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RESEARCH MEMORANDUM

LATERAL AND DIRECTIONAL STABILITY AND CONTROL CHARACTERISTICS OF A C-54D AIRPLANE

By

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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SUMMARY

The flying qualities of a C-54D airplane were measured as a preliminary to an investigation to determine whether the flying-qualities requirements needed to be revised or amended in view of the present problem of blind approaches and landings with modern large airplanes. This paper presents the lateral and directional stability and control characteristics of the test airplane.

The directional stability and control characteristics met all the requirements and were considered good. The lateral stability characteristics were satisfactory. The aileron effectiveness pb/2V with full aileron deflection was slightly less than the specified minimum of 0.07 in left rolls. Because of an asymmetry that may be peculiar to the particular airplane, approximately $3\frac{1}{2}^{\circ}$ left aileron was required for trim; however, had the airplane trimmed with the ailerons neutral, the value of pb/2V would have been 0.076 in the clean condition and 0.069 in the flaps and gear-down condition. The aileron control forces to obtain the maximum pb/2V exceeded 80 pounds above 175 miles per hour.

The friction in the aileron control system prevented the ailerons from returning to their trim positions when the control wheel was released in the tests for the dynamic lateral stability.

Several special tests were run at the request of the Airplane Handling Qualities Subcommittee of the Air Transport Association. The results of these tests show that:

1. The pitch due to yawing velocity and sideslip in skid turns was not sufficient to cause any appreciable loss in altitude.

2. An asymmetric load condition equivalent to an empty outboard tank required approximately 40 percent of full aileron deflection for lateral balance at 120 miles per hour but sufficient aileron deflection remained to fly the airplane safely.

3. The length of time to reach a dangerous attitude after the power of the most critical engine is lost during take-off or wave-off is long enough to allow the pilot to apply corrective action and recover.

INTRODUCTION

In connection with a study of the airline problem concerning instrument flying and blind landings in large airplanes, handling-qualities investigations were made of a Douglas C-54D, the military cargo version of the commercial DC-4 Skymaster. The tests were conducted at the Langley Aeronautical Laboratory, Langley Field, Va. in the latter part of 1946 and in the early part of 1947. Reference 1 discusses the blind-approach tests and shows that no new flying techniques were used and that the present handling-qualities requirements do not need additions or revisions in view of the necessity of performing such precision flying. Reference 2 discusses the particularly troublesome effects of excessive friction in the control system. This paper presents the results of the tests of the lateral and directional stability and control characteristics. The longitudinal stability and control characteristics and the stalling characteristics will be presented in subsequent papers.

DESCRIPTION OF AIRPLANE

The C-54D tested was a four-engine, low-wing monoplane with retractable tricycle landing gear, steerable nose wheel, and single slotted flaps. The control surfaces were fabric covered and the remainder of the airplane was metal covered. The elevator and the rudder had plain, round-nose overhanging balance and the ailerons had Frise type balance. The right aileron and the elevators had trim tabs and the rudder had a combination spring and trim tab. The tests were made at a take-off weight of approximately 54,000 pounds and a center-of-gravity position of about 17 percent mean aerodynamic chord with wheels up. General specifications for the airplane are given in table I.

Several photographs of the test airplane are shown as figure 1. The variations of the pilot's control position with control-surface angle for the elevator, aileron, and rudder are shown in figure 2. The characteristics of the rudder spring tab (or flying tab) are presented in figure 3; the ratio between rudder-pedal position and tab position with the rudder fixed could not be measured accurately because of stretch in the control system. It was estimated, however, that the pedal moved 0.02 inch per degree movement of the tab. The investigation was conducted with the automatic-pilot servo-units installed. In this condition, the friction in the control systems was ±15 pounds for the elevator, ±12 pounds for the ailerons, and ±30 pounds for the rudder as measured in flight. The servo-units were responsible for about ±10 pounds friction in each control system. The effects of this friction are discussed in references 1 and 2.

INSTRUMENTATION

The test data were recorded by the standard NACA continuous recording photographic instruments. The following is a list of the quantities measured and the NACA instrument recording each quantity:

Measured quantity	NACA instrument
Elevator, rudder, and aileron control-surface position and tab position; aileron wheel position	Electrical control-position recorder
Elevator control column and rudder-pedal position	Mechanical control-position recorder
Normal, transverse, and longitudinal accelerations	Sensitive normal air-damped recording accelerometer and three-component air-damped recording accelerometer; normal-acceleration indicator
Rolling, pitching, and yawing velocities	Electrical gyro-recording turn meters
Sideslip angle	Selsyn-motor sideslip-angle recorder and indicator
Angle of bank	Air-damped pendulum-type recording inclinometer
Control forces	Strain-gage-type force recorders
Airspeed and altitude	Pressure-cell-type pressure recorders with static orifices on a free swiveling head mounted on a boom 1 chord length ahead of the left wing tip and a sensitive airspeed indicator
Free-air temperature	Electrical resistance bulb thermometer and indicator
Position with respect to runway	35-mm camera in the nose
Time	Timer (synchronizing all records)

The electrical control-position transmitters were the slide-wire resistance-type and were mounted within the structure and connected to the elevator and rudder bell cranks and the aileron push-pull tubes and the aileron control wheel. The mechanical position recorders were connected to the copilot's control column and right rudder pedal.

The accelerometers and turn meters were mounted in the main cargo section, close to the center of gravity.

The sideslip angle was measured by a vane mounted on a boom 1 chord length ahead of the right wing tip. Previous tests have indicated that the spanwise flow at that point is negligible and therefore no corrections were applied.

The pilot's control wheel was removed and replaced by a special control wheel incorporating electrical strain gages installed to measure push and pull forces and circumferentially applied forces. The special wheel had a diameter of $13\frac{1}{4}$ inches, while the normal wheel had a diameter of 14 inches. No corrections were applied to the data presented due to the difference in wheel sizes, but the aileron control force for a standard wheel may be calculated by multiplying the forces presented by a factor of 0.946. The rudder-pedal force was measured by electrical strain-gage units attached to the pilot's pedals.

The calibrated airspeed given herein is that which would correspond to the reading of a standard Army-Navy airspeed indicator connected to a pitot-static head free from position error and is equal to the true airspeed at standard sea-level conditions. The calibrated airspeed is defined as follows:

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

where

f_o compressibility factor dependent on q_c/p_o

q_c impact pressure (difference between total pressure and free-stream static pressure)

p_o free-stream static pressure for standard sea-level conditions

The free-stream static pressure was measured by a free-swiveling static head mounted on a boom 1 chord length ahead of and slightly below the left wing tip. The static head was calibrated by means of a trailing airspeed head. The total head was measured by a shielded total-head pressure tube located on the airspeed boom behind the static pressure head.

TESTS, RESULTS, AND DICUSSION

The results are discussed according to the specifications set forth in reference 3.

DYNAMIC LATERAL AND DIRECTIONAL STABILITY

The lateral and directional short-period oscillations were investigated by abruptly deflecting and releasing the rudder and the ailerons separately while leaving the other controls free at several different speeds. Figure 4 shows time histories of typical rudder kicks and releases at a low speed and at a high speed and figure 5 shows similar time histories for the ailerons. The rudder did not return immediately to trim but came back gradually; however, it did not oscillate. The slow return of the rudder was due to its tendency to float with the relative wind. The directional oscillation as indicated by the sideslip angle was damped to less than 1/2 amplitude in one cycle. The ailerons did not return completely to the trim position due to the friction in the control system, but they did not oscillate. The airplane continued to roll slowly due to the displaced aileron.

STATIC LATERAL AND DIRECTIONAL STABILTIY

Adverse Aileron Yaw and Rudder to Overcome Adverse Aileron Yaw

The adverse aileron yaw (sideslip due to aileron deflection and rolling velocity) and the amount of rudder to overcome the adverse yaw were measured in rolls out of 45° banked turns in the clean condition at about 150 miles per hour and the approach condition (flaps 20°, gear down) at approximately 135 miles per hour. The approach condition was used rather than the full-flap, gear-down condition because it duplicated the condition used by the airlines during the approach where most maneuvering is done. The adverse aileron yaw was evaluated for rudder-fixed roll-outs, and figure 6 shows the maximum change in sideslip due to varying amounts of aileron deflection. The maximum sideslip angles attained with full aileron deflection was about 10° in the clean condition and about 8° for the approach condition.

A measure of the rudder control to overcome the yaw due to the ailerons was obtained by using several amounts of rudder deflection during the rolls out of turns. Time histories of rolls out of turns using varying amounts of rudder are given in figures 7 and 8. The rudder was sufficiently powerful to produce yawing velocity in the opposite direction without using full rudder deflection. About 100 pounds pedal force was required to offset the aileron yaw and therefore the requirements were met.

Sideslip Characteristics

The characteristics of the airplane in sideslip were measured in straight, steady sideslips in various flight conditions. Records were taken of the aileron, elevator, and rudder deflections and control forces, the angle of bank, and the angle of sideslip. Figures 9 through 13 show the results of these sideslips.

Directional stability.- The control-fixed static directional stability as shown by the variation of rudder deflection with sideslip angle was positive in all conditions (left rudder deflection was required for right sideslip and right rudder, for left sideslip). The sideslip angle was always proportional to the rudder deflection and therefore the requirements were met.

The control-free directional stability as shown by the variation of rudder-pedal force with sideslip was positive in all conditions (the forces were such as to tend to return the rudder to its trim position). The characteristics of the rudder-spring-tab system were the determining factors in the shape of the rudder-force curves and consequently the rudder force was not proportional to the sideslip angle up to the specified 15°. Although there were instances (figs. 9(a), 10(a), and 10(b)) in which the rudder force began to lighten at high deflections, the tendency was slight.

Dihedral effect.- The control-fixed dihedral effect as evidenced by the slope of the curve of the variation of total aileron angle with sideslip angle was positive in all conditions at all speeds. The airplane had a geometric dihedral angle of 7° and in the clean condition power off, the effective dihedral angle was 4.7° throughout the speed range. The effective dihedral was slightly less for the power-on condition and less still with the flaps full down but never reached zero. With the flaps full down, the effective dihedral decreased somewhat at higher angles of sideslip.

The control-free dihedral effect as shown by the variation of aileron force with sideslip angle was positive in the flap-up cases at all speeds. In the cases with the flap partially and fully down, the aileron control forces were all within the range of friction and, therefore, although the data show that at low speeds the aileron forces became less at greater angles of sideslip and, in one case (fig. 11(a)), reversed, the apparent reversing tendency may be caused by the effect of the friction force on the measurements. However, mild reversing of aileron control force at high sideslip angles was not considered dangerous as far as the handling qualities of the airplane were concerned. No tests were made of the sideslip characteristics with the reduced control friction reported in reference 2.

Pitch due to sideslip.– The pitching moment due to sideslip with the control fixed as shown by the variation of elevator angle with sideslip was slight in all conditions and always in the nose-down direction. The elevator control forces increased at higher angles of sideslip but were not objectionable to the pilot.

Special tests were made to determine the ability of the pilot to hold altitude while making wing-level skid turns. This maneuver was suggested as the manner of changing heading on blind approaches when the altitude is so low that the pilot would need to be cautious not to strike the ground with a wing tip. In such a maneuver, any unnoticed pitching could cause an undesirable loss in altitude. Figure 14 presents time histories of several skid turns in different conditions with the altitude controlled and with the altitude uncontrolled. With the altitude uncontrolled, the airplane lost altitude only in right turns. In left turns altitude was gained in a few cases as shown in figure 14(c) but in no instance was any loss in altitude found. This pitching tendency was not noticeable for changes of heading of 5° and less. Consequently, figure 14 presents only changes of heading of 10°. Since the main consideration of the tests was loss in altitude, records were taken of left-skid turns in only one condition. The tendency to pitch down in right turns and up in left turns can be traced to the gyroscopic action of the propellers.

Side-force characteristics.– The side force as shown by the variation of the angle of bank with sideslip angle was positive in all conditions throughout the speed range. Therefore, the requirement was fulfilled.

Asymmetric Load Tests

Special tests were made at the request of the Airplane Handling Qualities Subcommittee of the Air Transport Association to determine the feasibility of take-offs and landings with one outboard tank empty. Steady sideslips, the data for which are presented in figure 15, were made at several speeds in the clean conditions with the right wing-tip tank empty. The only disadvantage found was the restricted aileron travel in the right direction due to the amount of aileron necessary to balance the asymmetric load. The aileron travel, however, was not limited to such an extent that balancing at large angles of sideslip was impossible. Approximately 40 percent of full aileron deflection was required for lateral trim at 120 miles per hour. The restricted aileron travel would result in limited $pb/2V$ in the direction of the light wing, but since the remaining travel is still within the limits normally called for in blind approaches (reference 1), ferrying flights could be made with one outboard tank empty without undue risk.

Rudder-Free, Asymmetric Power Characteristics

The rudder-free, asymmetric power tests in the cruising condition are discussed in the section "Uncontrollable attitude changes due to asymmetric power."

Rolling Moment Due to Sideslip

The rolling moment due to sideslip is discussed in the section "Lateral control power."

LATERAL AND DIRECTIONAL CONTROL

Directional Trim

The directional-trim characteristics were measured in steady straight flight. These characteristics are presented in figure 16. The requirement that the rudder control shall give sufficient directional control to trim the airplane in steady level flight at all speeds in all conditions was satisfied.

Directional Control Take-Offs and Landings

No tests were made of crosswind take-offs and landings. The airplane was easily controllable on the ground with the steerable nose wheel which is operated through a power boost system and it is felt that the directional control is sufficient to meet the requirement without exceeding 180 pounds pedal force.

Asymmetric Power Operation

Uncontrolled attitude changes due to asymmetric power.- At the request of the Airplane Handling Qualities Subcommittee of the Air Transport Association special tests were run to determine the time it would take to reach a dangerous attitude if no corrective control were applied upon the complete loss of power of the most critical engine. Records were taken of the airplane motions and the control angles and forces during the simulated loss of number 1 engine (left outboard). Time histories of these maneuvers in both the take-off and wave-off condition with and without corrective control are presented in figures 17 and 18. The angle of bank presented was obtained from an integration of the record of the rolling velocity. The sideslip angle remained small throughout the maneuver and consequently the rapid deviation from the straight and level flight path associated with large angles of sideslip did not appear. The time to reach a dangerous attitude was about 7 seconds in the take-off condition and longer in the wave-off condition. It is felt that 7 seconds is sufficient time for the pilot to cope with the emergency and be able to recover with ease.

A record was also taken in the cruising condition (clean, power for level flight at the speed for maximum range) to determine the uncontrolled motions of the airplane. A time history of the motions of the airplane is presented in figure 19. The rolling moment can easily be counteracted by the ailerons and the yawing moment is quite small. Therefore, the airplane could be balanced in straight flight with rudder free by banking and sideslipping.

