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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

FLIGHT MEASUREMENTS OF LATERAL AND DIRECTIONAL STABILITY AND CONTROL CHARACTERISTICS OF THE GRUMMAN F8F-1 AIRPLANE

TED NO. NACA 2379

By

H. L. Crane and J. P. Reeder

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

JAN 29 1948

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SUMMARY

This paper presents the results of flight tests to determine the lateral and directional stability and control characteristics of the Grumman F8F-1 airplane with three vertical-tail configurations. The data presented herein have no bearing on the performance characteristics of the airplane, which were not measured but which were considered to be exceptionally good. The conclusions reached regarding the lateral and directional stability and control characteristics may be summarized as follows:

1. It was found that the directional stability was poor with the production vertical tail. Addition of a 12-inch extension to the vertical fin and rudder produced a desirable improvement in directional stability and control characteristics. However, further enlargement of the vertical tail would be required to make the directional stability satisfactory in all respects.

2. There was a tendency for the rudder control force to overbalance at large angles of right sideslip with the modified vertical tails. There was no such tendency with the production tail configuration which included a dorsal fin. It was concluded that the dorsal fin should have been retained on the modified vertical tails.

3. The aileron control characteristics were better than those of many comparable airplanes which have been tested. However, the ailerons did not satisfy the Navy requirements for satisfactory flying qualities with regard to either control forces or rolling effectiveness.

4. The power of the rudder trimming tab proved to be inadequate and the tab should be enlarged and/or be provided with an increased deflection range.

INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, flight tests have been made to determine the flying qualities of the Grumman F8F-1 airplanes (BuAer nos. 94873 and 90461) with three vertical-tail configurations. Flight tests were made with XF8F-1 airplane 90461 between May 10 and August 4, 1945 when the landing gear and propeller were damaged during an emergency landing. The test program was resumed under lower priority on June 6, 1946 when a second airplane, F8F-1 airplane 94873, was provided by the Bureau of Aeronautics. The results of the tests to determine the lateral and directional stability and control characteristics are presented in this report. The investigation included a rather complete measurement of the lateral and directional stability and control characteristics with the production F8F-1 vertical tail plus enough supplementary tests with the modified vertical tails to determine which configuration was the most satisfactory.

DESCRIPTION OF AIRPLANE

The F8F-1 airplane was a single-engine, single-place, low-wing, shipboard fighter. The F8F-1 airplane was equipped with slotted flaps and a conventional-type retractable landing gear. The construction was all metal except for the fabric covering on the control surfaces. The Frise ailerons were equipped with spring tabs. The rudder was horn-balanced and the elevator had an overhanging balance. Test airplane 90461 was equipped with trimming tabs on the rudder and elevator but had none on the ailerons. This airplane was equipped with dorsal and ventral fins. The fin was offset 2° leading edge left. During a large portion of the tests a 150-gallon external fuel tank was mounted below the fuselage. There were no dive-recovery flaps on airplane 90461. Power was supplied by a Pratt & Whitney R-2800-34 engine which turned a four-blade Aero Products propeller. The take-off weight of the airplane was approximately 9000 pounds with no external stores or 10,000 pounds with full belly tank. Photographs of the F8F-1 airplane with and without the 150-gallon belly tank are presented in figure 1. A three-view drawing, cross sections of the wing and aileron, and cross sections of the horizontal and vertical tail are shown in figure 2. General specifications of the airplane are given in table I.

The Grumman F8F-1 airplane 94873 differed from airplane 90461 in that it had a fin setting of 1.5°, leading edge left, and was equipped with dive-recovery flaps and an aileron trimming tab. Airplane 94873 was used to test the modified vertical-tail configurations.

Figure 3 presents the variation of rudder deflection with right-rudder-pedal position. Rudder deflection was measured with respect to the fin. The friction of the rudder system amounted to ± 6 pounds of pedal force. Figure 4 presents the aileron and spring-tab linkage characteristics. The relation between aileron deflection and control-stick position with no load on the system is shown in figure 4(a) (aileron tabs locked). The variation of aileron-spring-tab deflection with control-stick position is shown in figure 4(b) (ailerons locked). Figures 4(c) and 4(d) present the variation of aileron-spring-tab deflection with stick force for the left and right tab, respectively. The variation of tab deflection with stick force for the left tab was obtained with the left aileron locked and the right aileron free in order to measure only the resistance of the left tab. The process was then reversed for the right tab. The aileron control system included stops at the stick and stops on the tabs, but there were no stops at the ailerons. In this paper the direction of tab deflection is given with respect to the control surface.

Sketches of the three tail configurations are shown in figure 5(a). The F8F-1 production tail, vertical-tail configuration 1, was equipped with a dorsal fin and the rudder gap was not sealed. The two modified vertical-tail configurations were installed by the Grumman Company. The first modified configuration, hereinafter designated as tail configuration 2, resulted from adding 12 inches to the span of the fin by inserting an extension between the fuselage and the production fin and adding a 2-inch trailing-edge strip, which is shown in figure 5(b), to the rudder and trimming tab. The second modified configuration, hereinafter designated as tail configuration 3, had both the fin and rudder span extended 12 inches. The 2-inch trailing-edge strip was retained only on the trimming tab. Tail configurations 2 and 3 did not include a dorsal fin, but had the rudder gap sealed.

The rudder control system of F8F-1 airplane 94873 included a spring on the left rudder cable which had been installed to reduce the tendency of the rudder forces to lighten in right sideslip with tail configurations 2 and 3. The pedal-force gradient produced by the spring, which is illustrated in figure 6, was approximately 2.6 pounds per degree of left rudder deflection.

INSTRUMENTATION

The following instruments were mounted in the airplane:

Measured quantity	NACA instrument
Time	Timer (synchronizing all records)
Airspeed	Airspeed recorder and sensitive indicator
Control positions	Control-position recorders
Control forces	Strain-gage pedal-force and stick-force recorders
Sideslip angle	Sideslip-angle recorder and indicator
Normal, longitudinal, and transverse accelerations (and angle of bank)	Three-component recording accelerometer, sensitive normal accelerometer, and indicating normal accelerometer
Angular velocities	Gyroscopic rolling, pitching, and yawing velocity recorders
Flap position	Position recorder
Free-air temperature	Electrical resistance-bulb type thermometer

Airspeed was measured with a swiveling static head, mounted 1 chord length ahead of and slightly below the right wing tip, and a shielded total head tube also mounted ahead of the wing tip. The standard airspeed indicator was replaced with a sensitive meter which was connected to the NACA airspeed installation to enable the pilot to hold constant speed during maneuvers in which the angle of sideslip varied. The airspeed system was calibrated for position error with a trailing airspeed head.

Calibrated airspeed as used herein corresponds to the reading of a standard A-N airspeed meter connected to a pitot-static system that is free from position error and is defined by the formula

$$V_c = 45.08\, f_o \sqrt{q_c}$$

where

V_c in miles per hour

q_c difference between total pressure and correct static pressure in inches of water

f_o compressibility correction factor at sea level

Control positions were measured with both mechanical and electrical recorders. Transmitting elements of electrical recorders were mounted on the control surfaces, aileron tabs, and the wing flaps. A mechanical control-position recorder was connected into the rudder and the elevator system near the control stick. A chain attached to the control stick to make it possible for the pilot to hold constant stick deflection also served as a check on the aileron-control-position recorder.

In order to measure control forces the service stick was replaced with one of the same length, approximately 16.5 inches from hinge line to the center of the grip, which contained a strain-gage installation for stick-force measurement. The rudder pedals were modified to accommodate a strain-gage installation.

TESTS, RESULTS, AND DISCUSSION

The results of the tests are evaluated in terms of reference 1.

DYNAMIC LATERAL AND DIRECTIONAL STABILITY

Control-free lateral oscillations were made to determine the effect of speed, altitude, of the belly tank, and vertical-tail configuration. These tests were made in the clean condition with power for level flight either by abrupt deflection and freeing of the rudder or by releasing the controls in steady sideslips. Figures 7 and 8 present time histories of typical oscillations of each type. Summary plots which show the period of the lateral oscillations and the number of cycles required to damp to one-half amplitude as a function of speed are shown in figure 9.

The data of figure 9 show that in all cases the oscillation damped to one-half amplitude in well under 1 cycle. The tests showed that the belly tank had little effect on the damping of the lateral oscillations. The damping was increased by decreasing speed or altitude and by the increased size of vertical-tail configuration 3.

The period of the lateral oscillation was decreased noticeably with tail configuration 3. The effects of altitude or of the belly tank on the period were small. Shown in figure 9, the period ranged from approximately 2 seconds at 350 miles per hour to 4.5 seconds at 150 miles per hour.

Although the damping of the lateral oscillation satisfied the requirements of reference 1, a persistent small-amplitude oscillation of higher frequency, which was annoying to the pilot, often occurred even in smooth air. Time histories of such oscillations are presented in figure 10. The oscillation shown in figure 10(a) was induced by a rudder kick and was obtained with an empty belly tank installed and with the fuselage tank approximately half full (at a speed of 250 miles per hour). In some cases the oscillation was noted mainly in terms of lateral acceleration (fig. 10(a)) and in other cases the oscillation occurred in the three measured components of acceleration (fig. 10(b))

Variations of propeller pitch and fuel sloshing were considered as possible causes of the oscillation. The first possibility was eliminated by obtaining the oscillation with the propeller set against the low-pitch stops. It was then found that the oscillation could be induced by a maneuver such as an abrupt turn entry. During the oscillation there was a fluctuation of the fuel gage which led to the conclusion that the oscillation was due to fuel sloshing.

The data of figures 7 and 8 show that there was no tendency for the rudder itself to oscillate. The tendency of the spring-tab ailerons to oscillate was investigated by abruptly deflecting and freeing the ailerons. Time histories of the maneuver are presented in figure 11. Oscillation of the ailerons was completely damped in $1\frac{1}{2}$ cycles which satisfies the requirements of reference 1.

STATIC LATERAL AND DIRECTIONAL STABILITY

Sideslip Due to Deflection of Ailerons; Rudder to Overcome Adverse Aileron Yaw

The sideslip due to deflection of the ailerons with rudder fixed and the rudder required to overcome adverse aileron yaw were measured in rolls out of 45° banked turns. Figure 12 contains time histories of rolls out of turns which were made by applying approximately two-thirds aileron deflection at 5000 feet in the clean condition with belly tank off using power for level flight at 135 miles per hour. In these rolls the pilot attempted to coordinate the rudder and ailerons to maintain zero sideslip. Similar roll-outs made with full aileron and rudder deflection showed that there was a little more than sufficient rudder control to overcome the yawing moment due to ailerons. The rudder control force did not exceed 180 pounds during these maneuvers.

The maximum change in sideslip angle, which was measured with the belly tank installed and with no belly tank in rudder-fixed roll-outs at 135 miles per hour, is plotted in figure 13 as a function of the change in total aileron angle. The effect of the belly tank on the amount of sideslip obtained was small. Figure 13 also presents data which show a reduction in sideslip angle of approximately 15 percent with the enlarged vertical tail of configuration 2 or 3. Comparison of the data of figure 13 with the requirements of reference 1 indicates a lack of directional stability at moderate sideslip angles with the present aileron system. The deficiency in directional stability would become considerably greater if the aileron control system was modified to provide a maximum rolling effectiveness $pb/2V$ of 0.09, the value required by reference 1.

Rudder-fixed rolls out of 3g turns at an indicated airspeed of 290 miles per hour at 5000 feet were made in the rated power, clean condition with tail configuration 1. The data obtained are plotted in figure 14. In these maneuvers the pilot attempted to maintain a constant acceleration as the airplane rolled. The pitching moments caused by sideslip and by yawing velocity during the roll made it difficult for the pilot to maintain exactly constant acceleration, and as a result the data obtained show some scatter. Figure 14(a) contains a plot of the change in sideslip angle as a function of the change in total aileron angle. In figure 14(b) the same data are plotted in another form as the variation of $\Delta\beta/C_N$, the change in sideslip angle divided by the normal-force coefficient, with $pb/2V$. Plotting in this form makes possible a comparison of the directional stability of different airplanes without regard to the effect of normal-force coefficient on the change in sideslip angle or to relative aileron size.

The data were obtained in rolls out of 3g turns rather than in rolls out of more highly accelerated turns in order to limit the sideslip angles obtained to safe values. It should be noted, however, that the yawing moments acting on the airplane will increase in proportion to the lift coefficient and as a result larger sideslip angles could be obtained in rolls out of turns at high accelerations. The yawing moments also increase in proportion to $pb/2V$. If the aileron power were increased to provide a value of $pb/2V$ of 0.09, the maximum sideslip angle would also be increased. Extrapolation of the available data on the assumption that the yawing moment varied linearly with sideslip angle indicates that a sideslip angle of 40° would result in a roll at 290 miles per hour from a 6g turn with a $pb/2V$ of 0.09. Actually, the directional stability probably increases at such large sideslip angles and the resultant angle of sideslip would be somewhat less than 40°. It appears, however, that the directional stability of the XF8F-1 airplane with tail configuration 1 is inadequate to limit the sideslip angles in rolling maneuvers to reasonable values.

All measurements of directional stability with tail configurations 2 and 3 were made with a belly tank installed, and therefore no accelerated maneuvers were performed. The directional stability in accelerated rolling maneuvers would be considerably improved with tail configurations 2 and 3 but not enough to eliminate the possibility of overloading the vertical tail. Modification to improve the lateral control system would increase the possibility of overloading the tail.

Sideslip Characteristics

The sideslip characteristics were investigated in steady sideslips with all three vertical-tail configurations. Tests were made with tail configuration 1 with and without the belly tank at an altitude of 5000 feet. Tests were also made at 300 miles per hour in the rated power, clean condition at an altitude of 20,000 feet with tail configuration 1 with the belly tank installed. Measurements of steady sideslip characteristics were made at 5000 feet with belly tank installed with tail configurations 2 and 3. The test conditions and speeds were as follows:

Condition	Power setting	Position of					Approximate speed (mph)	Tail configuration
		Flaps	Landing gear	Canopy	Cowl flaps	Oil cooler		
Rated power, clean	41 in. Hg, 2600 rpm	Up	Up	Closed	Closed	Open	150	[a]1, 2, 3
						Closed	245	1, 2, 3
						Closed	345	1, 2, 3
						Closed	395	1
Gliding	Idling	Up	Up	Closed		Closed	150	1
						Closed	245	1
Power approach	Approximately 20 in. Hg, 2300 rpm	Down	Down	Open		Open	90	1, 2, 3
						Closed	150	1, 2, 3
Landing	Idling	Down	Down	Open		Closed	105	1
						Closed	150	1

[a]Tests with configuration 1 were both with belly tank installed and off and tests with configurations 2 and 3 were with belly tank installed.

The sideslip data which gave measurements of directional stability (variation of rudder angle and force with sideslip angle), dihedral effect (variation of aileron angle and force with sideslip angle), pitching moment due to sideslip (variation of elevator angle and force with sideslip angle), and the side-force characteristics (variation of angle of bank with angle of sideslip) are shown in figures 15 to 22 for tail configuration 1.

The results of the tests with tail configuration 1 will be discussed first.

Directional stability.- The curves of rudder position against sideslip angle indicate that without the belly tank the rudder-fixed directional stability was always positive, but was low at small angles of sideslip. In the rated-power, clean condition near zero sideslip the values of the variation of rudder angle with sideslip $d\delta_r/d\beta$ increased from about 0.15 at 150 miles per hour to 0.5 at 250 miles per hour and decreased to 0.35 at 400 miles per hour. The variation of rudder force with sideslip angle indicated that there was a very slight degree of rudder-free directional stability in left sideslips at 150 miles per hour. At higher speeds the variation of rudder force with angle of sideslip was stable but relatively small.

Addition of the belly tank reduced the directional stability in all conditions so that the value of $d\delta_r/d\beta$ in the rated-power, clean condition increased from 0.10 at small angles of left sideslip at 150 miles per hour to about 0.35 at 350 miles per hour and decreased to 0.25 at 395 miles per hour. The rudder-free directional stability was neutral in left sideslips up to 20° at 150 miles per hour. At higher speeds the variation of rudder force with sideslip angle was small in comparison with that of other fighter-type airplanes previously tested. For example, the sideslip obtained per pound of pedal force was almost three times that obtained with the F6F-3 airplane at 300 miles per hour.

As a general rule, decreasing the power or lowering the flaps increased the directional stability. The effect of altitude on the directional stability was determined by comparison of the data of figure 22 which were obtained at an altitude of 20,000 with those of figures 16(b) and 16(c) for an altitude of 5000 feet. The comparison showed that $d\delta_r/d\beta$ for small angles of sideslip was reduced from approximately 0.25 at 5000 feet to 0.1 at 20,000 feet (300 mph, tank on).

Dihedral effect.- The effective dihedral was positive control-fixed in all test conditions with or without the belly tank. There was a slight increase in effective dihedral due to the belly tank. The control-free effective dihedral was positive in all test conditions except at 90 miles per hour in the power-approach condition. In that condition the control-free effective dihedral was neutral with the belly tank off and very slightly positive with the belly tank on.

Pitching moment due to sideslip.- The variation of elevator position with angle of sideslip was usually not large. The variation of elevator force with angle of sideslip is not presented in all cases because the elevator-force recorder used during the tests of tail configuration 1 was found to be unreliable. However the data obtained with tail configuration 2 (fig. 23) indicate that a fairly large pull force was required to maintain longitudinal trim in sideslips. This effect was greatest in right sideslips.

Side-force characteristics.- The variation of angle of bank with angle of sideslip, which is a measure of the side-force characteristics, is presented in figures 15 to 21. The requirement that the direction of bank should always be the same as the direction of sideslip was satisfied in all flight conditions at all speeds.

Effect of sideslip on flap deflection.- The landing flaps on the F8F-1 airplane were spring-loaded to permit them to blow up as the airspeed increased and thus to prevent overloading. Figure 24 presents data obtained during the sideslip tests which show the variation of flap deflection with angle of sideslip for two power settings at 150 miles per hour.

Sideslip Characteristics with Three Tail Configurations

The following discussion will be in the form of a comparison of the directional stability of the airplane with the three vertical-tail configurations described earlier in the report.

Figures 25 and 26 present a comparison of the directional stability characteristics with the three vertical-tail configurations with the belly tank installed. The data of figures 25 and 26 indicate that either vertical-tail configuration 2 or configuration 3 improved the directional stability at small sideslip angles where there had been a deficiency with tail configuration 1. In the rated-power, clean condition at 150 miles per hour (fig. 25(a)) where the control-free directional stability in left sideslips had been zero with tail configuration 1, there was definite positive control-free stability with either tail configuration 2 or 3.

Comparison of the curves of rudder force and position against angle of sideslip in figures 25 and 26 shows that tail configurations 2 and 3 produced increases in directional stability. The following table presents the values of the directional-stability parameters, $d\delta_r/d\beta$, the rate of change of rudder position with angle of sideslip, and $dF_r/d\beta$, the rate of change of rudder control force with angle of sideslip, measured between 0° and 5° with the three vertical tails in two flight conditions with belly tank installed at several speeds. The minimum slopes usually occurred between 0° and 5° left sideslip.

Condition	Airspeed	$d\delta_r/d\beta$			$dF_r/d\beta$ (lb/deg)		
		Tail 1	Tail 2	Tail 3	Tail 1	Tail 2	Tail 3
Rated power, clean (41 in. Hg at 2600 rpm)	150	0.1	0.3	0.2	0	1.3	2.0
	250	0.15	0.5	0.4	2.3	3.7	3.7
	350	0.35	0.7	0.5	3	7.3	10
Power approach (18 in. Hg at 2300 rpm)	95	0.4	0.9	0.6	2.7	4.3	2.0
	150	0.6	0.9	0.6	2.7	4.8	4.5

In right sideslips of about 15°, there was a tendency toward rudder overbalance with tail configurations 2 and 3 at low speeds. This tendency was counteracted somewhat by the spring in the left rudder cable so that no overbalance occurred in the range of angles of sideslip covered by the data presented in figures 25 and 26. However, a small amount of rudder overbalance has been measured with tail configuration 3 when there was a small yawing velocity at angles of sideslip from 20° to 35° right in the power-approach condition at low speeds. A time history of such data is presented in figure 27. The tendency toward rudder-force reversal was hardly noticeable with tail configuration 1 which had a dorsal fin. It is believed that retention of the original dorsal fin on tail configurations 2 and 3 would have greatly reduced the tendency toward rudder-force reversal.

LATERAL AND DIRECTIONAL CONTROL

Rudder to Overcome Adverse Aileron Yaw

The ability of the rudder to overcome the yawing moment due to full aileron deflection with a control-force increment of less than 180 pounds has been discussed in the section on sideslip due to aileron deflection.

Rudder Control in Take-Off and Landing

No take-offs or landings were recorded in a 90° cross wind. Figures 28 to 30 present time histories of take-offs made with tail configurations 1 and 3 and a landing made with tail configuration 1. No indication of a lack of directional control or of excessive rudder forces was obtained.

Inadequate directional control in the wave-off condition has been reported. The tests showed that approximately 90 percent of the available rudder deflection was required for trim in level flight near the stalling speed in the wave-off condition with power for level flight with tail configurations 1 or 2. It was found that with tail configuration 3 there was sufficient rudder control to sideslip 20° to the left at 85 miles per hour in the wave-off condition at rated power. This amount of sideslip was 10° more than that required for trim with wings level and would provide a reserve of control for use in a wave-off.

Directional Control in Straight Flight and in Strafing Runs

Figures 31 and 32 present the variation of directional trim characteristics over the test speed ranges in the rated-power clean, and the wave-off conditions for all three tail configurations. The change of rudder force with speed between the stall and a speed of 400 miles per hour in the rated-power clean condition for a trim speed of 250 miles per hour was approximately 60 pounds with tail configuration 1 (calculated from the data of fig. 31), 160 pounds with tail configuration 2, and 110 pounds with tail configuration 3. The rudder-force change with speed satisfied the Navy requirement for diving flight. However, a desirable reduction in the force variation with speed could be effected by use of a springy tab.

In order to investigate how well the F8F-1 could hold an aiming point, strafing runs on fixed targets have been made. Two time histories typical of the data obtained are presented in figure 33. Figure 33(a) illustrates a strafing run which was made by a service pilot in an F8F-1 airplane with belly tank installed and with tail configuration 1.

In later tests a gun camera synchronized with the other recording instruments was used to obtain a record of relative motion between the aiming point and the target. Figure 33(b) illustrates a strafing run which was made by an NACA pilot in an F8F-1 airplane with belly tank installed and with tail configuration 3. The gun camera and sideslip data of figure 33 show that throughout the range of speeds covered (250 to 400 miles per hour) the airplane was subject to pitching and yawing motions of approximately $\pm 0.2^{\circ}$ amplitude.

Power of Rudder Trimming Tab

Data on the variation of rudder-tab angle for trim with airspeed are presented in figure 34. A table of minimum directional trim speeds for the various tail configurations follows:

Condition	Approximate stalling speed	Approximate minimum directional trim speed (mph)			Tab setting	
	Calibrated (mph)	Configuration 1 original tail	Configuration 2 tall fin, wide rudder and tab	Configuration 3 tall fin and rudder, wide tab	Indicator	Degree from rudder
Gliding	105	---------	-----------	106	7.2° nose left	16.4 right
Normal rated power clean	90	140	130	129	Full nose right	17.2 left
Landing	90	90	-----------	128	Full nose left	17.8 right
Power approach	-----	100	92	94	Full nose right	17.2 left
Wave-off	75	---------	120	111	Full nose right	17.2 left

The requirement of reference 1 that the rudder trimming tab should be capable of reducing the rudder-pedal force to zero in the gliding and rated-power, clean conditions at 120 percent of the stalling speeda was not satisfied, but with tail configuration 3 the minimum trim speeds in the power-on conditions were reduced about 10 miles per hour from those with tail configuration 1.

Aileron Control Characteristics

The aileron control characteristics were measured in rudder-fixed abrupt aileron rolls at various speeds in the following flight conditions. The figures which present the data obtained in the various conditions are also listed.

Power	Flaps	Landing gear	Average speed	Figure
Level flight	Up	Up	148	36(a)
			196	36(a)
			245	36(a)
			294	36(a)
			343	35,36(a)
			397	36(a)
	Down	Down	87	36(b)
			136	36(b)

Figure 35 presents time histories of typical aileron rolls obtained at 340 miles per hour in the rated-power, clean condition. The variation of rolling effectiveness and control force with total aileron deflection are presented in figure 36 for each flight condition and speed investigated. Figure 37 shows the variation of right-aileron spring-tab angle with right-aileron deflection in aileron rolls with power for level flight in the clean condition at speeds from 148 to 397 miles per hour. The variation with airspeed of rolling velocity at 10,000 feet, total aileron angle, and helix angle $pb/2V$ for a control force of 30 pounds and for full stick deflection is presented in figure 38. The variation of lateral trim force with speed is given in figure 39.

The aileron control characteristics of the F8F-1 airplane may be summarized as follows:

(a) The control force required and the rolling velocity obtained in abrupt aileron rolls varied smoothly with aileron deflection throughout the speed range.

(b) The ailerons exhibited no undesirable lag characteristics and the rolling accelerations were always in the correct directions.

(c) No reversal of rolling velocity due to adverse aileron yaw ever occurred.

(d) Examination of figure 38 indicates that the aileron effectiveness $pb/2V$ in the clean condition with a control force of not over 30 pounds varied from approximately 0.075 at 150 miles per hour to 0.036 at 400 miles per hour. Due to the large reduction of available aileron deflection with increasing airspeed, the value of $pb/2V$ at 400 miles per hour was approximately 0.046 for full stick deflection. The requirements of reference 1 with regard to aileron effectiveness were not satisfied.

It would be possible, although difficult mechanically, to increase the aileron effectiveness without changing the control-force gradient by reducing the spring constant and the length of the tab horn in the same ratio. As a result of this modification the available aileron deflection would be greater at all speeds.

(e) The maximum value of $pb/2V$ obtained in the landing condition was approximately 0.08.

(f) There was no tendency for the aileron forces to overbalance.

(g) Figure 39 indicates that the variation of aileron trimming force with speed was small. The aileron trimming tab was found to be adequate.

CONCLUSIONS

The results of the tests to determine the lateral and directional stability and control characteristics of F8F-1 airplanes (BuAer Nos. 90461 and 94873) with three vertical-tail configurations may be summarized as follows:

1. The control-free lateral and directional oscillations of the airplane were always damped to half amplitude in less than 1 cycle in all test conditions or configurations. However, there was an annoying, persistent, small-amplitude oscillation of the airplane caused by fuel sloshing. Oscillations of the aileron and rudder were satisfactorily damped.

2. The rudder-fixed directional stability was not great enough to restrict satisfactorily the adverse yaw due to abrupt aileron deflection. The above deficiency was considerably reduced by the enlarged vertical tails of configurations 2 and 3.

3. With tail configuration 1 the rudder-fixed and rudder-free directional stability was low at small angles of sideslip. Addition of the 150-gallon belly tank caused a noticeable reduction in directional stability. The rudder-free directional stability was zero in left sideslips at 150 miles per hour in the rated-power, clean condition with belly tank installed.

The enlarged vertical tails of configurations 2 and 3 increased the directional stability in all flight conditions which were investigated. However, there was a tendency toward rudder overbalance at about 15° right sideslip with tail configurations 2 and 3. It is believed that addition of a dorsal fin similar to the one on tail configuration 1 would eliminate the tendency toward overbalance.

4. The effective dihedral, control fixed and control free, was positive except in the power-approach condition at speeds near the stall where the control-free effective dihedral was neutral.

5. The pitching moment due to sideslip was such that a fairly large pull force was required to maintain longitudinal trim in sideslips. This effect was greatest in right sideslips.

6. The rudder control characteristics were satisfactory for overcoming adverse aileron yaw, for maintaining straight ground paths, and for maintaining straight flight paths with the wings level in all flight conditions at any speed. There was a greater reserve of rudder control available for coordinated turns in the wave-off condition with tail configuration 3 than with the other configurations.

7. The variation of rudder control force for directional trim throughout the test speed range in the rated power, clean condition for a trim speed of 250 miles per hour was about 60 pounds with tail configuration 1, 160 pounds with tail configuration 2, and 110 pounds with tail configuration 3. Although the rudder-force change with speed satisfied the Navy requirements for diving flight, it would be desirable to reduce this variation of force with speed possibly by use of a springy tab. No excessive rudder forces were required during take-off, landing, or the maneuvers covered in these tests. The variation of aileron force with speed was small. The power of the aileron trimming tab was adequate. The rudder triming tab did not meet the low-speed requirements with any of the three tail configurations but was most adequate on tail configuration 3.

8. There usually were small-amplitude ($\pm 0.2^\circ$) pitching and yawing oscillations during strafing runs.

9. The response to abrupt aileron deflection was satisfactory, and the aileron rolling effectiveness $pb/2V$ for full stick deflection ranged from approximately 0.08 at 90 miles per hour to approximately 0.04 at 400 miles per hour. The aileron effectiveness was roughly 20 percent below the required value for maneuvering but was satisfactory for control during landing. Full stick deflection could be obtained with a stick force of not over 30 pounds up to a speed of 250 miles per hour (average for left and right roll). Full stick deflection at 400 miles per hour required a control force of 45 pounds.

10. Of the tail configurations tested, configuration 3 was the most satisfactory and would probably be more so if a dorsal fin were added.

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

Harold L. Crane

Harold L. Crane
Aeronautical Engineer

John P. Reeder

John P. Reeder
Engineer - Test Pilot

Approved: Melvin N. Gough

Melvin N. Gough
Chief of Flight Research Division

bbs

REFERENCE

1. Anon.: Specification for Stability and Control Characteristics of Airplanes. SR-119A, Bur. Aero., April 7, 1945. Restricted

TABLE I

GENERAL SPECIFICATIONS OF THE AIRPLANE

Make and designation	Grumman F8F-1 (BuAer Nos. 94873 and 90461)
Engine	Pratt & Whitney R-2800-34-W double Wasp
Power ratings:	
Take-off	2100 hp at 2800 rpm at sea level
Military	1600 hp at 2800 rpm at 16,000 ft
Normal maximum:	
Low blower	1700 hp at 2600 rpm at 7000 ft
High blower	1450 hp at 2600 rpm at 18,500 ft
Propeller	Hydraulically controlled four-blade constant-speed Aeroprop
Model	A 642 G-1
Blade number	65065
Basic pitch settings, deg	Maximum 63.0, minimum 28.5
Diameter	12 ft 7 in.
Fuel capacity, gal:	
Main tank	175
Droppable (belly)	100 or 150
Droppable (wings)	100
Oil capacity, gal:	
One tank (in engine compartment)	17
War emergency power system fluid, gal:	
One tank (in engine compartment)	16
General:	
Span (wings spread), ft	35.5
Span (wings folded), ft	23.25
Length (over all), ft	27.5
Length (tail wheel on ground), ft	28.25
Height (tail wheel on ground, propeller blade vertical), ft	13.67
Weight for tests (approx.), lb	8,500 to 10,000

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TABLE I - Continued

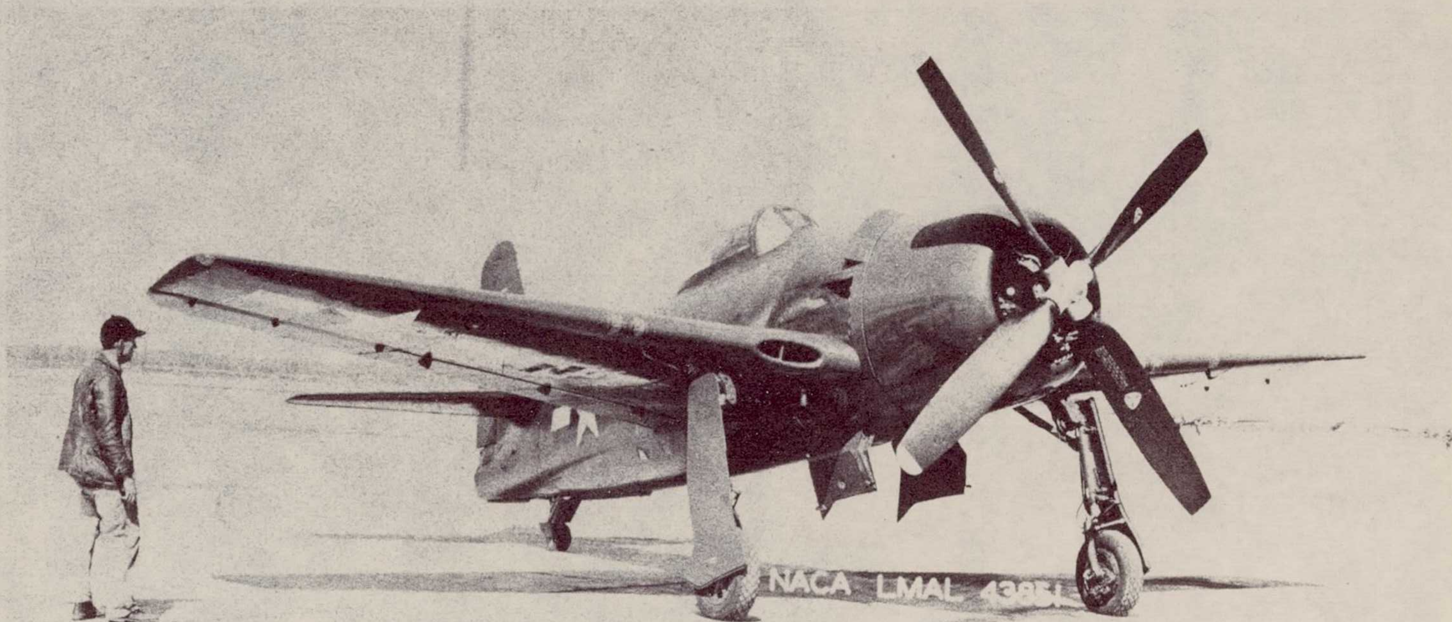
GENERAL SPECIFICATIONS OF THE AIRPLANE - Continued

Wings:	
Area, sq ft	244
Airfoil section:	
Root	Modified 23018
Tip	23009
Mean aerodynamic chord, in.	87.55
Leading edge M.A.C. aft of leading edge of root chord, in.	8.17
Root chord, in.	115.9
Tip chord (6 in. inboard of actual tip), in.	51.5
Incidence, deg	3.0
Dihedral, deg.	5.5
Sweepback of leading edge, deg	5.1
Wing flaps:	
Total area, sq ft	18.18
Deflection, maximum down, deg	40
Ailerons:	
Total area, sq ft	15
Spring-tab area (total), sq ft	1.4
Trimming-tab area, sq ft	0.7
Trimming-tab deflection angle, deg	±5
Horizontal tail:	
Span, in.	189
Total area, sq ft	52.27
Elevator area (including tabs), sq ft	18.63
Elevator-trimming-tab area (total), sq ft	1.0
Elevator-tab range (approx.), deg	8 up 20 down
Tail incidence, deg	0.5
Vertical tail:	
Configuration 1	
Total area, sq ft	17.7
Rudder area, sq ft	6.7
Rudder-tab area	0.6
Fin offset, deg	2.0
Rudder-tab range (approx.), deg	±17
Configuration 2	
Total area, sq ft	21.7
Rudder area, sq ft	6.7
Rudder-tab area, sq ft	0.8
Fin offset, deg	1.5
Rudder-tab range (approx.), deg	±17

TABLE I - Concluded

GENERAL SPECIFICATIONS OF THE AIRPLANE - Concluded

Vertical tail (concluded):
  Configuration 3
    Total area, sq ft 20.7
    Rudder area, sq ft 8.2
    Rudder-tab area, sq ft 0.8
    Fin offset, deg 1.5
    Rudder-tab range (approx.), deg . . . . ±17



(a) Without belly tank.

