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RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

MEASUREMENTS OF THE LATERAL AND DIRECTIONAL STABILITY AND CONTROL CHARACTERISTICS OF A P-51H AIRPLANE

(AAF No. 44-64164)

By

Christopher C. Kraft, Jr. and J. P. Reeder

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Langley Field, Va.

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RESEARCH MEMORANDUM

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MEASUREMENTS OF THE LATERAL AND DIRECTIONAL STABILITY AND CONTROL CHARACTERISTICS OF A P-51H AIRPLANE

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SUMMARY

Flight tests of a P-51H airplane with two different vertical-tail assemblies were made to determine lateral and directional stability and control characteristics. The airplane had satisfactory directional stability in the landing, approach, and wave-off conditions with either tail. In the power-on clean and glide conditions, however, the airplane had weak directional stability with the original tail. The production tail, which had a 7-inch fin extension and a shorter span rudder, improved the directional stability in the power-on clean and glide conditions, but the stability was still weak in the power-on clean condition. Increased altitude in either case caused a slight decrease in the stability. The rudder-trim-force change with speed with either vertical-tail assembly was high. The general aileron control characteristics were satisfactory but the aileron effectiveness failed to meet the Army handling-qualities requirements.

INTRODUCTION

At the request of the Air Materiel Command, Army Air Forces, flight tests have been made to determine the lateral and directional stability and control characteristics of a North American P-51H airplane with the original and the production vertical-tail assemblies. Tests of the longitudinal stability and control and stalling characteristics will be presented in a later paper.

For previous tests of the P-51D airplane, the NACA designed and built a fin extension for this airplane to improve its directional stability. Very satisfactory results were obtained from the addition of this extension as reported in reference 1. When the P-51H airplane was brought out, the North American Aviation, Inc. conducted preliminary flight tests at the same time as the NACA, and found the need for increased directional stability. They therefore added a fin extension in accordance with the design previously developed by the NACA for the P-51D airplane. This extended tail on the P-51H airplane is designated as the production tail. At the time these tests were being made, the Army Air Forces were very much interested in obtaining this particular airplane for use in the war in the Pacific. Therefore, the NACA conducted tests on both the original and the production tails in order to determine the improvement in directional stability that resulted from this change.

DESCRIPTION OF AIRPLANE AND TESTS

The P-51H is a low-wing fighter airplane equipped with a Merlin V-1650-9 engine (fig. 1). The original vertical tail had a full-span rudder with $\pm 30^{\circ}$ travel and the production vertical tail had a 7-inch fin extension and a shorter span rudder with the travel limited to $\pm 25^{\circ}$. The original rudder had a 0.4 to 1 unbalancing tab which also served as a trim tab, whereas the production rudder had only a trim tab. Both fins were offset 1° left from the thrust axis. A photograph of the airplane showing a comparison of the two vertical tails is shown in figure 2 and a drawing of the two tails, in figure 3. Photographs of the airplane with the production tail are shown in figures 4 to 6. Pertinent dimensions of the airplane are given in table I.

All of the control surfaces were metal covered and the ailerons had sealed internal balances. The variations of the elevator and aileron position with stick position and rudder-angle variation with rudder-pedal position are shown in figures 7 to 9 and the friction in these control systems is shown in figure 10. The stretch in the aileron control system was 2.5° per 20 pounds of control force, and the stretch in the rudder control system was 7.5° per 100 pounds of rudder-pedal force. These characteristics are shown in figure 11.

The airplane was tested in the configurations shown in the following table. The center of gravity for these tests was at 24.4 percent mean aerodynamic chord at take-off with the wheels down.

Condition	Power	Flaps	Gear	Canopy
Glide (power-off clean)	Engine idling	Up	Up	Closed
Power on clean	46 in. Hg at 2700 rpm	Up	Up	Closed
Landing	Engine idling	Down	Down	Open
Approach	23 in. Hg at 2700 rpm	Down	Down	Open
Wave-off	46 in. Hg at 2700 rpm	Down	Down	Open

In addition, tests were run at high altitude in the glide and power-on clean conditions. These tests were run for both the vertical-tail assemblies.

The sideslip data given in this paper were obtained by the steady-sideslip method; that is, the airplane was sideslipped to a certain angle, and when conditions were steady, a record was taken of the various quantities indicated in the section on instrumentation.

INSTRUMENTATION

Standard NACA photographic recording instruments were used to obtain the data contained in this paper along with pilot's readings of altitude, free-air temperature, and fuel-gage readings. The following recording instruments were installed in the test airplane:

Accelerometer (three-component)
Stick-force recorder
Rudder-pedal-force recorder
Airspeed recorder
Roll turn meter
Pitch turn meter
Yaw turn meter
Recording inclinometer (angle of bank)
Sideslip-angle recorder
Control-positon recorders
Timer (synchronizing all records)

The airspeed was measured by means of a swiveling static head and a shielded total head mounted on a boom approximately 1 chord length ahead of the right wing tip. (See fig. 5.) The airspeed installation was calibrated for position error by means of a trailing airspeed head that measured the static pressure in the free-air stream. The trailing airspeed head and the reel were built into an auxiliary droppable fuel tank which was attached to the airplane under the right wing and operated by the pilot from the cockpit. With the airspeed head trailing, the airplane was flown at a series of speeds from the stall to 250 miles per hour and the position error of the airplane's static pressure head was determined from these data. The term "calibrated airspeed" as used in this paper may be defined by the following equation:

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

where

V_c calibrated airspeed in miles per hour; that is, the reading in miles per hour that would be given by a standard Army-Navy airspeed meter if it were connected to a pitot static system free from position error

f_o standard sea-level compressibility correction factor

q_c pressure differential in inches of water between total and static head, corrected for position error

The yaw vane used to measure the angle of sideslip was mounted on a boom approximately 1 chord length ahead of the left wing tip. (See fig. 5.) The term "indicated sideslip" used in this paper is the uncorrected value given by the yaw vane. The change in sideslip angle is believed to be correct, but the exact magnitude may be in slight error because of the lack of symmetry of the yaw vane and/or angularity of flow at the yaw vane.

LATERAL AND DIRECTIONAL STABILITY AND CONTROL

The discussion of results that follows is based on the flying-qualities requirements set forth in reference 2.

Dynamic Directional Stability

The dynamic directional stability of the airplane was tested in all of the different configurations at various speeds. These tests were performed by trimming the airplane at a certain speed and starting an oscillation by deflecting and releasing the rudder quickly or by starting the oscillation from about 5° of steady sideslip. There was no oscillation of the rudder itself in any configuration at any speed or altitude. In the power-on clean condition, when the oscillation was started from a left sideslip or a right rudder kick, the ensuing motion of the airplane resulted in a spiral to the left. Typical time histories of these oscillations are shown in figures 12 to 16.

Static Directional Stability

Power-off clean condition.- In the power-off clean condition (figs. 17 and 18), the airplane with the original vertical tail possessed positive rudder-fixed and rudder-free stability, but the parameters $\frac{d\delta_r}{d\beta}$ and $\frac{dF_r}{d\beta}$ (the variation of rudder angle and rudder force required for trim with sideslip angle) through zero sideslip were low; this was especially so at the speed of 150 miles per hour (fig. 17(a)). With the production tail the airplane had good rudder-free and rudder-fixed stability and showed a marked improvement over the airplane with the original tail assembly. The dihedral effect in both configurations was positive and satisfactory.

The effect of altitude was to decrease the stability in both of the configurations (fig. 18) except at 150 miles per hour with the original tail where there was little change in $\frac{d\delta_r}{d\beta}$. (The actual values of $\frac{d\delta_r}{d\beta}$

and $\frac{dF_r}{d\beta}$ for the conditions tested are given in table II. These values are only approximate because of the scatter of test points in some of the conditions tested.)

Power-on clean condition.- The airplane in the power-on clean condition (figs. 19 and 20) had positive rudder-fixed and rudder-free stability through zero sideslip with both the original and the production vertical-tail configurations. However, with the original tail, at the speed of 150 miles per hour (fig. 19(a)) a flattening of the rudder-force variation occurred between 7° and 16° of left sideslip angle, and the airplane had neutral to negative stick-fixed and stick-free dihedral effect beyond 10° left sideslip and neutral stick-free dihedral effect beyond 15° right sideslip. The large angles of sideslip that can be obtained with this configuration are also objectionable at this speed. At the higher speeds, 300 and 400 miles per hour, the directional stability improved but the values of $\frac{d\delta_r}{d\beta}$ were still low.

Although the airplane with the production tail was an improvement over the airplane with the original tail, the rudder-free stability through zero sideslip at 150 miles per hour was still low. There was no negative dihedral effect at any speed and the stability at high speeds was satisfactory. It should be noted that the increased tail height corrected the negative dihedral effects experienced at large angles of sideslip with the original tail.

The effect of altitude was to decrease the stability in both configurations and at all the speeds tested. At 150 miles per hour with the original tail, the rudder-force curve reverses in slope from 10° to 20° left sideslip and reduces to 5 pounds of rudder force at 20° left sideslip. The negative dihedral effect at large sideslip angles was also pronounced at high altitude (fig. 20(a)). At both the high speeds tested, 300 and 350 miles per hour, the rudder-fixed stability was low and the slope $\frac{d\delta_r}{d\beta}$ appeared to be practically zero through the rangle of left sideslip angles.

The airplane with the production tail still had positive rudder-fixed and rudder-free stability through zero sideslip at high altitude, but the rudder force flattened out between 6° and 20° left sideslip so that zero change in rudder force was required to sideslip the airplane in this range of sideslip angles. There was a slight amount of negative stick-fixed dihedral effect beyond 12° left sideslip but this was not considered objectionable (fig. 20(b)). At the higher speeds tested at high altitude, both the rudder-fixed and rudder-free stability were satisfactory.

Power-off landing condition.- In the power-off landing condition (fig. 21), the airplane had satisfactory directional stability at 120 and 150 miles per hour for both the original and production vertical-tail configurations. The production tail had higher values of the stability parameters and the rudder-force and rudder-angle variations with sideslip were more linear than the original tail.

Approach condition.- In the approach condition (fig. 22), the airplane had satisfactory directional stability at 120 and 150 miles per hour for both the original and production vertical-tail configurations. The original tail showed a slight nonlinearity in the variation of rudder force and rudder angle with sideslip which the production tail did not encounter.

Wave-off condition.- In the wave-off condition (fig. 23), the airplane had good directional stability with both the original- and production-tail configurations at 120 miles per hour, the only speed tested in this condition.

Rudder Control Power

Adverse aileron yaw.- The adverse aileron yaw of the airplane (fig. 24) was measured by performing aileron rolls with various amounts of aileron deflection with the rudder fixed and allowing the airplane to reach maximum sideslip angle. These data are plotted in figures 24(a) and 24(b) as the variation of change in sideslip angle with change in total aileron deflection. These tests were made at 135 miles per hour in the power-off landing condition and at 150 miles per hour in the power-on clean condition.

In the 135-mile-per-hour landing condition, 5-percent total aileron deflection produced approximately 1° of sideslip with both the original- and production-tail configurations which satisfies the requirements of reference 2. However, in the 150-mile-per-hour power-on clean condition, in left aileron rolls, the amount of sideslip obtained was much more than 1° per 5 percent of the total aileron deflection. The airplane exhibited rapidly increasing sideslip angles in these maneuvers which would have resulted in dangerous attitudes in yaw if the pilot had permitted maximum sideslip angles to be reached. This unsatisfactory condition existed with either the original or production tail.

Rudder control power to overcome adverse aileron yaw.- In order to measure the power of the rudder to overcome adverse aileron yaw (fig. 25) the airplane was rolled abruptly out of 45° banked turns using full aileron deflection and varying amounts of rudder deflection at 150 miles per hour in the power-on clean condition. The change in sideslip angle obtained by application of varying amounts of change in rudder angle is plotted in figures 25(a) and 25(b). In making left rolls, it was impossible for the pilot to apply full aileron and rudder deflection simultaneously because of interference of the pilot's leg movement by the control stick.

The tests showed that the rudder had enough power to overcome the adverse aileron yaw in this condition with either of the vertical-tail configurations.

Rudder control during take-off and landings.- Both the original and production rudders were sufficiently powerful to control the airplane during take-off and landing.

Directional Trim Characteristics

The rudder trim tab was sufficiently powerful to trim the airplane at all speeds above 140 miles per hour. With power on in any configuration, the rudder force could not be trimmed to zero below 140 miles per hour. The directional trim characteristics with speed are shown in figures 26(a) and 26(b). The rudder force with the original tail was high at high speeds and exceeded the 100-pound limit specified in the requirements. The rudder force with the production tail also exceeded the 100-pound limit of the handling-qualities requirements and showed very little improvement over the original tail.

Aileron Control Characteristics

The aileron control characteristics of the airplane (figs. 27 to 29) were measured by rolling the airplane to the left and to the right by abruptly applying various amounts of aileron deflection up to full aileron deflection with the rudder held fixed. These tests were performed at approximately 5000 feet altitude and at 150, 250, 350, and 400 miles per hour calibrated airspeed in the power-on clean condition using normal rated power. The variation of rolling acceleration with time was always in the correct direction and the rolling velocity varied smoothly with time at all the speeds tested. These characteristics are illustrated in the time histories of figure 27.

The aileron effectiveness, or helix angle $pb/2V$ and the aileron-force variation with total aileron deflection are shown in figure 28. These data show the maximum $pb/2V$ obtainable with maximum aileron deflection to be 0.064 which occurs at speeds of 150 and 250 miles per hour. The aileron forces required to produce the rolls vary smoothly with aileron deflection and show no tendency to overbalance. There is also enough force to return the controls to neutral when the stick is released. The maximum $pb/2V$ obtainable with a 30-pound stick force is shown in figure 29 and is compared with the Army requirements of reference 2. From these data it can be seen that the $pb/2V$ obtainable with a 30-pound stick force in this airplane is considerably less than that specified in the Army requirements. The aileron trim tab was sufficiently powerful to trim the airplane at all the speeds and in all the configurations tested.

CONCLUSIONS

1. There was no oscillation of the rudder itself during the directional oscillations started either from a rudder kick or a sideslip. The oscillations produced were always damped to one-half amplitude or less in 1 cycle. In the low-speed power-on clean condition, the airplane had a rapid spiral divergence when the oscillation was started either from a rudder kick or a sideslip with either tail configuration.

2. With the original vertical tail, the directional stability of the airplane in the power-on clean and glide conditions was weak both rudder-fixed and rudder-free. The directional stability in the landing, approach, and wave-off conditions was satisfactory. The addition of the production tail was an improvement but the stability in the power-on clean condition was still low.

3. The effect of higher altitude, approximately 25,000 feet, was to decrease slightly the static directional stability.

4. The airplane with the original tail had neutral to negative stick-fixed and stick-free dihedral effect at large sideslip angles in the low-speed power-on clean condition. This undesirable effect was not encountered with the production tail installed on the airplane.

5. With either the original or production tail the airplane showed unsatisfactory characteristics in left aileron rolls with rudder fixed with regard to adverse aileron yaw in the low-speed power-on clean condition. The airplane exhibited rapidly increasing sideslip angles in these maneuvers which would have resulted in dangerous attitudes in yaw if the pilot had permitted maximum sideslip angles to be reached.

6. Both of the rudders tested were sufficiently powerful to overcome the adverse aileron yaw at 150 miles per hour in the power-on clean condition and to control the airplane easily during take-off and landing.

7. The rudder-trim-force change with speed was high with either tail and the rudder trim tab was not able to trim the airplane with power on below 140 miles per hour.

8. The general characteristics of the aileron control were satisfactory but the aileron effectiveness was below the Army requirements. The maximum aileron effectiveness $pb/2V$ obtainable was 0.064 as compared to the Army requirement of 0.090.

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REFERENCES

1. Williams, Walter C., and Hoover, Herbert H.: Flight Measurements of the Directional Stability and Control of a P-51D-NA Airplane (AAF No. 44-13257) with a High-Aspect-Ratio Vertical Tail. NACA MR No. L5E05b, Army Air Forces, 1945.

2. Anon.: Stability and Control Characteristics of Airplanes. AAF Specifications No. R-1815-A, April 7, 1945. Restricted

TABLE I

PERTINENT DIMENSIONS OF THE P-51H AIRPLANE

Engine	Merlin V-1650-9
Propeller (four blades)	Aeroproducts Model H-20-156-23M5
Wing area, sq ft	235.73
Wing span, ft	37.03
Aspect ratio	5.82
Wing-flap area, sq ft (two)	31.53
Aileron area, sq ft (one)	6.35
Aileron deflection, deg	±15
Total horizontal tail area, sq ft	48.35
Elevator area, sq ft (one)	6.43
Original vertical-tail area, sq ft	23.40
Original rudder area, sq ft	10.24
Rudder deflection of original tail, deg	±30
Production vertical-tail area, sq ft	24.76
Production rudder area, sq ft	9.77
Rudder deflection of production tail, deg	±25
Dorsal fin area, sq ft	1.93
Original rudder trim tab area, sq ft	0.74
Unbalancing ratio of original rudder tab	0.4:1
Production rudder trim tab area, sq ft	0.74
Unbalancing ratio of production rudder trim tab	0
Rudder trim tab deflection, deg	14 left and 8 right

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TABLE II

VALUES OF DIRECTIONAL-STABILITY PARAMETERS OF P-51H AIRPLANE

FOR ORIGINAL AND PRODUCTION VERTICAL TAILS

Condition	Speed (mph)	Altitude		Original tail		Production tail	
		Original	Production	$d\delta_r/d\beta$ (a)	$dF_r/d\beta$ (a)	$d\delta_r/d\beta$ (a)	$dF_r/d\beta$ (a)
Glide	150	5,000	5,000	0.12	2.0	0.66	4.0
	150	21,000	21,000	.14	1.0	.55	2.0
	300	5,000	4,000	.51	20.0	.70	25.0
	300	20,000	20,000	.15	15.0	.57	26.0
Power on clean	150	5,000	7,000	.41	8.0	.70	4.0
	150	22,000	25,000	.34	4.0	.55	5.0
	300	5,000	4,000	.50	62.0	.80	26.0
	300	22,000	21,000	.65	29.0	.57	26.0
	400	5,000	5,000	.31	43.0	.84	39.0
	350	21,000	21,000	.20	42.0	.48	33.0
Power off landing	120	5,000	5,000	1.00	4.0	1.37	5.0
	150	5,000	5,000	1.25	13.0	1.70	14.0
Approach	120	5,000	5,000	1.00	6.0	1.27	14.0
	150	5,000	5,000	1.20	14.1	1.24	18.0
Wave-off	120	5,000	5,000	.83	9.0	1.51	14.0

[a]Slopes $\frac{d\delta_r}{d\beta}$ and $\frac{dF_r}{d\beta}$ taken near zero sideslip. (These values are only approximate because of scatter of test points in some conditions tested.)

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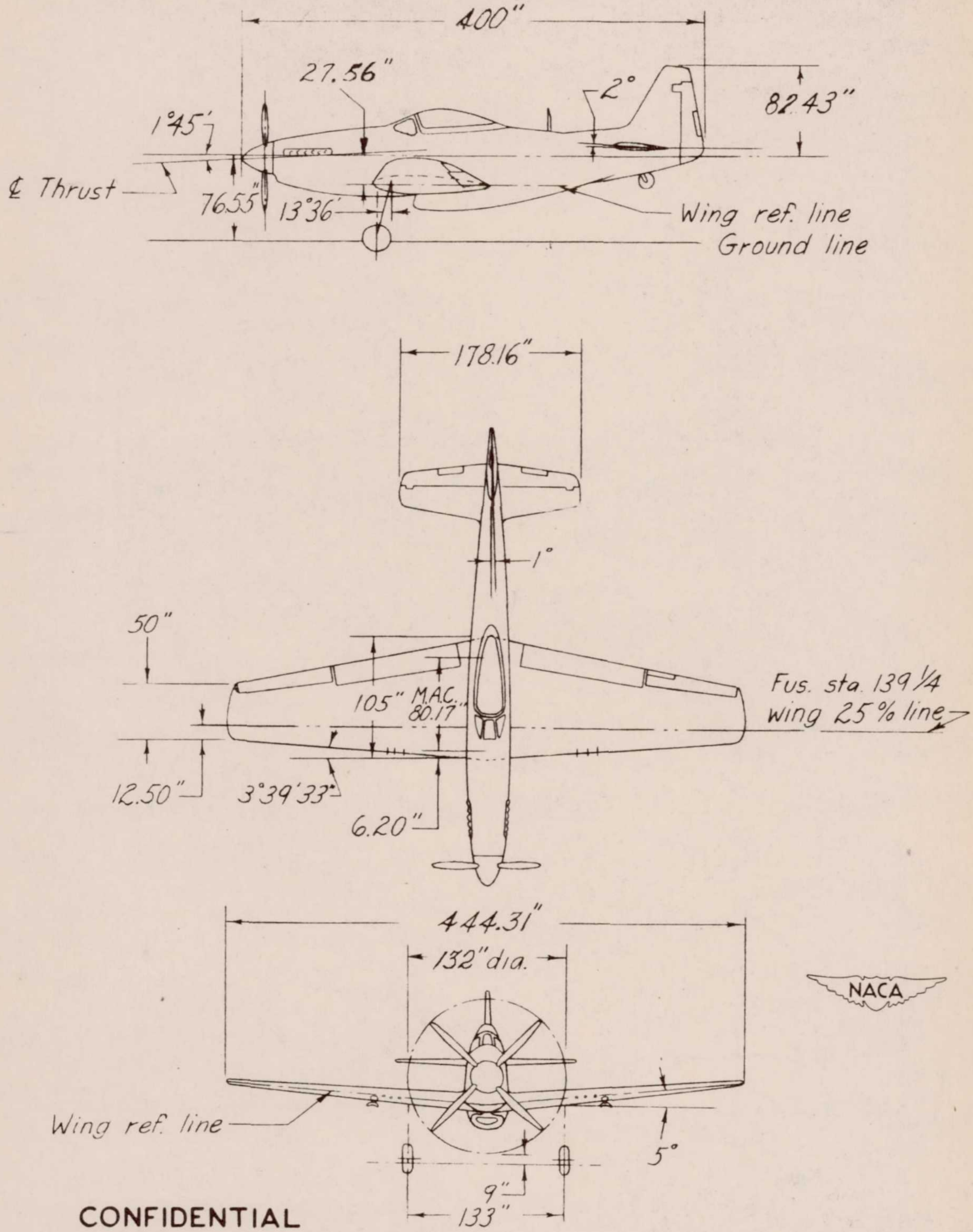

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Figure 1.- Three-view drawing of the P-51H airplane with the production tail.

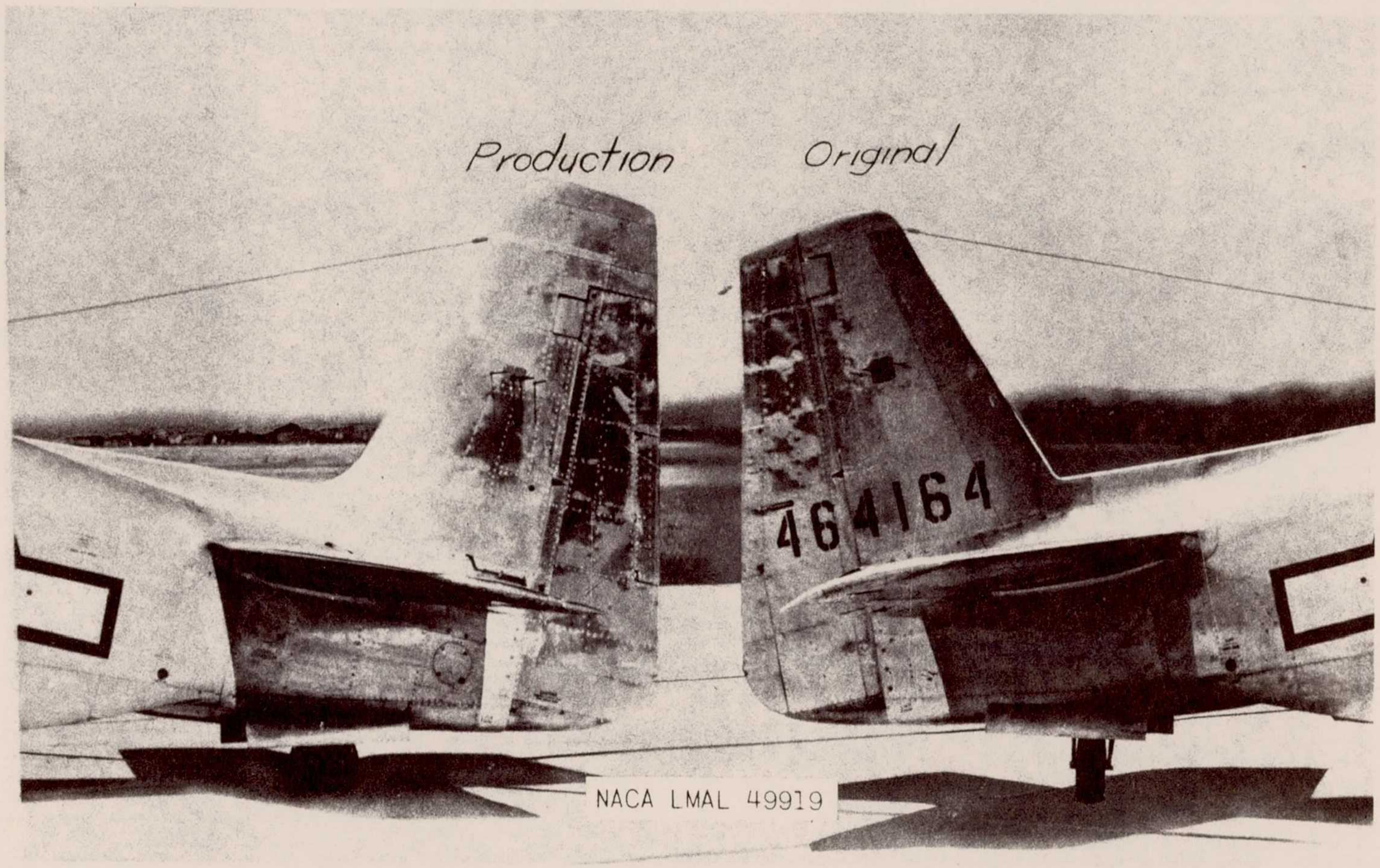

Figure 2.- Comparison of the original and production vertical tail assemblies.

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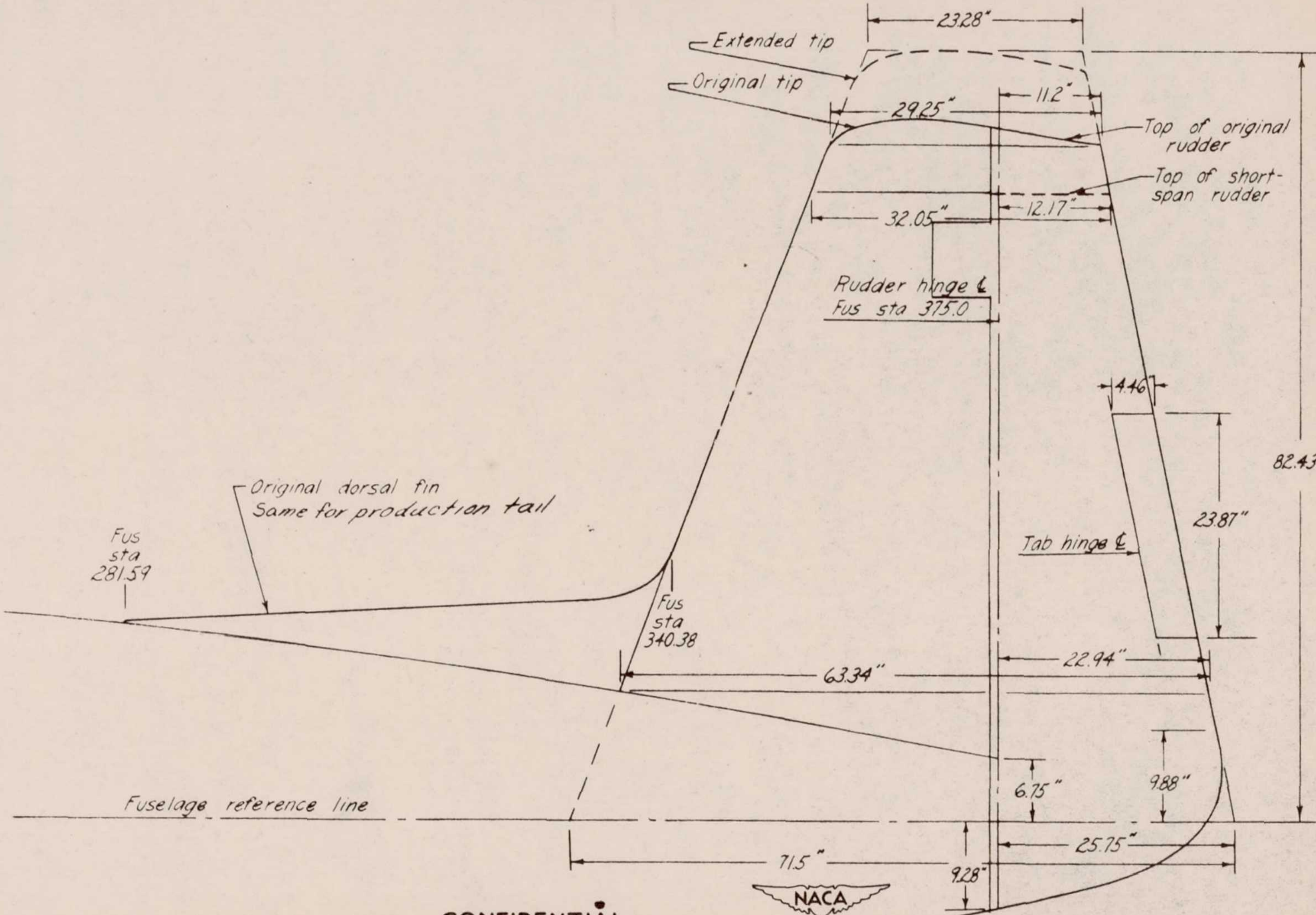

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Figure 3.- Drawing showing comparison of the original and production vertical tail assemblies. P-51H airplane.