Directional control power.- Tests were made in simulated asymmetric power conditions to determine the minimum speed at which the airplane could still fly with zero sideslip. These tests were made in the take-off and wave-off conditions with the most critical engine (no. 1) idling and the remaining three engines delivering full take-off power. Spot records were taken in steady straight flight at decreasing airspeed until the full rudder control was used. The directional characteristics during the asymmetric power operation in the take-off and the wave-off conditions are presented in figure 20. The speeds at which the rudder pedals reached their stops were 109 miles per hour in the wave-off condition and 115 miles per hour in the take-off condition. The stalling speeds with power off were 87 and 96 miles per hour, respectively, at approximately 54,000 pounds and would be higher with the normal gross load. In the take-off condition, then, the requirement that the rudder be able to hold zero sideslip at all speeds above 1.2 times the stalling speed with power off is met. In the wave-off condition, the lowest speed reached was 5 miles per hour higher than 1.2 times the stalling speed with power off, but there is no requirement for this condition even though it is usually a more critical condition.

The rudder forces in the take-off condition were 185 pounds at the lowest speed and 165 pounds at the lowest speed in the wave-off condition. Therefore, the C-54D is marginal in meeting the requirements for rudder forces in the take-off condition with the most critical engine idling while the remaining engines deliver take-off power.

Lateral control power.- The lateral control power was sufficient to balance the airplane laterally in the foregoing conditions without exceeding 32 pounds of force applied tangentially to the wheel. Therefore, the lateral requirement that the ailerons should be capable of balancing the airplane during asymmetric power operation without exceeding 80 pounds wheel force was easily met.

Lateral and directional trim devices.- The ability of the trim tabs to trim the forces to zero throughout the speed range in the cruising condition (clean, power for level flight at speed for maximum range) with number 1 engine idling is presented in figure 21. The trim tabs are sufficiently powerful to trim the control forces to zero down to a speed of 116 miles per hour with one engine idling. The condition with both number 1 and number 2 engines idling was not tested. However, since number 2 engine would produce less yawing moment than number 1 with equal power, to trim the airplane directionally with both number 1 and number 2 engines idling would require less than twice the tab deflection. From figure 21 the lowest speed at which twice the rudder tab deflection would be obtained without exceeding the maximum tab deflection available would be approximately 140 miles per hour.

Rudder to Overcome Adverse Aileron Yaw

The rudder required to overcome the adverse aileron yaw was measured in rolls out of turns and is discussed in the section "Adverse Aileron Yaw and Rudder to Overcome Adverse Aileron Yaw."

Aileron Control Power

The power of the ailerons was tested by making abrupt rolls from straight flight with the rudder held in its trim position. Time histories of typical aileron rolls are presented in figure 22.

Rolling acceleration.- The time histories show that the rolling acceleration is in the correct direction and that the peak rolling acceleration occurs less than 0.3 second after the maximum aileron deflection is reached. Therefore, the requirements are satisfied.

Aileron effectiveness.- The aileron-effectiveness factor $pb/2V$ and aileron-force variations with change in aileron angle are shown in figure 23. At any given speed the rolling velocity is directly proportional to the aileron-effectiveness factor. The rolling velocity, therefore, varied smoothly with aileron deflection and was proportional to the aileron deflection.

This airplane trimmed in steady flight with approximately $3\frac{1}{2}^{\circ}$ left aileron in most conditions. This was apparently due to some twist in the wing and would not be representative of all C-54 airplanes. Since the total aileron angle was restricted to 26° left and right, there was a greater change in total aileron angle available to the right than to the left. Consequently, with full aileron a greater $pb/2V$ was measured to the right than to the left. The maximum $pb/2V$ available to the left was 0.065 in the clean condition, 0.059 in the flaps full-down condition if extrapolated to full aileron deflection. The requirement that a minimum $pb/2V$ of 0.07 be available is not satisfied. Had the airplane trimmed with the aileron in neutral the value of $pb/2V$ would have been 0.076 in the clean condition and 0.069 in the approach condition.

The aileron control forces to obtain the maximum pb/2V of 0.065 in the clean condition was in excess of 80 pounds above speeds 175 miles per hour. In the flaps-down, gear-down condition, the wheel force to obtain the maximum pb/2V exceeded 80 pounds at all test speeds except the lowest (100 miles per hour). Figure 24 shows the maximum pb/2V available at various speeds without exceeding 80 pounds wheel force in both the clean and the flaps-down, gear-down conditions. In the flaps-down, gear-down condition, a pb/2V in excess of 0.05 is available at all speeds below 140 miles per hour. Therefore, the requirement that the ailerons given a pb/2V of at least 0.05 at speeds of 1.1 to 1.5 V_s in the landing condition is satisfied.

Rolling moment due to sideslip.- The time histories of typical rudder-fixed aileron rolls presented in figure 22 show that the rolling velocity did not reverse, and, therefore, the requirement is satisfied.

LATERAL AND DIRECTIONAL TRIM DEVICES

The lateral and directional trim tabs were sufficiently powerful to trim the control forces to zero throughout the speed ranges in steady straight flight with all four engines operating. The trim tabs retained their setting indefinitely and therefore the requirements were met.

CONCLUSIONS

1. The C-54D test airplane met all the military requirement for lateral and directional stability and control except as follows:

(a) The ailerons, when deflected and released, did not completely return to the trim position due to the friction in the system and the airplane continued to roll.

(b) The rudder forces for trim in the take-off configuration with number 1 engine idling were only slightly less than the required value of 180 pounds at the lowest speed.

(c) The aileron effectiveness pb/2V with full aileron deflection was slightly less than the specified minimum of 0.07 in left rolls. Approximately $3\frac{1}{2}^{\circ}$ left aileron was used for trim because of some minor asymmetry in the airplane which may be peculiar to the particular airplane. If the airplane had trimmed with neutral ailerons, the value of pb/2V would have been 0.076 in the clean condition and 0.069 in the flaps and gear-down condition.

(d) The aileron control forces to obtain the maximum pb/2V exceeded 80 pounds above 175 miles per hour.

2. If the altitude were uncontrolled, losses in altitude in skid turns were negligible unless large and abrupt right heading changes of the order of 10° were made. Even in this maneuver, the altitude losses encountered could be easily controlled.

3. An empty outboard tank required approximately 40 percent full aileron deflection in the clean condition at 120 miles per hour to balance the asymmetric load but did not make flight dangerous.

4. The time to reach a dangerous attitude, when the power on the most critical engine is lost on take-off or wave-off, was long enough to allow the pilot to apply corrective action.

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1. Talmage, Donald B.: A Time History of Control Operation of a C-54 Airplane in Blind Landing Approaches. NACA RM No. L7F20, 1947.

2. Talmage, Donald B., and Reeder, John P.: The Effects of Friction in the Control System on the Handling Qualities of a C-54D Airplane. NACA RM No. L8G30a, 1948.

3. Anon.: Stability and Control Characteristics of Airplanes. AAF Specification No. R-1815-A, April 7, 1945.

TABLE I

DIMENSIONS OF TEST AIRPLANE

General:	
Span, ft	117.5
Length (over all), ft	93.5
Height, ft	27.5
Wing:	
Chord at root (NACA 23016), ft	19.08
Chord at tip (NACA 23012), ft	5.88
Incidence at theoretical root, deg	4
Incidence at theoretical tip, deg	1
Dihedral (measured at wing reference plane), deg	7
Sweepback at 30 percent chord, deg	1.28
Horizontal stabilizer:	
Span, ft	39.5
Maximum chord, ft	11.25
Incidence, deg	1
Dihedral, deg	0
Vertical stabilizer:	
Height, ft	14.25
Maximum chord, ft	12.33
Fuselage:	
Width, ft	10.42
Height, ft	11.5
Area:	
Wings (less ailerons), sq ft	1341.6
Ailerons (including tab), sq ft	120.4
Aileron trim tab, sq ft	3.3
Wing flaps, sq ft	241.6
Gross horizontal tail surface, sq ft	324.9
Elevators (aft of hinge line and including tabs), sq ft	86.5
Elevator trim tab, sq ft	6.84
Gross vertical tail surface, sq ft	179.3
Rudder (aft of hinge line and including tab), sq ft	47.6
Rudder spring and trim tab, sq ft	4.75
Ailerons:	
Up, deg	15
Down, deg	11.5
Wing flaps, down, deg	40

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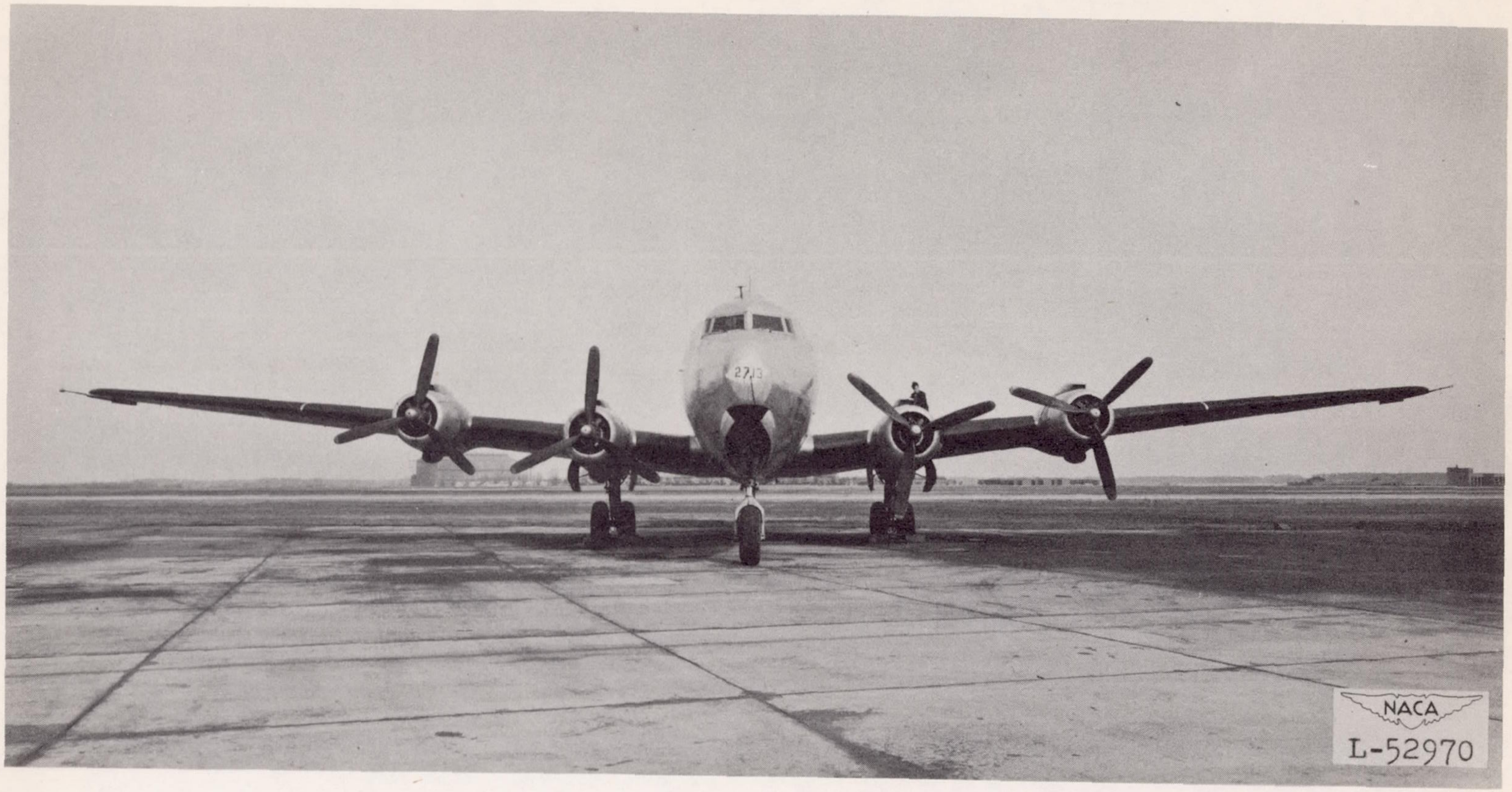
TABLE I – Concluded

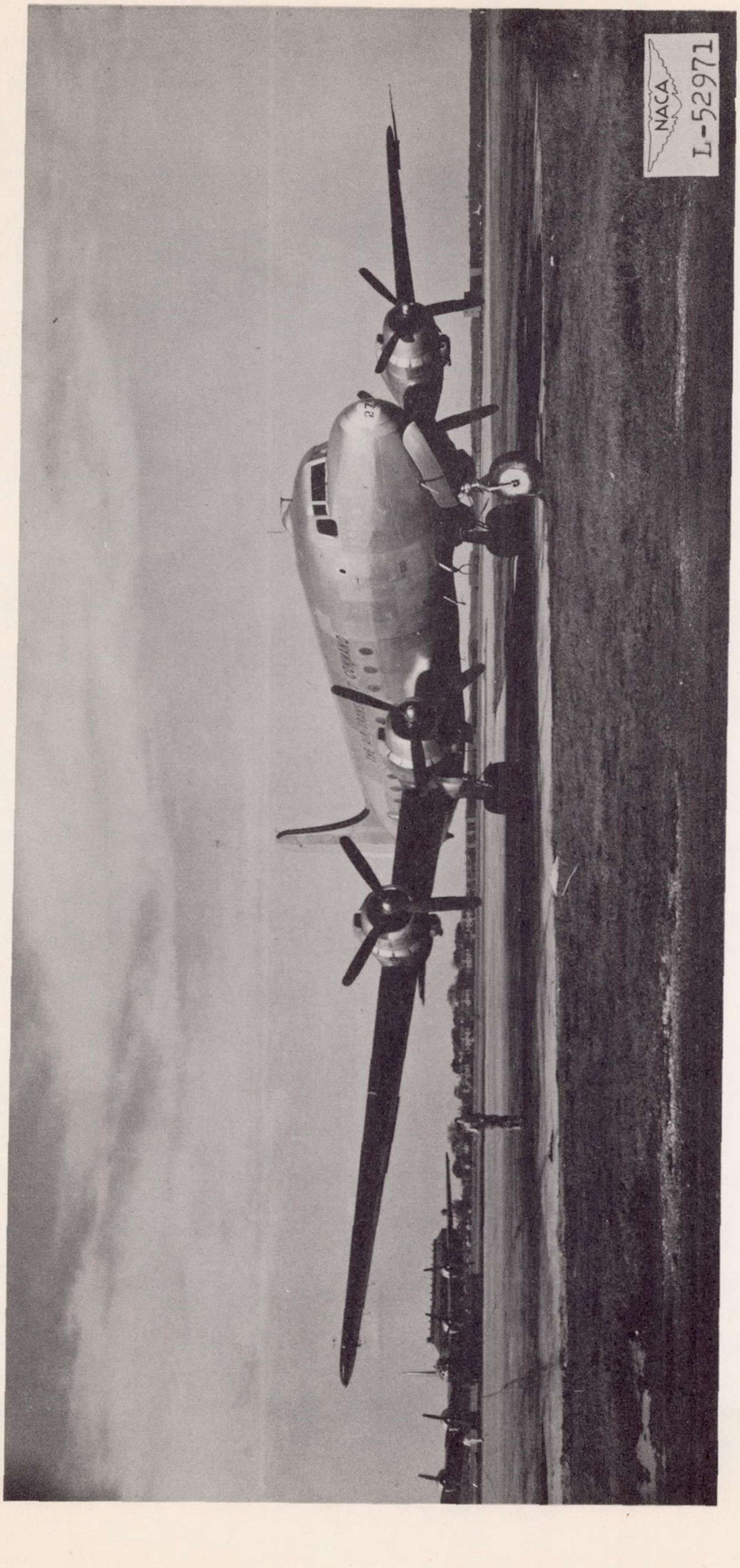
DIMENSIONS OF TEST AIRPLANE – Concluded

Elevator:	
Up, deg	25
Down, deg	15
Rudder:	
Right, deg	20
Left, deg	20
Elevator trim tab:	
Up, deg	15
Down, deg	15
Rudder tab (rudder neutral):	
Right, deg	20
Left, deg	20
Aileron trim tab:	
Up, deg	15
Down, deg	15