Figure 1.- Three-quarter front view of Grumman XF8F-1 airplane.

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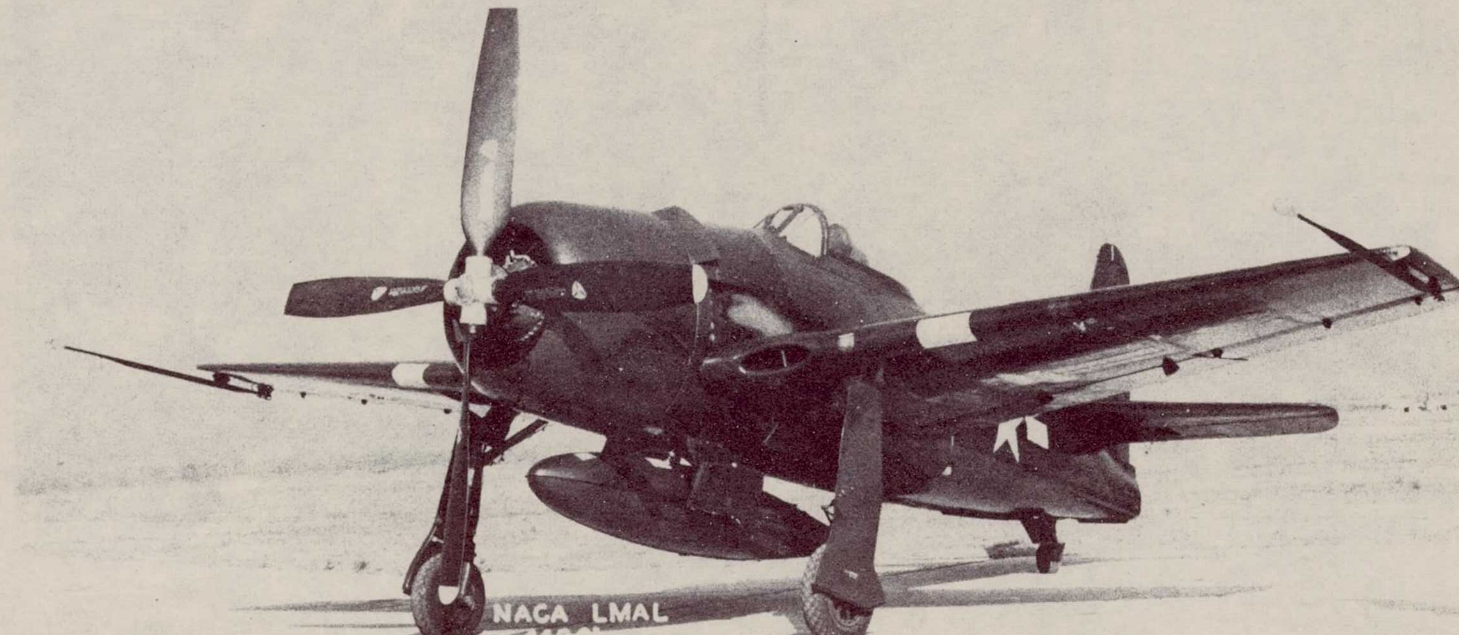
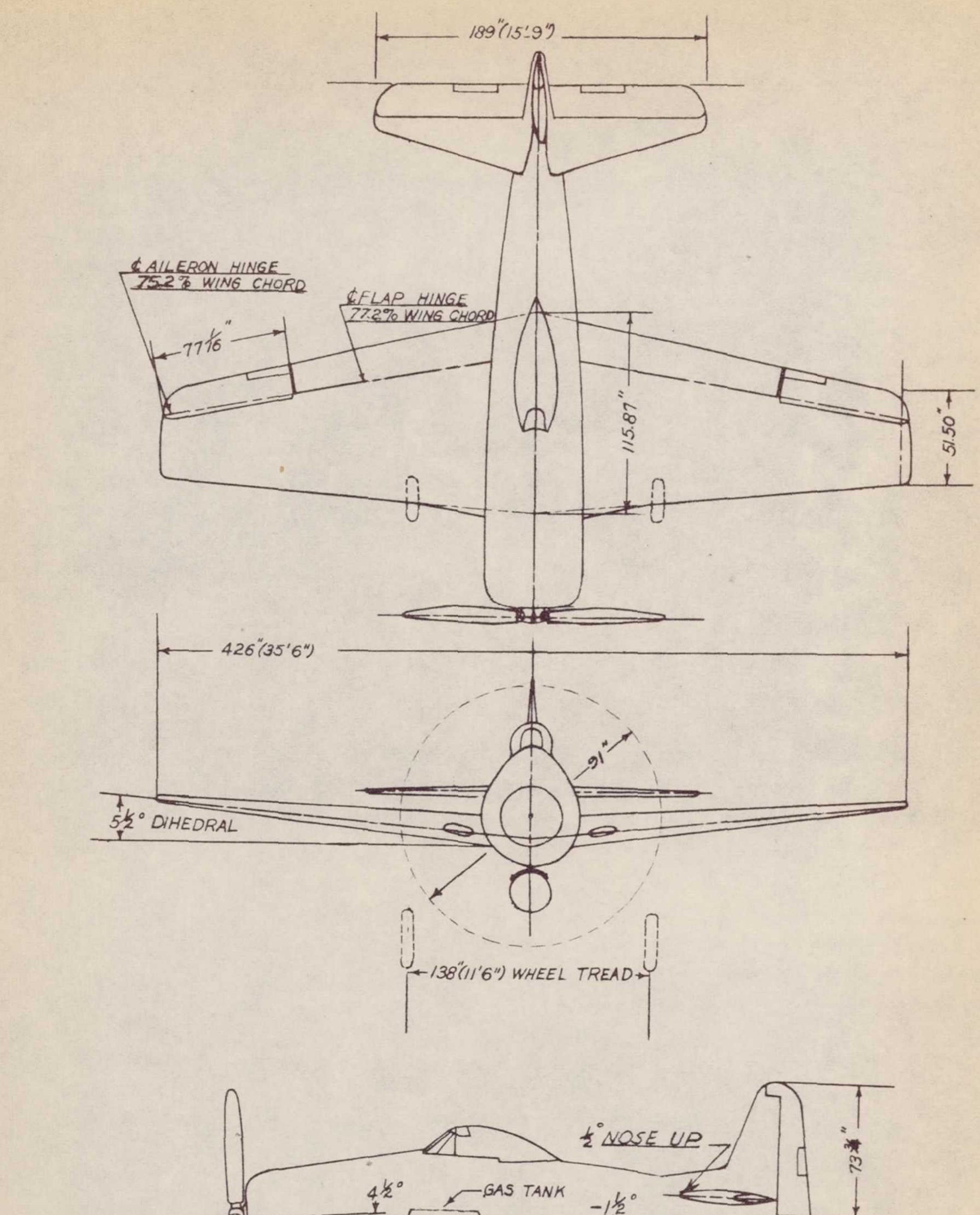


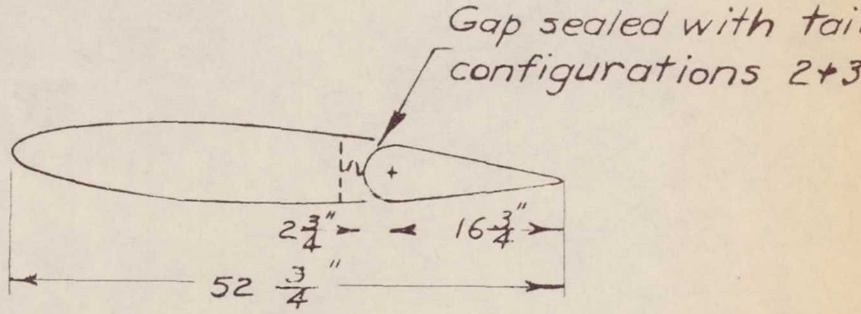
(b) With belly tank.

Figure 1.- Concluded.

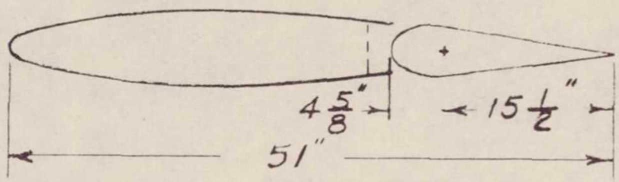


(a) Three-view drawing with tail configuration number 1.

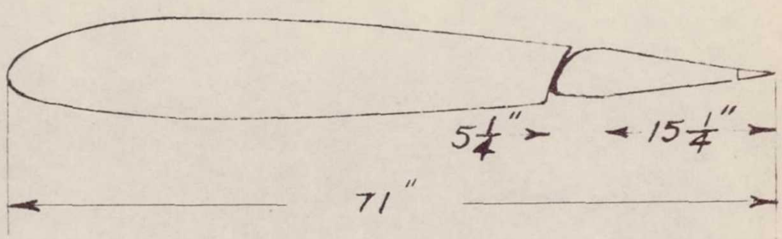
Figure 2.- Drawings of F8F-1 airplane.



Vertical tail, 21 inches above fuselage reference line



Horizontal tail, 15 inches from center line



Wing and aileron, 64 inches from tip.

(b) Section views through aerodynamic surfaces of F8F-1 airplane.

Figure 2.- Concluded.

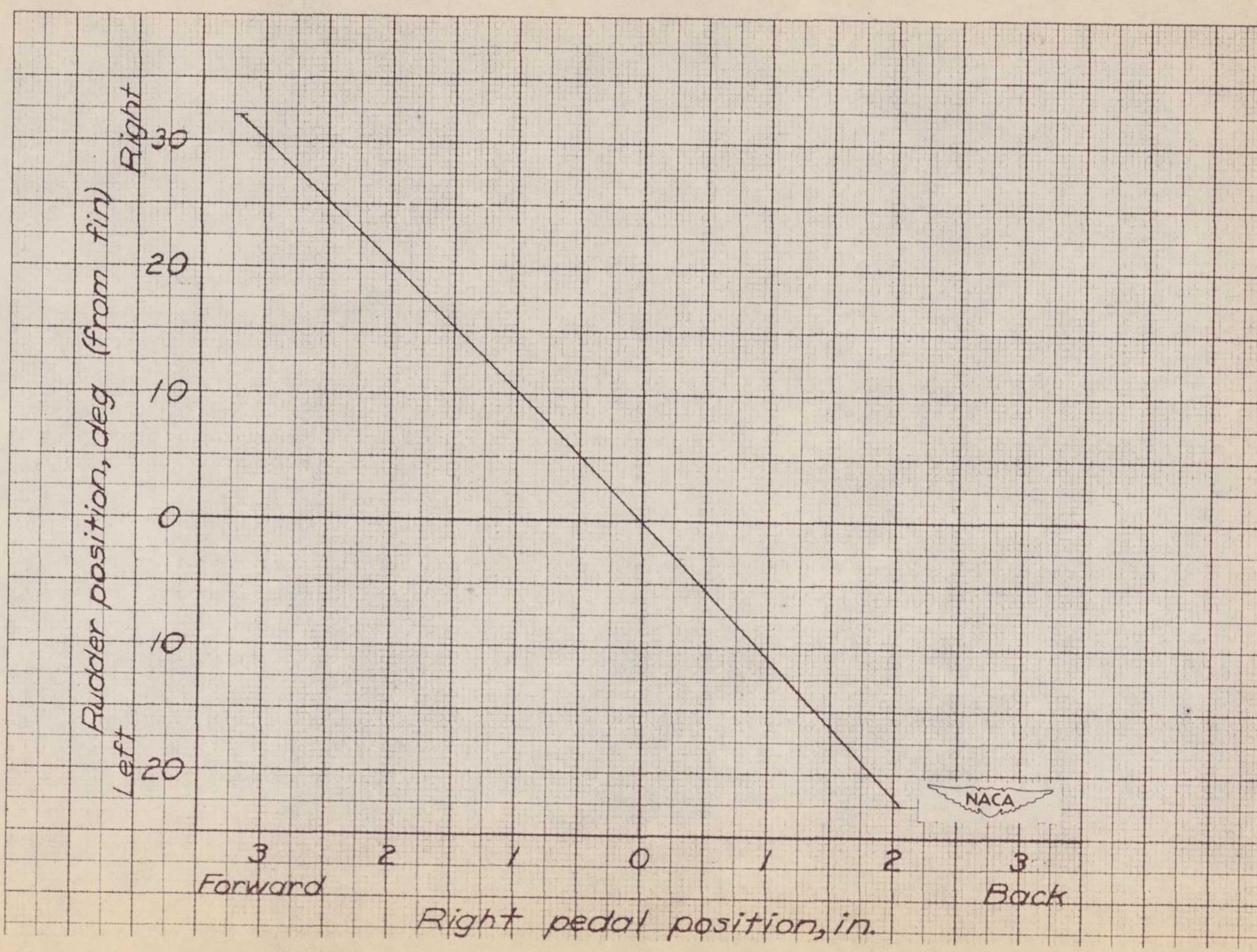
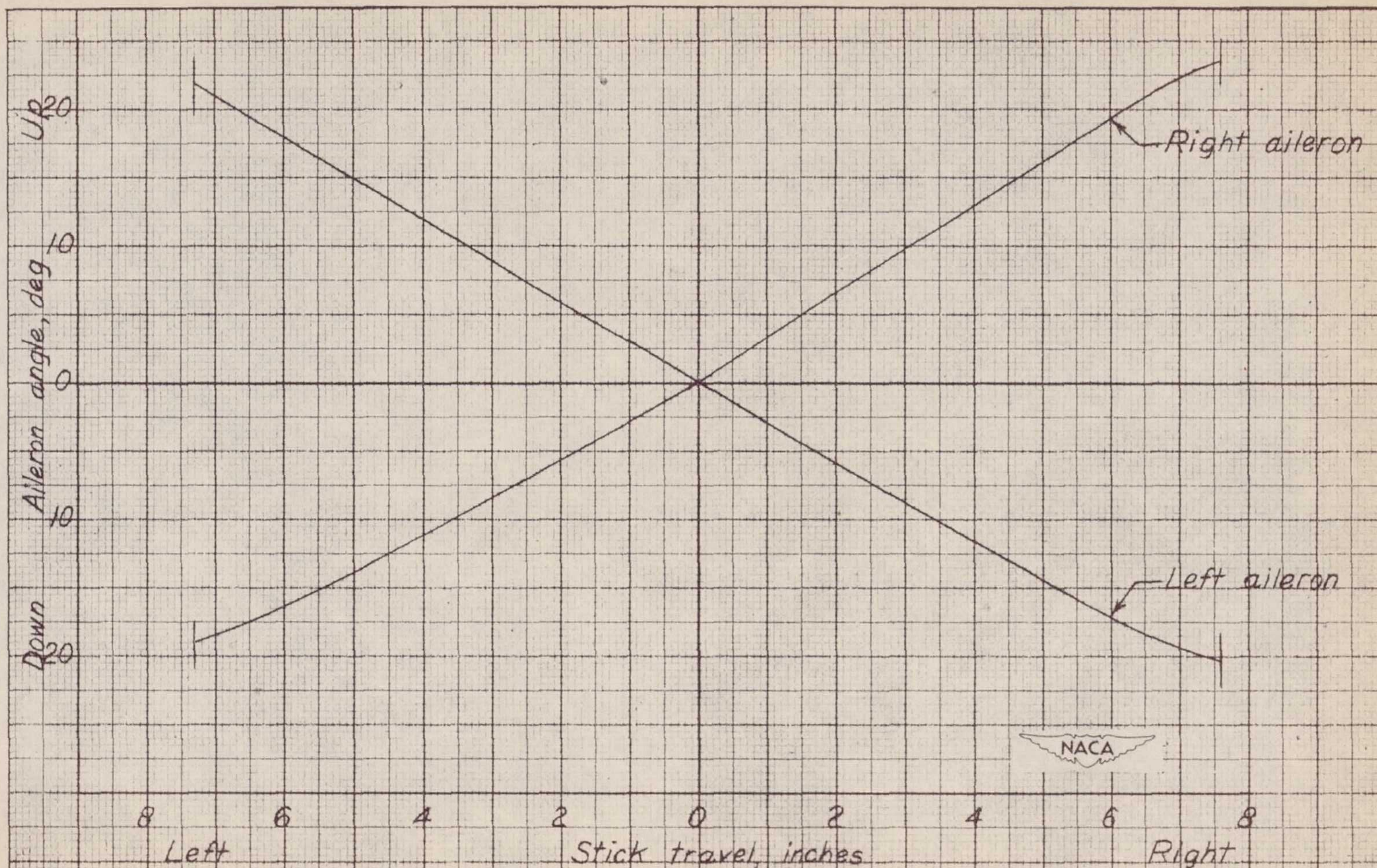
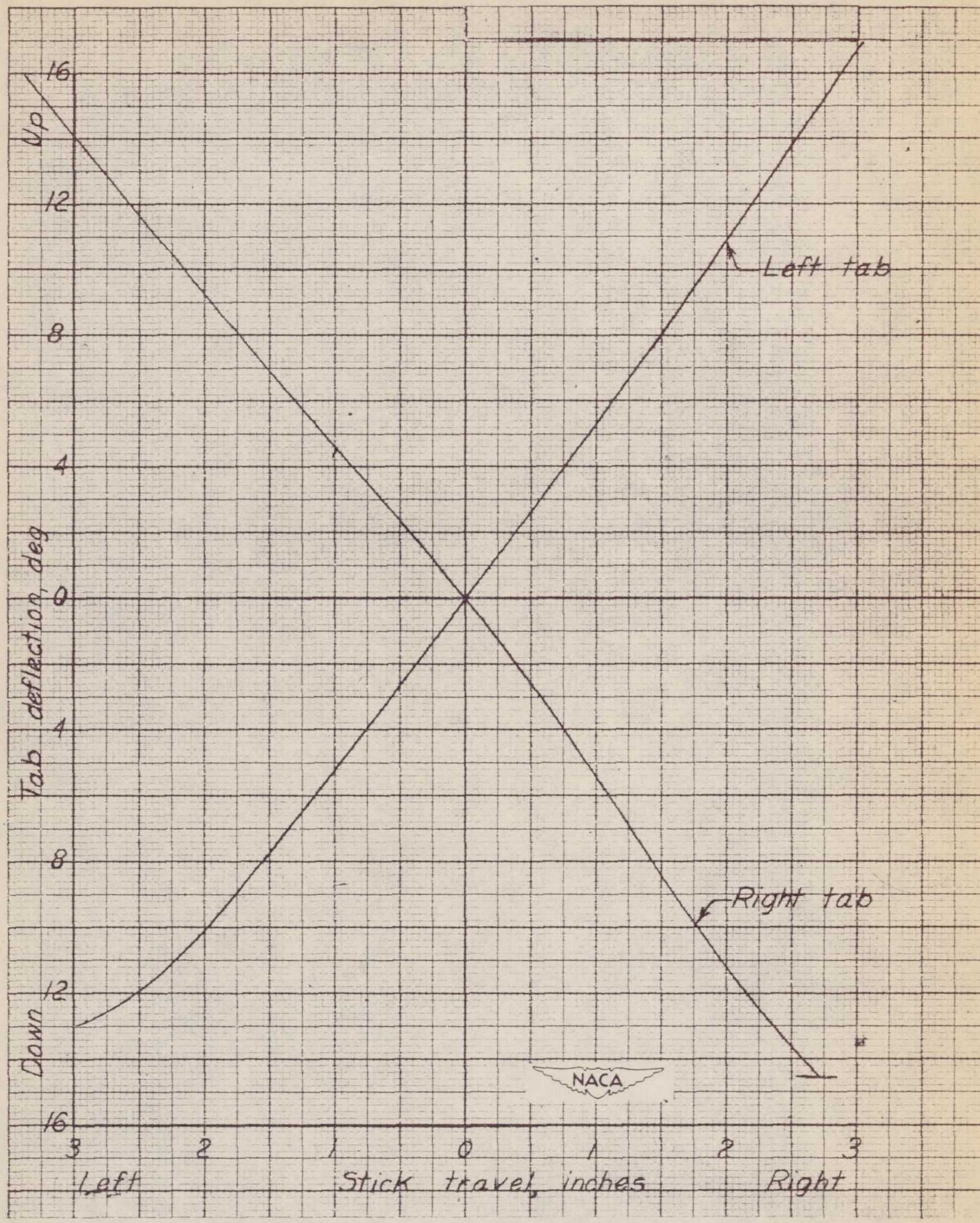


Figure 3.- Linkage between rudder and rudder pedal, F8F-1 airplane.



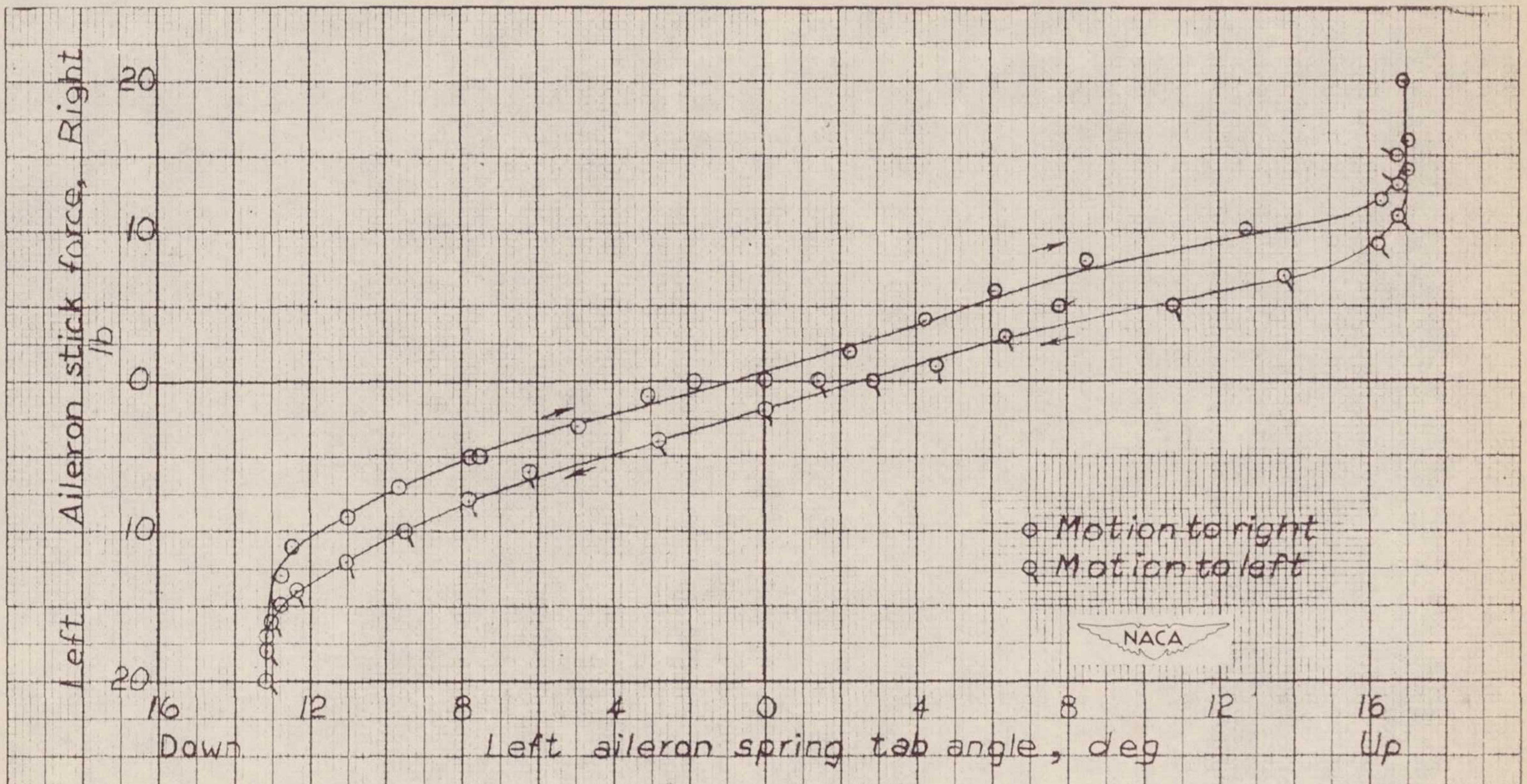
(a) Variation of aileron deflection with stick position (no aerodynamic load).

Figure 4.- Characteristics of the aileron control system of an F8F-1 airplane (Bu. Aero. No. 90461).



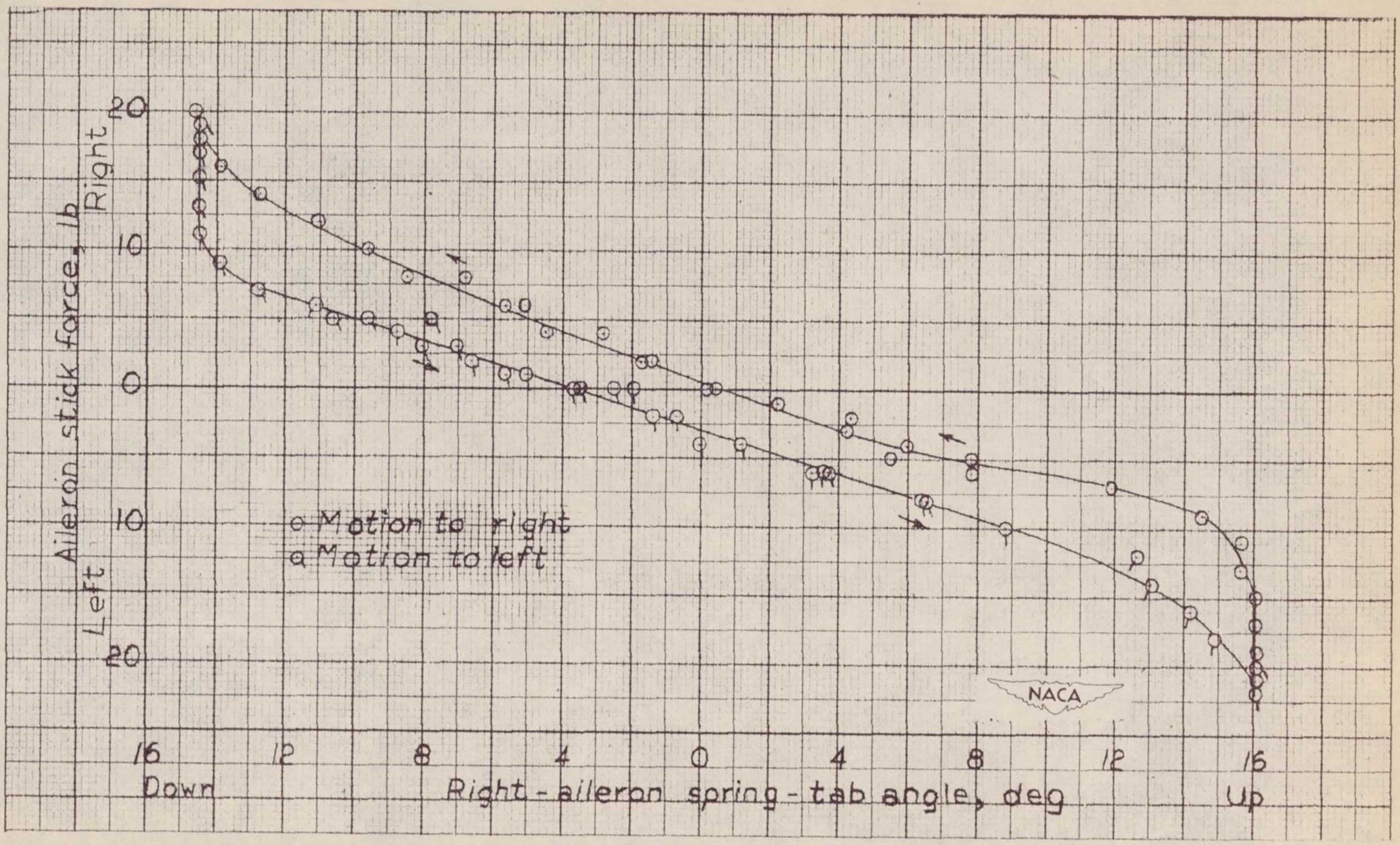
(b) Variation of aileron-spring-tab deflection with stick position with ailerons locked.

Figure 4.- Continued.



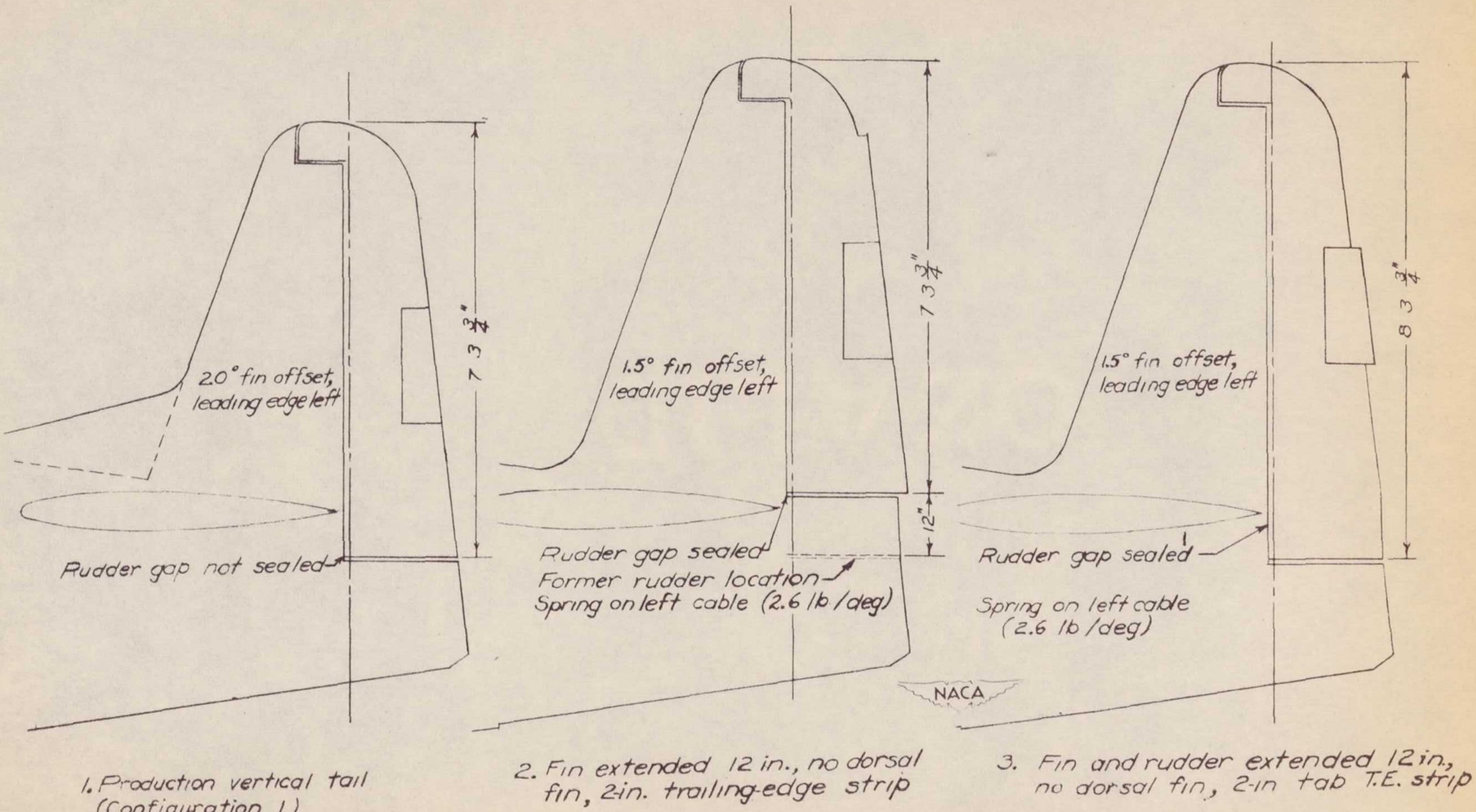
(c) Variation of left aileron-spring-tab deflection with stick force with left aileron fixed.

Figure 4.- Continued.



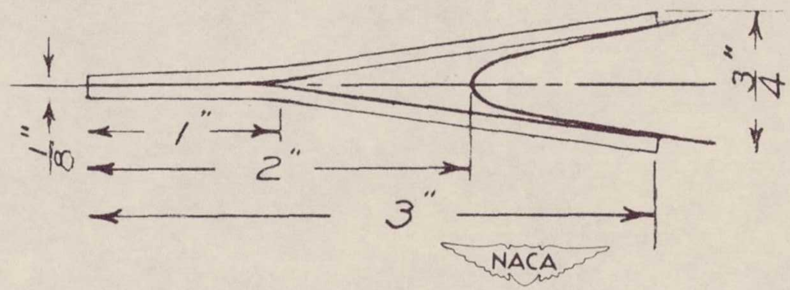
(d) Variation of right aileron-spring-tab deflection with stick force with right aileron fixed.

Figure 4.- Concluded.



(a) Plan view.

Figure 5.- Sketches of the three tail configurations.



(b) Sketch of rudder trailing-edge extension used on tail configuration 2.

Figure 5.- Concluded.

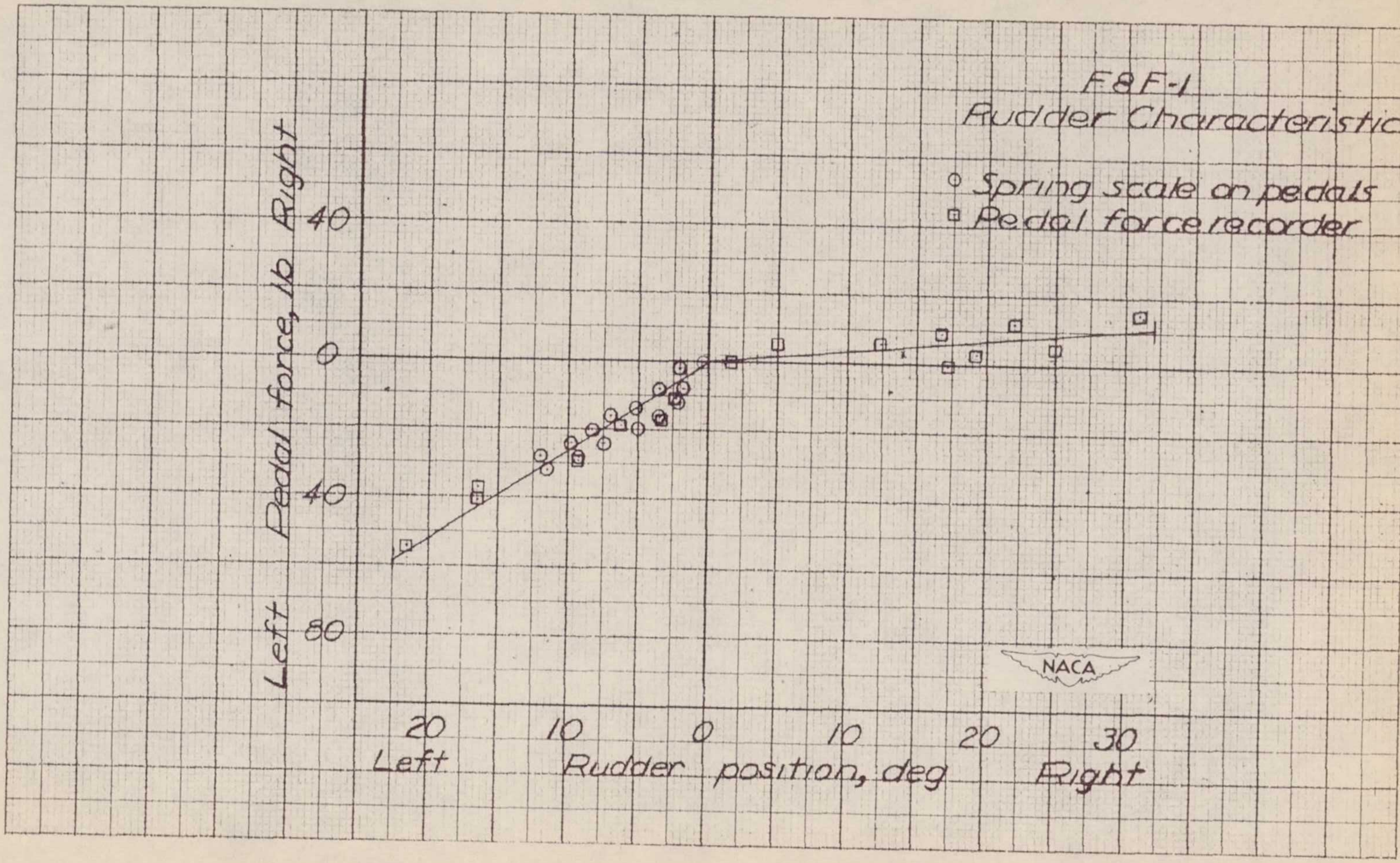


Figure 6.- Variation of rudder pedal force with rudder position, F8F-1 airplane (BuAero No. 94873) with spring on left rudder cable.