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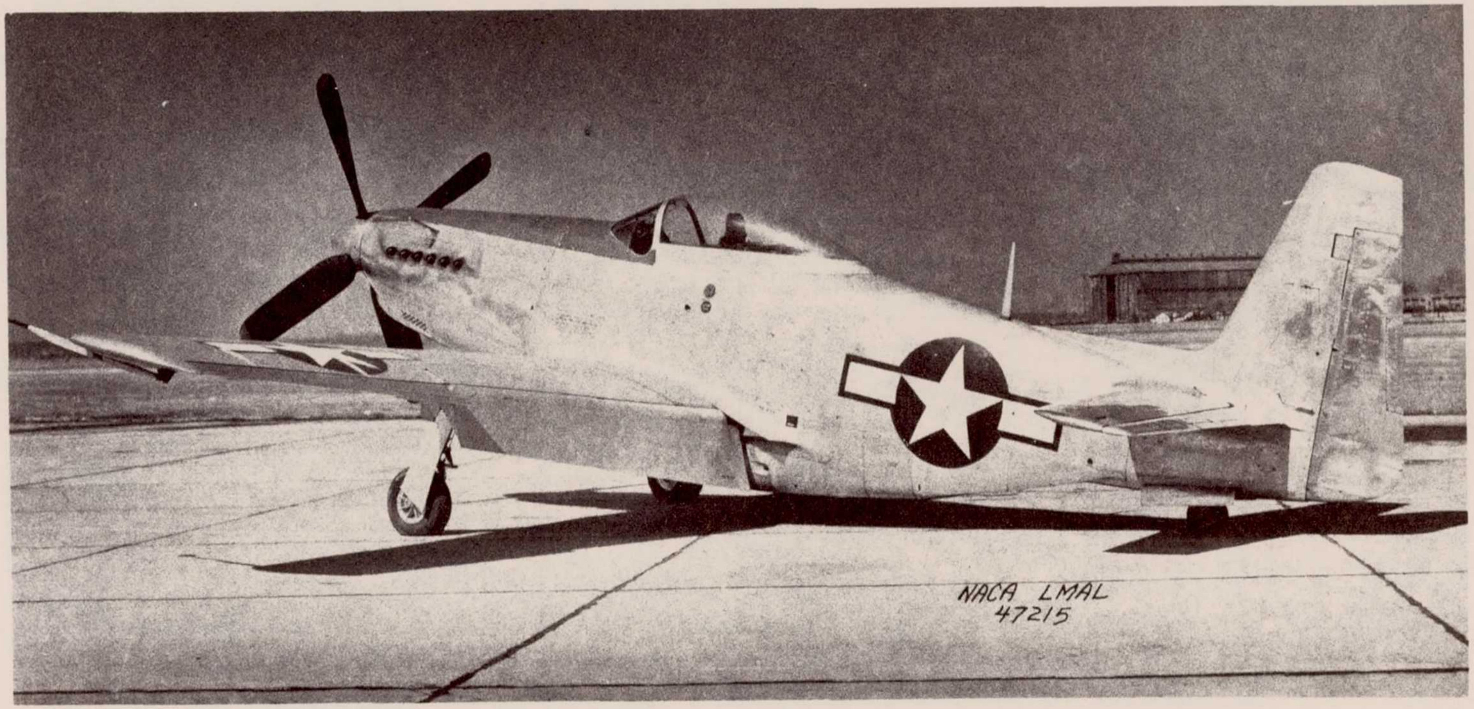

Figure 4.- Three-quarter rear view of P-51H test airplane with production tail.

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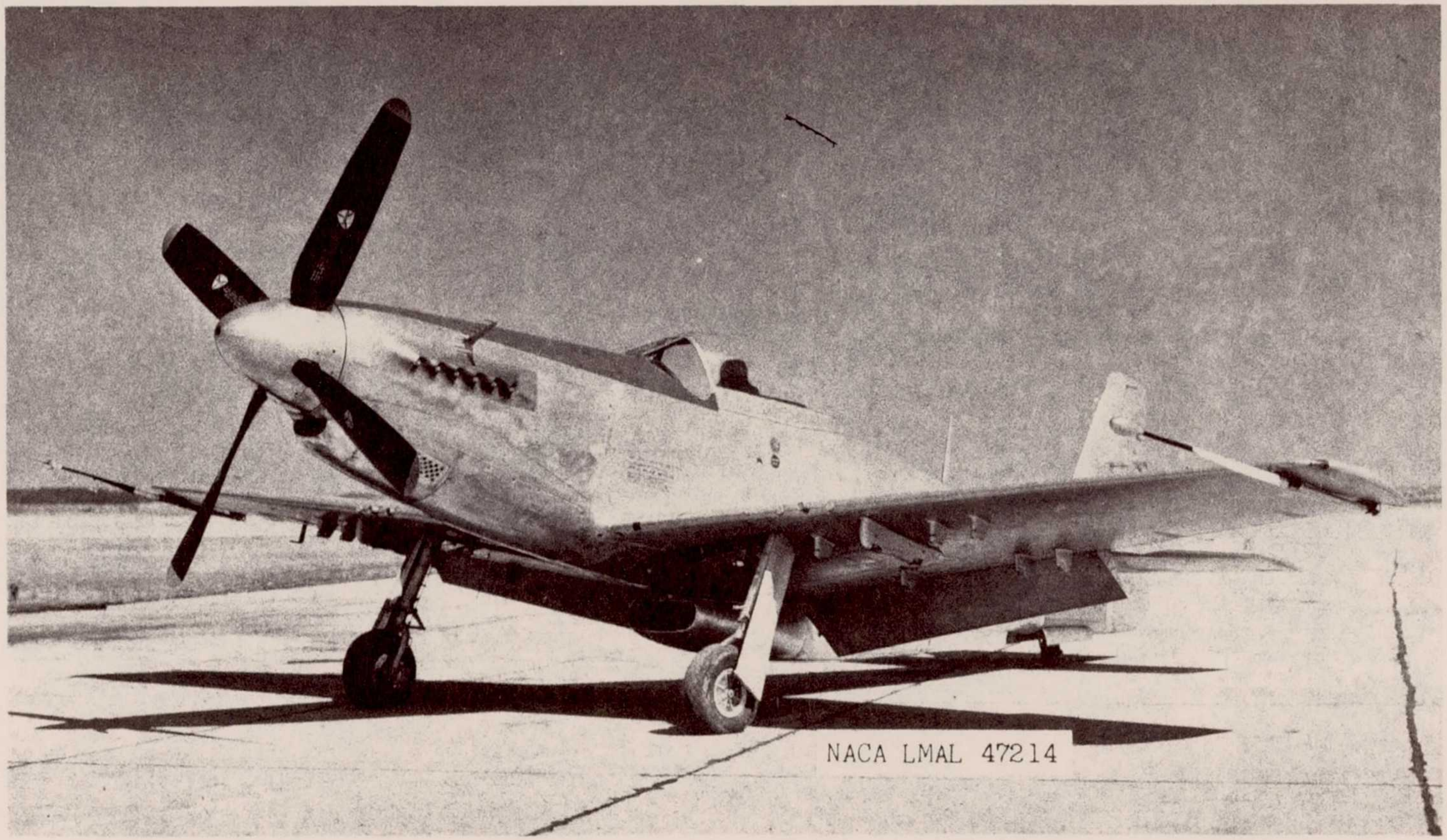

Figure 5.- Three-quarter front view of P-51H test airplane with production tail.

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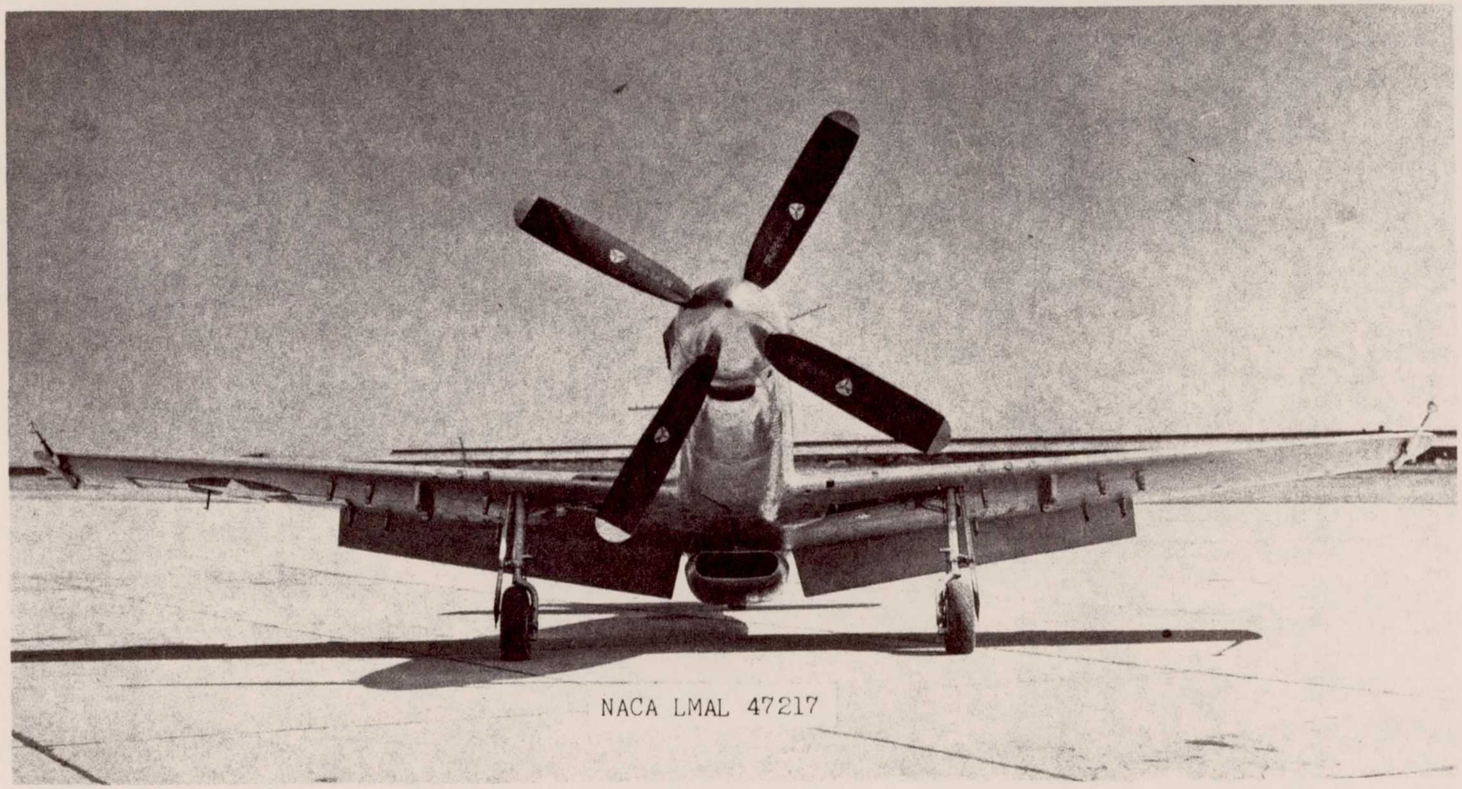

Figure 6.- Front view of P-51H test airplane.

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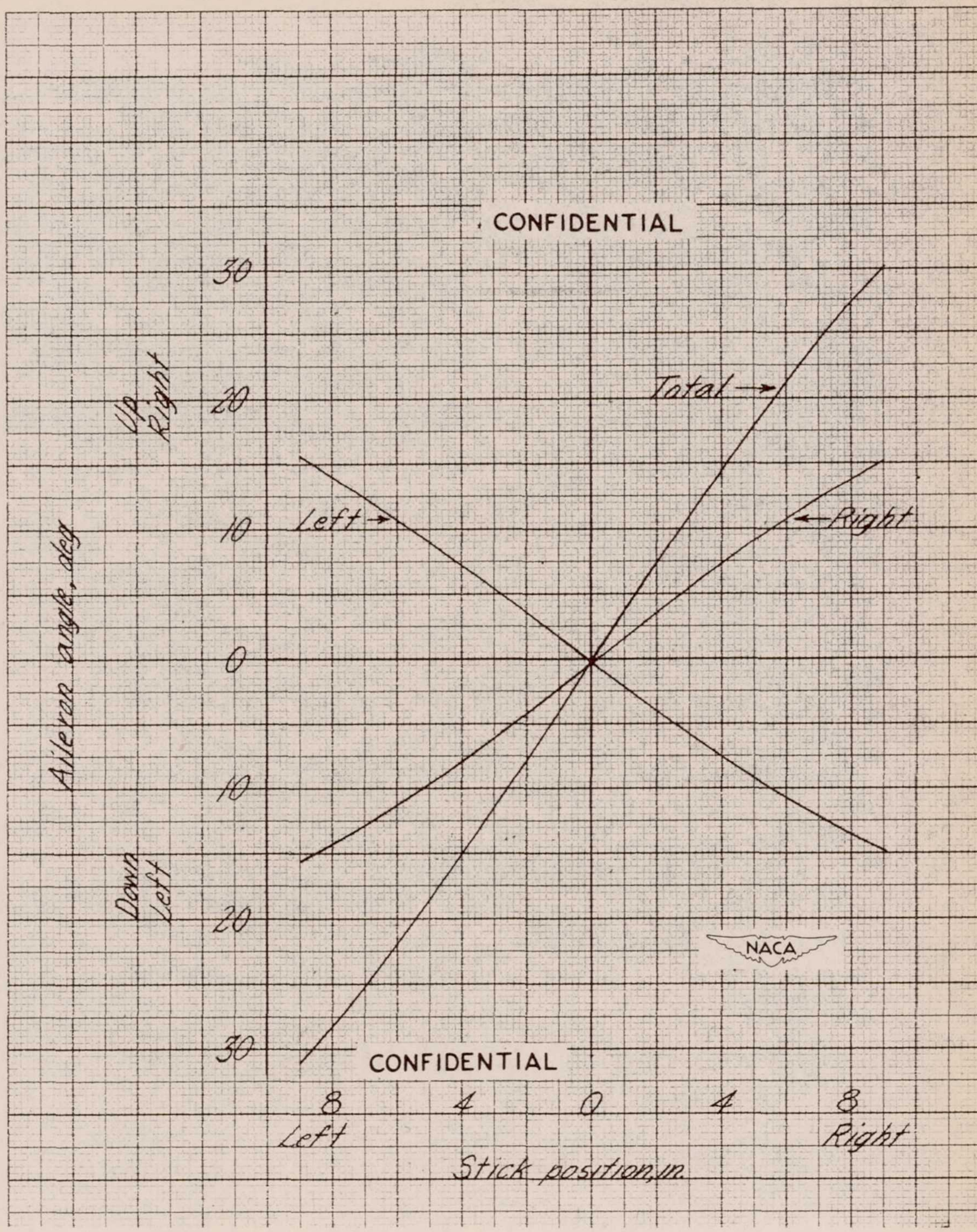

Figure 7.- Variation of aileron angle with stick position as measured on the ground with no aileron load. P-51H airplane.

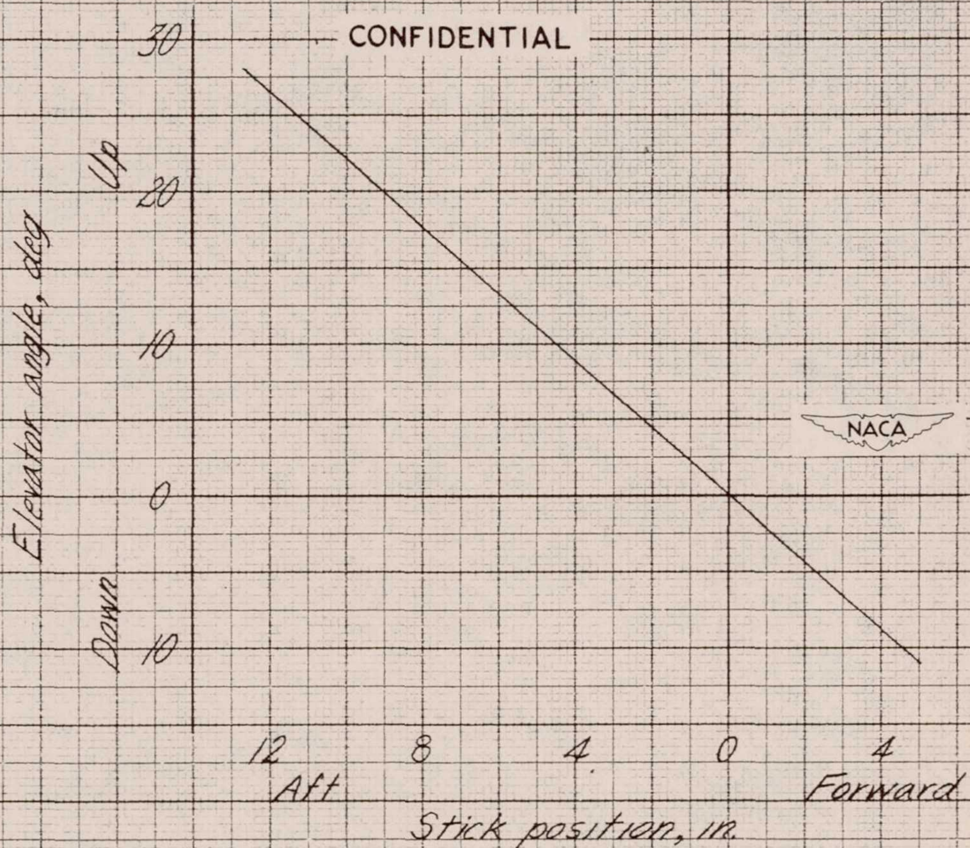

Figure 8.- Variation of elevator angle with stick position as measured on the ground with no load on the elevator. P-51H airplane.

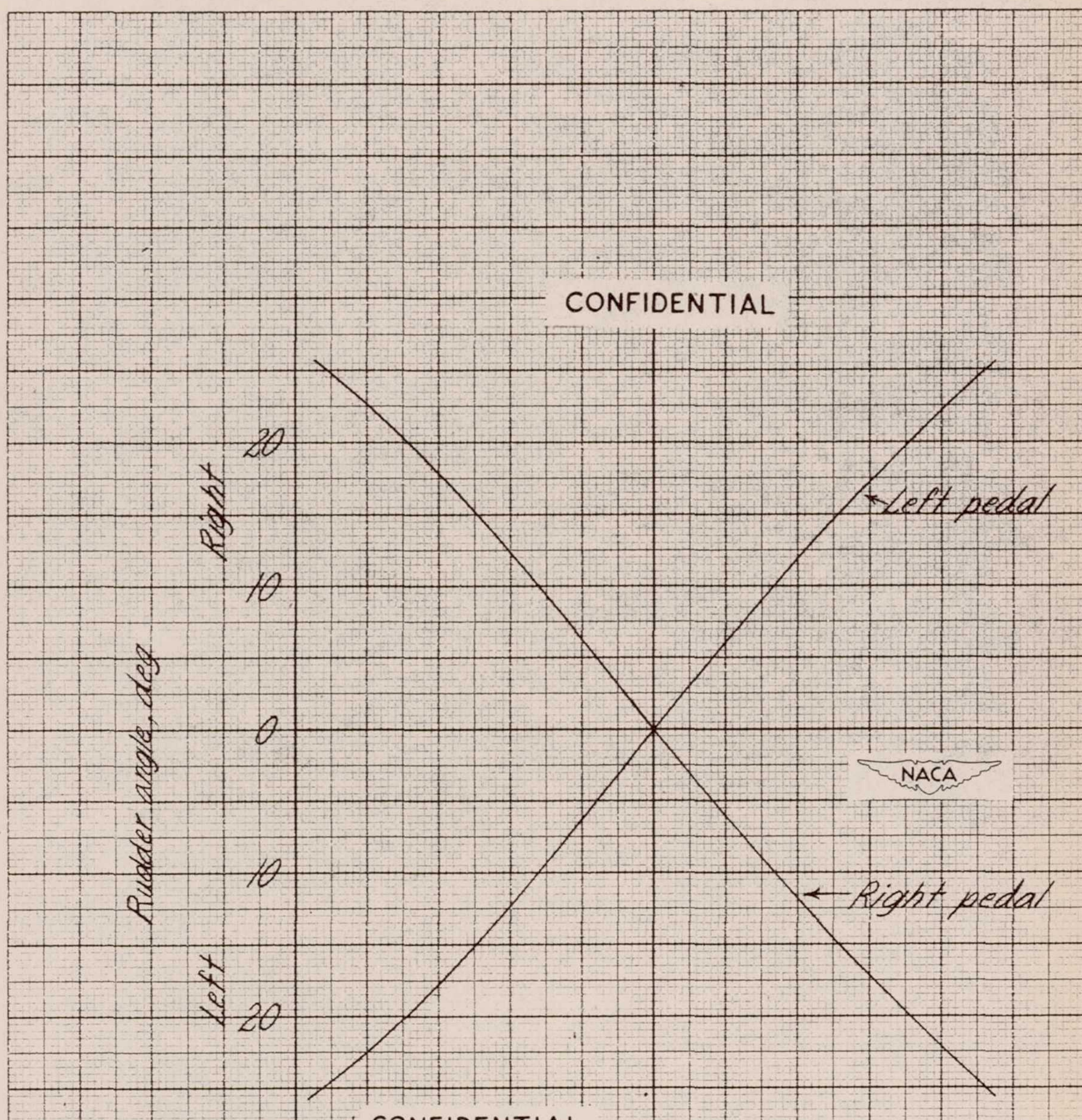

Figure 9.- Variation of rudder angle with pedal position with no load on the rudder. P-51H airplane. This measurement was made with the production tail installed; the same plot may be used for the original tail by extrapolating the curves to 30 degrees of right or left rudder.

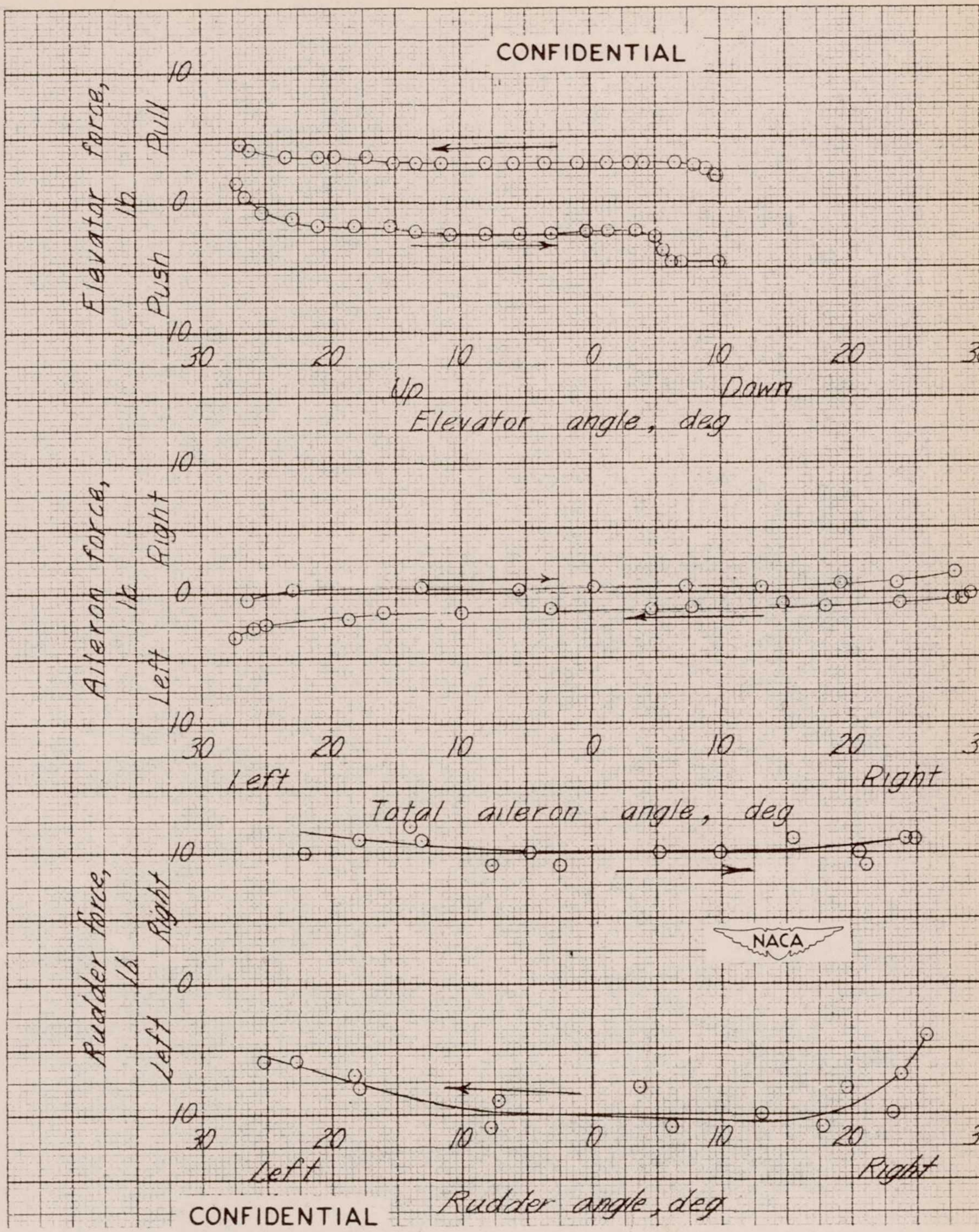

Figure 10.- Variation of control-friction force with control deflection as measured on the ground with no load on the control surfaces. P-51H airplane.

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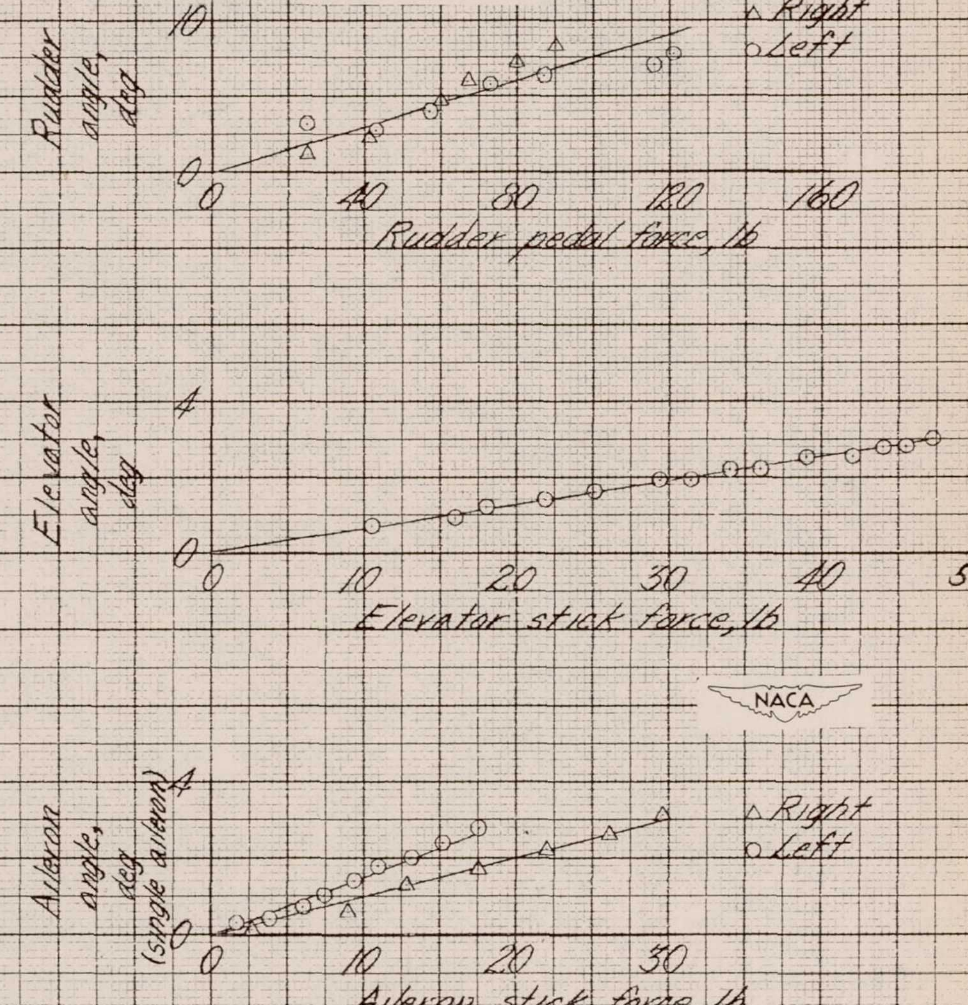

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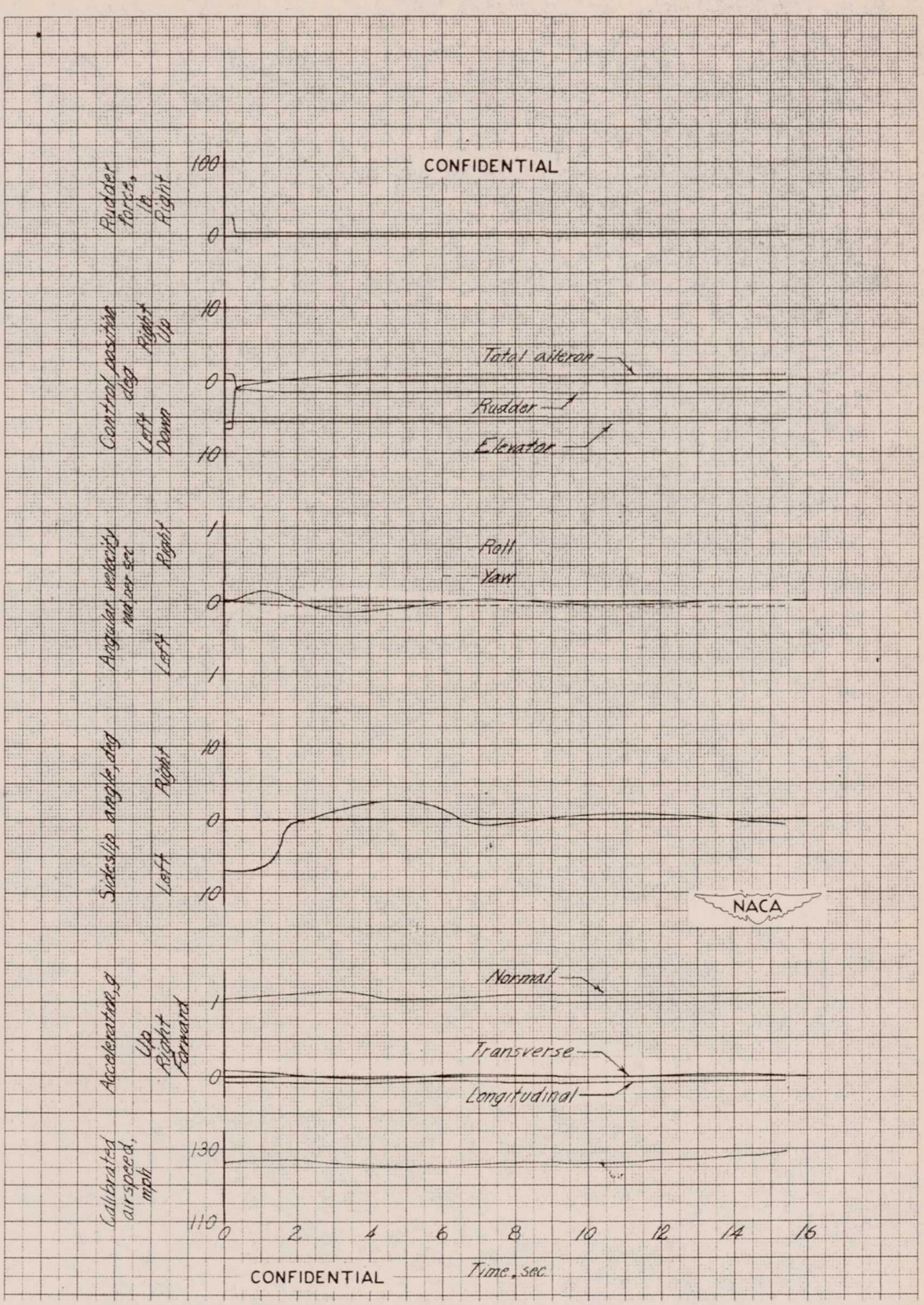
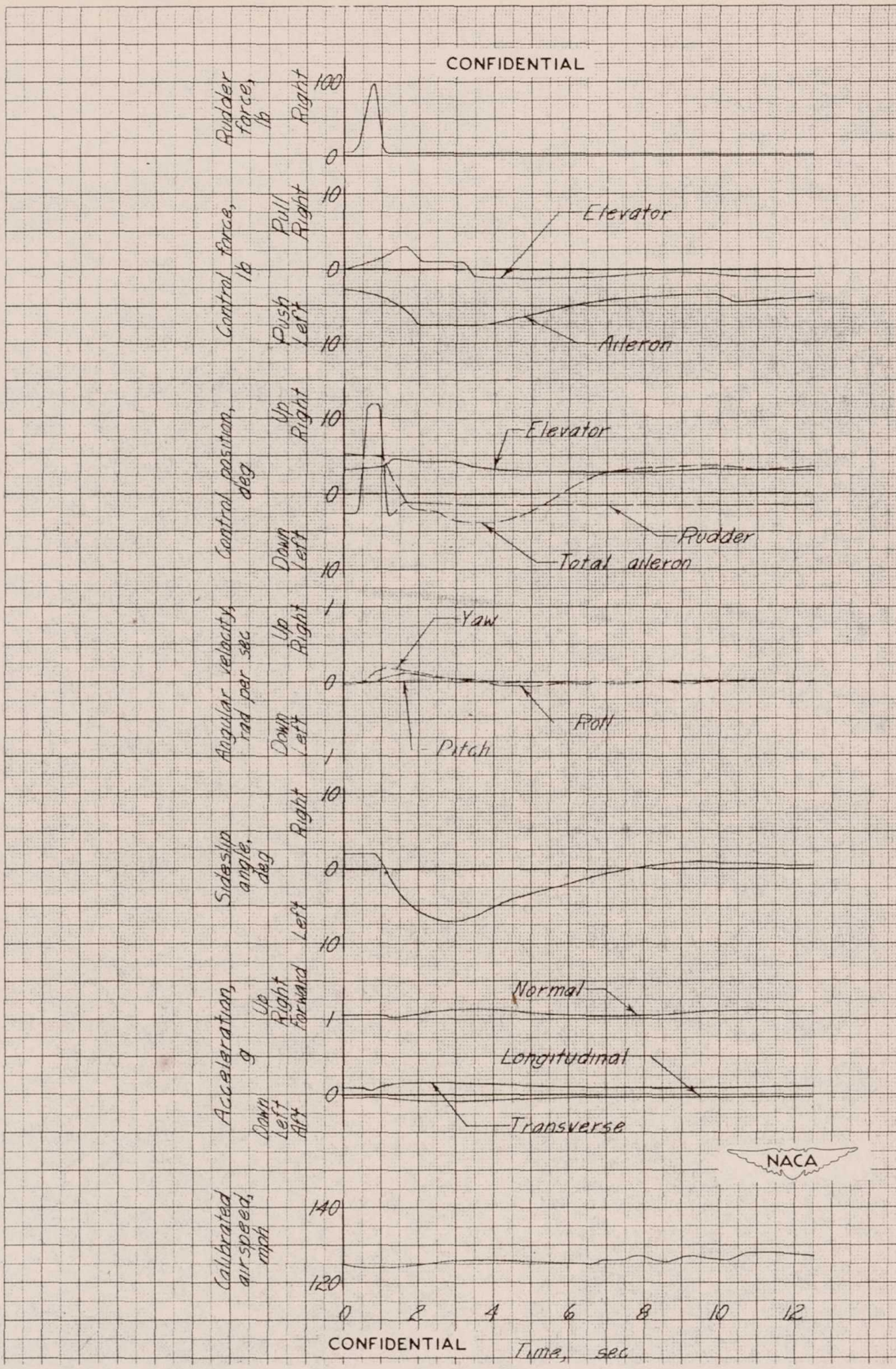
Figure 11.- Decrease in aileron, elevator, and rudder angle due to stretch in the control system. P-51H airplane.