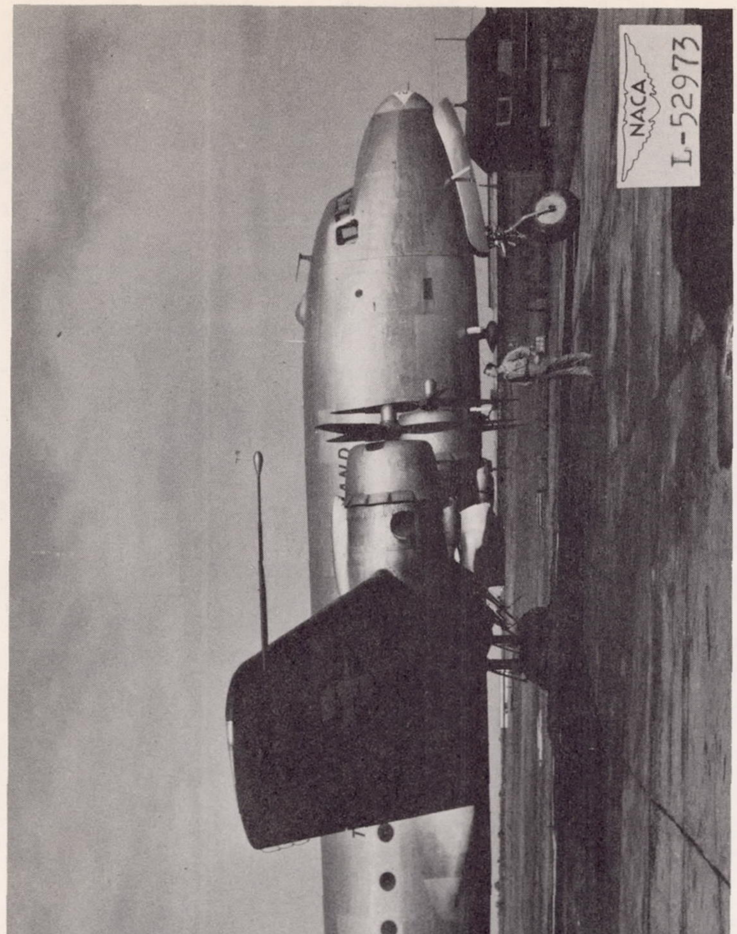
(a) Front view.

Figure 1.– Photographs of the C–54D airplane on which the tests were conducted.



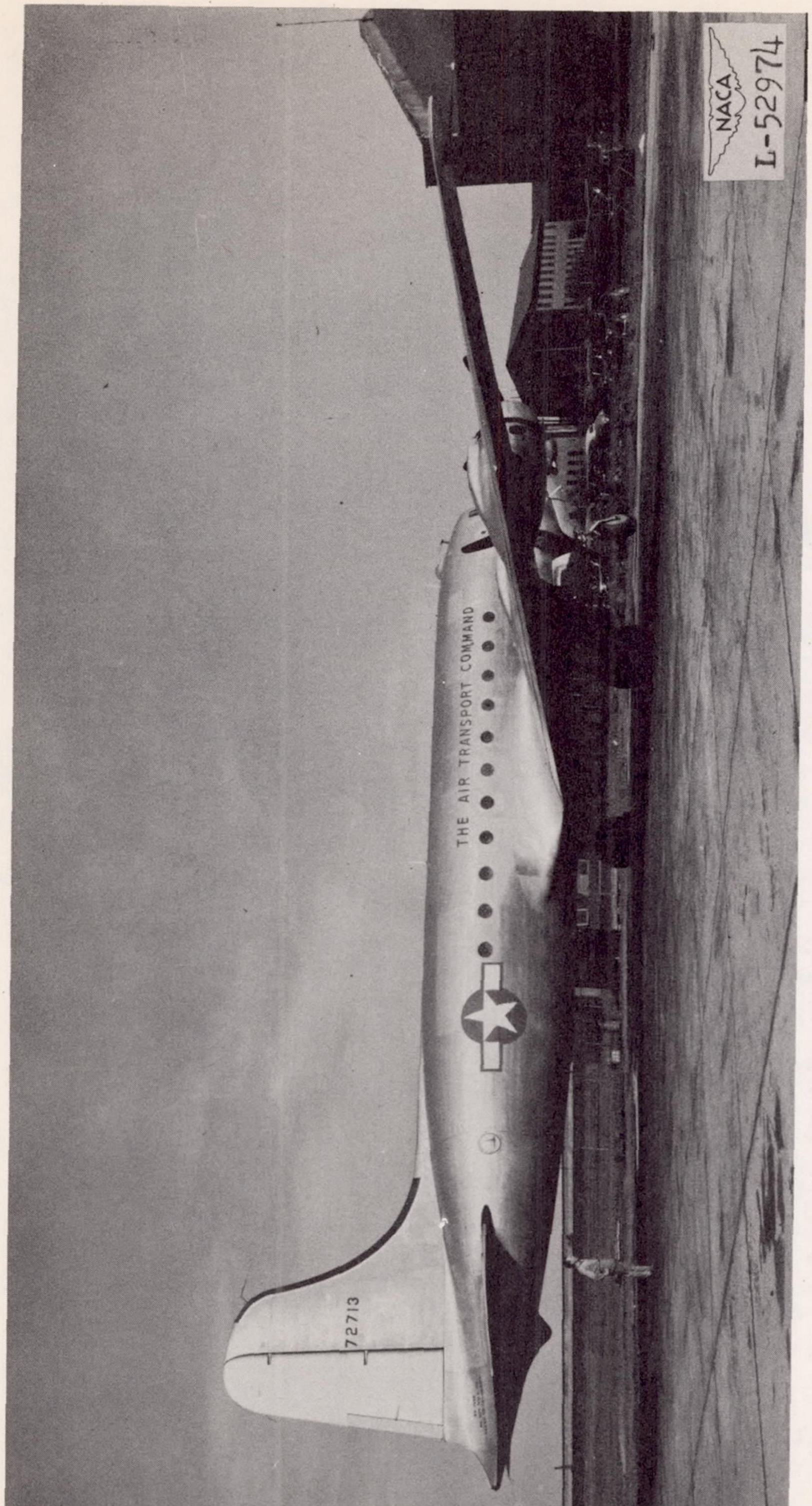
(b) Three-quarter front view.

Figure 1.- Continued.



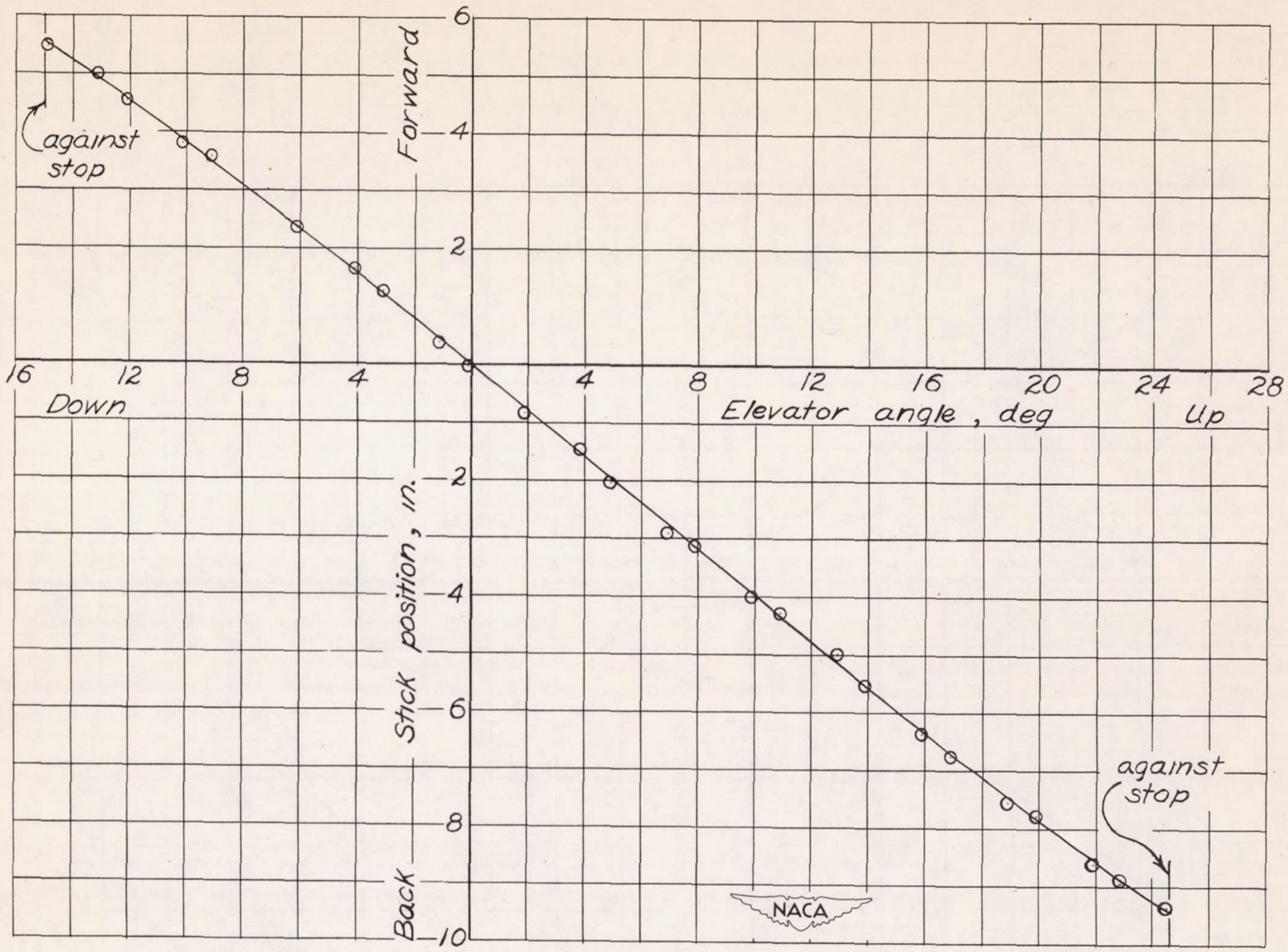
(c) Side view.

Figure 1.- Continued.



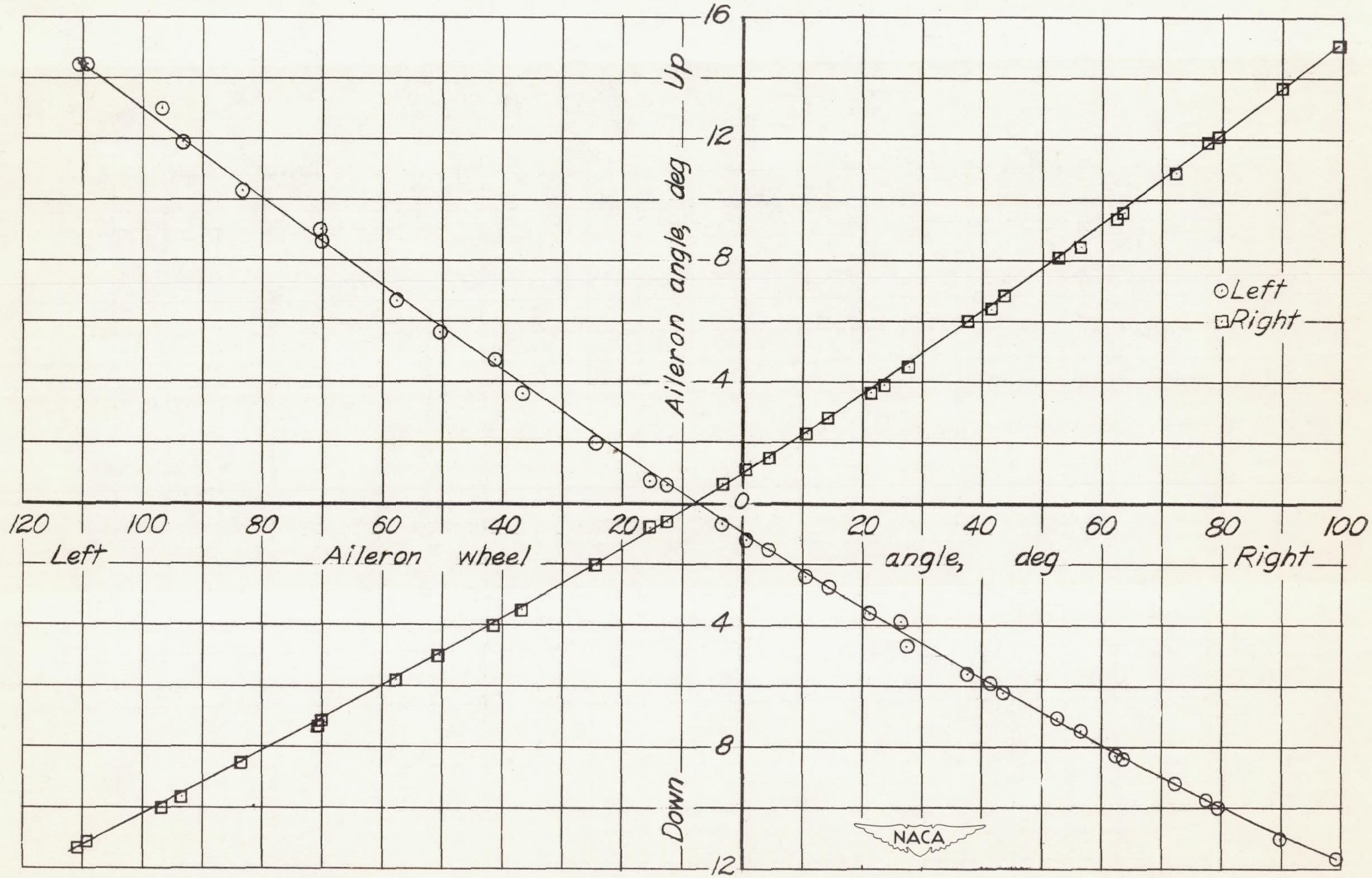
(d) Three-quarter rear view.

Figure 1.- Concluded.