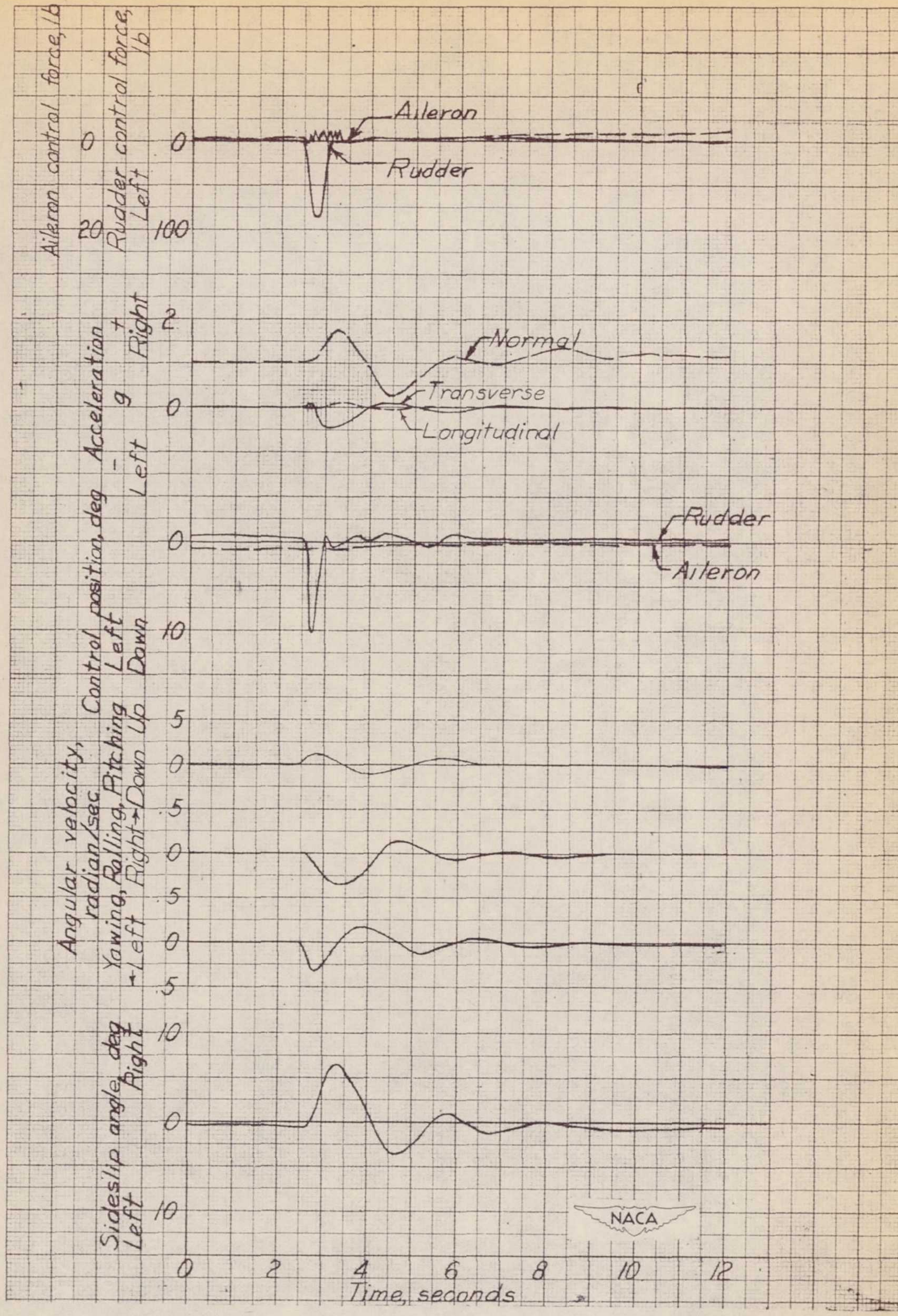
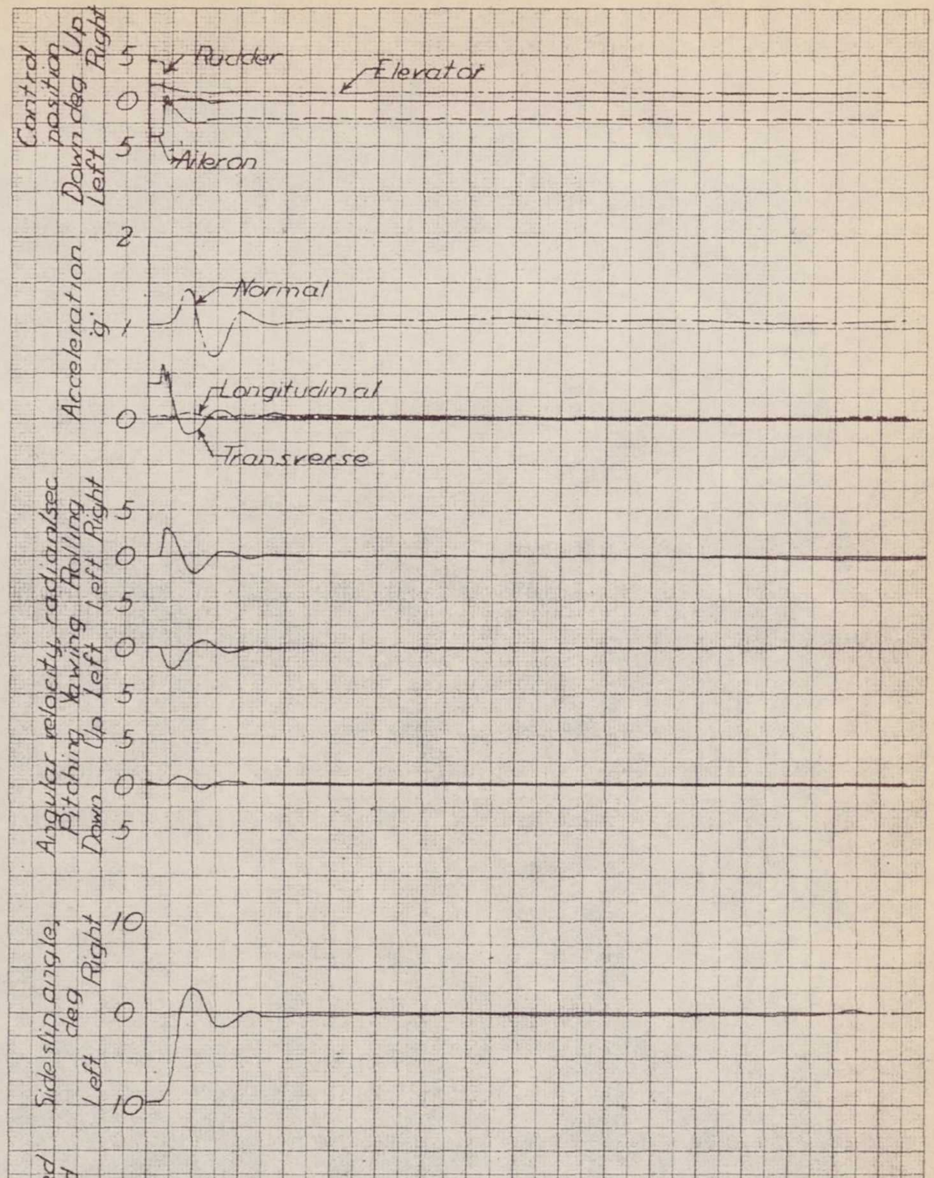
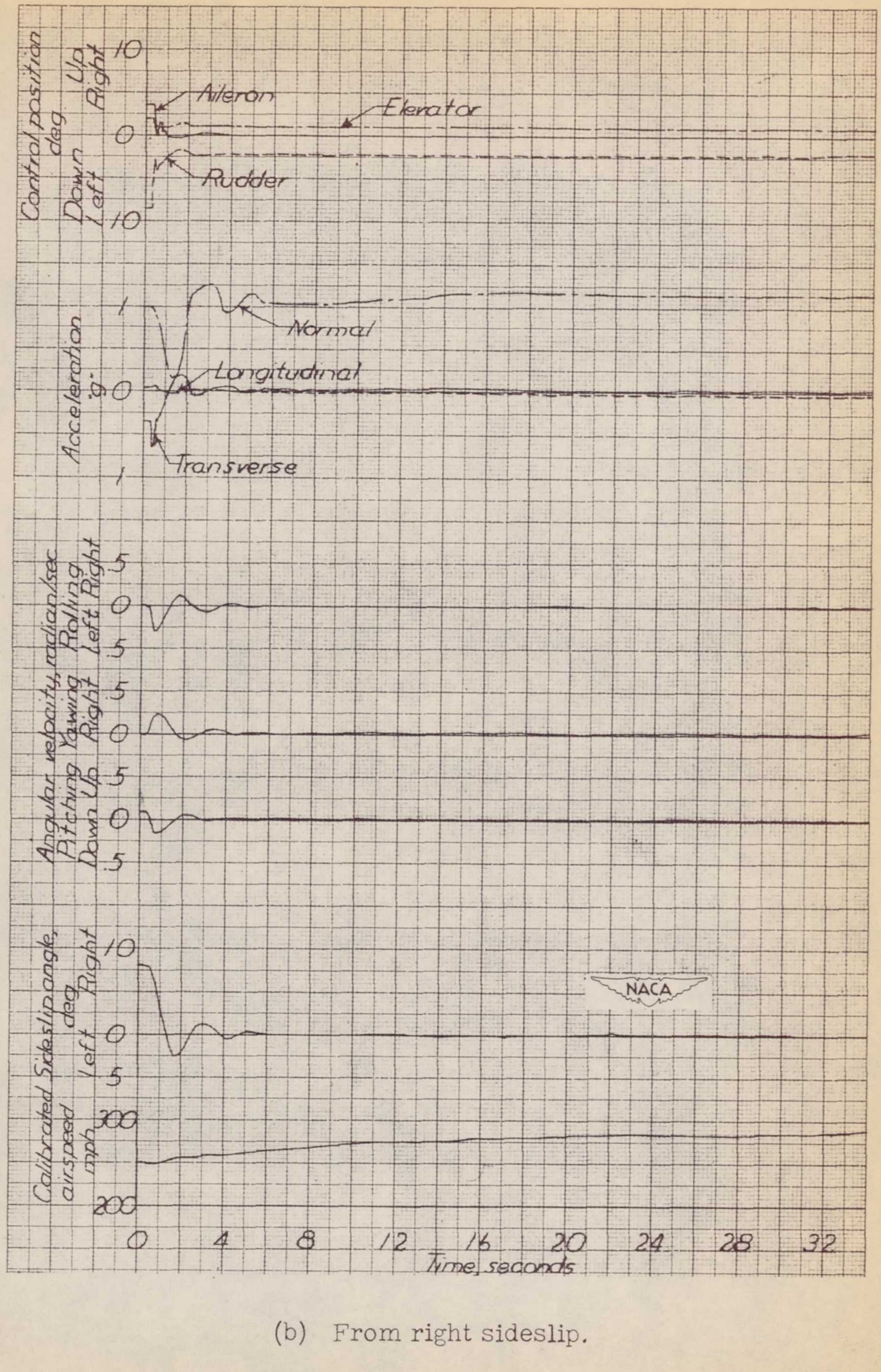


Figure 7.- Oscillations of F8F-1 airplane in the clean condition with power for level flight at 290 miles per hour at an altitude of 5000 feet, caused by a left rudder kick and release. (Tail configuration 1, belly tank off.)



(a) From left sideslip.

Figure 8.- Oscillations of F8F-1 airplane in the clean condition with power for level flight at 250 miles per hour at an altitude of 5000 feet caused by releasing the controls in steady sideslips. (Tail configuration 3 with belly tank on.)



(b) From right sideslip.

Figure 8.- Concluded.

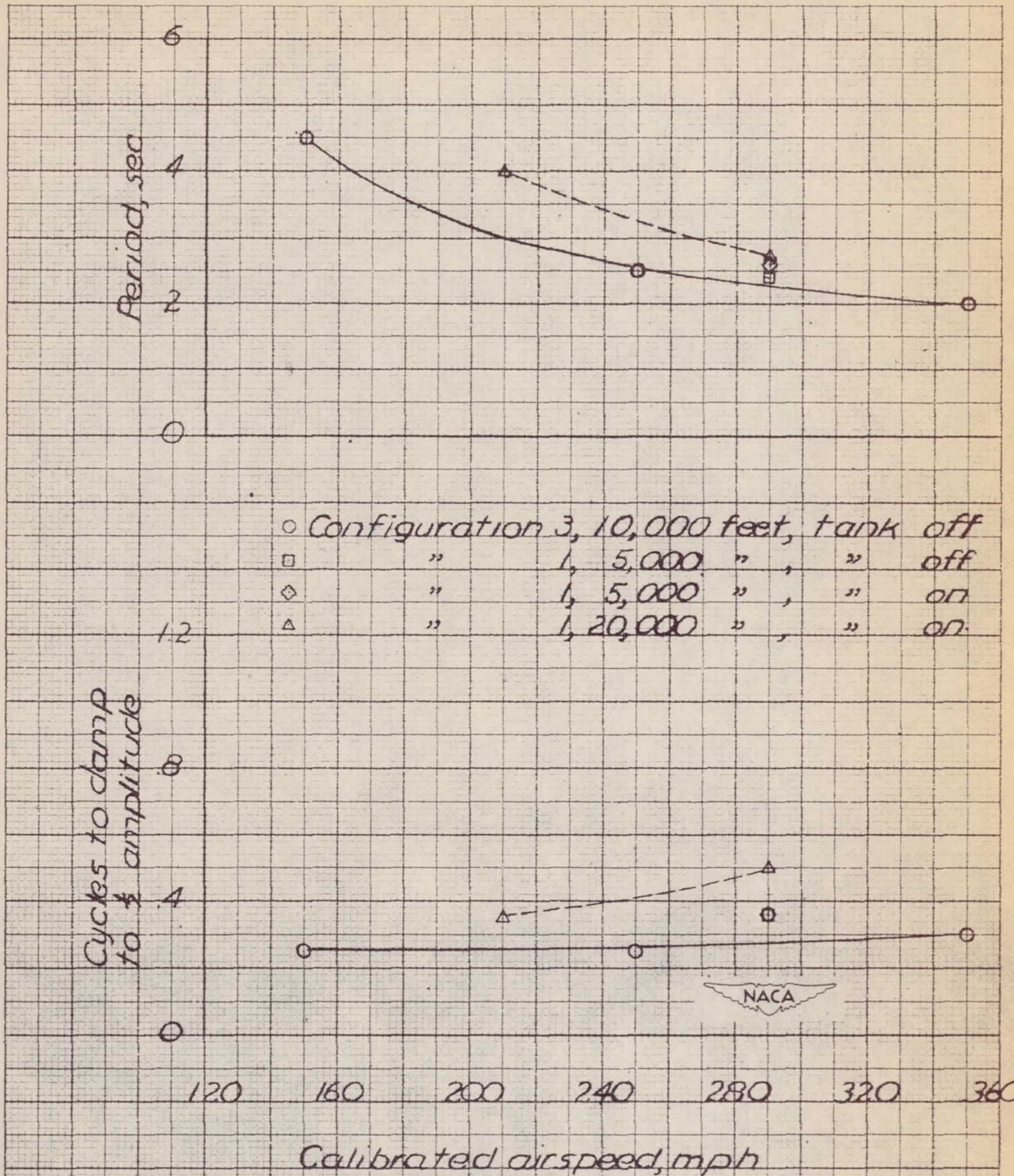
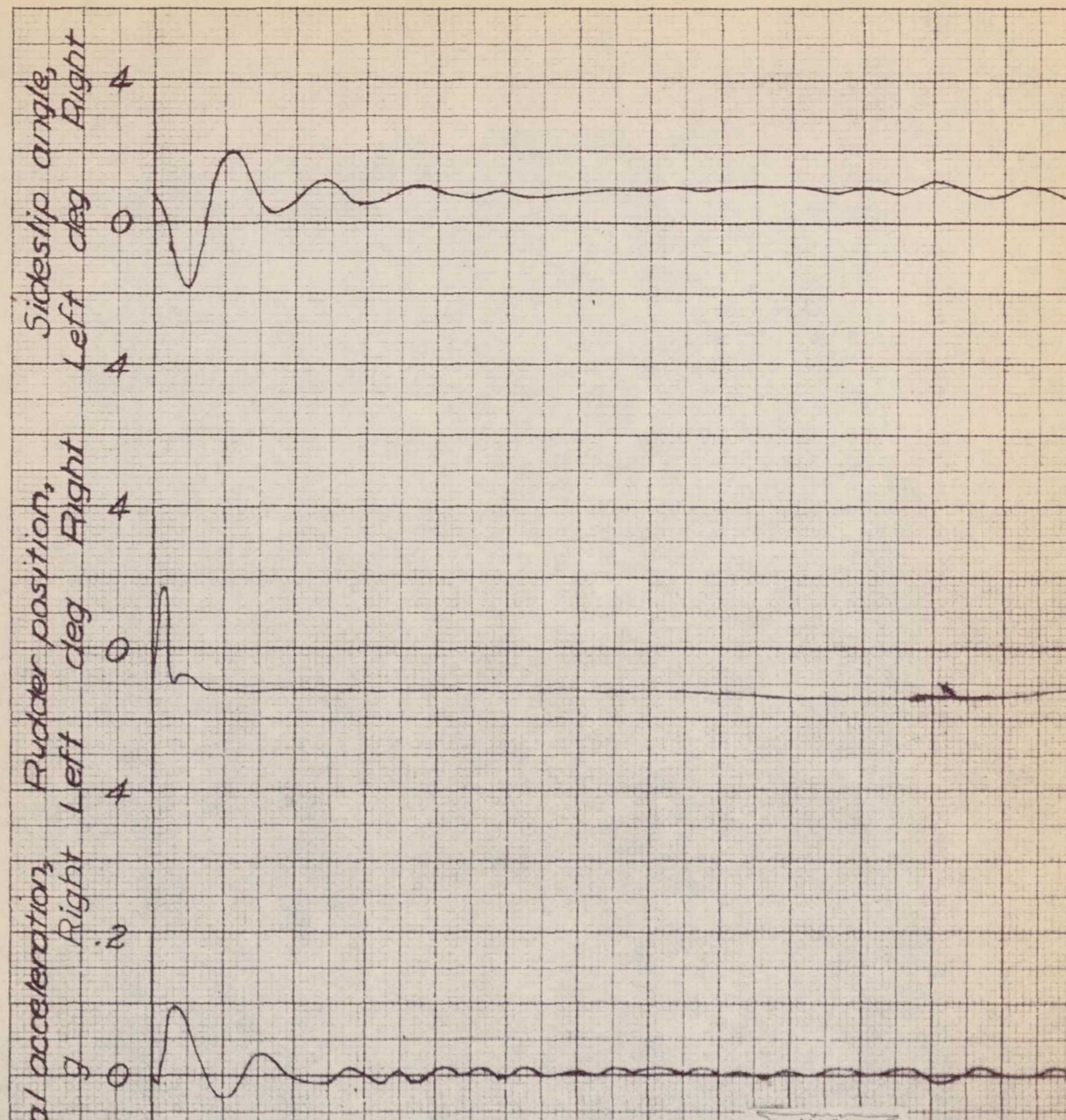
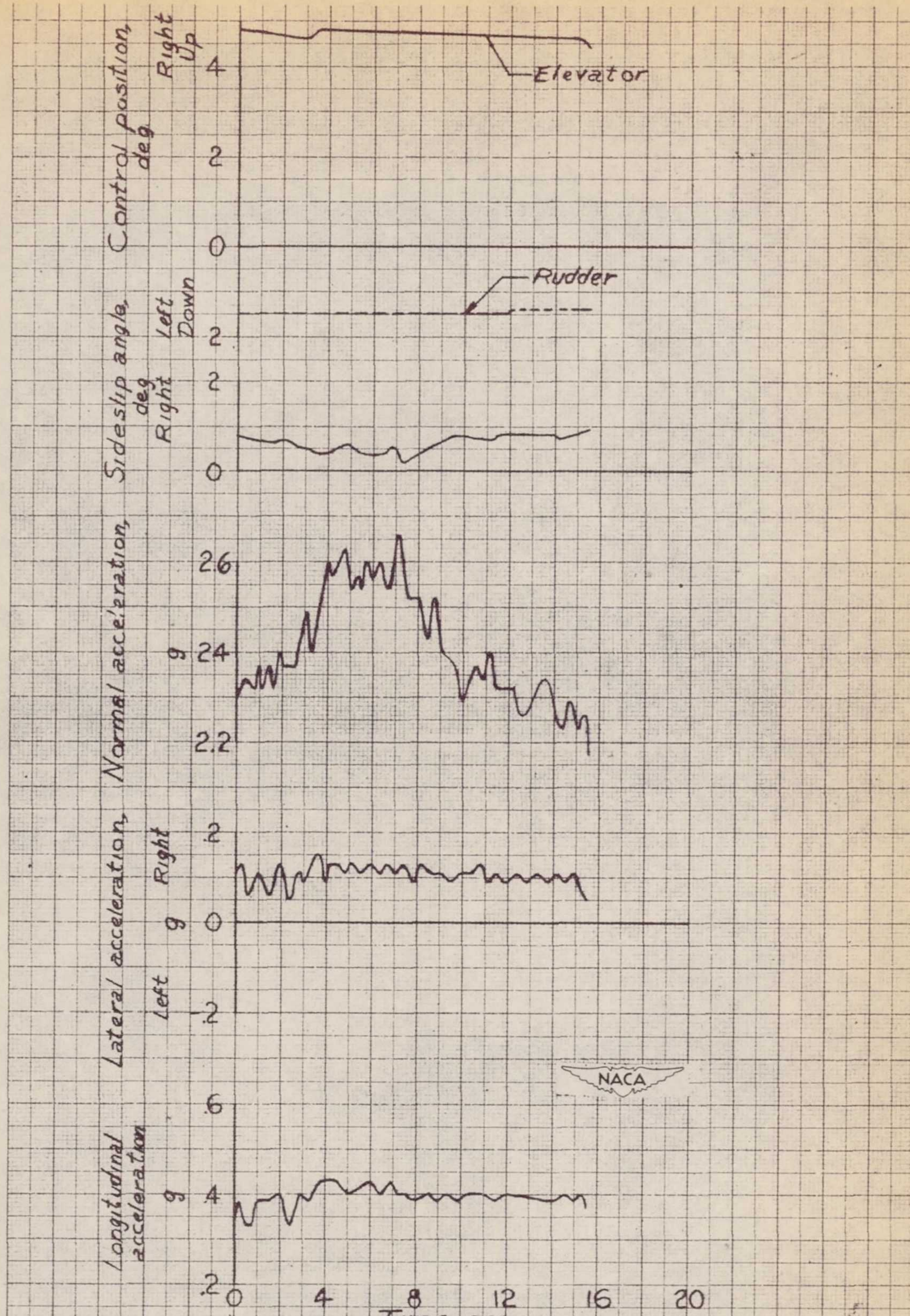


Figure 9.- Variation with speed of the period and rate of damping of lateral oscillations in the clean condition with power for level flight, F8F-1 airplane.



(a) Induced by a rudder kick at 250 miles per hour with fuselage tank approximately half full and an empty belly tank installed.

Figure 10.- Time histories of lateral oscillations in smooth air due to fuel sloshing, F8F-1 airplane with tail configuration 3.



(b) Induced by rapid turn entry at 250 miles per hour with fuselage tank approximately half full.

Figure 10.- Concluded.

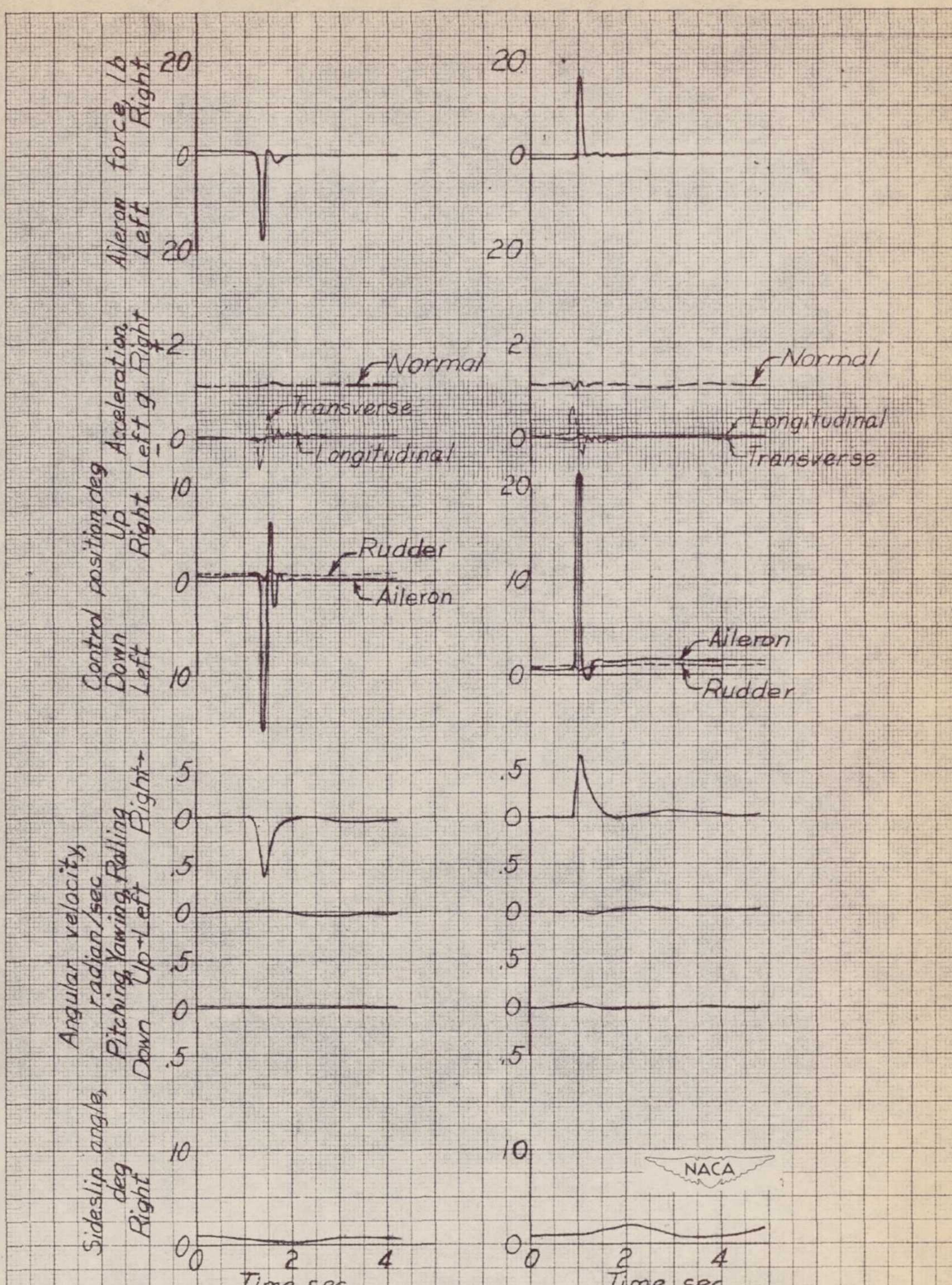


Figure 11.- Time histories of oscillation produced by abrupt left and right aileron deflection and release, F8F-1 airplane with tail configuration 1; belly tank installed. (290 mph)

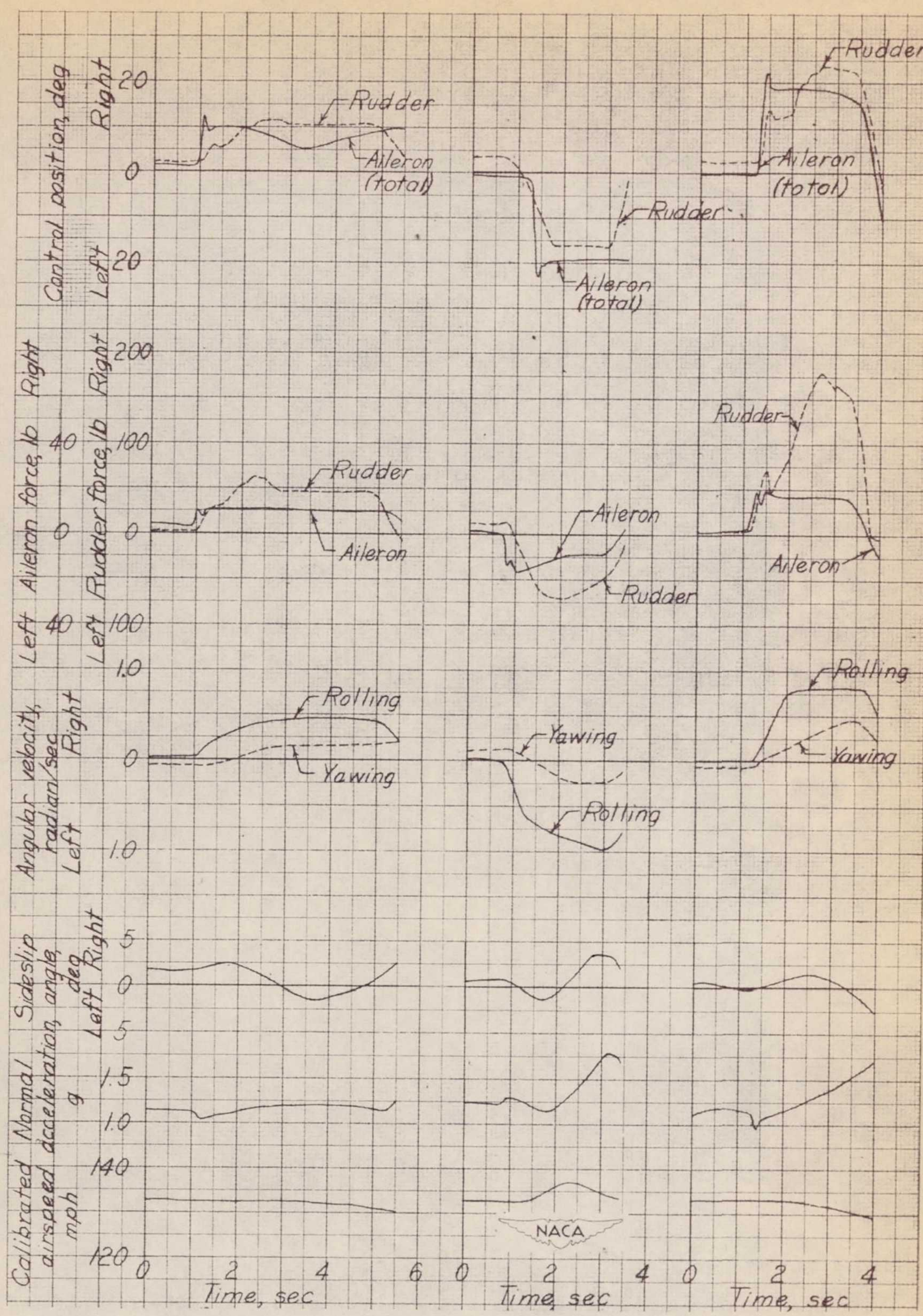


Figure 12.- Time histories of coordinated rolls out of 45° banked turns at 135 miles per hour in the clean condition with power for level flight (15 in. Hg at 2300 rpm) at 5000 feet, F8F-1 airplane with tail configuration 1, without belly tank.