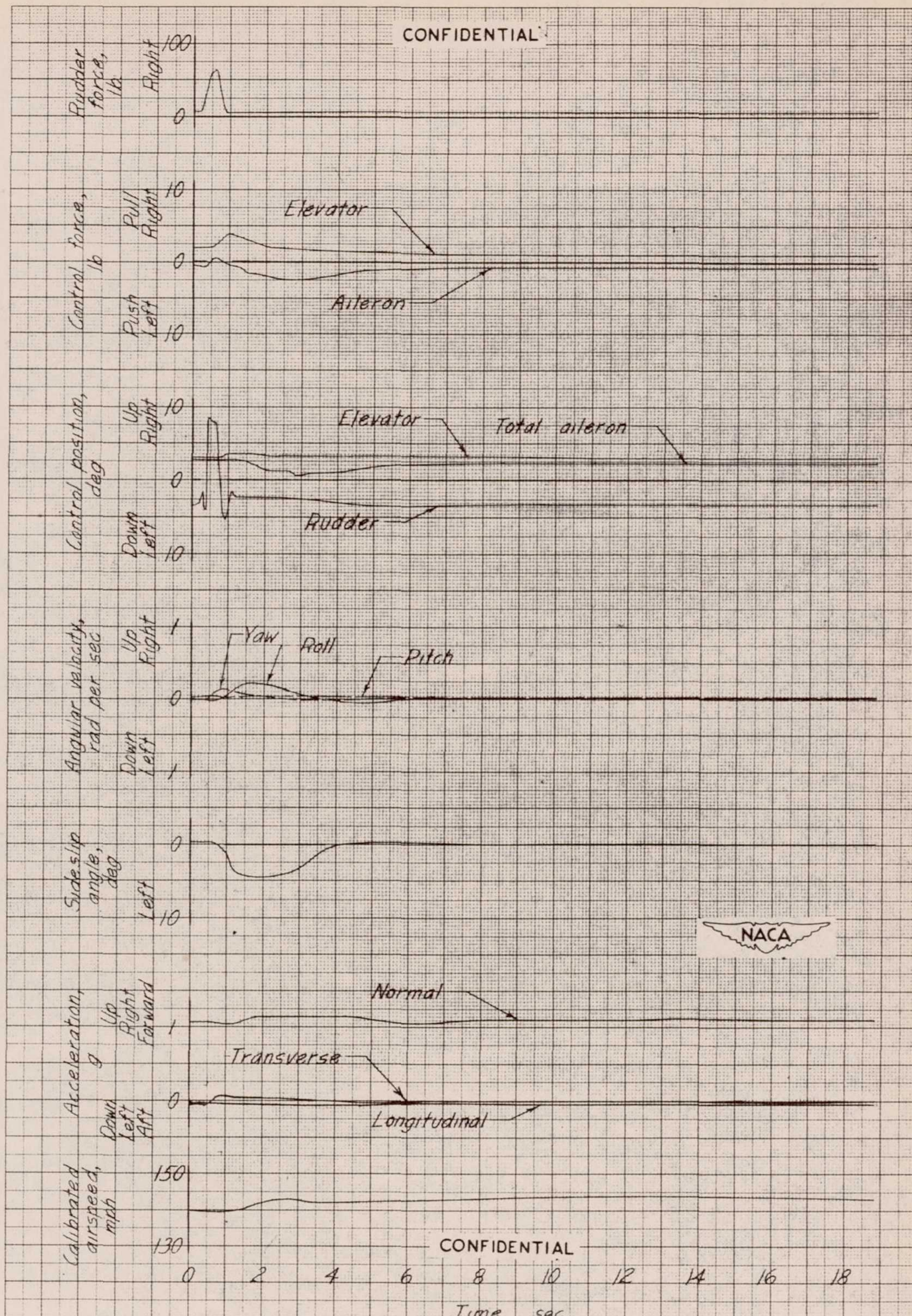
(a) 5000 feet altitude. Oscillation started from a steady sideslip. Original tail.

Figure 12.- Time history of a directional oscillation in the low-speed glide condition. P-51H airplane.



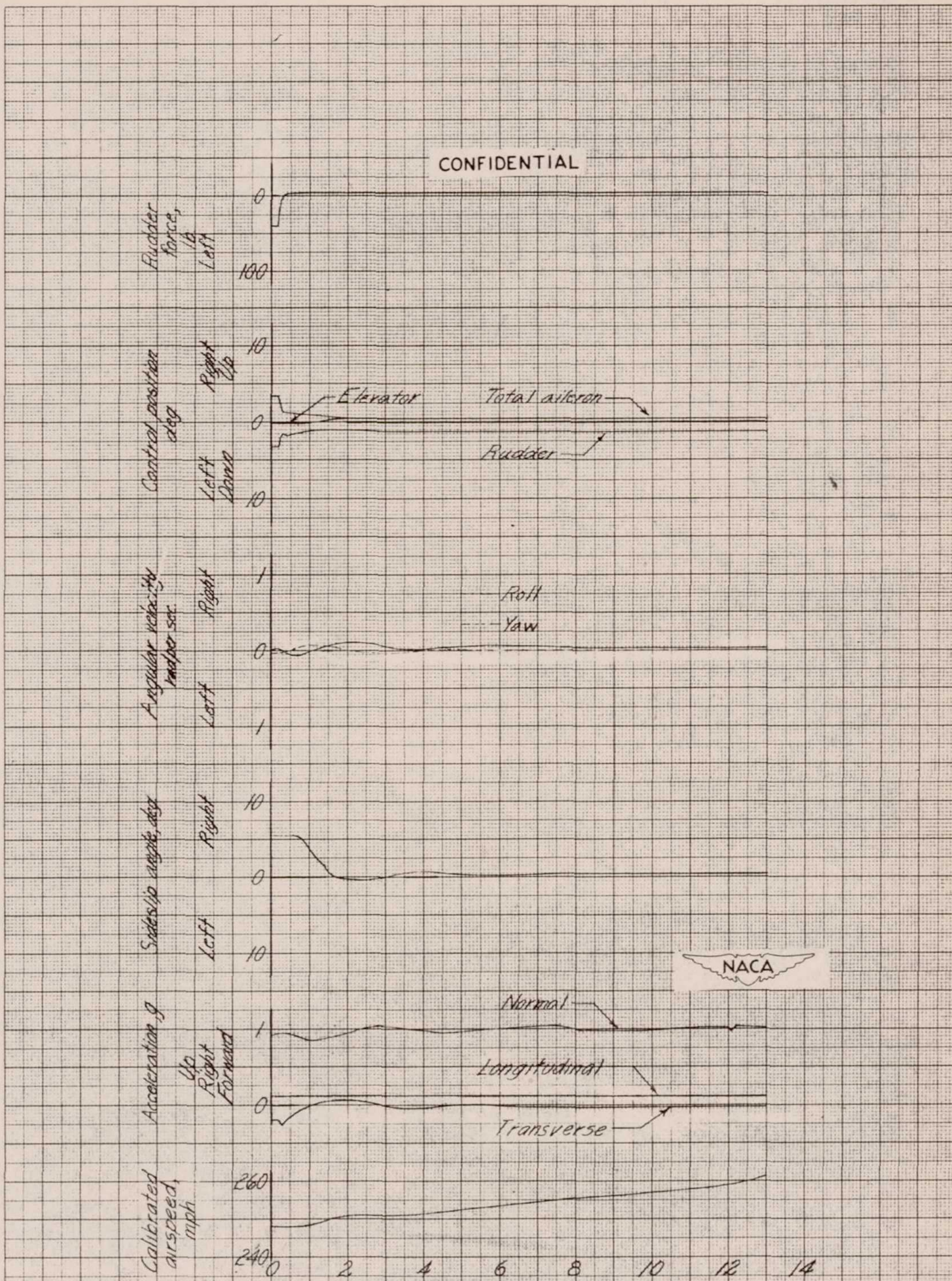
(b) 5000 feet altitude. Oscillation started from a rudder kick. Pilot used ailerons to control airplane. Production tail.

Figure 12.- Continued.



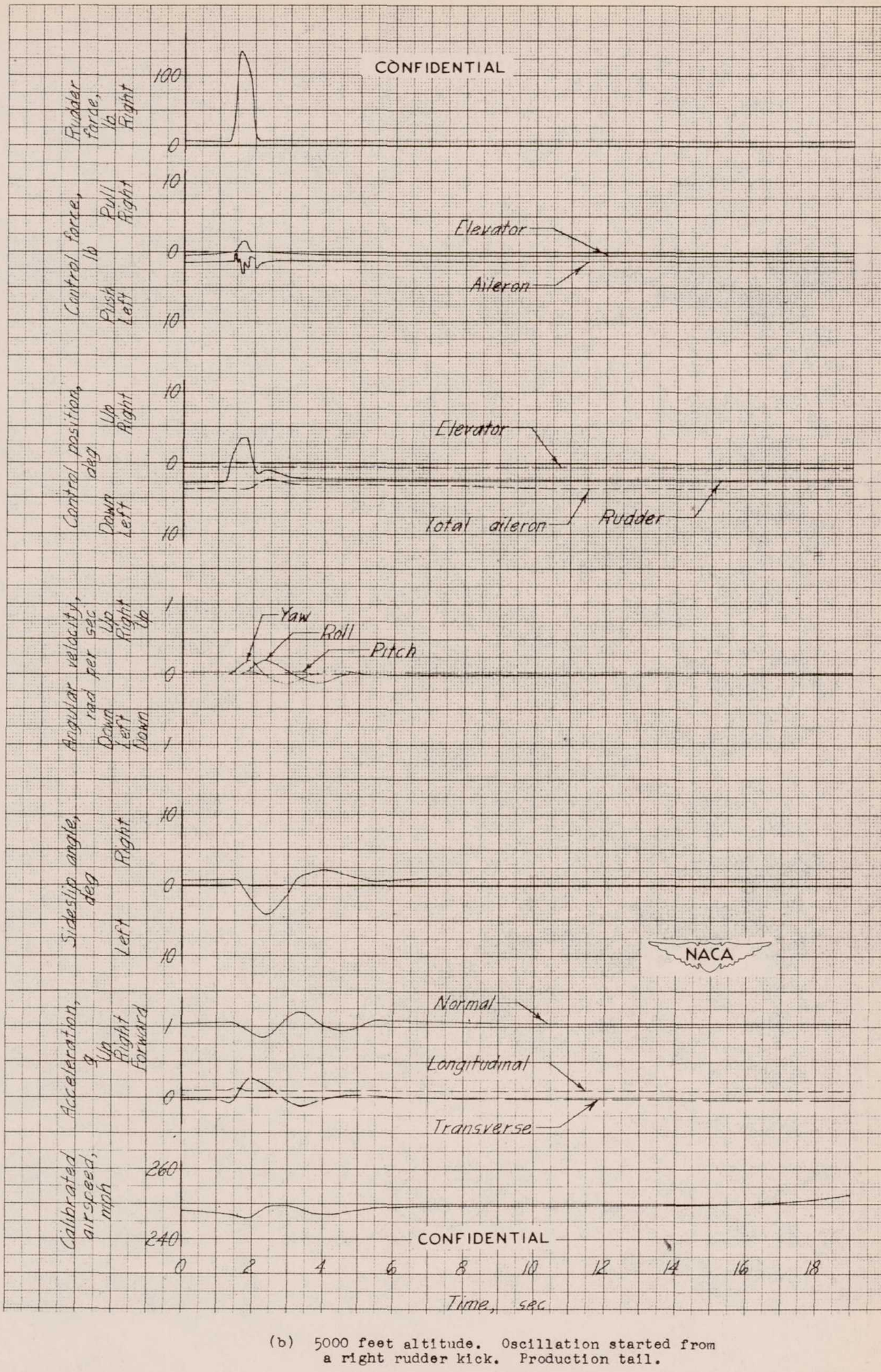
(c) 26000 feet altitude. Oscillation started from a right rudder kick. Production tail.

Figure 12.- Concluded.



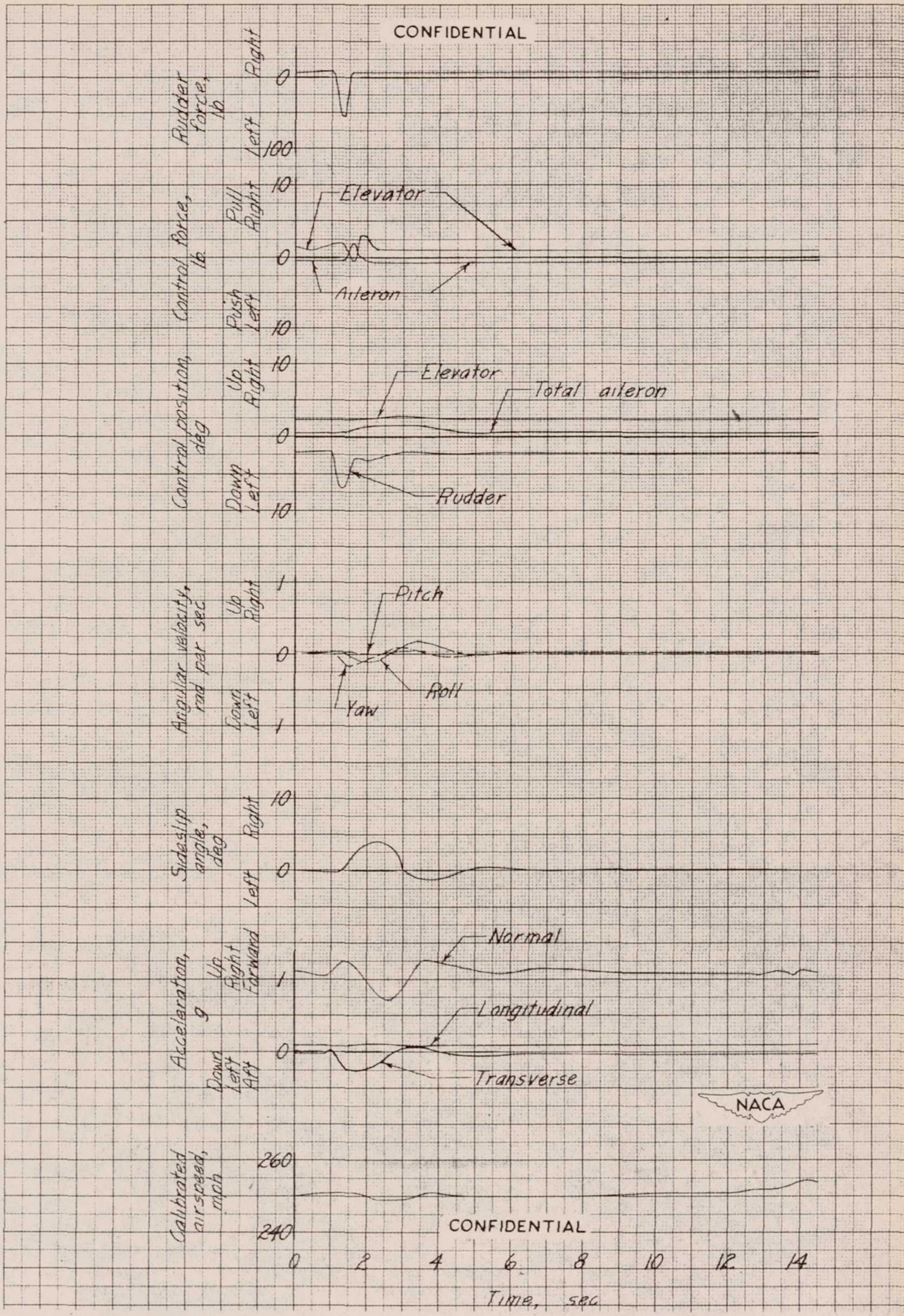
(a) 5000 feet altitude. Oscillation started from a steady sideslip. Original tail.

Figure 13.- Time history of a directional oscillation in the high-speed glide condition. P-51H airplane.



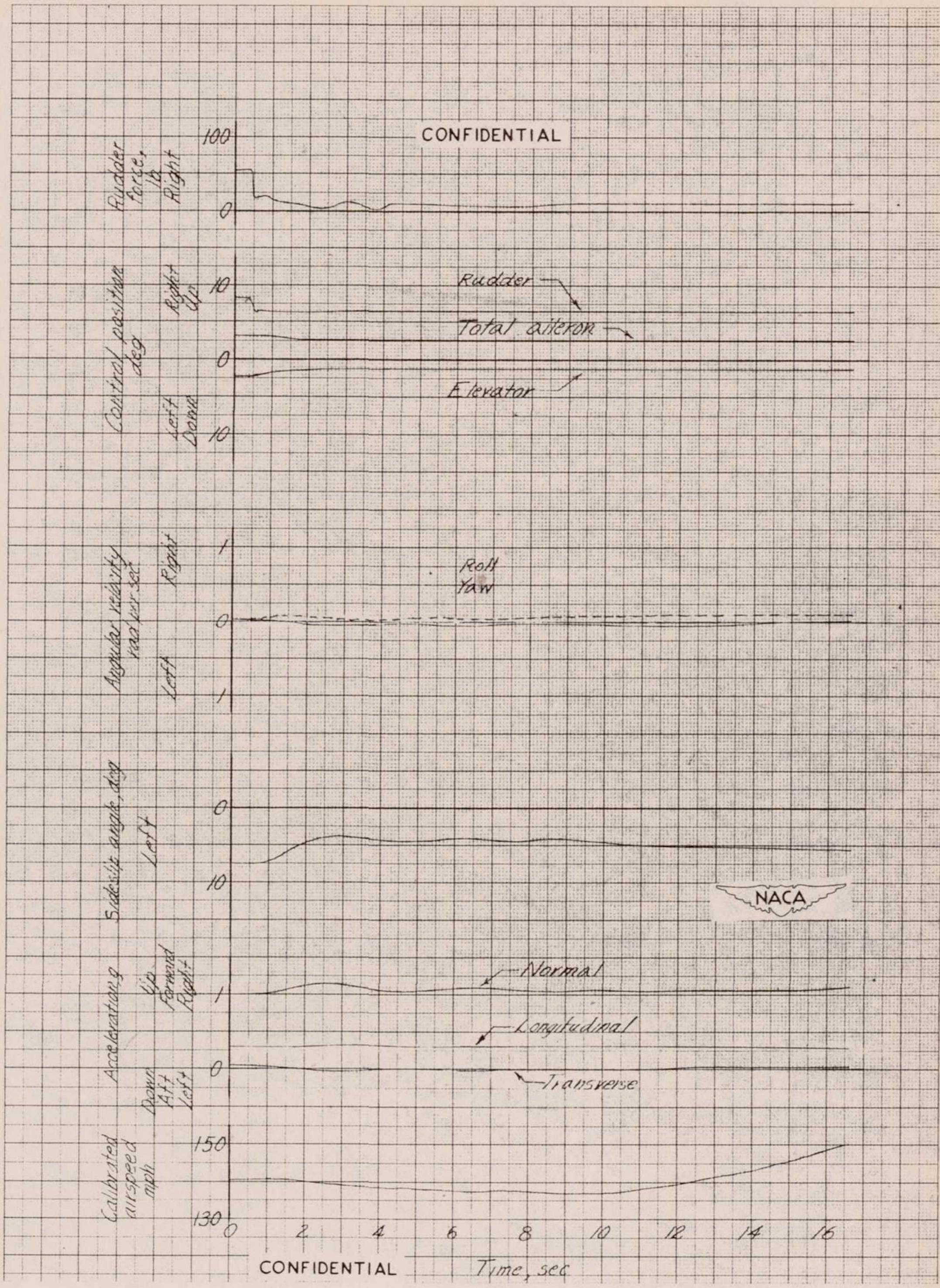
(b) 5000 feet altitude. Oscillation started from a right rudder kick. Production tail.

Figure 13.- Continued.



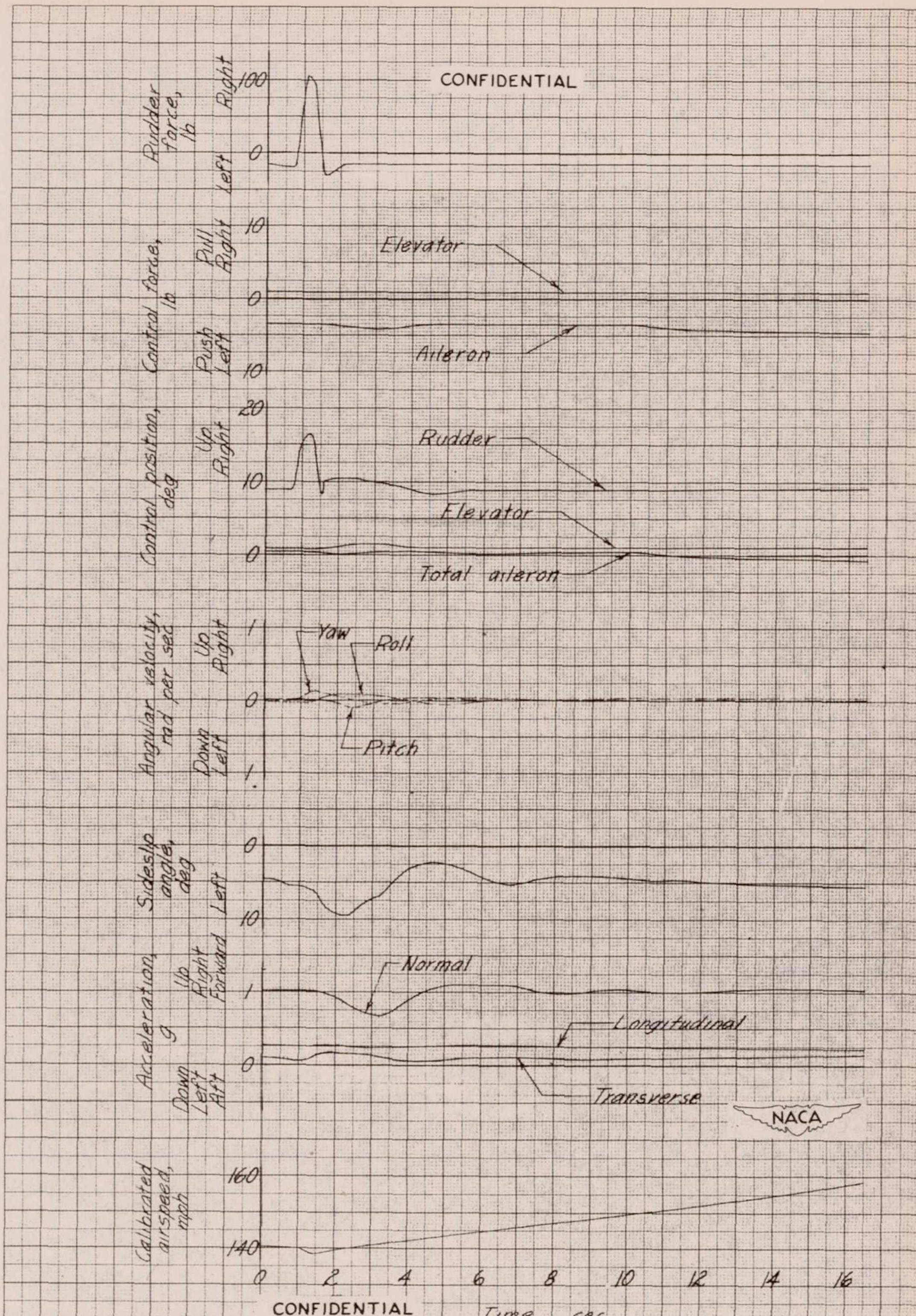
(c) 20,000 feet altitude. Oscillation started from a left rudder kick. Production tail.

Figure 13.- Concluded.



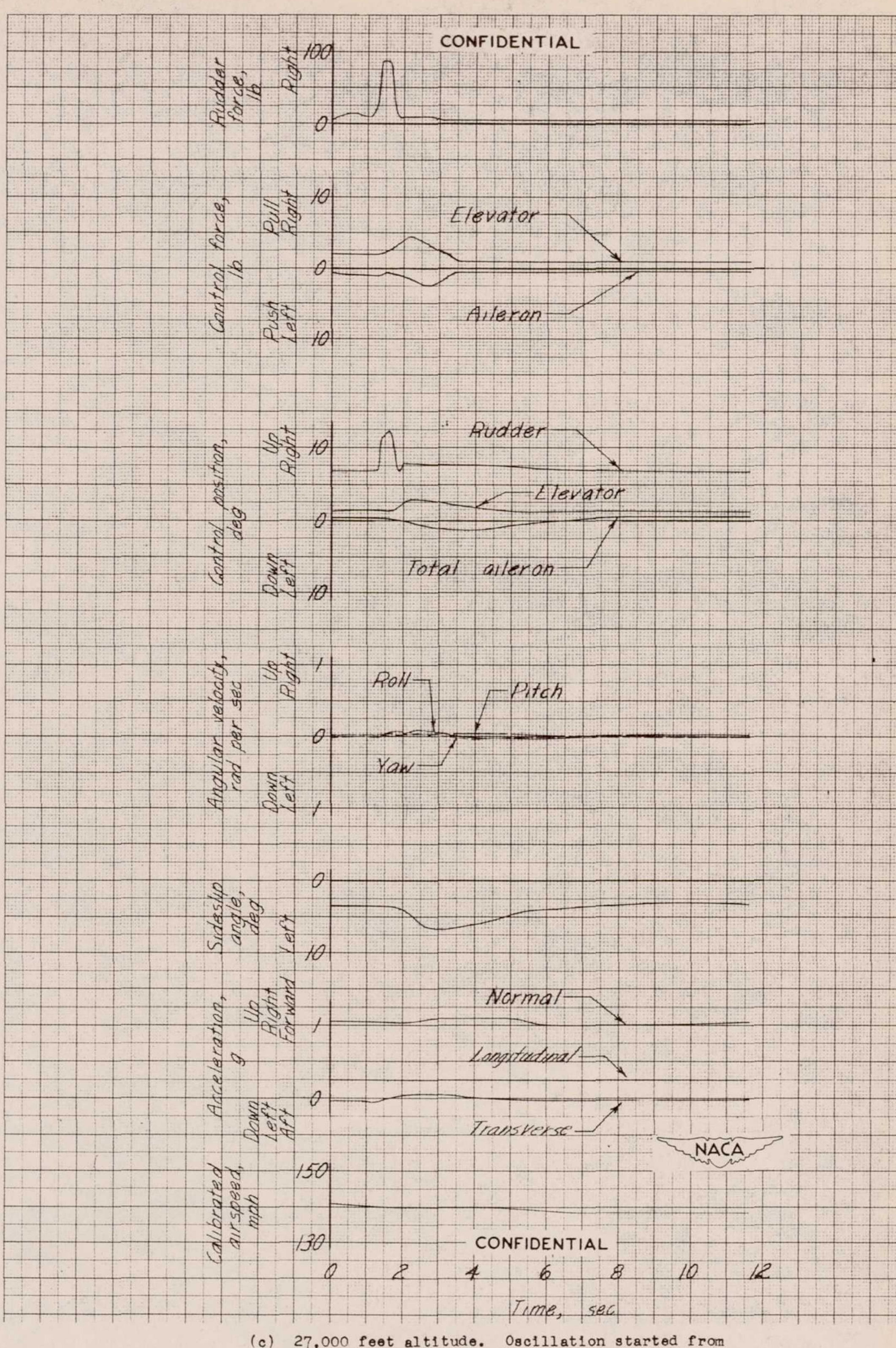
(a) 5000 feet altitude. Oscillation started from a steady sideslip. Original tail.

Figure 14.- Time history of a directional oscillation in the low speed power-on clean condition. P-51H airplane.



