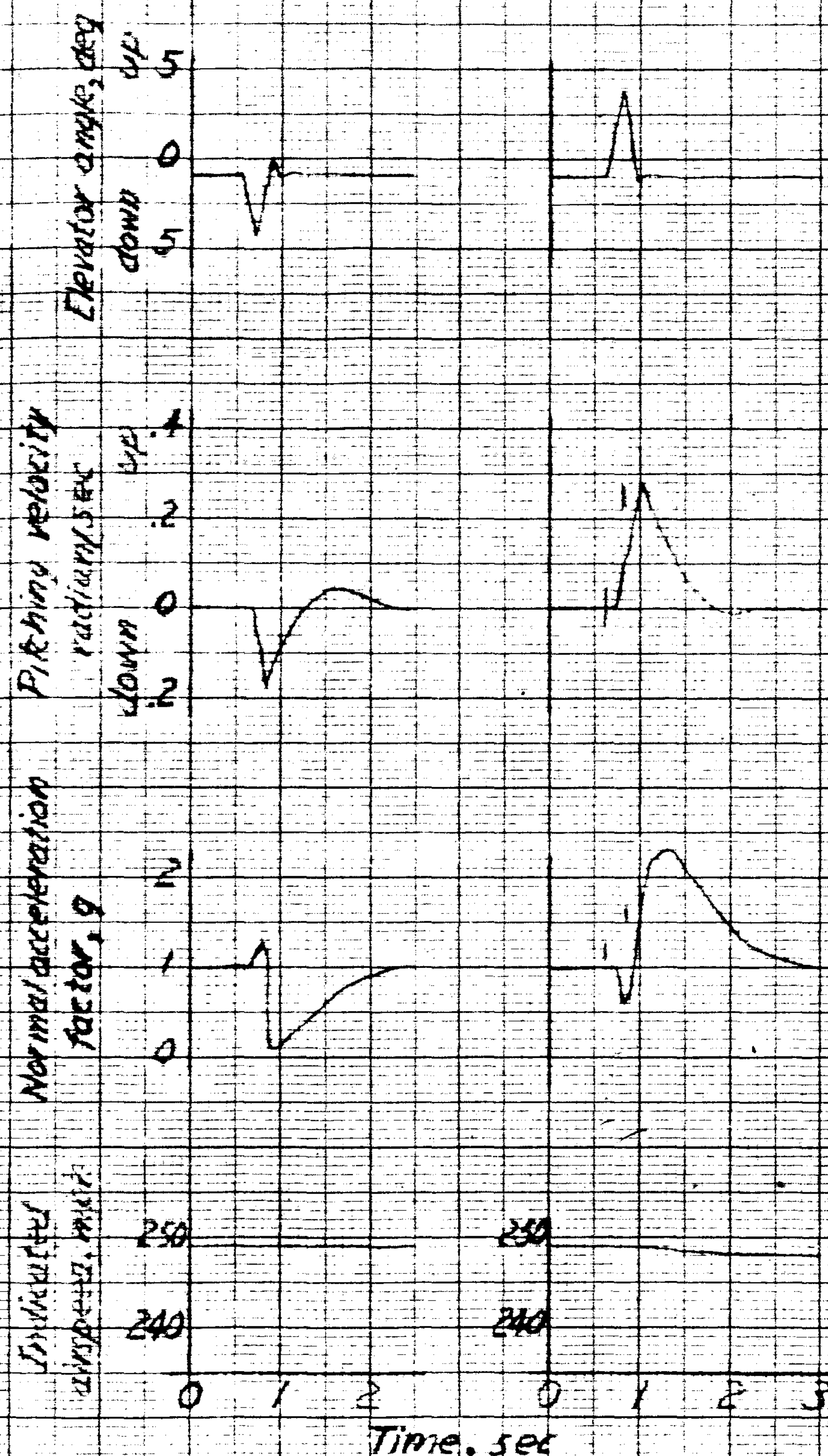
Fig. 9



(b) Average pressure altitude 25,400 ft

Figure 9.- Concluded. Chance Vought F4U-4 airplane.

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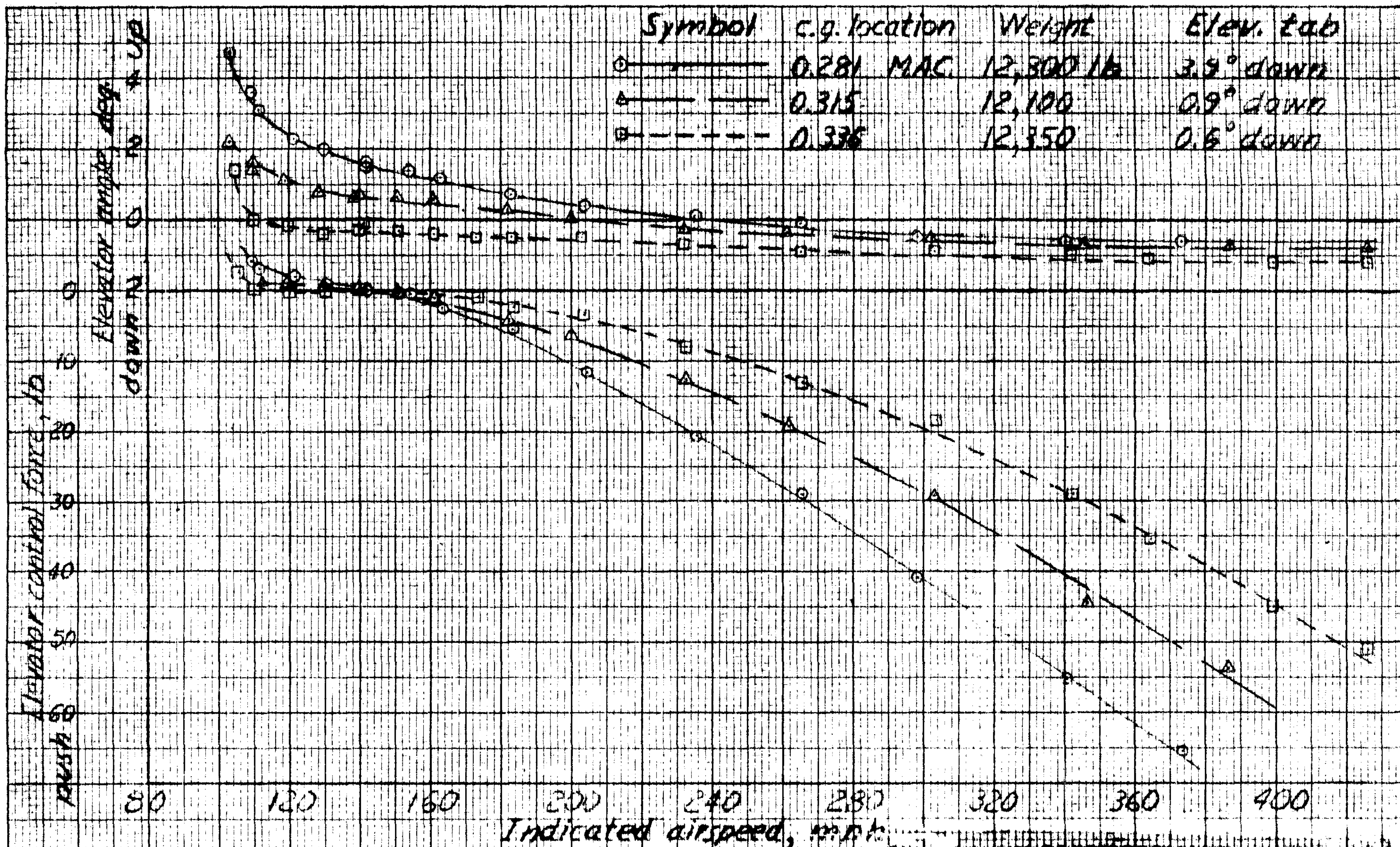
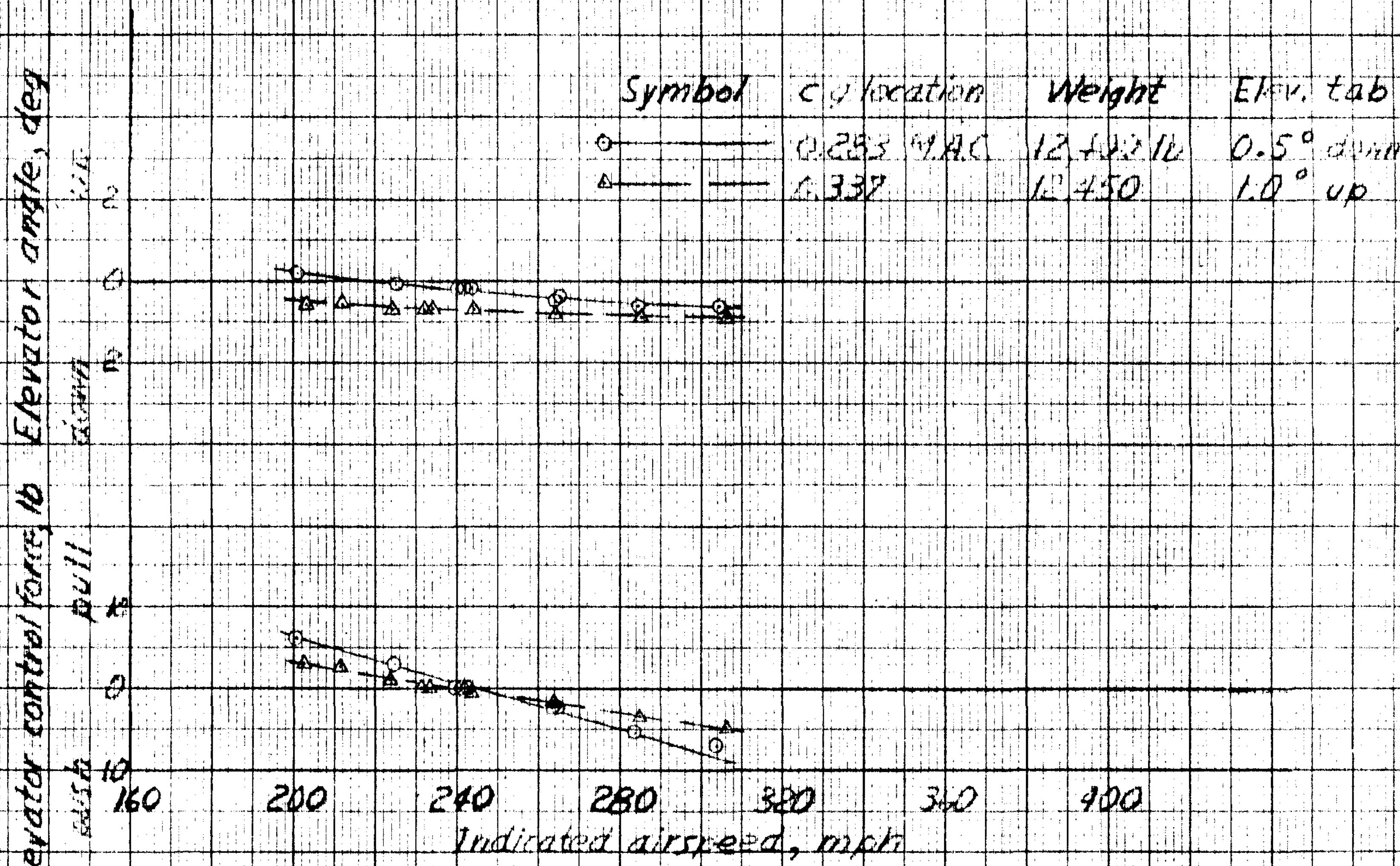


(a) Glide configuration.

Figure 10. – Variation of elevator angle and elevator control force with airspeed in steady straight unbanked flight. Chance Vought F4U-4 airplane.



(b) Cruise configuration

Figure 10.– Continued. Chance Vought F4U-4 airplane.

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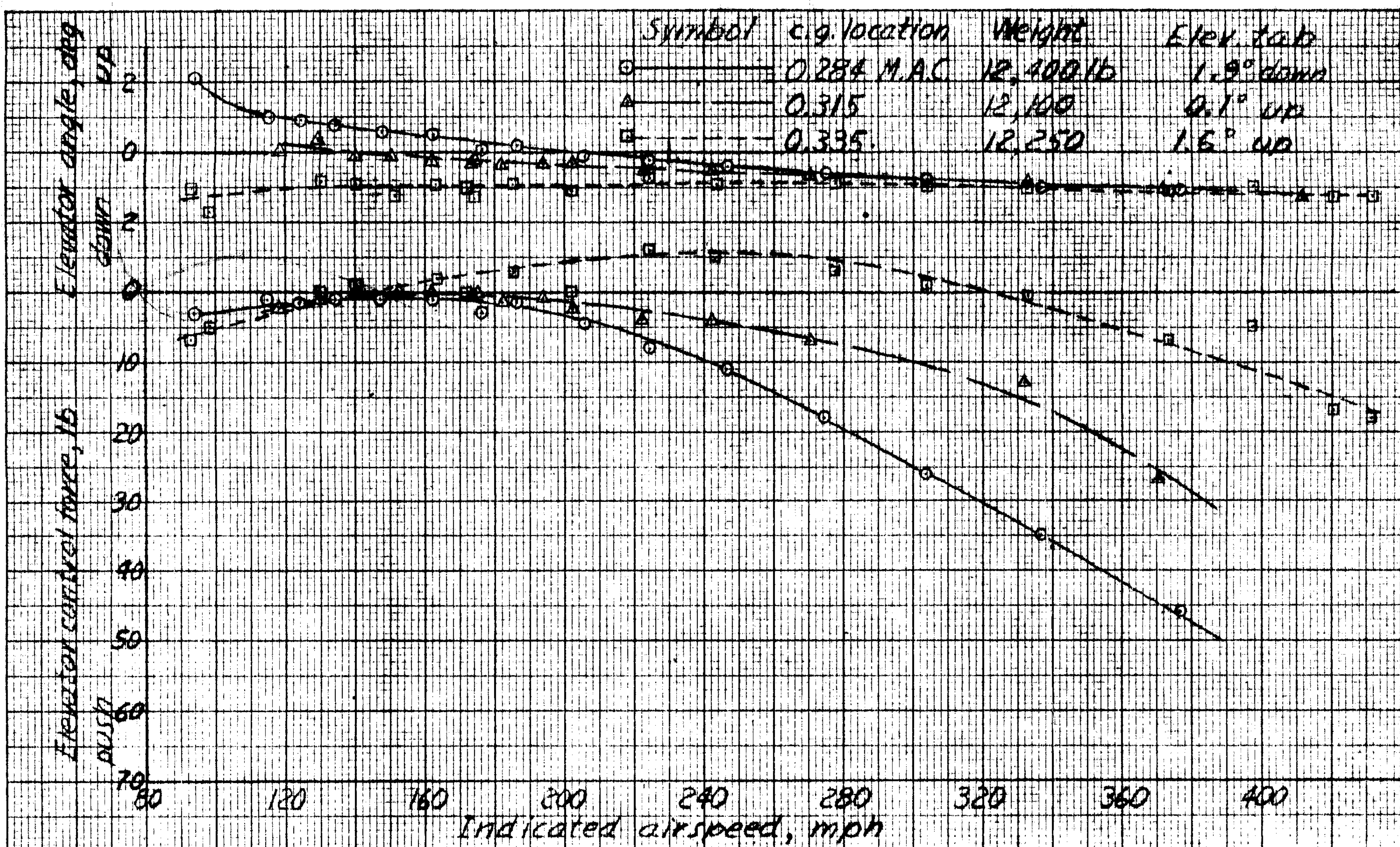

(c) Power-on-clean configuration at low altitude (9000 ft alt.)

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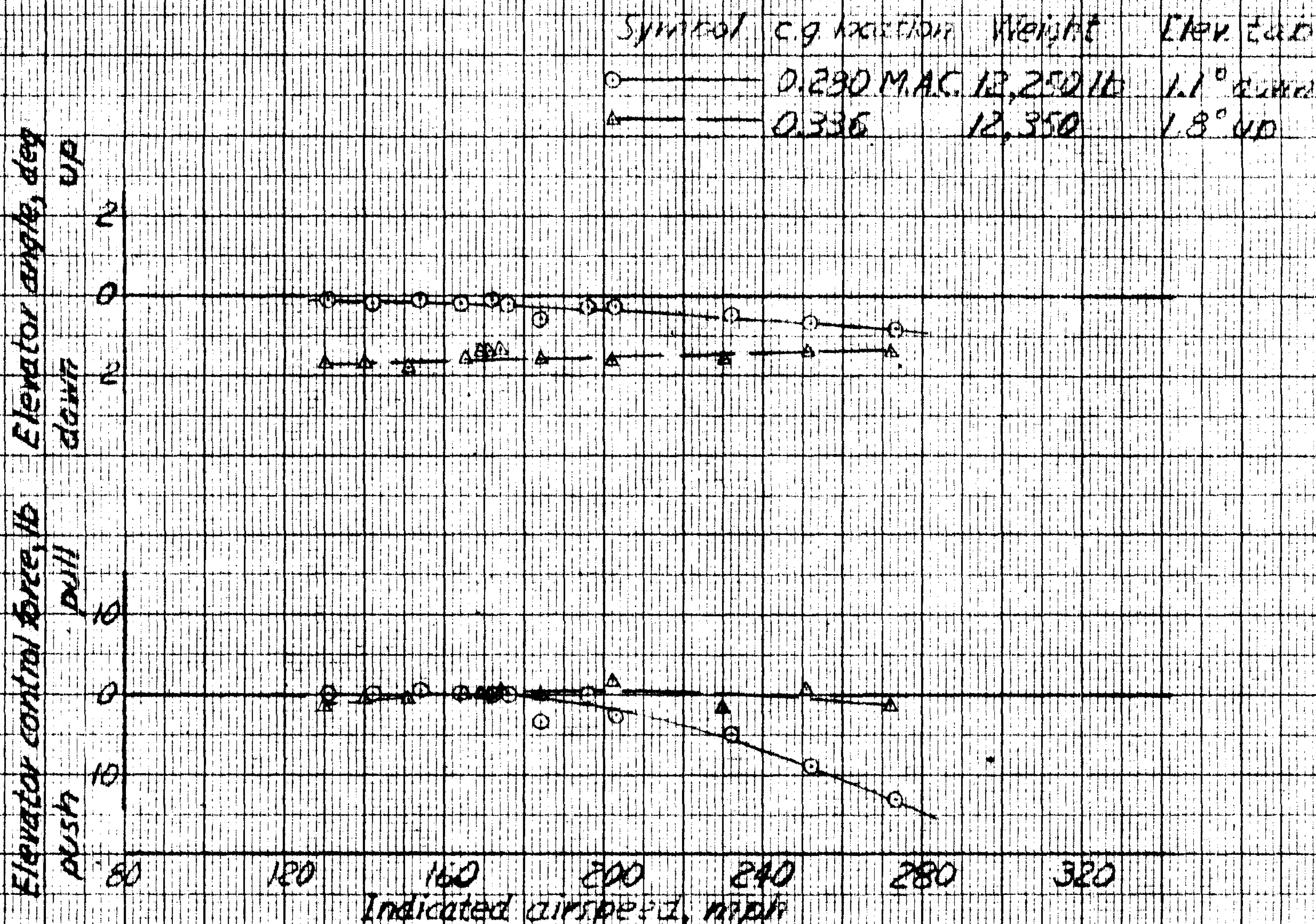
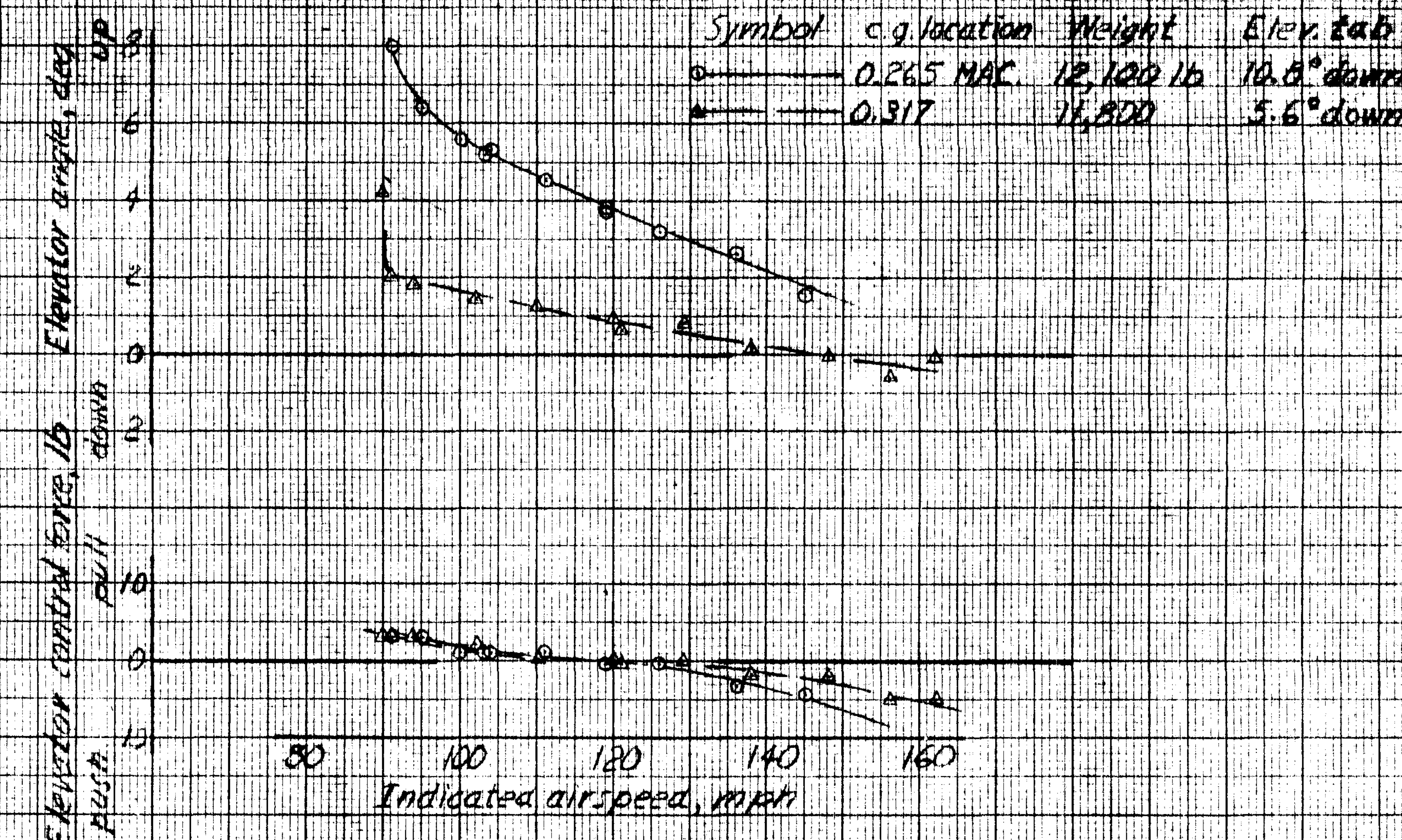
Figure 10. — Continued. Chance Vought F4U-4 airplane.



[redacted] (d) Power-on-clean configuration at high altitude (25,000 ft av.)

Figure 10. – Continued. Chance Vought F4U-4 airplane.



(e) Landing configuration

Figure 10. – Continued. Chance Vought F4U-4 airplane.

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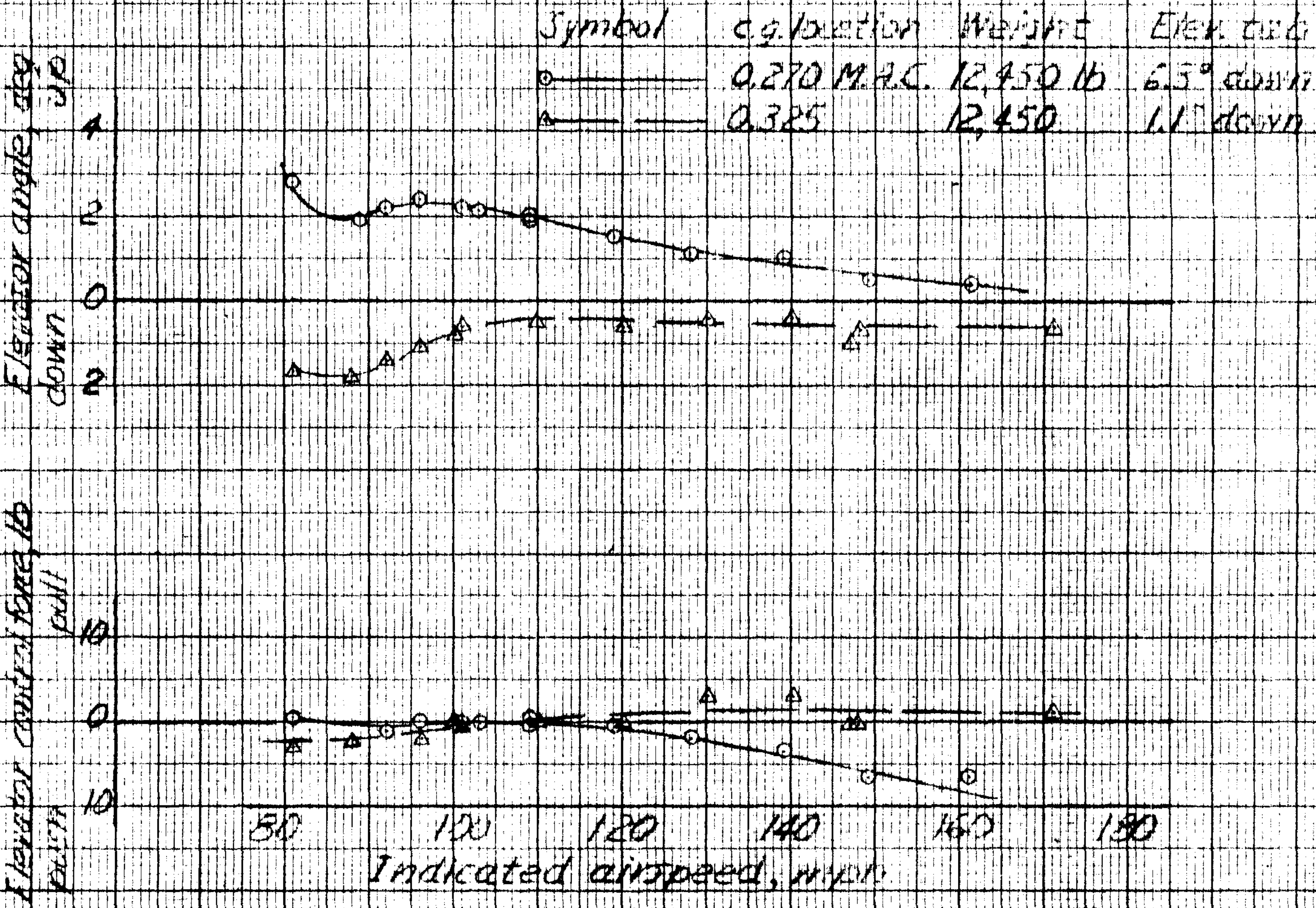
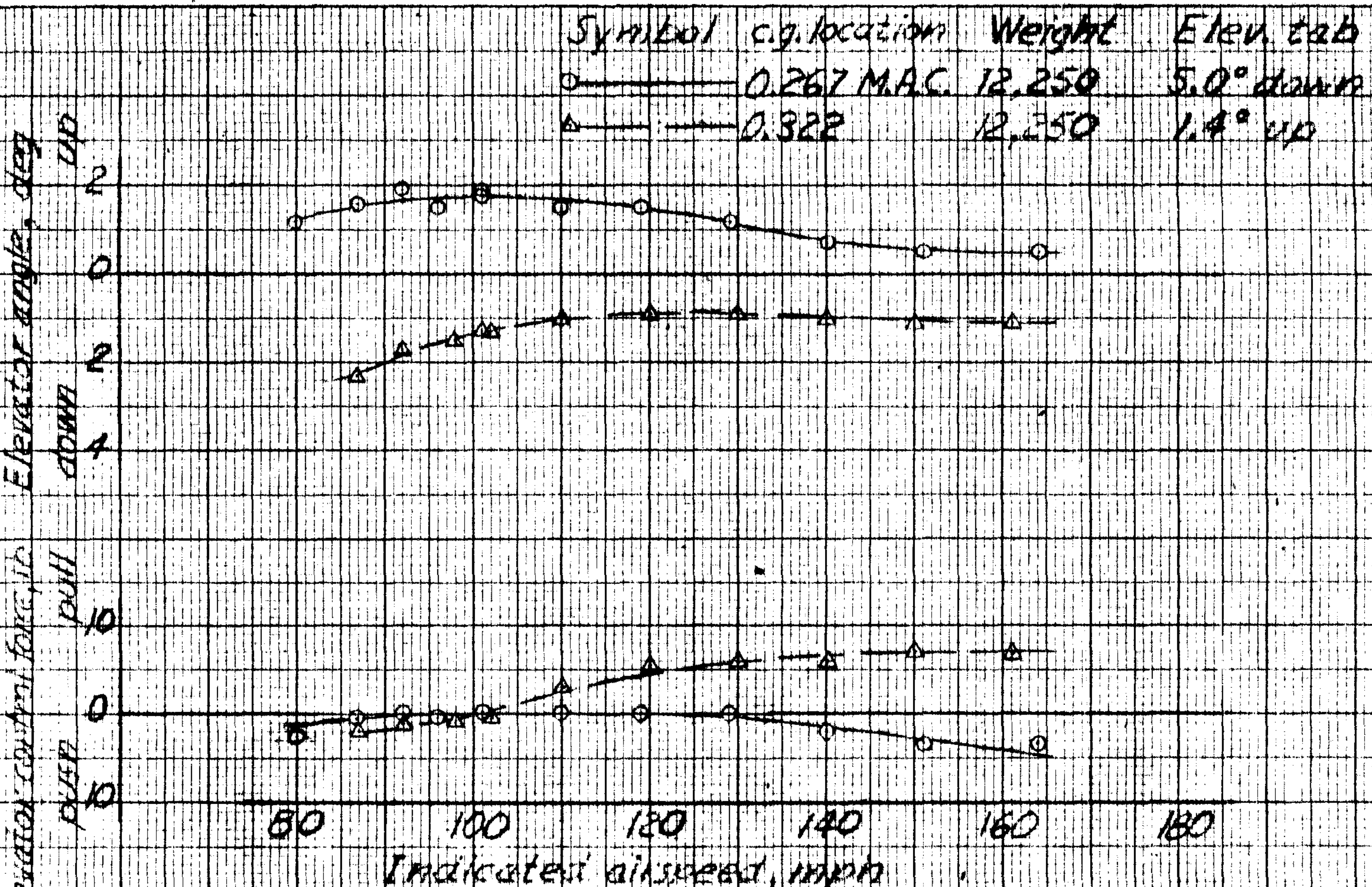


(f) Approach configuration.