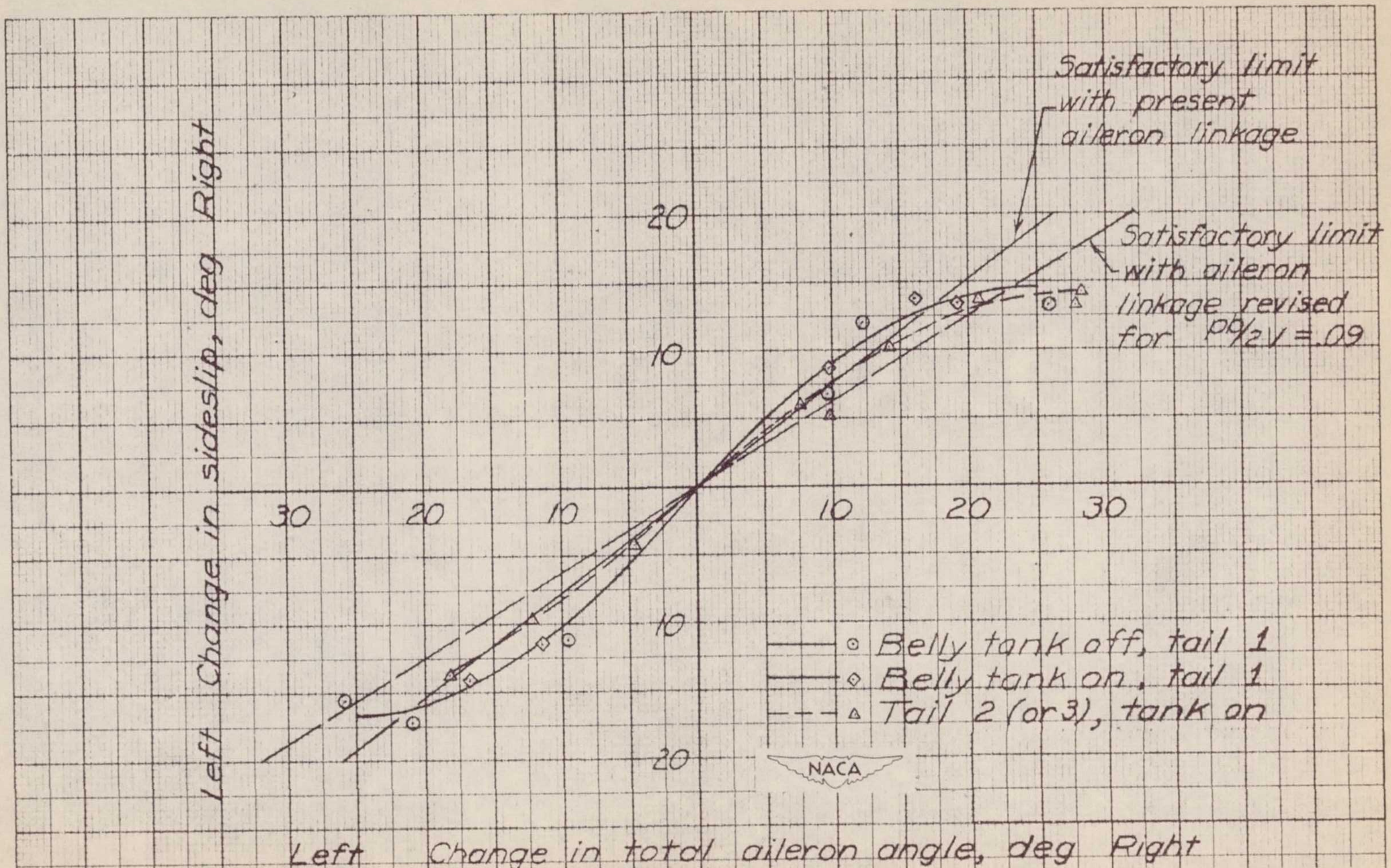
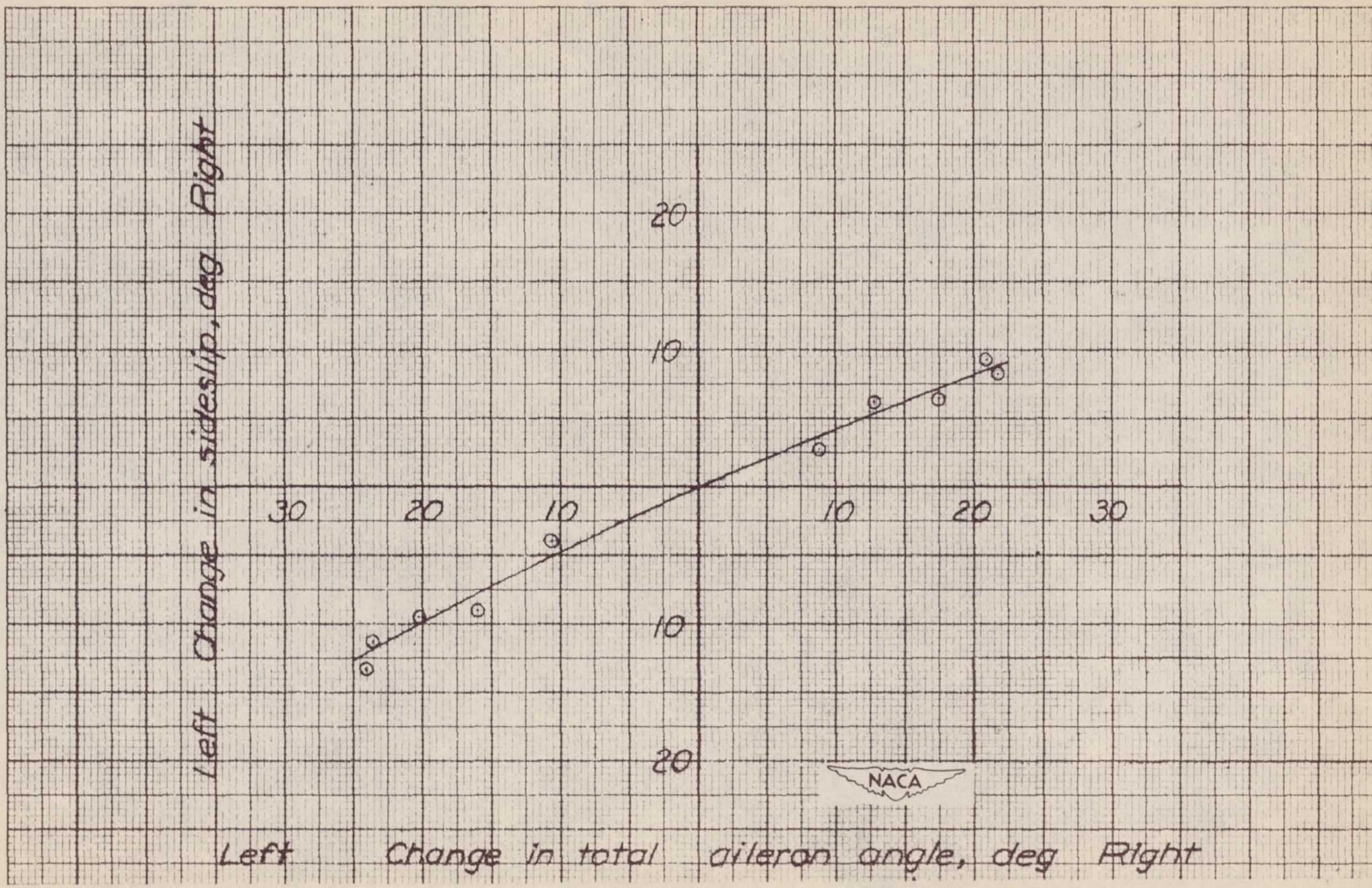
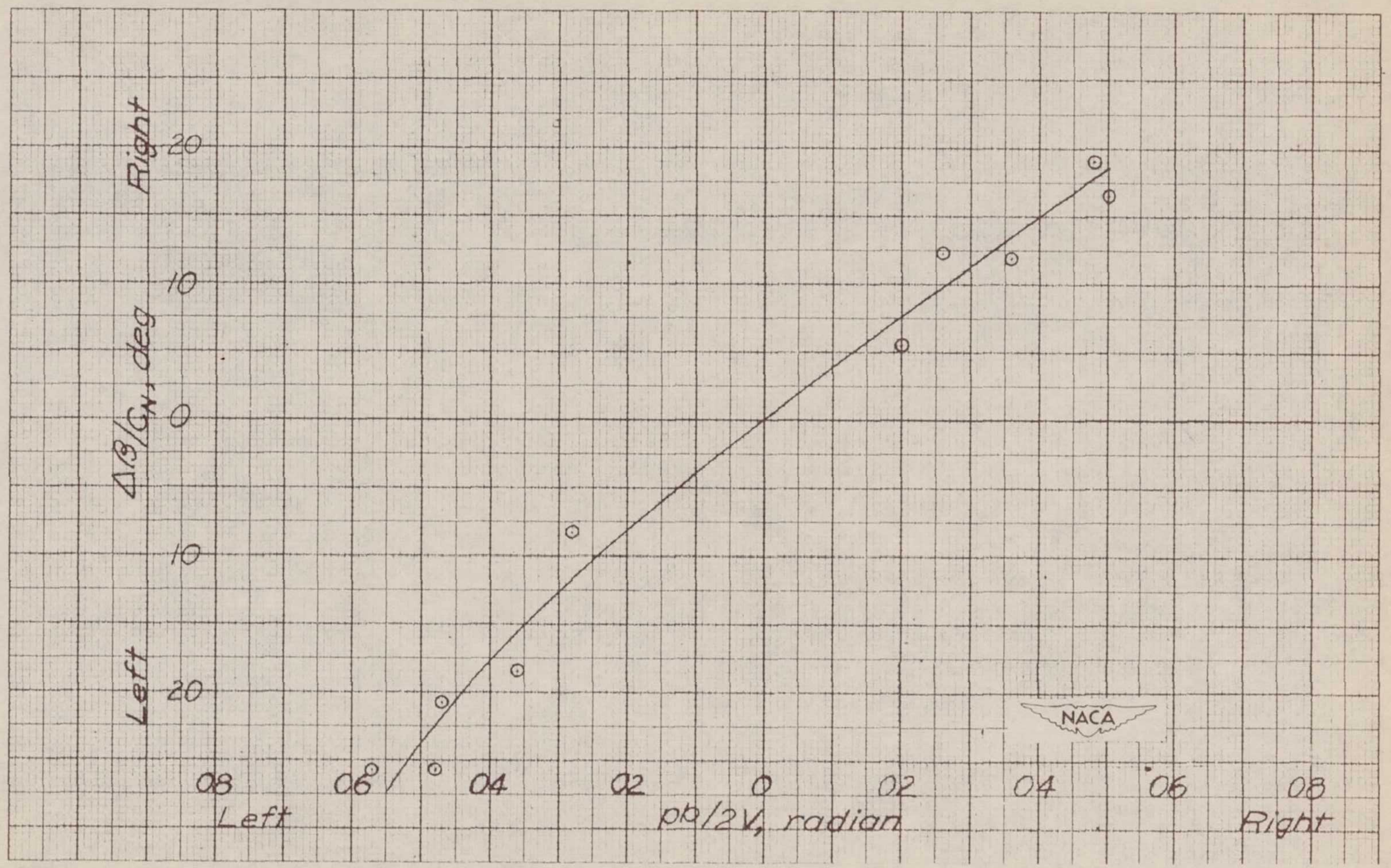


Figure 13.- Rudder-fixed rolls out of 45 degree banked turns at 135 miles per hour in the clean condition with power for level flight (15 in. Hg at 2300 rpm) at 5000 feet, F8F-1 airplane.



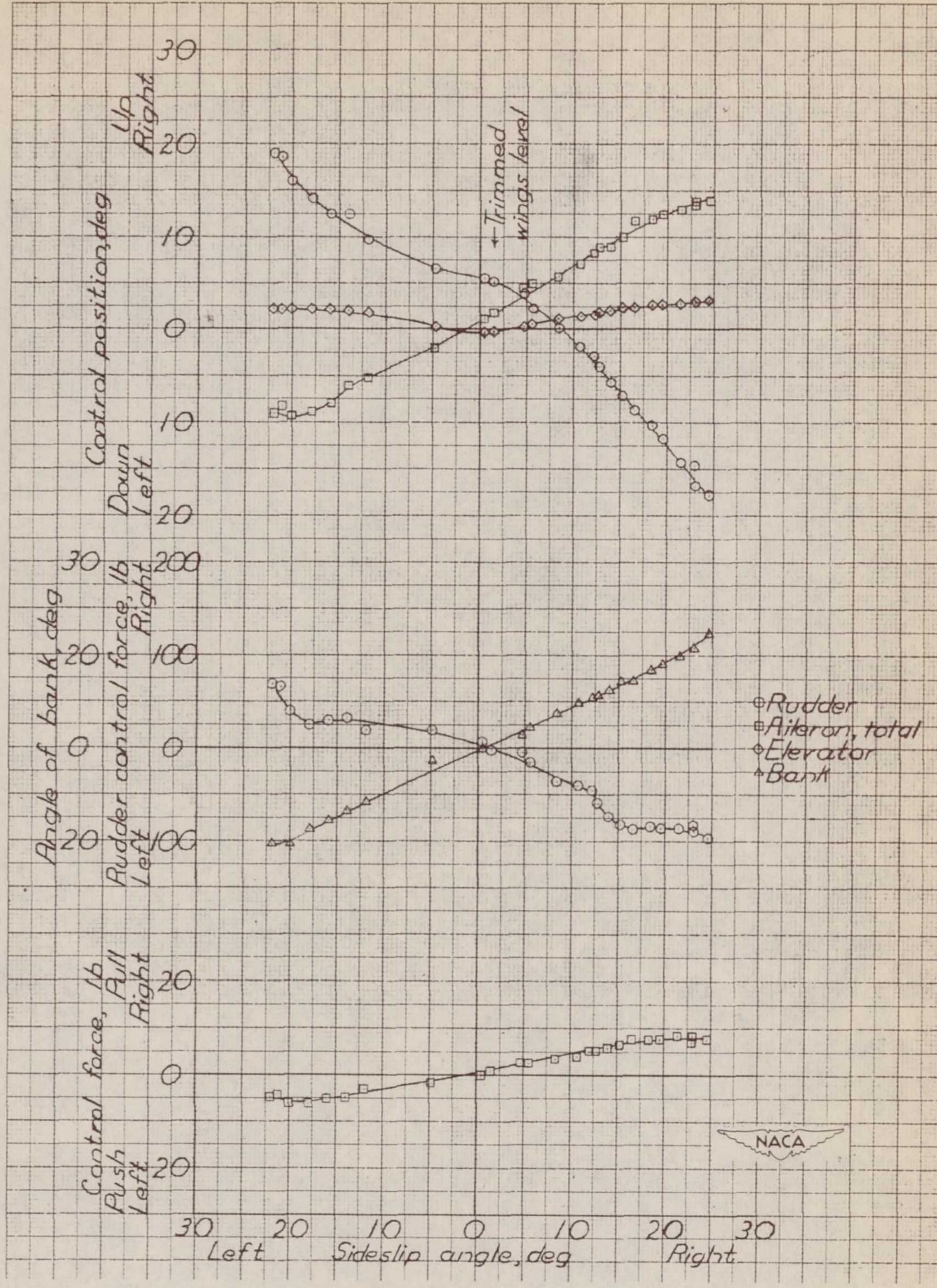
(a) Plot of change in sideslip angle against change in total aileron angle.

Figure 14.- Rudder-fixed rolls out of 3 g turns at 290 miles per hour in the rated-power clean condition (41 in. Hg at 2600 rpm) without belly tank, F8F-1 airplane with tail configuration 1.



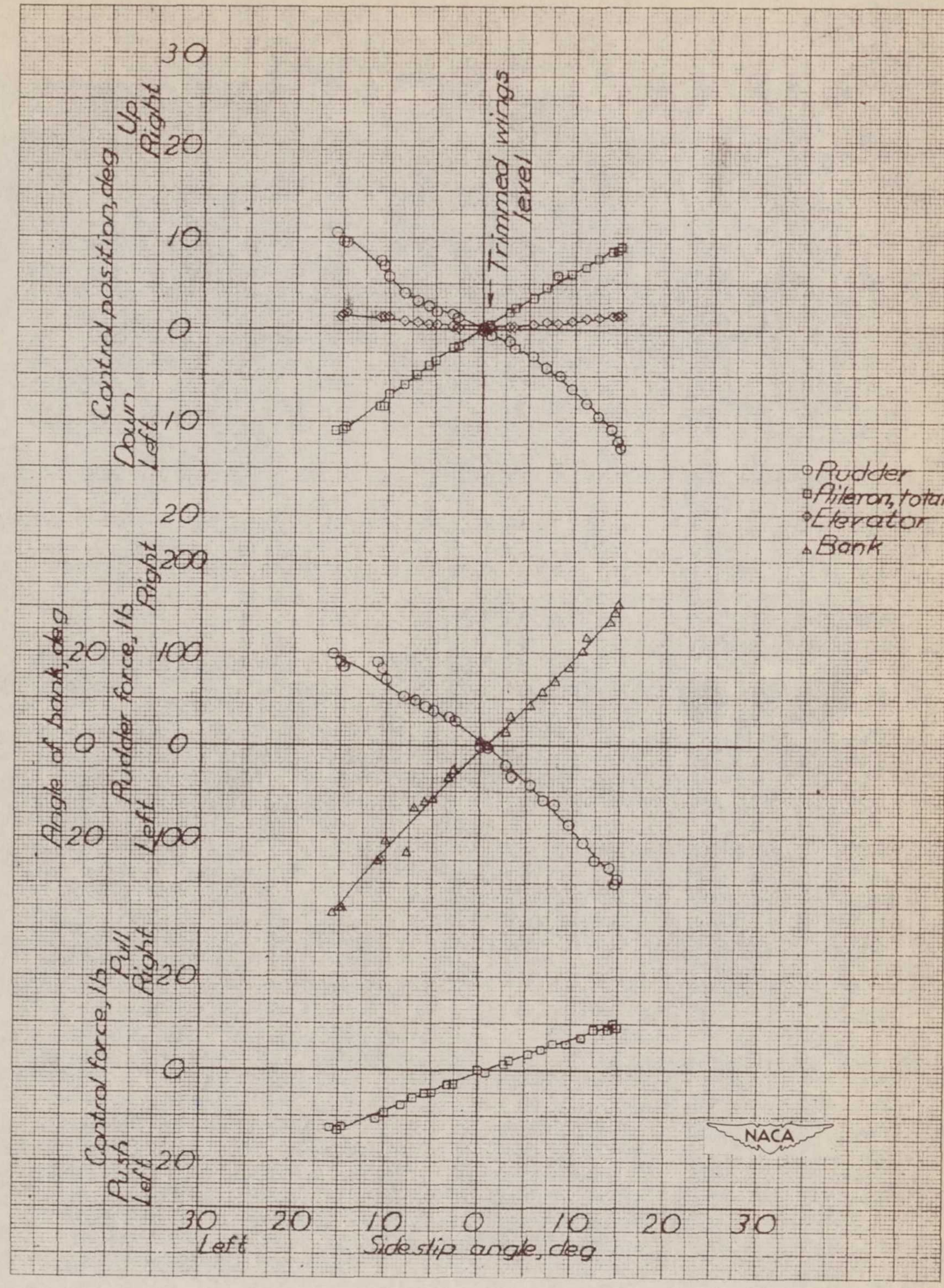
(b) Plot of change in sideslip angle divided by normal force coefficient against maximum pb/2V.

Figure 14.- Concluded.



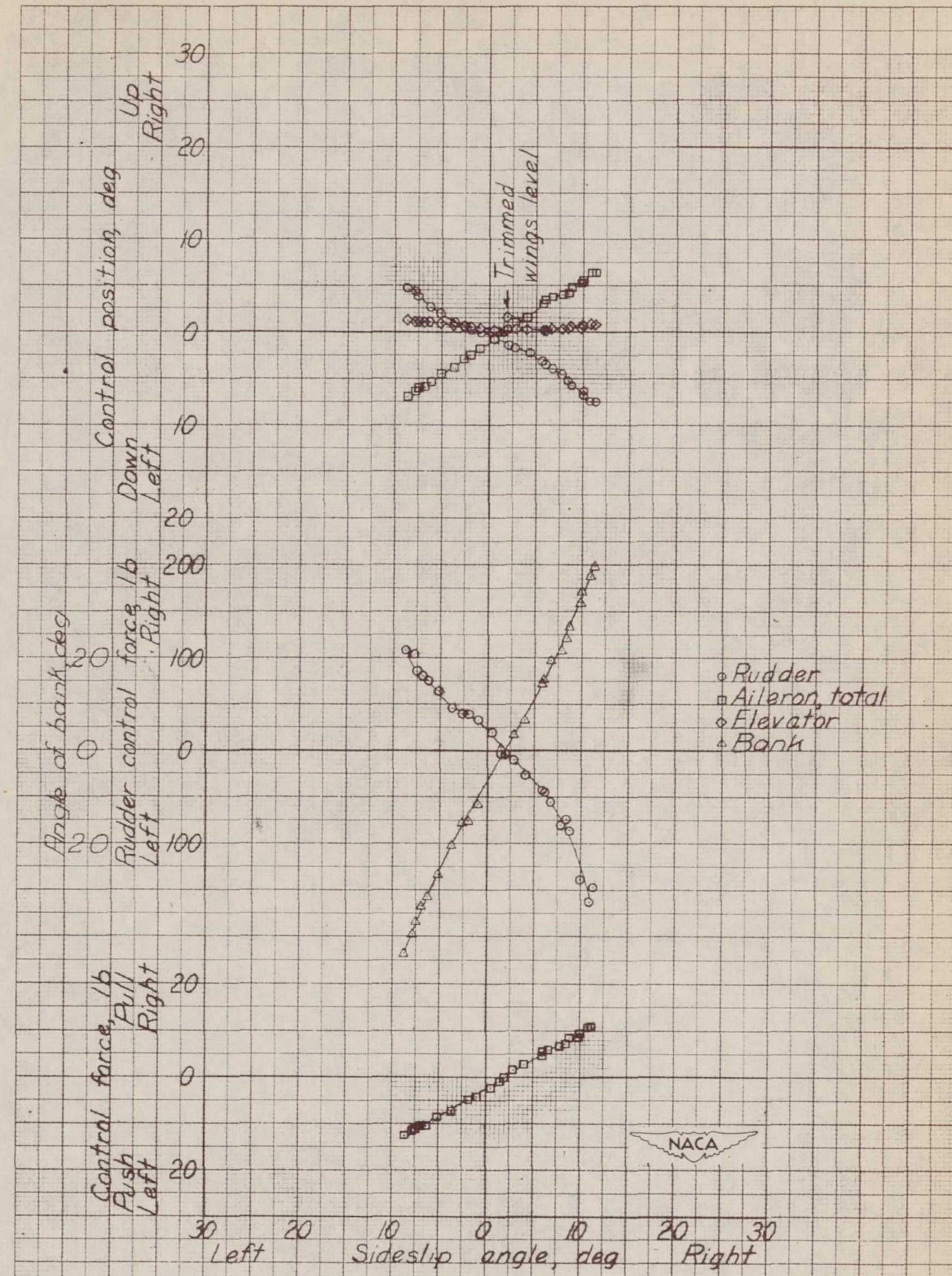
(a) 150 miles per hour, oil cooler open.

Figure 15.- Sideslips in the rated-power, clean condition (41 in. Hg at 2600 rpm) at 5000 feet with belly tank off, cowl closed, canopy closed, F8F-1 airplane with tail configuration 1.



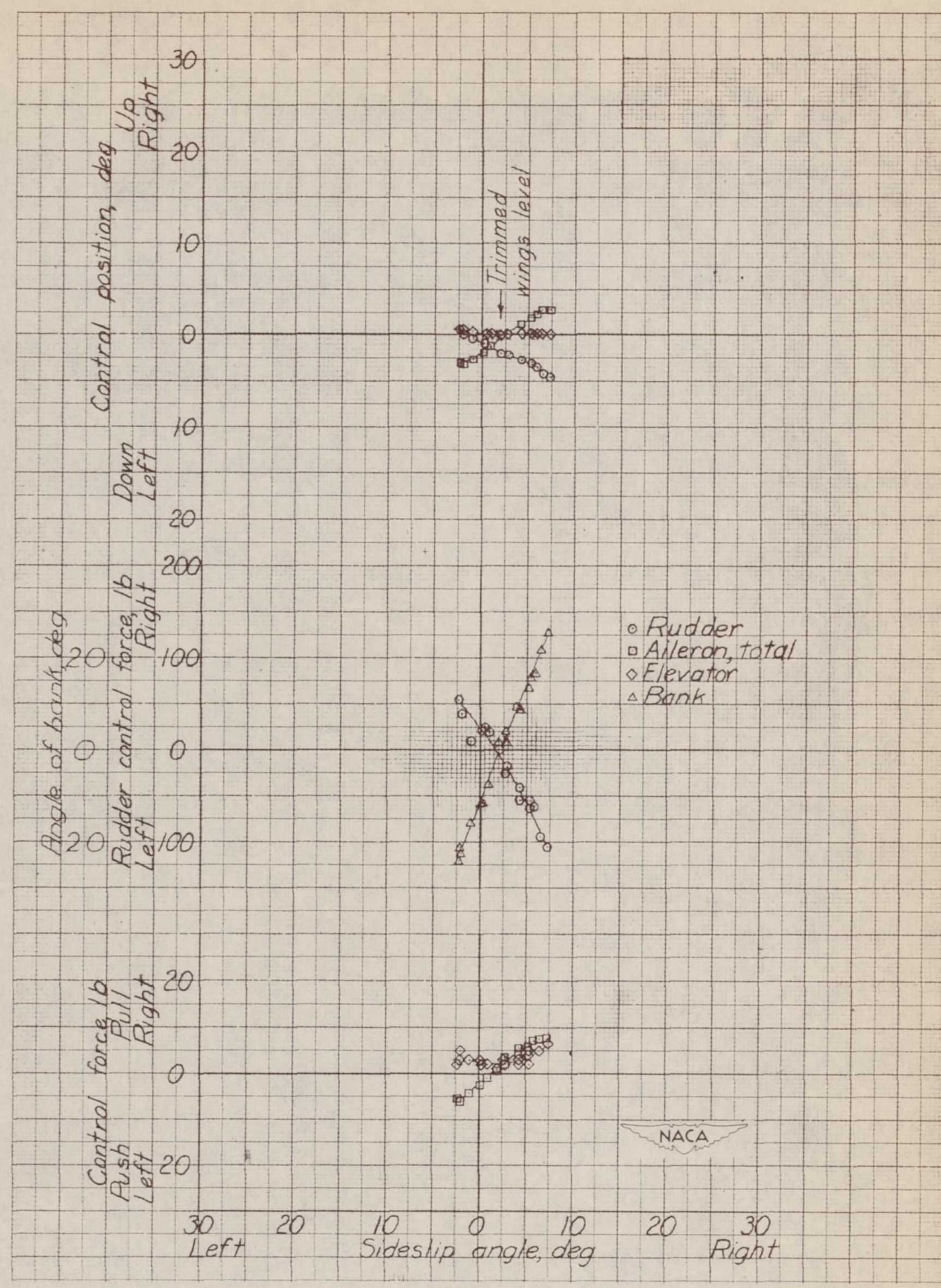
(b) 245 miles per hour, rudder tab 0.5° left, oil cooler closed.

Figure 15.- Continued.



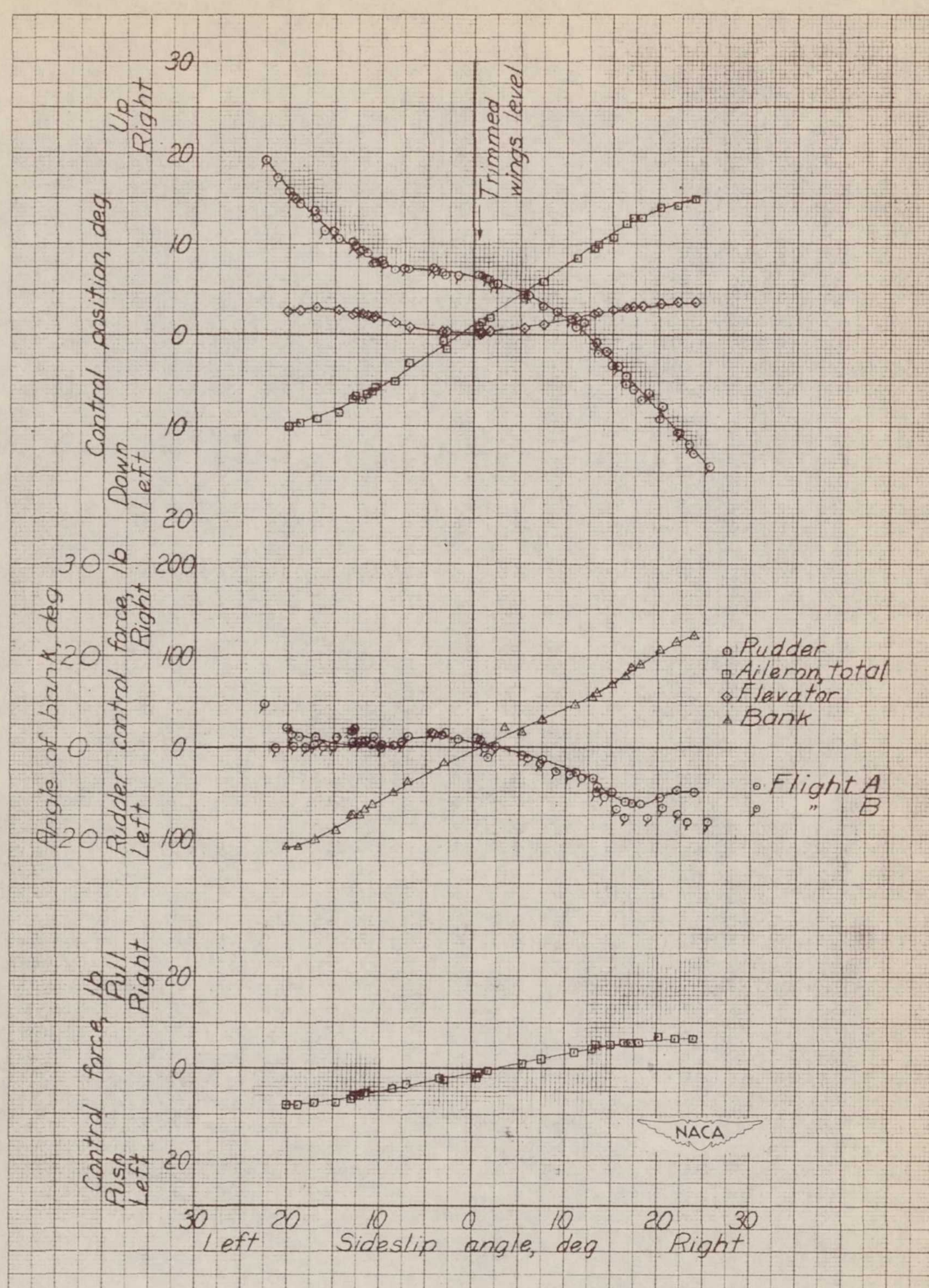
(c) 345 miles per hour, oil cooler closed.

Figure 15.- Continued.



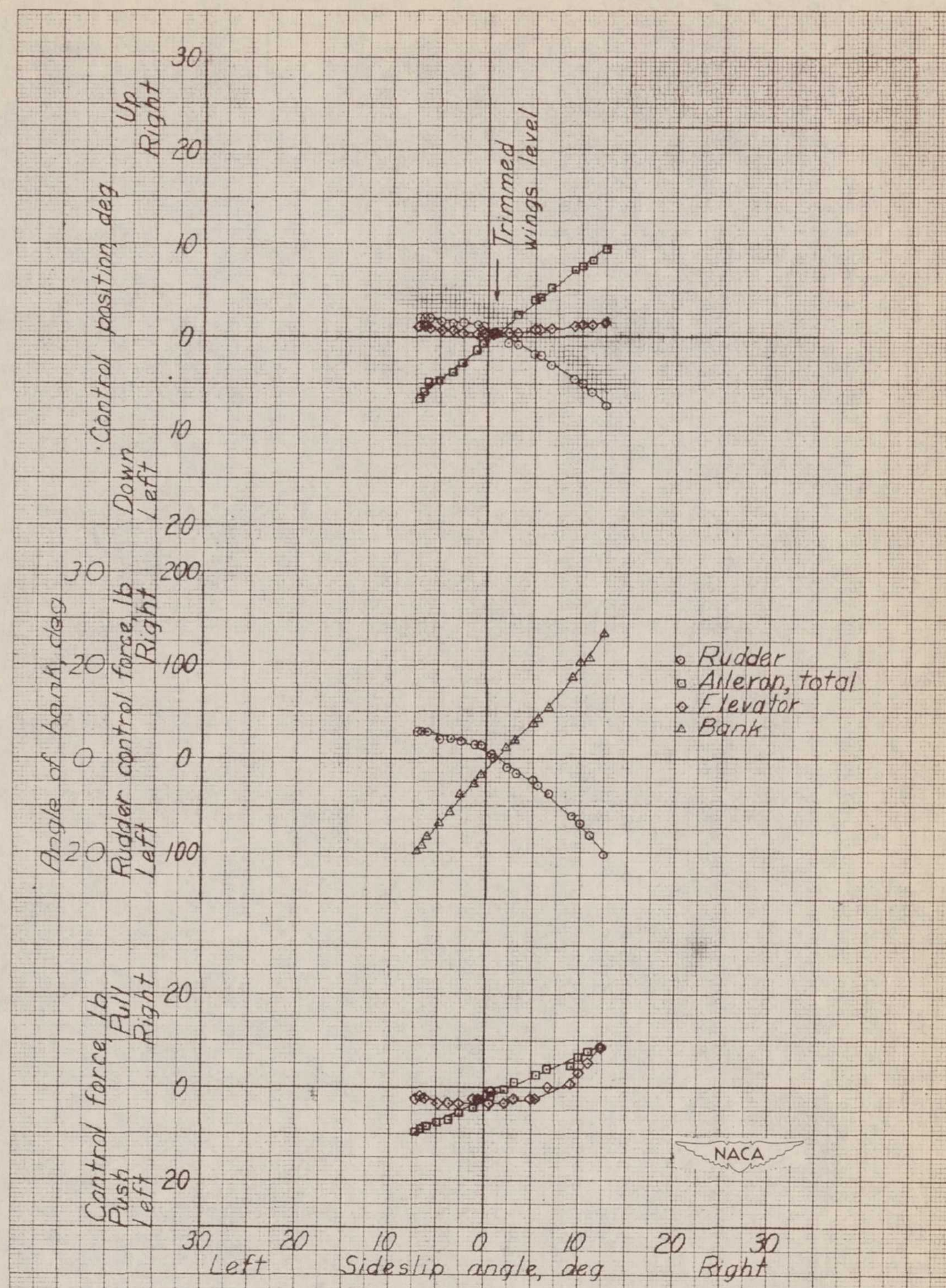
(d) 395 miles per hour, rudder tab 2.0° right, oil cooler closed.

Figure 15.- Concluded.



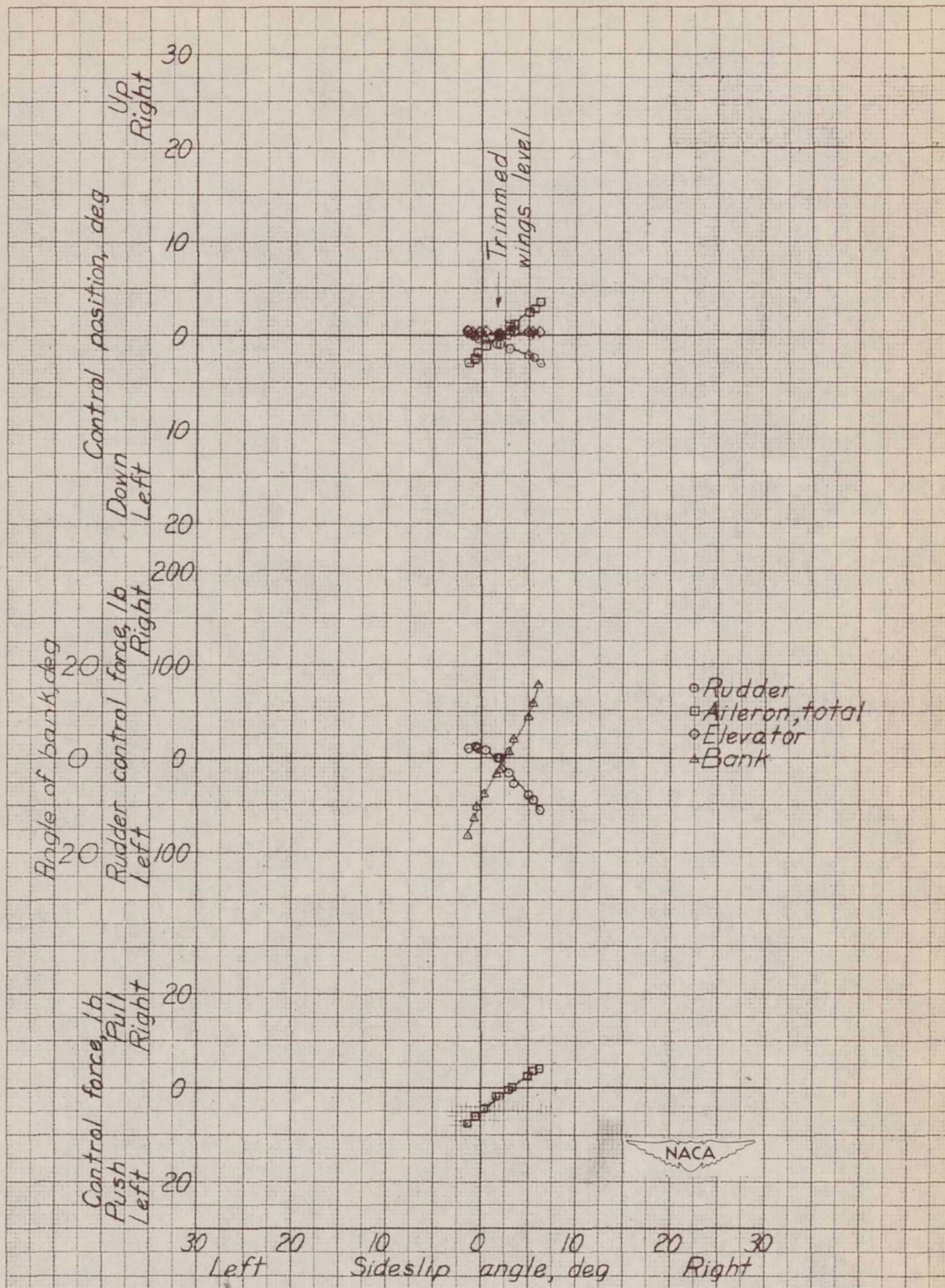
(a) 150 miles per hour, rudder tab 14.0° left, oil cooler open.