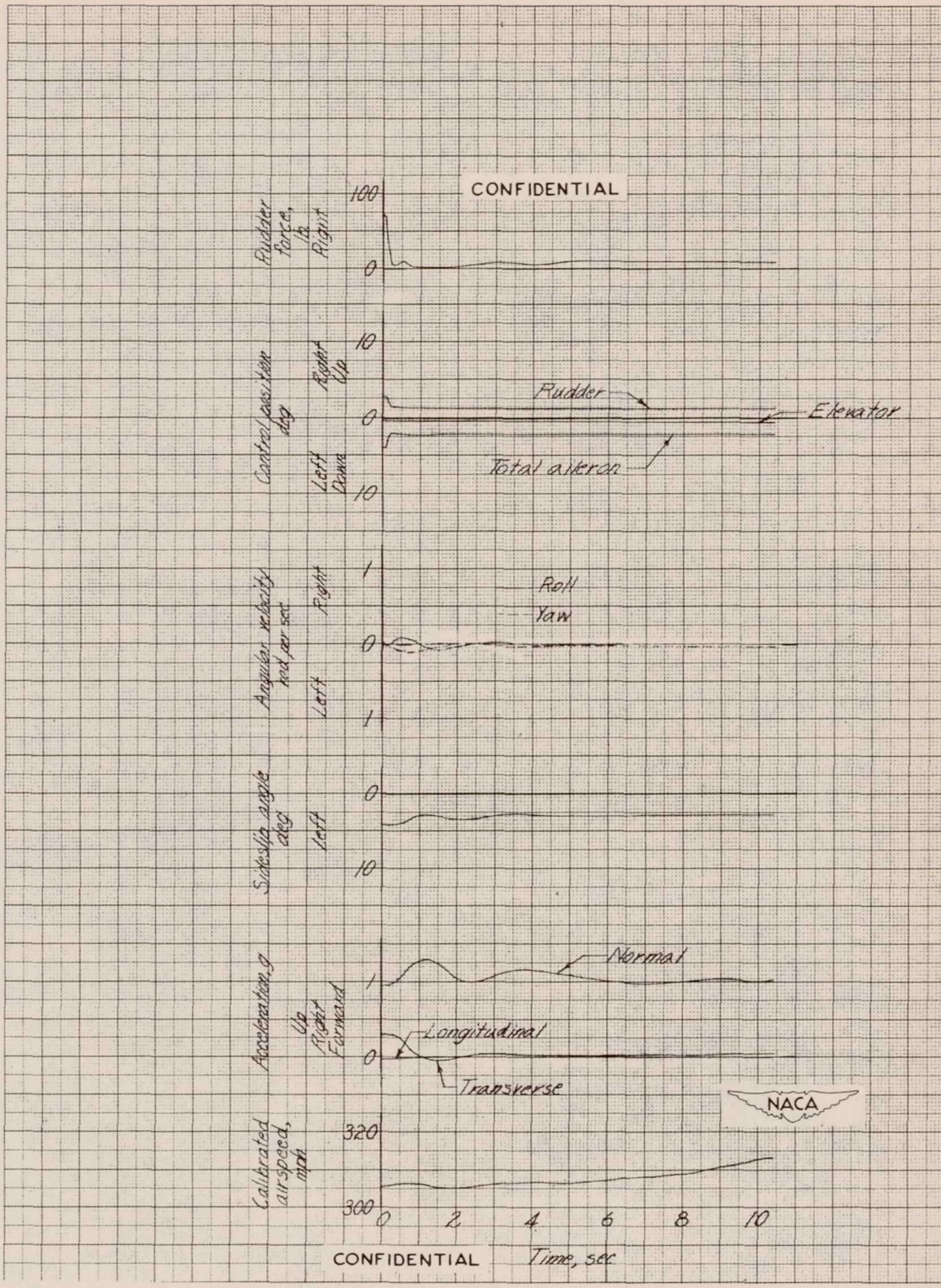
(b) 5000 feet altitude. Oscillation started from a right rudder kick. Airplane tended to spiral to right. Ailerons used to hold wings level. Production tail.

Figure 14.- Continued.



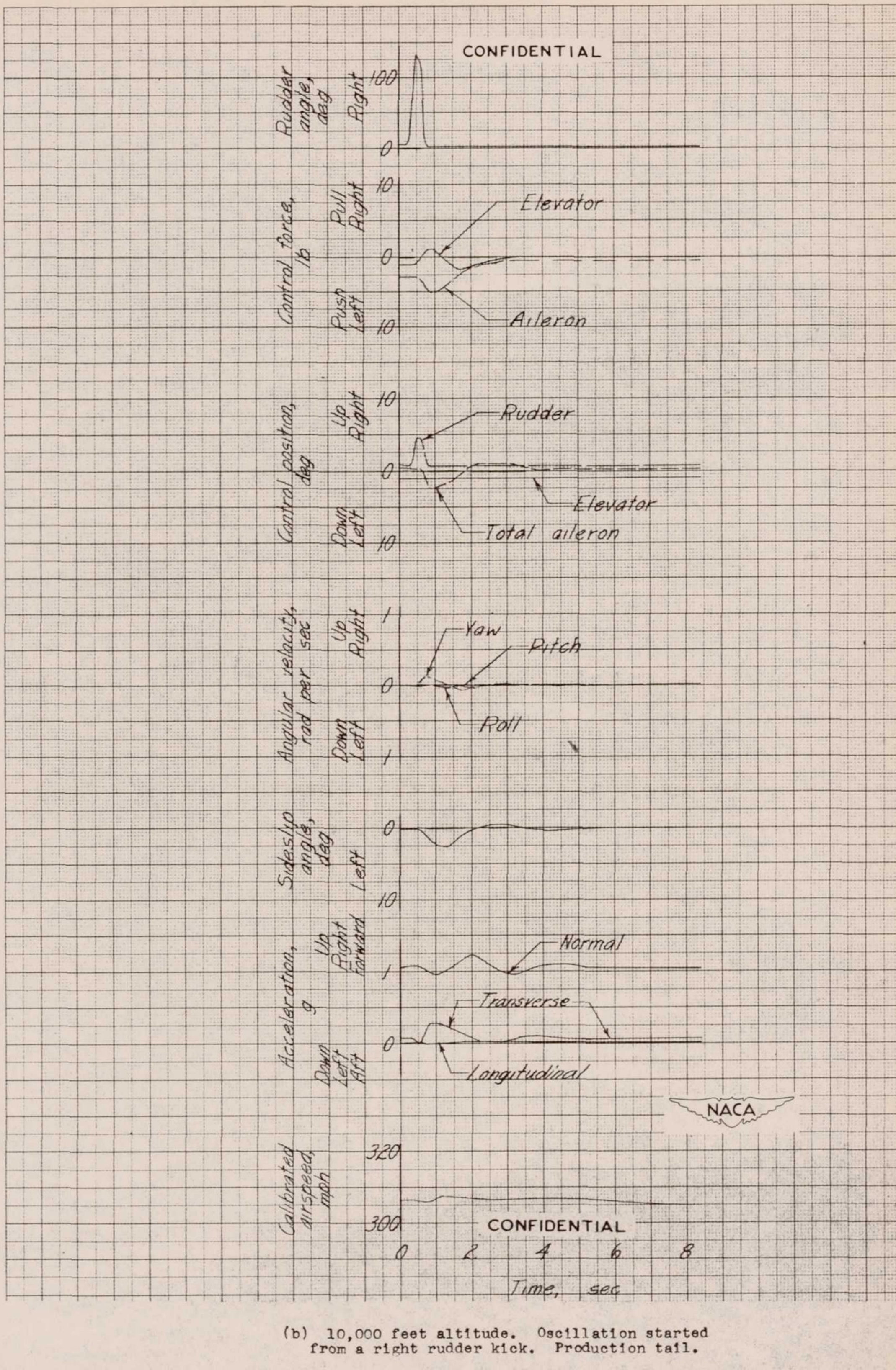
(c) 27,000 feet altitude. Oscillation started from a right rudder kick. Production tail.

Figure 14.- Concluded.



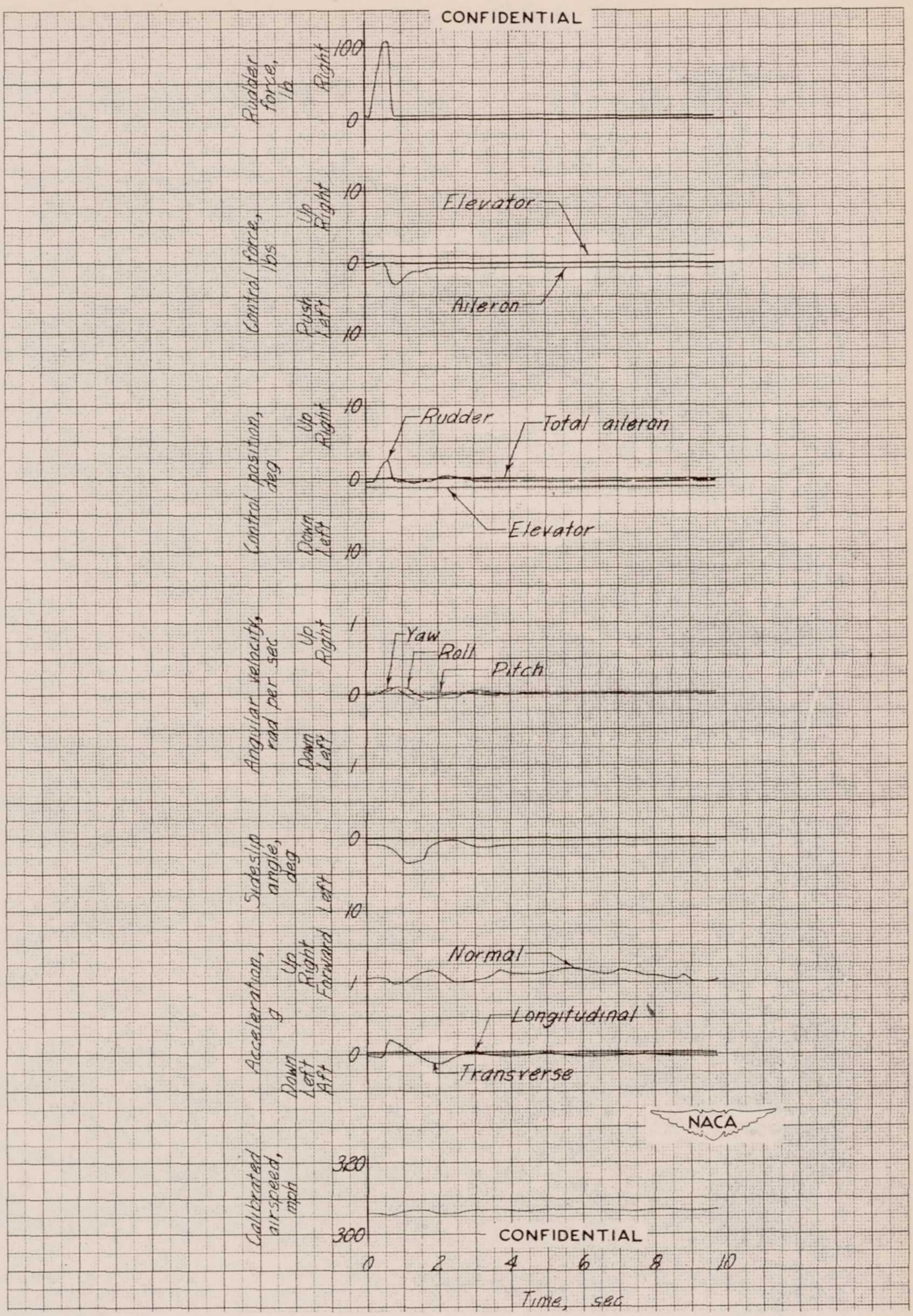
(a) 5000 feet altitude. Oscillation started from a steady sideslip. Airplane spiralled to left. Original tail.

Figure 15.- Time history of a directional oscillation in the high-speed power-on clean condition. P-51H airplane.



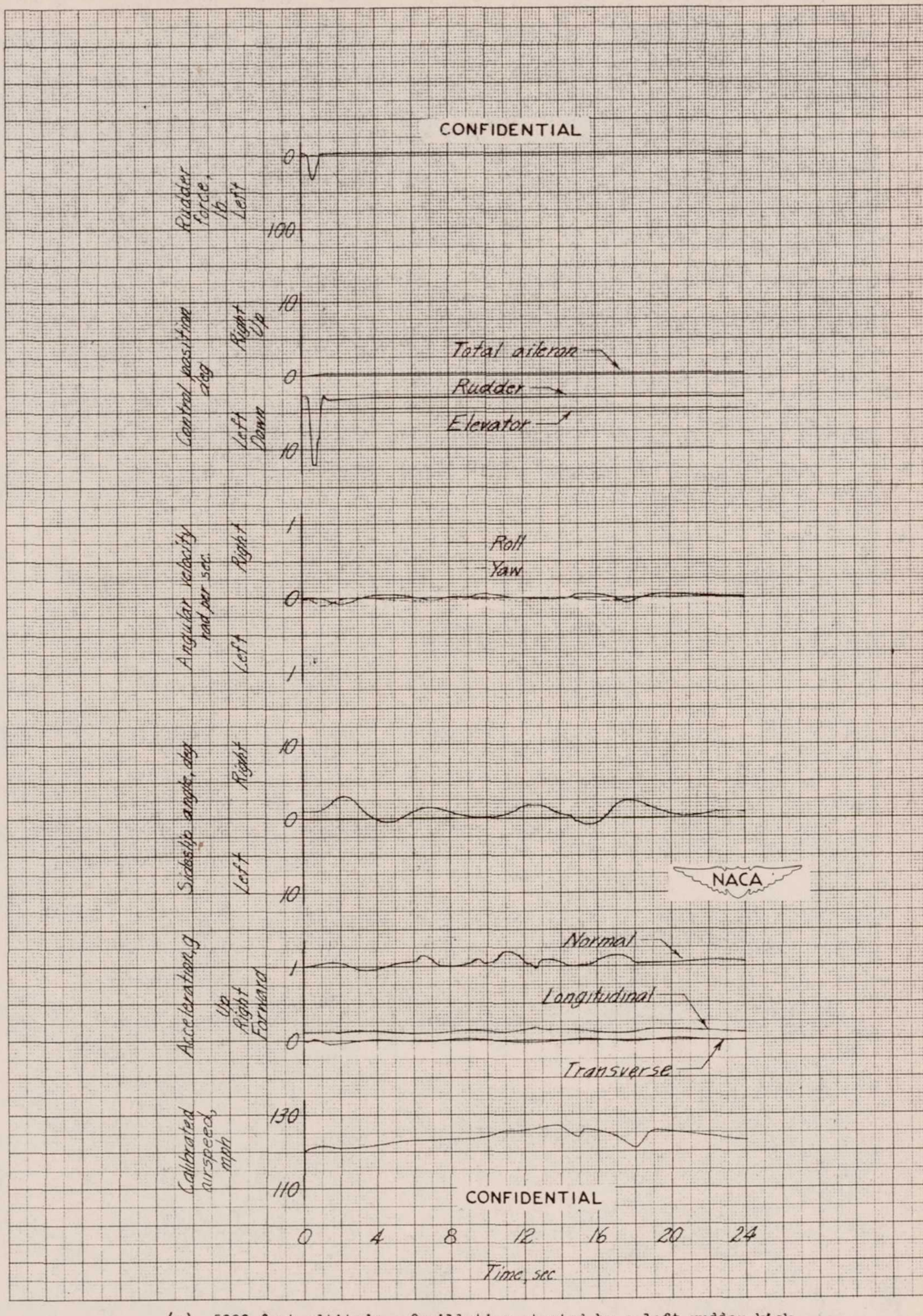
(b) 10,000 feet altitude. Oscillation started from a right rudder kick. Production tail.

Figure 15.- Continued.



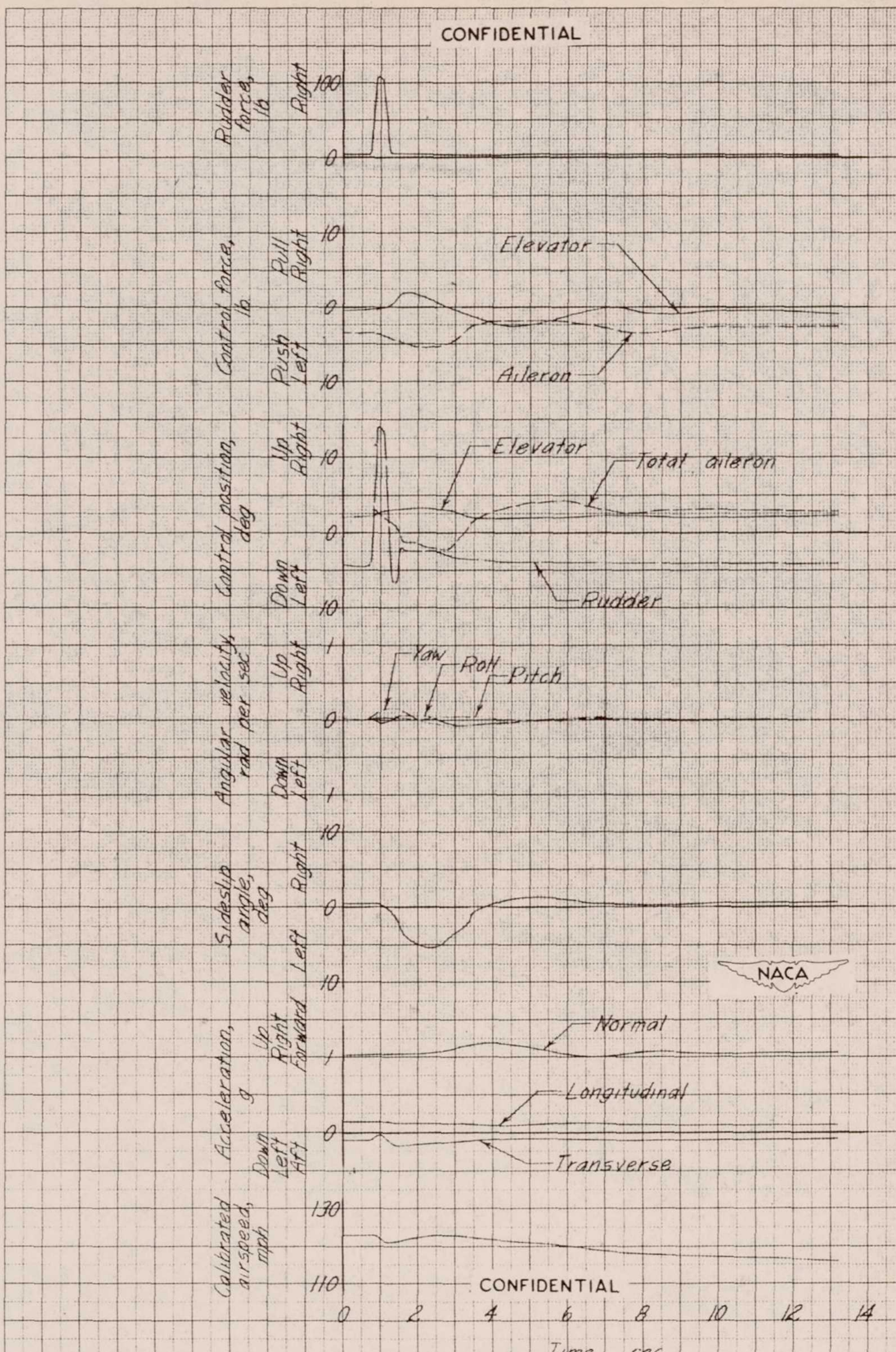
(c) 23,000 feet altitude. Oscillation started from a right rudder kick. Production tail. Record unsteady because of rough air.

Figure 15.- Concluded.



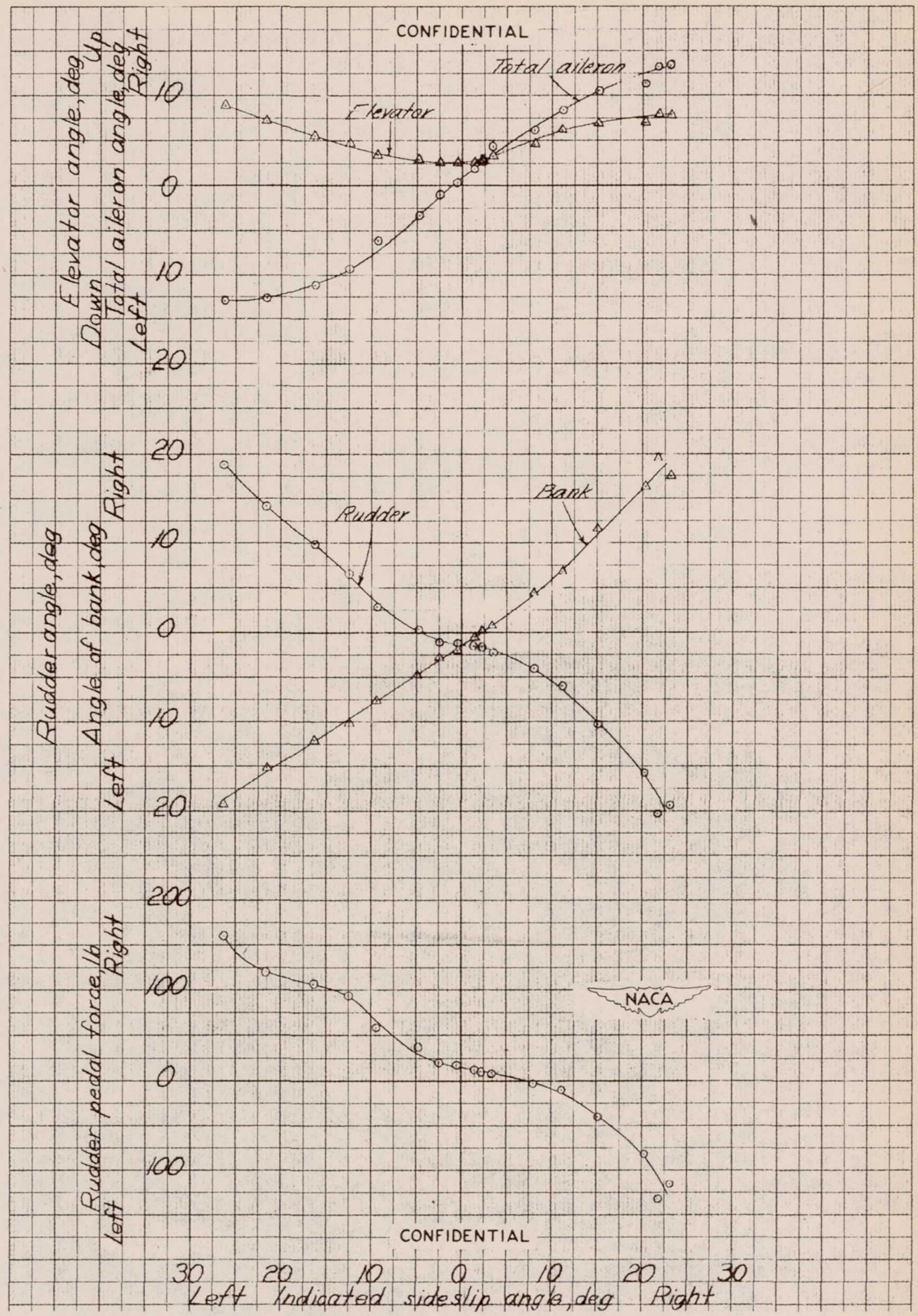
(a) 5000 feet altitude. Oscillation started by a left rudder kick. Maneuver performed in rough air. Original tail.

Figure 16.- Time history of a directional oscillation in the landing condition. P-51H airplane.



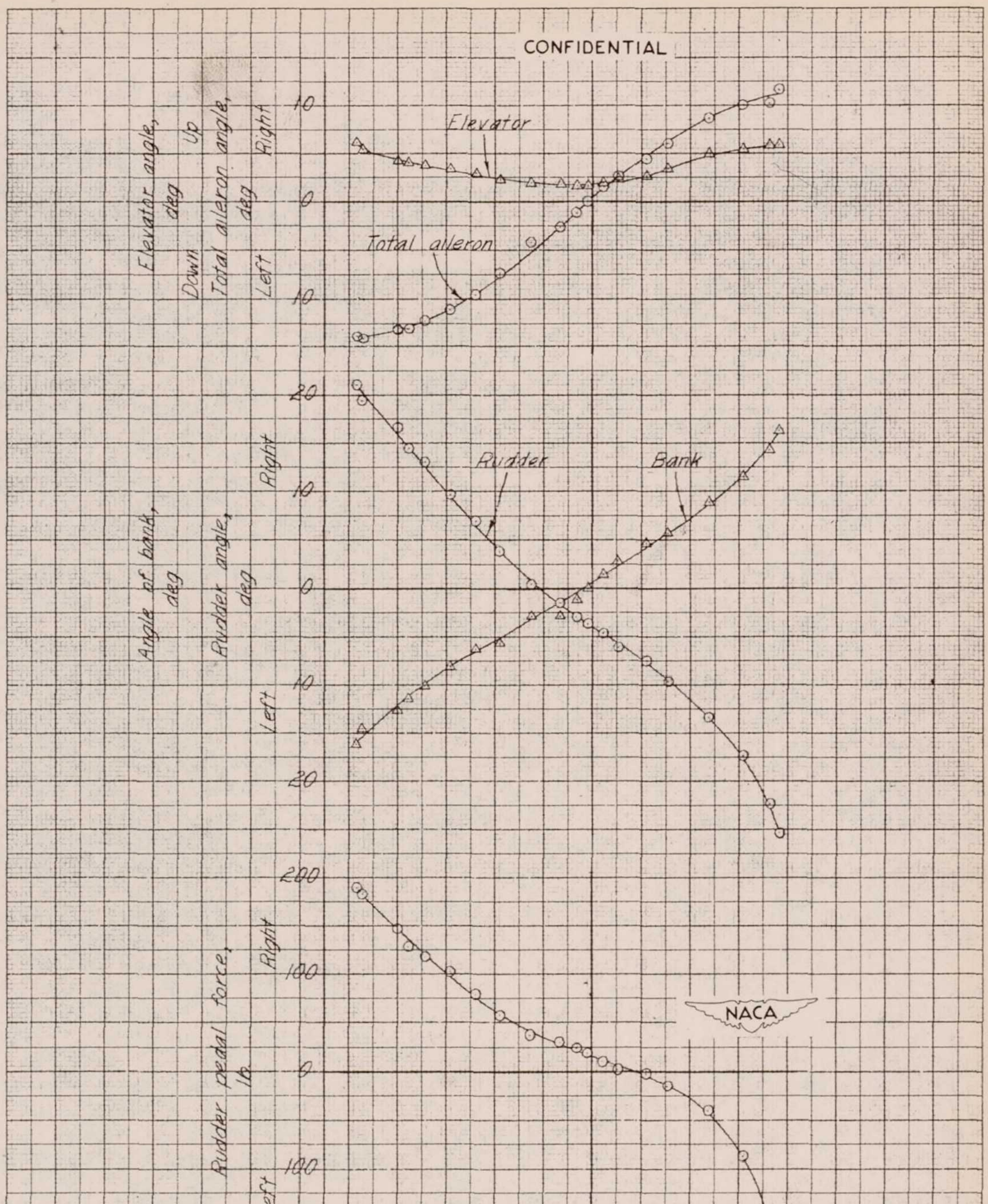
(b) 5000 feet altitude. Oscillation started from a right rudder kick. Stick used to hold wings level. Production tail.

Figure 16.- Concluded.



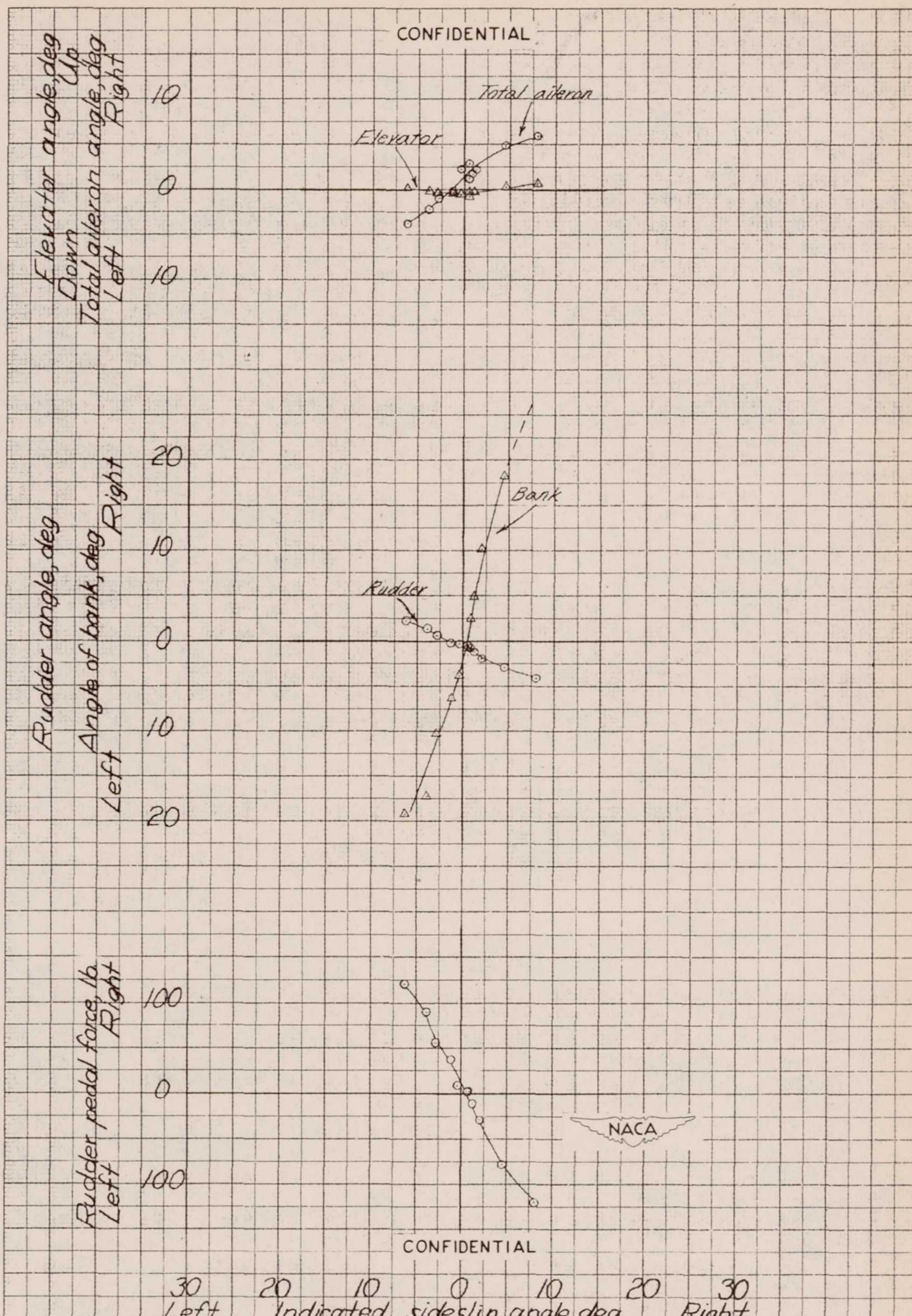
(a) 152-miles-per-hour, calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 17.- Directional stability and control characteristics of the P-51H airplane in the power-off clean condition at low altitude.