Figure 10. — Continued. Chance Vought F4U-4 airplane.



(g) Wave-off configuration.

Figure 10.- Concluded. Chance Vought F4U-4 airplane.

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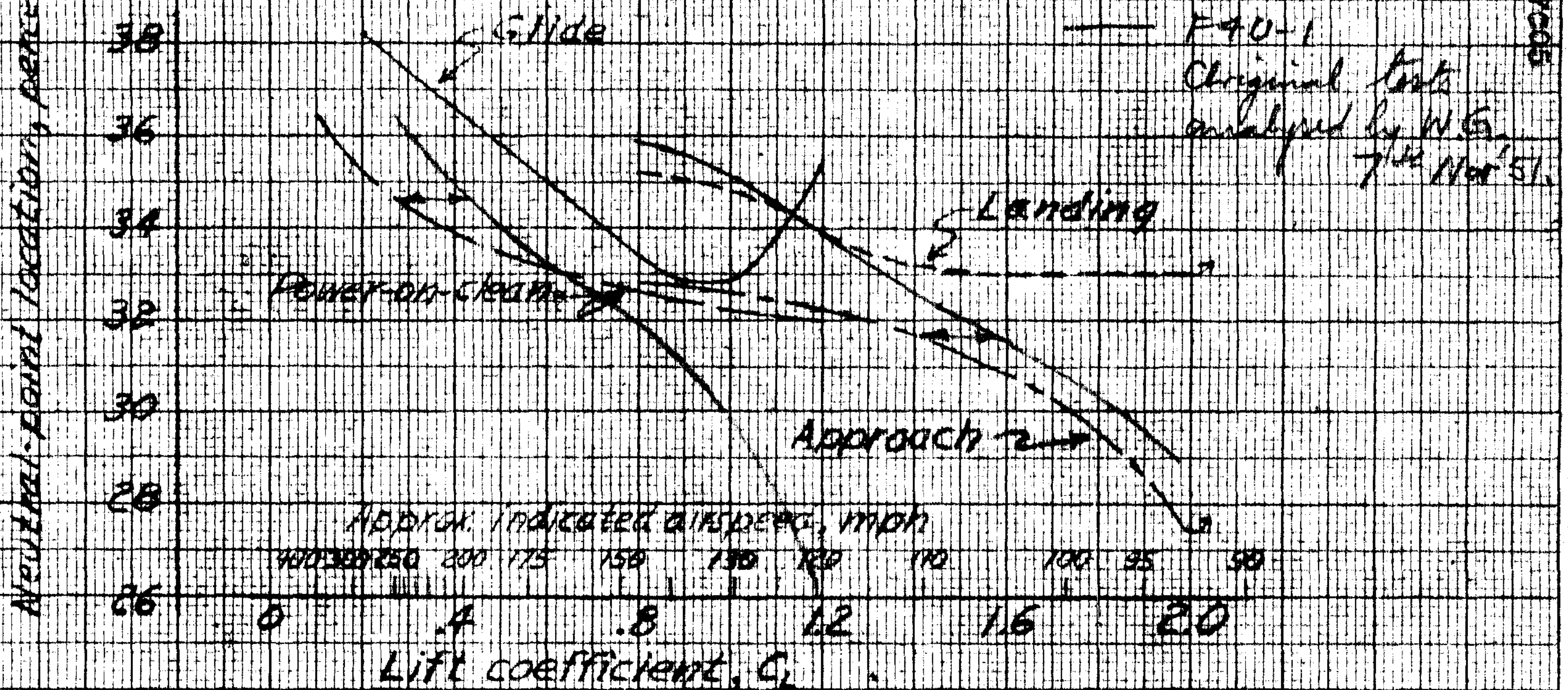

(a) Stick fixed

Figure 11. - Variation of neutral-point location with lift coefficient. Approximate altitude 9000 ft. Approximate weight 12,200 lb. Chance Vought F4U-4 airplane.

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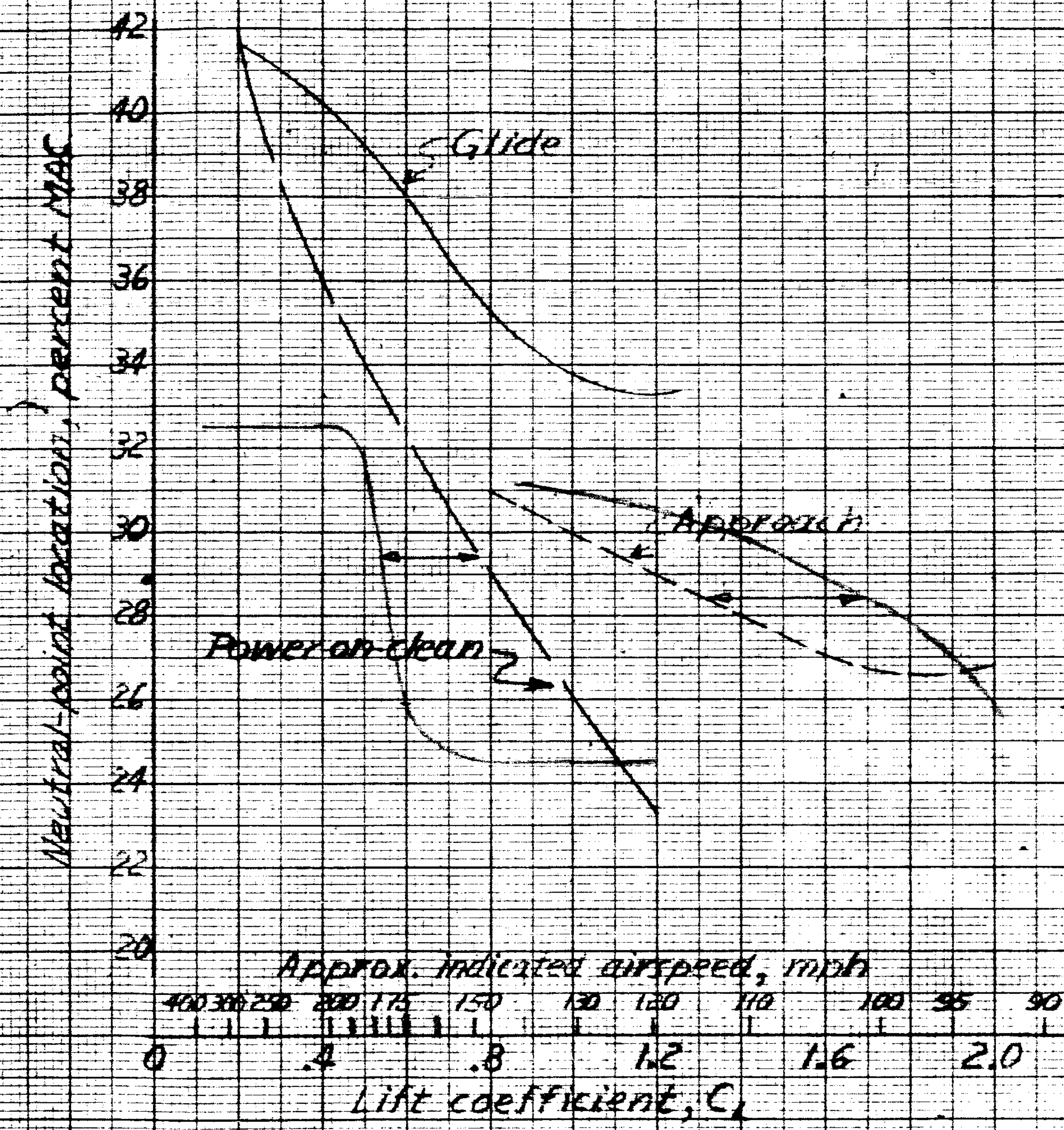

(b) Stick free

Figure 11. – Concluded. Chance Vought F4U-4 airplane.

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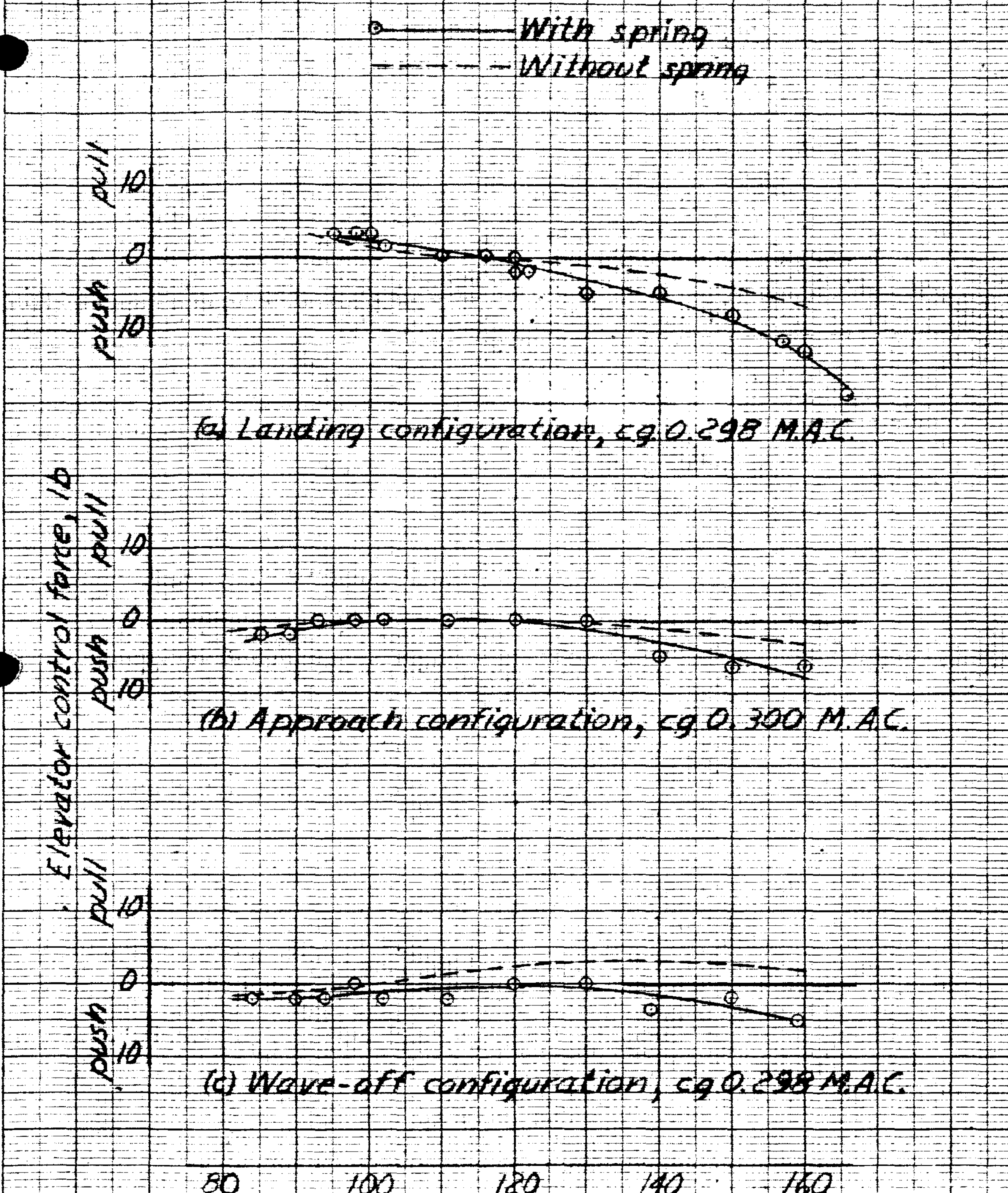

Figure 12 .- Variation of elevator control force with airspeed in steady, straight, unbanked flight with and without spring installed. Chance Vought F4U-4 airplane.

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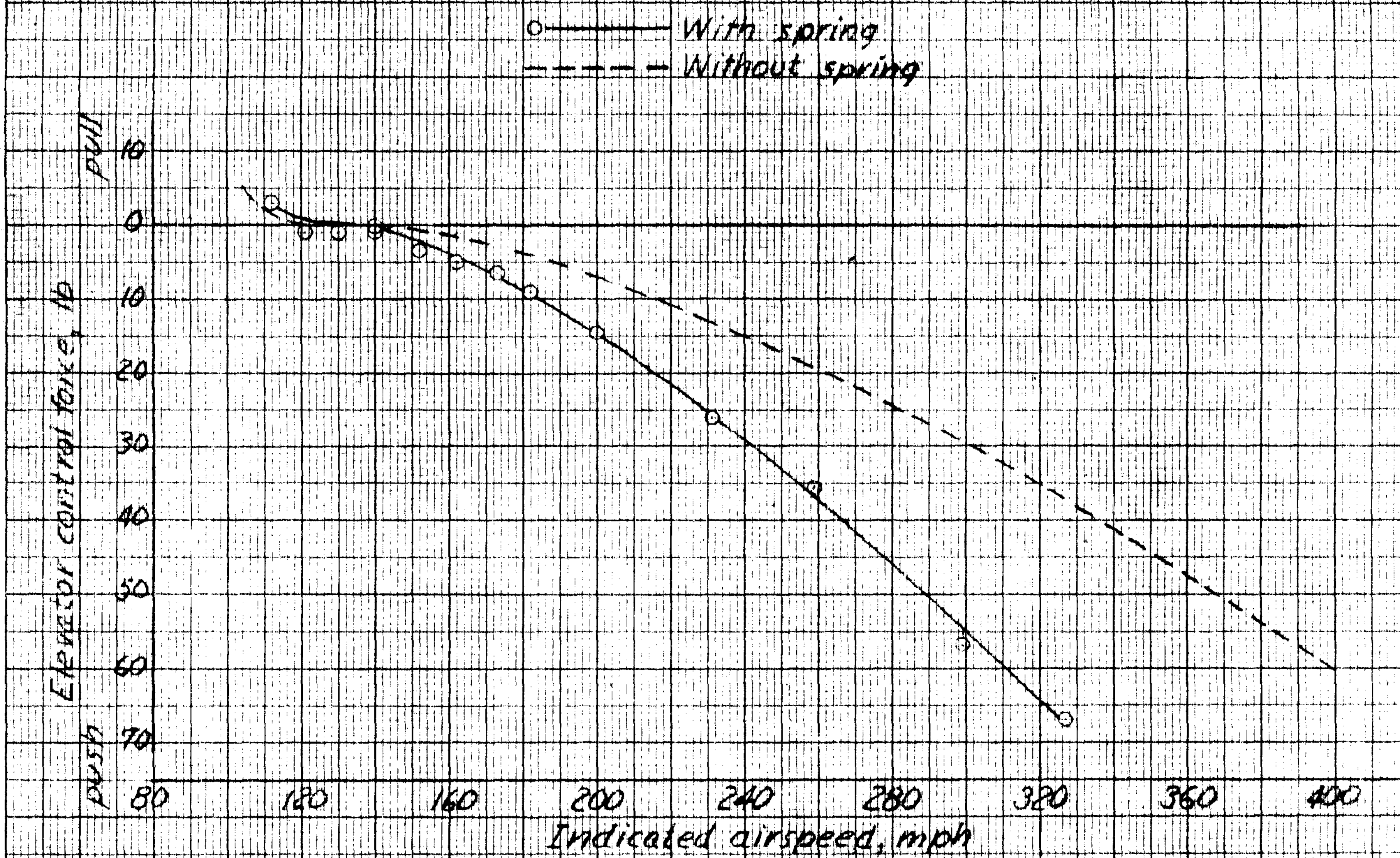

(d) Glide configuration, c.g 0.313 M.A.C.

Figure 12 . - Continued. Chance Vought F4U-4 airplane.

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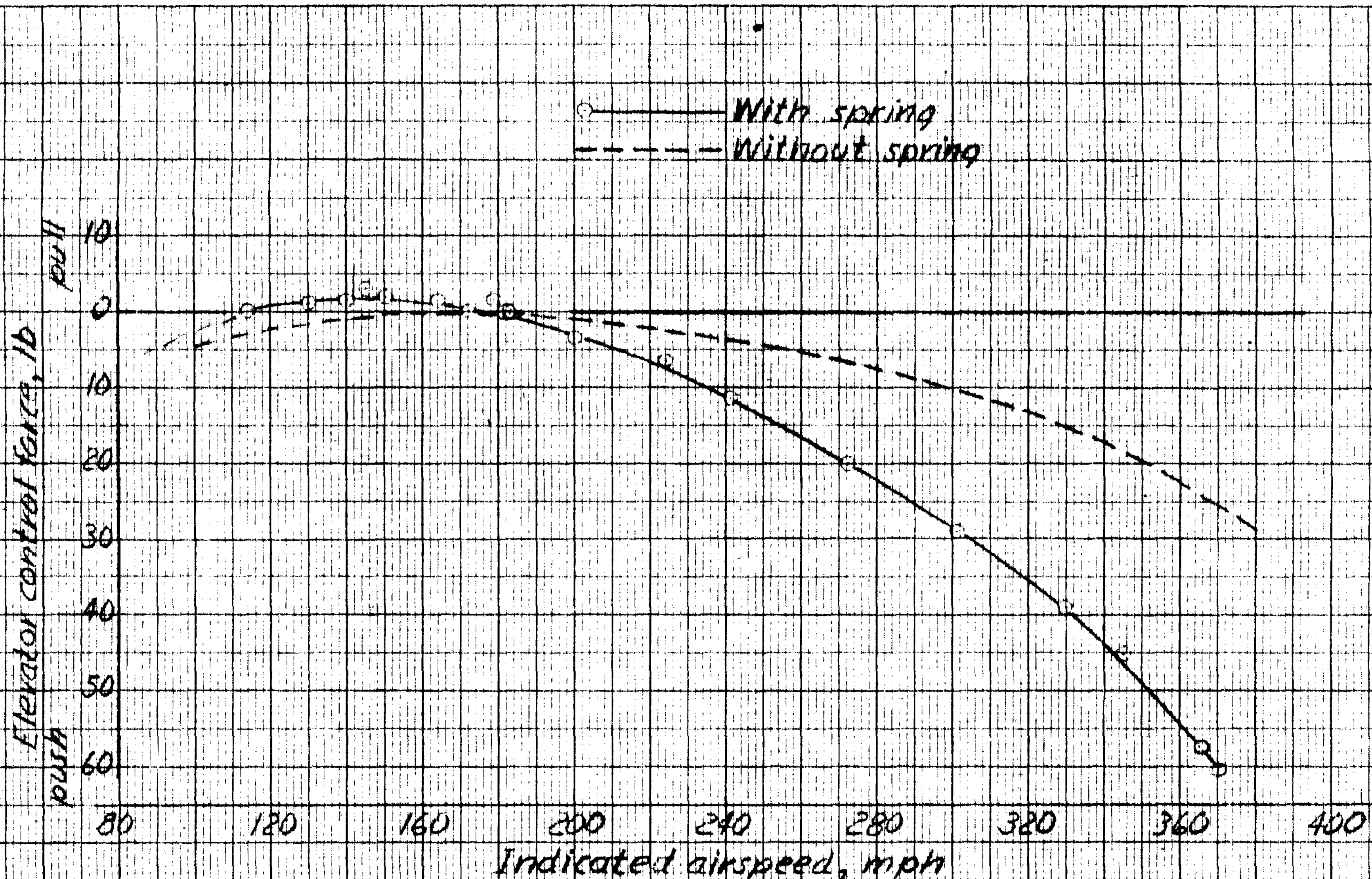

(c) Power-on-clean configuration, c.g. 0.313 M.A.C.

Figure 12.- Concluded. Chance Vought F4U-4 airplane.

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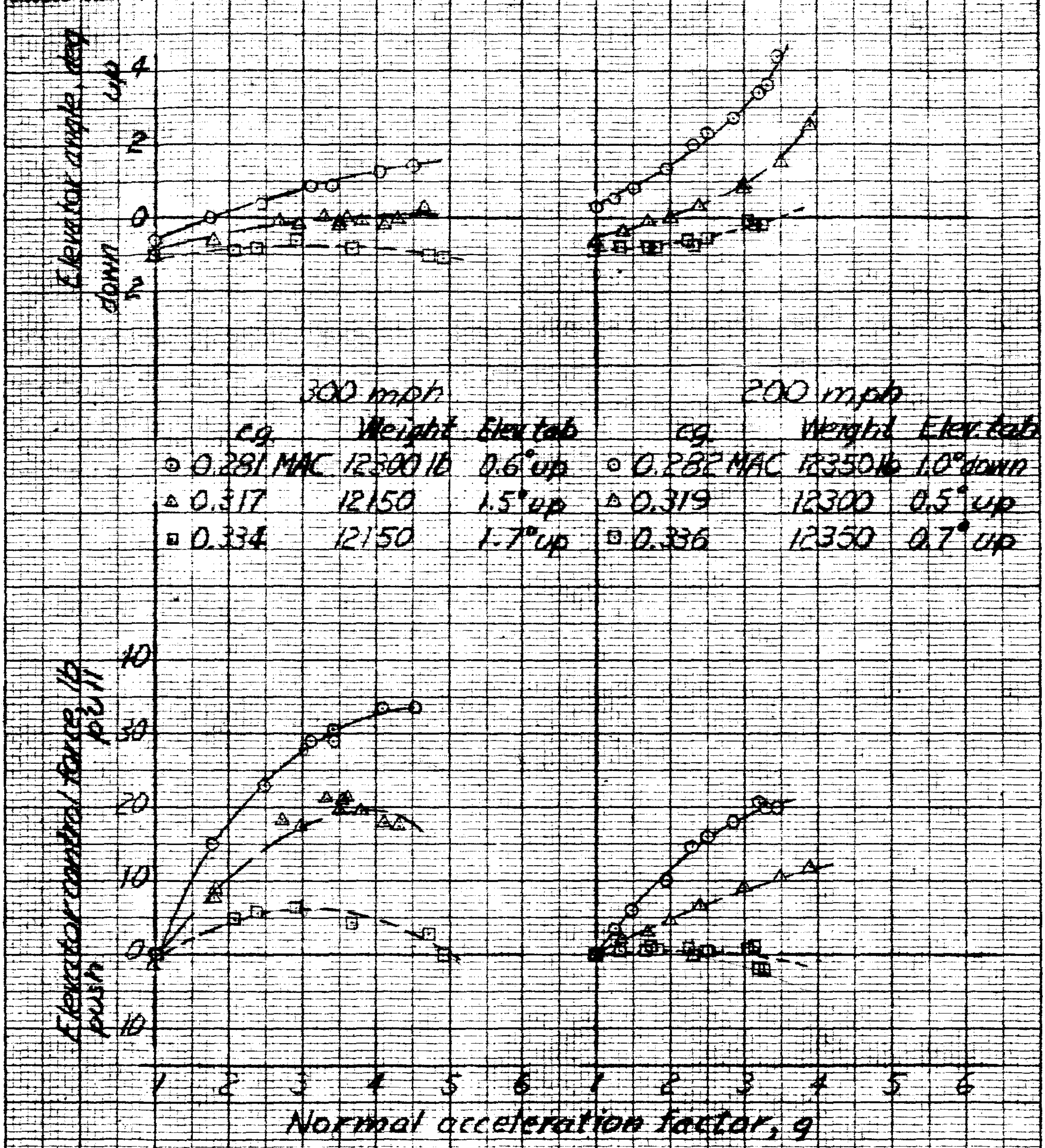

(a) Left turns

Figure 13.- Variation of elevator angle and elevator control force with normal acceleration factor in steady turns. Power on-clean configuration. Average pressure altitude 8500 ft. Chance Vought F4U-4 airplane.

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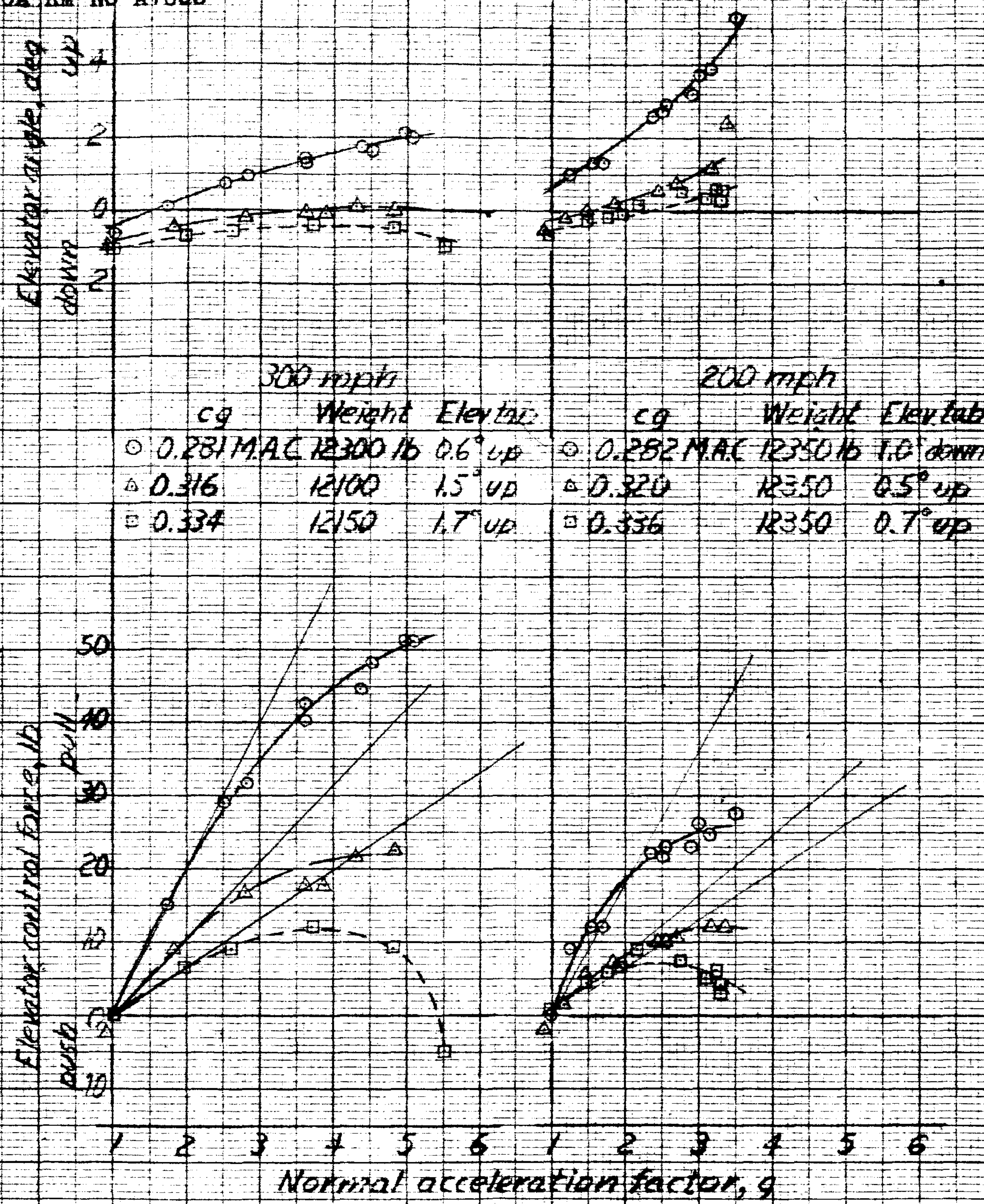

(b) Right turns

Figure 13. – Concluded. Chance Vought F4U-4 airplane.