Figure 16.- Sideslips in the rated-power, clean condition (41 in. Hg, 2600 rpm) at 5000 feet with belly tank on, cowl closed, canopy closed, F8F-1 airplane with tail configuration 1.



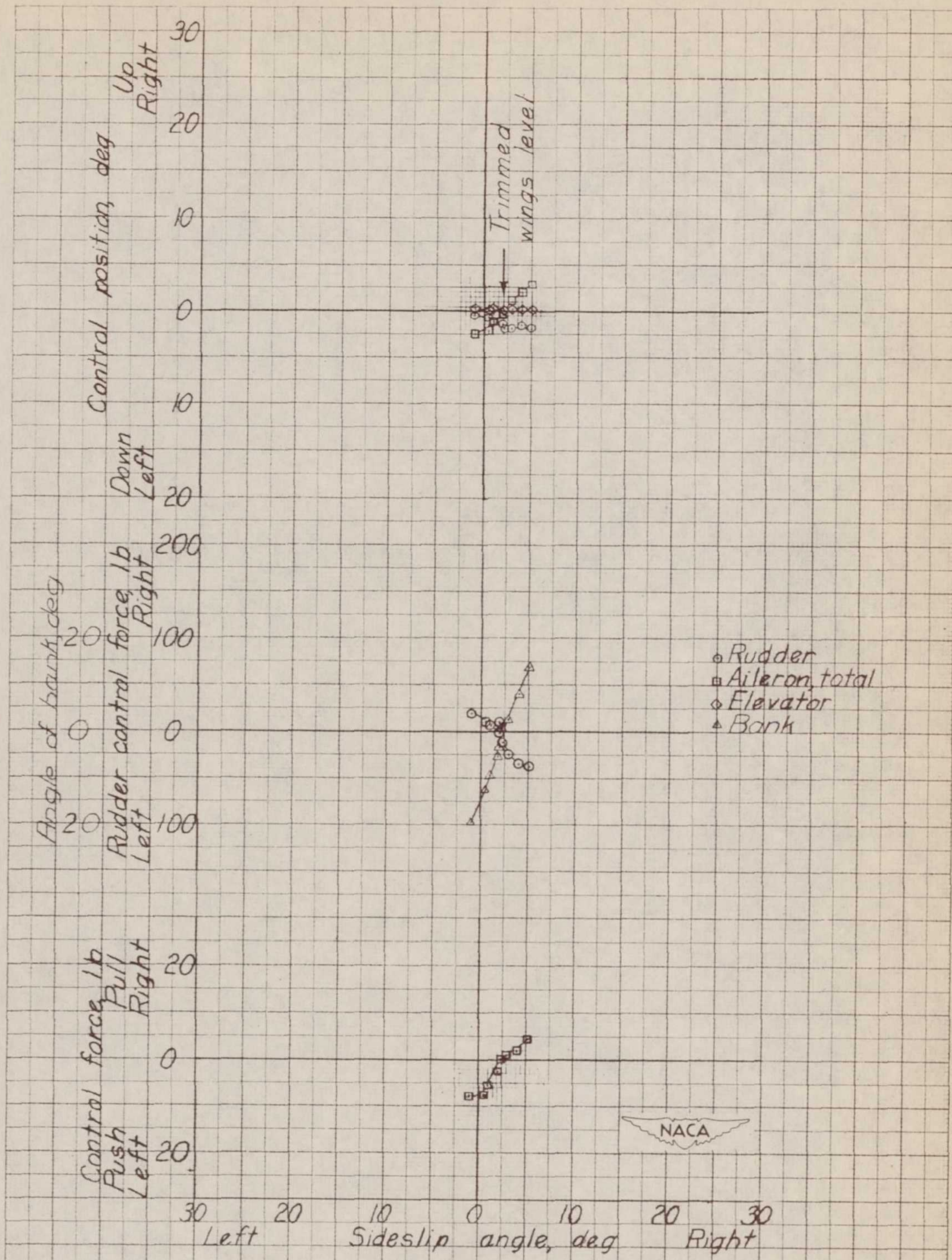
(b) 245 miles per hour, rudder tab 1.3° left, oil cooler closed.

Figure 16.- Continued.



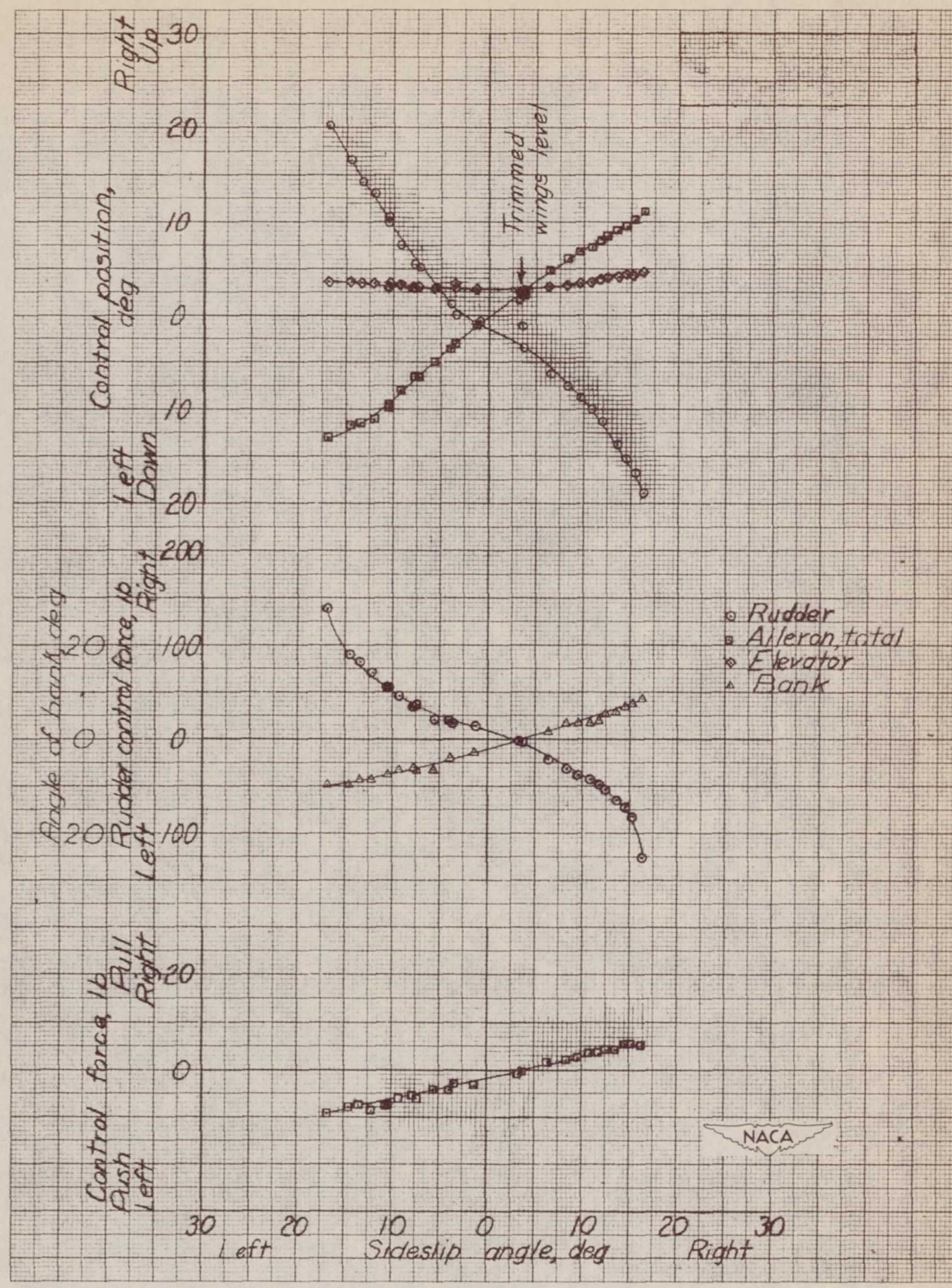
(c) 345 miles per hour, rudder tab 0.3° right, oil cooler closed.

Figure 16.- Continued.



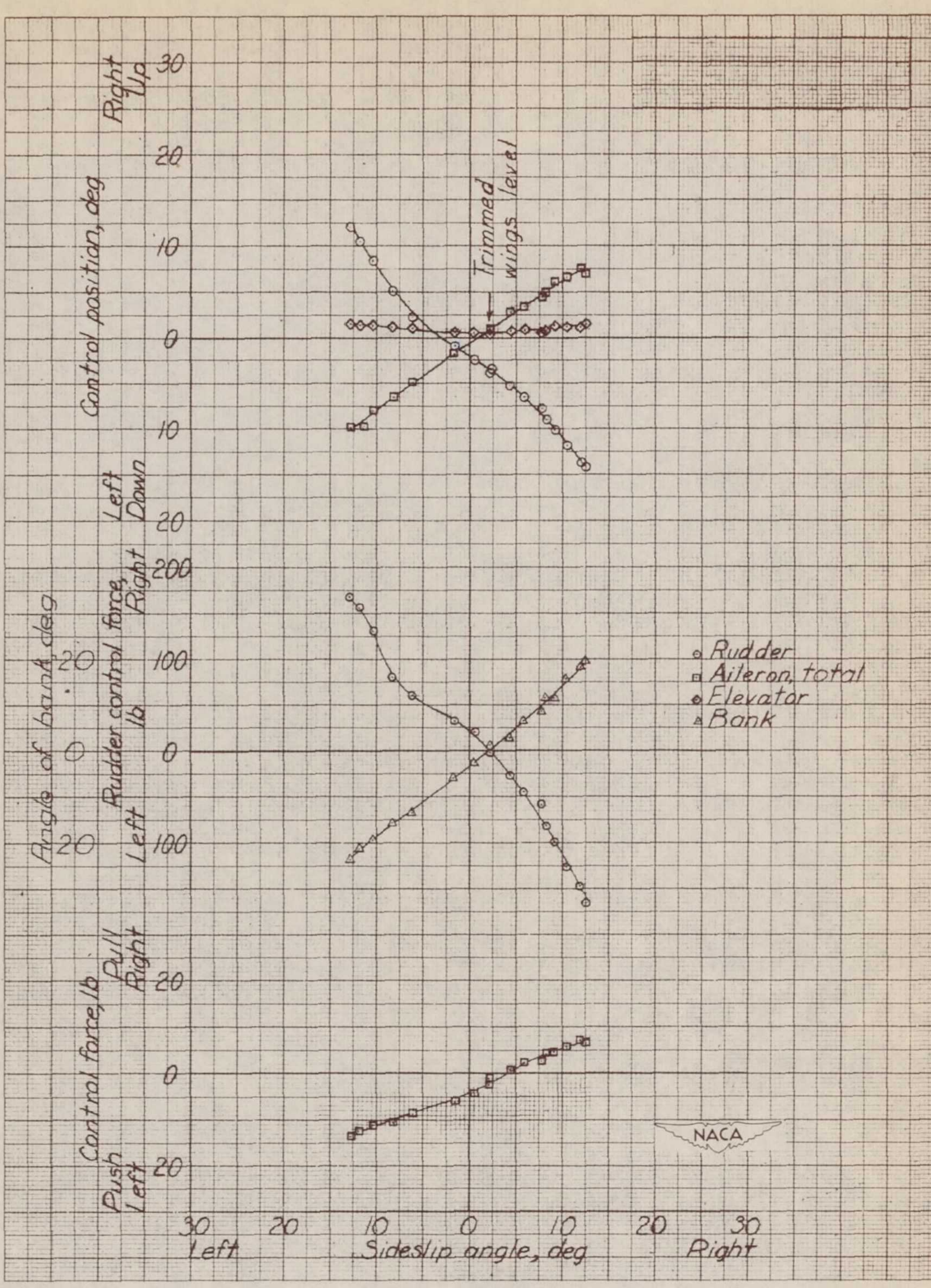
(d) 395 miles per hour, rudder tab 1.7° right, oil cooler closed.

Figure 16.- Concluded.



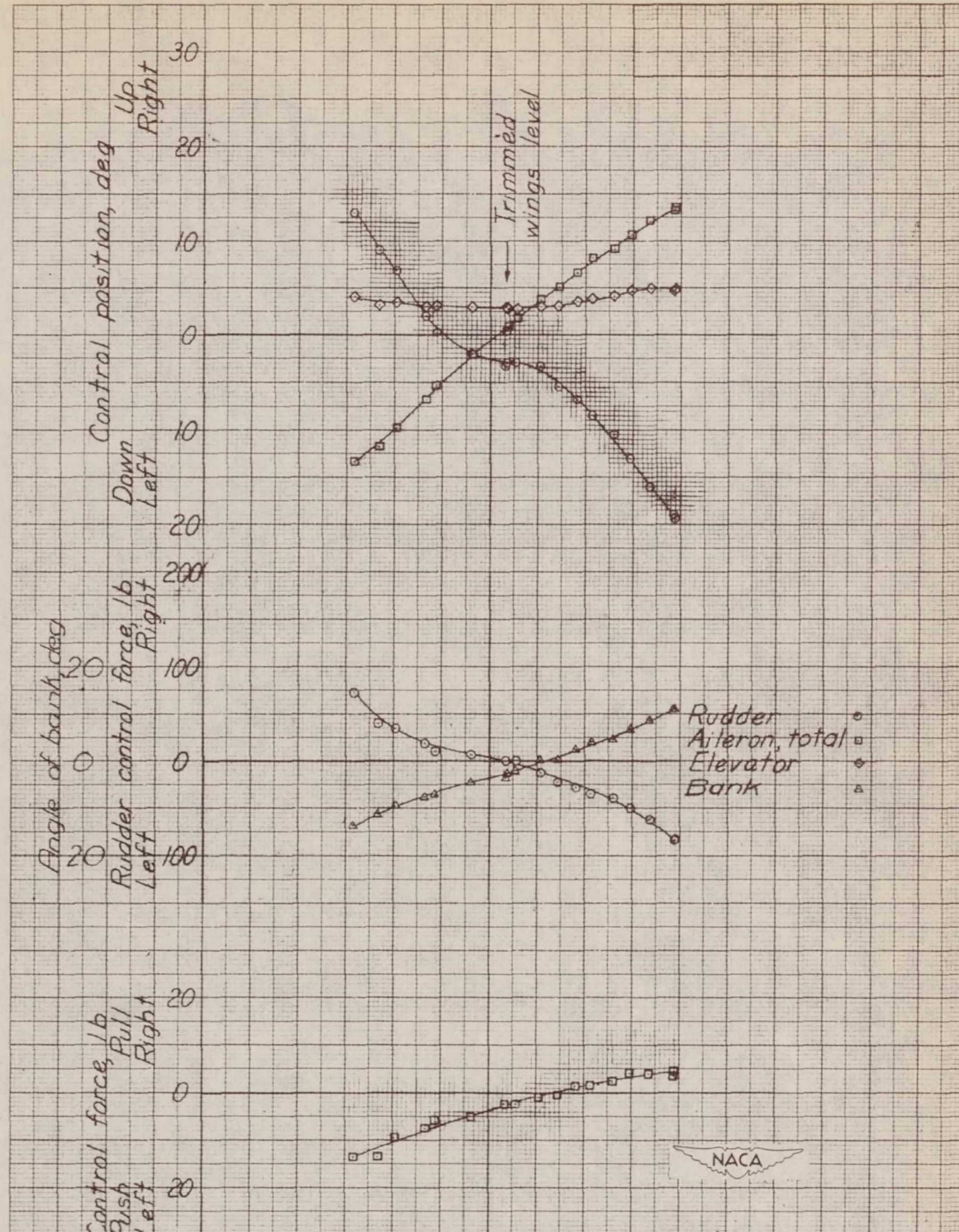
(a) 150 miles per hour, rudder tab 5.7° right.

Figure 17.- Sideslips in the clean, engine-idling condition at 5000 feet with belly tank off, cowl closed, oil cooler closed, canopy closed, F8F-1 airplane with tail configuration 1.



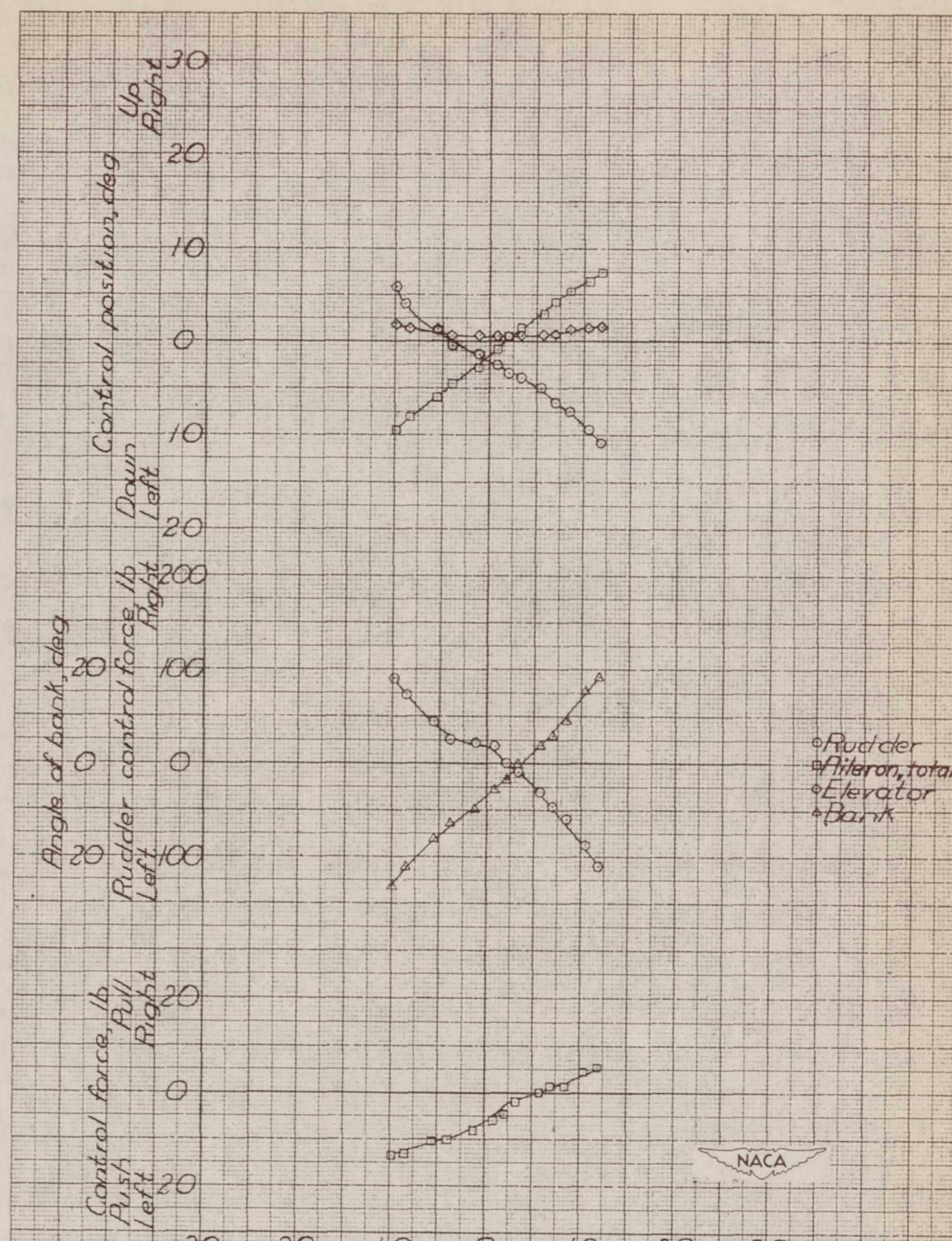
(b) 245 miles per hour, rudder tab 5.7° right.

Figure 17.- Concluded.



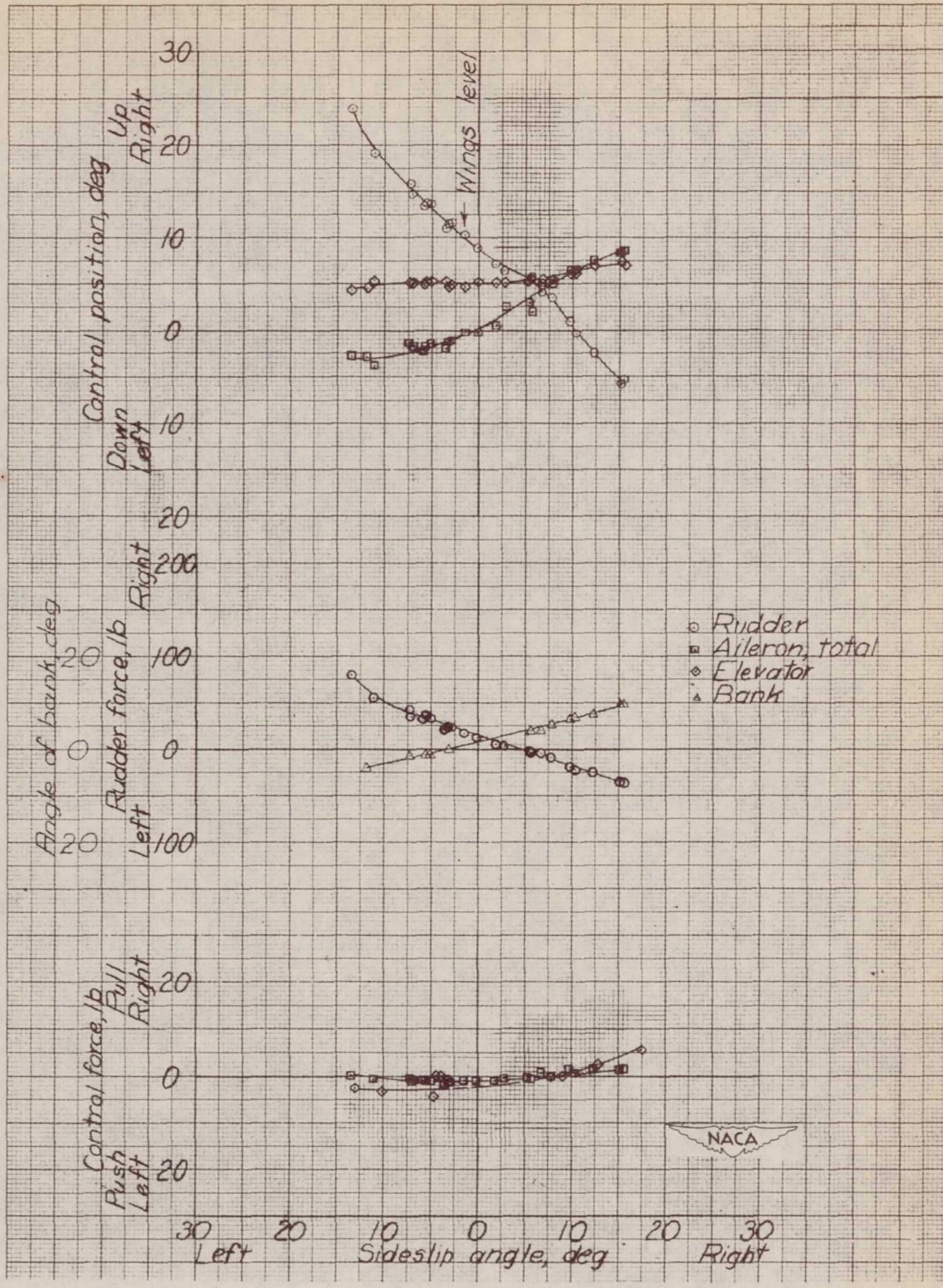
(a) 150 miles per hour, rudder tab 5.7° right.

Figure 18.- Sideslips in the clean, engine-idling condition at 5000 feet with belly tank on, cowl closed, oil cooler closed, canopy closed, F8F-1 airplane with tail configuration 1.



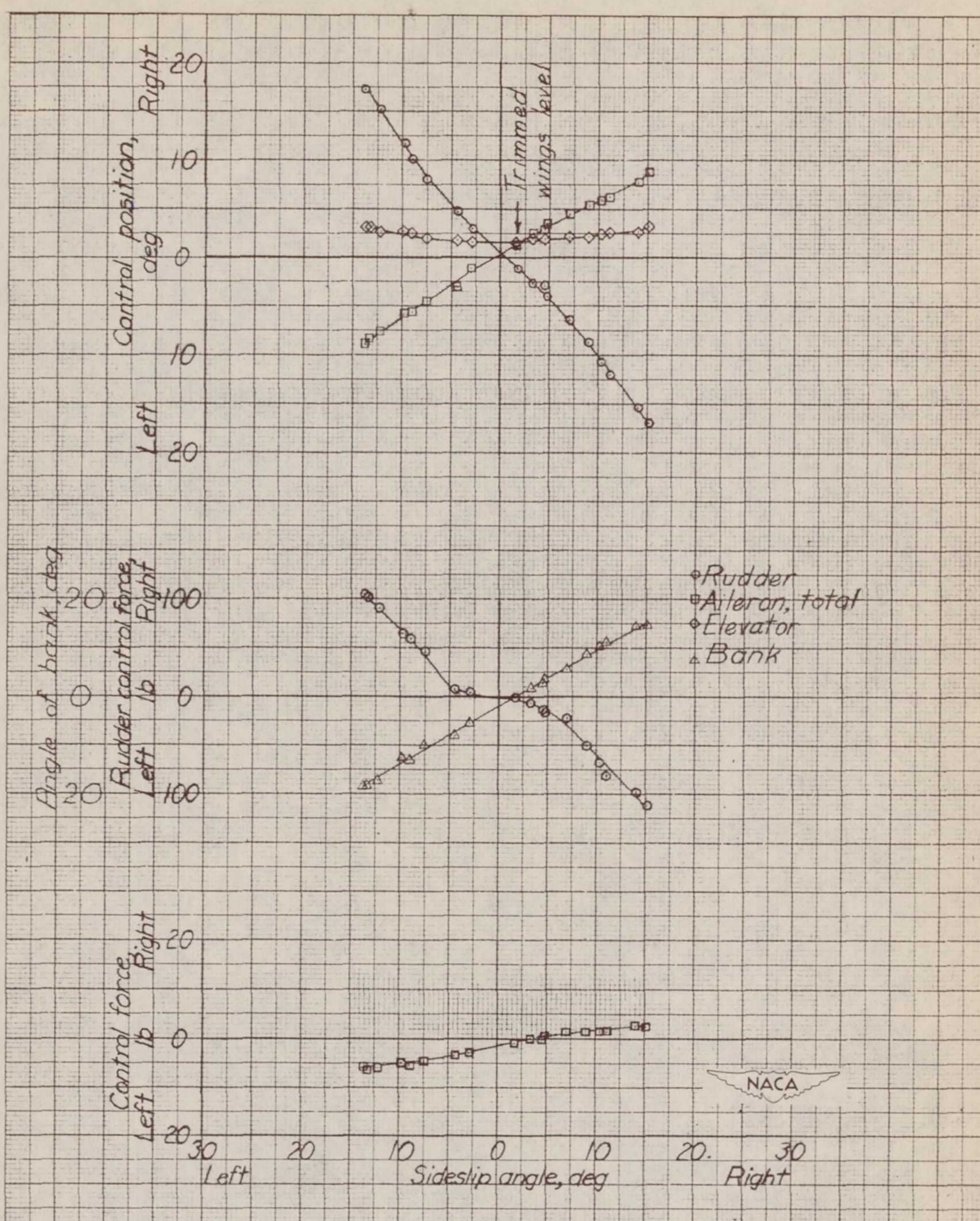
(b) 245 miles per hour, rudder tab 6.3° right.

Figure 18.- Concluded.



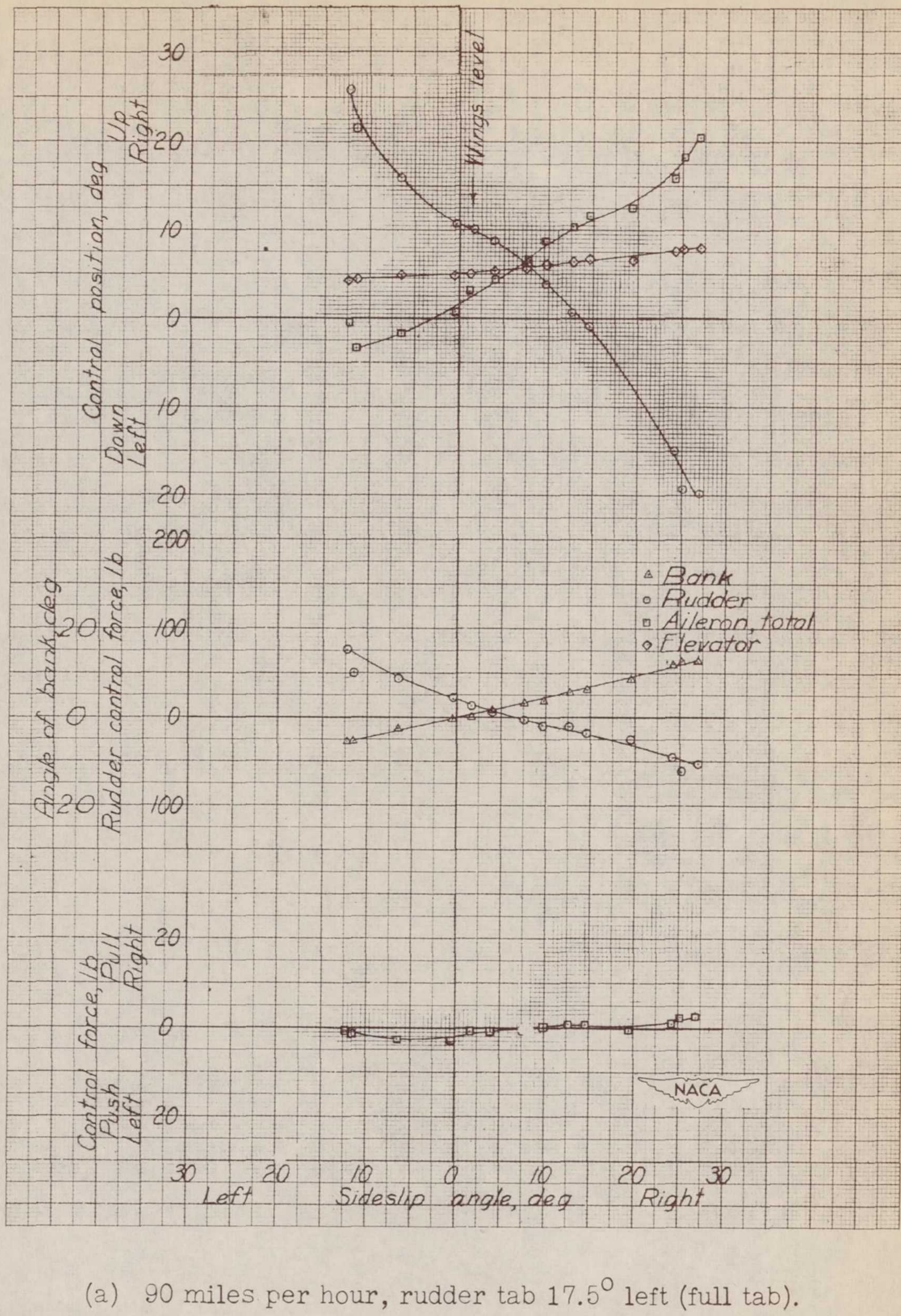
(a) 90 miles per hour, rudder tab 17.5° left (full tab).

Figure 19.- Sideslips in the power-approach condition (20 in. Hg at 2300 rpm) flaps and landing gear down at 5000 feet with belly tank off, cowl closed, oil cooler closed, canopy open, F8F-1 airplane with tail configuration 1.



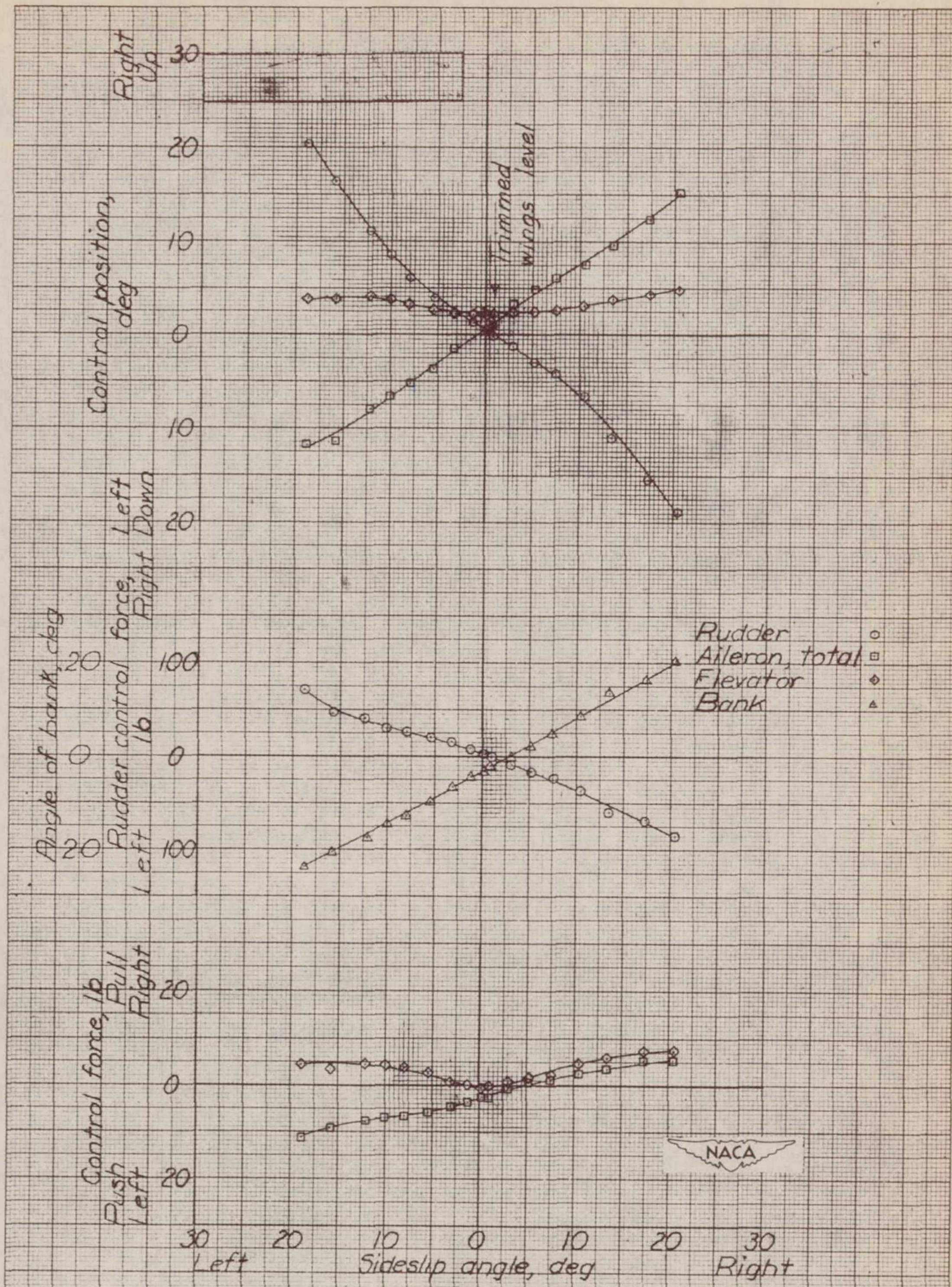
(b) 150 miles per hour, rudder tab 0.8° right.