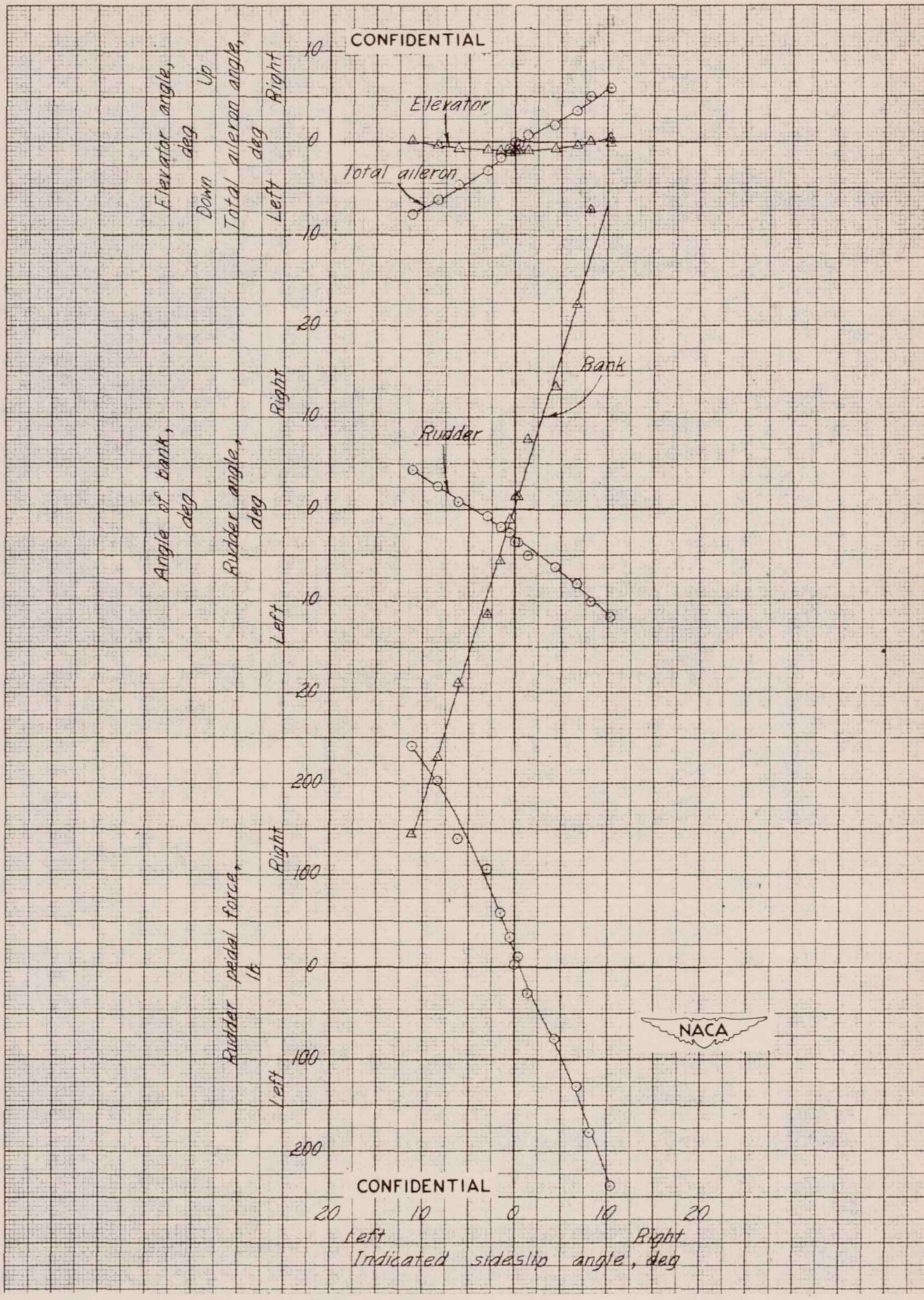
(b) 152-miles-per-hour, calibrated airspeed at 5000 feet average altitude. Production tail.

Figure 17.- Continued.



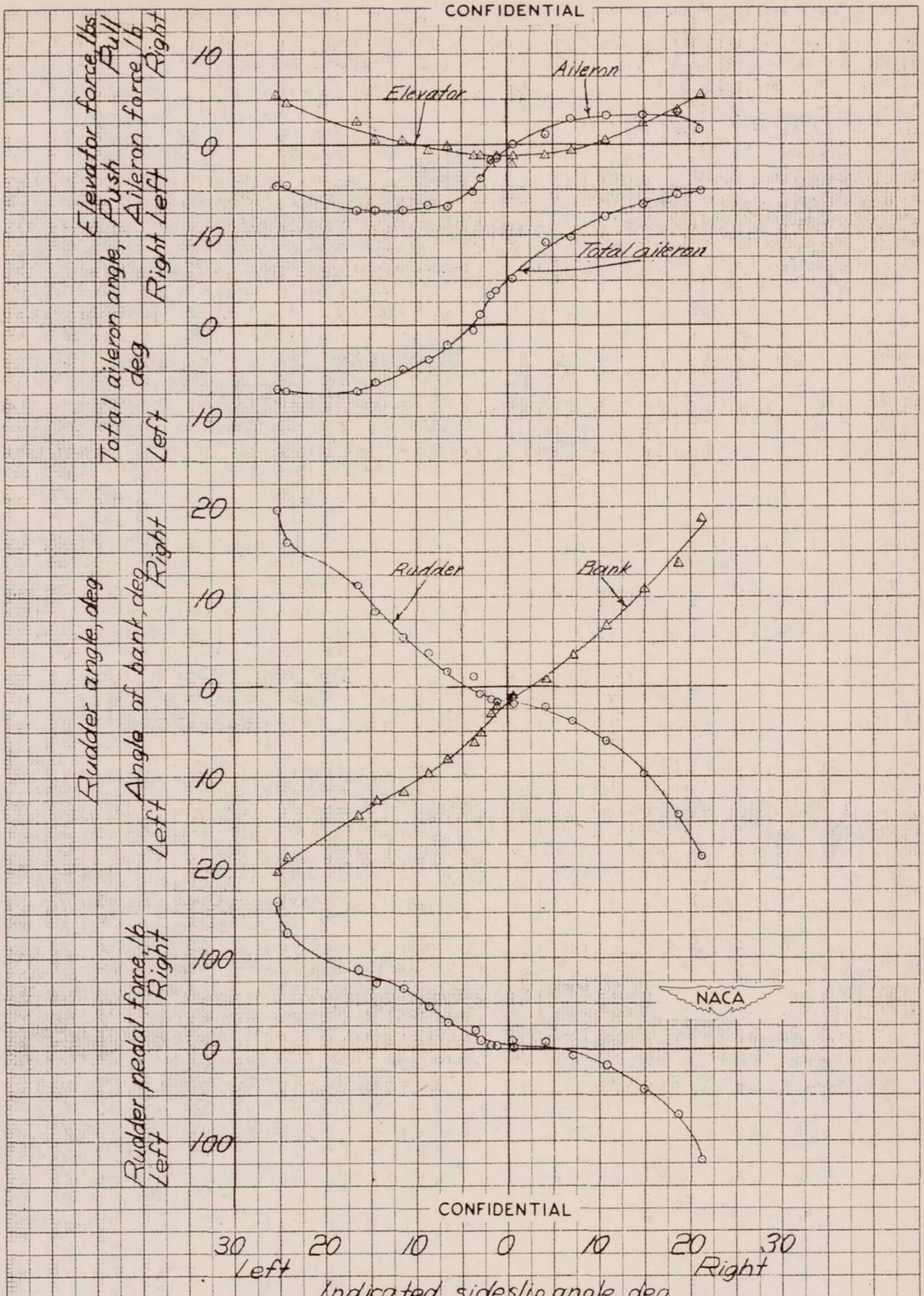
(c) 302-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 17.- Continued.



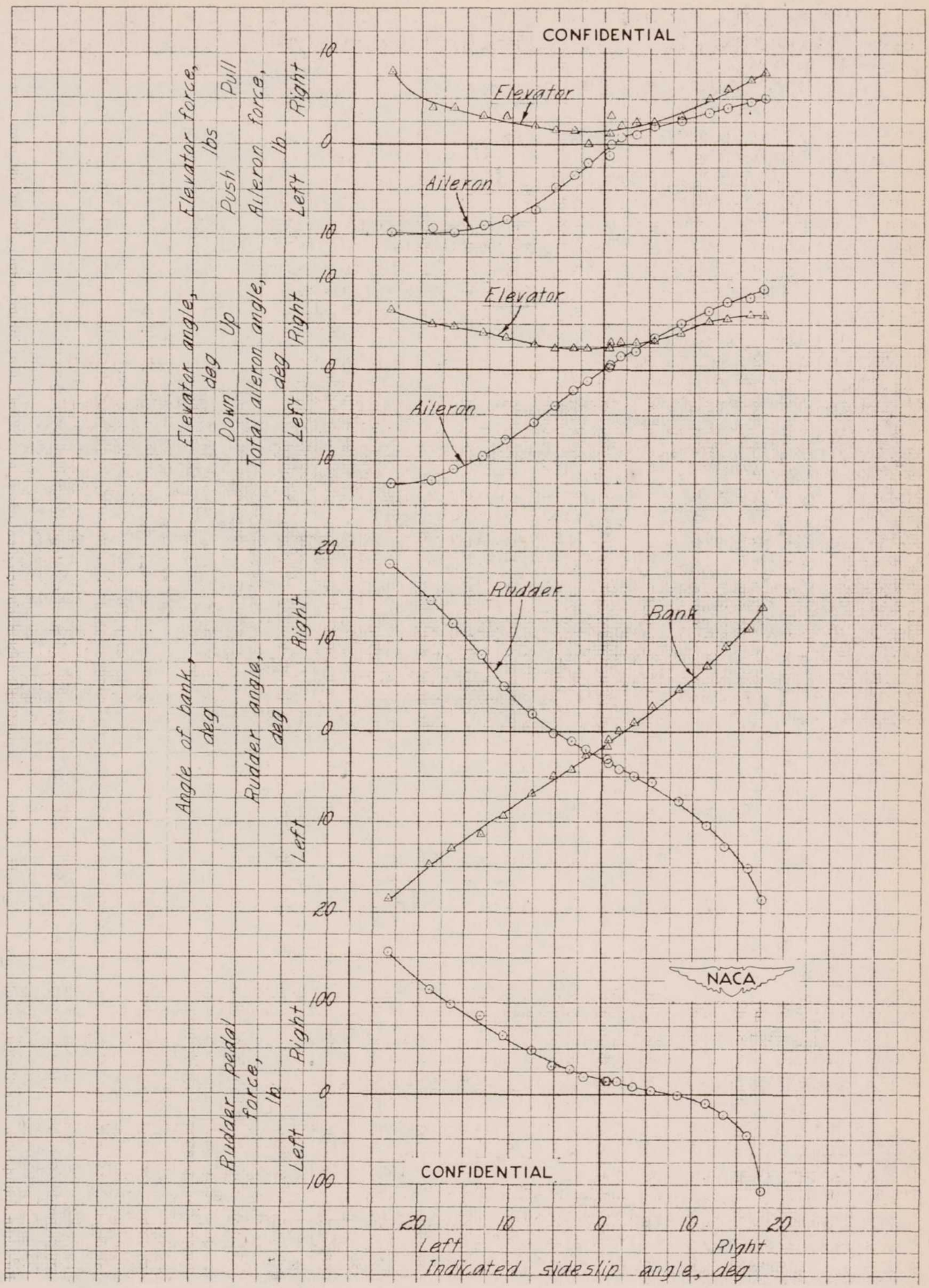
(d) 304-miles-per-hour calibrated airspeed at 4000 feet average altitude. Production tail.

Figure 17.- Concluded.



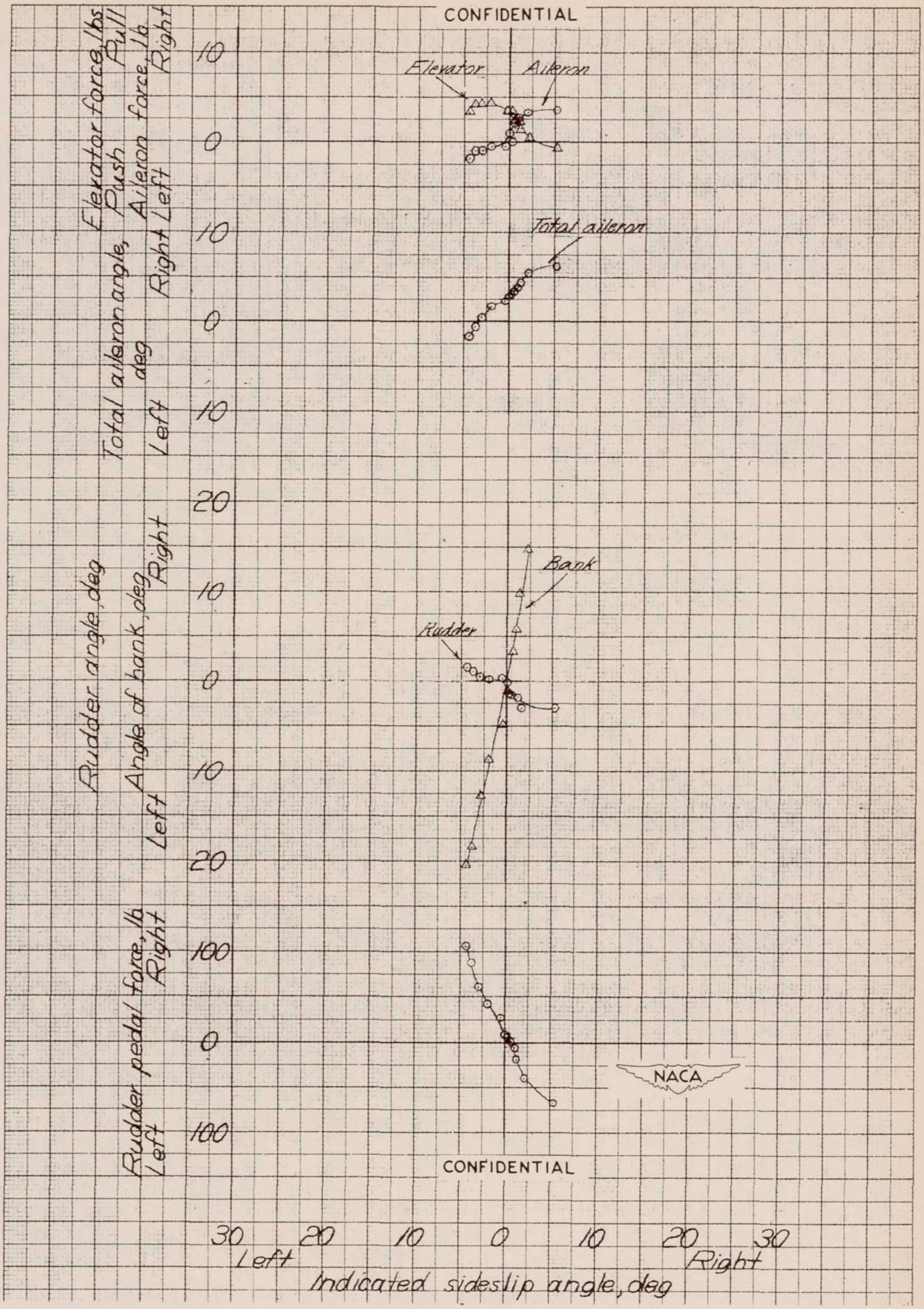
(a) 154-miles-per-hour, calibrated airspeed at 21,000 feet average altitude. Original tail.

Figure 18.- Directional stability and control characteristics of the P-51H airplane in the power-off clean condition at high altitude.



(b) 154-miles-per-hour calibrated airspeed at 21,000 feet average altitude. Production tail.

Figure 18.- Continued.



(c) 306-miles-per-hour calibrated airspeed at 20,000 feet average altitude. Original tail.

Figure 18.- Continued.

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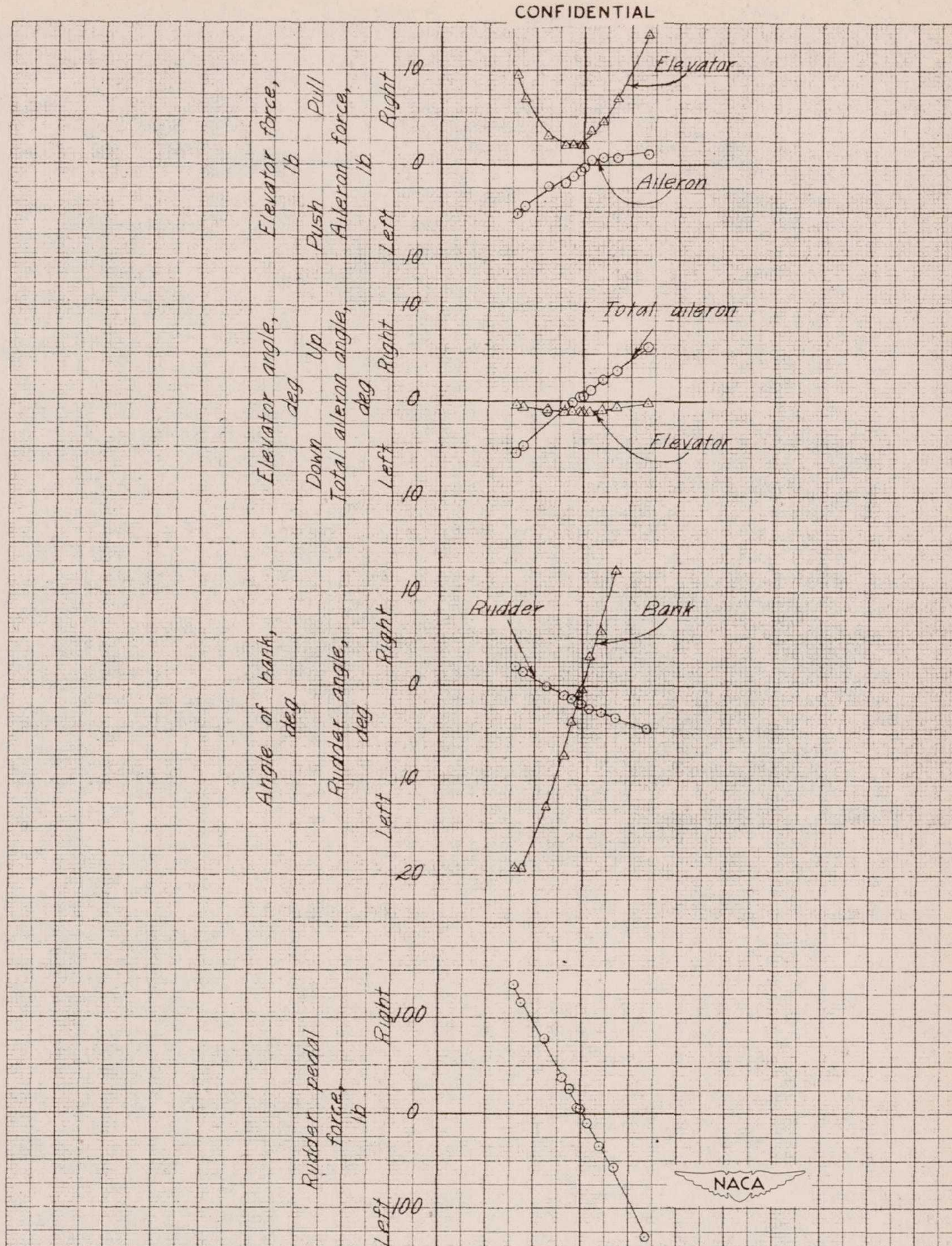

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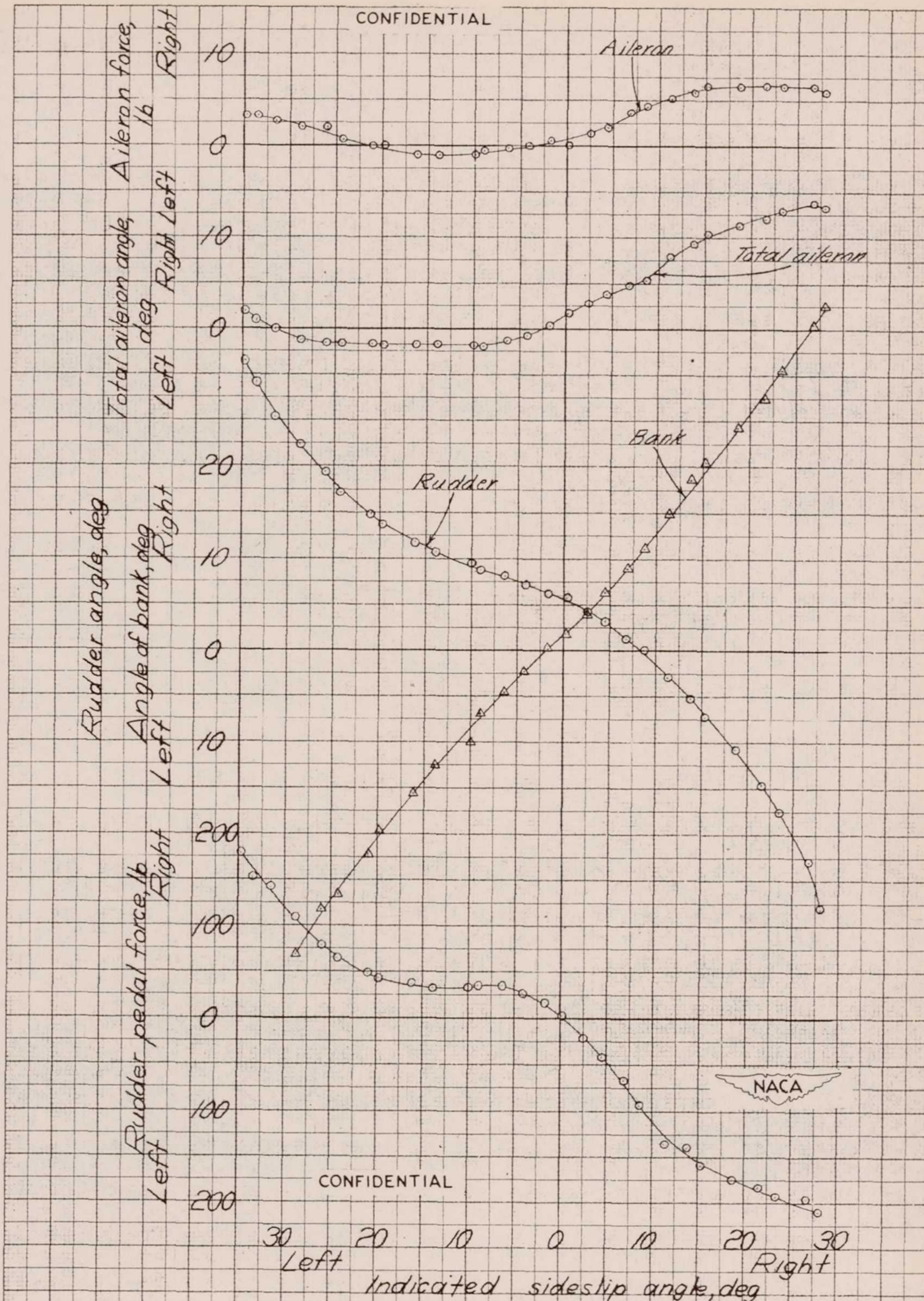
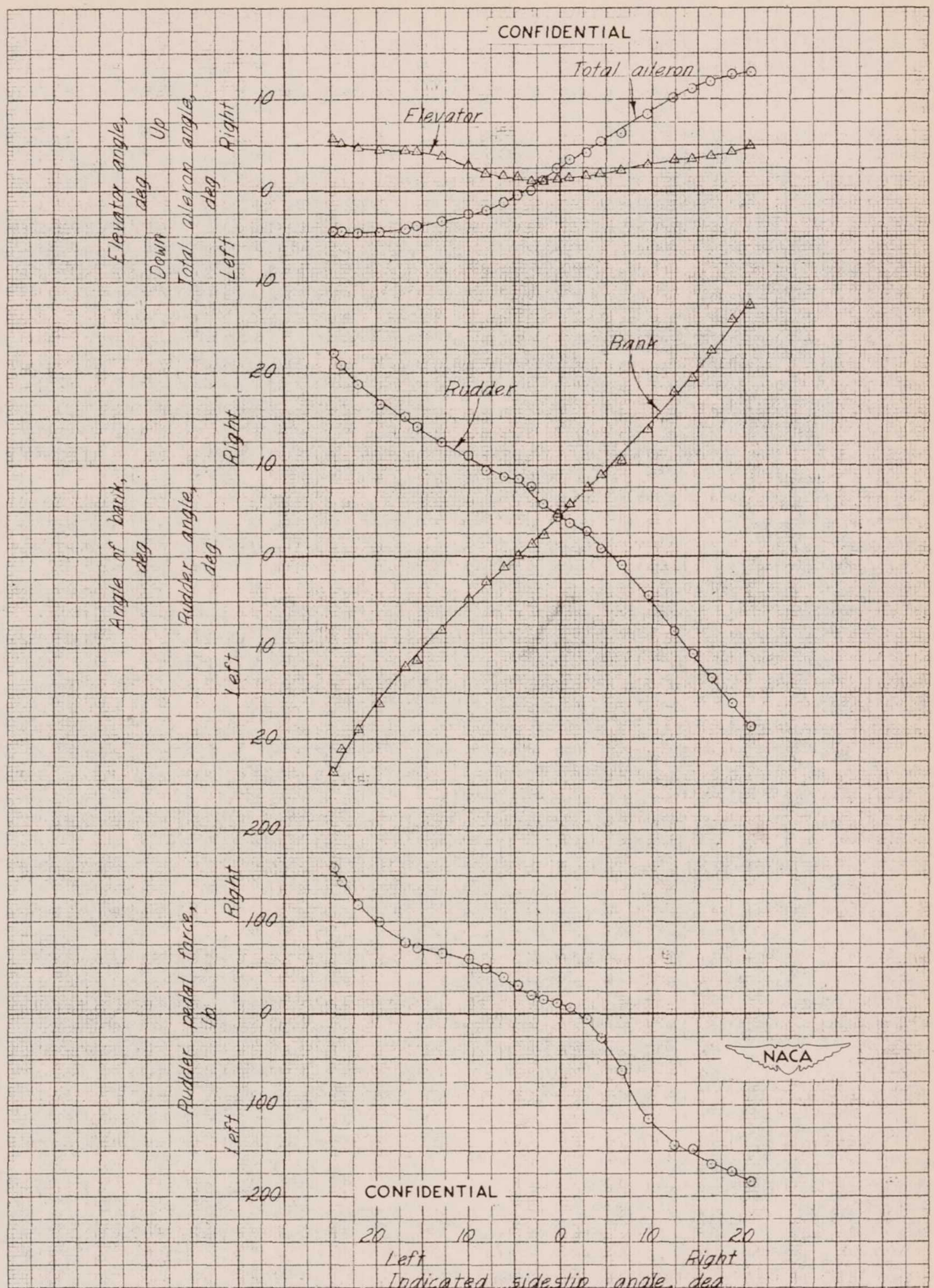
(d) 302-miles-per-hour calibrated airspeed at 20,000 feet average altitude. Production tail.

Figure 18.- Concluded.



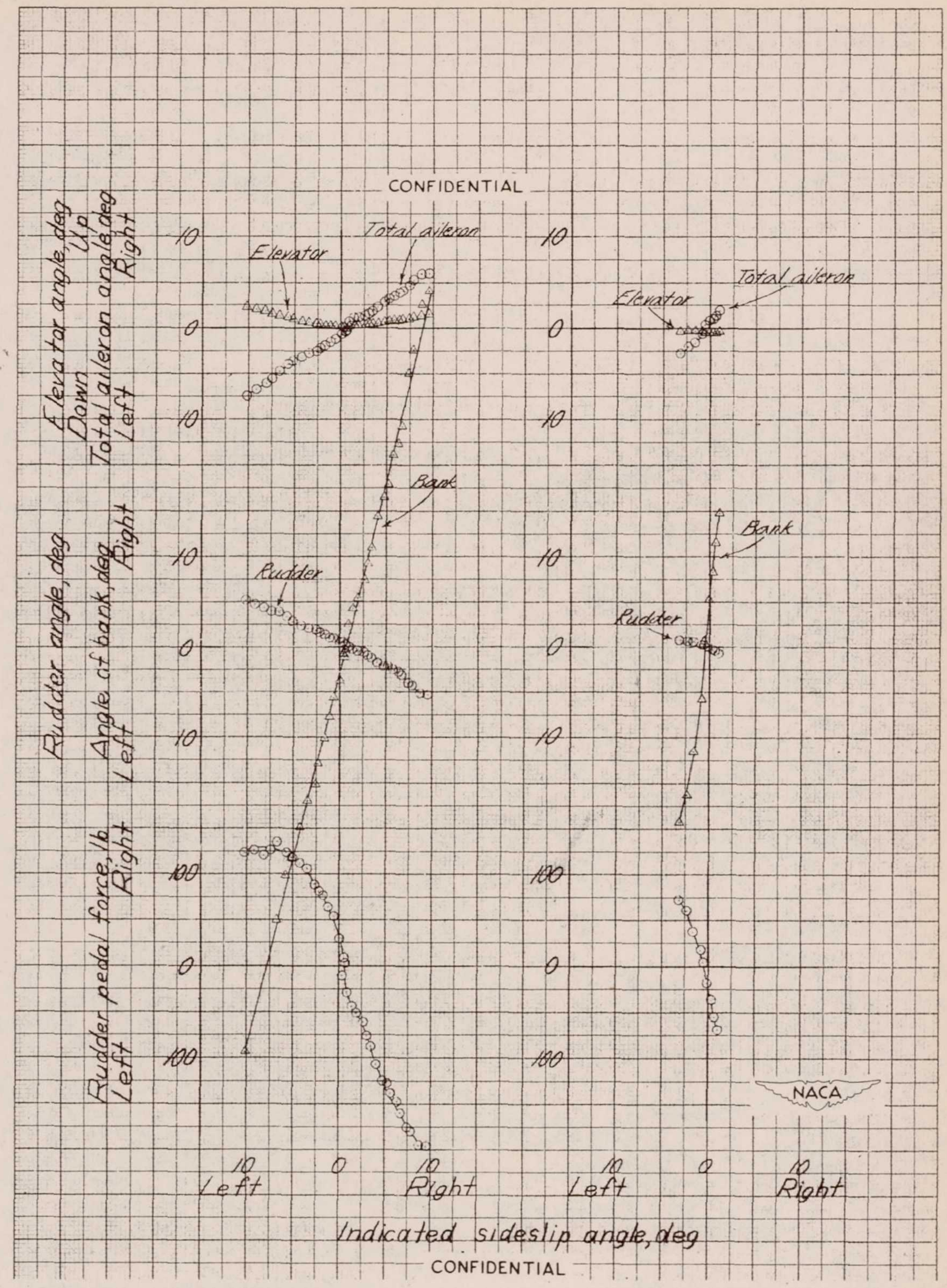
(a) 153-miles-per-hour, calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 19.- Directional stability and control characteristics of the P-51H airplane in the power-on clean condition at low altitude.



(b) 151-miles-per-hour calibrated airspeed at 7000 feet average altitude. Production tail.