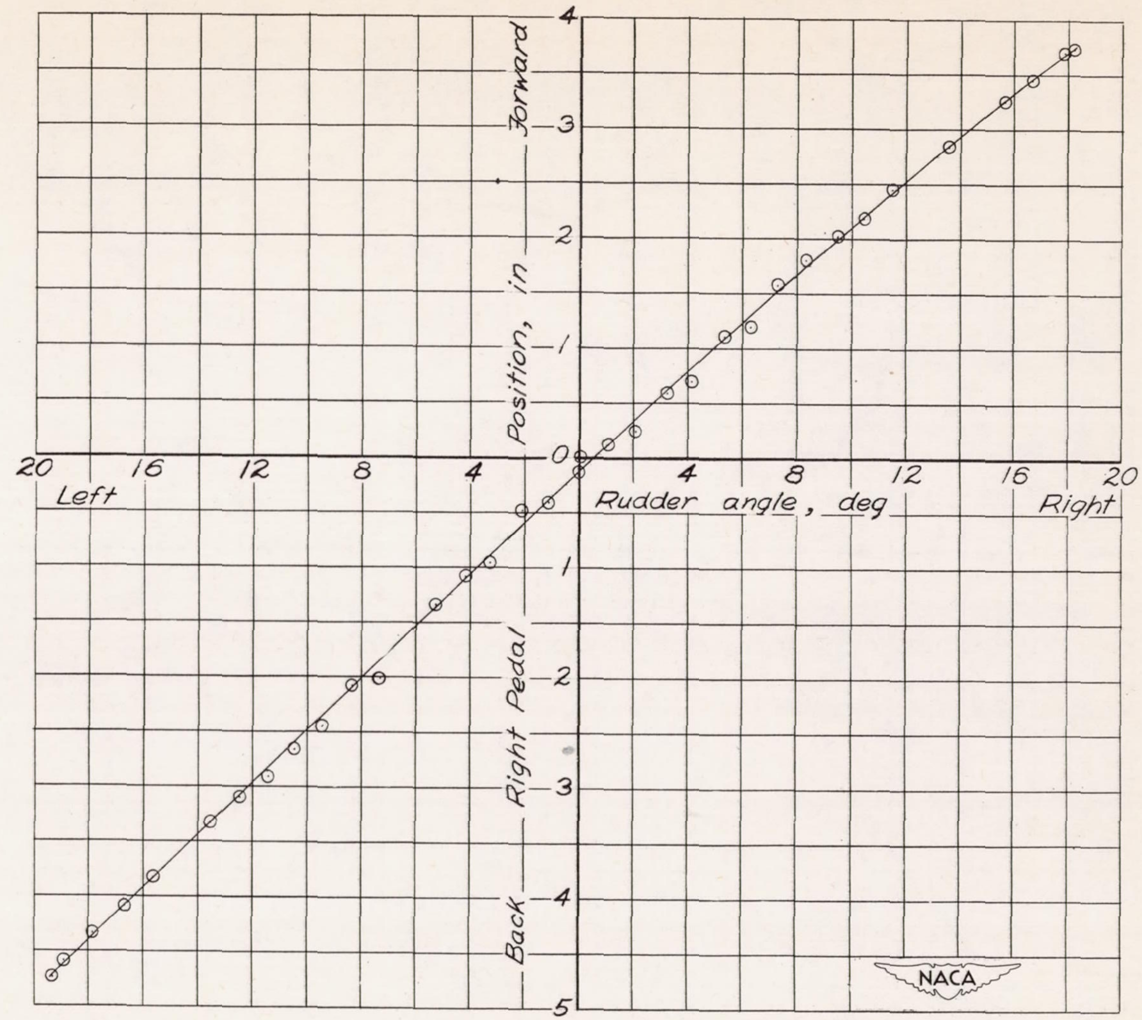
(a) Elevator control.

Figure 2.– Control linkage with no load. C–54D airplane.



(b) Aileron control.

Figure 2.– Continued.



(c) Rudder control.

Figure 2.- Concluded.

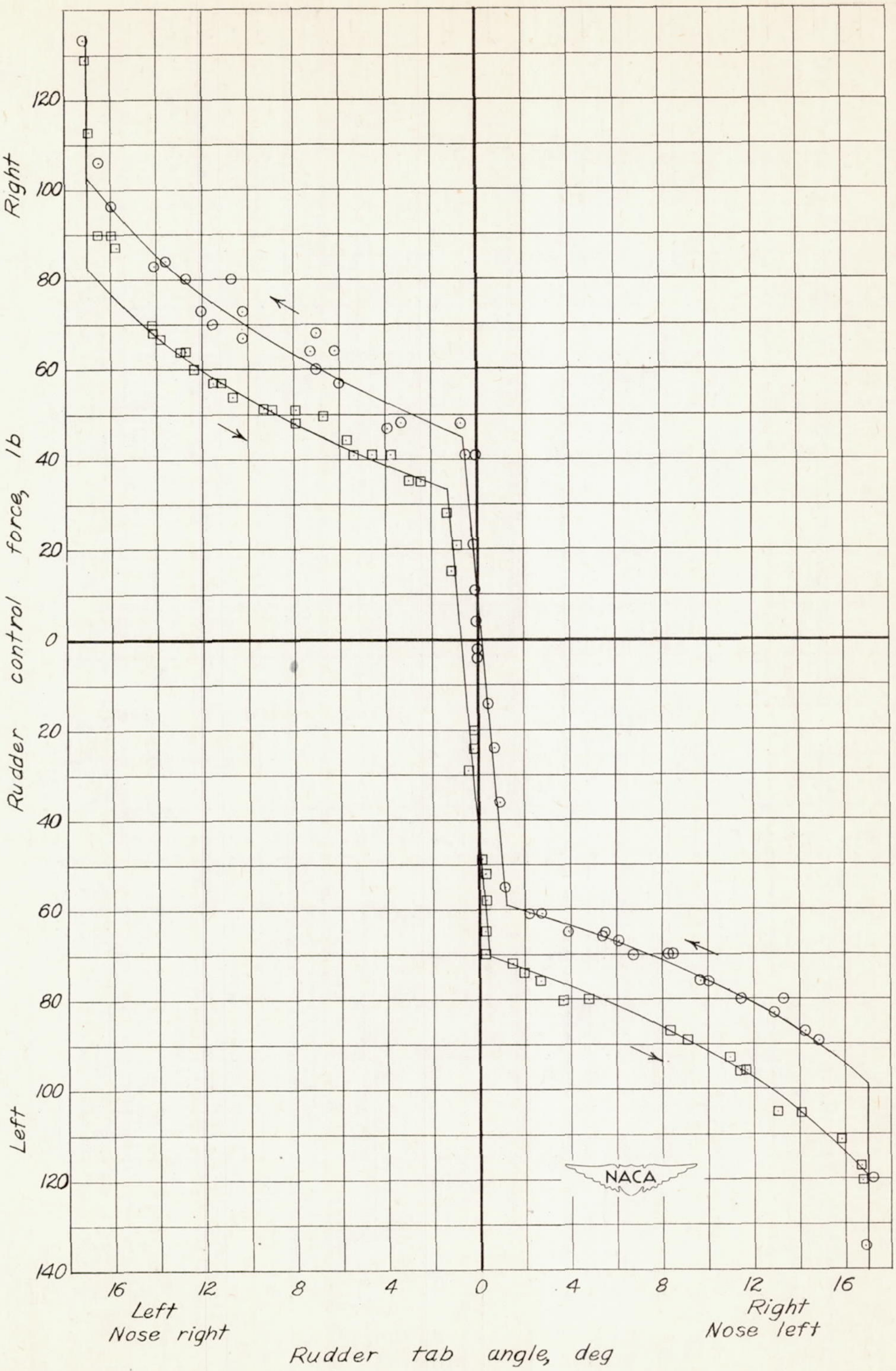
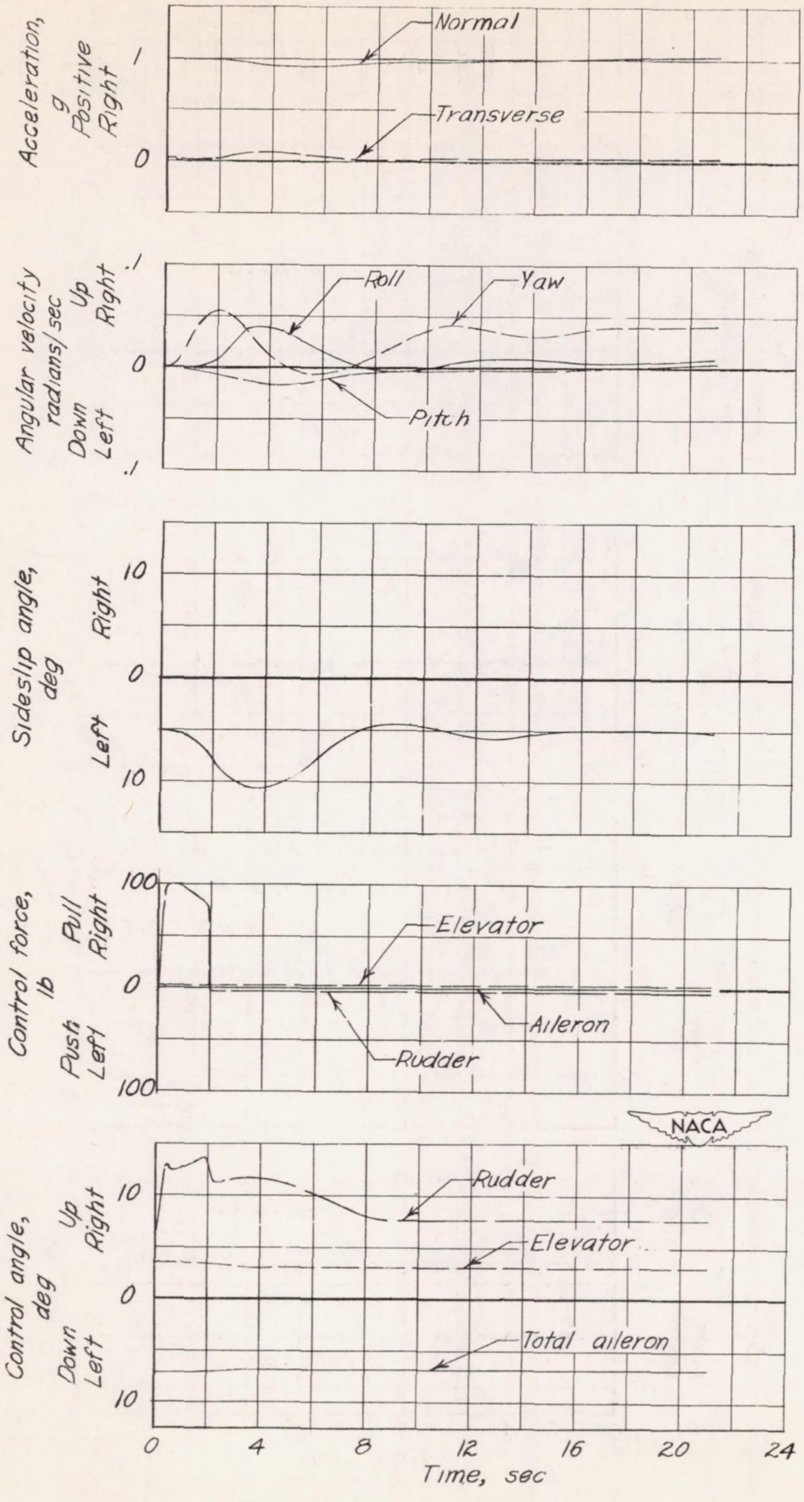
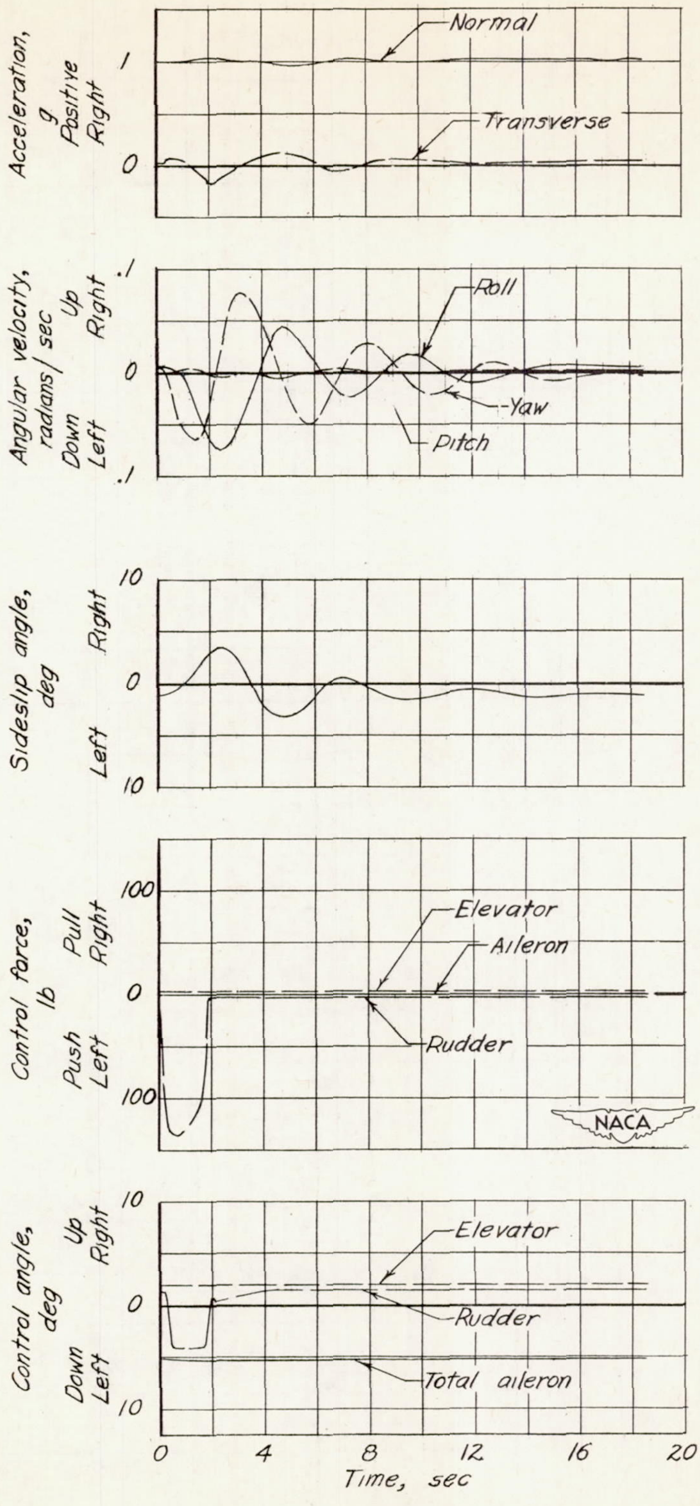


Figure 3.- Characteristics of the rudder spring tab with no load on the tab. C-54D airplane. Rudder fixed at neutral.