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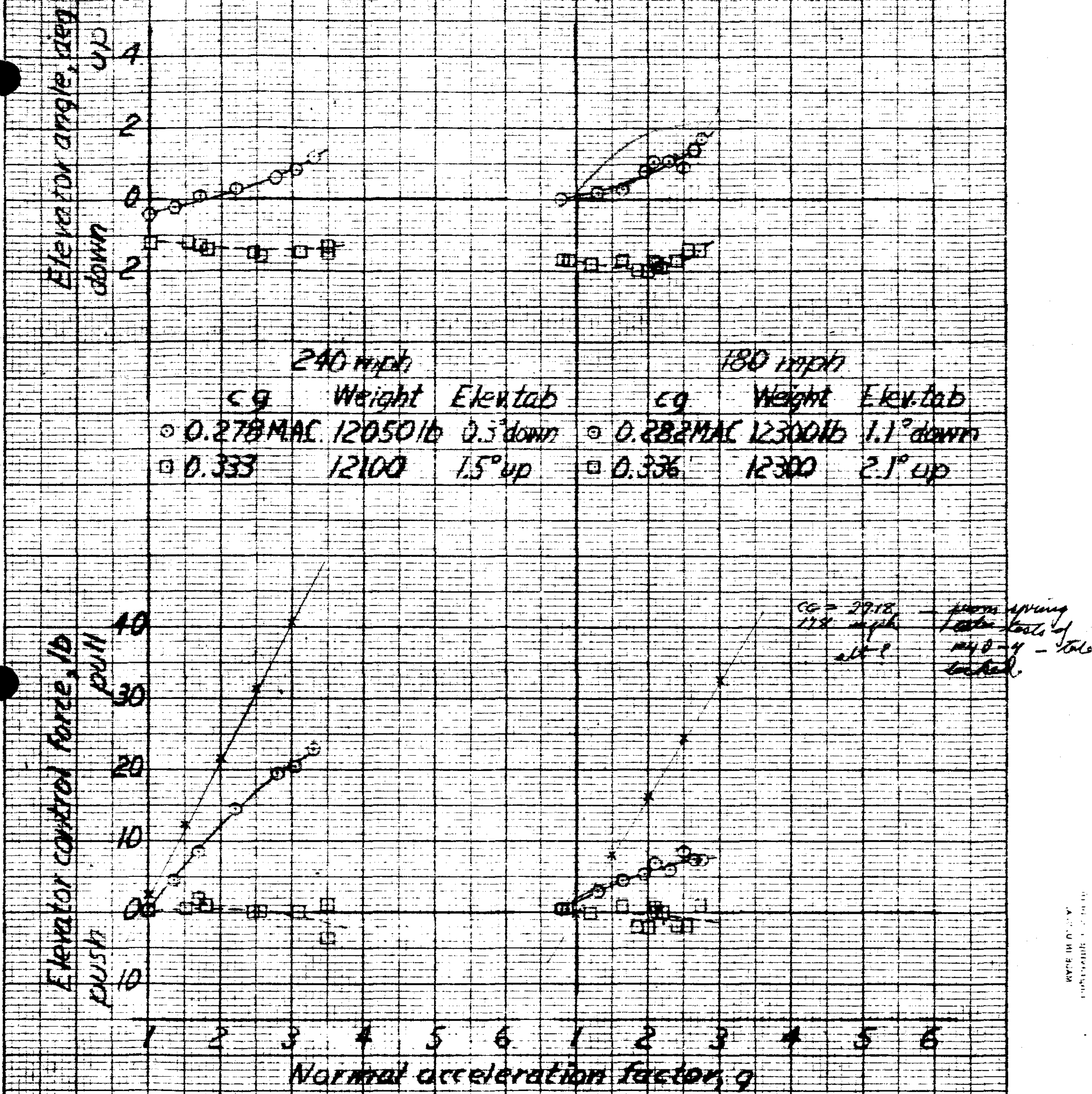

(a) Left turns

Figure 14.- Variation of elevator angle and elevator control force with normal acceleration factor in steady turns. Power-on-clean configuration. Average pressure altitude 25,300 ft. Chance Vought F4U-4 airplane.

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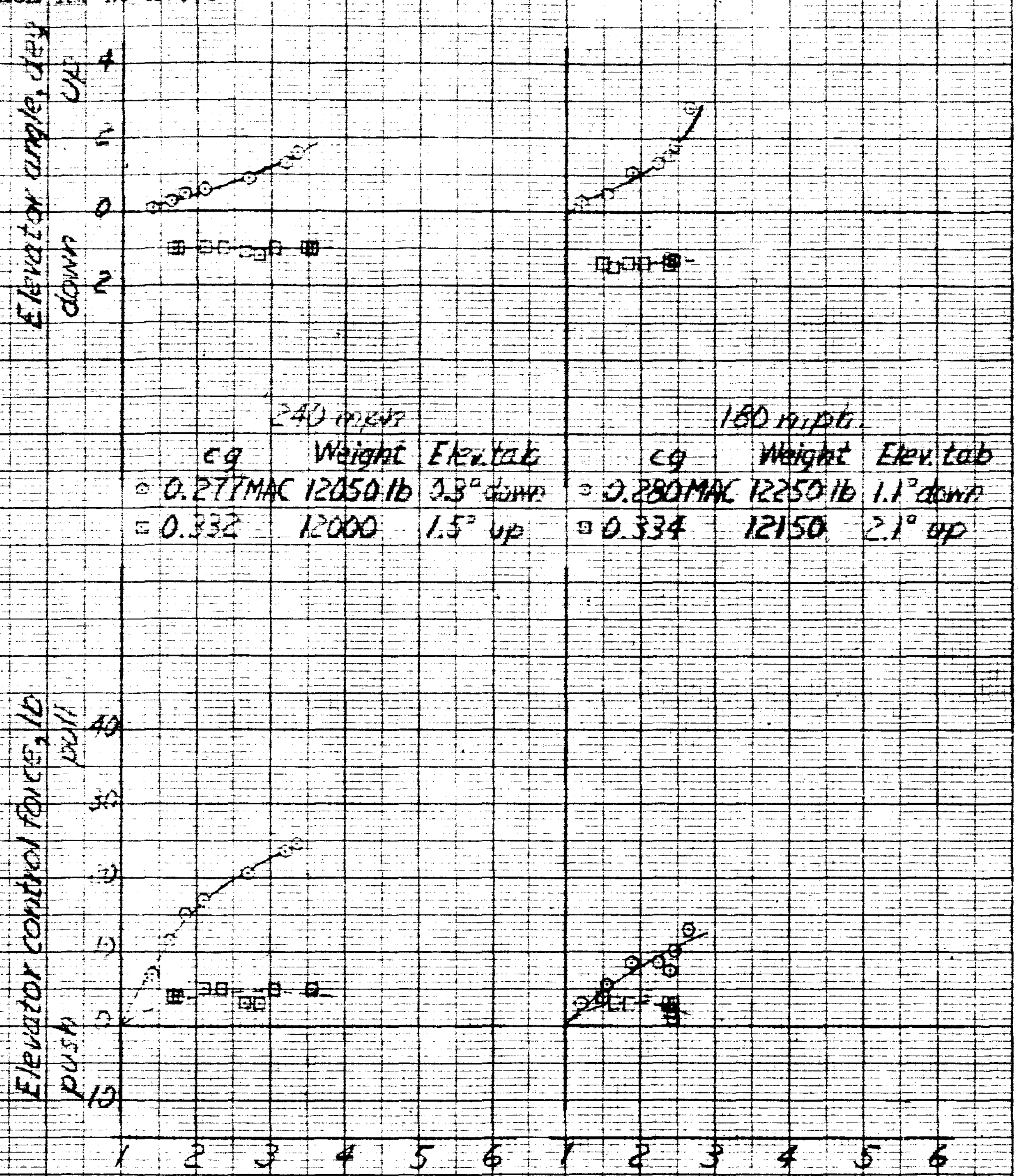

(b) Right turns

Figure 14.- Concluded. Chance Vought F4U-4 airplane

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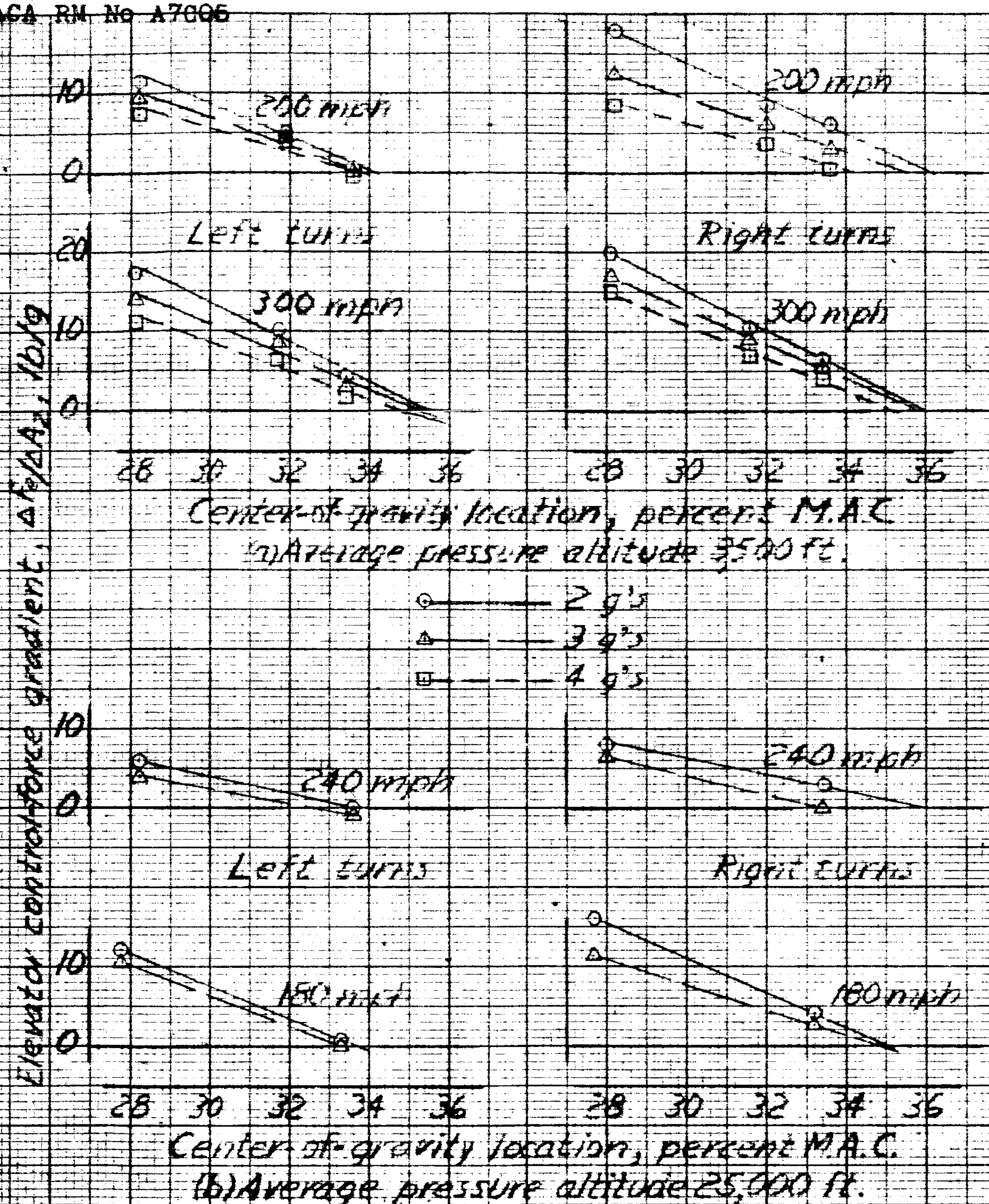

Figure 15.- Variation of elevator control-force gradient with center-of-gravity location. Flaps and gear up, normal rated power. Chance Vought F4U-4 airplane.

[redacted]

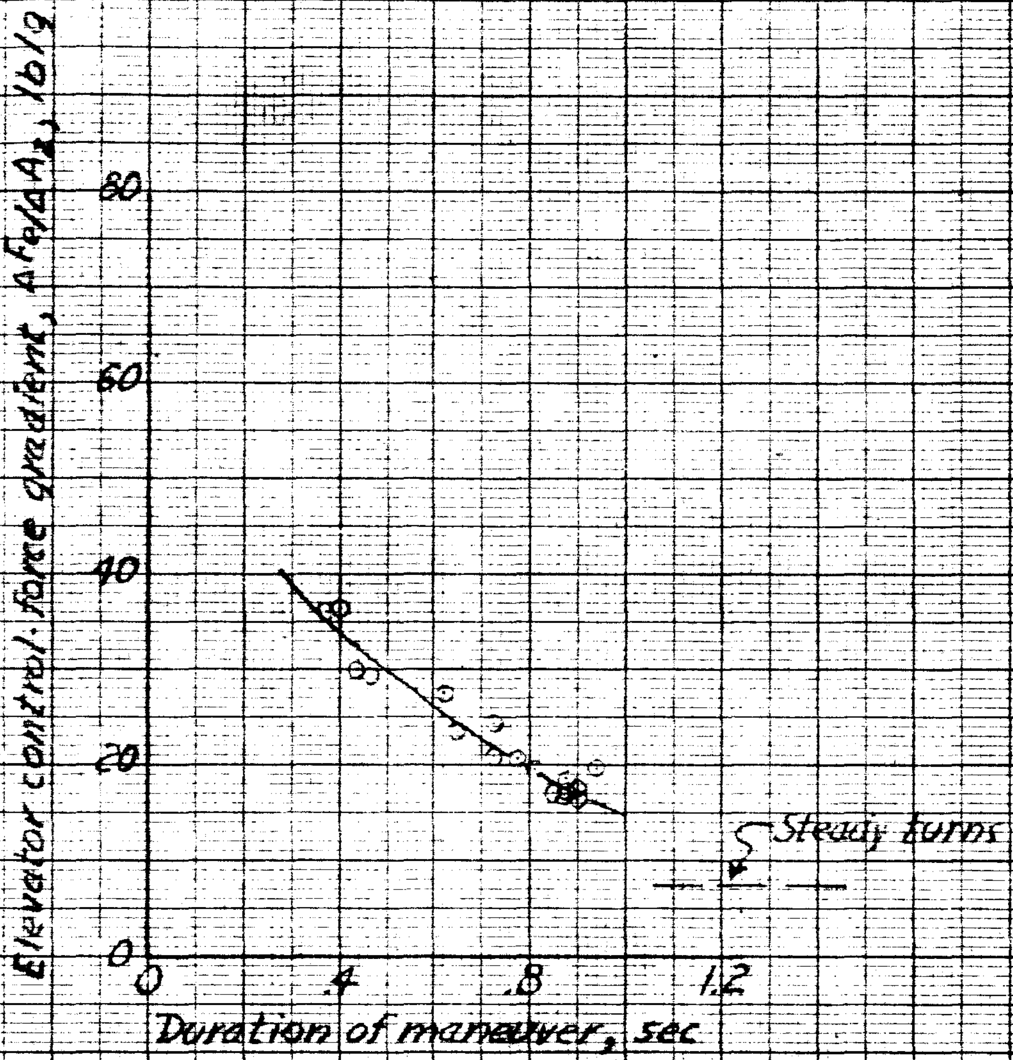

Figure 16. - Variation of elevator control-force gradient $\Delta F_e/\Delta A_z$ in abrupt pull-ups with duration of maneuver. $V_i \approx 200$ mph. C.g at 0.318 MAC. Altitude $\approx$ 8500 ft. Chance Vought F4U-4 airplane.

[redacted]

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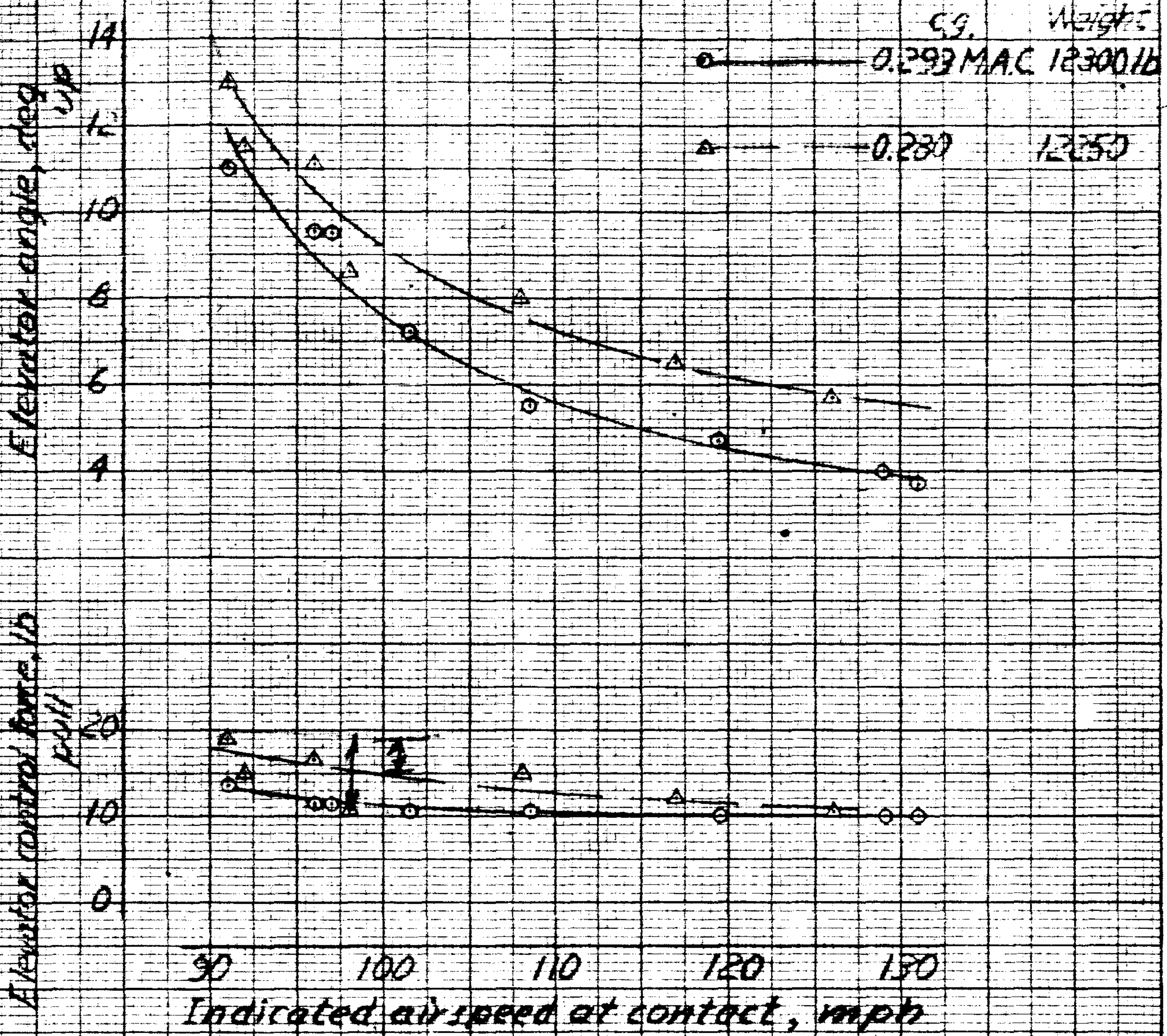


Figure 17.- Variation with airspeed of elevator angle and elevator control force required for landing. Chance Vought F4U-4 airplane.

[redacted]

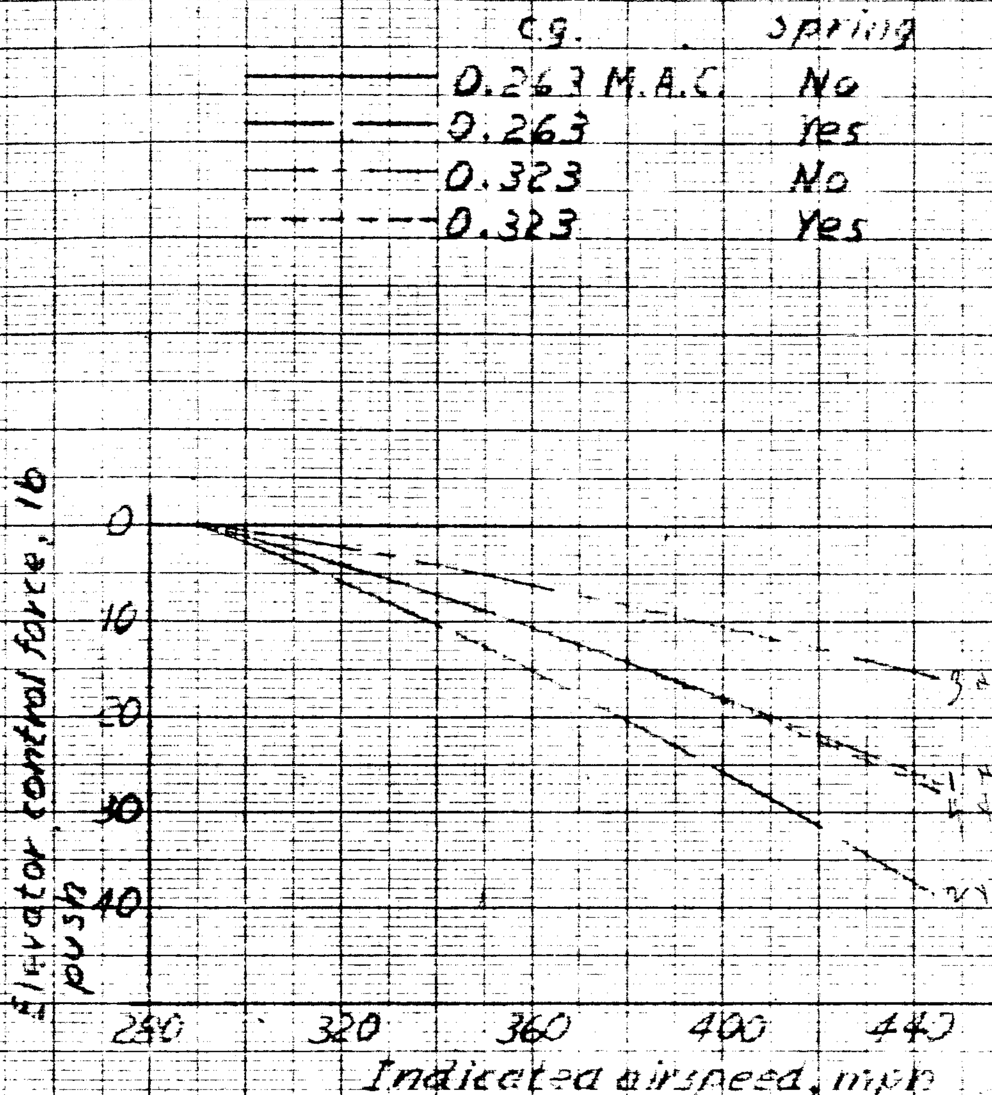


Figure 18.- Variation with airspeed of elevator control force in a dive, with and without spring installed. Trim speed 290 mph. Chance Vought F4U-4 airplane.

[redacted]

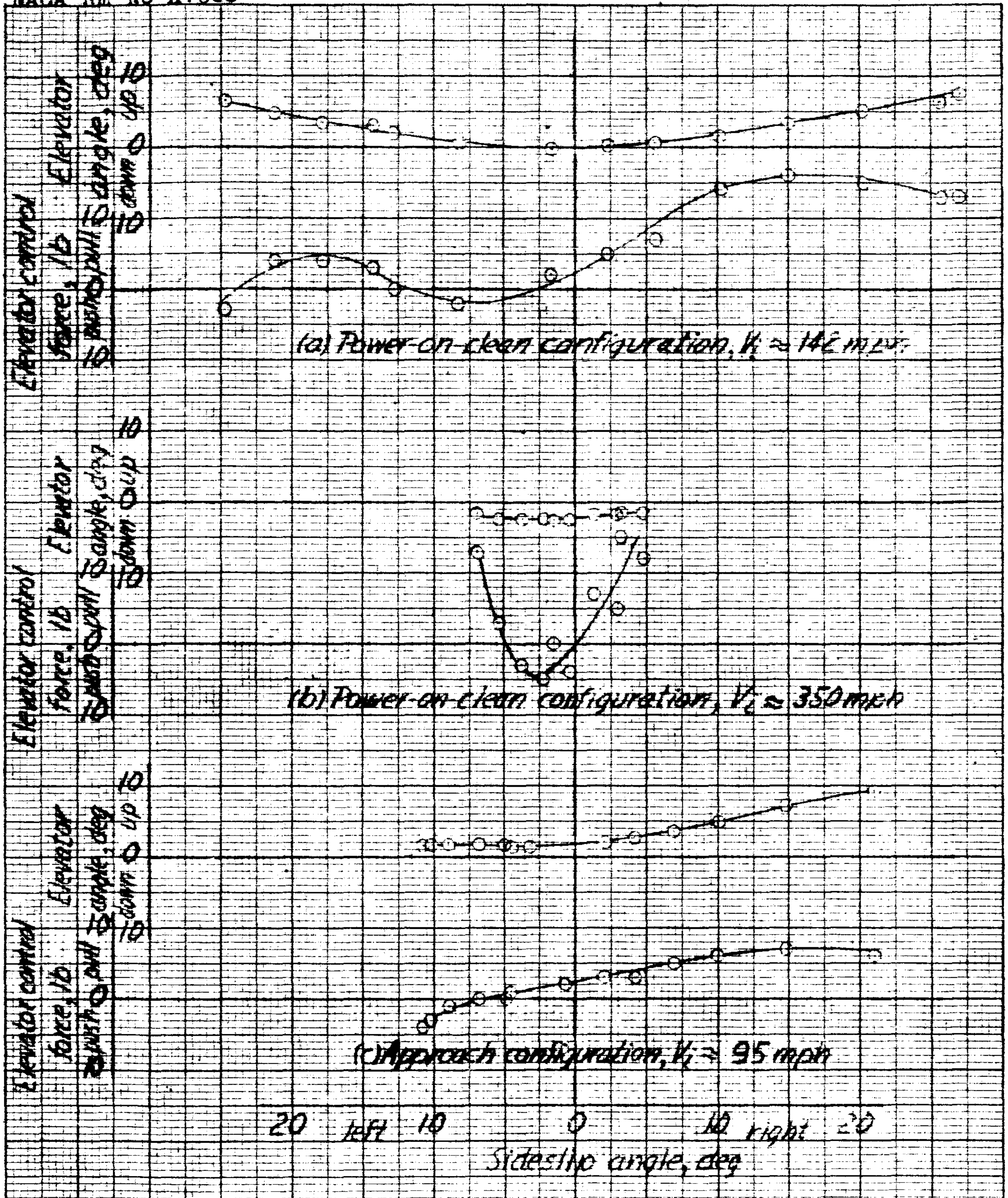


Figure 15 .- Variation of elevator angle and elevator control force with angle of steady sideslip. Chance Vought F4U-4 airplane.

[redacted]

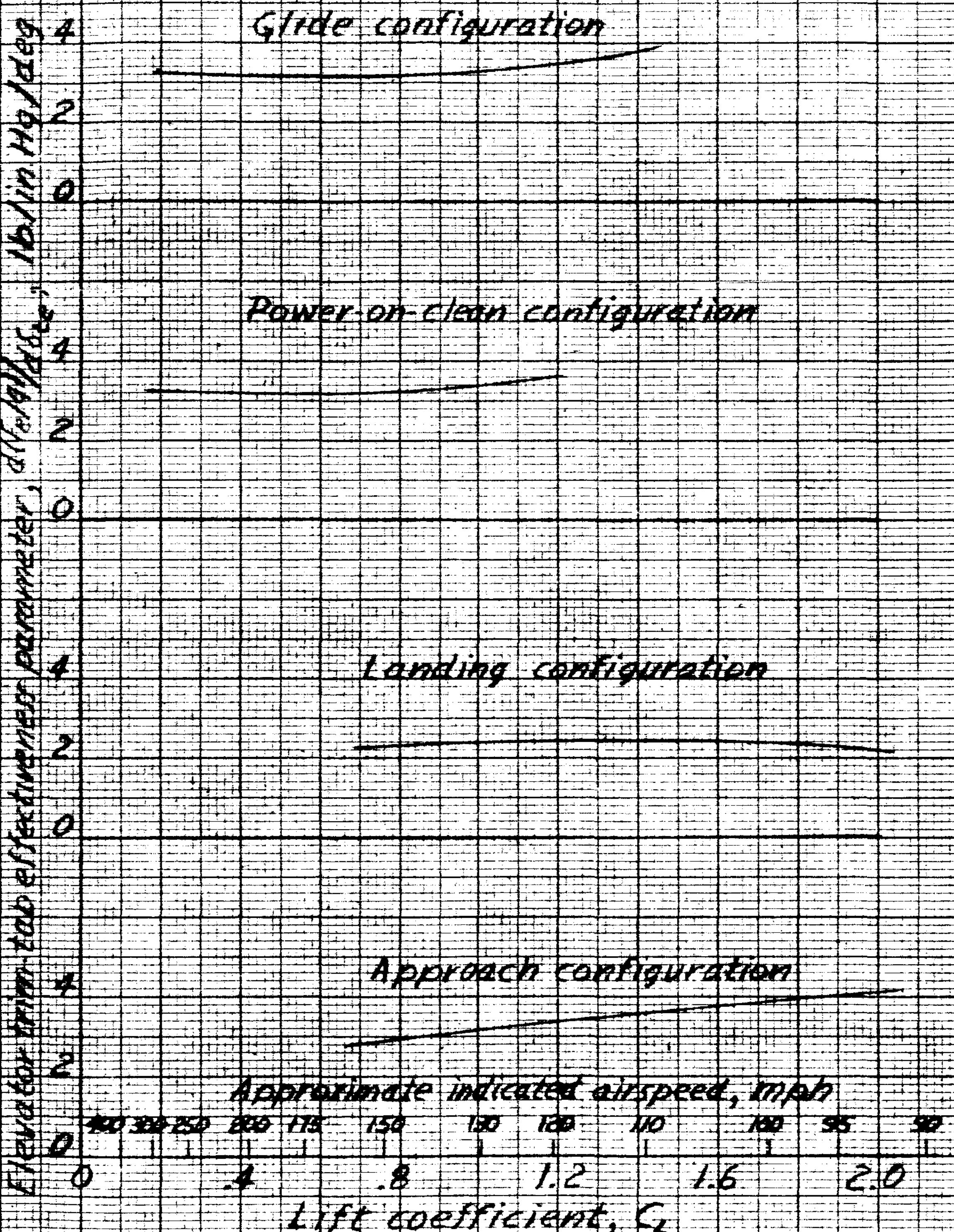
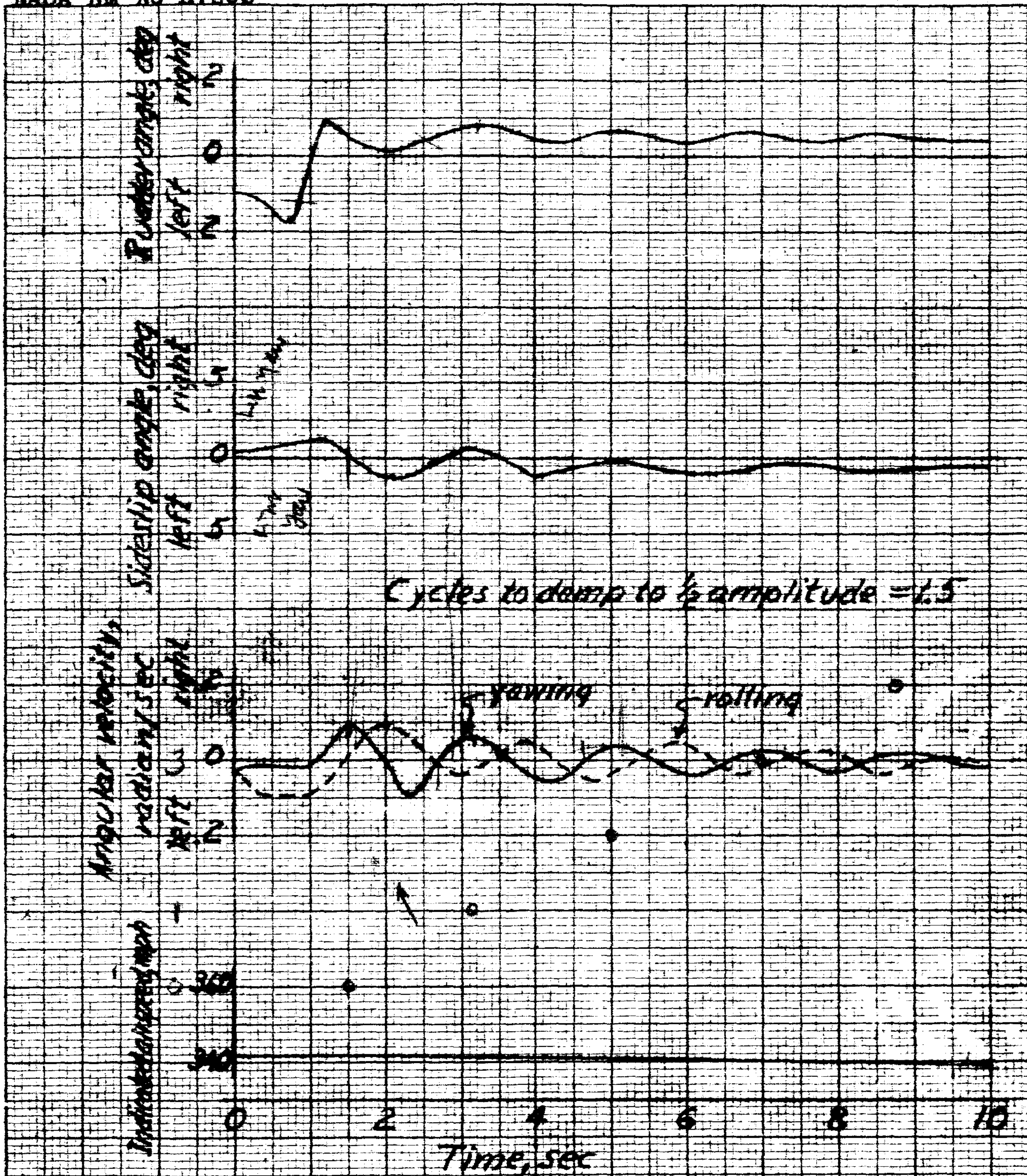