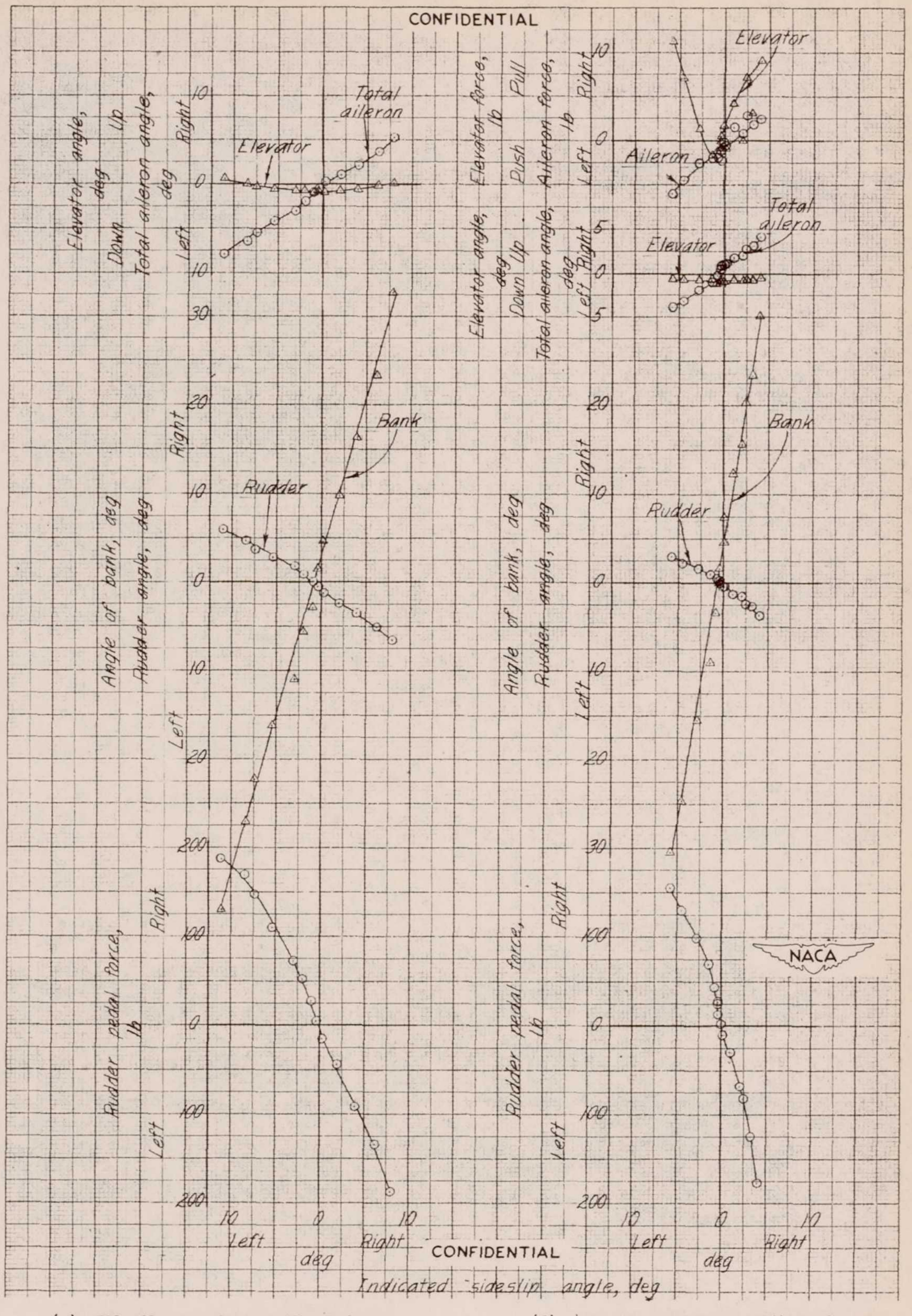
Figure 19.- Continued.



(c) 306-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

(d) 404-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

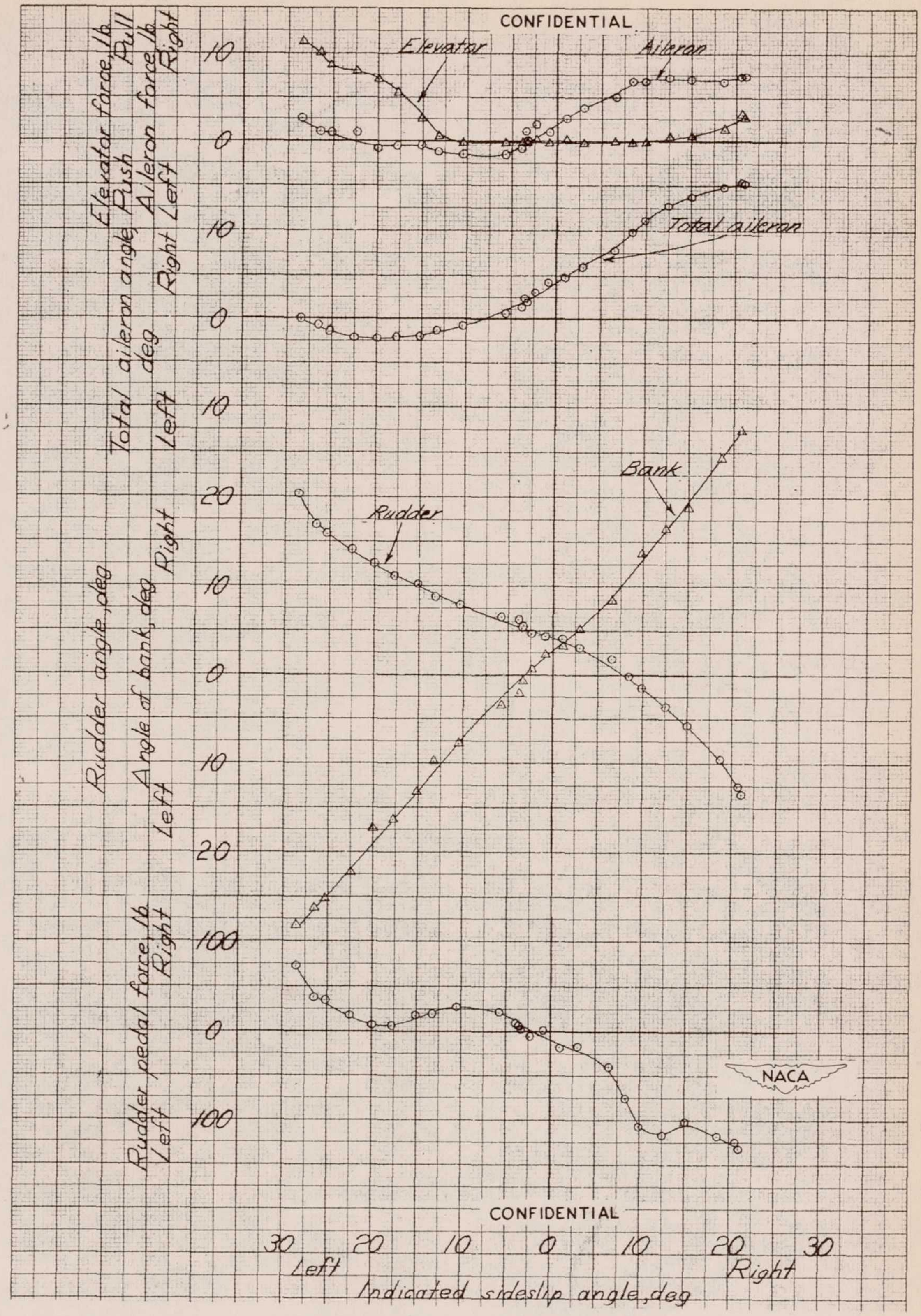
Figure 19.- Continued.



(e) 309-miles-per-hour calibrated air-speed at 4000 feet average altitude. Production tail.

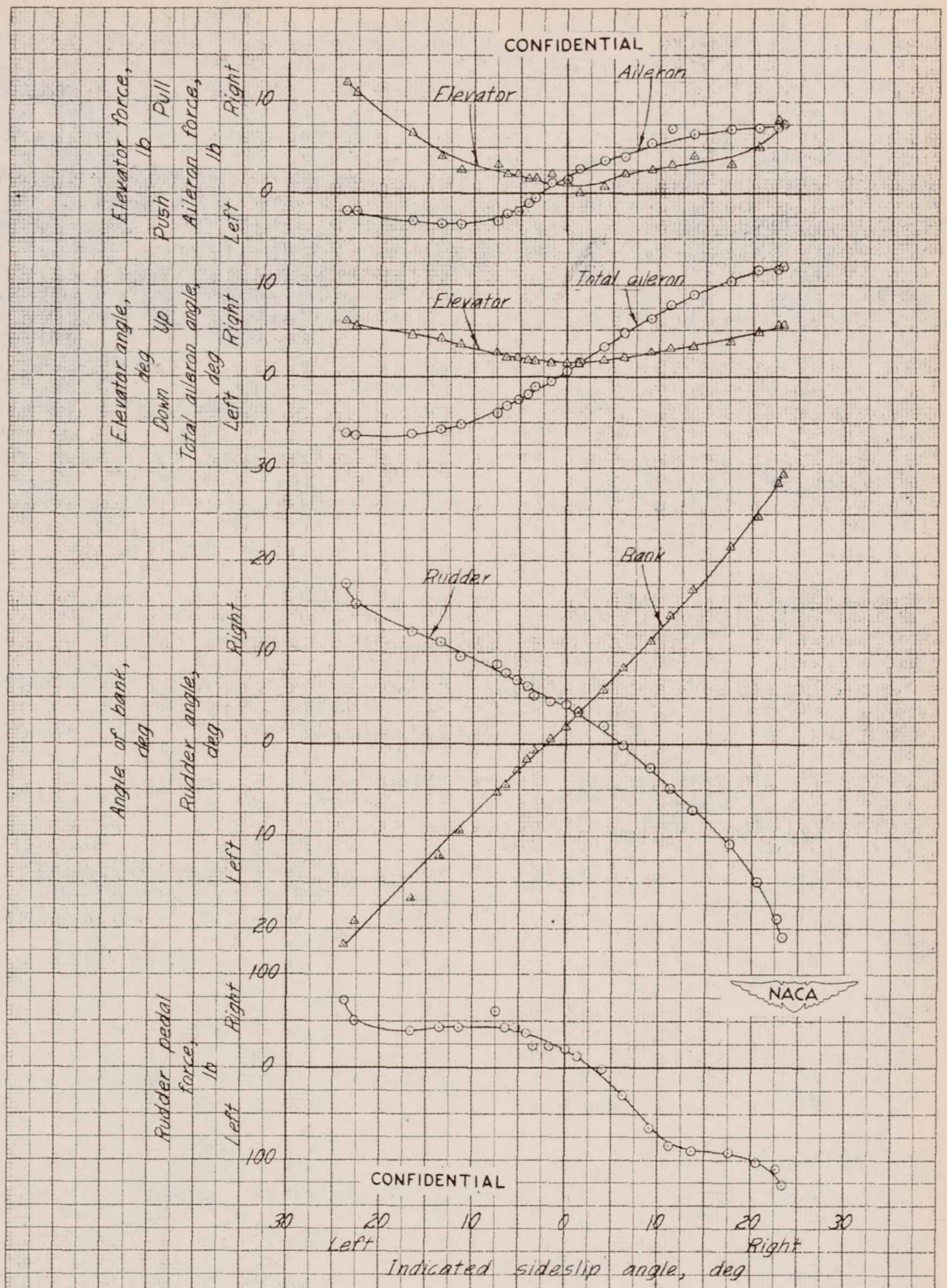
(f) 405-miles-per-hour calibrated air-speed at 5000 feet average altitude. Production tail.

Figure 19.- Concluded.



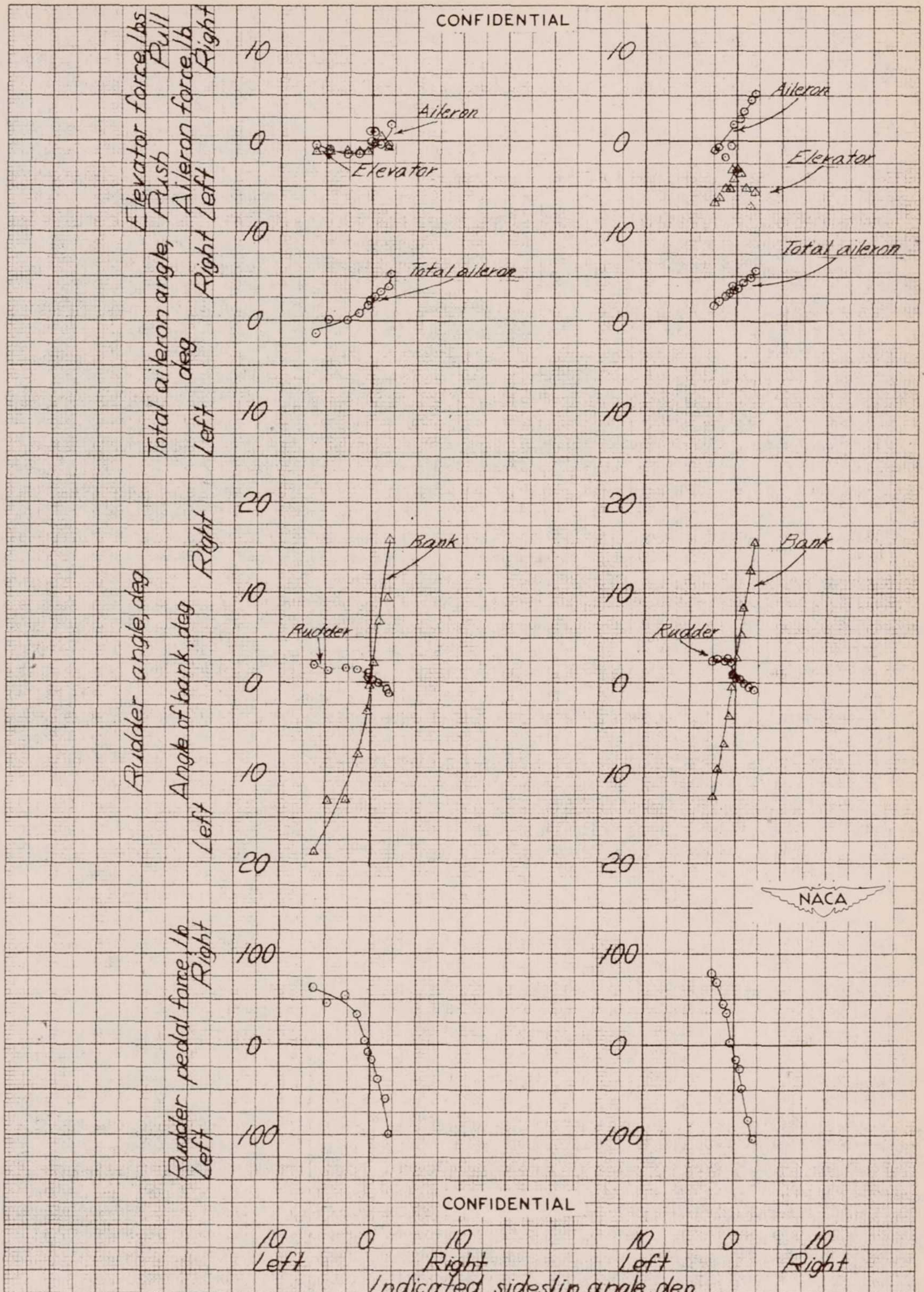
(a) 153-miles-per-hour calibrated airspeed at 22,000 feet average altitude. Original tail.

Figure 20.- Directional stability and control characteristics of the P-51H airplane in the power-on clean condition at high altitude.



(b) 154-miles-per-hour calibrated airspeed at 25,000 feet average altitude. Production tail.

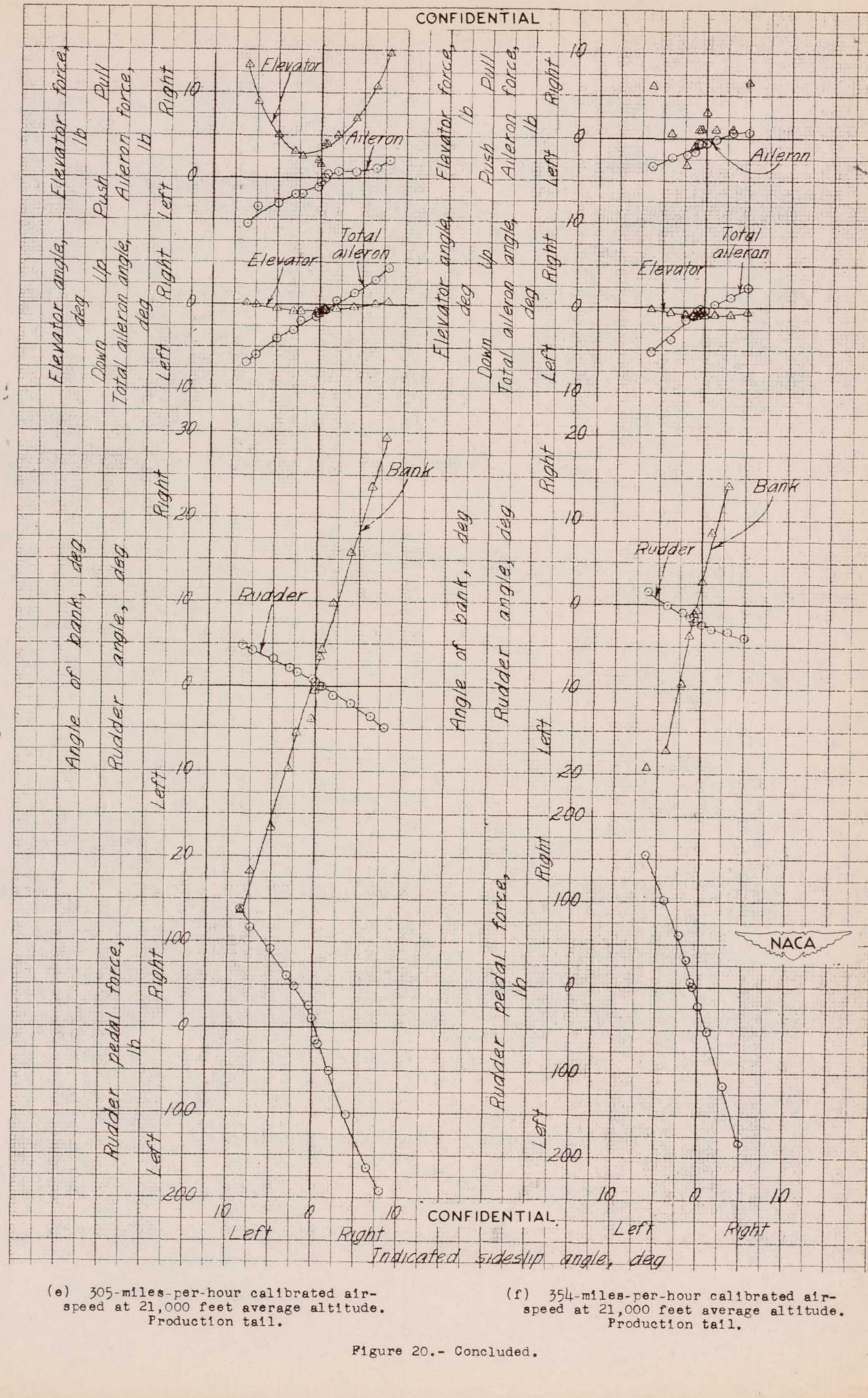
Figure 20.- Continued.



(c) 304-miles-per-hour calibrated airspeed at 22,000 feet average altitude. Original tail.

(d) 355-miles-per-hour calibrated airspeed at 21,000 feet average altitude. Original tail.

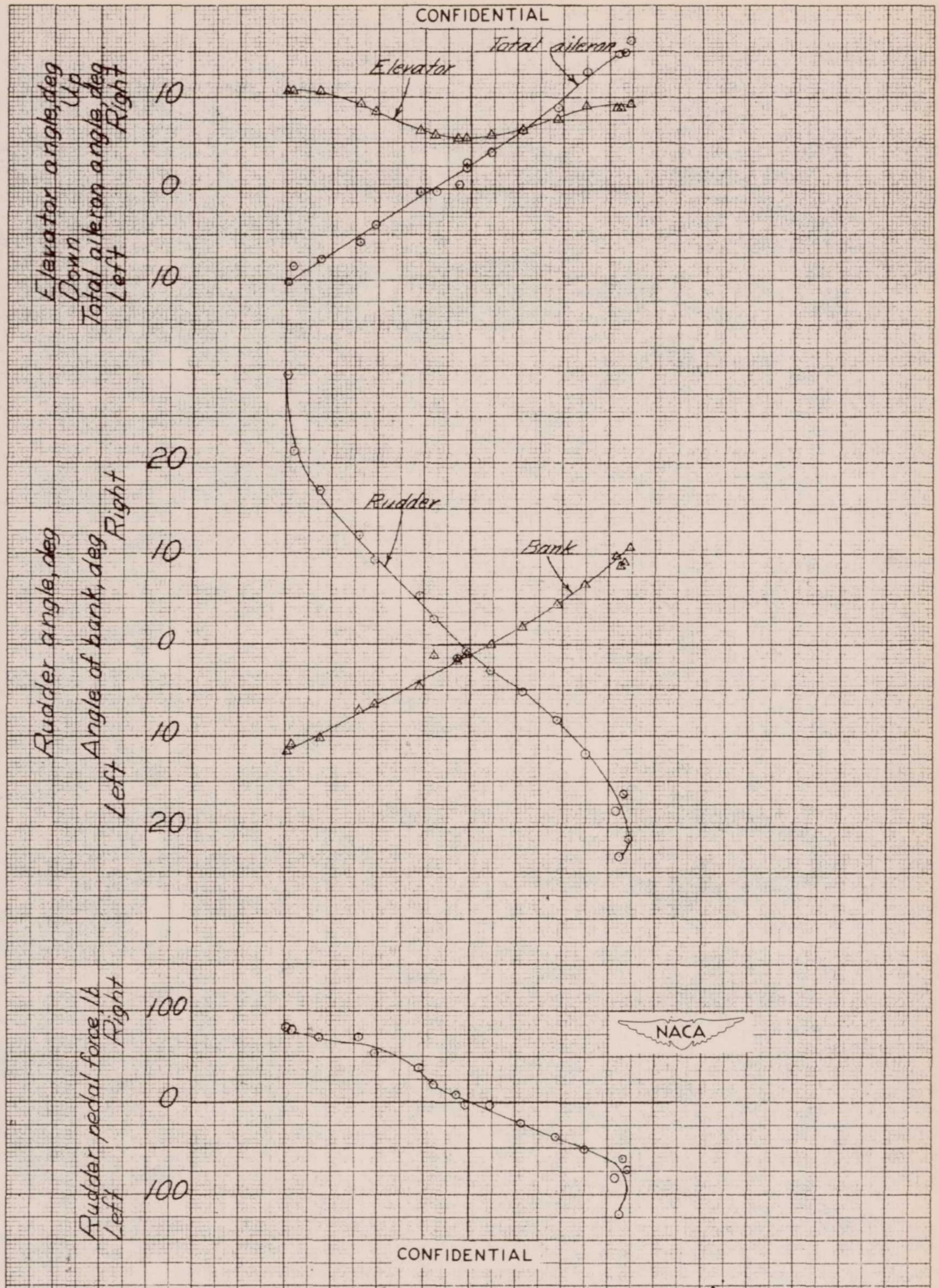
Figure 20.- Continued.



(e) 305-miles-per-hour calibrated airspeed at 21,000 feet average altitude. Production tail.

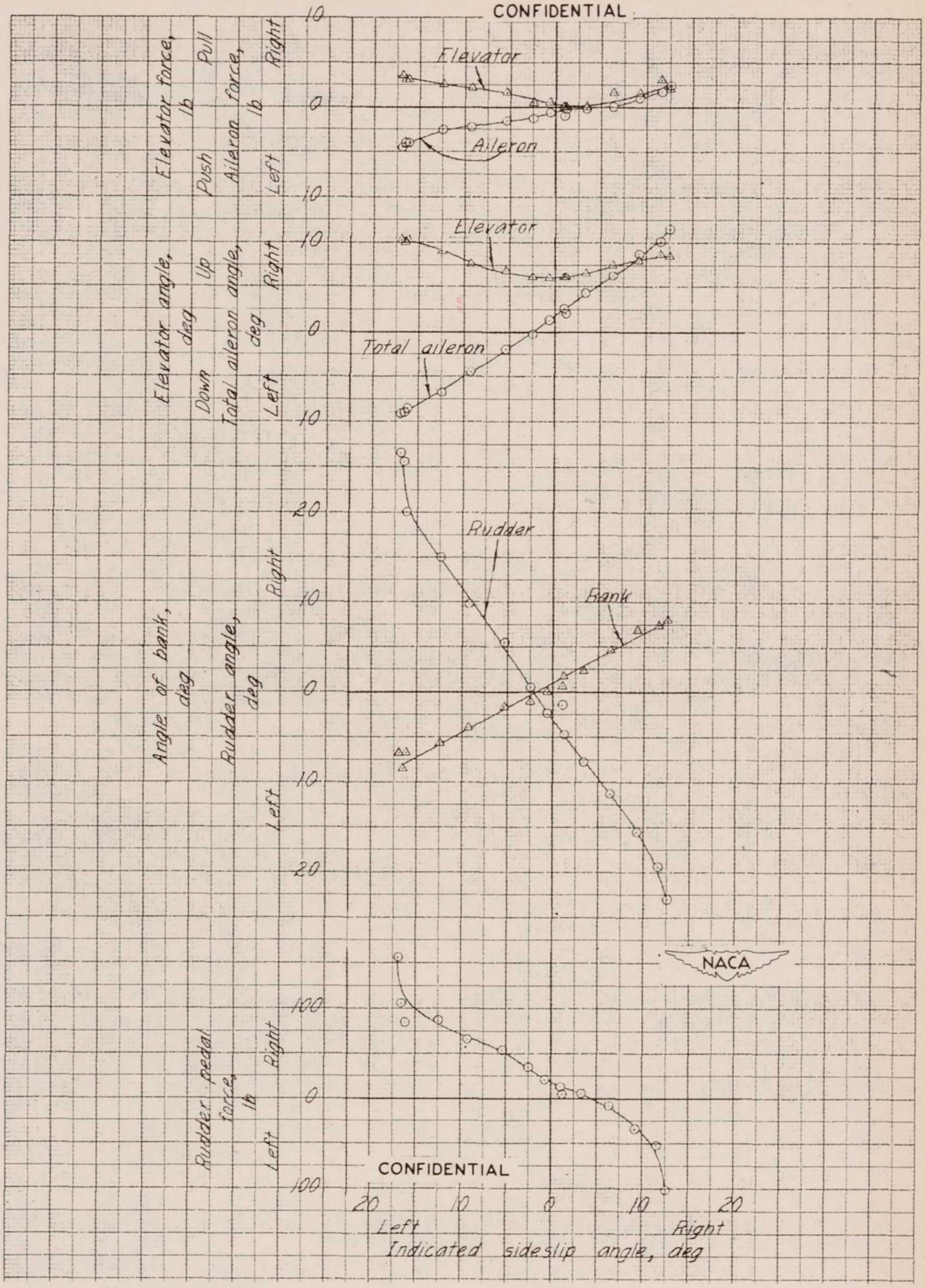
(f) 354-miles-per-hour calibrated airspeed at 21,000 feet average altitude. Production tail.

Figure 20.- Concluded.



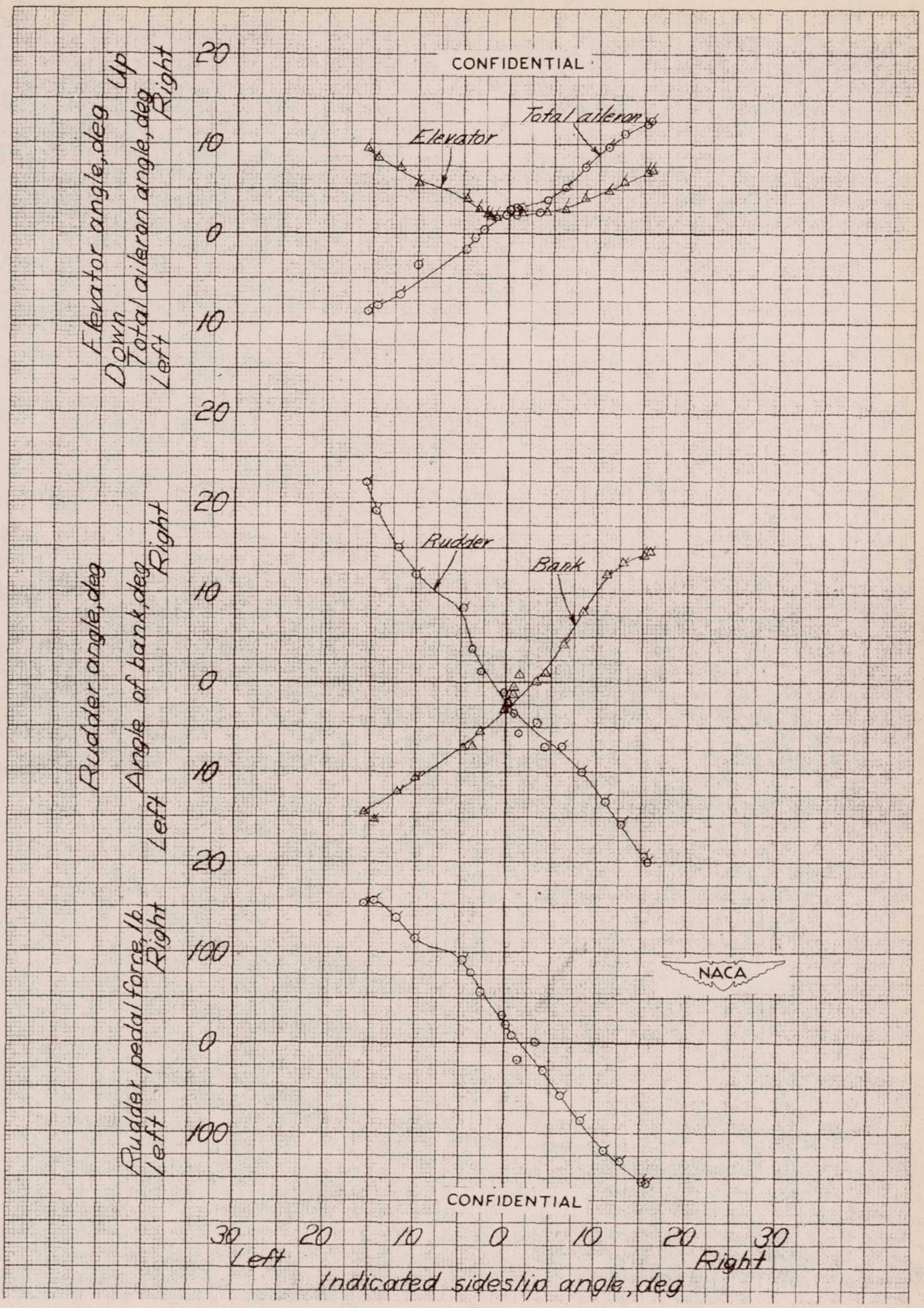
(a) 122-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 21.- Directional stability and control characteristics of the P-51H airplane in the power-off landing condition.



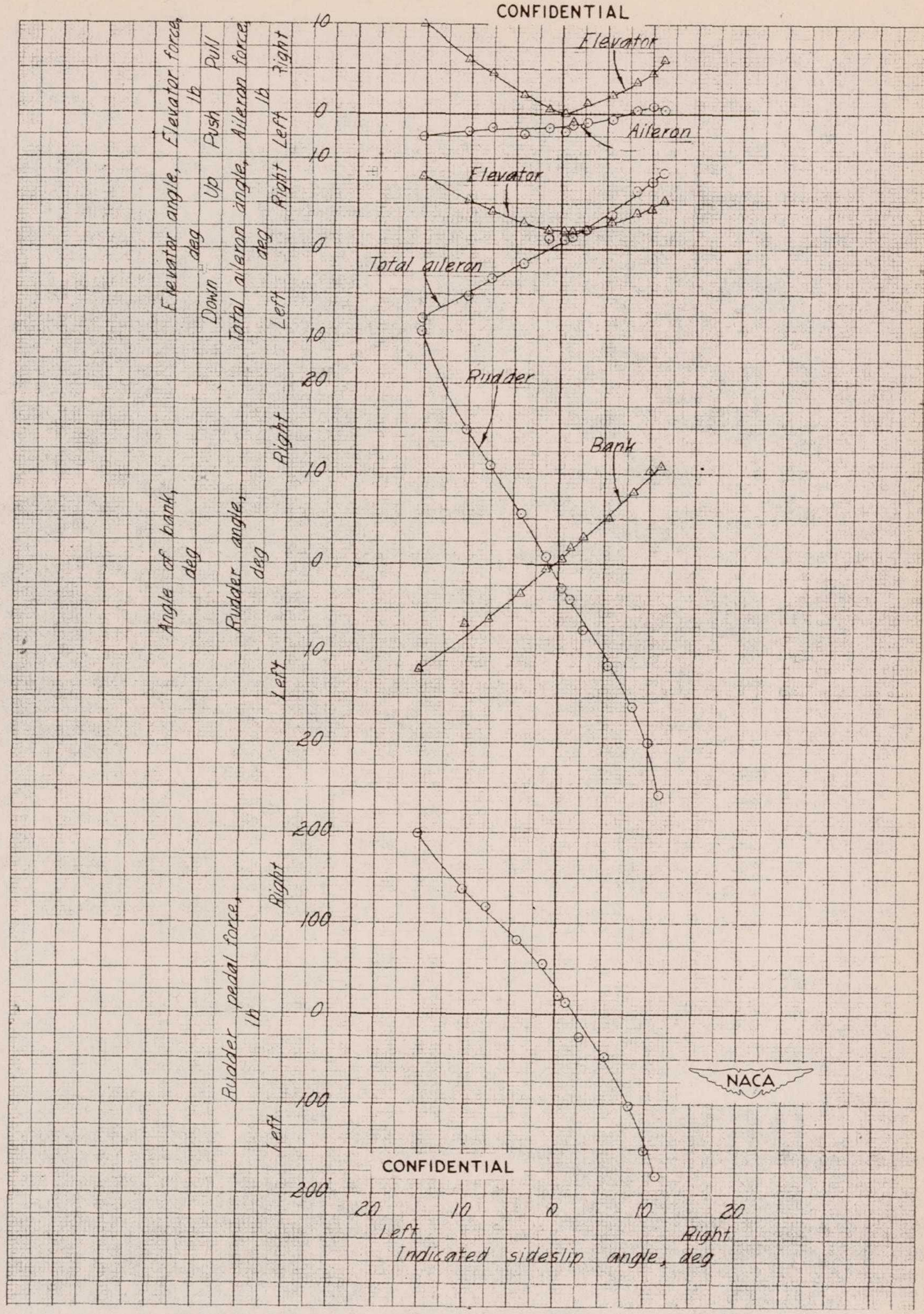
(b) 117-miles-per-hour calibrated airspeed at 5000 feet average altitude. Production tail.