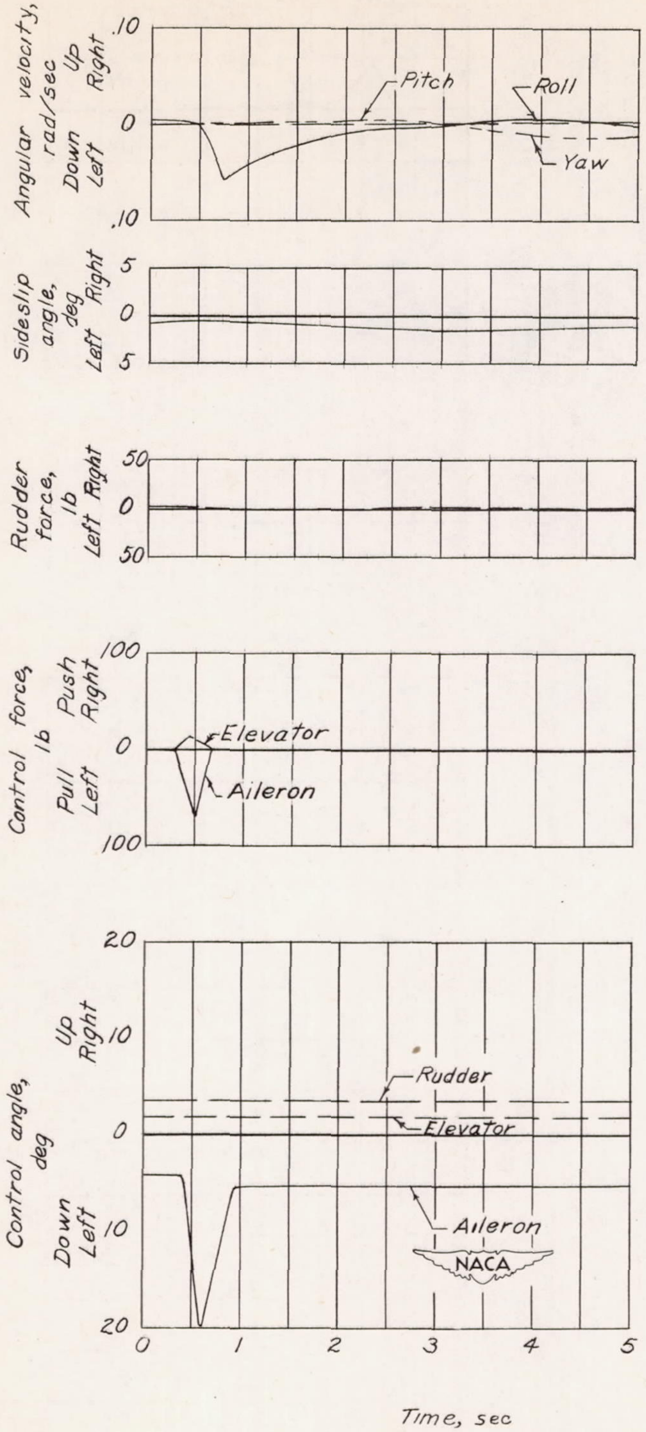
(a) 120 miles per hour.

Figure 4.– Time history of a rudder kick and release. Airplane condition, clean; normal rated power; C–54D airplane.



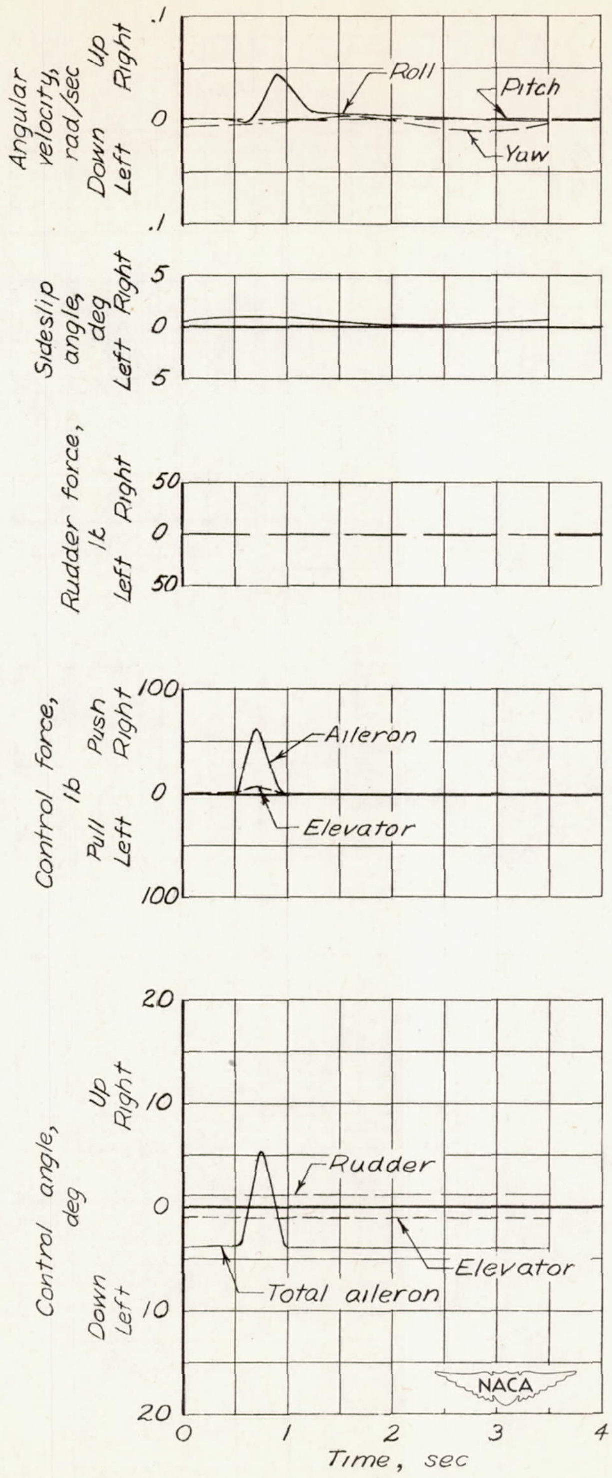
(b) 202 miles per hour.

Figure 4.– Concluded.



(a) 151 miles per hour.

Figure 5.- Time history of an aileron deflection and release. Airplane condition, clean; power for level flight. C-54D airplane.



(b) 237 miles per hour.

Figure 5.- Concluded.

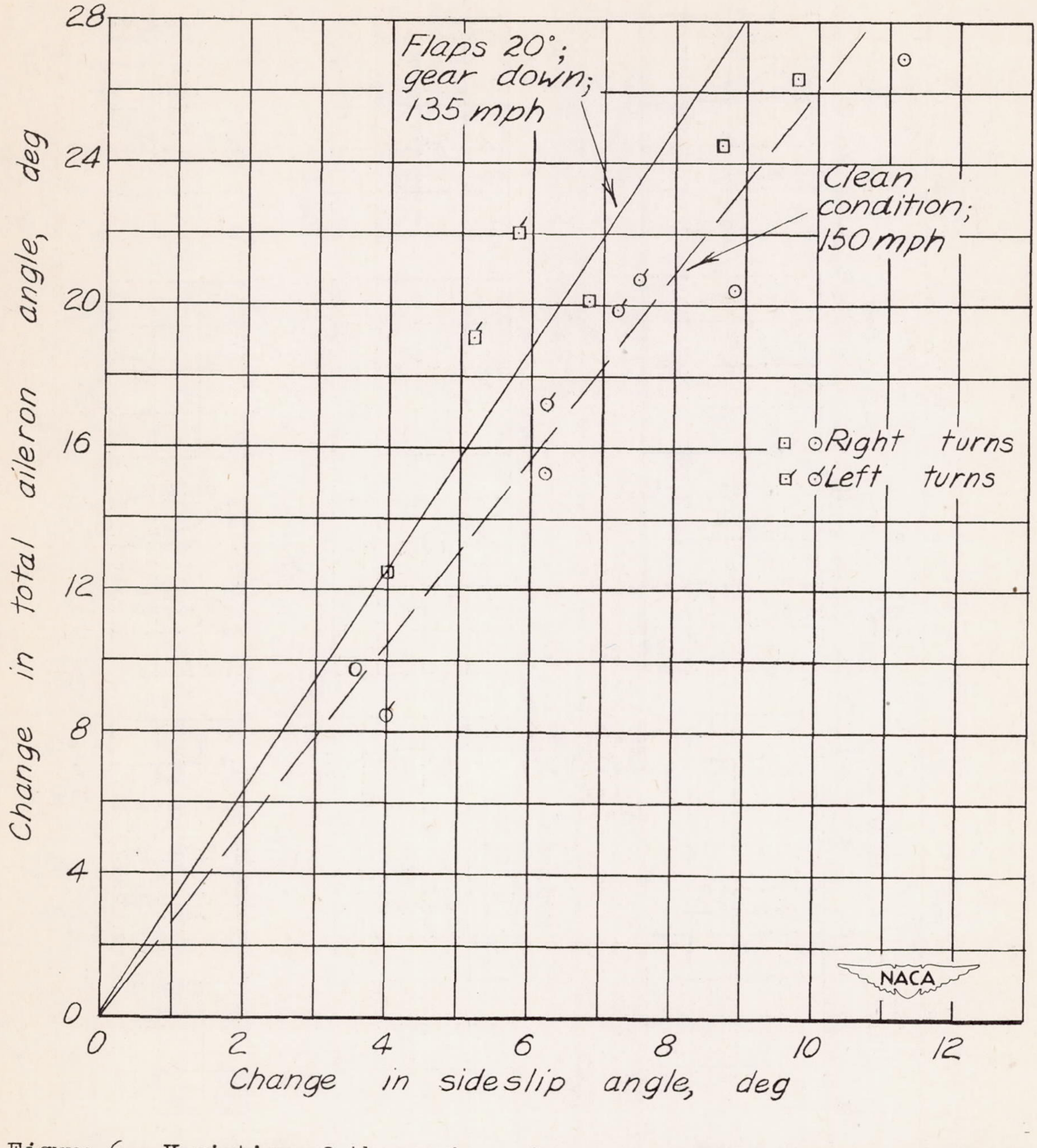
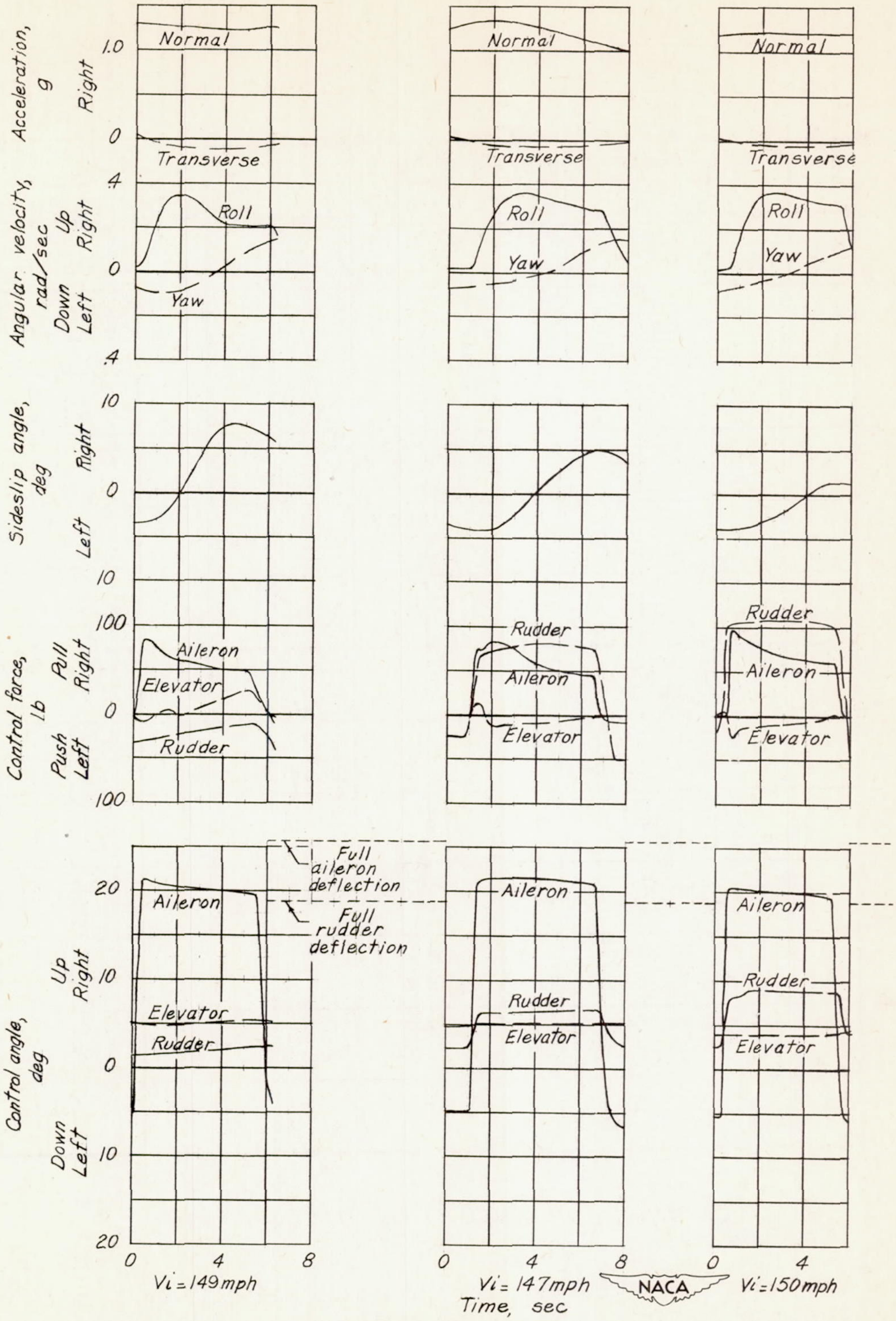


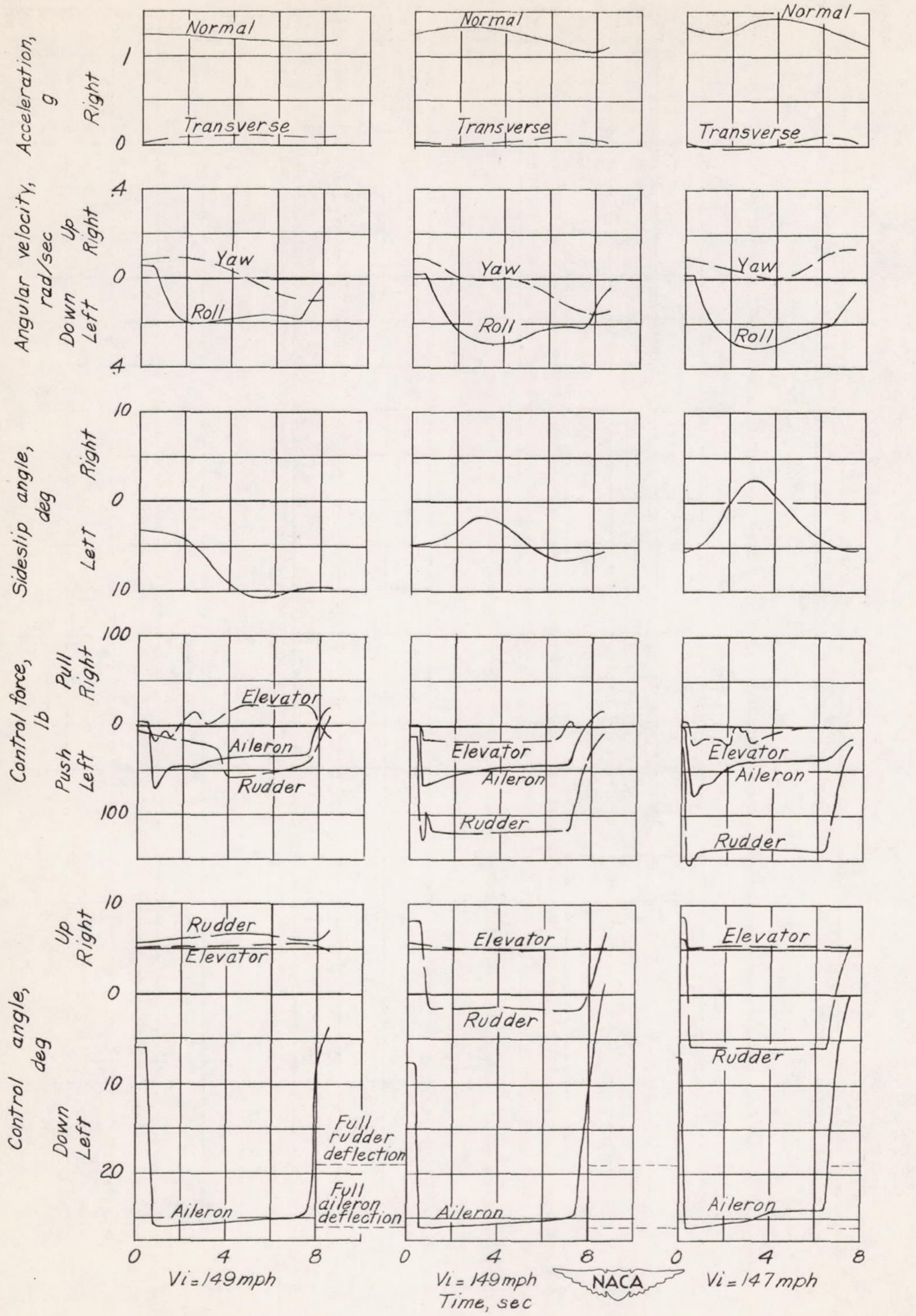
Figure 6.– Variation of the maximum change in sideslip angle with change in aileron angle in rudder locked rolls out of 45° banked turns. C-54D airplane.