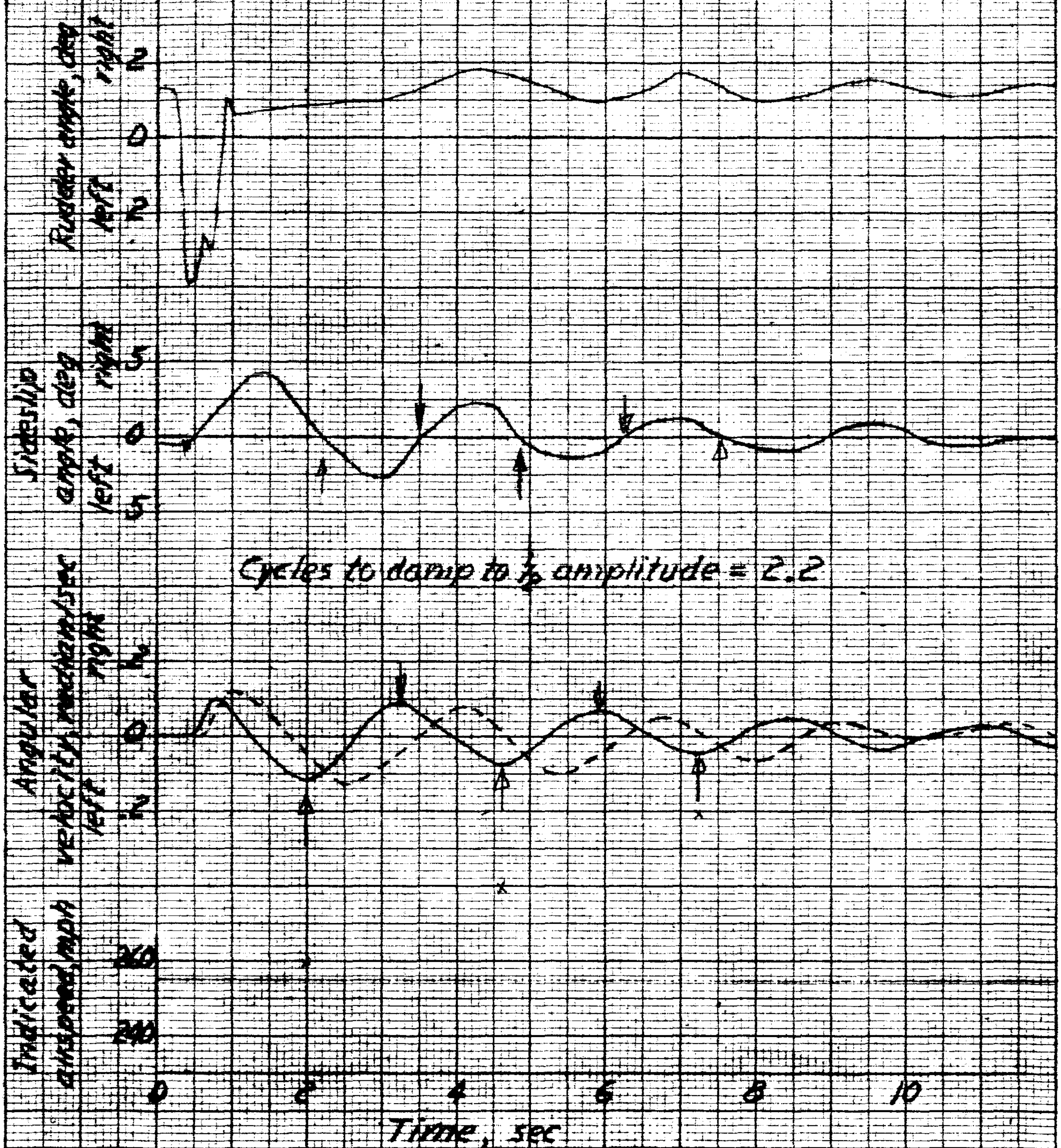
Figure 20. – Variation of elevator trim-tab effectiveness parameter with lift coefficient. Chance Vought F4U-4 airplane.

[redacted]



(a) Pressure altitude ≈ 5500 ft

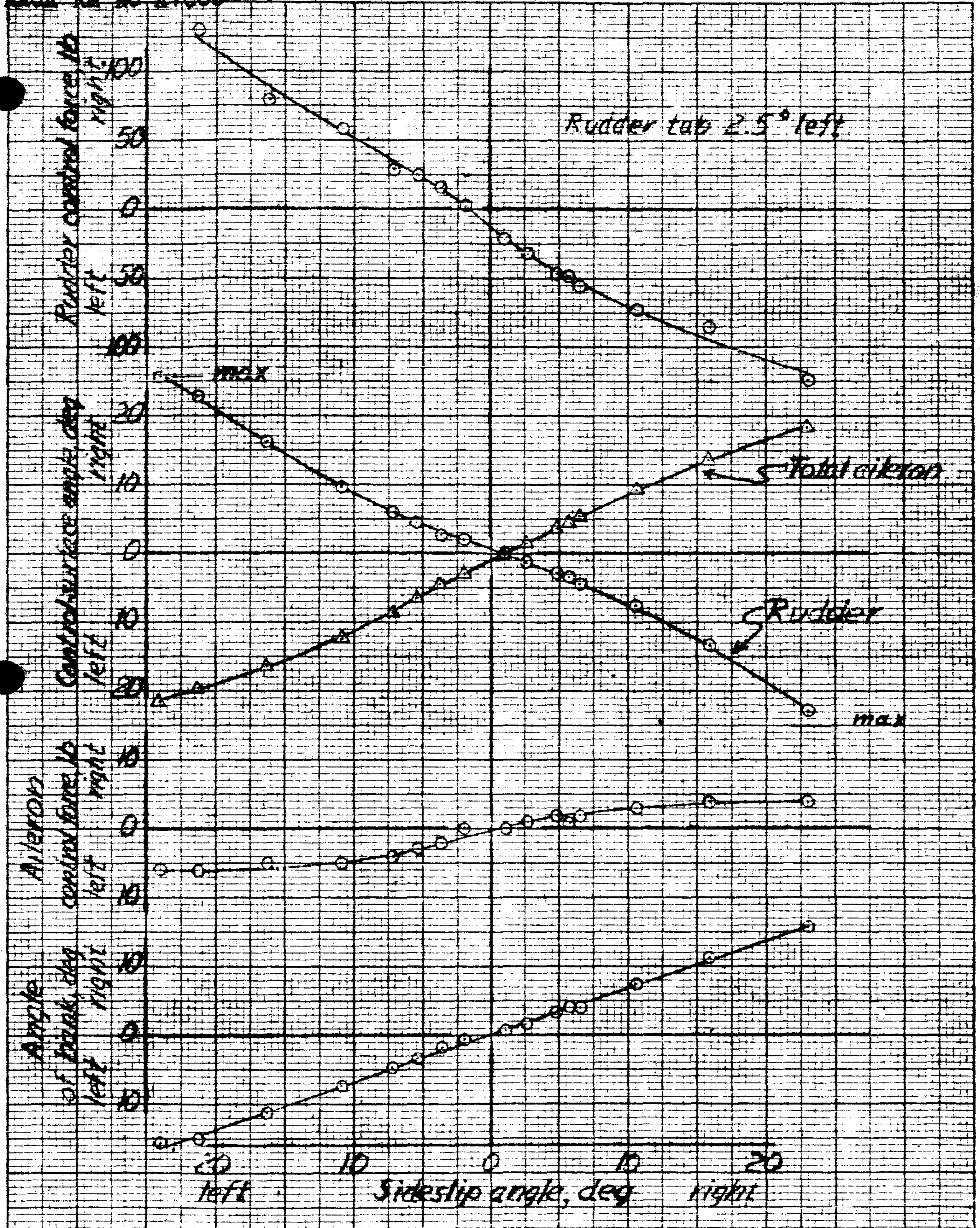
Figure 21. — Typical time history of rudder-free directional and lateral oscillations. Power-on clean configuration. Chance Vought F4U-4 airplane.



(b) Pressure altitude ≈ 25,500 ft

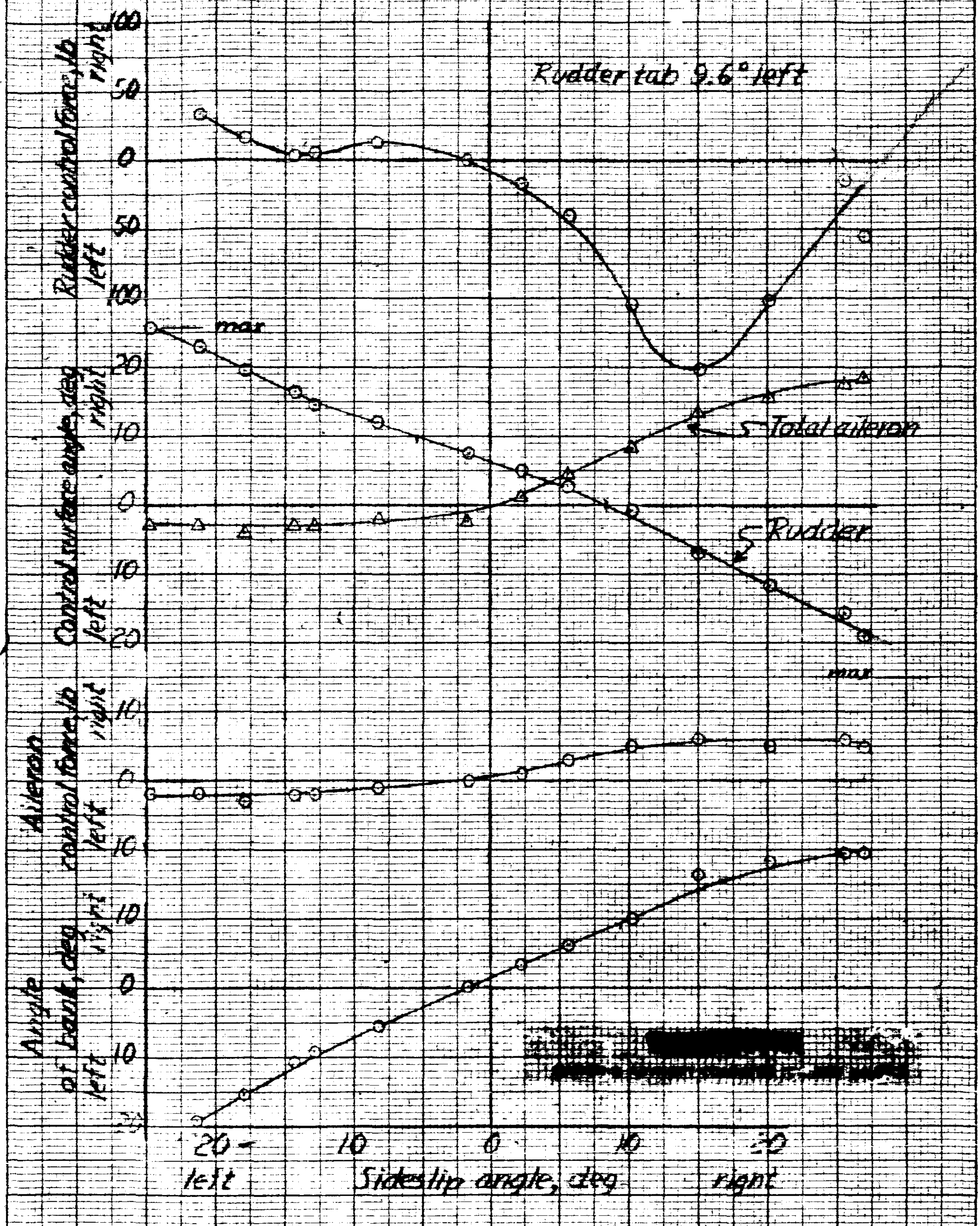
Figure 21 .- Concluded. Chance Vought F4U-4 airplane.

[redacted]



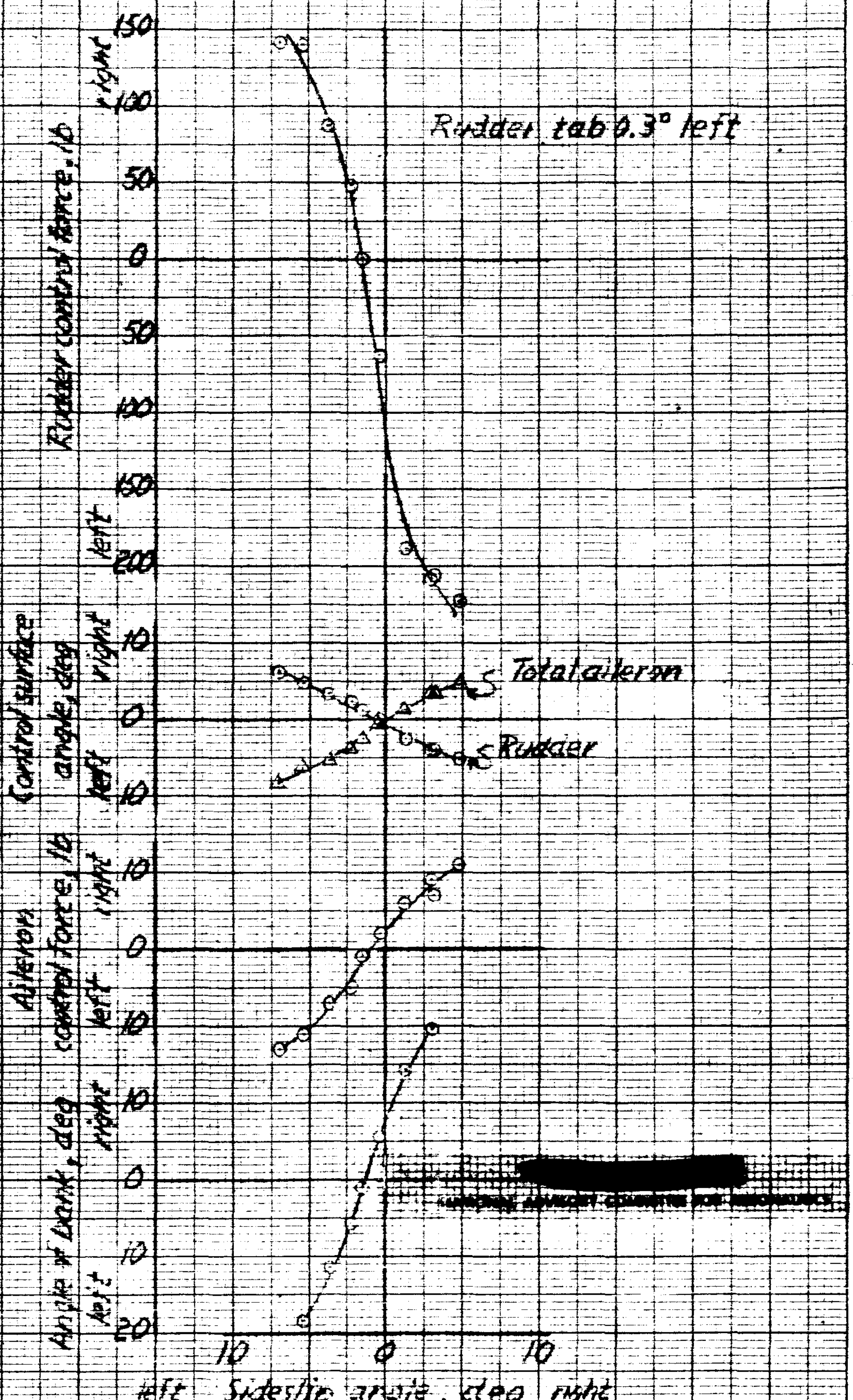
(a) Glide configuration, V_i = 140 mph.

Figure 22.- Characteristics in steady sideslips. Chance Vought F4U-4 airplane. [redacted]



(b) Power-on-clean configuration, $V_i \approx 140$ mph

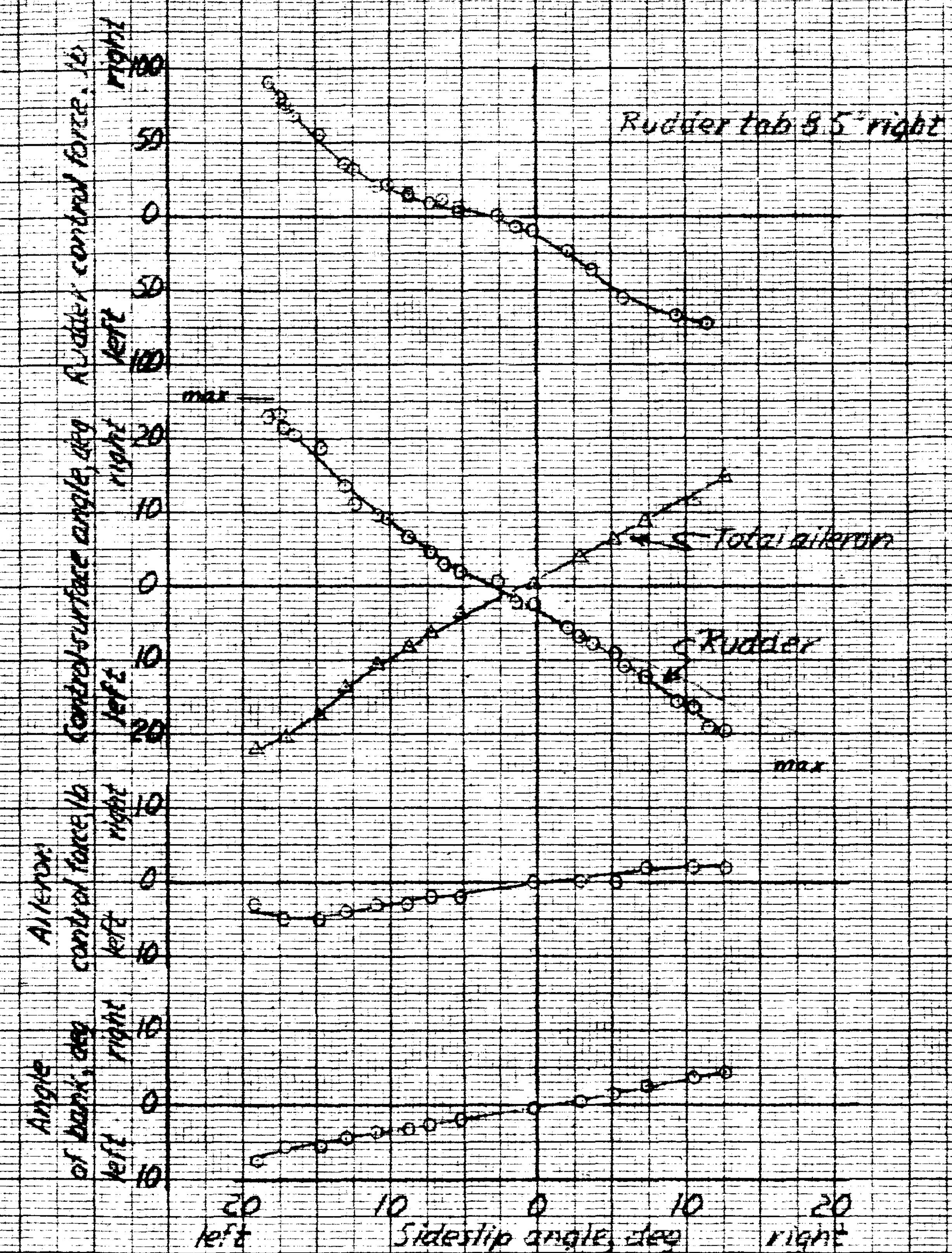
Figure 22.– Continued. Chance Vought F4U-4 airplane.



[redacted]

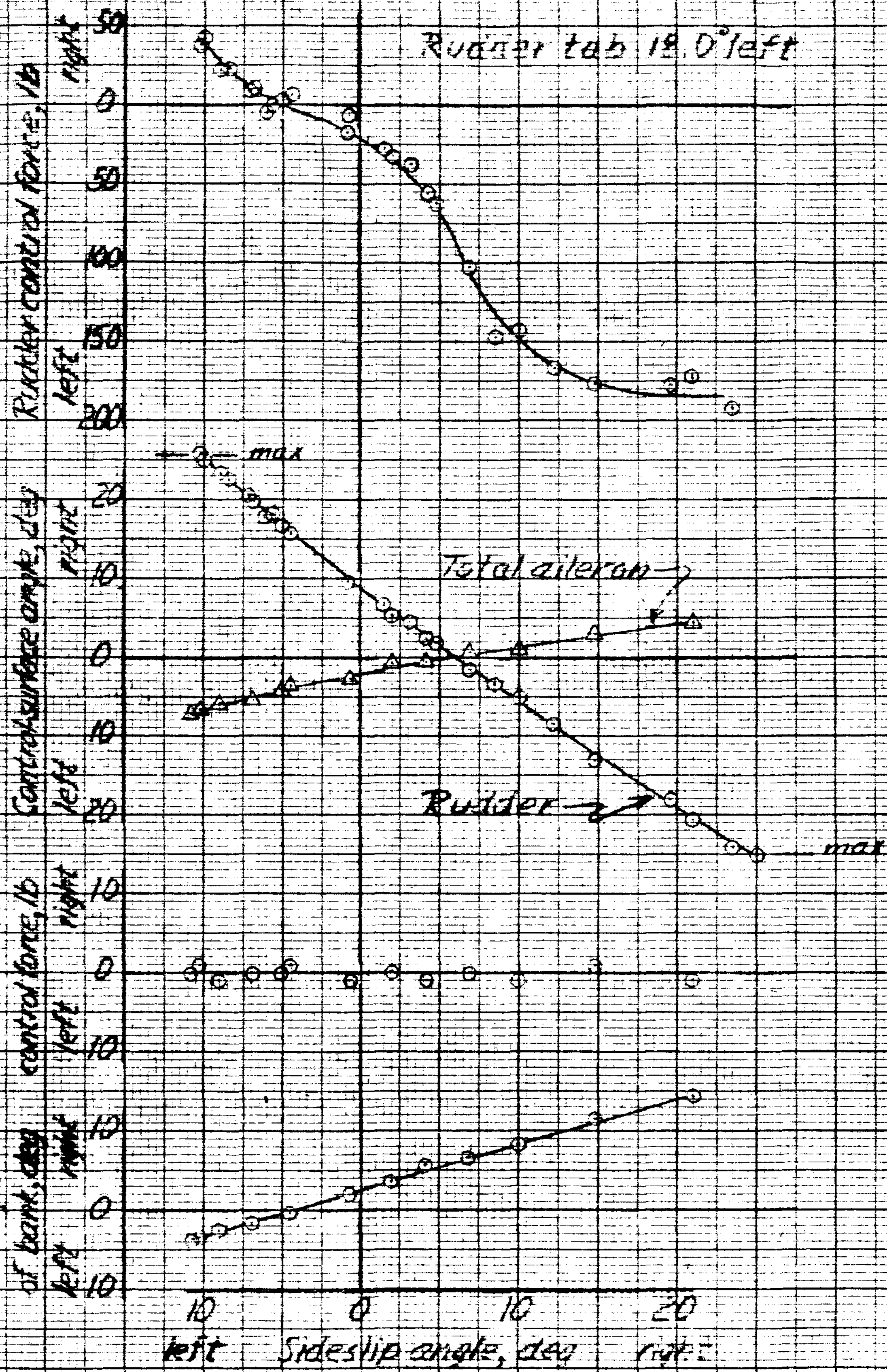
(c) Power-on clean configuration, $V_i \approx 350$ mph.

Figure 22.- Continued. Chance Vought F4U-4 airplane.



(d) Landing configuration, $V_i \approx 100$ mph

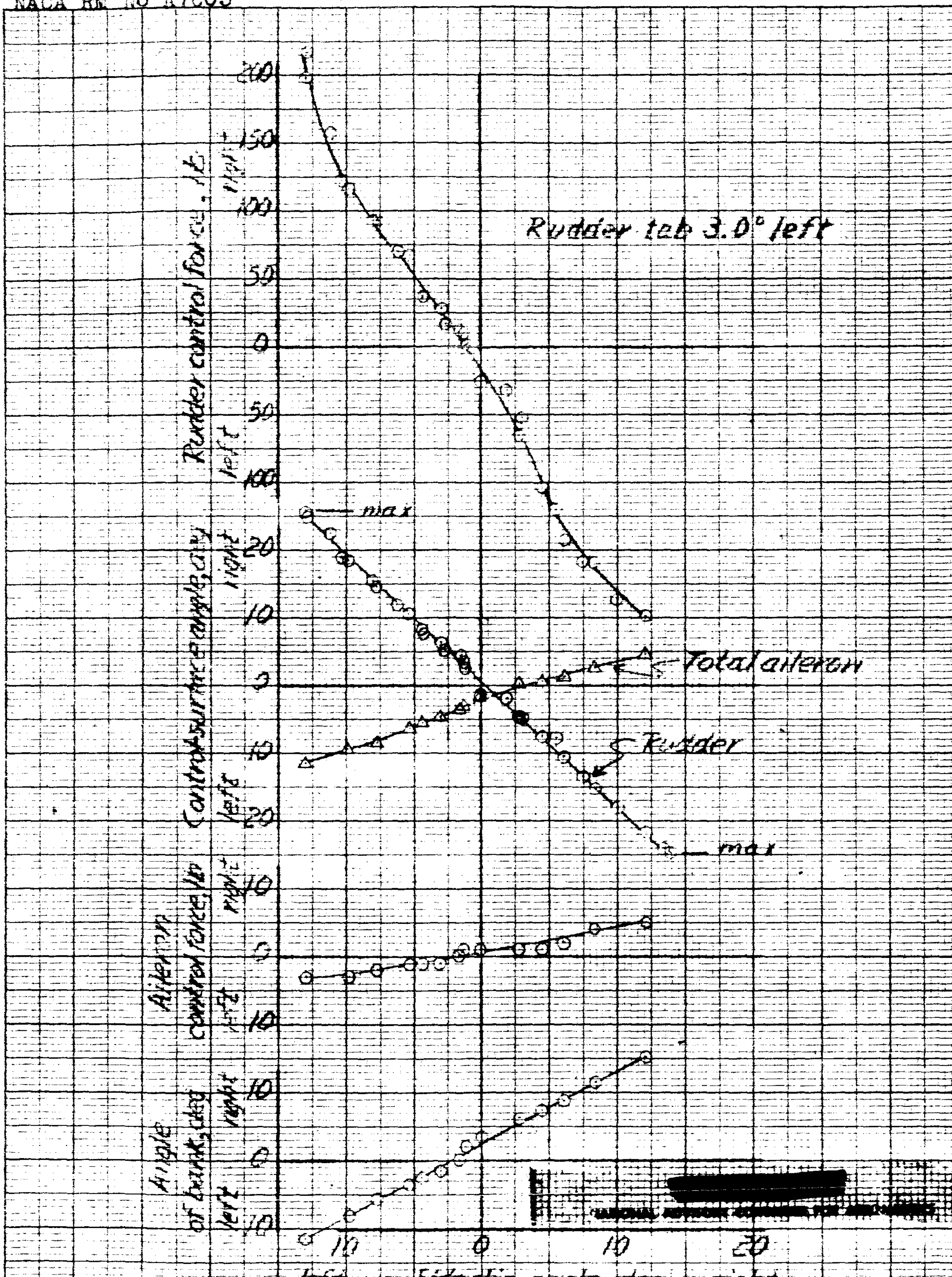
Figure 22. - Continued. Chance Vought F4U-4 airplane.