Figure 21.- Continued.



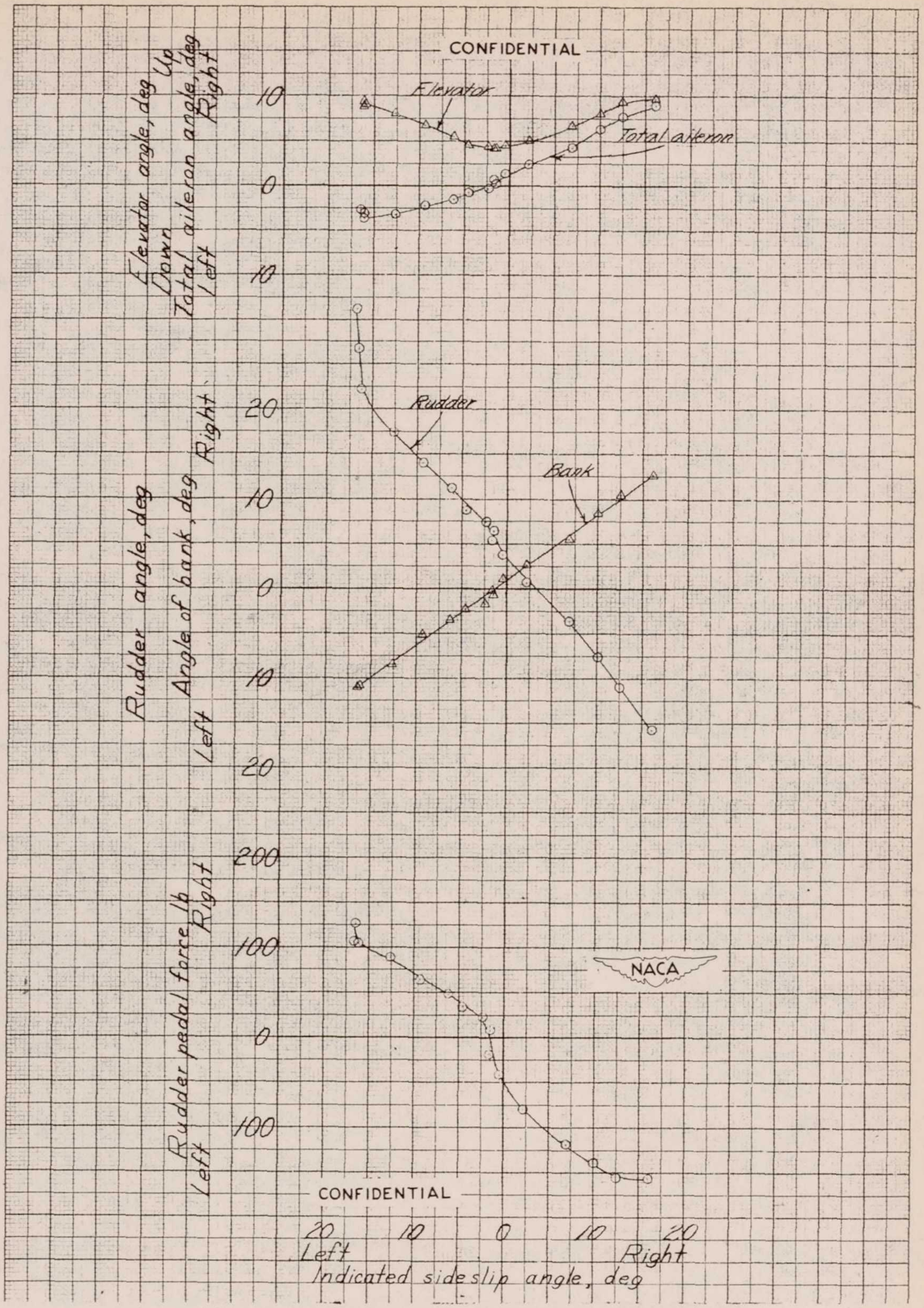
(c) 154-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 21.- Continued.



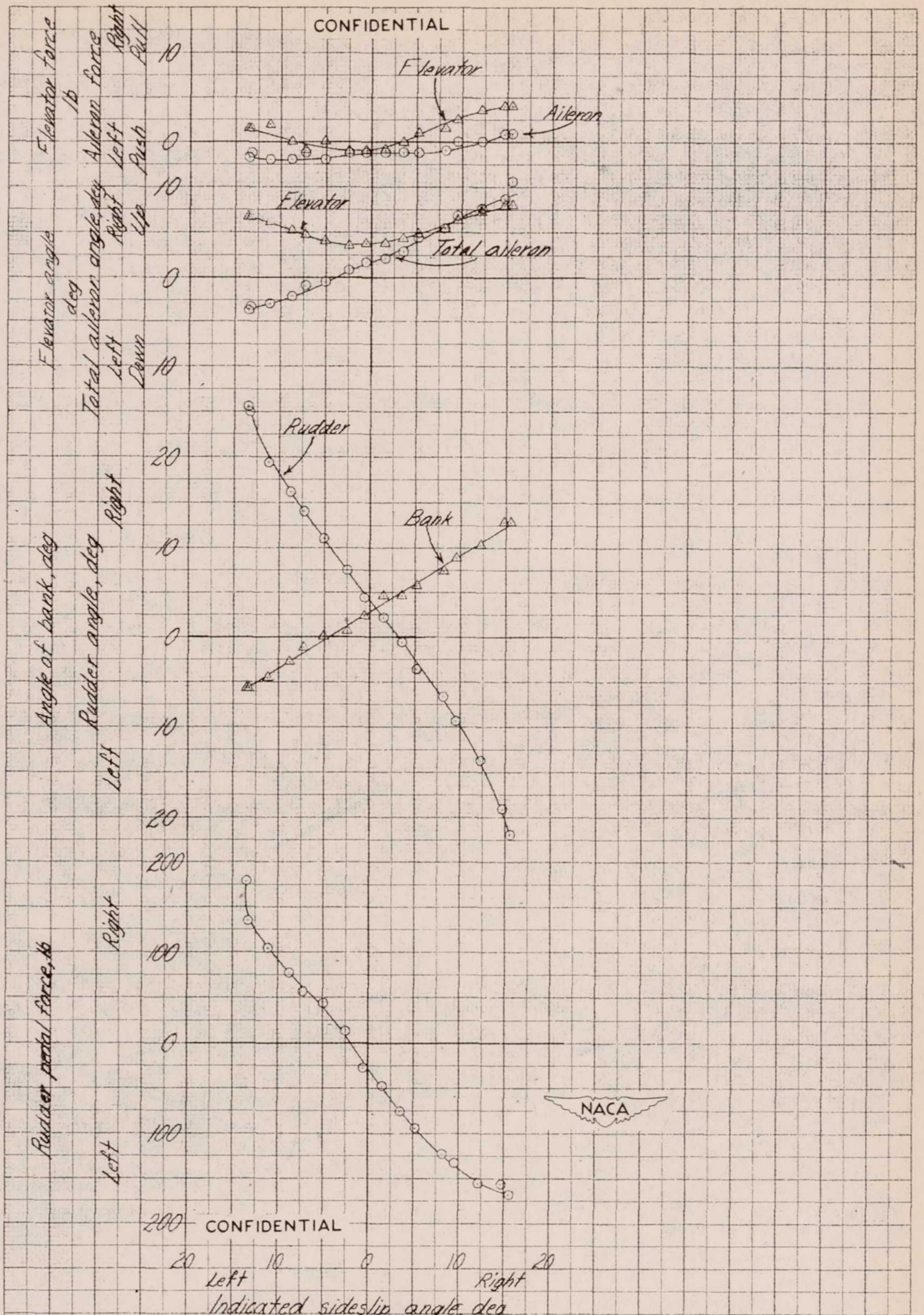
(d) 153-miles-per-hour calibrated airspeed at 5000 feet average altitude. Production tail.

Figure 21.- Concluded.



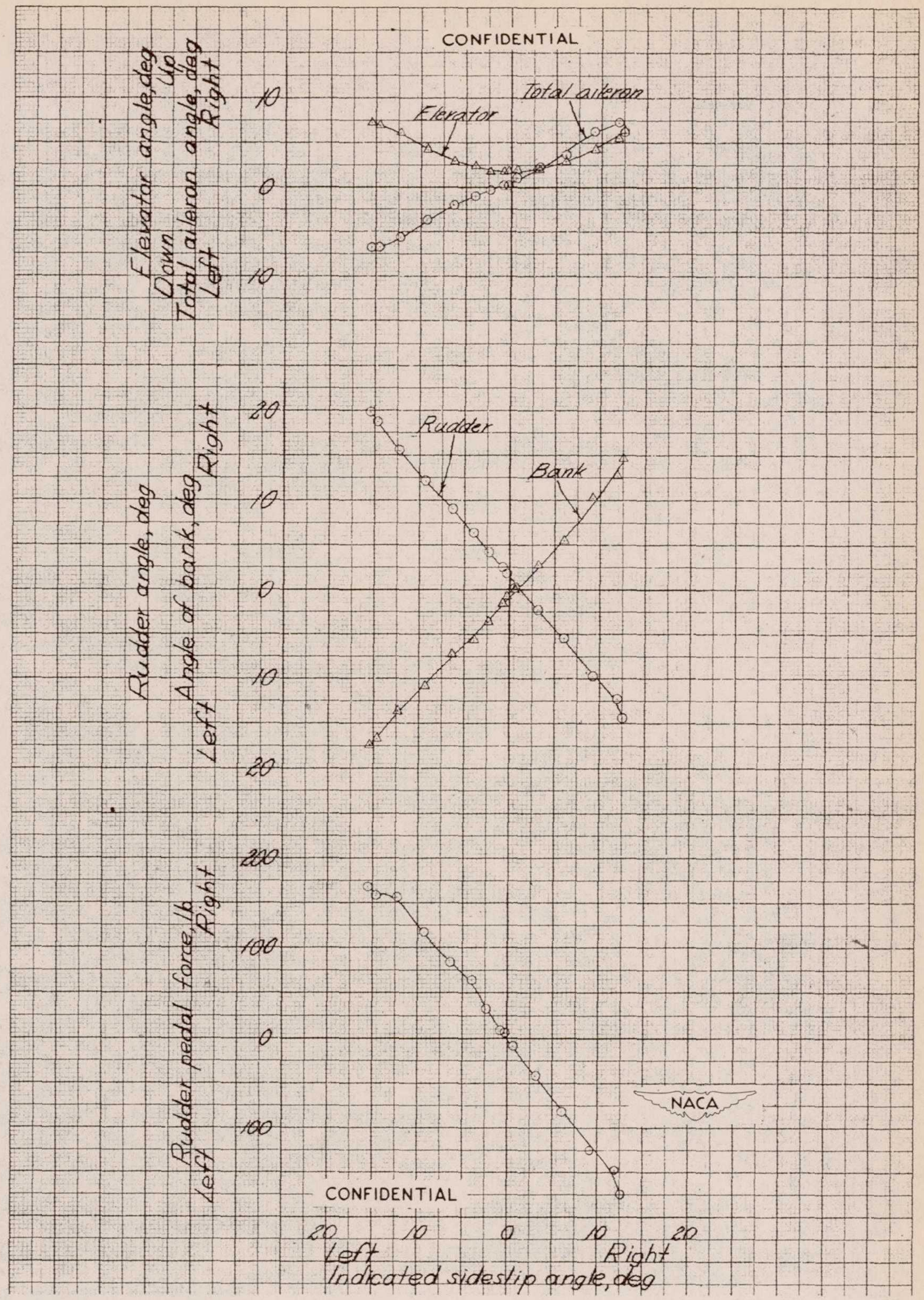
(a) 120-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 22.- Directional stability and control characteristics of the P-51H airplane in the approach condition.



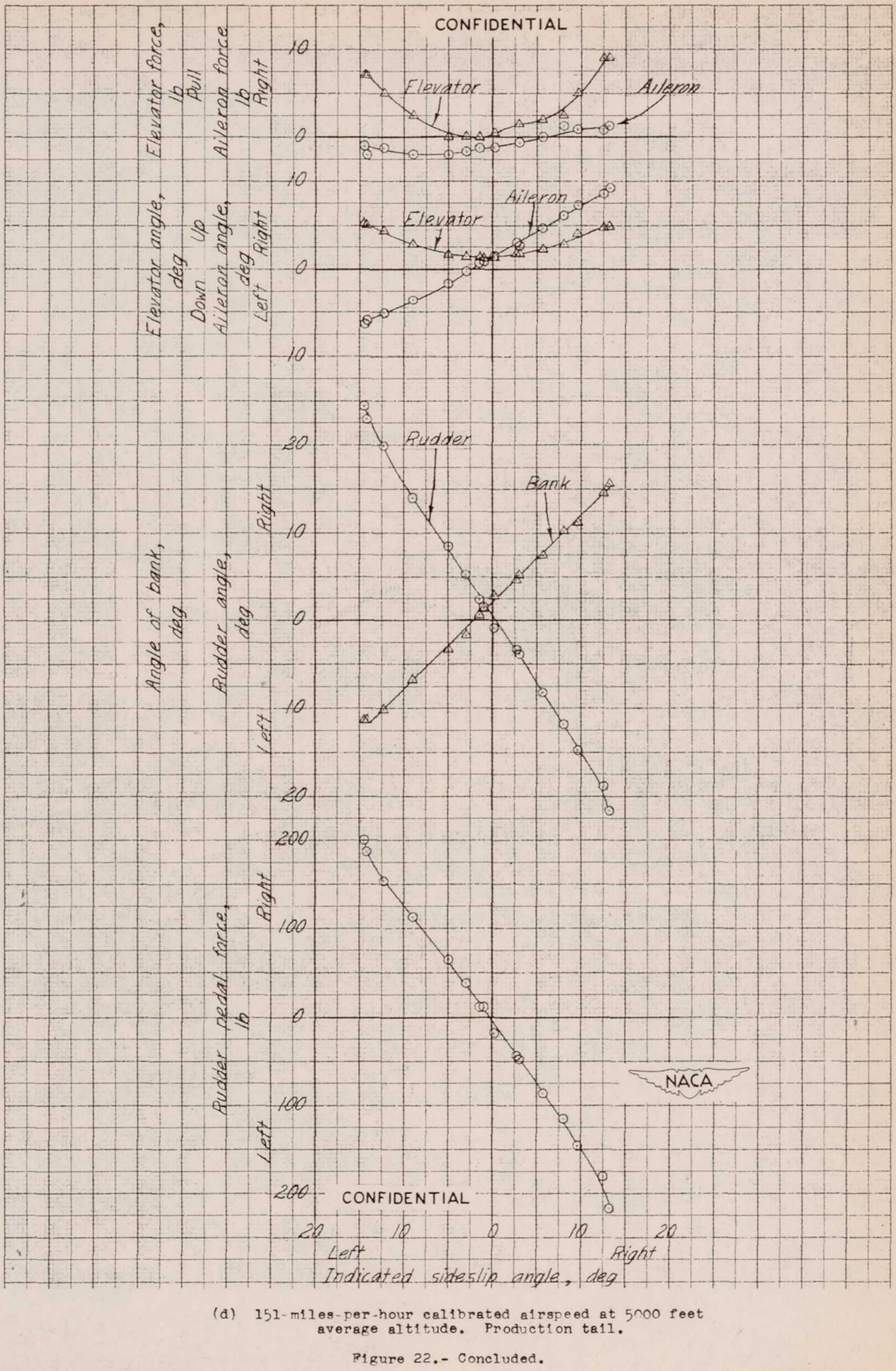
(b) 122-miles-per-hour calibrated airspeed at 5000 feet average altitude. Production tail.

Figure 22.- Continued.



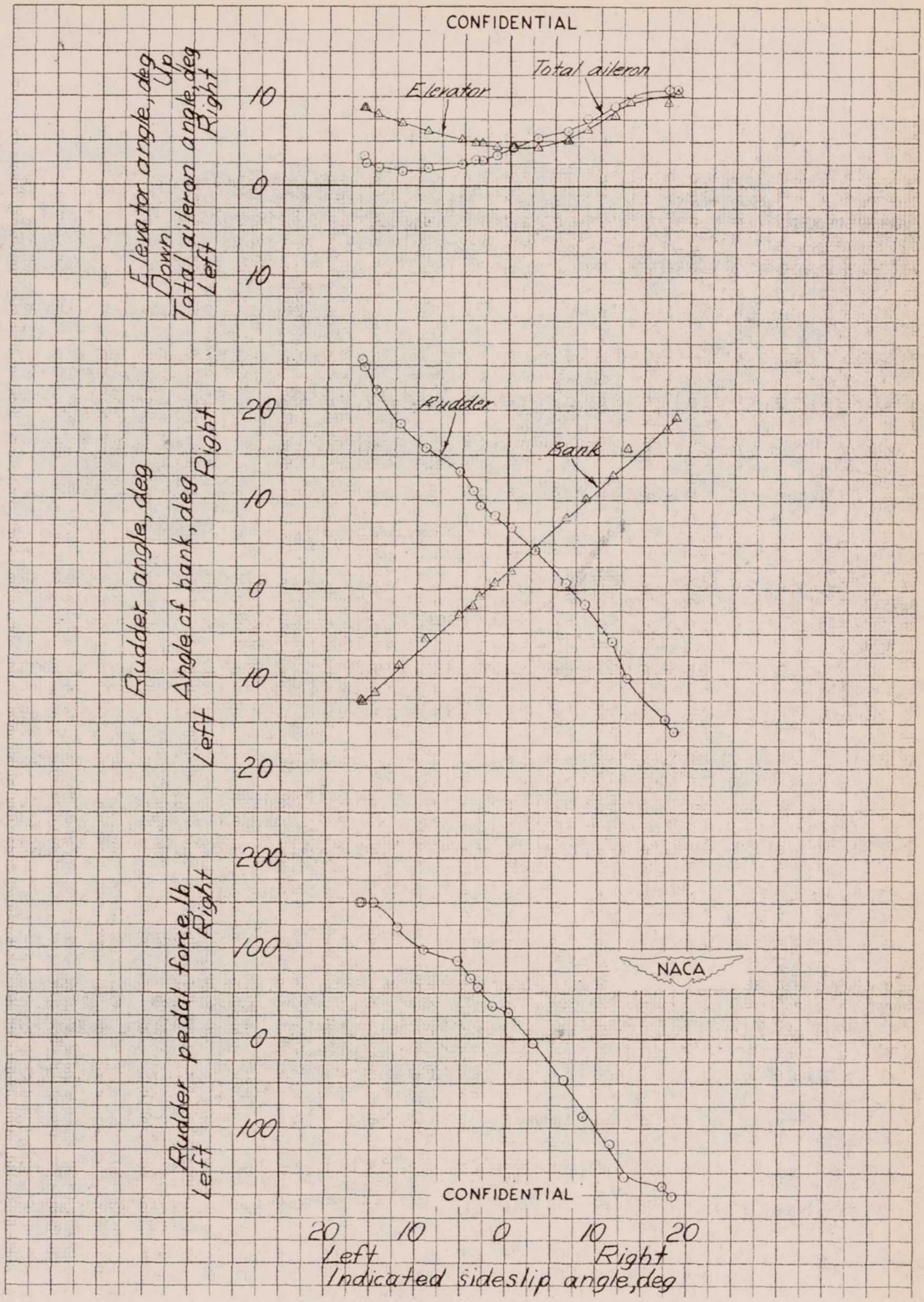
(c) 152-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 22.- Continued.



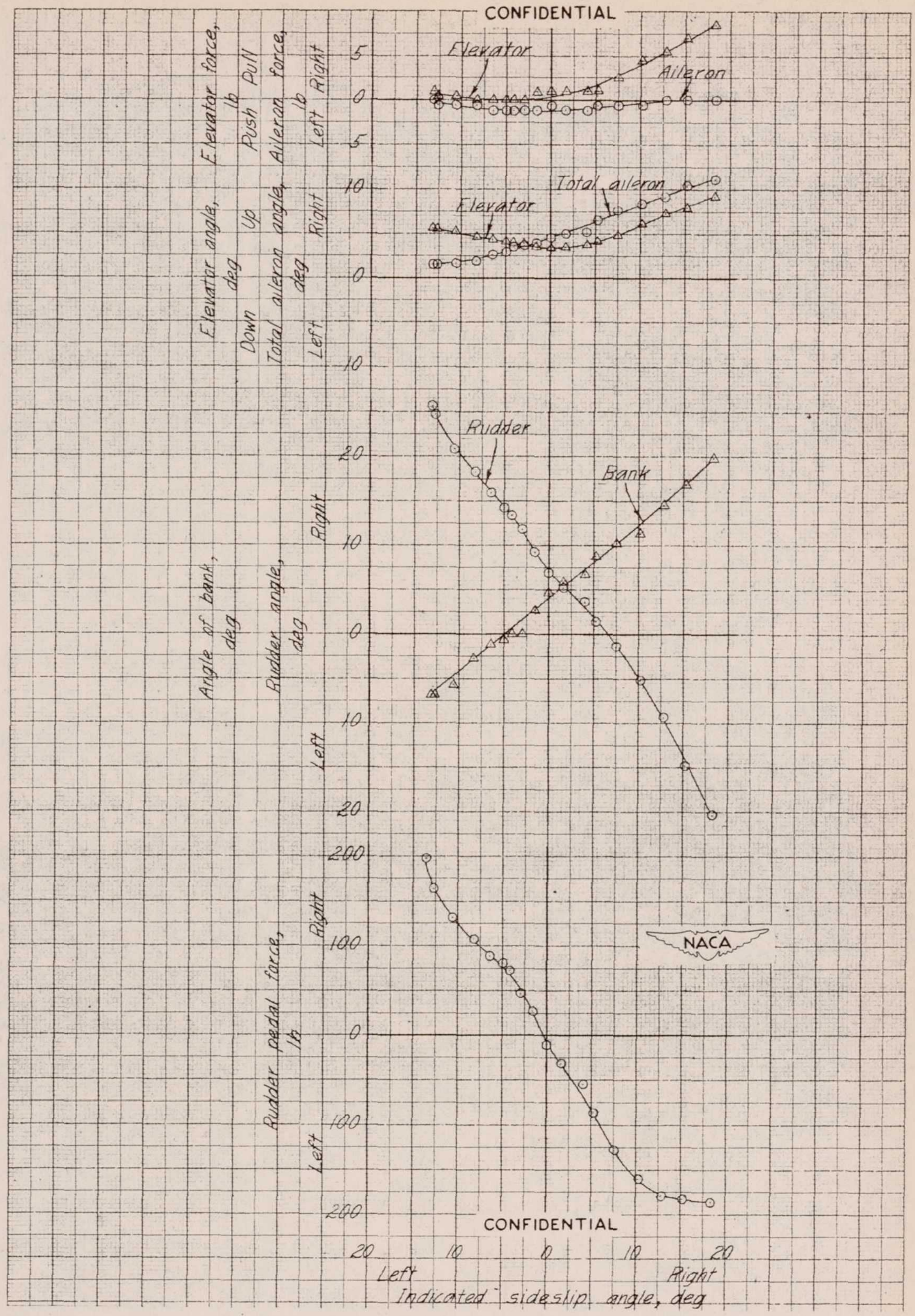
(d) 151-miles-per-hour calibrated airspeed at 5000 feet average altitude. Production tail.

Figure 22.- Concluded.



(a) 121-miles-per-hour calibrated airspeed at 5000 feet average altitude. Original tail.

Figure 23.- Directional stability and control characteristics of the P-51H airplane in the wave-off condition.



(b) 122-miles-per-hour calibrated airspeed at 5000 feet average altitude. Production tail.

Figure 23.- Concluded.

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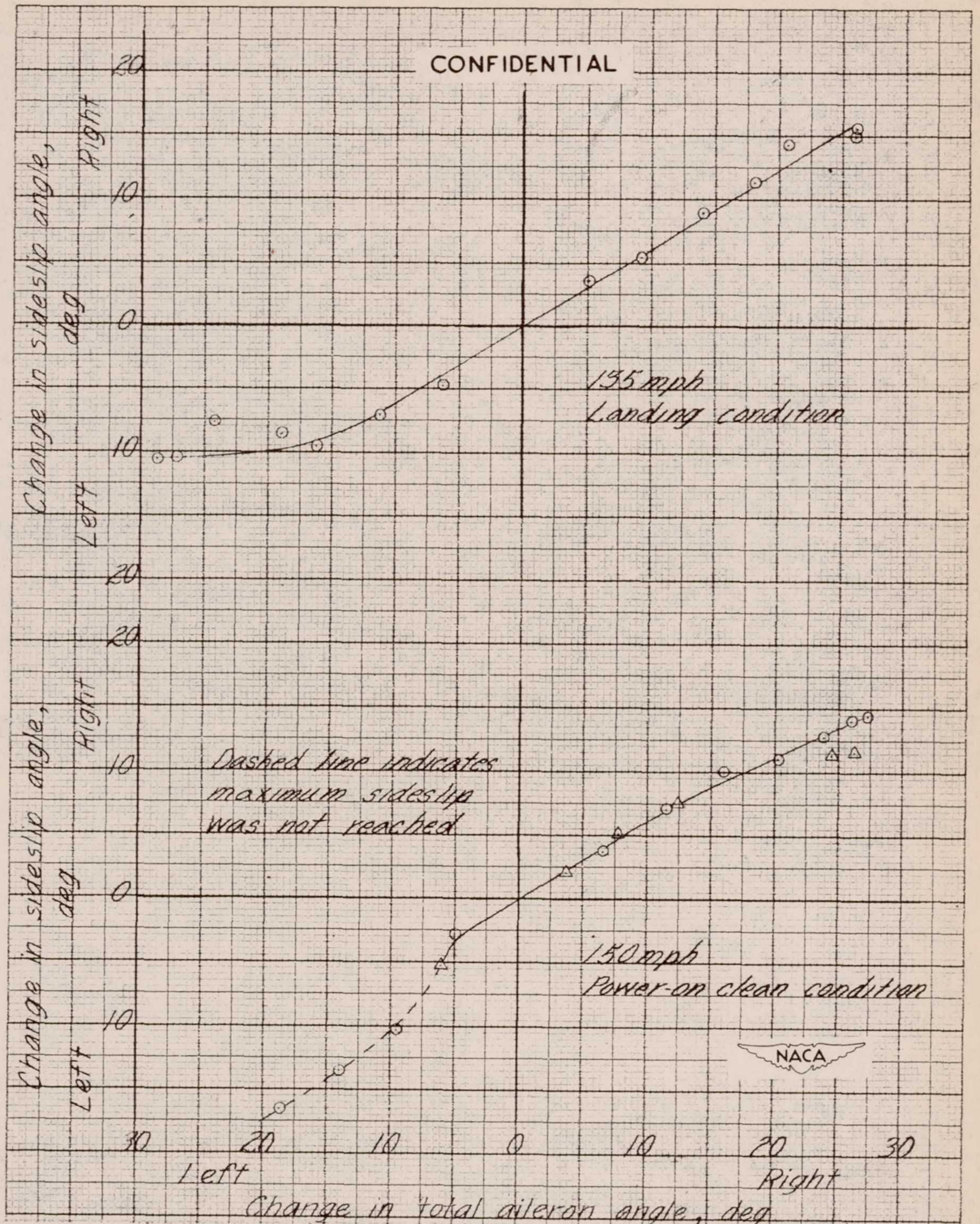

(a) Original tail.

Figure 24.- Maximum change in sideslip attained during abrupt aileron rolls out of 45 degree banked turns with rudder fixed. Different symbols indicate different flights. P-51 H airplane.