(1) Rudder locked. (2) Rudder deflected. (3) Rudder deflected farther.

(a) Rolls out of left turns.

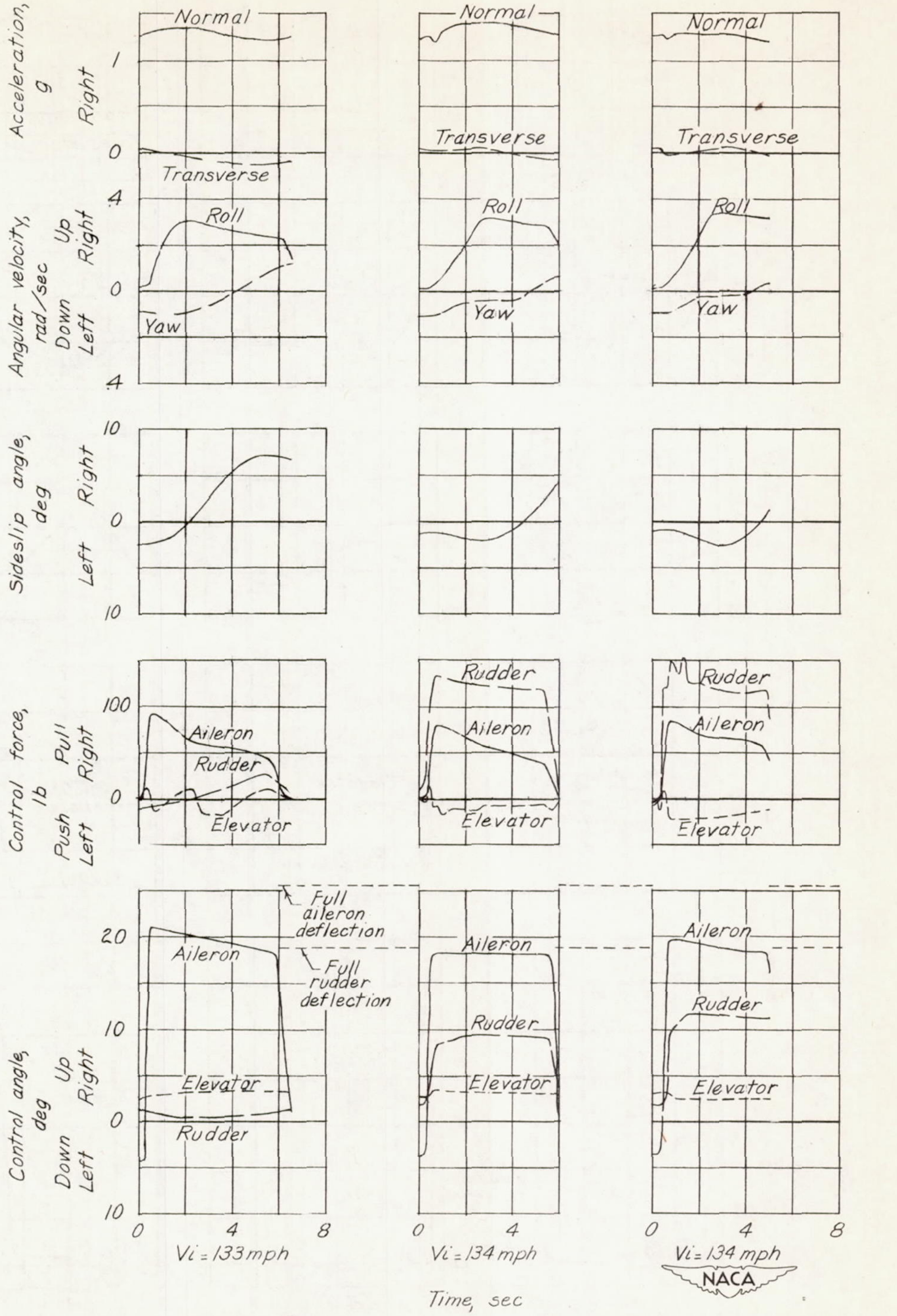
Figure 7.– Time histories of rolls out of 45° banked turns. Clean condition; power for level flight; C–54D airplane.



(1) Rudder locked. (2) Rudder deflected. (3) Rudder deflected farther.

(b) Rolls out of right turns.

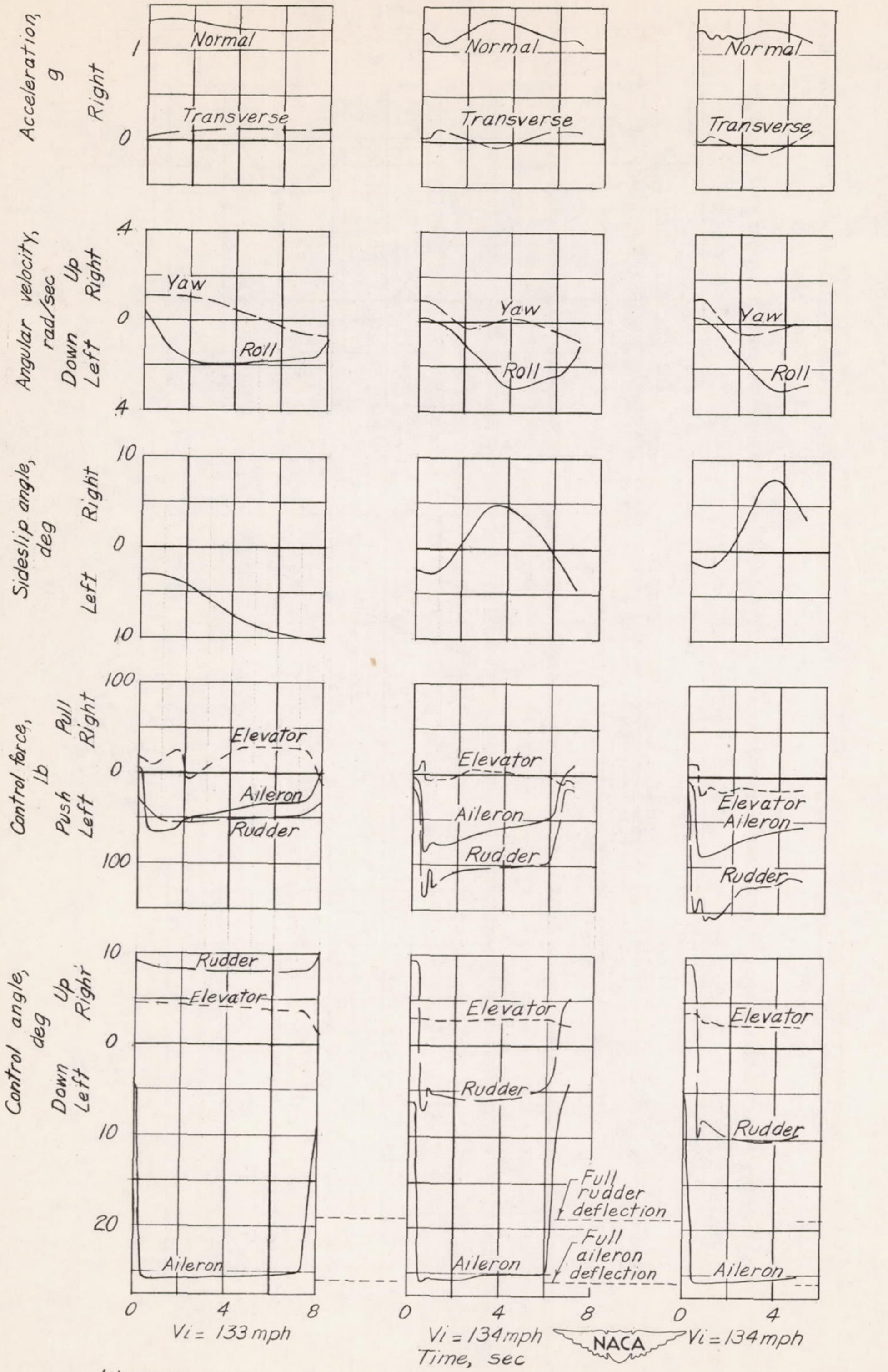
Figure 7.— Concluded.



(1) Rudder locked. (2) Rudder deflected. (3) Rudder deflected farther.

(a) Rolls out of left turns.

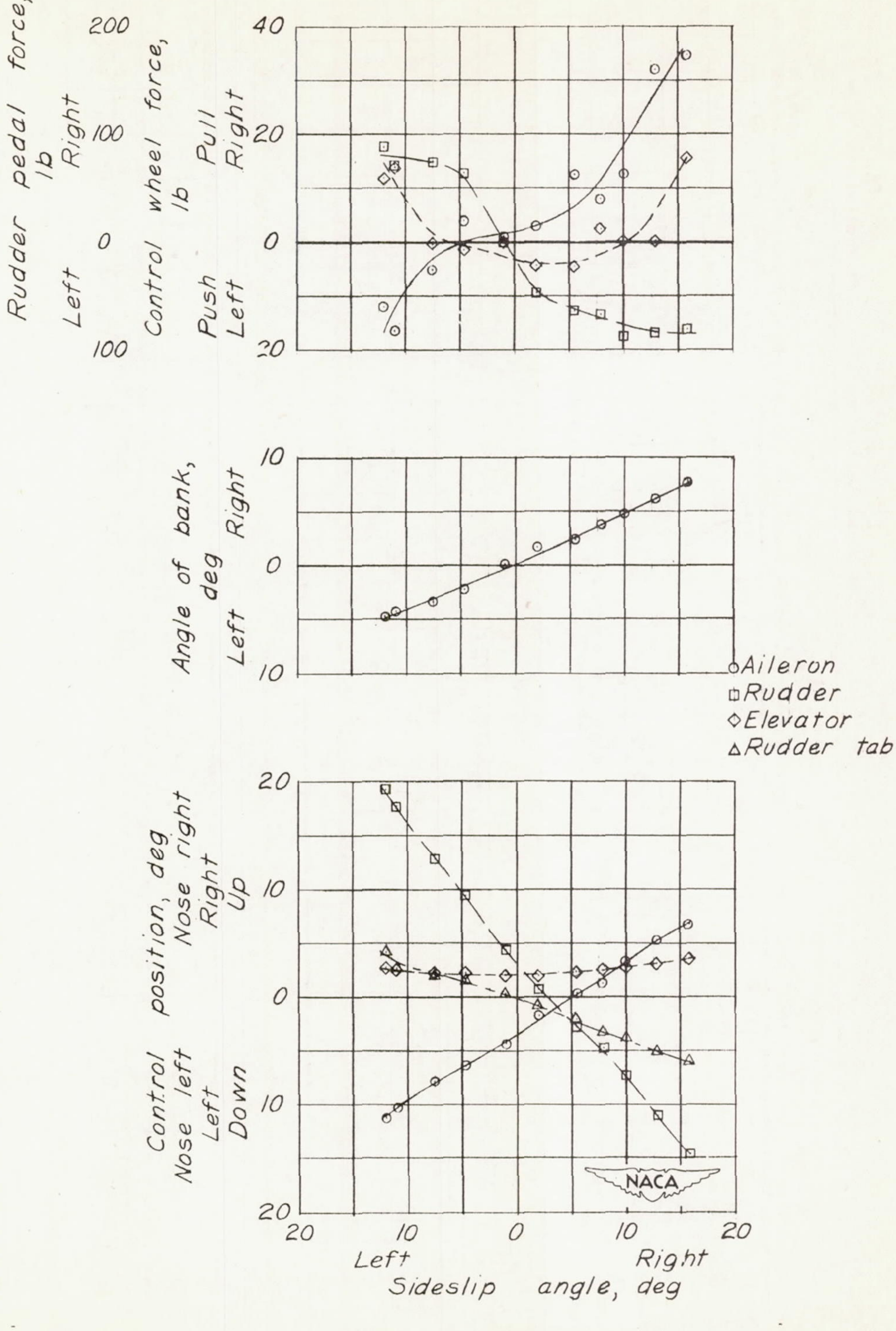
Figure 8.– Time histories of rolls out of 45° banked turns. Flaps down; gear down; power for level flight. C–54D airplane.



(1) Rudder locked. (2) Rudder deflected. (3) Rudder deflected farther.