Figure 19.- Concluded.



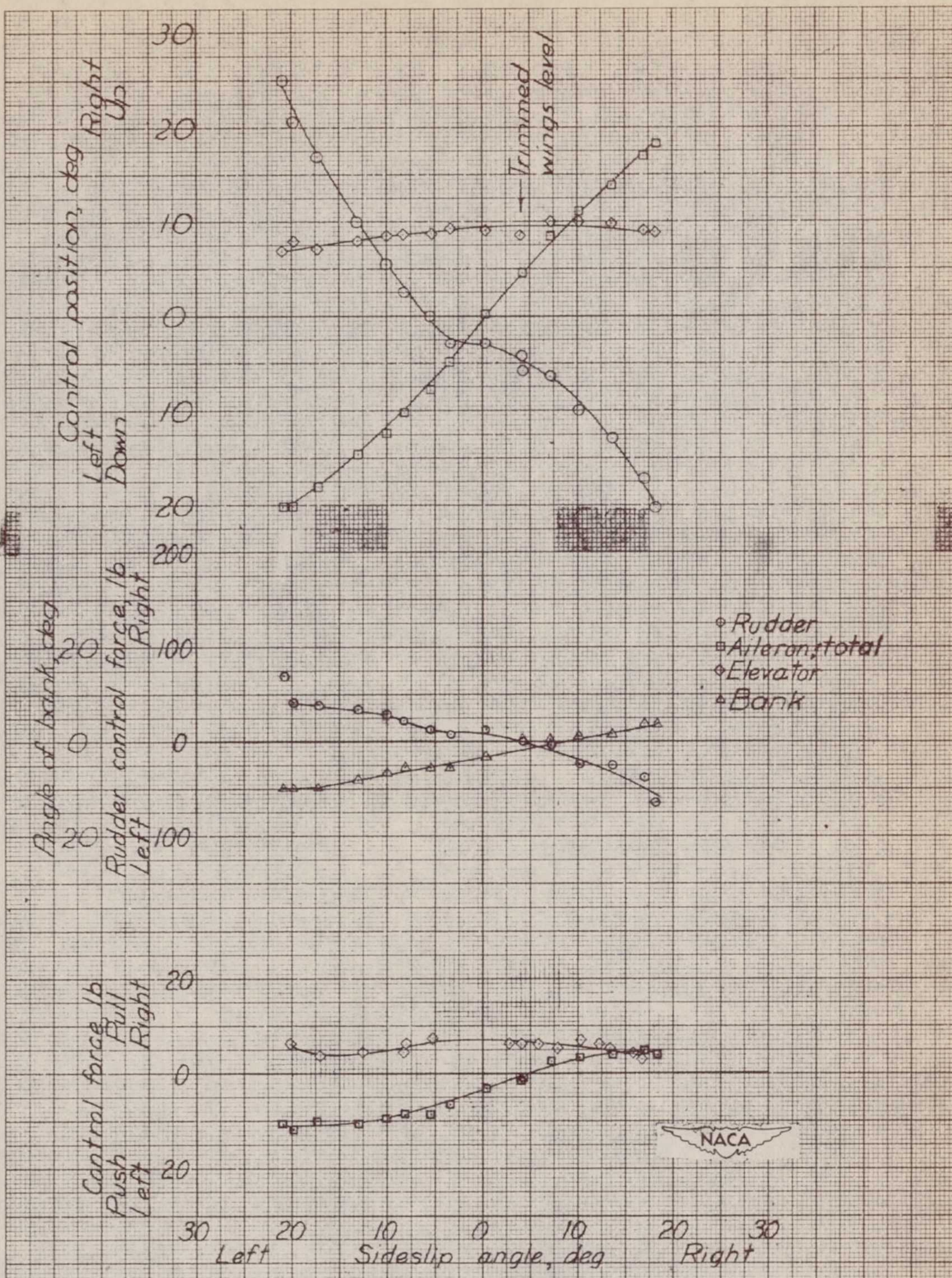
(a) 90 miles per hour, rudder tab 17.5° left (full tab).

Figure 20.- Sideslips in the power-approach condition (20 in. Hg at 2300 rpm) with flaps and landing gear down at 5000 feet, with belly tank on, cowl closed, oil cooler closed, canopy open, F8F-1 airplane, with tail configuration 1.



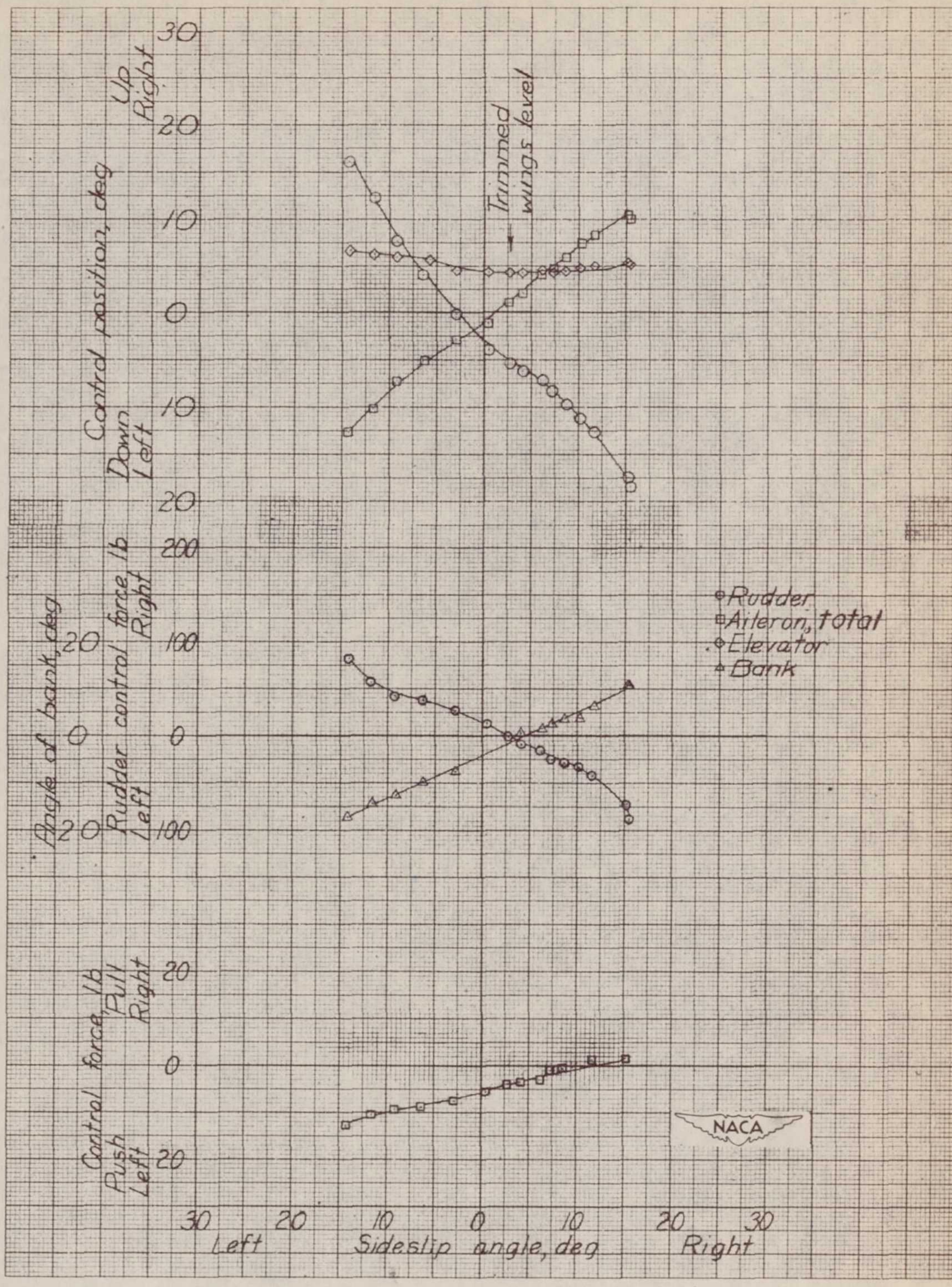
(b) 150 miles per hour, rudder tab 2.3° left.

Figure 20.- Concluded.



(a) 105 miles per hour, rudder tab 14.7° right.

Figure 21.- Sideslips in the landing condition with engine idling and flaps and landing gear down at 5000 feet, with belly tank on, cowl closed, oil cooler closed, canopy open, F8F-1 airplane with tail configuration 1.



(b) 150 miles per hour, rudder tab 12.8° right.

Figure 21.- Concluded.

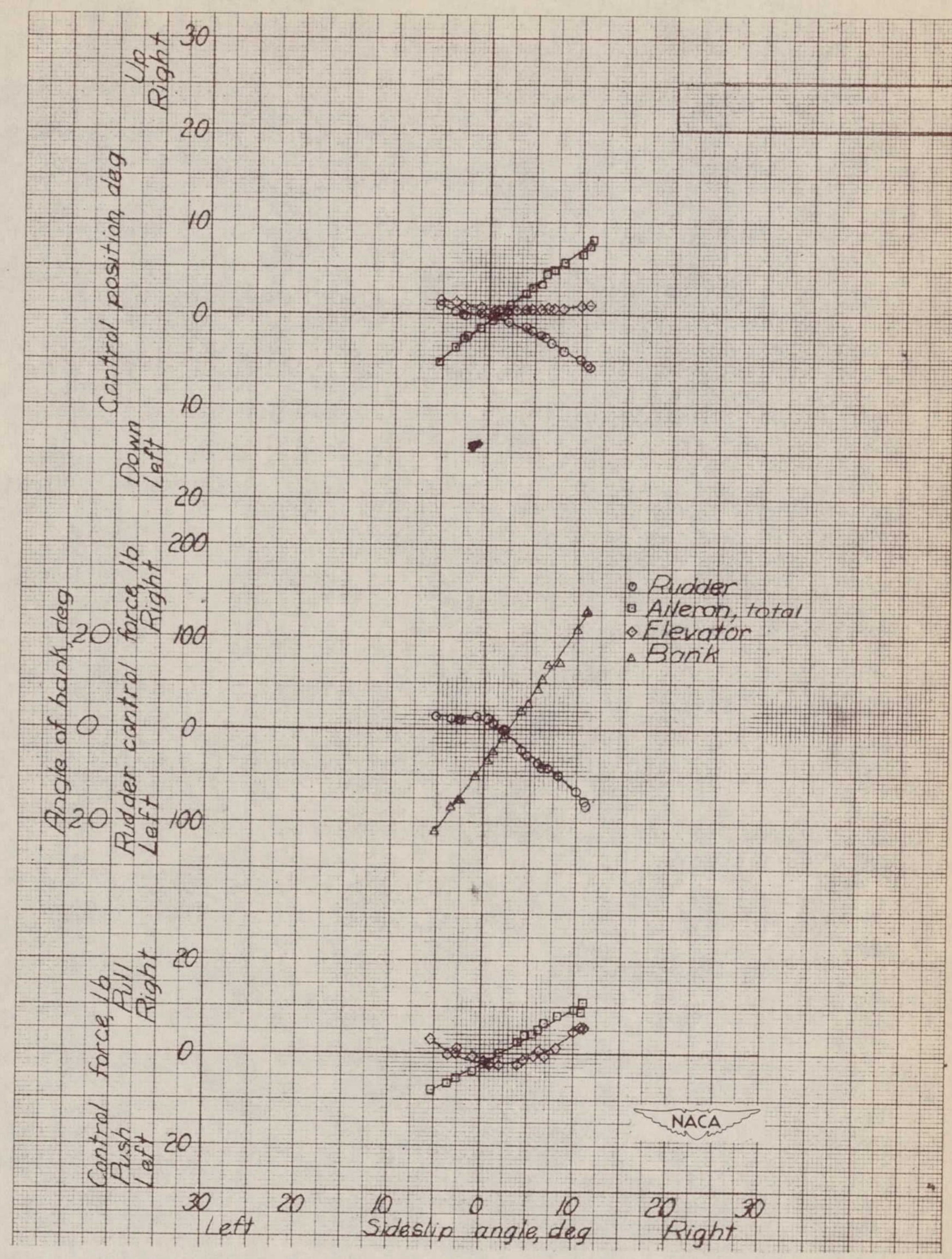
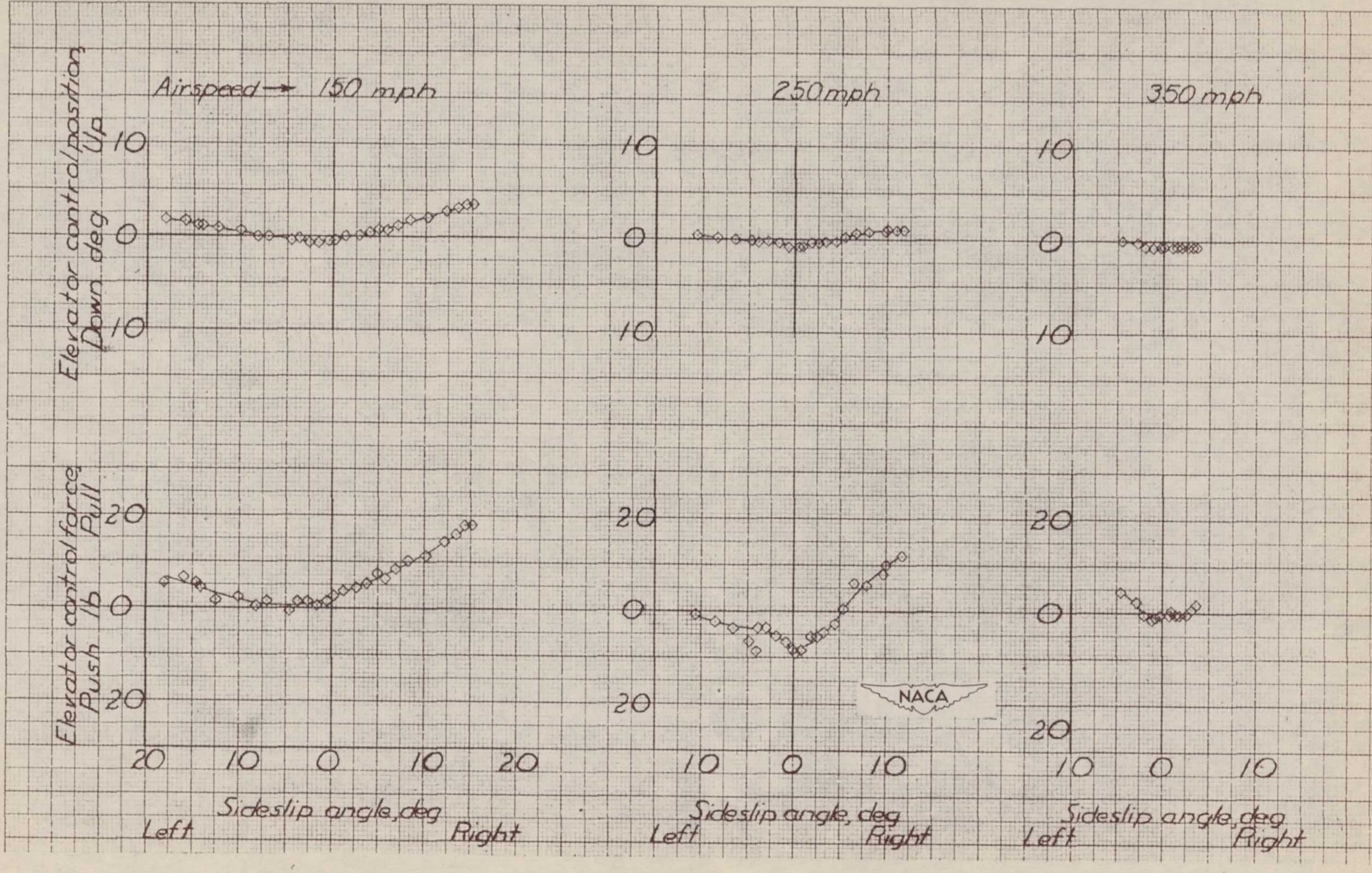
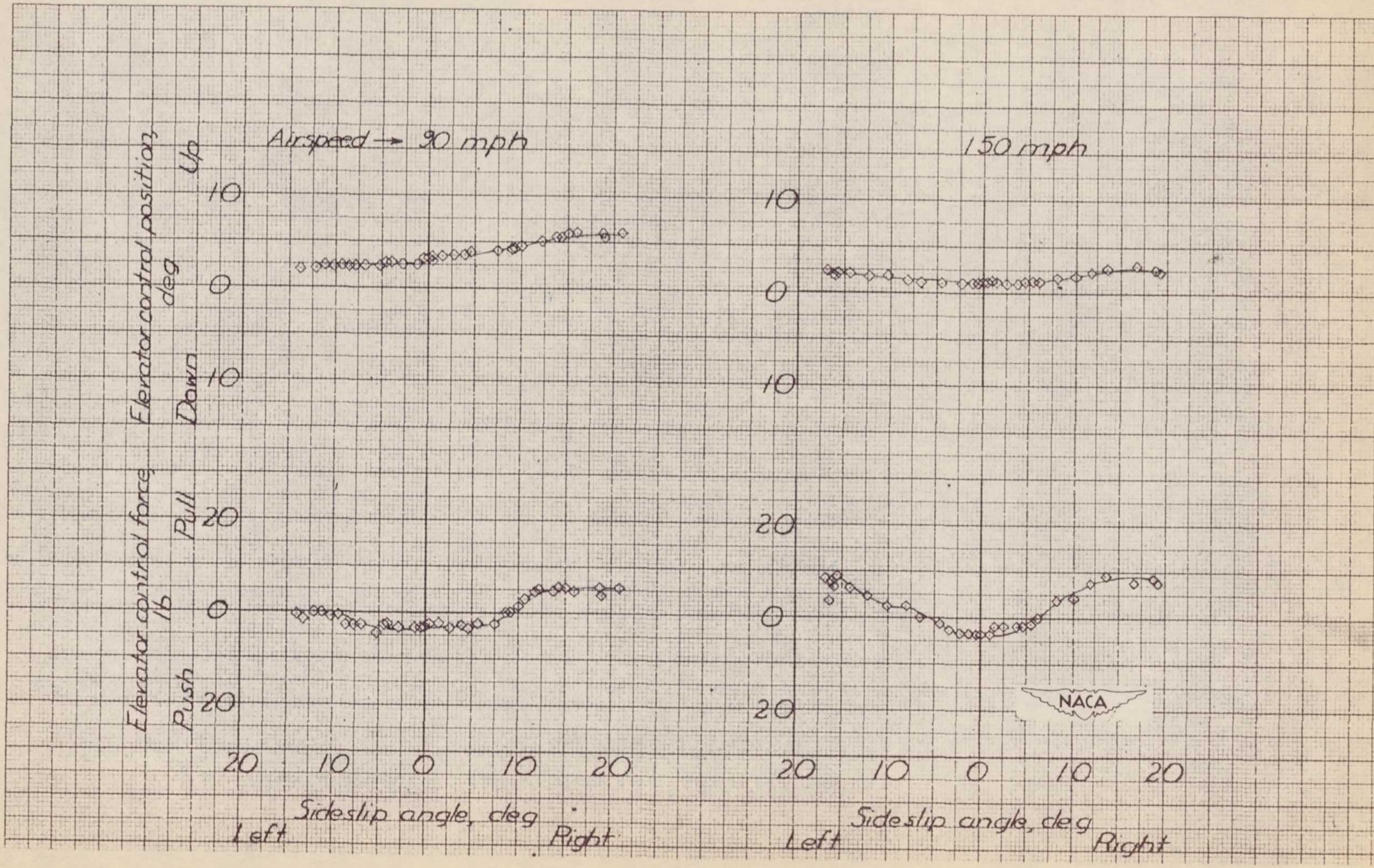


Figure 22.- Steady sideslips at 20,000 feet in the rated-power, clean condition (41 in. Hg at 2600 rpm) at 300 miles per hour with belly tank on. F8F-1 airplane with tail configuration 1.



(a) Rated-power, clean condition.

Figure 23.- Variation of elevator position and control force with angle of sideslip. F8F airplane with tail configuration 2.



(b) Power-approach condition.

Figure 23.- Concluded.

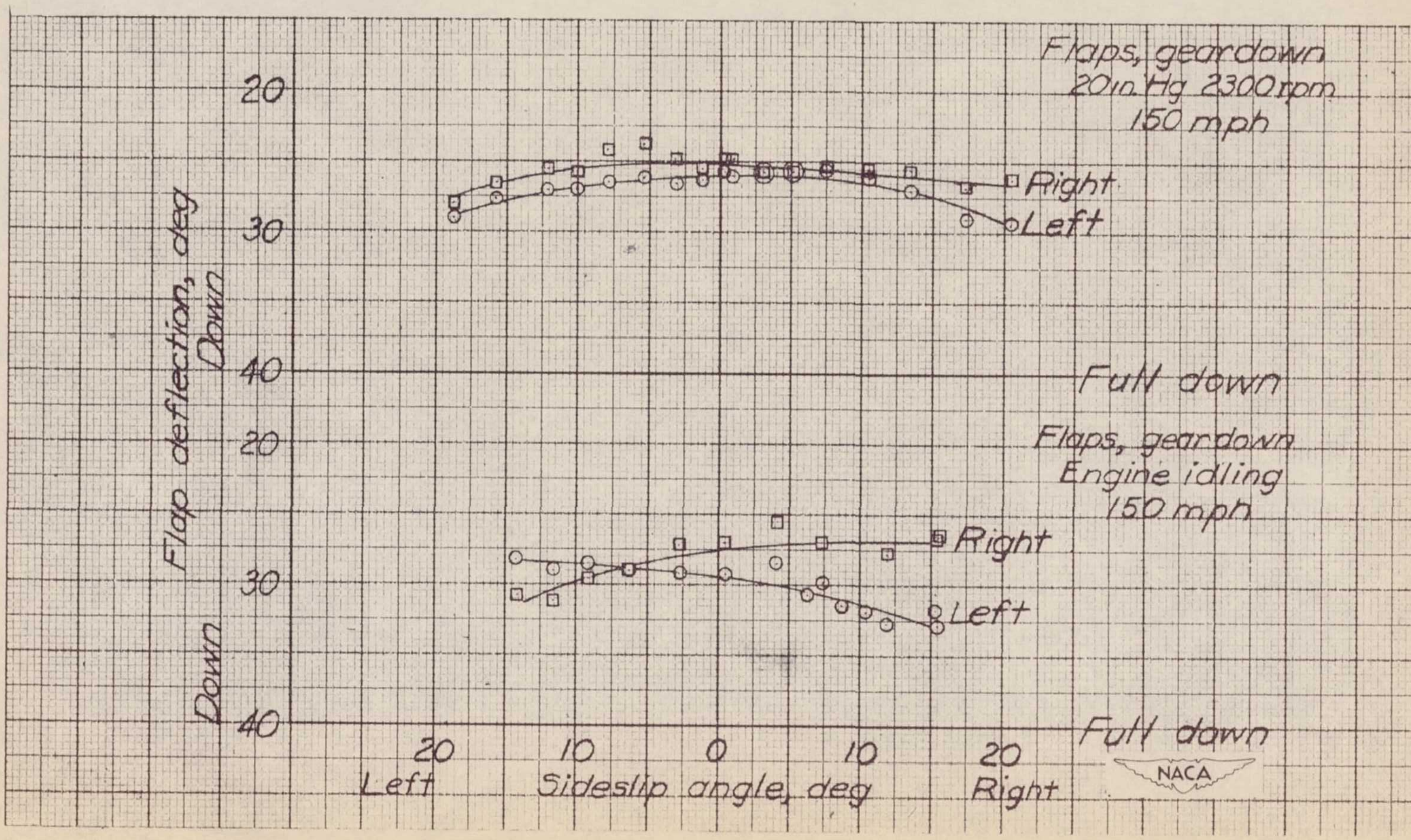
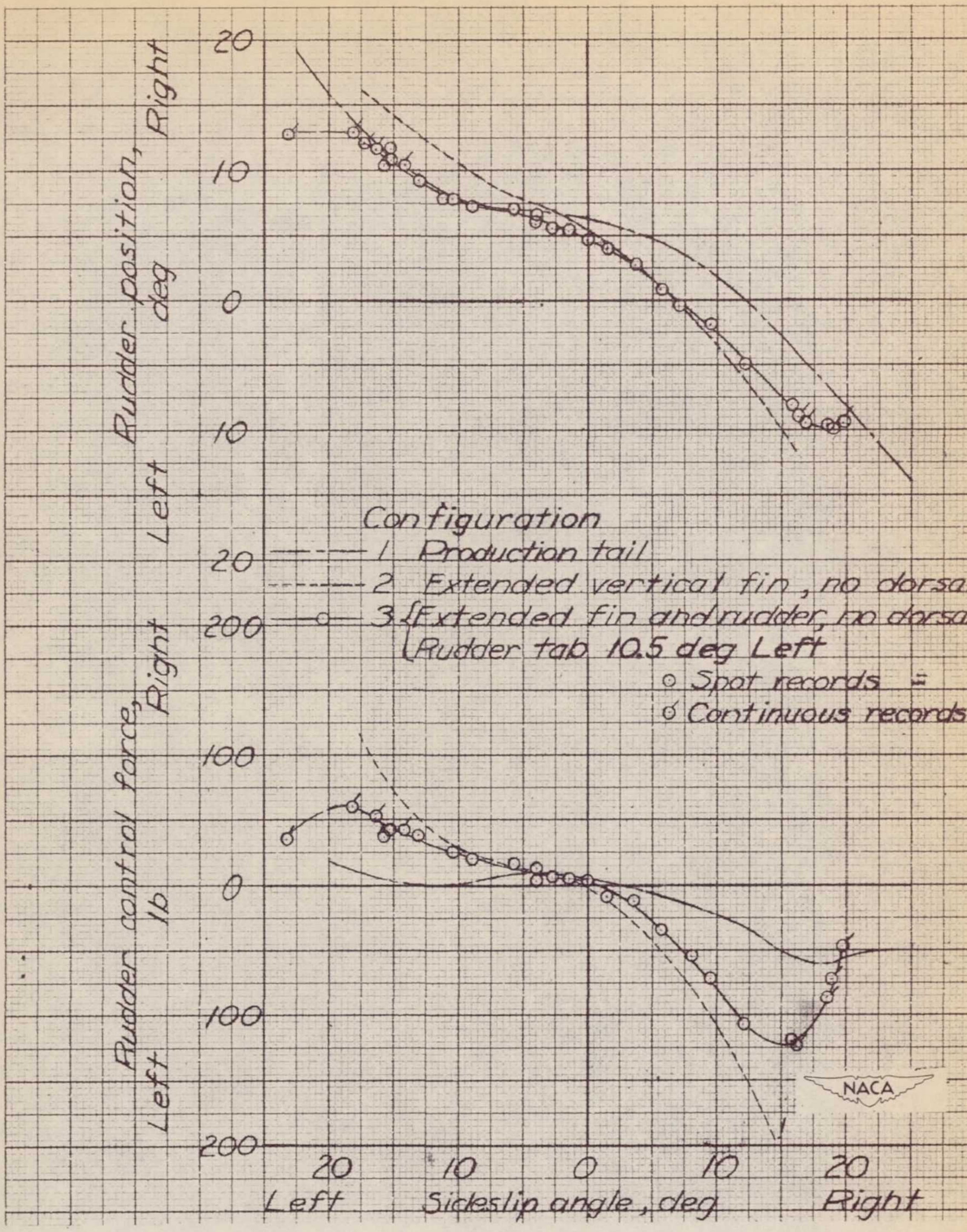
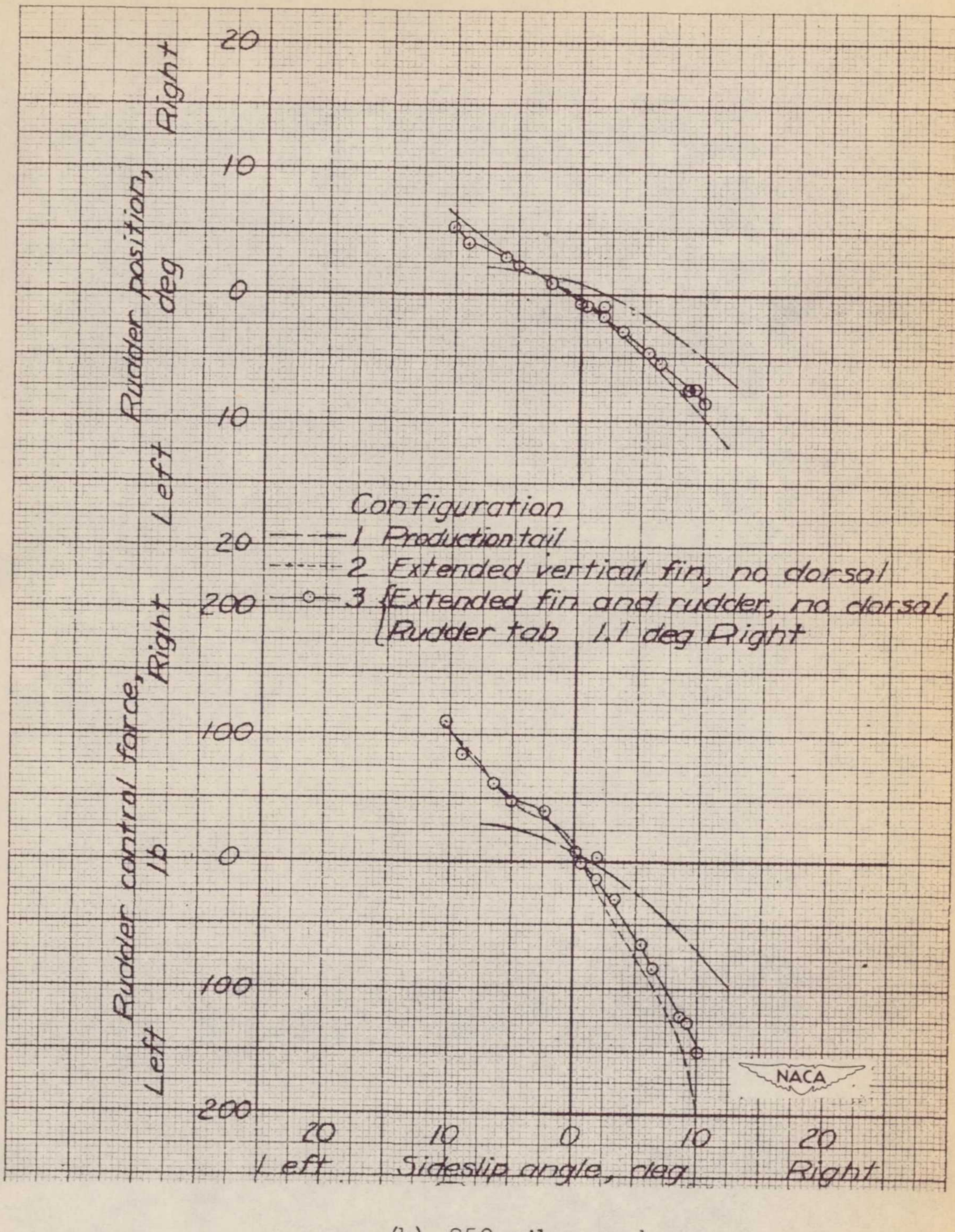


Figure 24.- Flap blow-up in sideslips at 150 miles per hour, belly tank on, F8F-1 airplane.



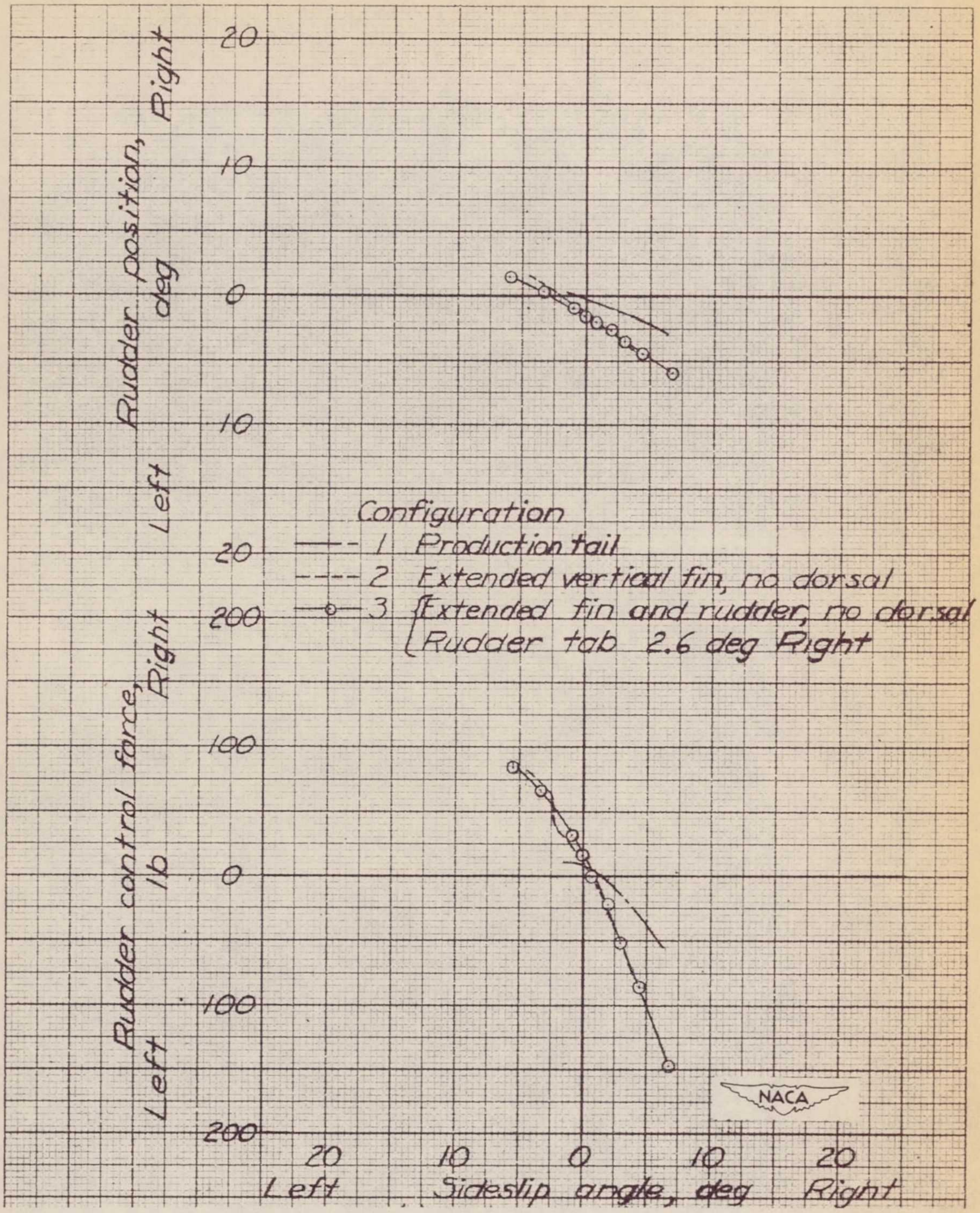
(a) 150 miles per hour.