(e) Approach configuration, $V_i \approx 100$ mph

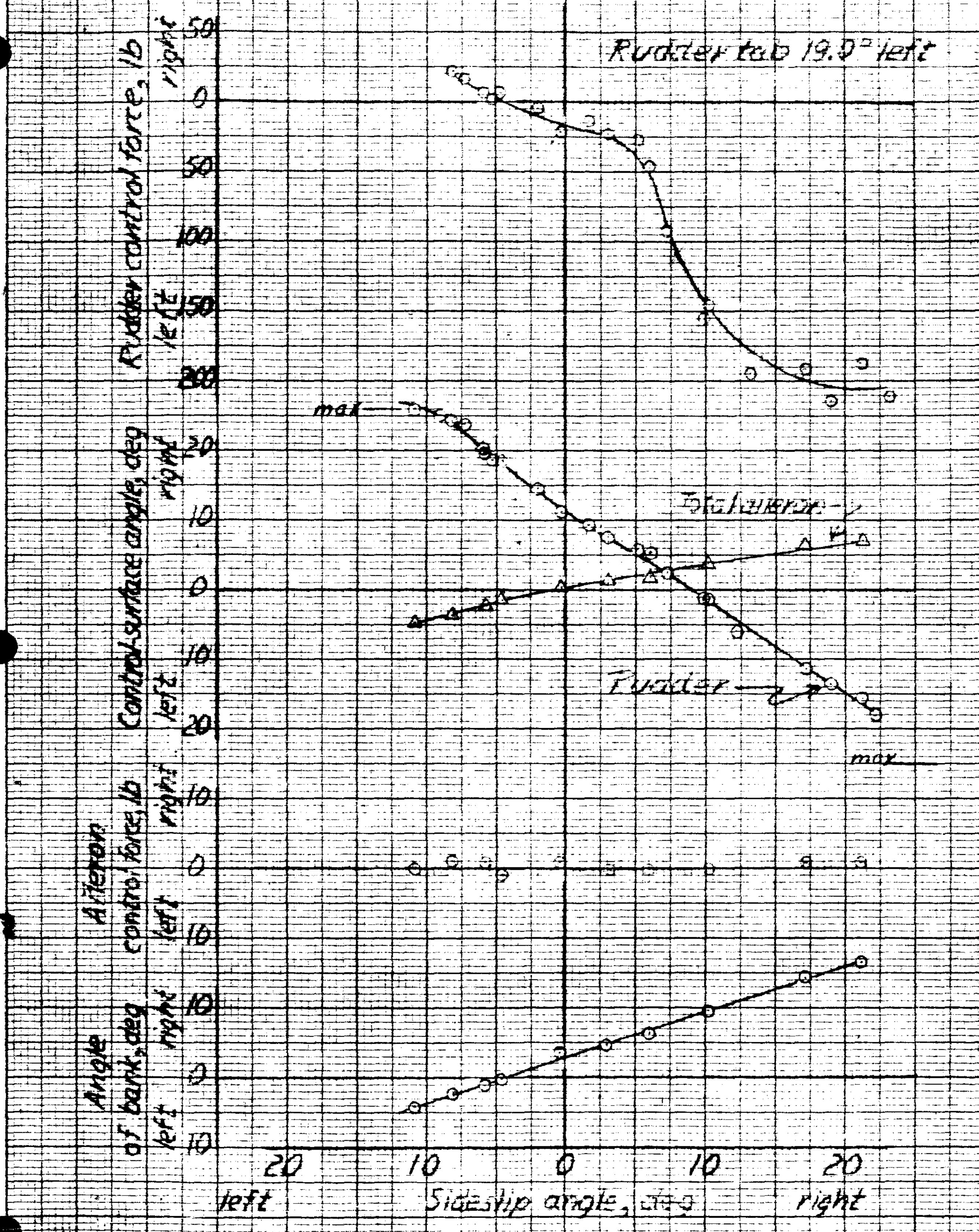
Figure 22. – Continued. Chance Vought F4U-4 airplane.

[redacted]



(f) Approach configuration, $V_i \approx 140$ mph

Figure 22.- Continued. Chance Vought F4U-4 airplane.



(g) Wave-off configuration, $V_i \approx 100$ mph

Figure 22 .- Concluded. Chance Vought F4U-4 airplane.

[redacted]

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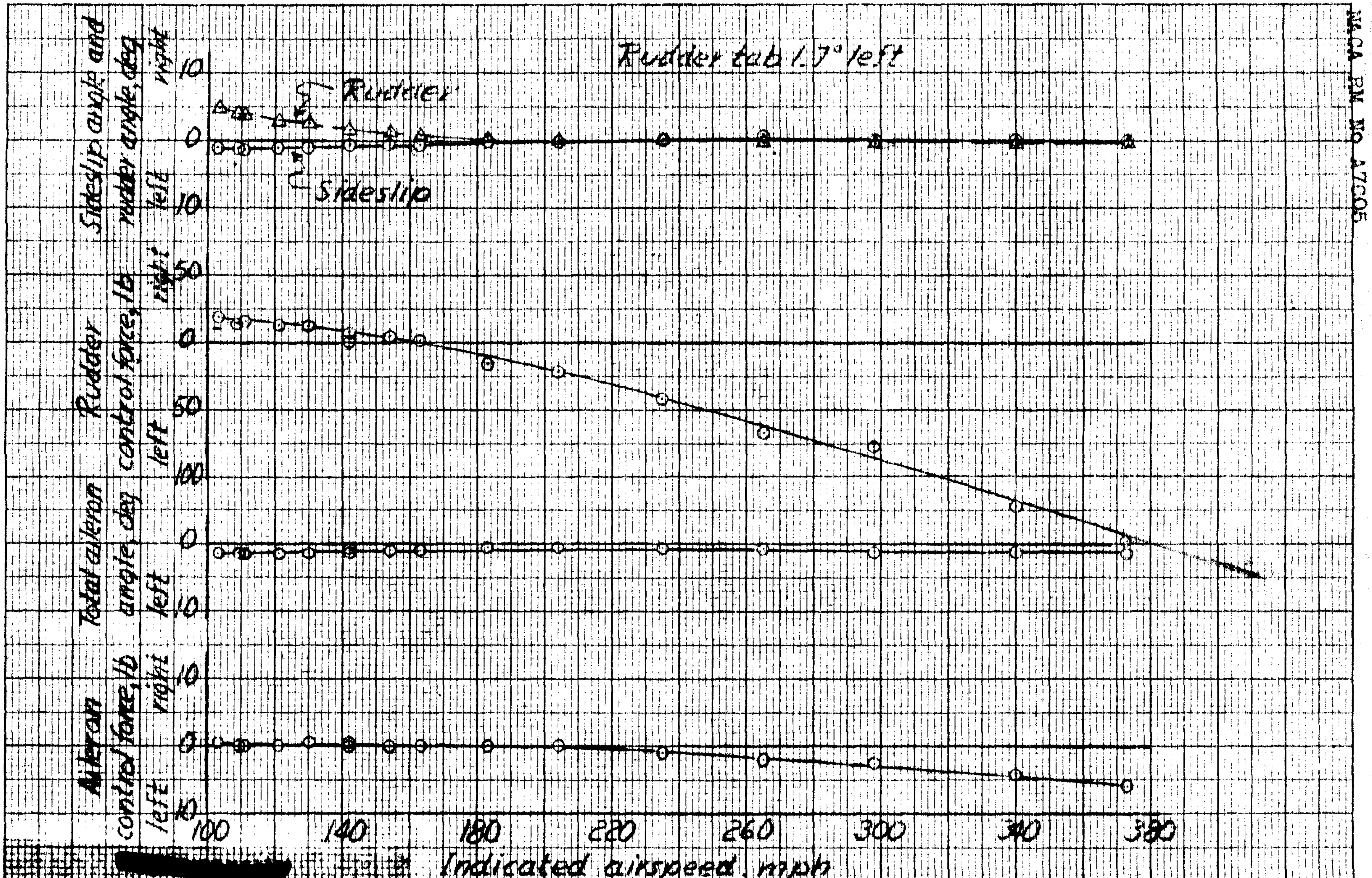
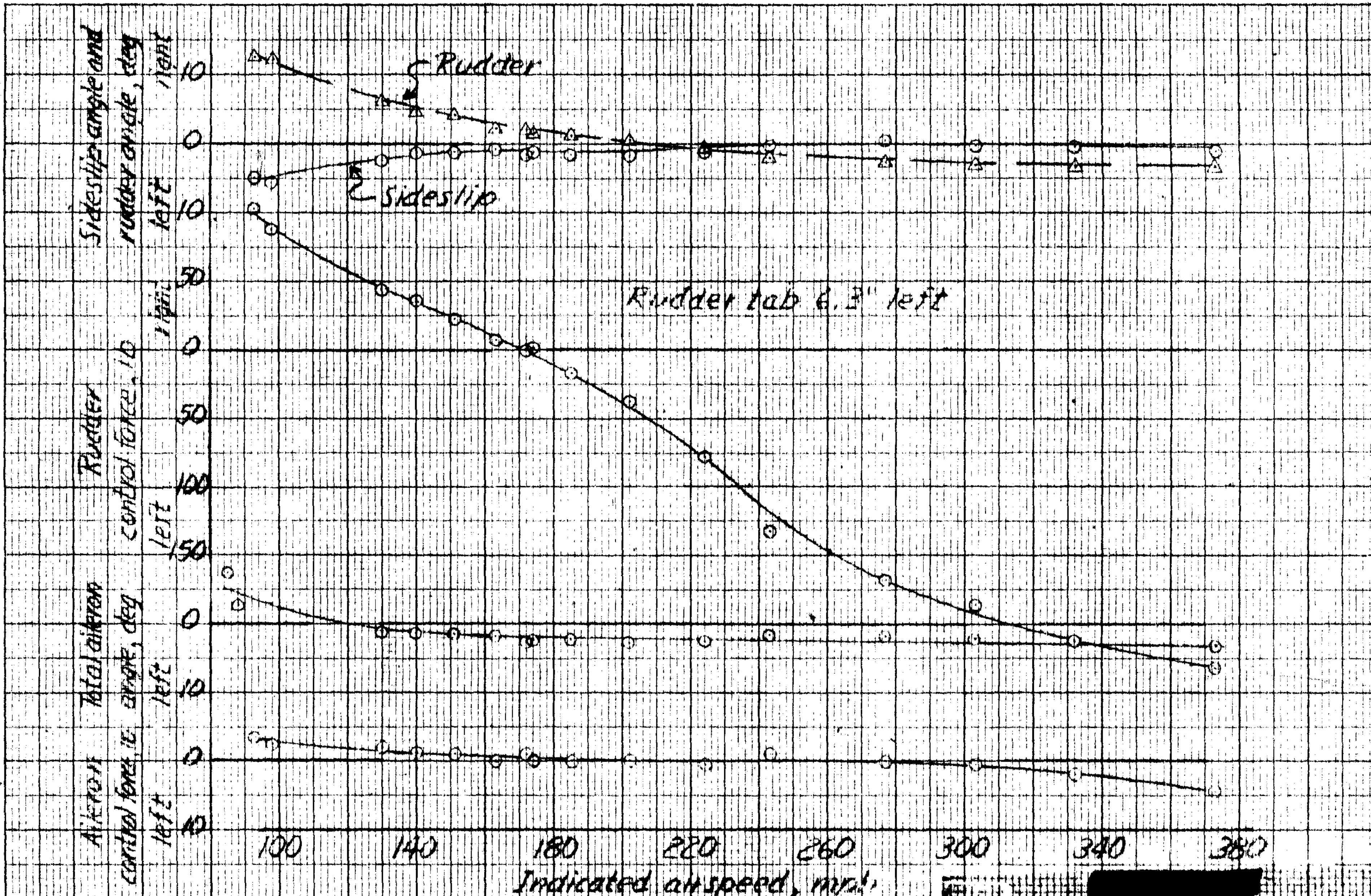


[redacted]

(a) Glide configuration

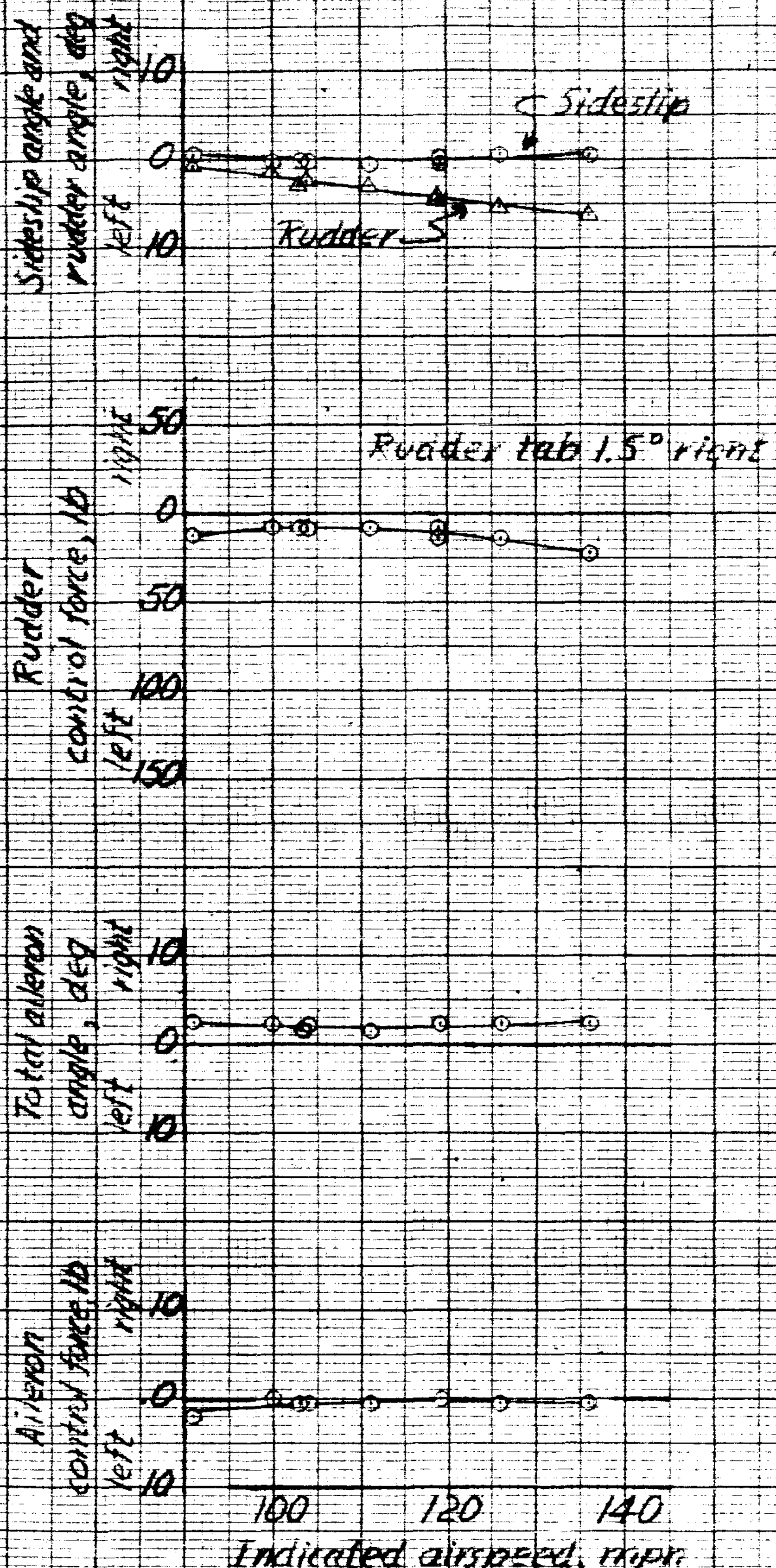
Figure 23.- Lateral and directional characteristics in steady, straight unbanked flight. Chance Vought F4U-4 airplane.



(b) Power-on-clean configuration

[redacted]

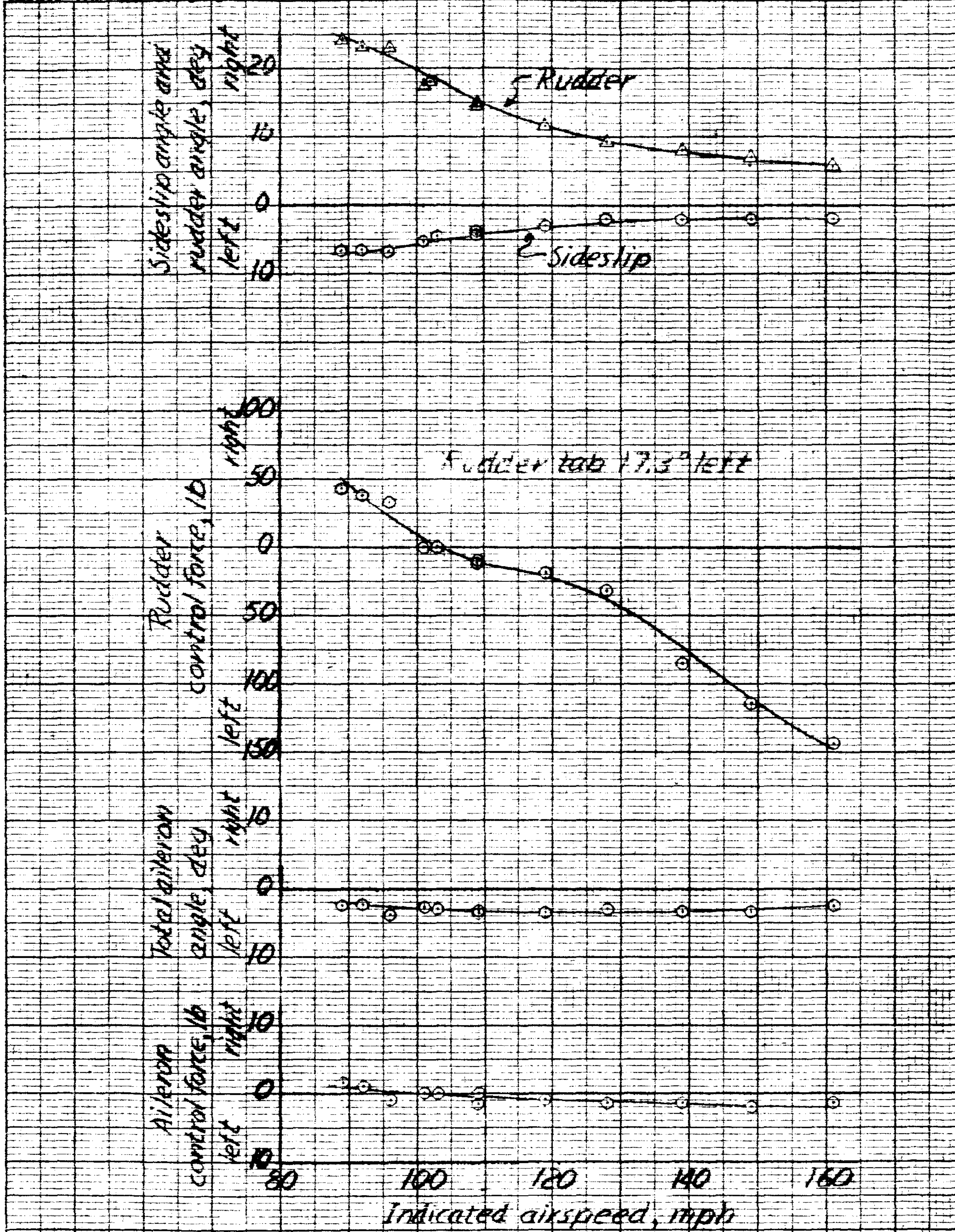
Figure 23. - Continued. Chance Vought F4U-4 airplane.



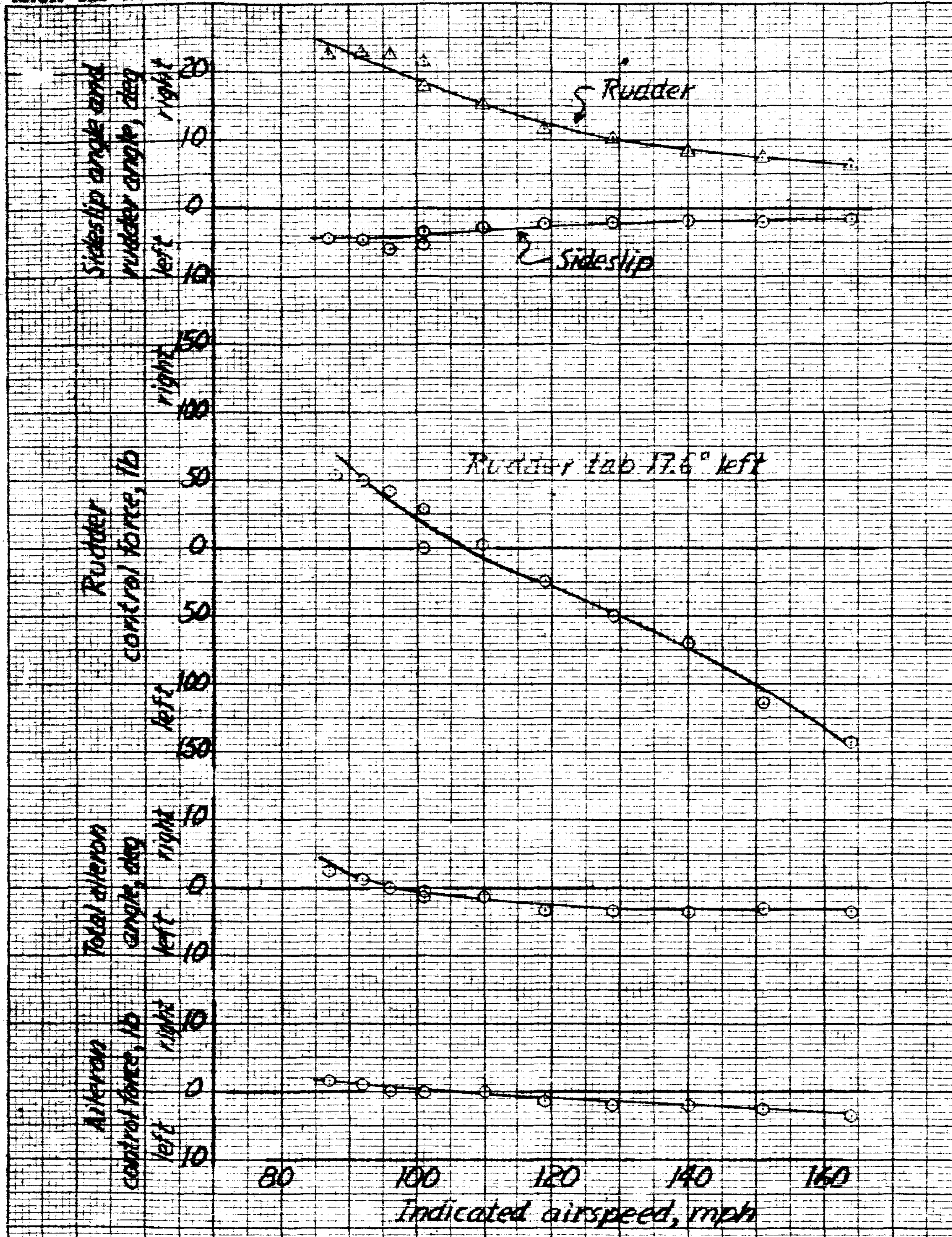
(c) Landing configuration

Figure 23. - Continued. Chance Vought F4U-4 airplane.

[redacted]



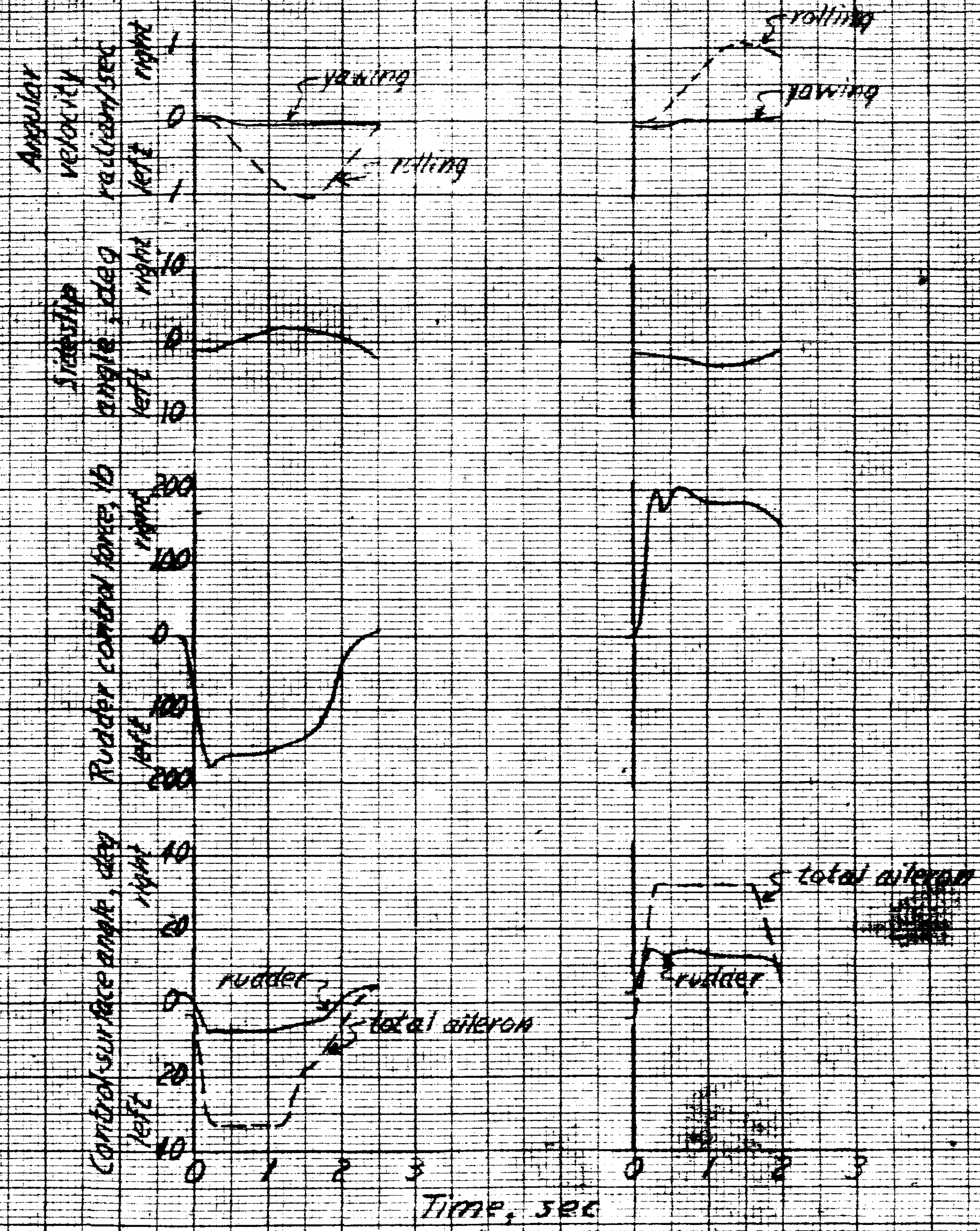
(d) Approach configuration
Figure 23. – Continued. Chance Vought F4U-4 airplane.



(e) Wave-off configuration

Figure 23. – Concluded. Chance Vought F4U-4 airplane.