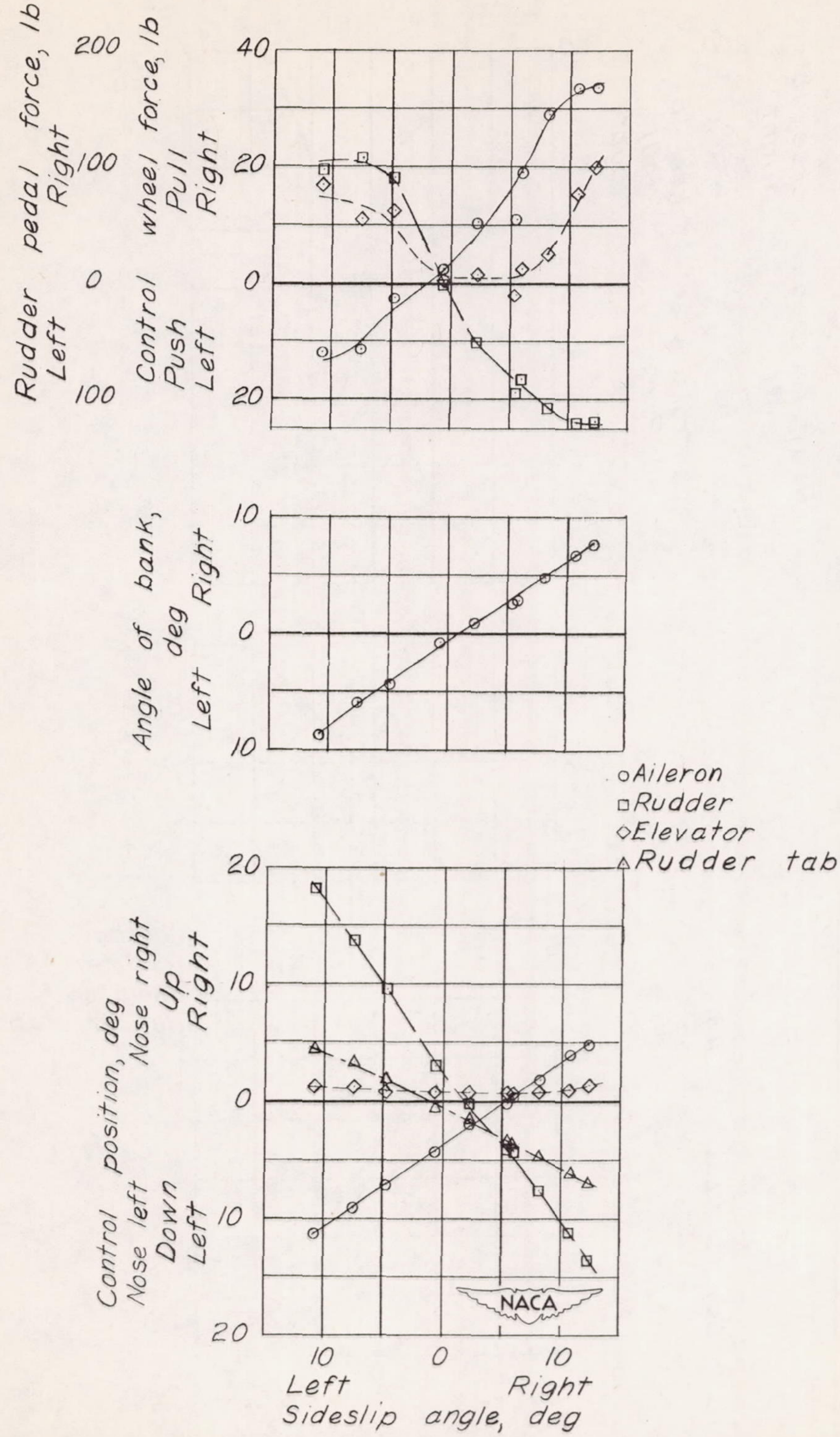
(b) Rolls out of right turns.

Figure 8.– Concluded.



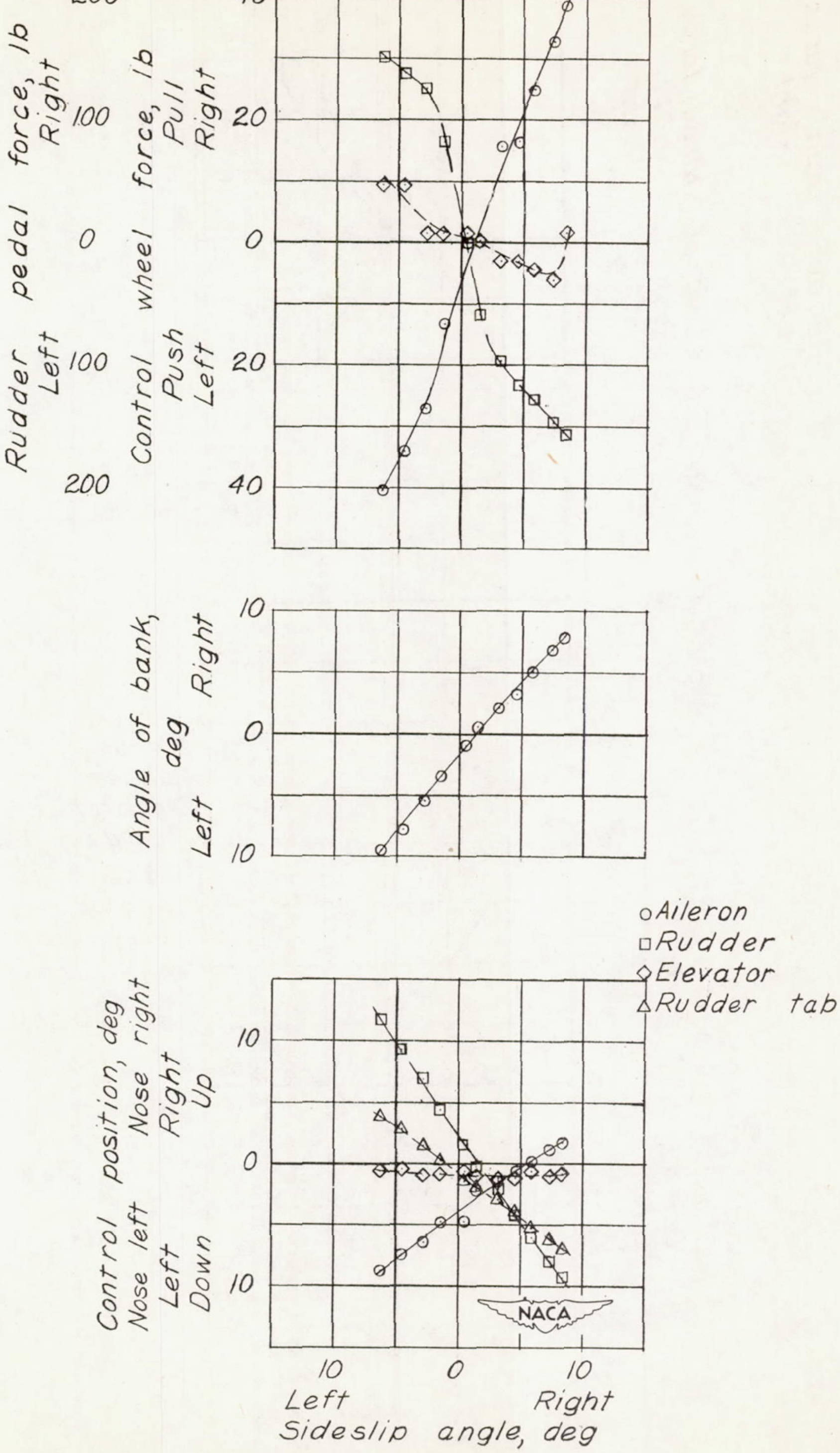
(a) 120 miles per hour.

Figure 9.- Sideslip characteristics. C-54D airplane; clean condition; normal rated power.



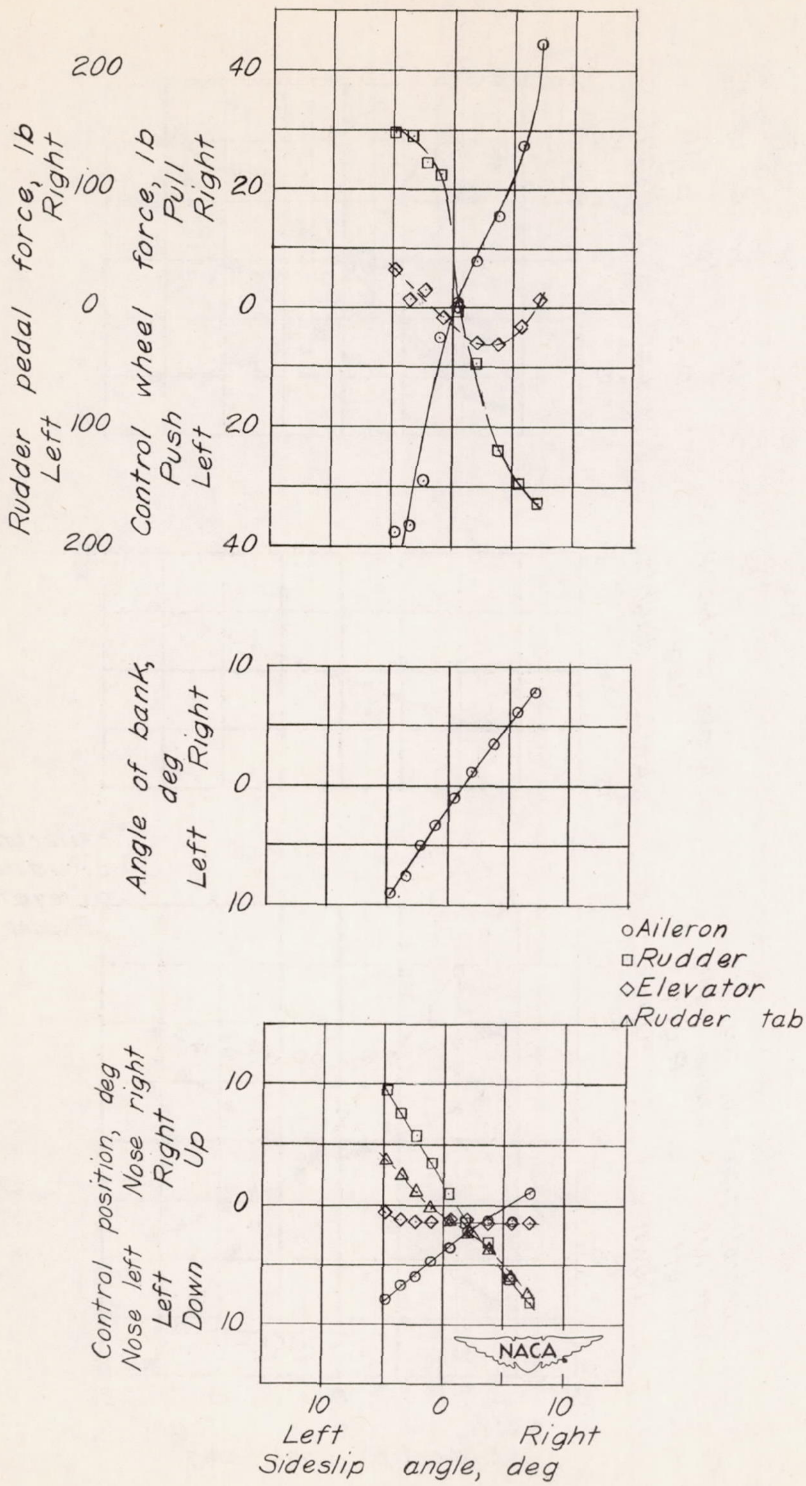
(b) 150 miles per hour.

Figure 9.– Continued.



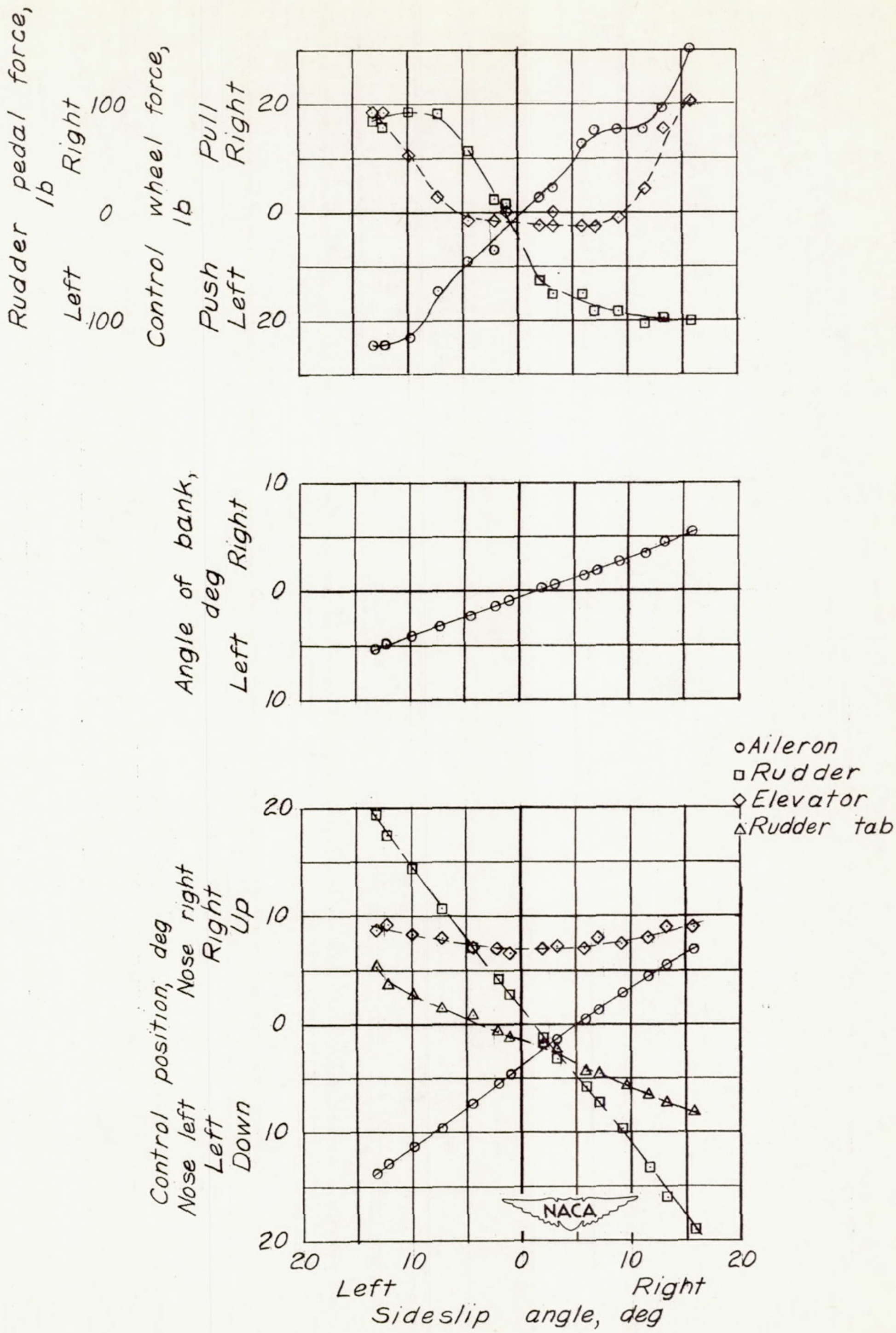
(c) 200 miles per hour.

Figure 9.— Continued.