Figure 25.- Steady sideslip characteristics in the rated-power, clean condition (41 in. Hg at 2600 rpm) with three vertical tail configurations. F8F-1 airplane.



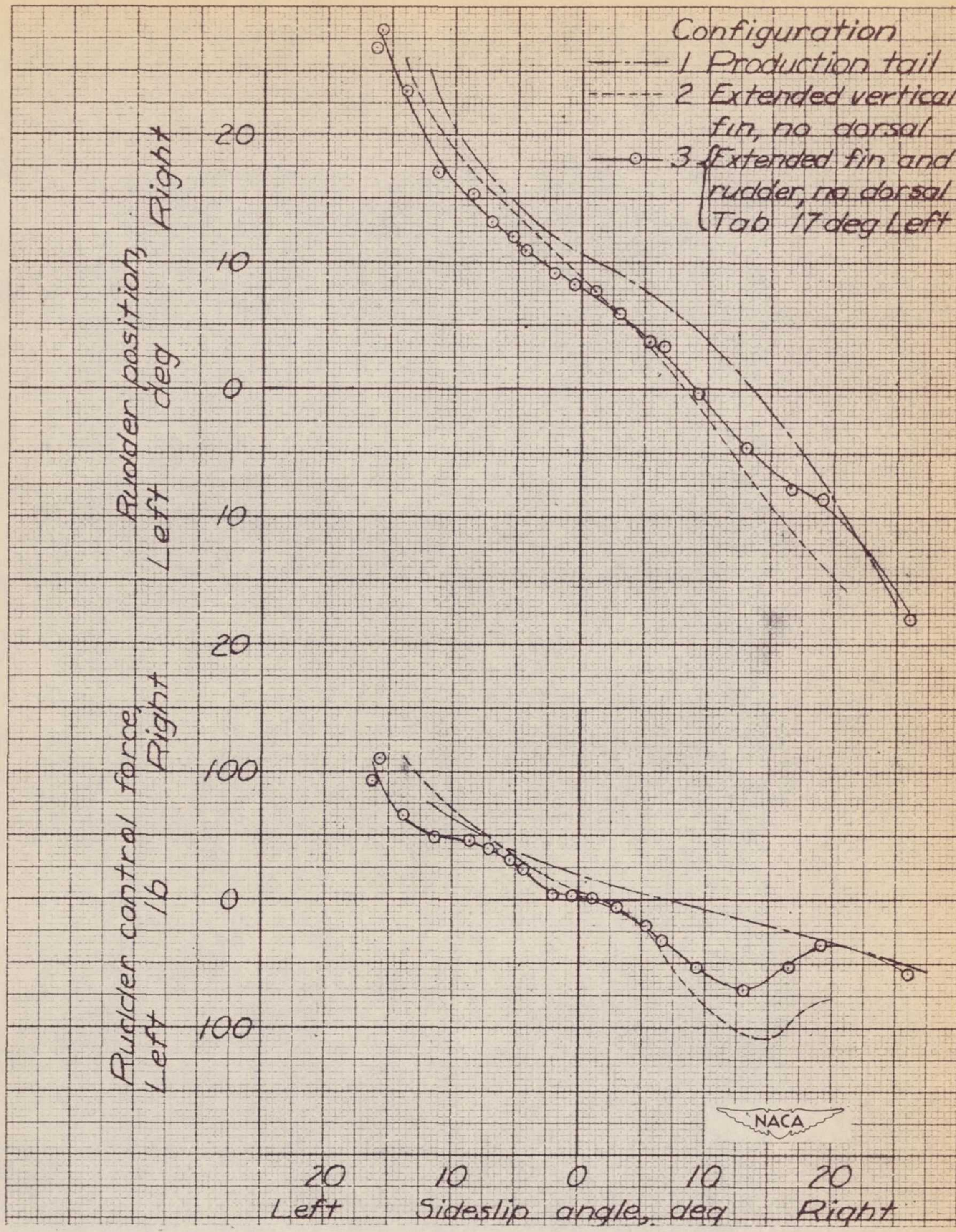
(b) 250 miles per hour.

Figure 25.- Continued.



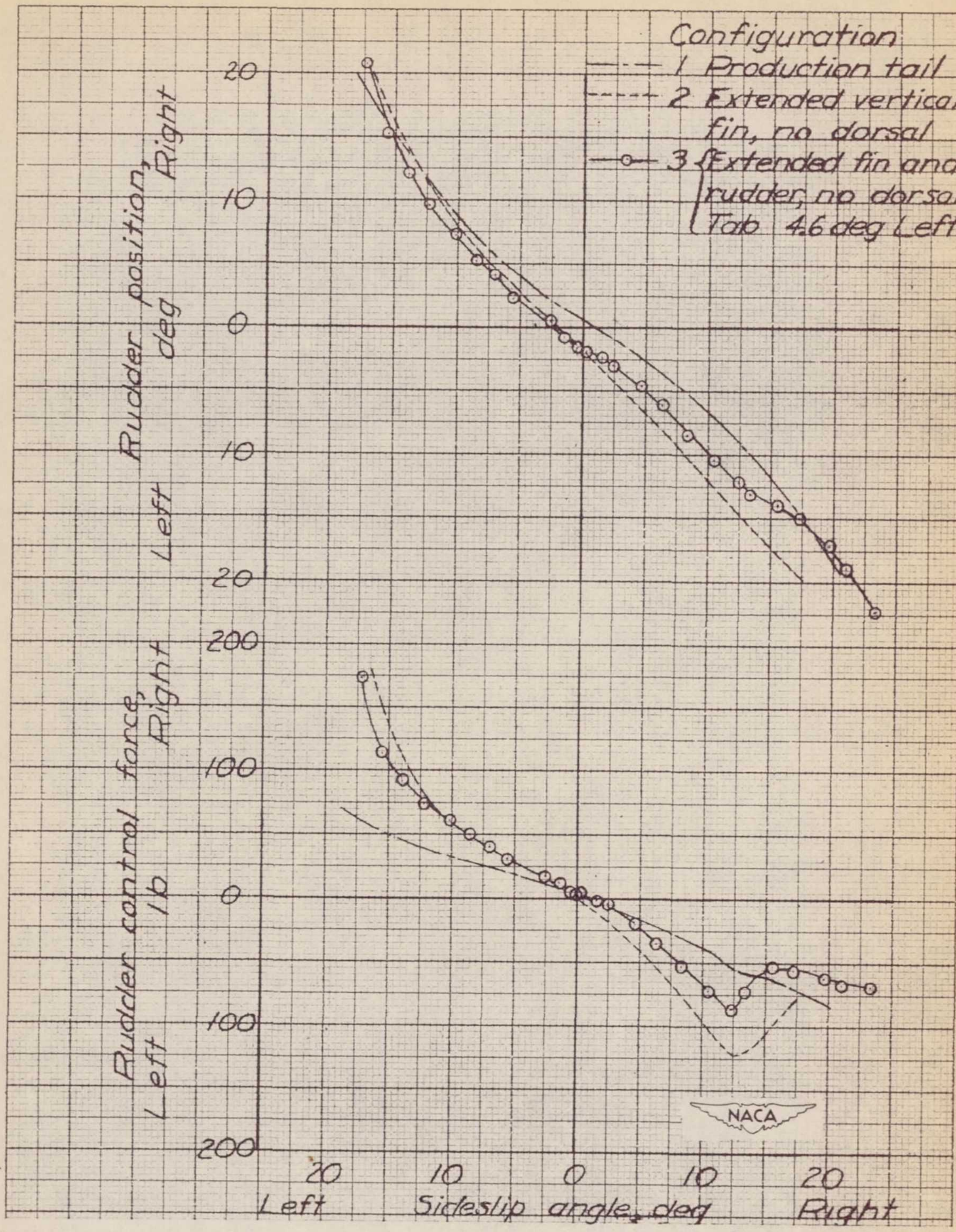
(c) 350 miles per hour.

Figure 25.- Concluded.



(a) 90 miles per hour.

Figure 26.- Steady sideslip characteristics in the power-approach condition (18-20 in. Hg at 2300 rpm), flaps and landing gear down with three vertical tail configurations F8F-1 airplane.



(b) 150 miles per hour.

Figure 26.- Concluded.

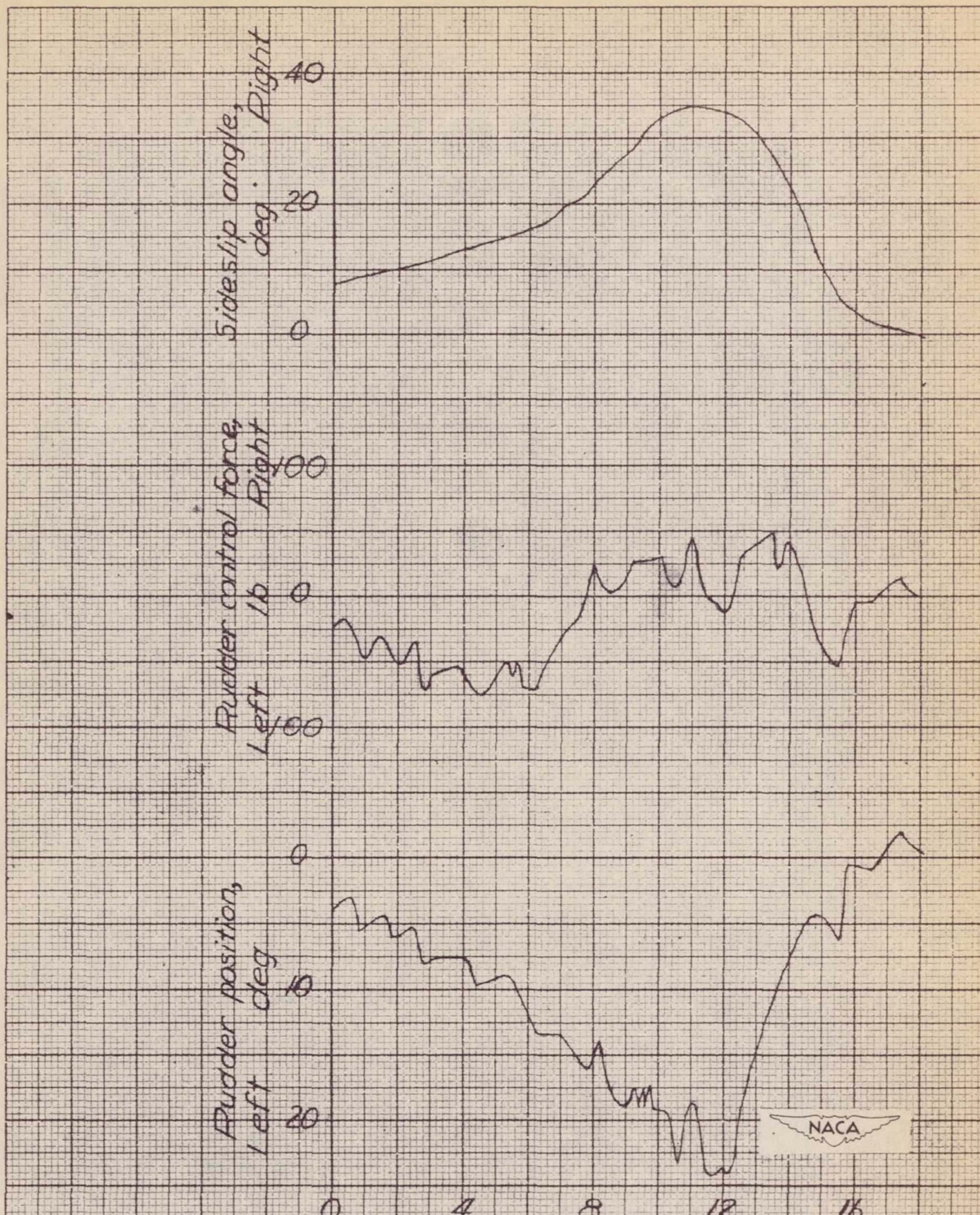


Figure 27.- Time history of right sideslip at approximately 120 miles per hour in the power-approach condition (30 in. Hg, 2200 rpm, flaps and landing gear down) during which rudder overbalance occurred, F8F-1 airplane with tail configuration three, belly tank on.

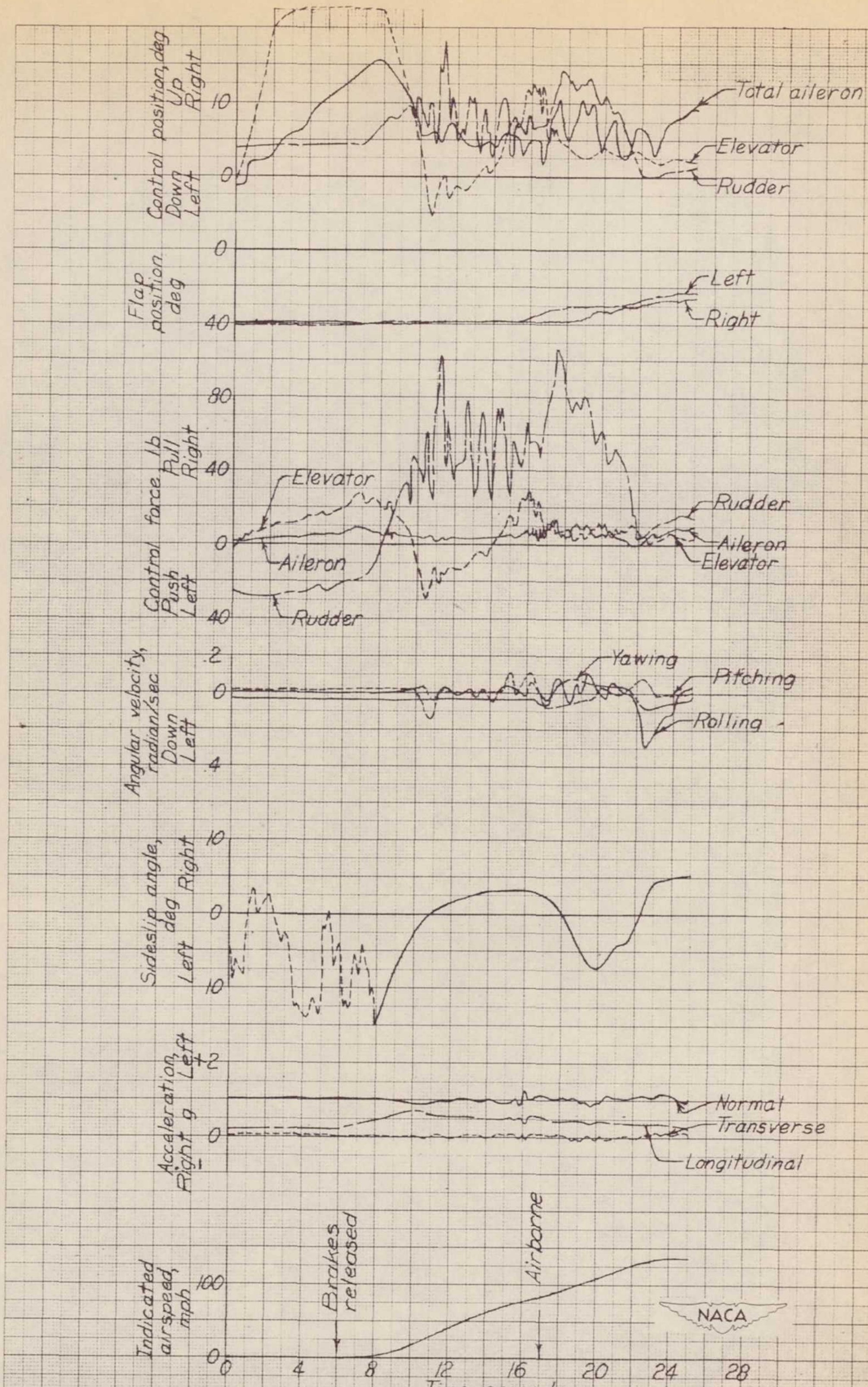
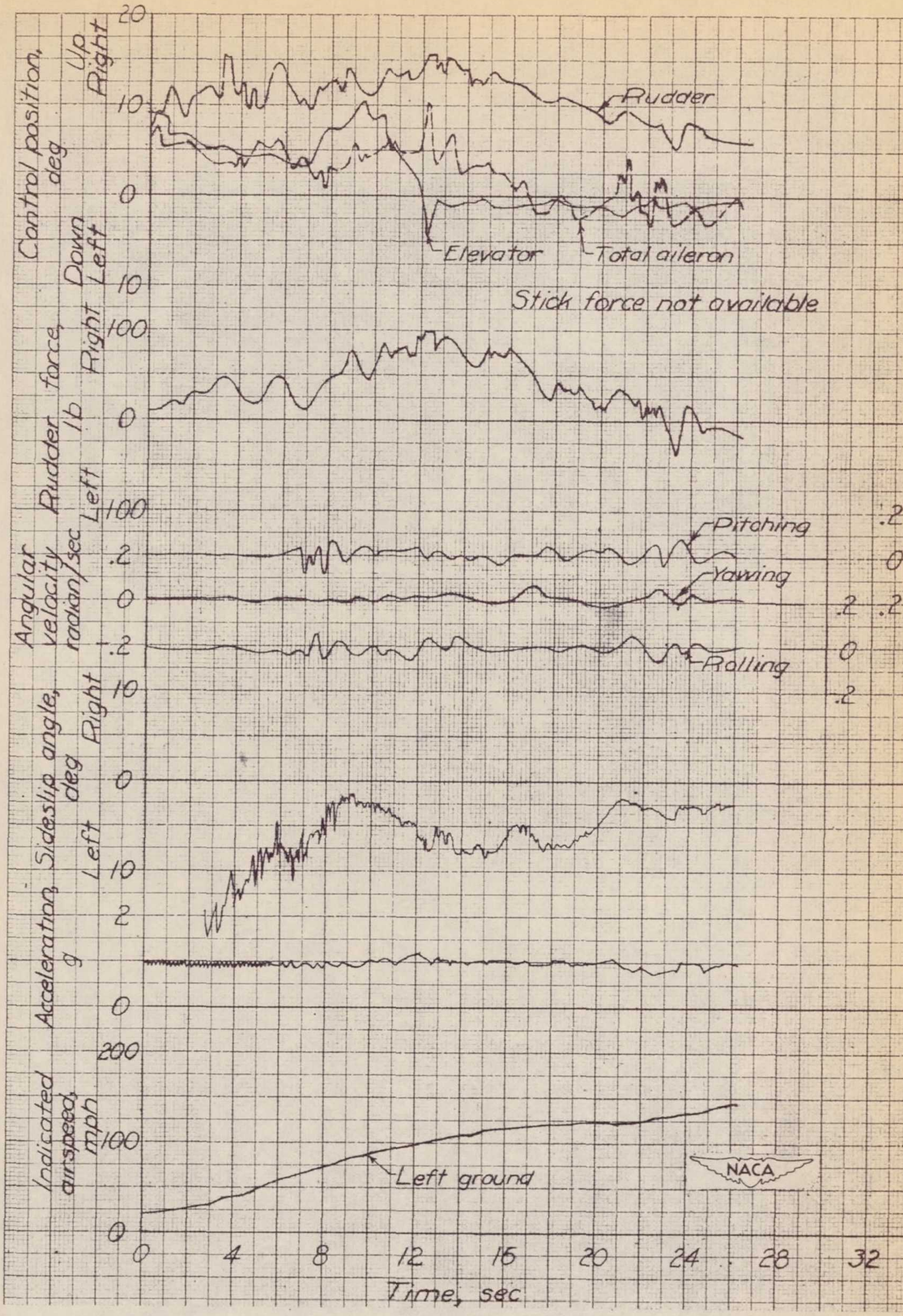
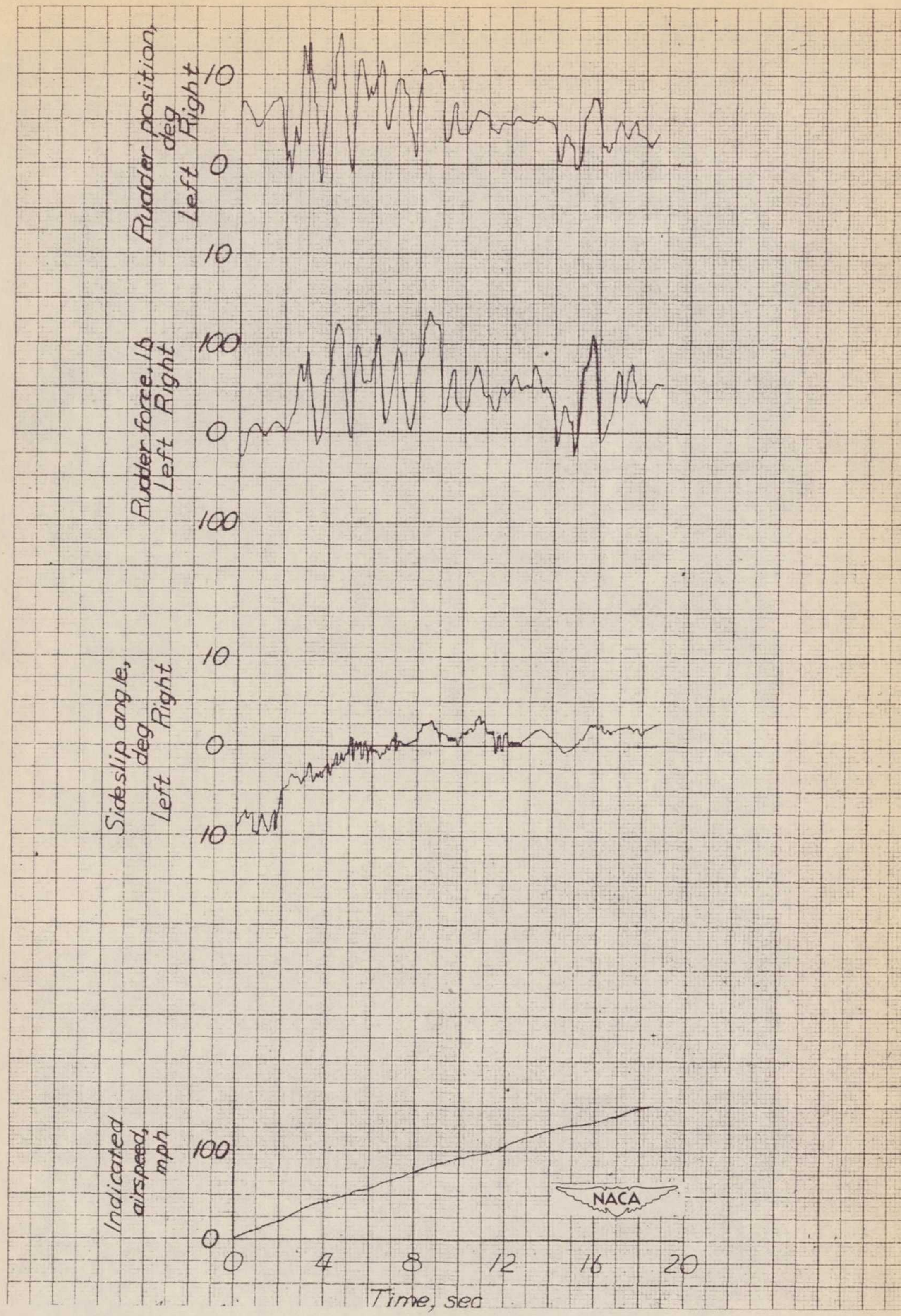


Figure 28.- Time history of simulated carrier take-off (54 in. Hg, 2800 rpm), by a service pilot. F8F-1 airplane with tail configuration 1.



(a) Made by NACA pilot.

Figure 29.- Time histories of take-offs, F8F-1 airplane with tail configuration 3.



(b) Made by service pilot. (Elevator and aileron records eliminated for clarity.)

Figure 29.- Concluded.

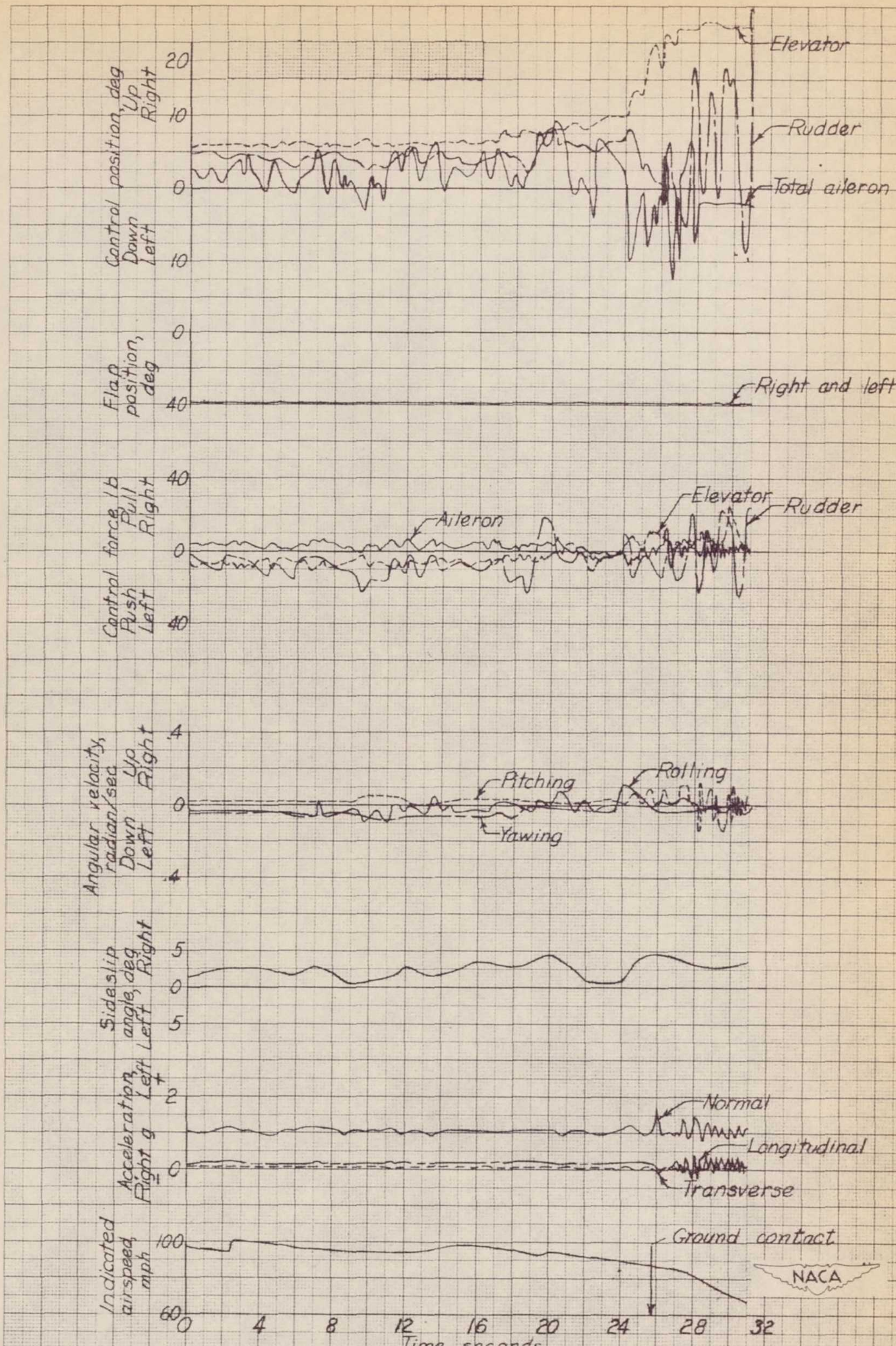


Figure 30.- Time history of simulated carrier landing (22 in. Hg, 2400 rpm), F8F-1 airplane, with tail configuration 1, made by service pilot.

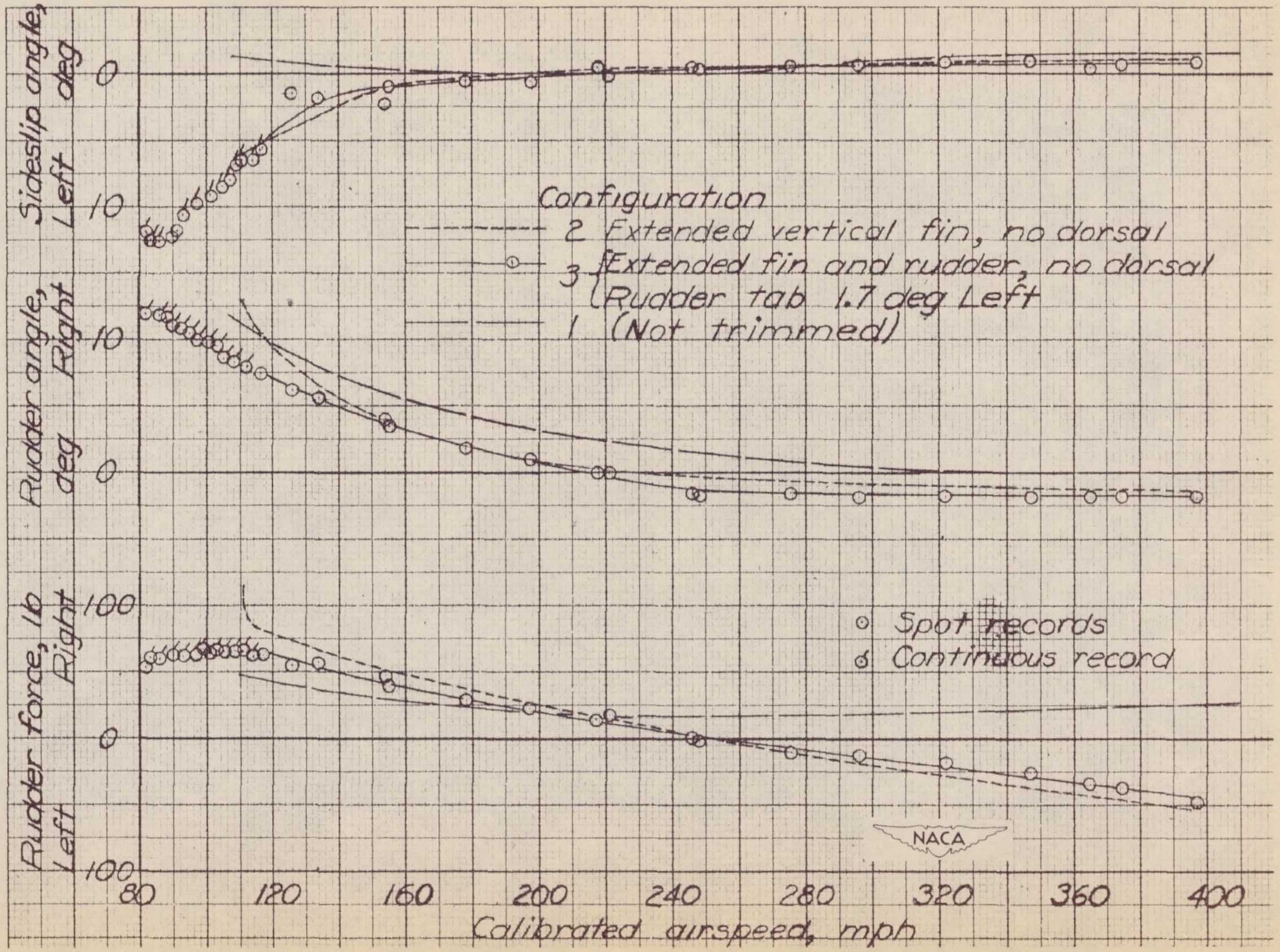


Figure 31.- Directional trim characteristics in the rated-power, clean condition (41 in. Hg at 2600 rpm), with three vertical tail configurations, F8F-1 airplane.