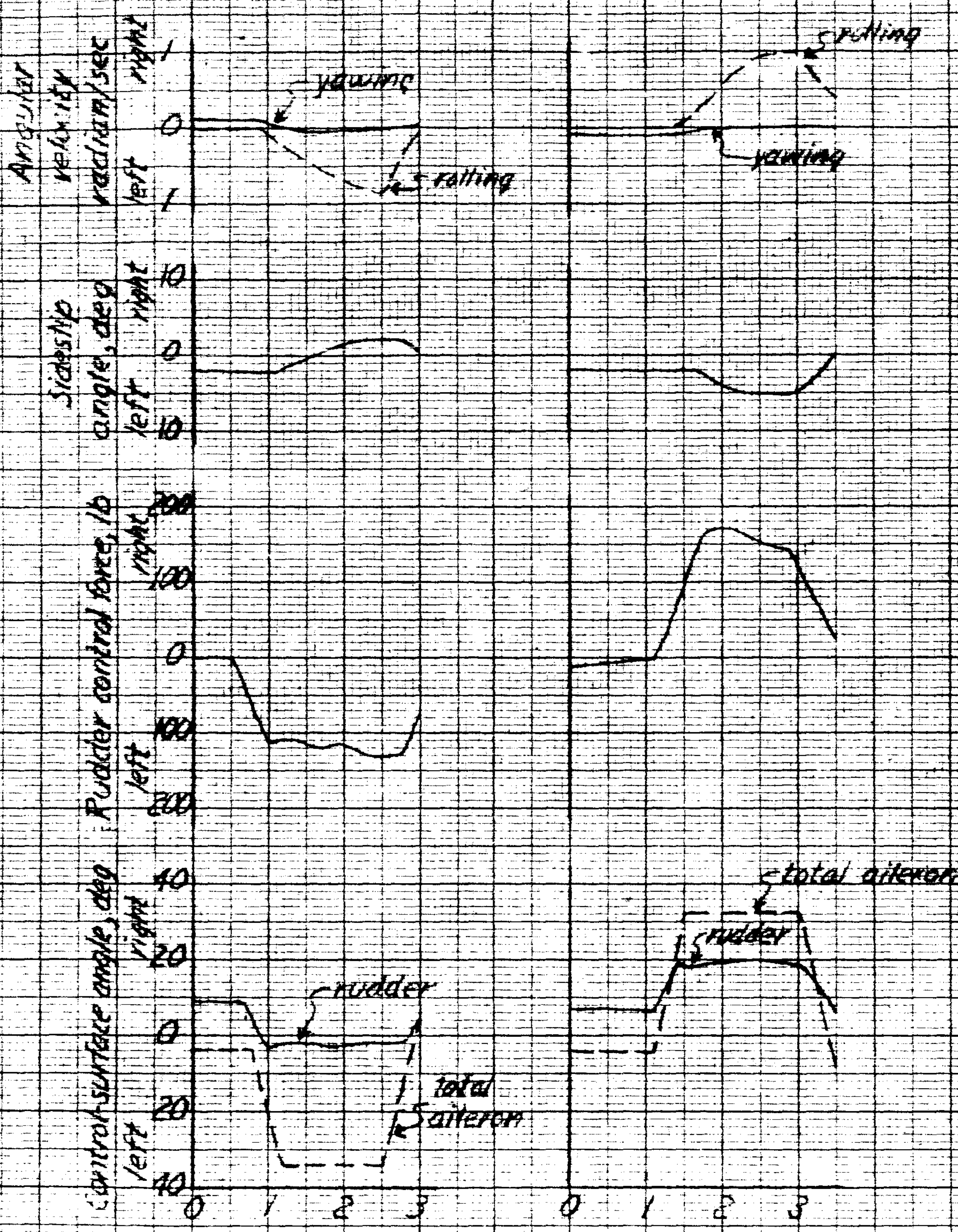
[redacted]



(a) Clean, power for level flight, 140 mph

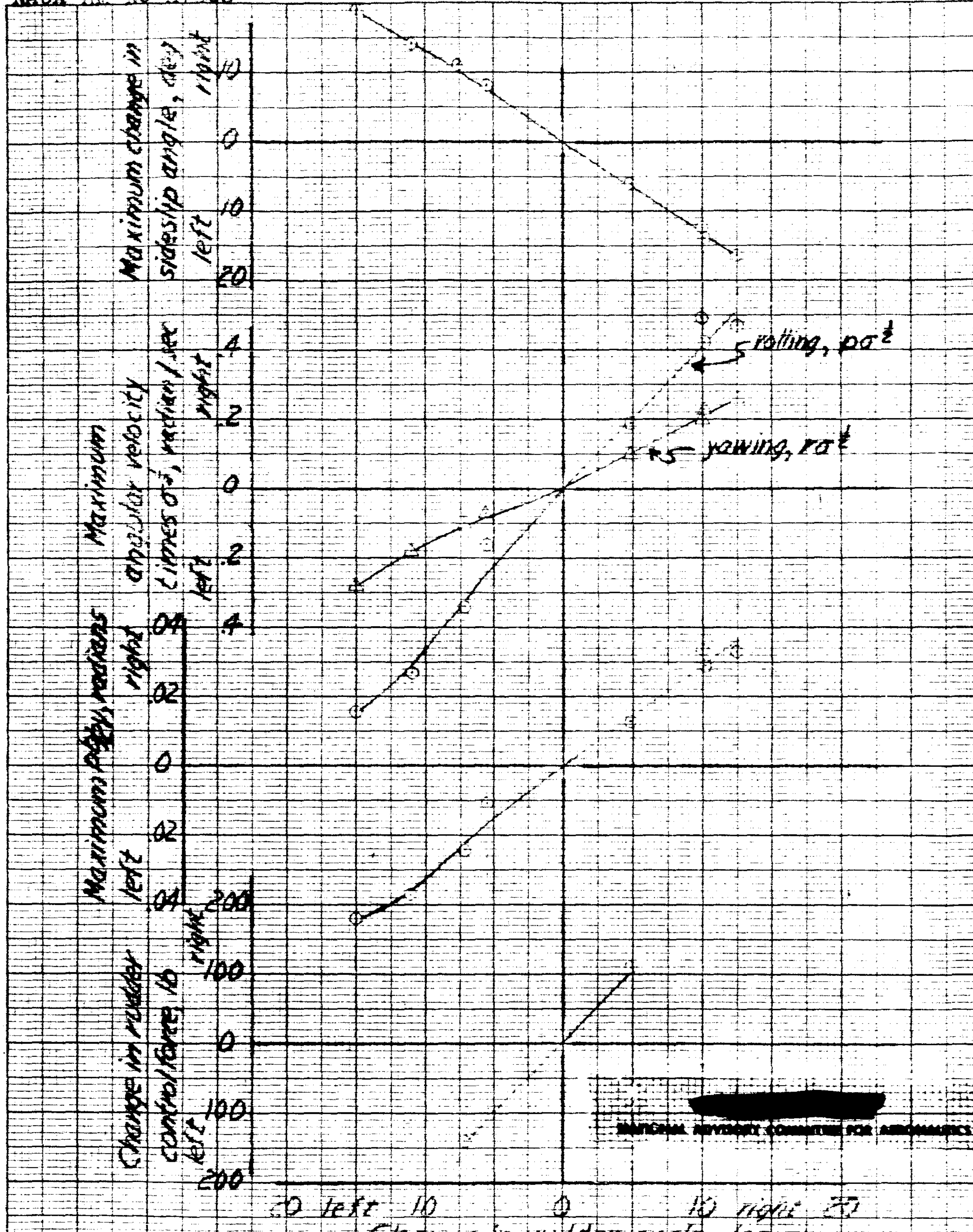
Figure 24. – Time histories of aileron-rudder rolls out of turns of about 45° bank. Chance Vought F4U-4 airplane.

[redacted]



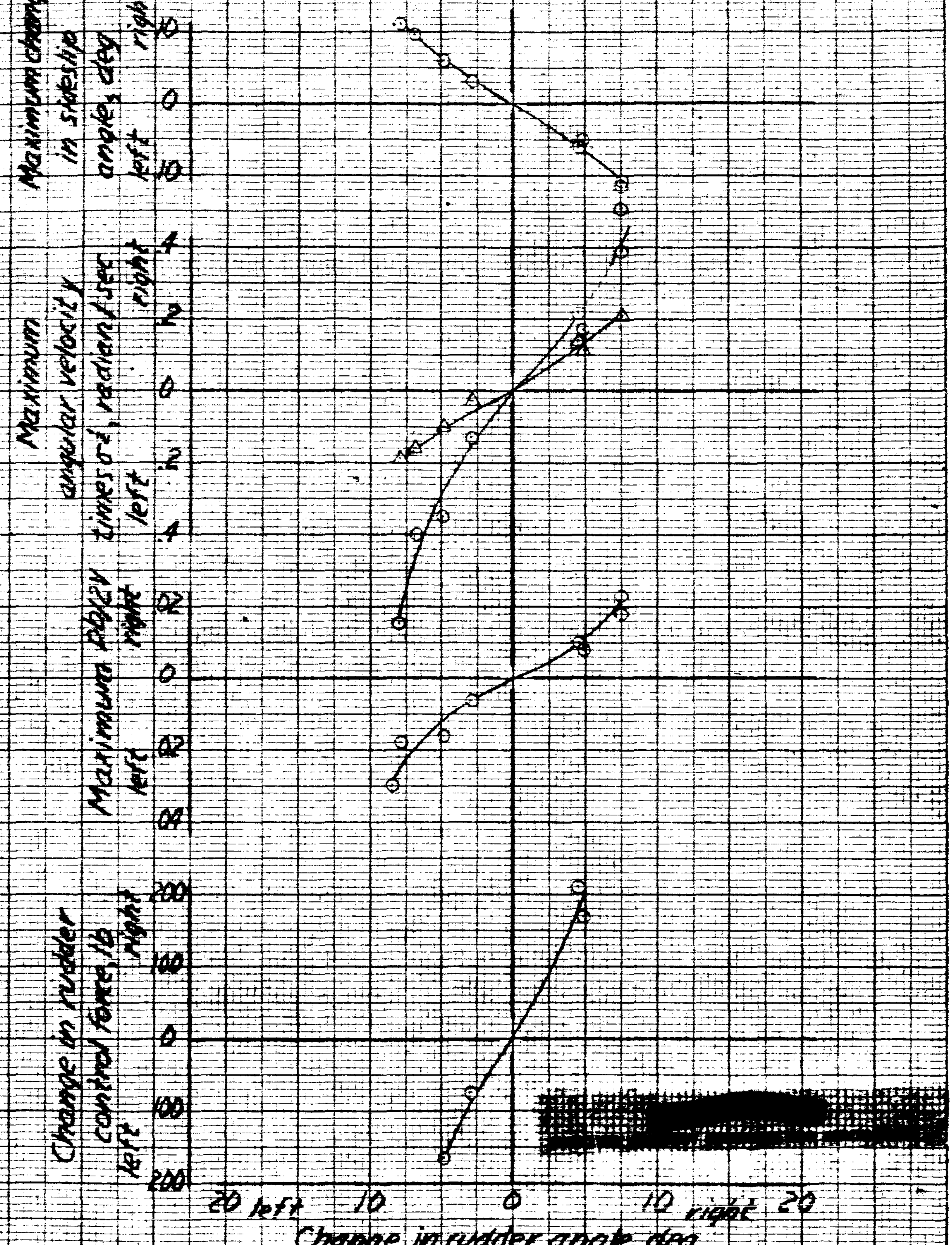
(b) Approach configuration, 120 mph

Figure 24. - Concluded. Chance Vought F4U-4 airplane.



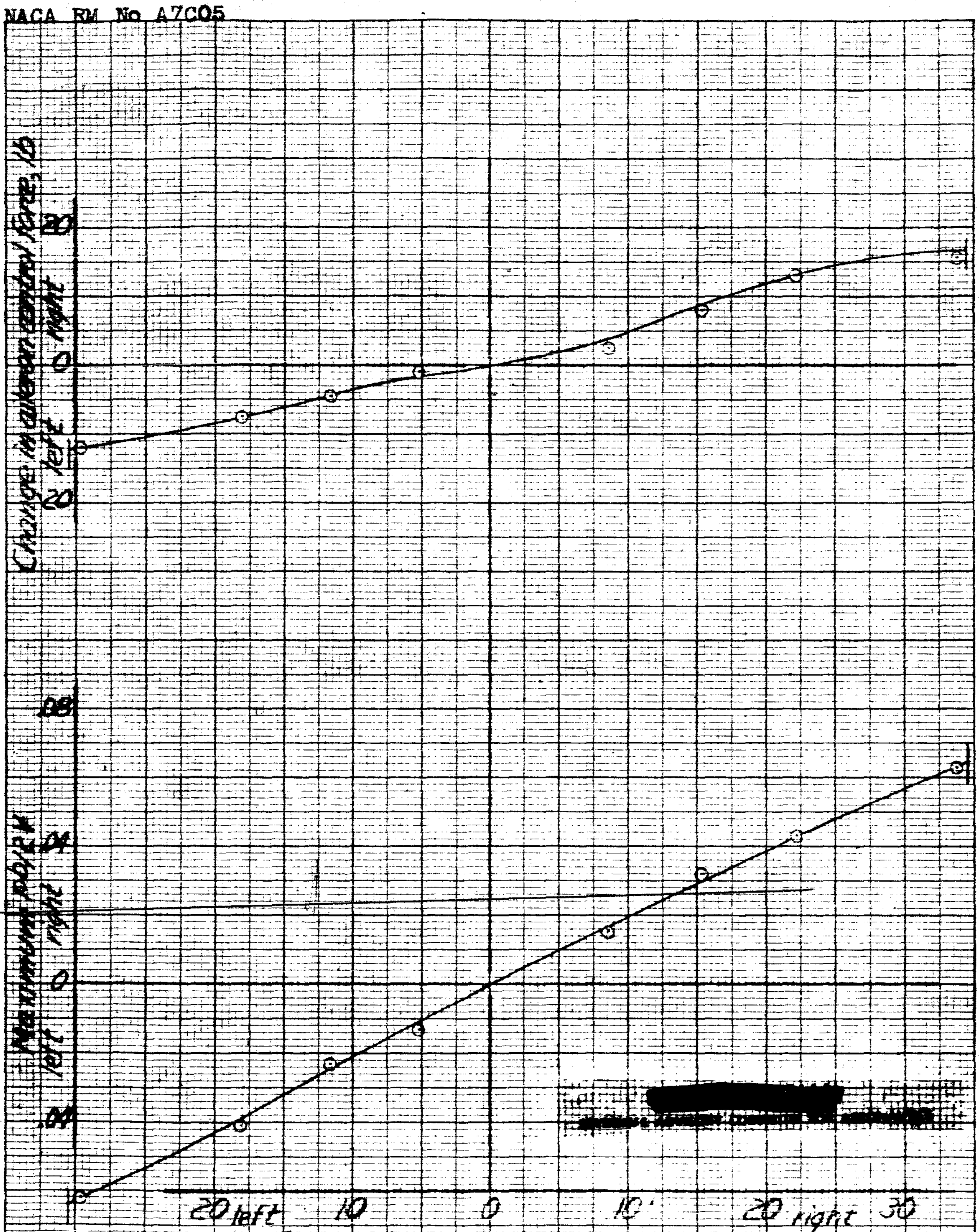
(a) $V_i \approx 200$ mph

Figure 25. – Characteristics in aileron-fixed rudder rolls. Power-on-clean configuration. Chance Vought F4U-4 airplane.



(b) $V_i \approx 302$ mph

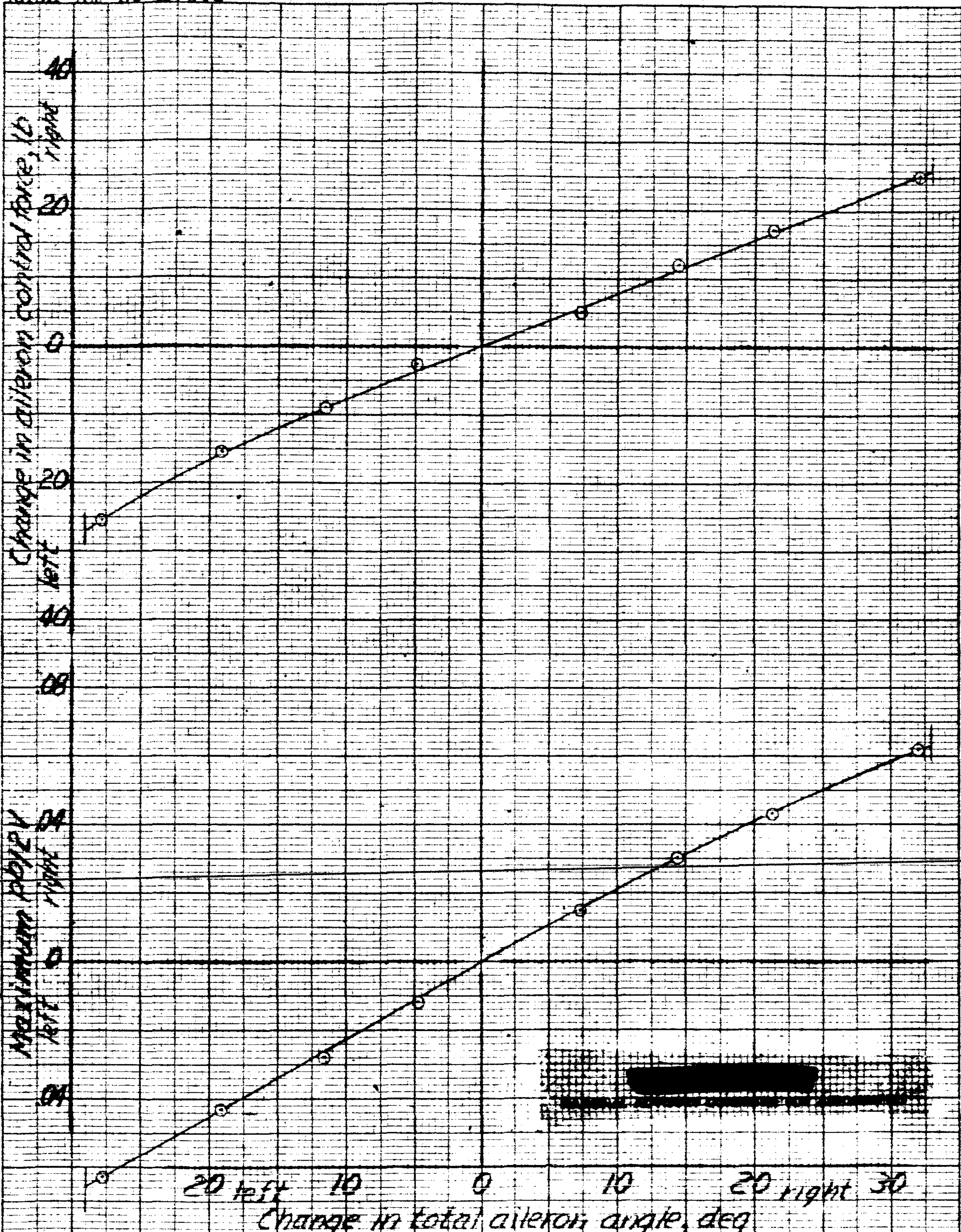
Figure 25. – Concluded. Chance Vought F4U-4 airplane.



Change in total aileron angle, deg

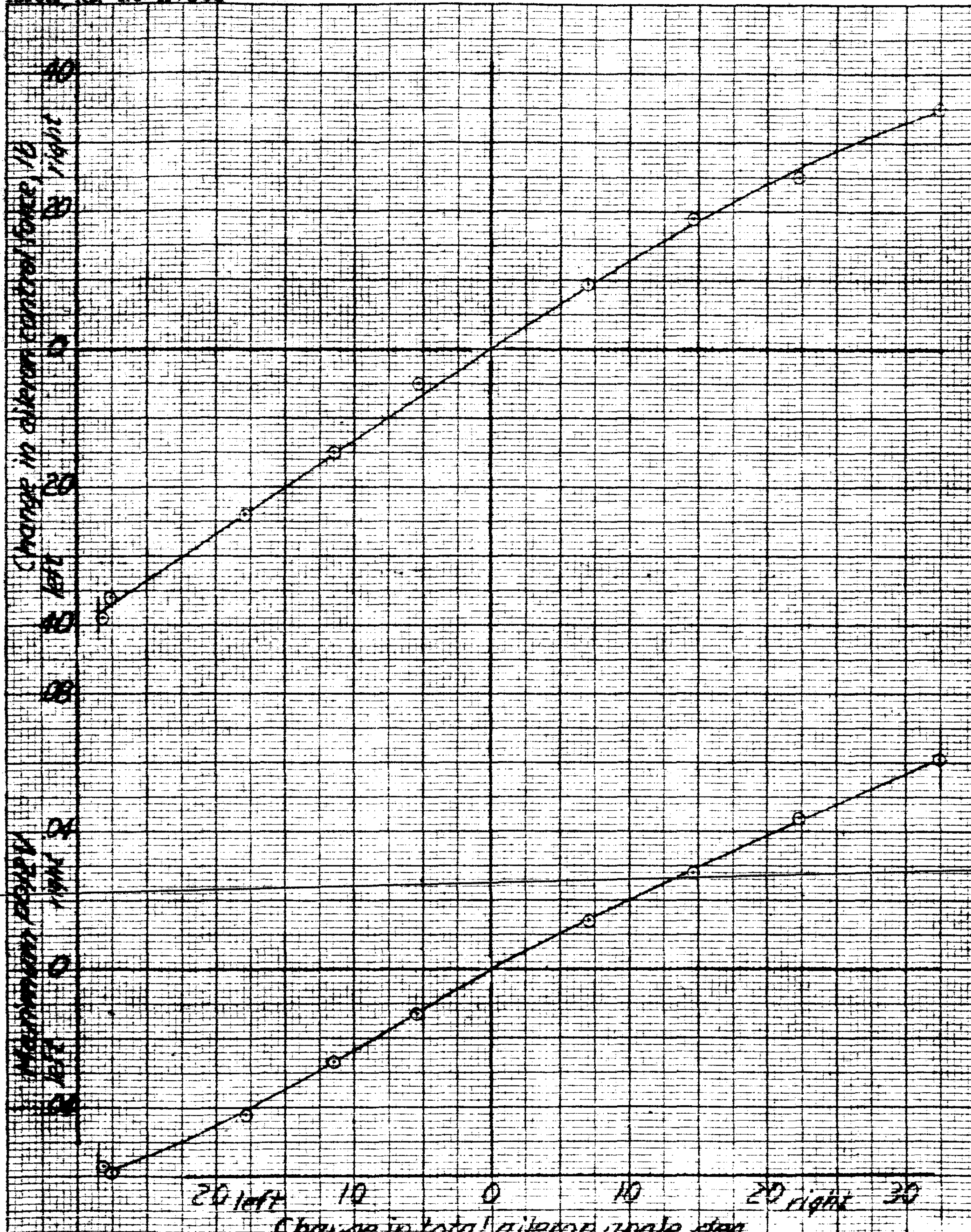
(a) $V_i \approx 145$ mph

Figure 26.— Variation with change in total aileron angle of maximum $pb/2V$ and change in aileron control force in abrupt rudder-fixed rolls. Flaps and gear up, power on. Average altitude 8500 ft. Chance Vought F4U-4 airplane.



(b) $V_i \approx 197$ mph

Figure 25. - Continued. Chance Vought F4U-4 airplane.



(c) $V_i \approx 253$ mph

[redacted]

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Figure 26. - Continued. Chance Vought F4U-4 airplane.

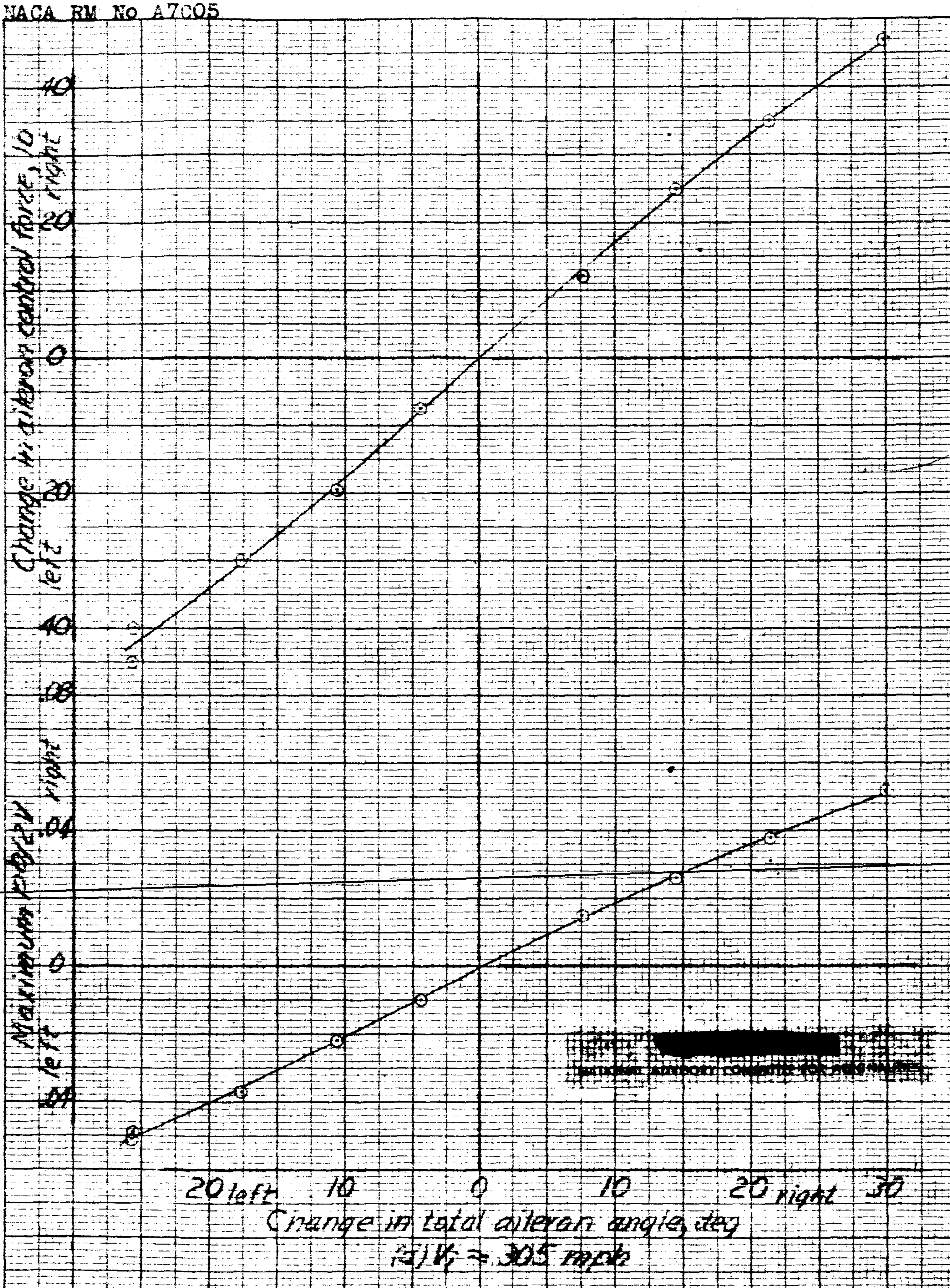
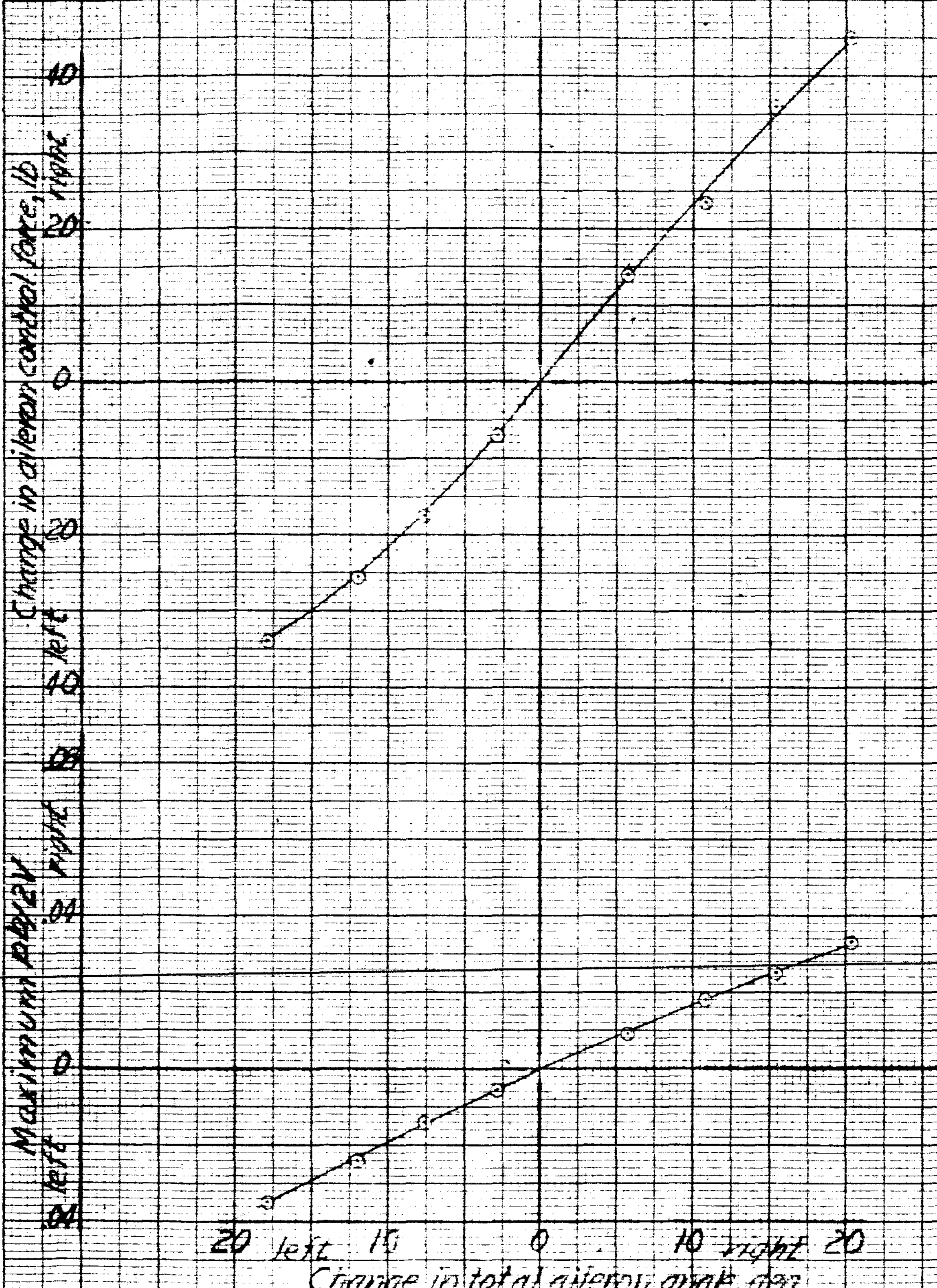


Figure 26. - Continued. Chance Vought F4U-4 airplane.



(e) $V_i \approx 354$ mph

Figure 26. Concluded. Chance Vought F4U-4 airplane.