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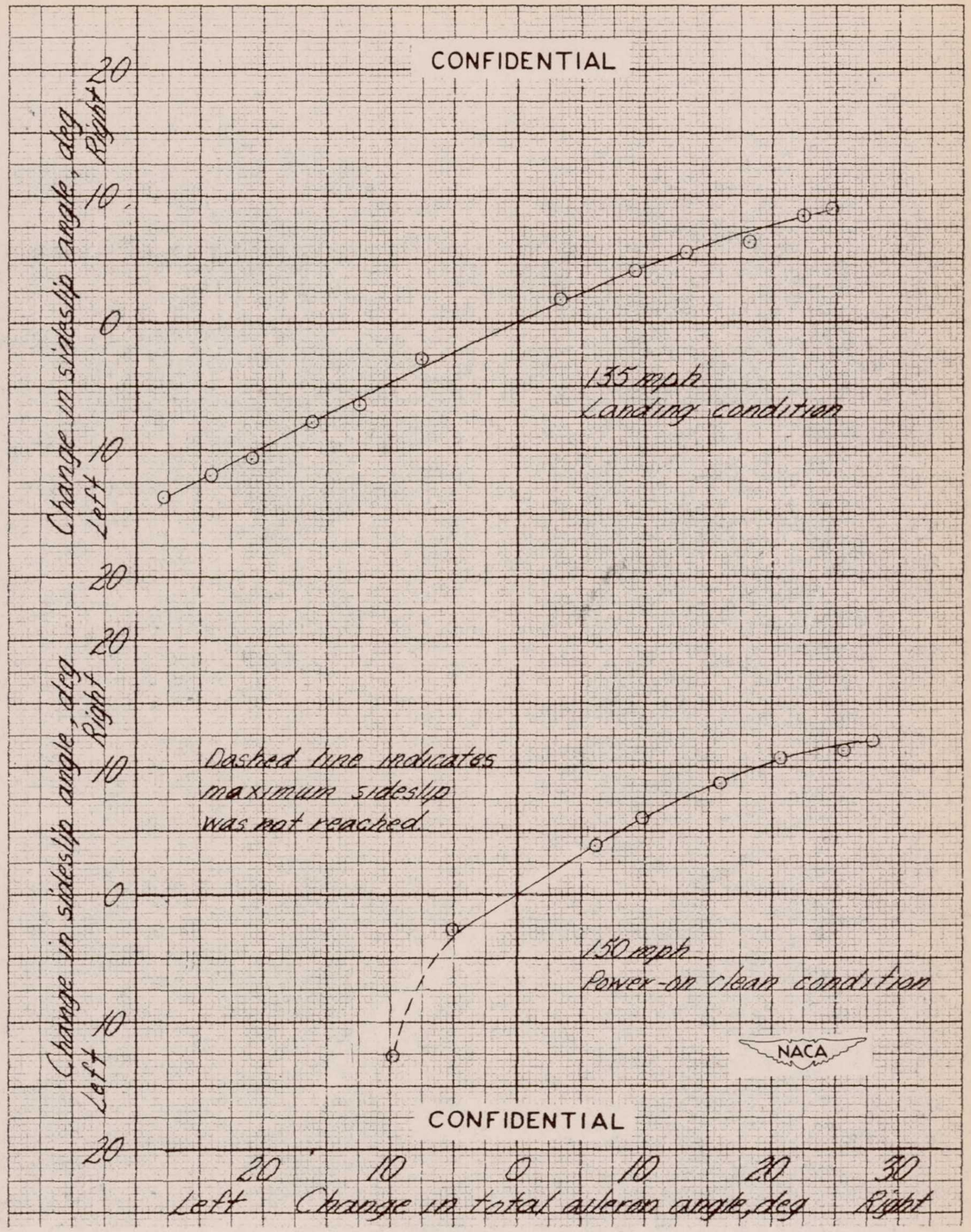
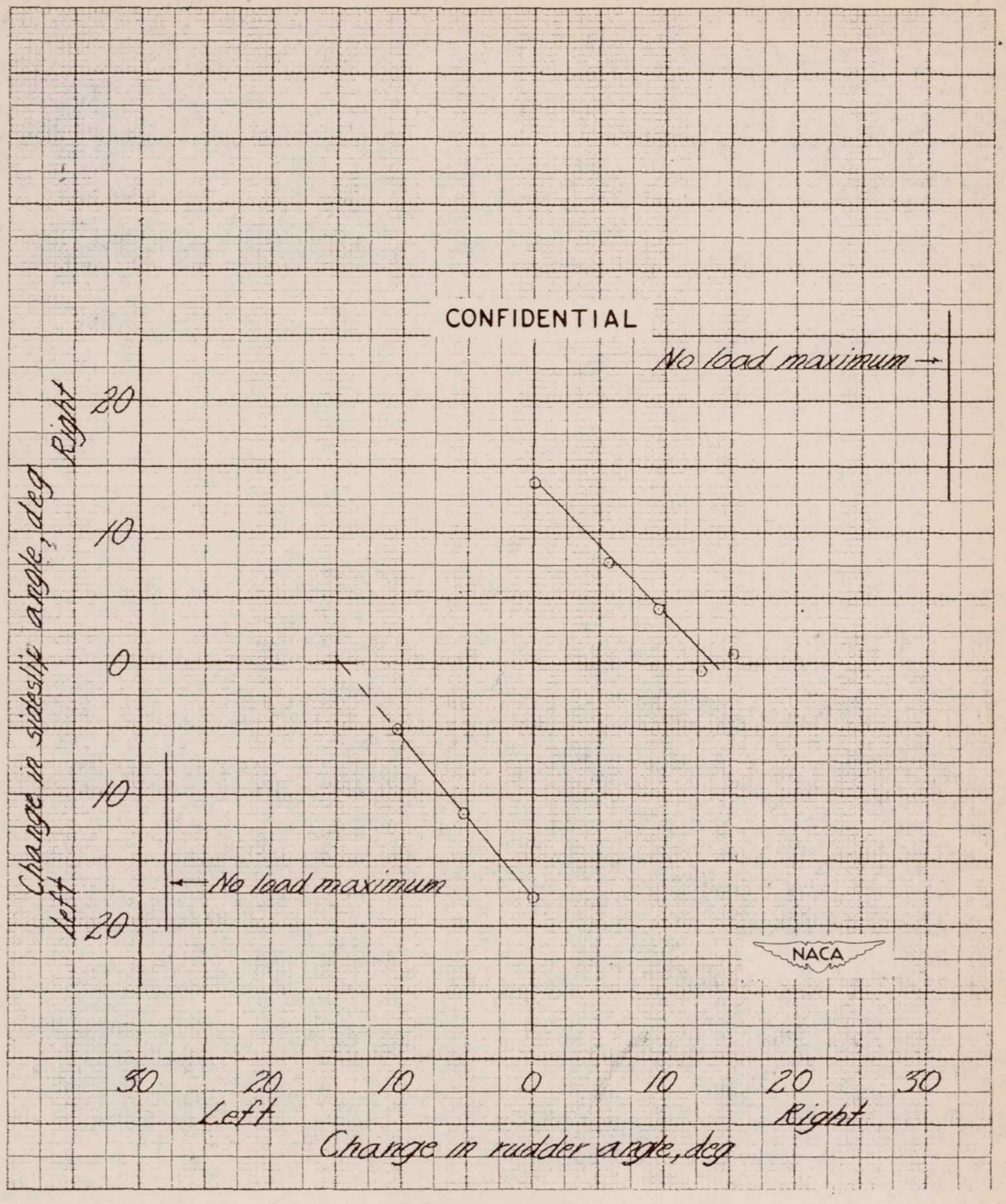


(b) Production tail.

Figure 24.- Concluded.



(a) Original tail.

Figure 25.- Maximum change in sideslip attained during abrupt aileron rolls out of 45 degree banked turns using full aileron deflection and varying amounts of rudder deflection. 152-miles-per-hour calibrated airspeed in the power-on clean condition. P-51H airplane.

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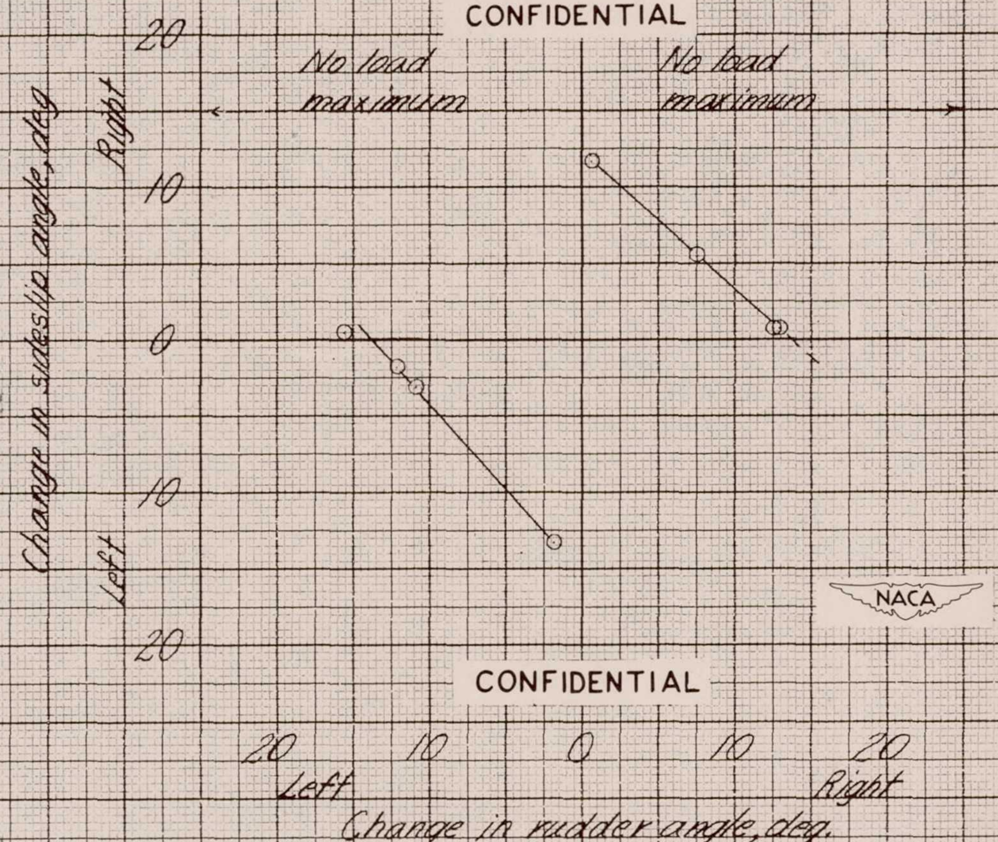
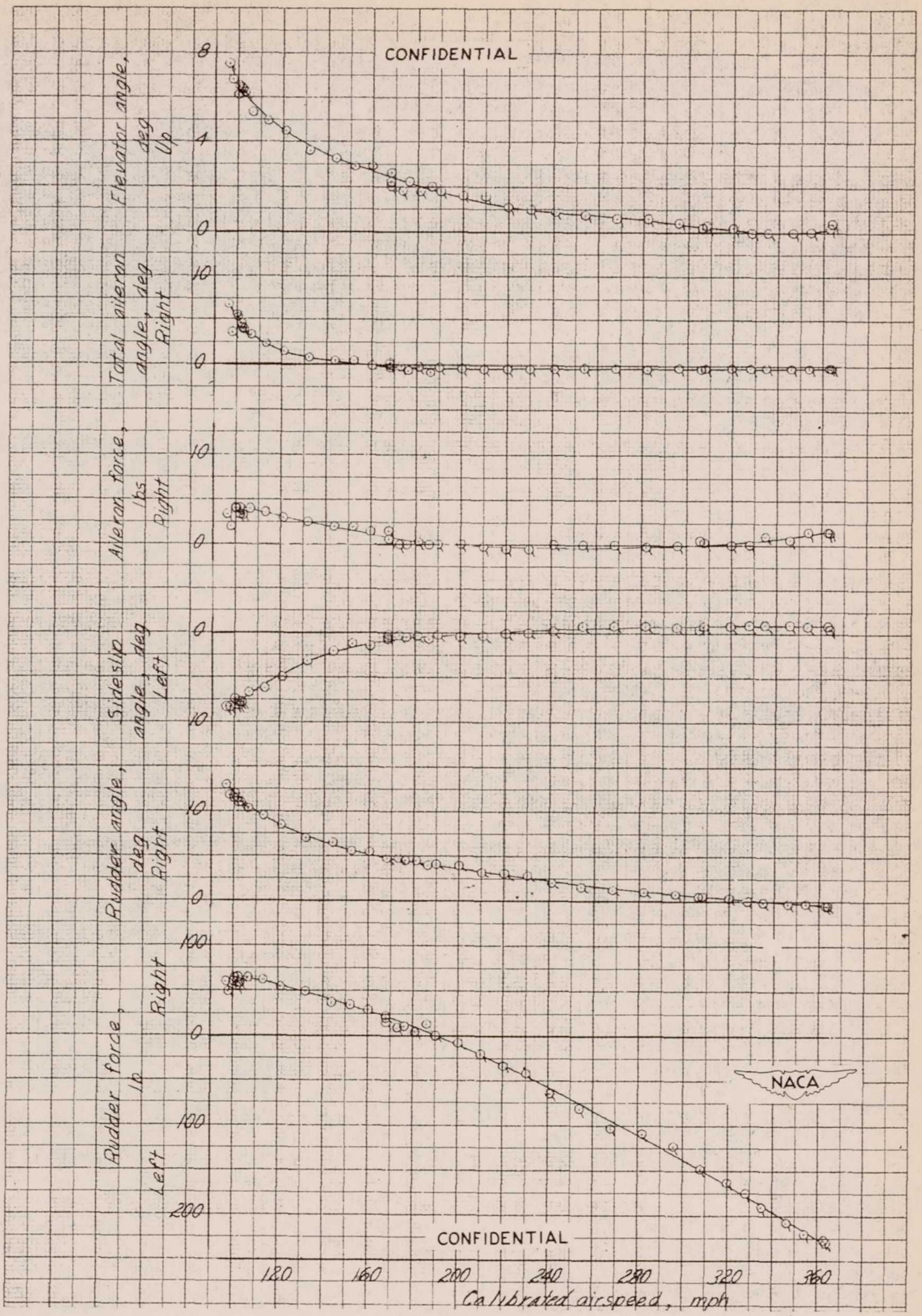


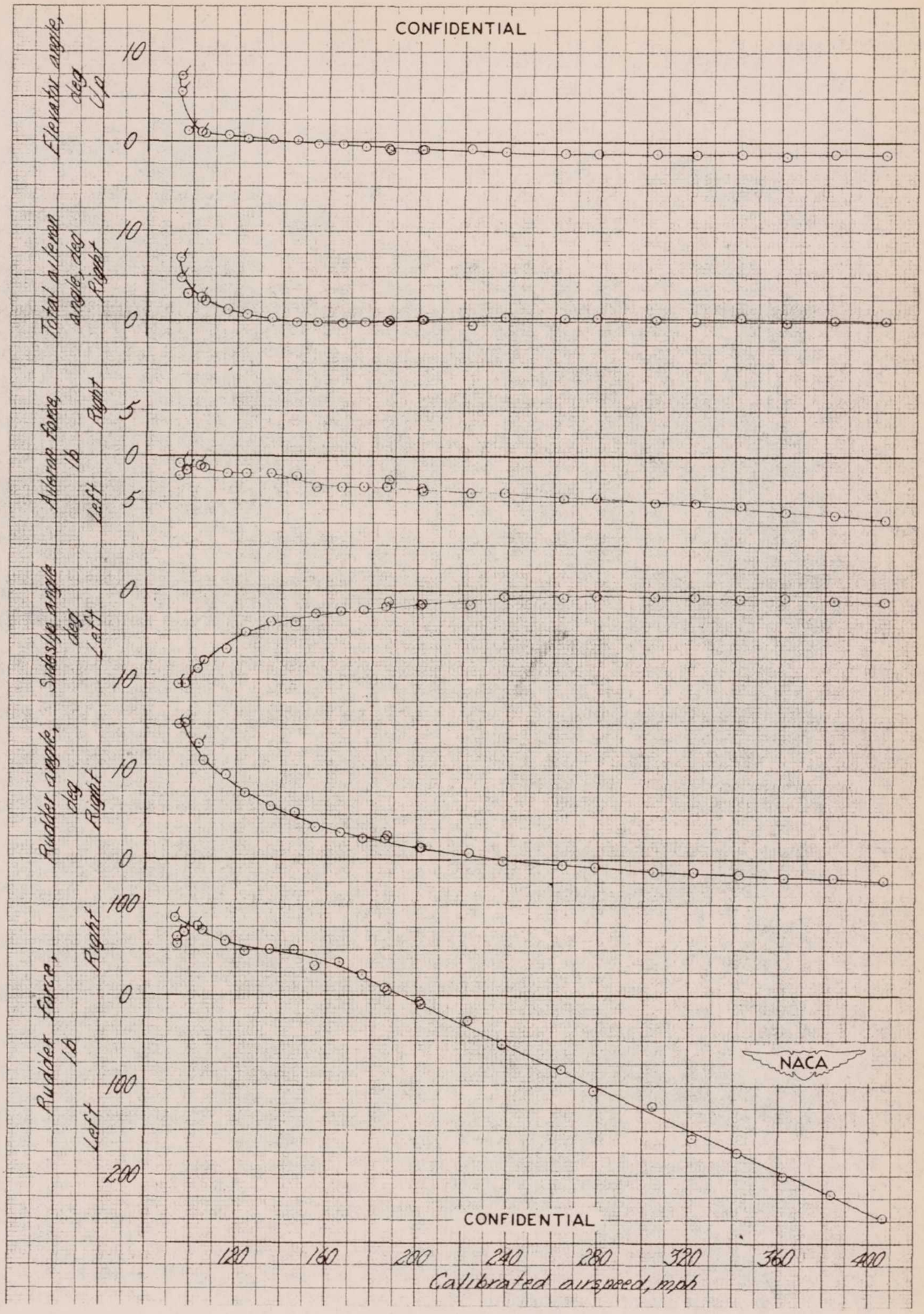
(b) Production tail.

Figure 25.- Concluded.

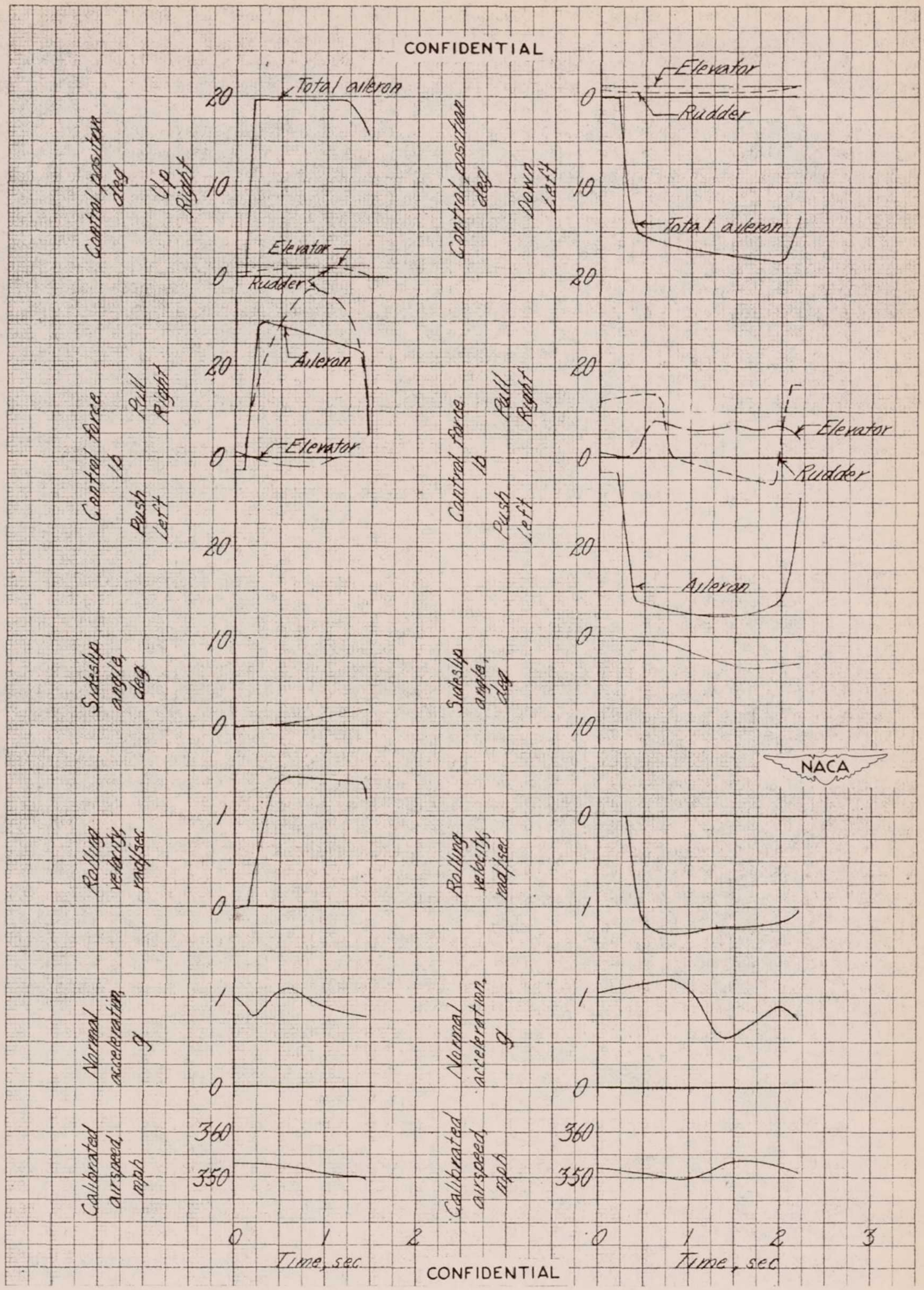


(a) Original tail.

Figure 26.- Directional trim characteristics of the P-51H airplane in the power-on clean condition.



(b) Production tail.
Figure 26.- Concluded.



(a) Right roll.

(b) Left roll.

Figure 27.- Time history of typical aileron rolls performed with rudder held fixed to measure the aileron effectiveness pb/2V. P-51H airplane.

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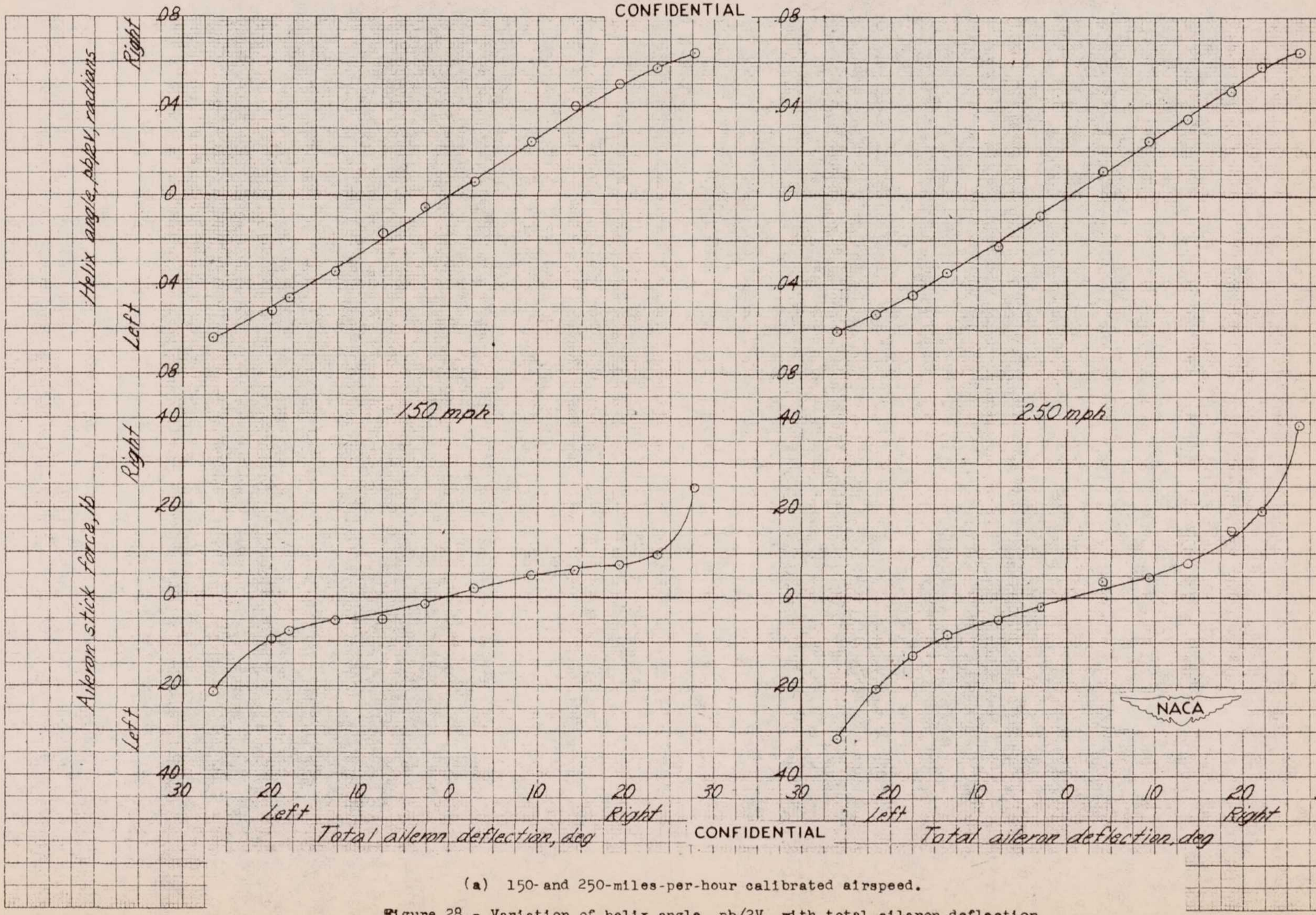

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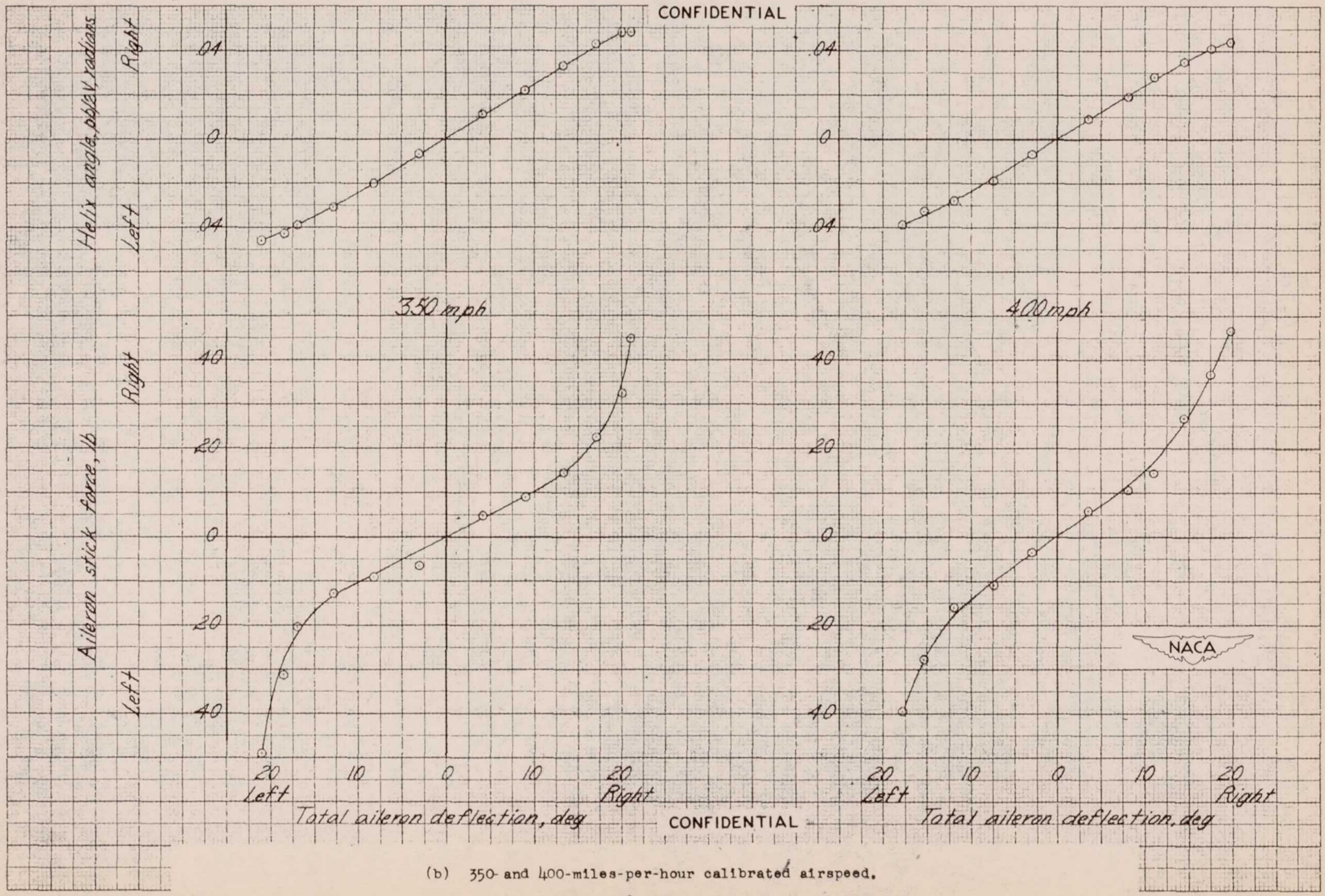
(a) 150- and 250-miles-per-hour calibrated airspeed.

Figure 28.- Variation of helix angle. pb/2V with total aileron deflection in the power-on clean condition at an average altitude of 5000 feet. Normal rated power. P-51H airplane.



(b) 350- and 400-miles-per-hour calibrated airspeed.

Figure 28.- Concluded.

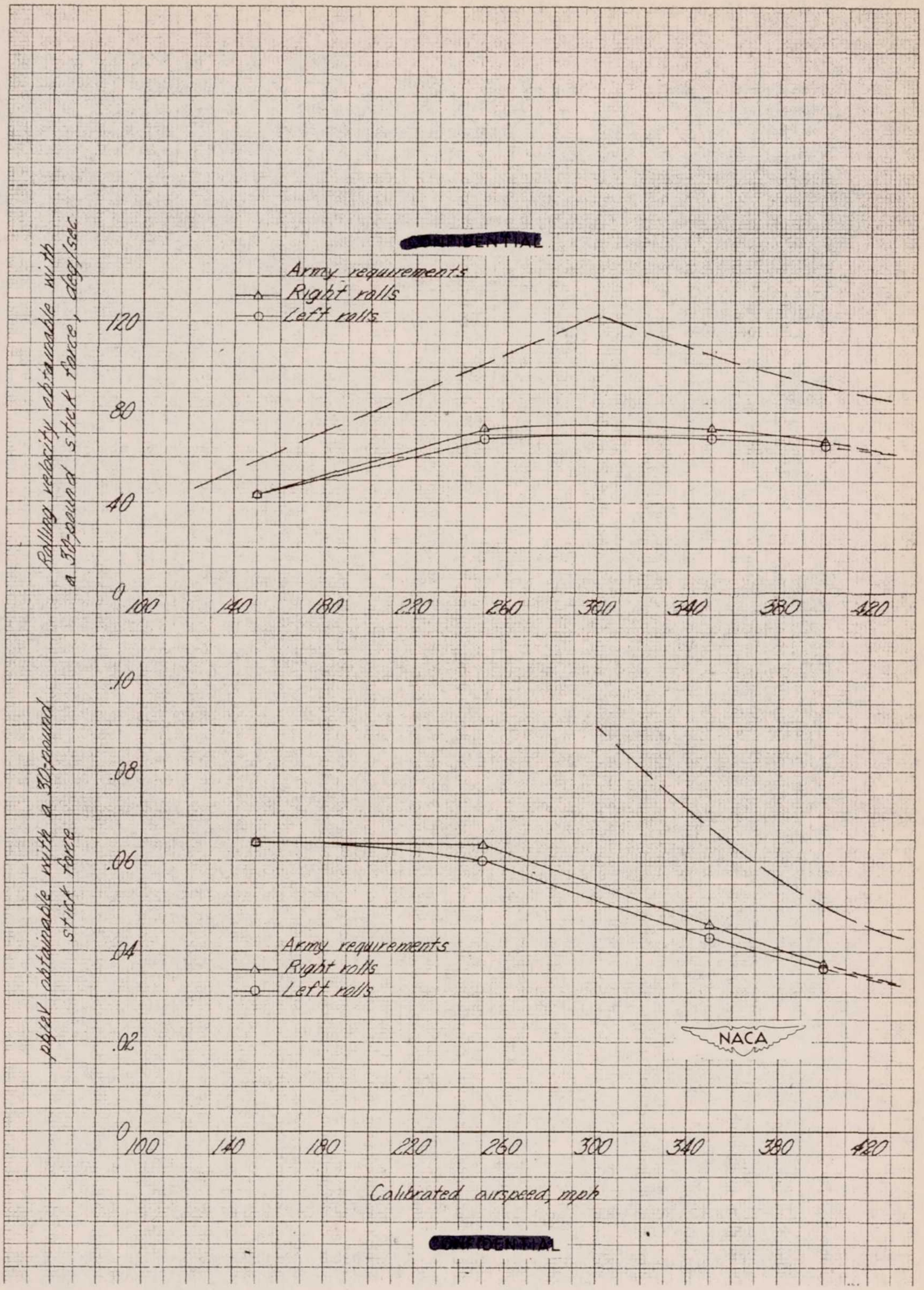


Figure 29.- Maximum pb/2V and rolling velocity obtainable with a 30-pound stick force as a function of speed. These tests were made on the production airplane at an average altitude of 5000 feet. P-51H airplane.