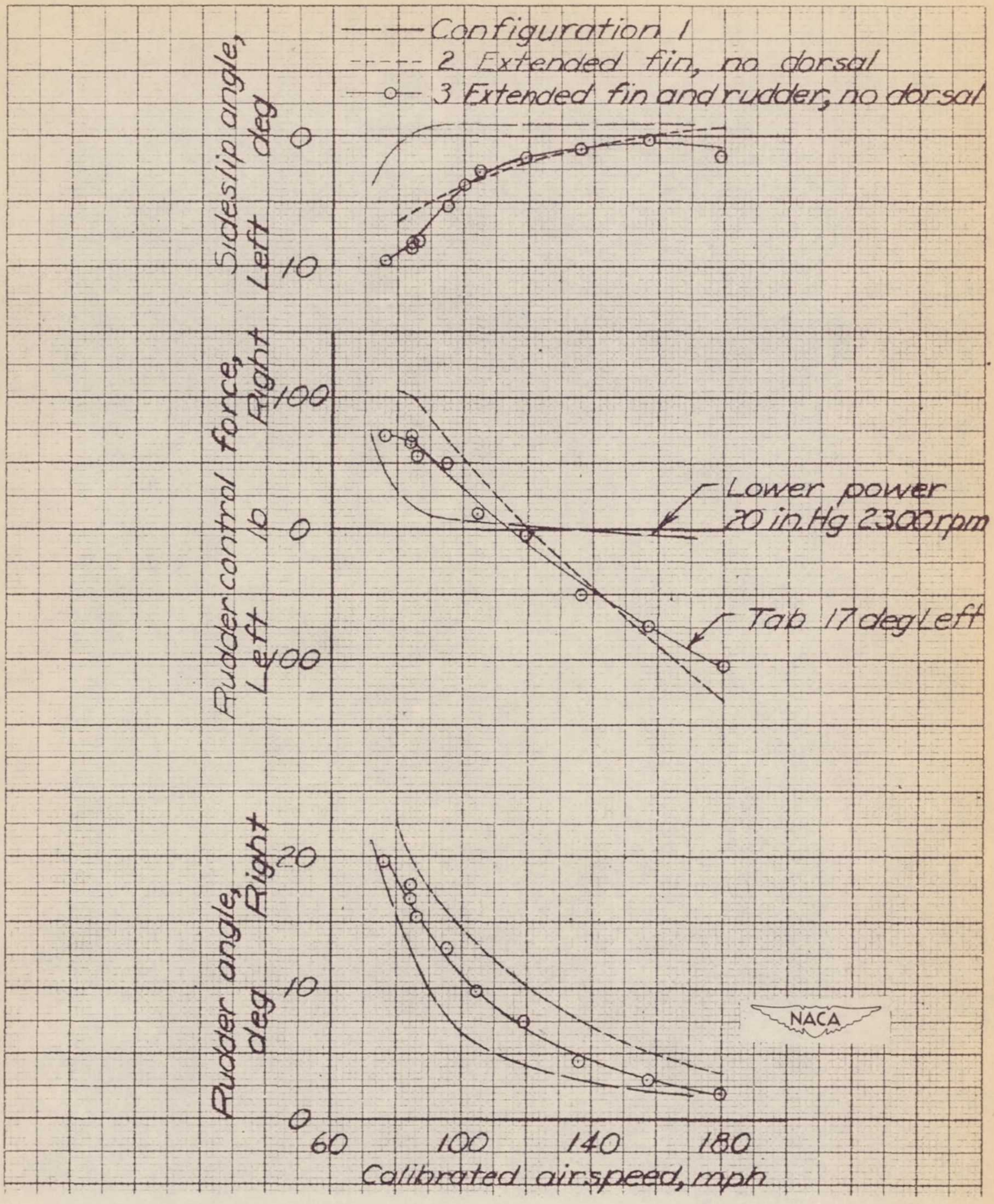
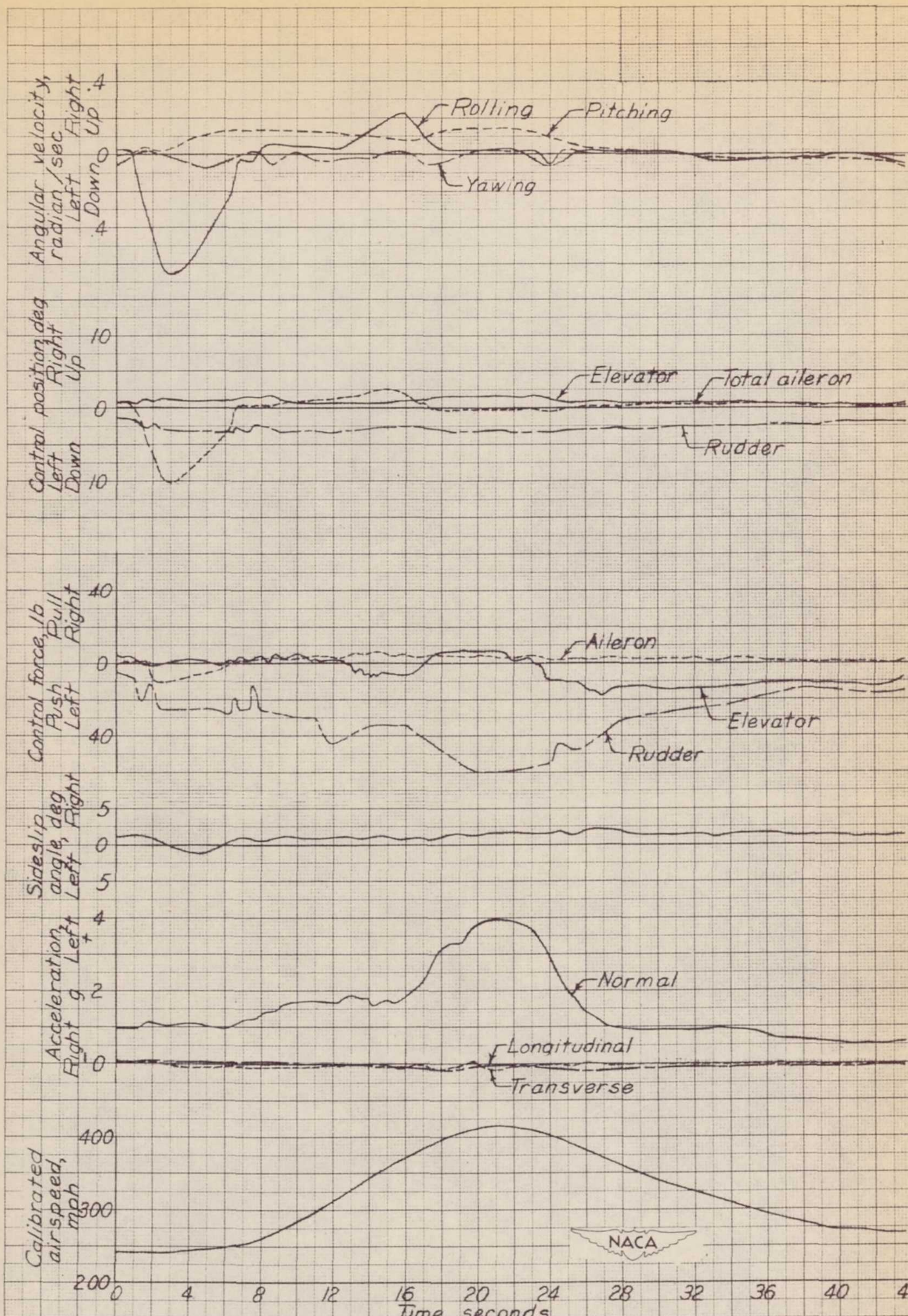
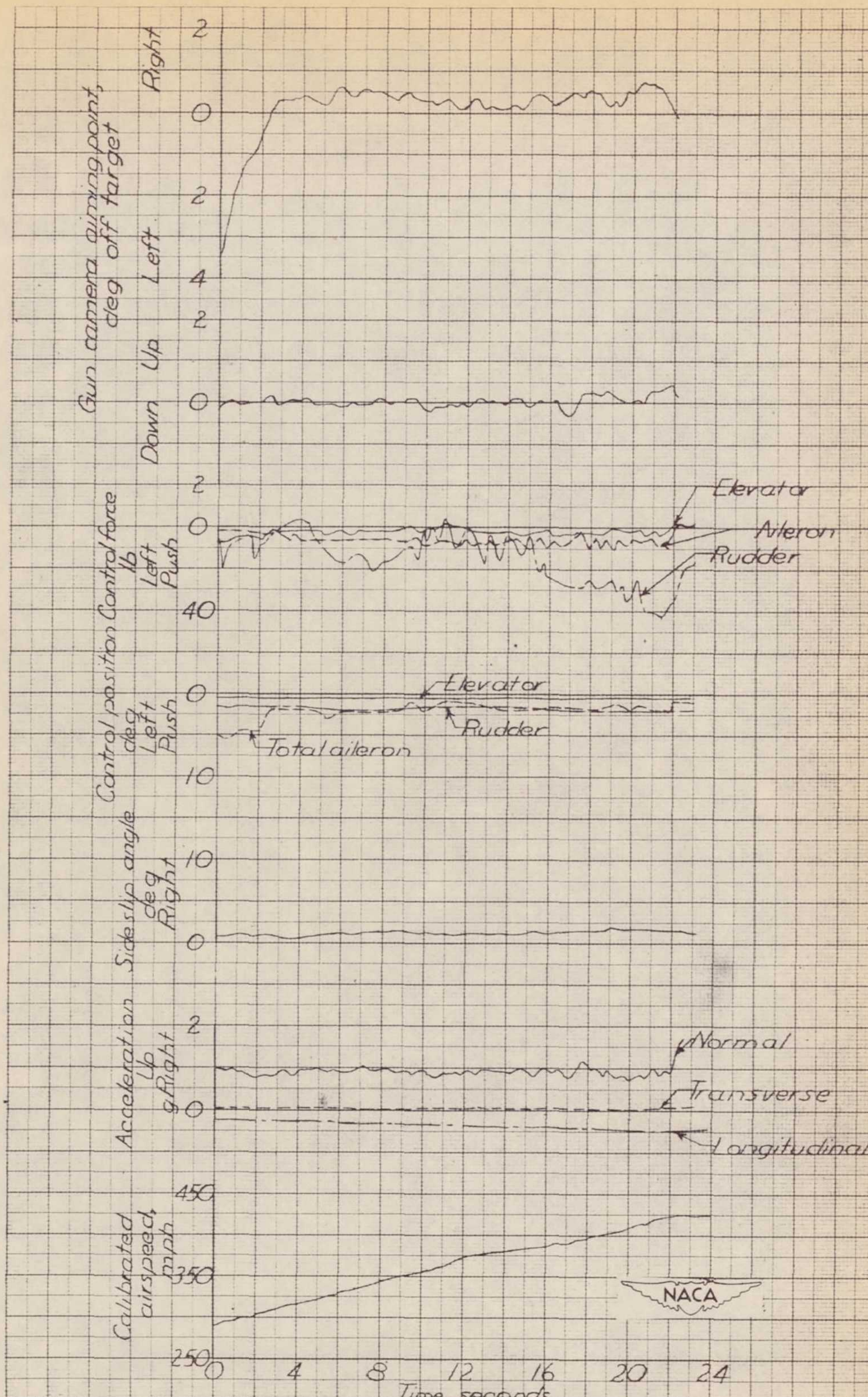


Figure 32.- Directional trim characteristics in the wave-off condition, flaps and landing gear down and normal rated power (41 in. Hg at 2600 rpm), with two modified vertical tail configurations, F8F-1 airplane.



(a) With tail configuration 1, made by service pilot.

Figure 33.- Time histories of strafing runs, F8F-1 airplane with belly tank on, oil coolers closed.



(b) With tail configuration 3, made by NACA pilot.

Figure 33.- Concluded.

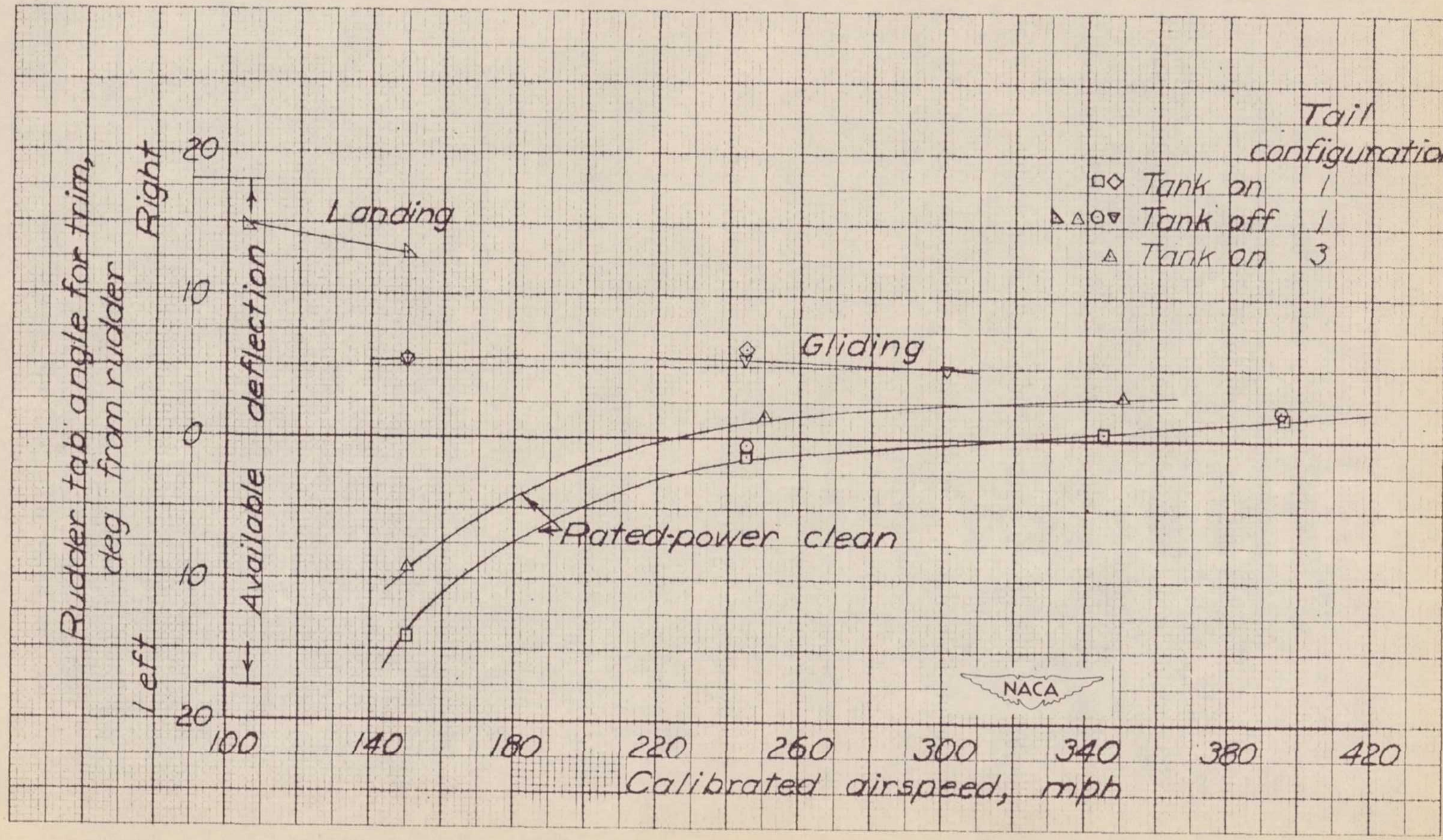
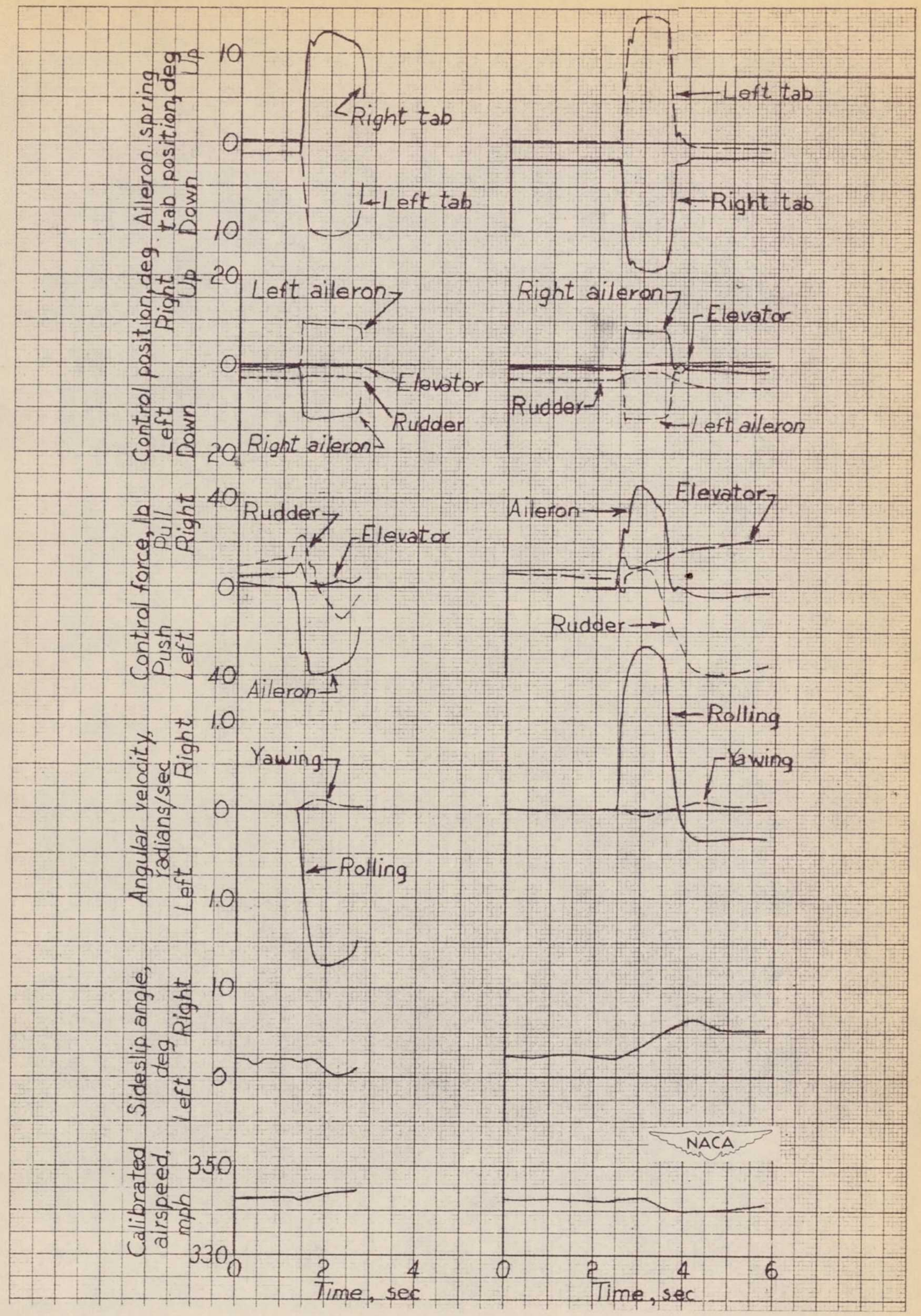
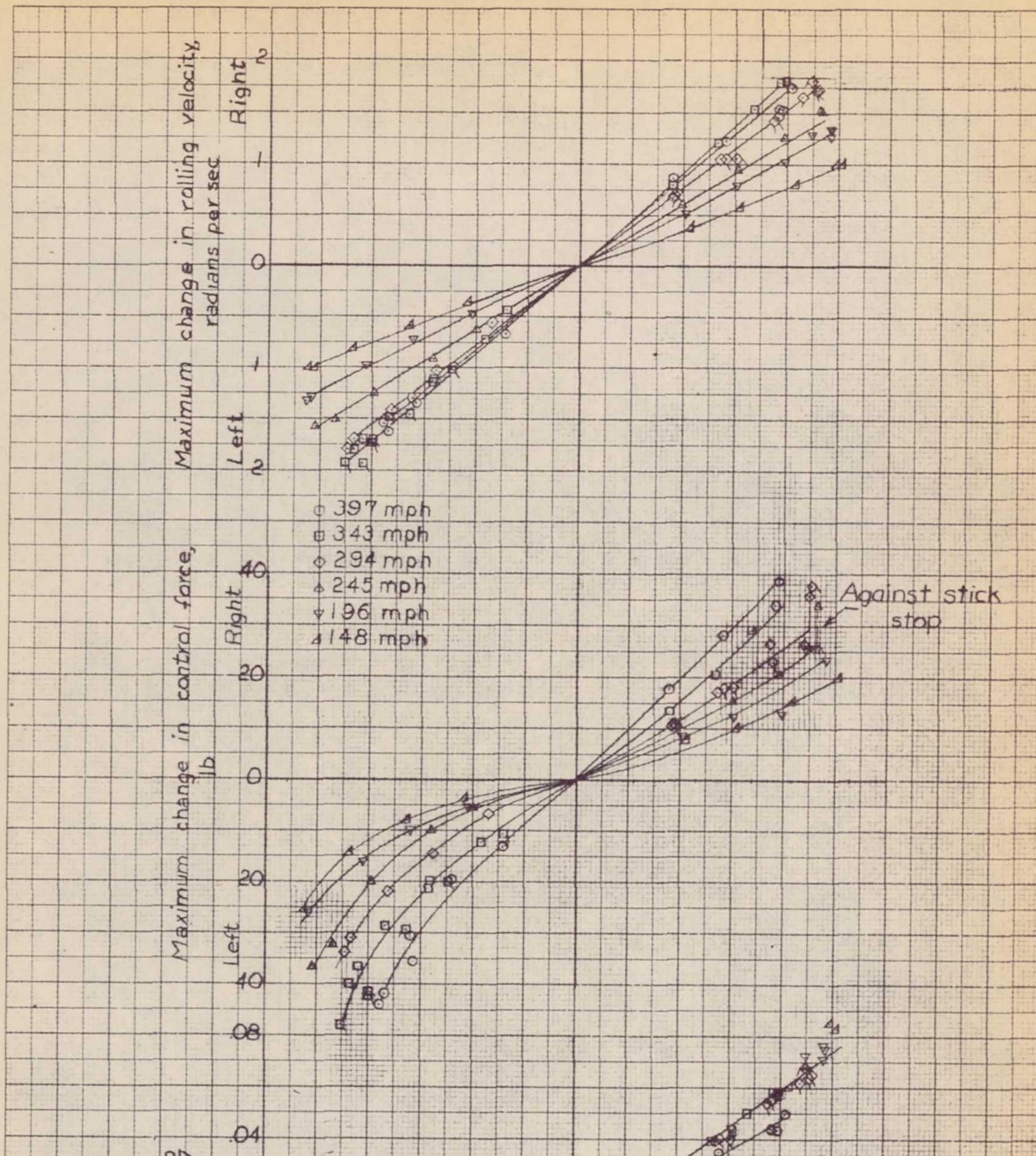


Figure 34.- Variation of rudder tab angle for trim with airspeed, F8F-1 airplane.



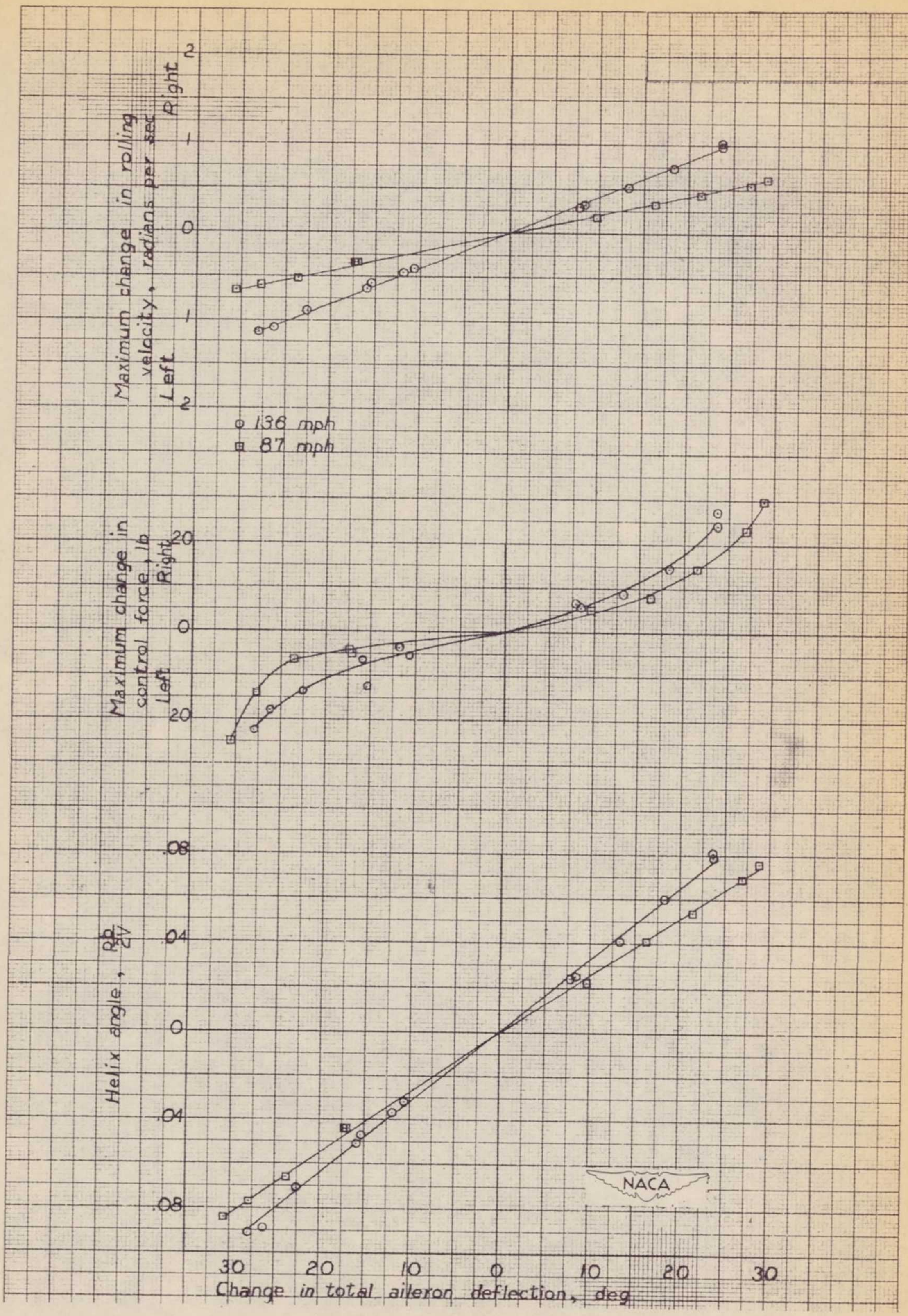
(a) Left roll. (b) Right roll.

Figure 35.- Time histories of rolls at approximately 340 miles per hour, rated power, flaps and gear up. F8F-1 airplane.



(a) Power for level flight, flaps and gear up.

Figure 36.- Aileron characteristics in rolls at 5000 feet, F8F-1 airplane.



(b) Power for level flight, flaps and gear down.

Figure 36.- Concluded.

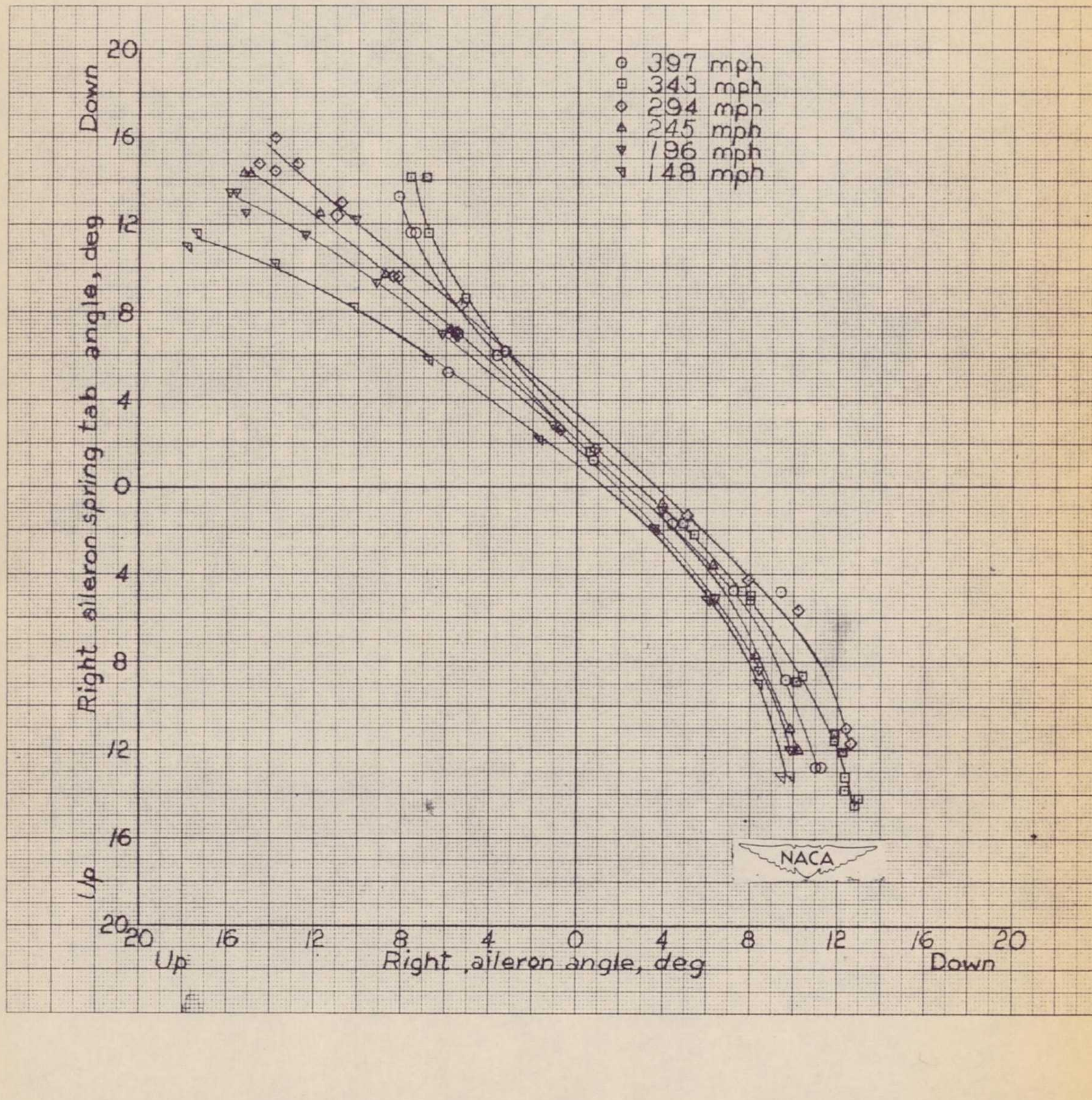


Figure 37.- Variation of right aileron spring tab angle with right aileron angle. Power for level flight, flaps and gear up. F8F-1 airplane.

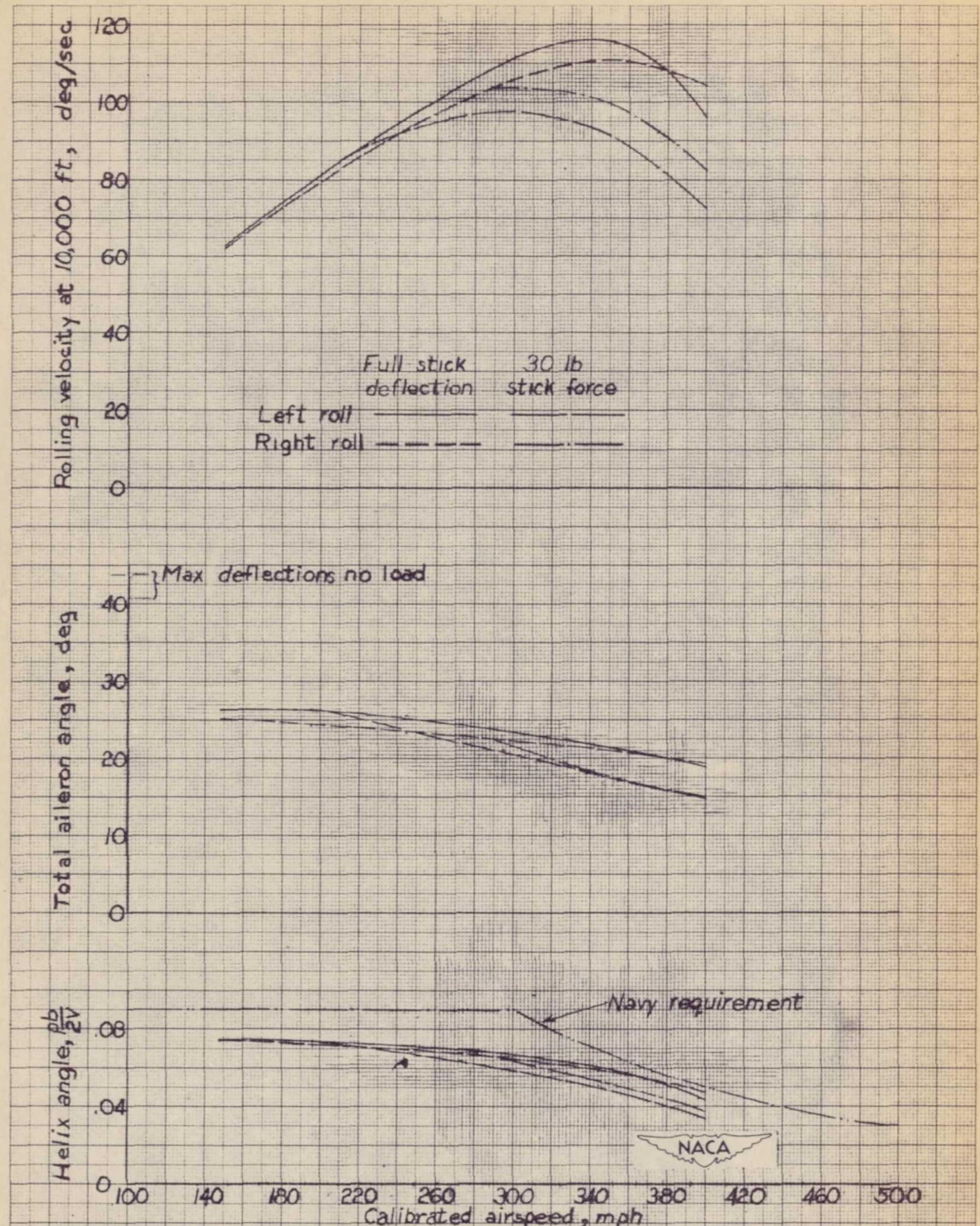


Figure 38.- Variation of rolling velocity at 10,000 feet, total aileron angle, and helix angle with indicated airspeed, power for level flight, flaps and gear up. F8F-1 airplane.

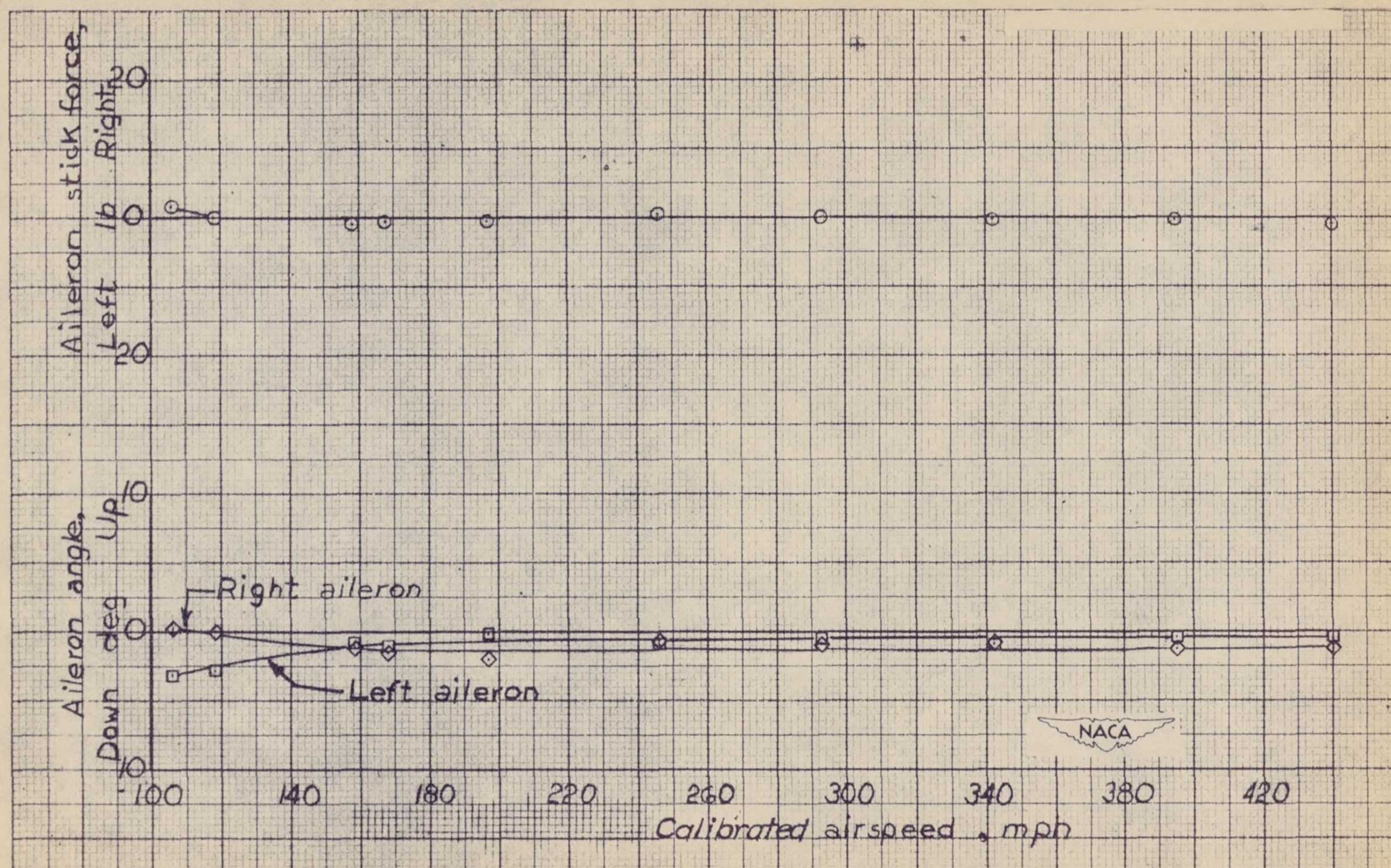


Figure 39.- Variation of aileron stick force and aileron angle with indicated airspeed, rated power, flaps and gear up, F8F-1 airplane (90461).