[redacted]

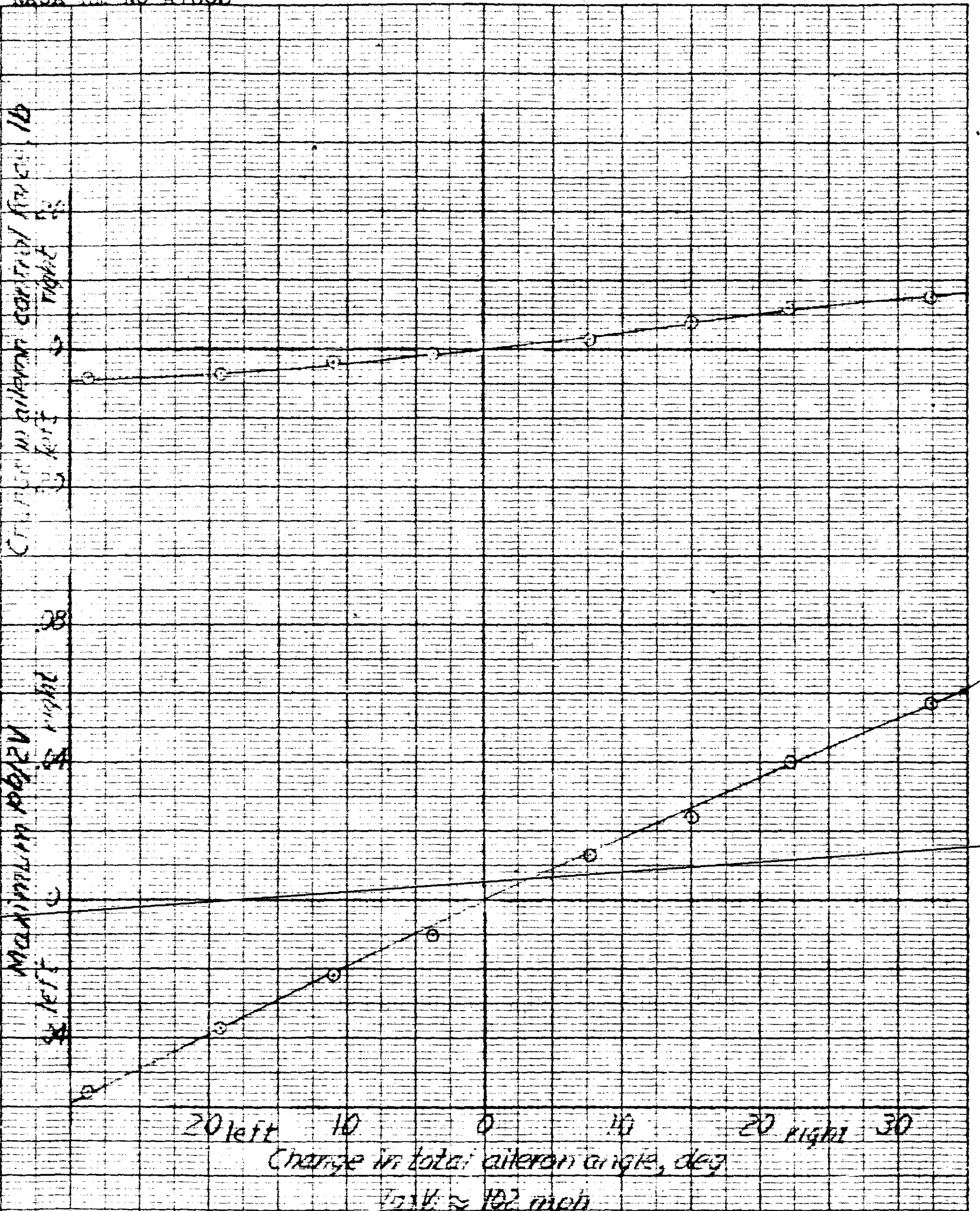
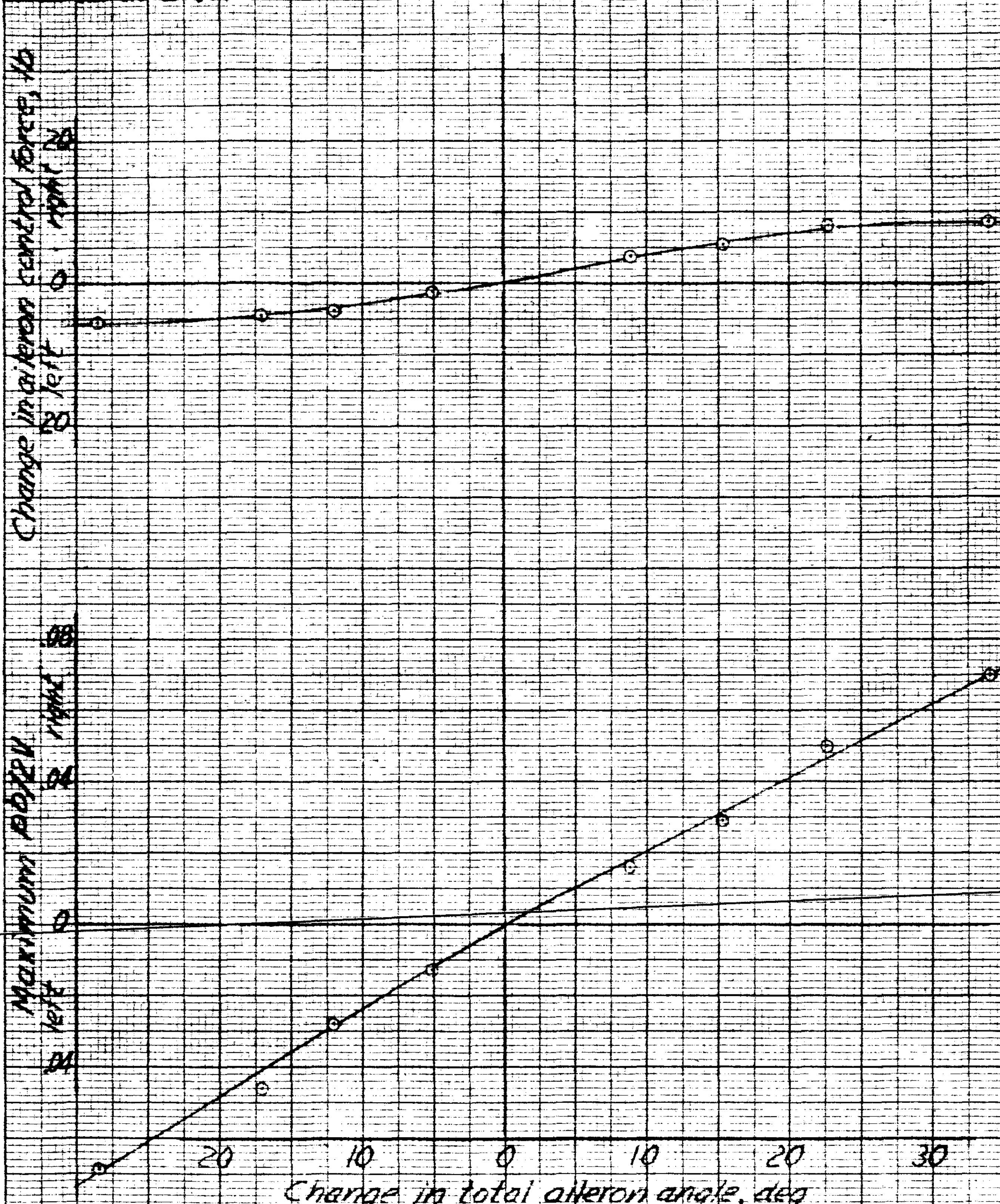


Figure 27. - Variation with change in total aileron angle of maximum pb/2V and change in aileron control force in abrupt rudder-fixed rolls. Flaps and gear down, power off. Average altitude 8500 ft. Chance Vought F4U-4 airplane.

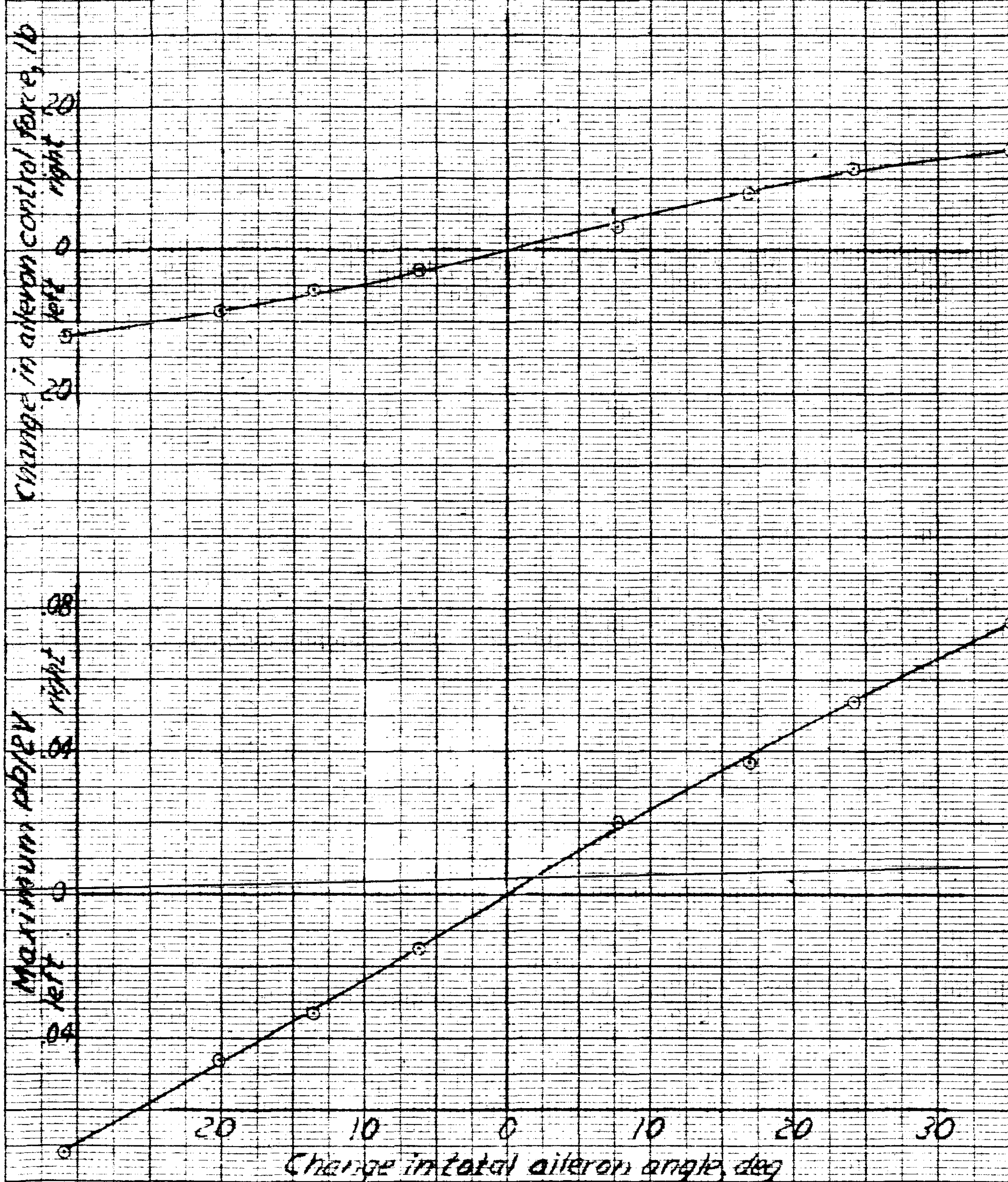
[redacted]



(b) $V_i \approx 117$ mph

Figure 27.- Continued. Chance Vought F4U-4 airplane.

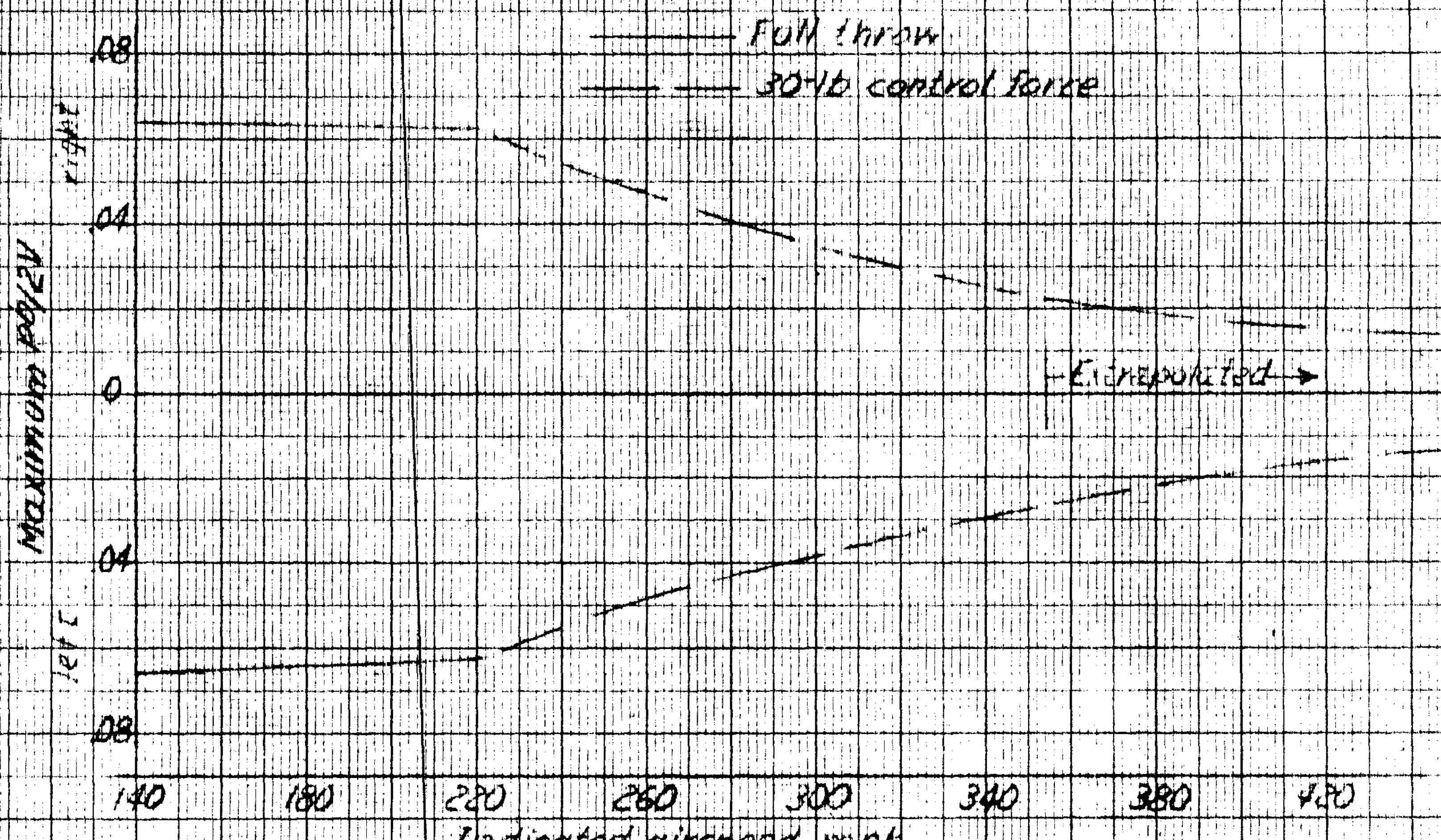
[redacted]



(c) $V_i \approx 137$ mph

Figure 27. – Concluded. Chance Vought F4U-4 airplane.

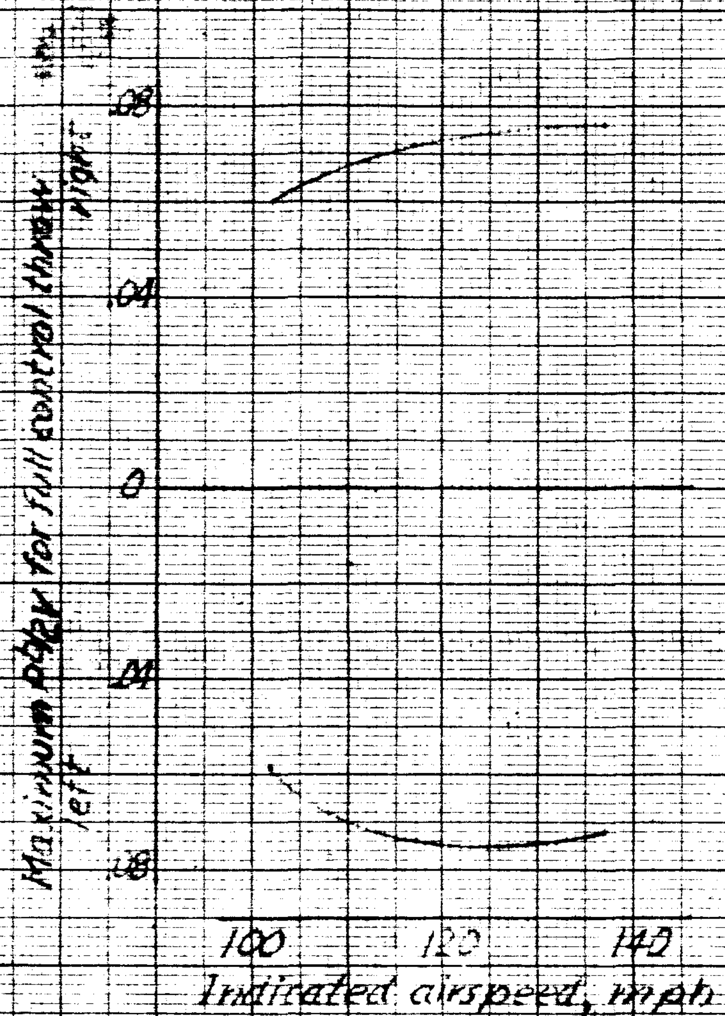
[redacted]



(a) Flaps and gear up, power on.

Figure 28. - Variation of maximum pb/2V with indicated airspeed. Chance Vought F4U-4 airplane.

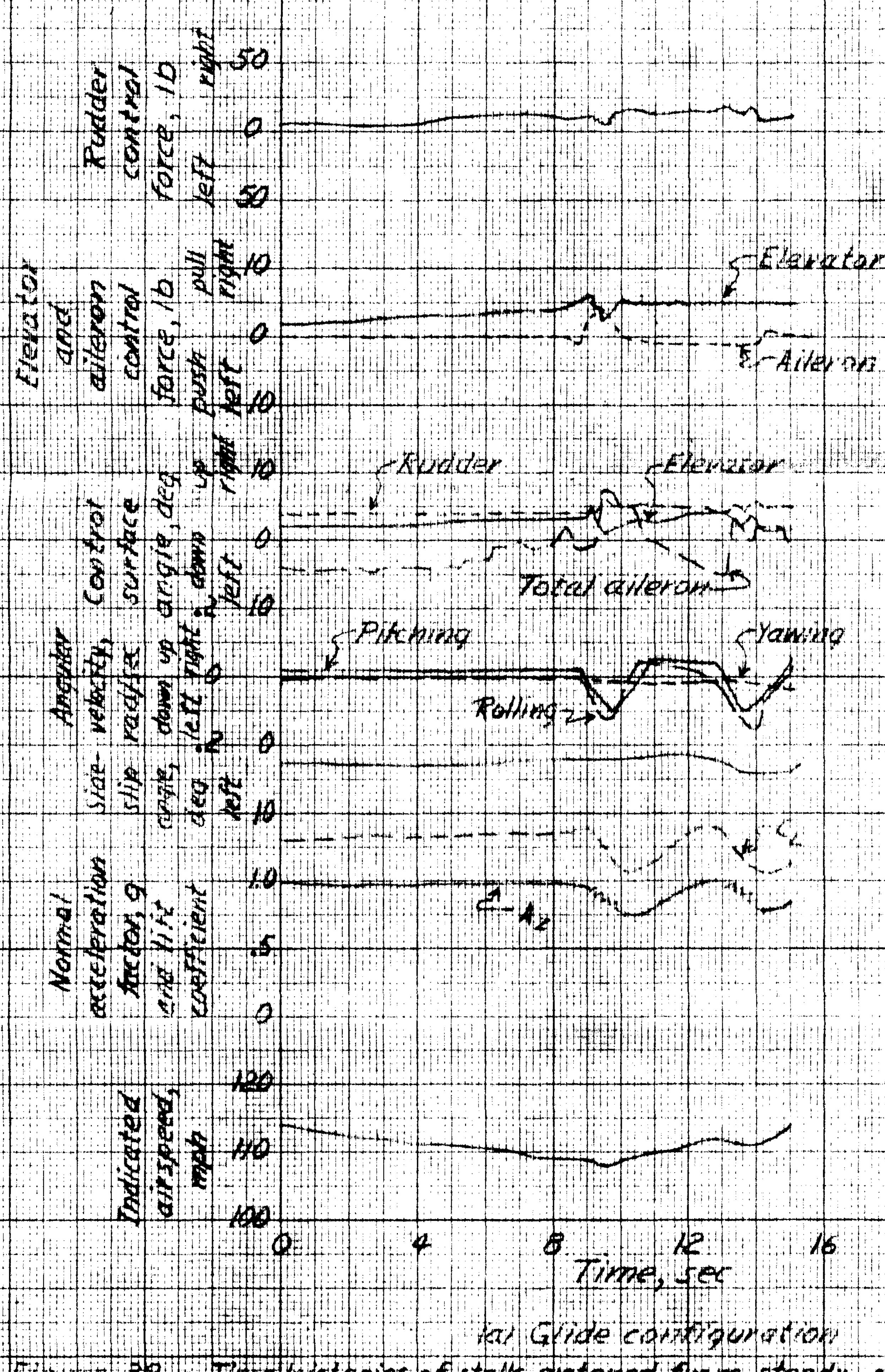
[redacted]



(b) Flaps and gear down, power off

Figure 28.- Concluded. Chance Vought F4U-4 airplane.

[redacted]



(a) Glide configuration

Figure 29.- Time histories of stalls entered from steady, straight, unbanked flight. Chance Vought F4U-4 airplane.

[redacted]

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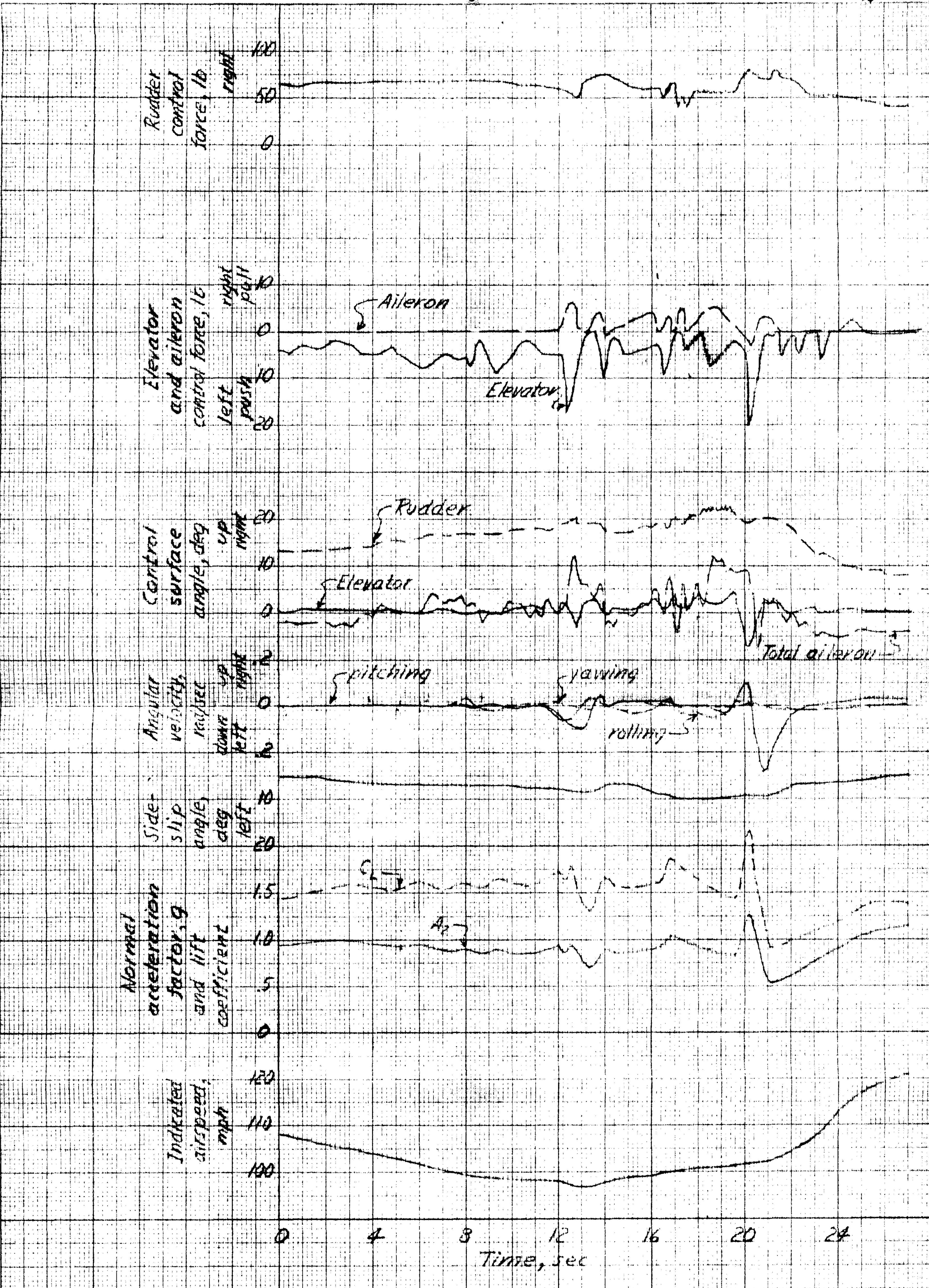
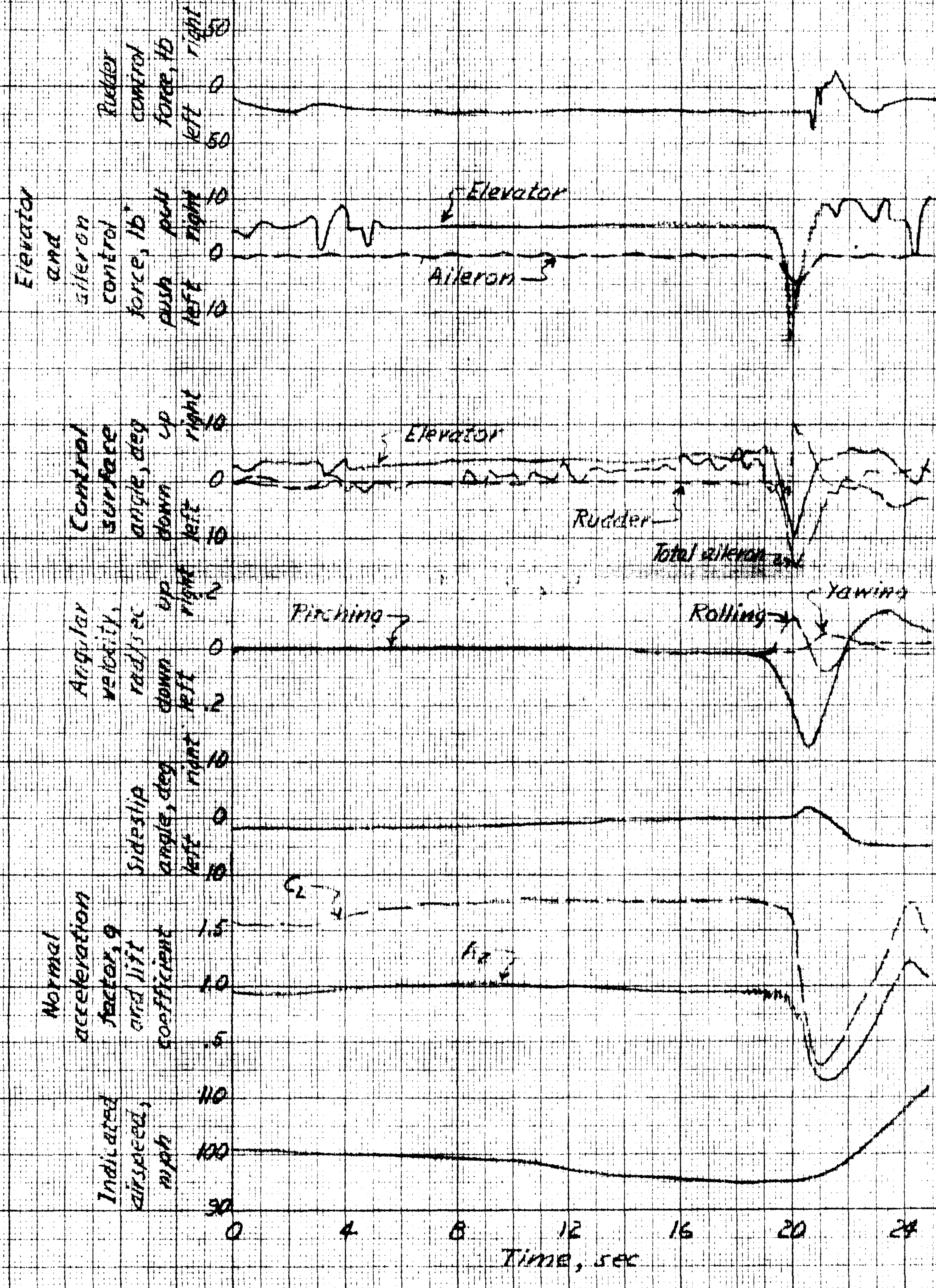


(b) Power-on-clean configuration

Figure 29.- Continued. Chance Vought F4U-4 airplane.

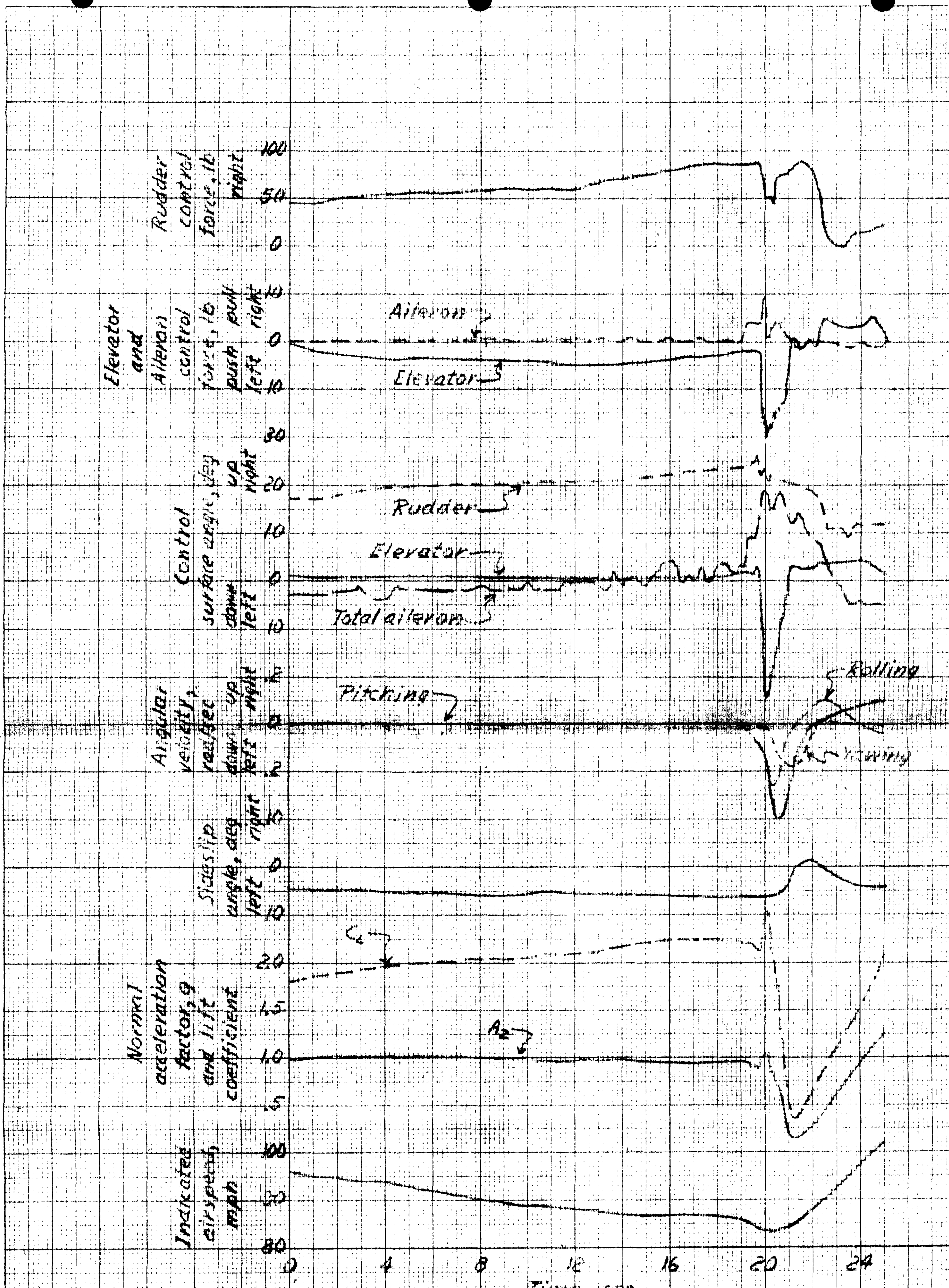
[redacted]



(c) Landing configuration

Figure 29.- continued. Chance Vought F4U-4 airplane.

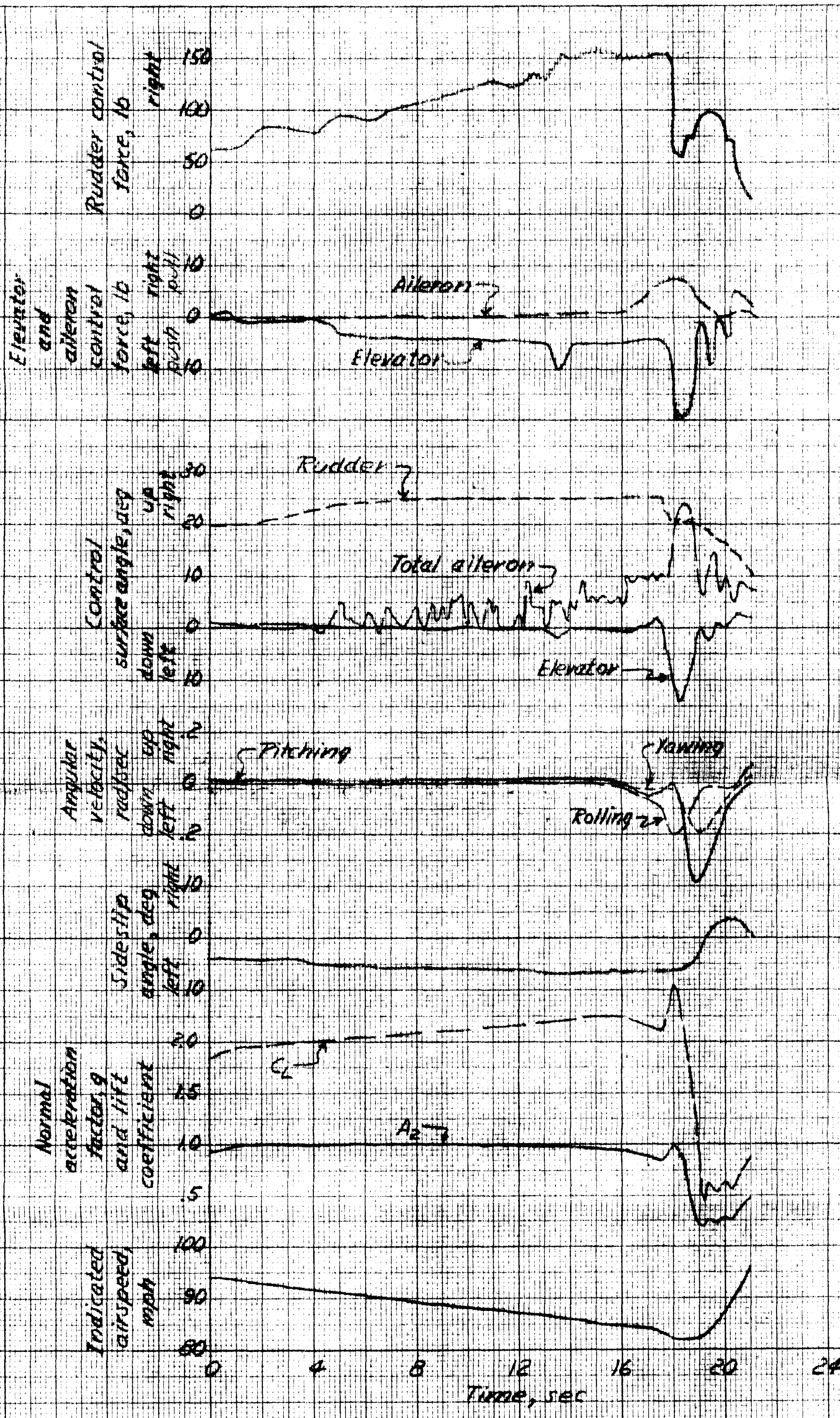
[redacted]



(d) Approach configuration.

Figure 29.- Continued. Chance Vought F4U-4 airplane.

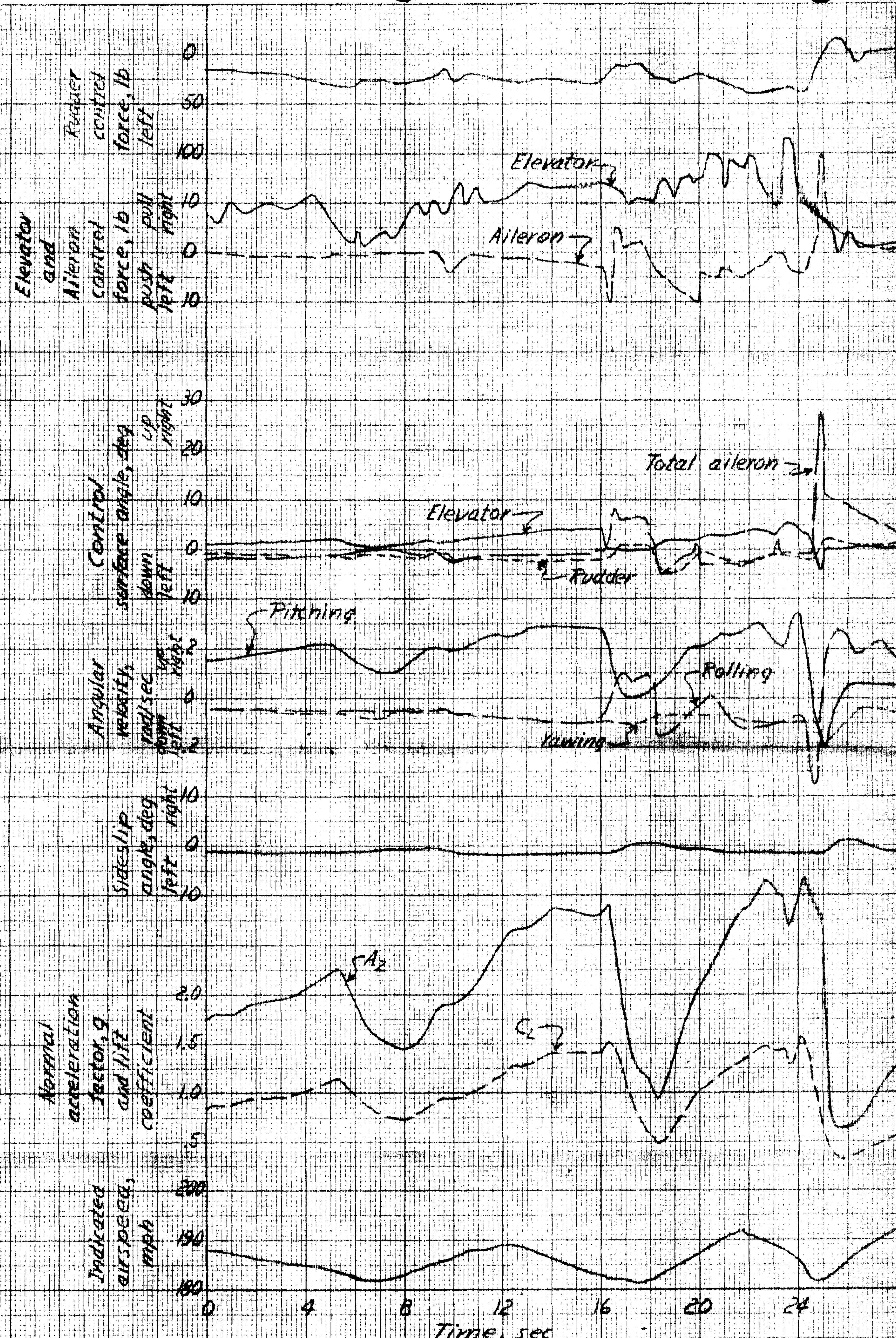
[redacted]



(e) Wave-off configuration.

Figure 29. - Concluded. Chance Vought F4U-4 airplane.

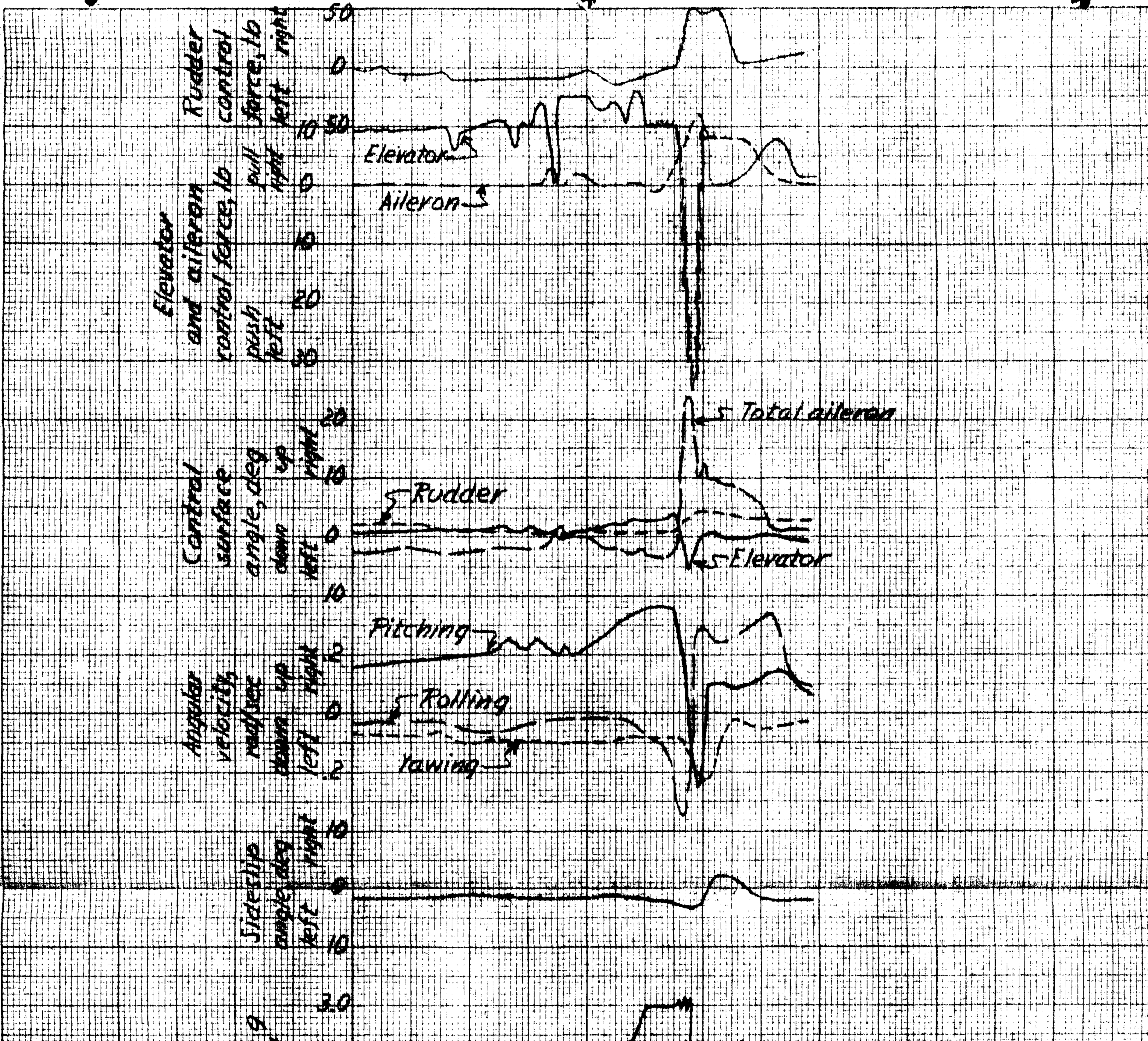
[redacted]



(a) Glide configuration

Figure 30.- Time histories of stalls entered from turning flight. Chance Vought F4U-4 airplane.

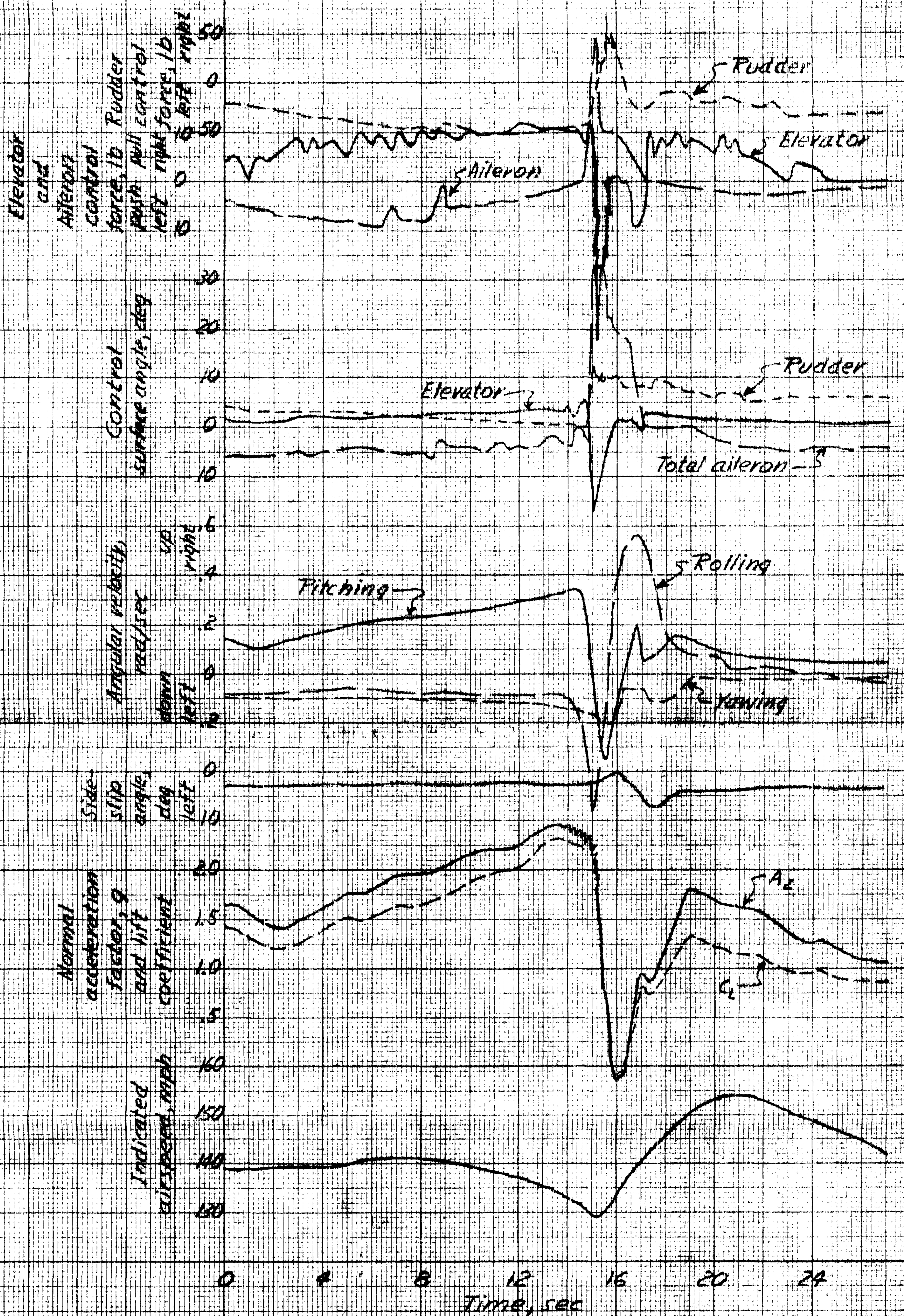
[redacted]



(b) Power-on-clean configuration

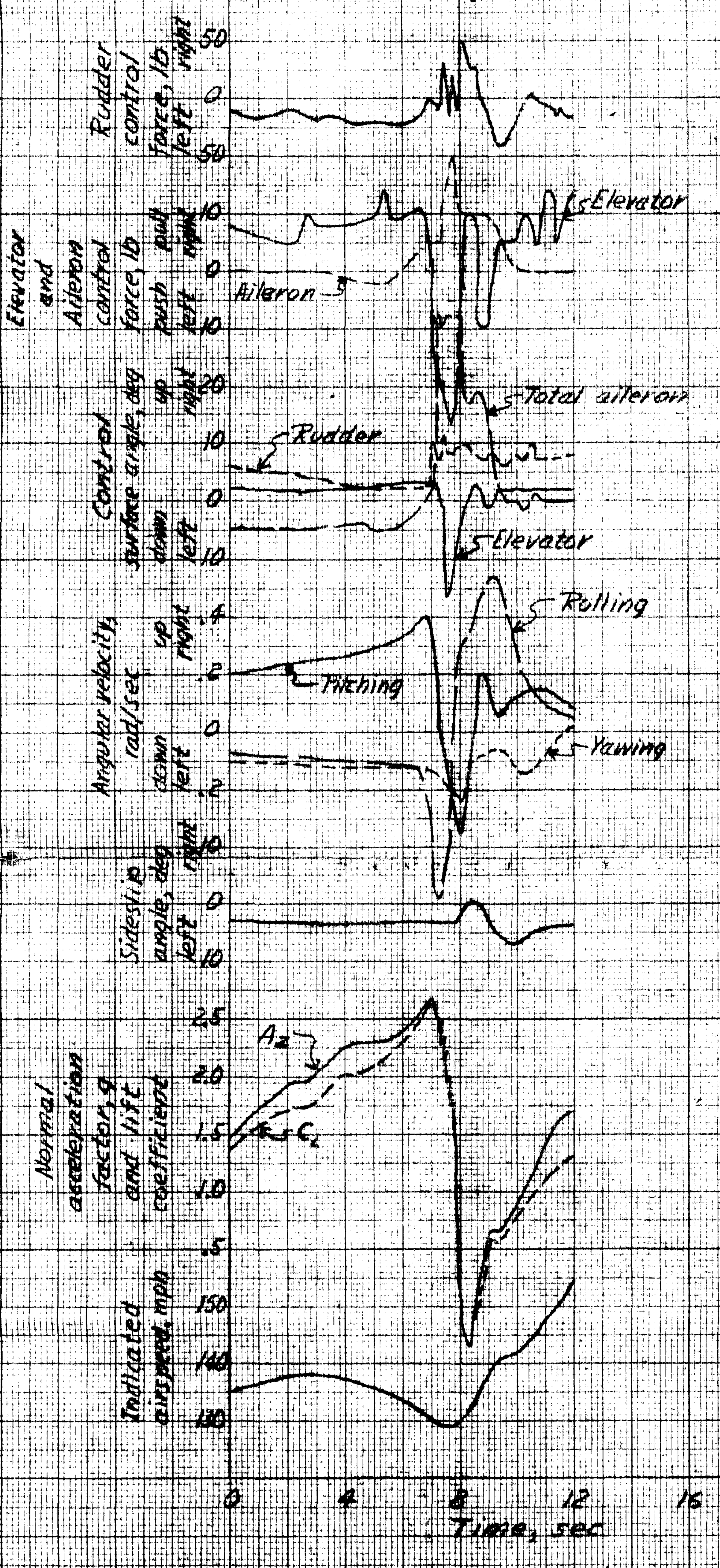
Figure 30. - Continued. Chance Vought F4U-4 airplane.

[redacted]



(c) Approach configuration

Figure 30.- Continued. Chance Vought F4U-4 airplane.



(d) Wave-off configuration

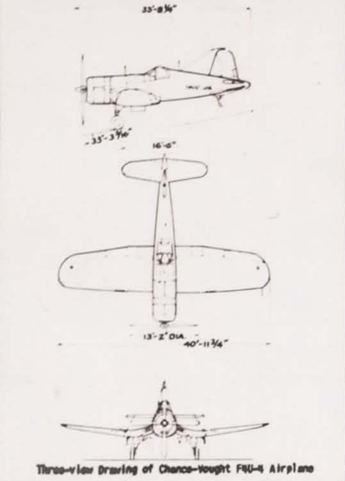
Figure 30.- Concluded. Chance Vought F4U-4 airplane.

CHANCE VOUGHT F4U-4

SUMMARY OF HANDLING CHARACTERISTICS

NACA FLIGHT DETERMINATION

AIRPLANE AS TESTED



Three-view Drawing of Chance-Vought F4U-4 Airplane

PERTINENT DETAILS:

Span	40.98 ft
Mean Aerodynamic Chord	94.0 in.
Wing Area	276.3 sq ft
Airfoil, root	NACA 23018
Airfoil, tip	NACA 23009
Type Flap	Slotted blow-up
Control Surface Deflections:	
Elevator	29° up, 17° down
Ailerons	19° up, 14° down
Rudder	25° right, 25° left
Engine and Ratings:	
Pratt & Whitney	R-2800-18W
Take-off and military power	2100 bhp at 2800 rpm
Maximum continuous	1700 bhp at 2600 rpm
Combat power (with water injection)	2800 bhp at 2800 rpm

CONTROL FRICTION:

Elevator	±2.5 lb
Aileron	±1.0 lb
Rudder	±6.5 lb

REMARKS:

Test gross weight approximately 12,100 lb, center-of-gravity range 28.1 - 34.0 percent M.A.C. (gear up). No external tanks or armament installed.

Manufactured by:
Chance-Vought Aircraft, Division of United Aircraft Corporation, Stratford, Connecticut

REFERENCE:

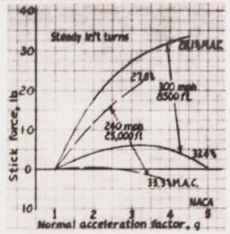
Liddell, Charles J. Jr., Reynolds, Robert M., and Christofferson, Frank E.:
Measurements in Flight of the Flying Qualities of a Chance-Vought F4U-4 Airplane.
NACA RM No. A7C06, 1947.

LONGITUDINAL

LOCATION OF CENTER OF GRAVITY FOR NEUTRAL STABILITY:

Configuration	Stick-fixed neutral point (Percent M.A.C.)	C_L	Stick-free neutral point (Percent M.A.C.)	C_L
Power-on-clean	35.2 33.9 32.2	0.2 .4 1.0	42.0 35.0 26.0	0.2 .4 1.0
Glide	35.6 32.8 33.8	.4 1.0 1.1	40.2 35.2 33.3	.4 .8 1.2
Approach	32.8 31.7 28.6	.8 1.4 1.9	31.0 28.0 26.6	.8 1.4 1.9
Landing	35.2 33.2 33.0	.8 1.4 1.8		

MANEUVERING CHARACTERISTICS:



TRIM CHANGES DUE TO POWER, FLAP, AND GEAR VARIATIONS:

V_i (mph)	Flap	Gear	Manifold Pressure (in. Hg)	Engine speed setting (rpm)	Elevator angle (deg)	Elevator tab setting (deg)	Elevator control force change (lb)
141	up	up	27	2400	0.2 down	0.9 down	6.5 pull
	up	down	27	2400	1.0 up		
140	up	down	27	2400	1.2 up	3.4 down	0.5 push
	down	down	27	2400	0.1 down		
120	down	down	15	2150	0.5 up	5.0 down	5.5 push
	down	down	48	2600	0.4 up		

CONTROL IN TAKE-OFF AND LANDING:

Satisfactory over test center-of-gravity range.

LONGITUDINAL TRIMMING DEVICE:

Adequate over test center of gravity and speed ranges.

DYNAMIC STABILITY:

Short-period control-free oscillations of elevator and airplane were satisfactorily damped.

REMARKS:

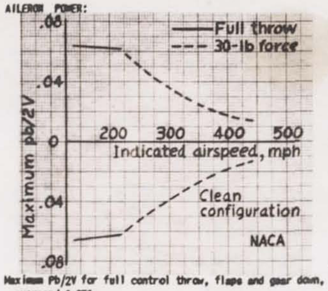
Spring in elevator system which gave 5-pound pull force on stick improved the low-speed elevator-force characteristics slightly, but causes undesirably high push forces at high speed.

LATERAL

VARIATION OF CONTROL FORCE AND Pb/2V WITH AILERON DEFLECTION:

Smooth and approximately proportional to aileron deflection at all speeds.

AILERON POWER:



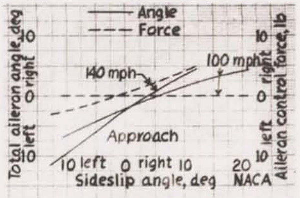
Maximum Pb/2V for full control throw, flaps and gear down, averaged 0.070.

AILERON TRIM CHARACTERISTICS:

Changes with speed, power, or flap changes were desirably small, and tab power was ample.

DIHEDRAL EFFECT:

In general, moderately positive stick fixed; neutral to moderately positive stick free, depending on configuration and speed.



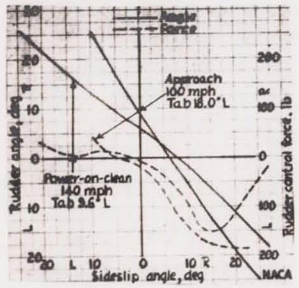
DIRECTIONAL

YAWING MOMENT DUE TO AILERON DEFLECTION:

In abrupt rudder-fixed aileron rolls at low speed the maximum angle of sideslip per 5-percent full aileron deflection was approximately 0.8°. The rudder control was sufficiently powerful to permit abrupt zero-yaw turn exits with satisfactory rudder forces.

STATIC DIRECTIONAL STABILITY:

Positive rudder-fixed and rudder-free over a ±15° steady sideslip range. In the power-on-clean configuration at low speed, rudder forces were very small in left sideslip and tended to reverse at large angles of right sideslip.



RUDDER TRIM CHARACTERISTICS:

The rudder control was satisfactory for steady unbanked flight in the required conditions. The rudder-tab effectiveness was adequate in all conditions. Rudder control force change with airspeed was excessive.

RUDDER CONTROL IN TAKE-OFF AND LANDING:

Control was adequate and the associated forces were not excessive.

DYNAMIC STABILITY:

The control-free oscillations of the rudder itself did not damp completely within one cycle. The dynamic stability of the airplane was always positive, but the airplane motion was not damped sufficiently at high altitude (25,000 ft).

STALLING

STRAIGHT FLIGHT:

Configuration	$C_{L_{max}}$	Remarks
Power-on-clean	1.62	Fair warning in the form of buffeting, elevator tug, or slight rolling tendencies.
Glide	1.37	
Approach	2.24	No warning prior to left roll and pitch-down at stall.
Landing	1.78	No warning prior to roll and pitch-down at stall.

The airplane motions in the stall were not considered violent. Recovery was readily effected by normal use of the controls.

TURNING FLIGHT:

Stall warning was unsatisfactory in all configurations. Recovery could be made with normal use of the controls.

Configuration	Flaps	Gear	Manifold Pressure (in. Hg)	Engine speed setting (rpm)
Power-on-clean	up	up	48	2600
Glide	up	up	15	2150
Approach	down	down	27	2400
Landing	down	down	Throttled	2400

CHANCE VOUGHT F4U-4

FIGURE 31.- SUMMARY OF FLYING QUALITIES OF CHANCE VOUGHT F4U-4 AIRPLANE.