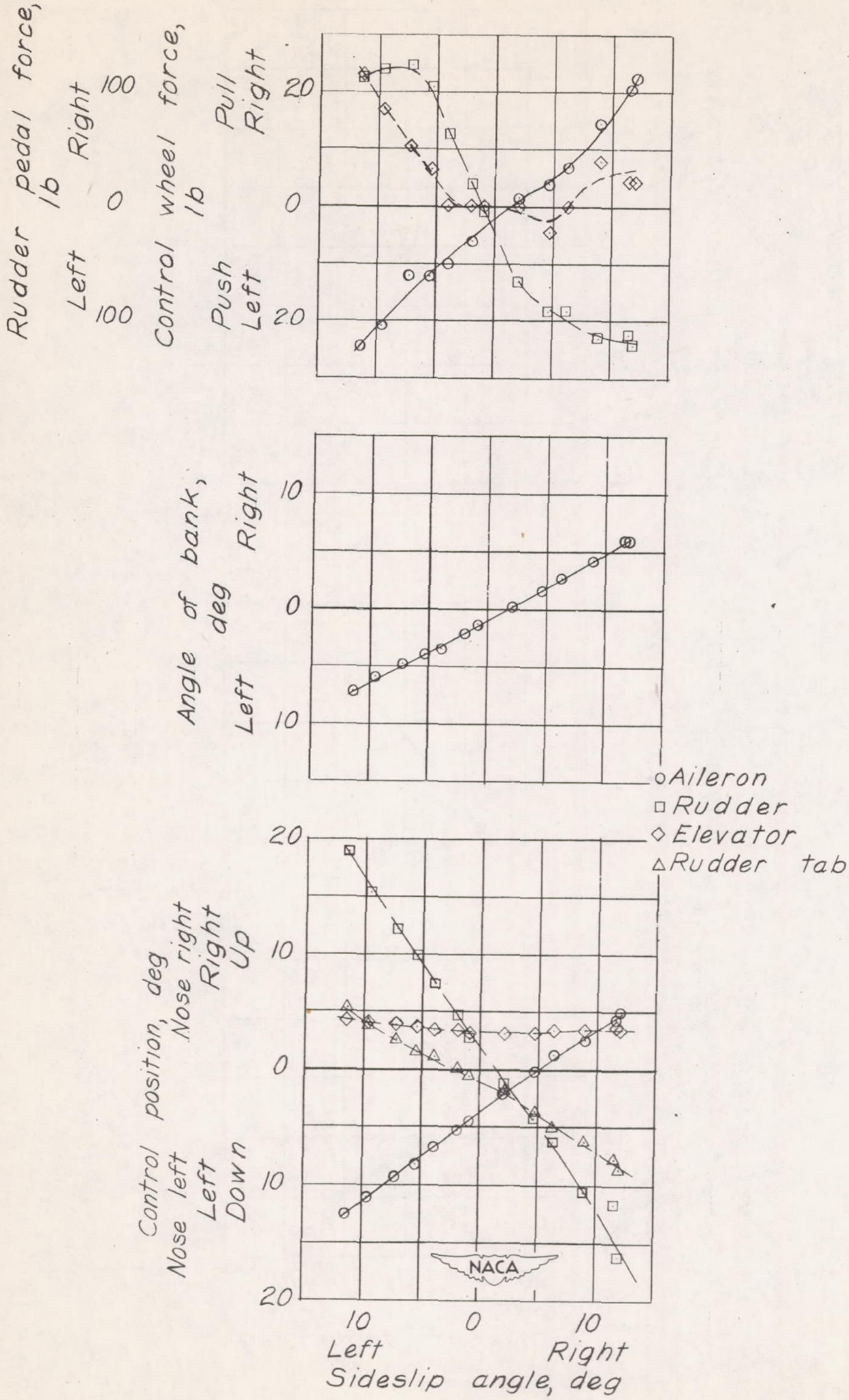
(d) 225 miles per hour.

Figure 9.– Concluded.



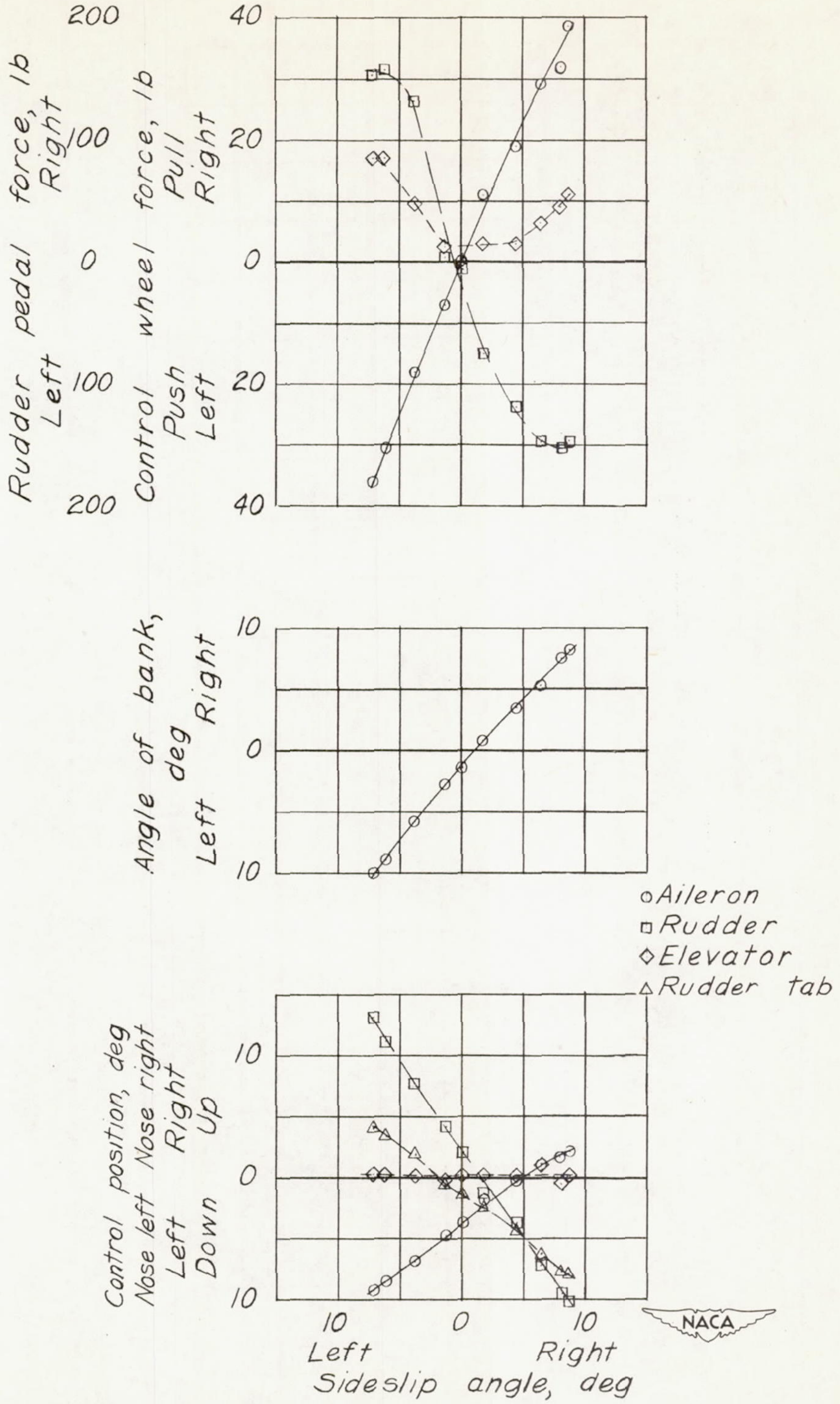
(a) 120 miles per hour.

Figure 10.- Sideslip characteristics. C-54D airplane; flaps and gear up; power off.



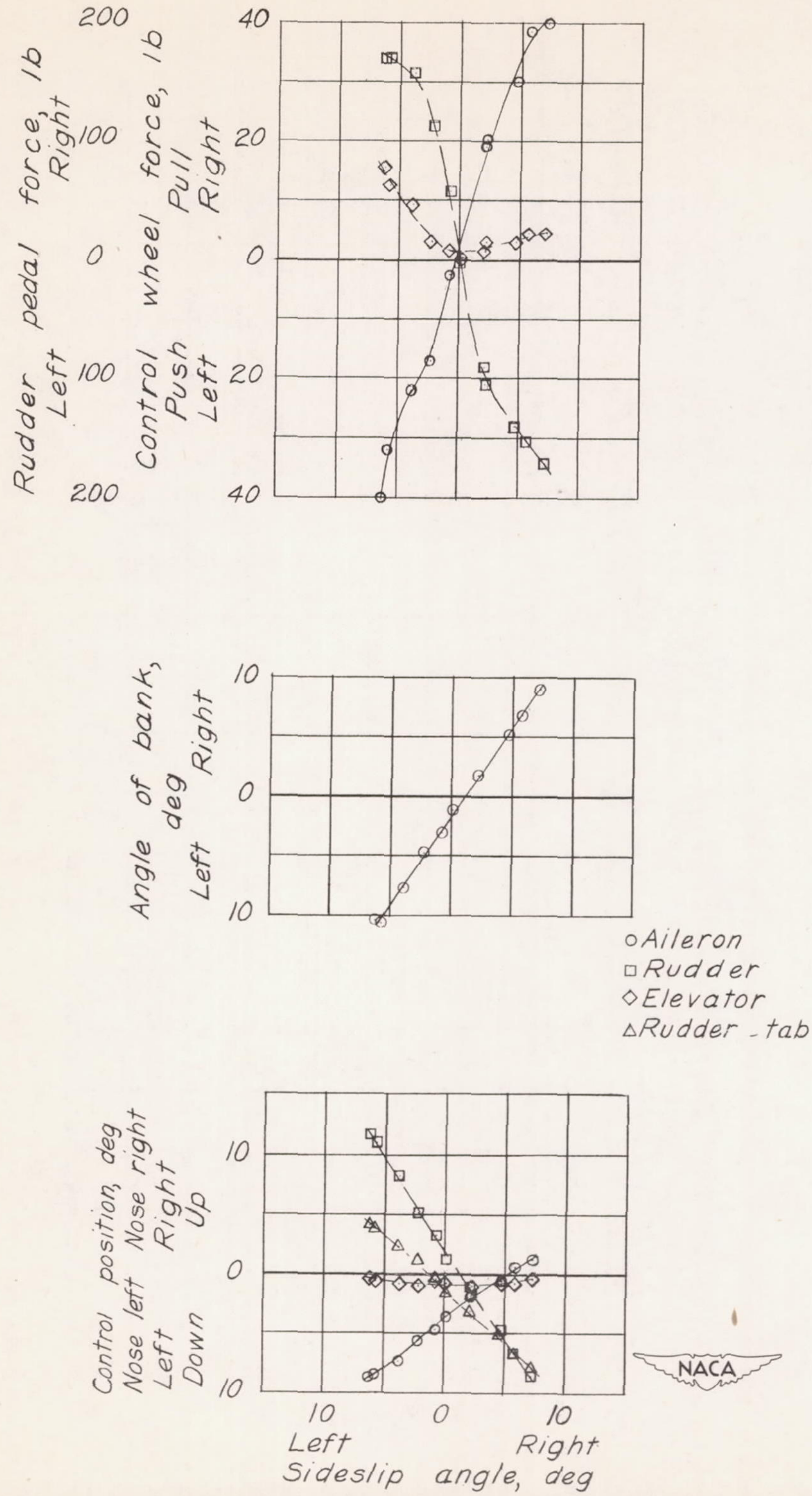
(b) 150 miles per hour.

Figure 10.– Continued.



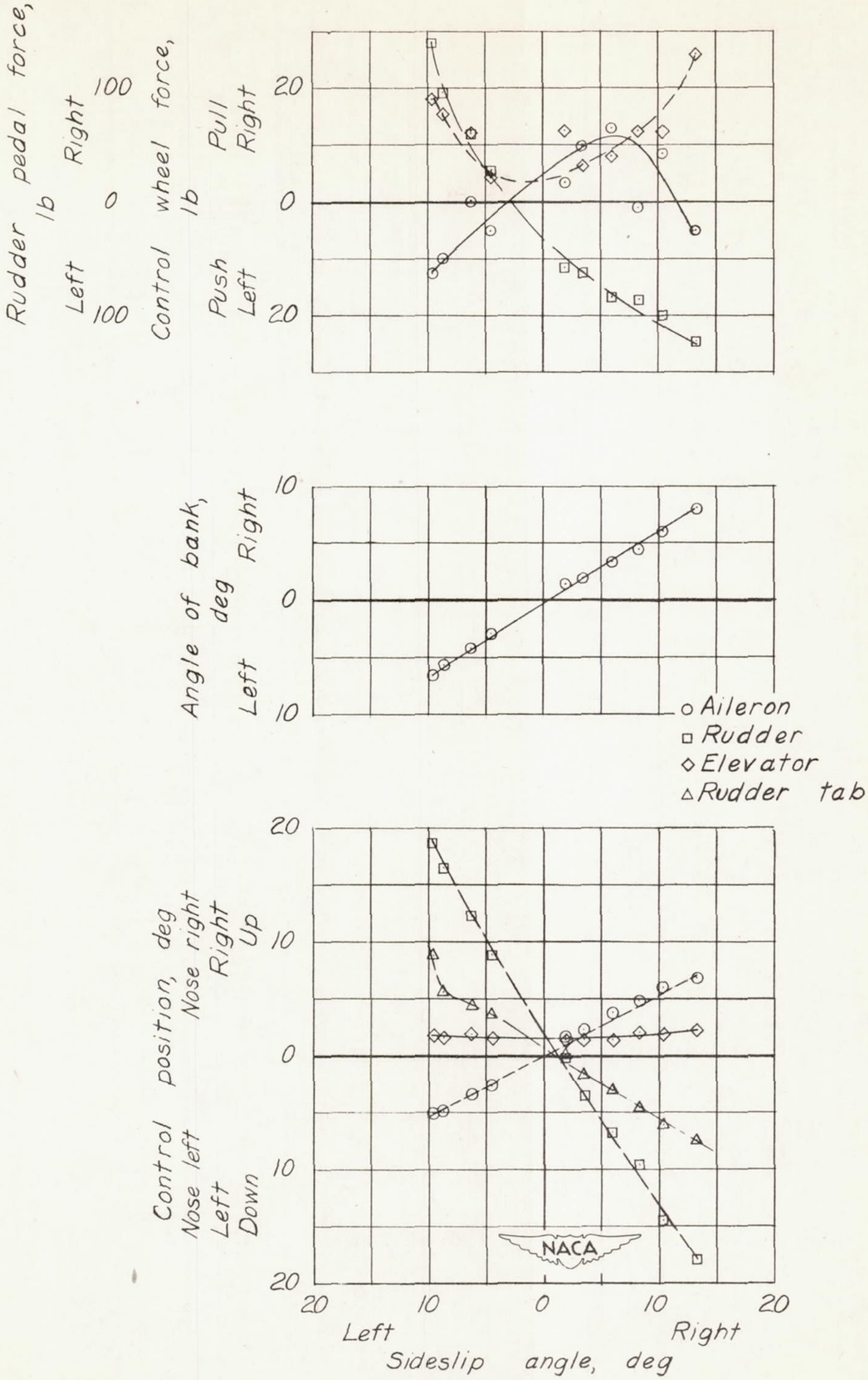
(c) 200 miles per hour.

Figure 10.– Continued.



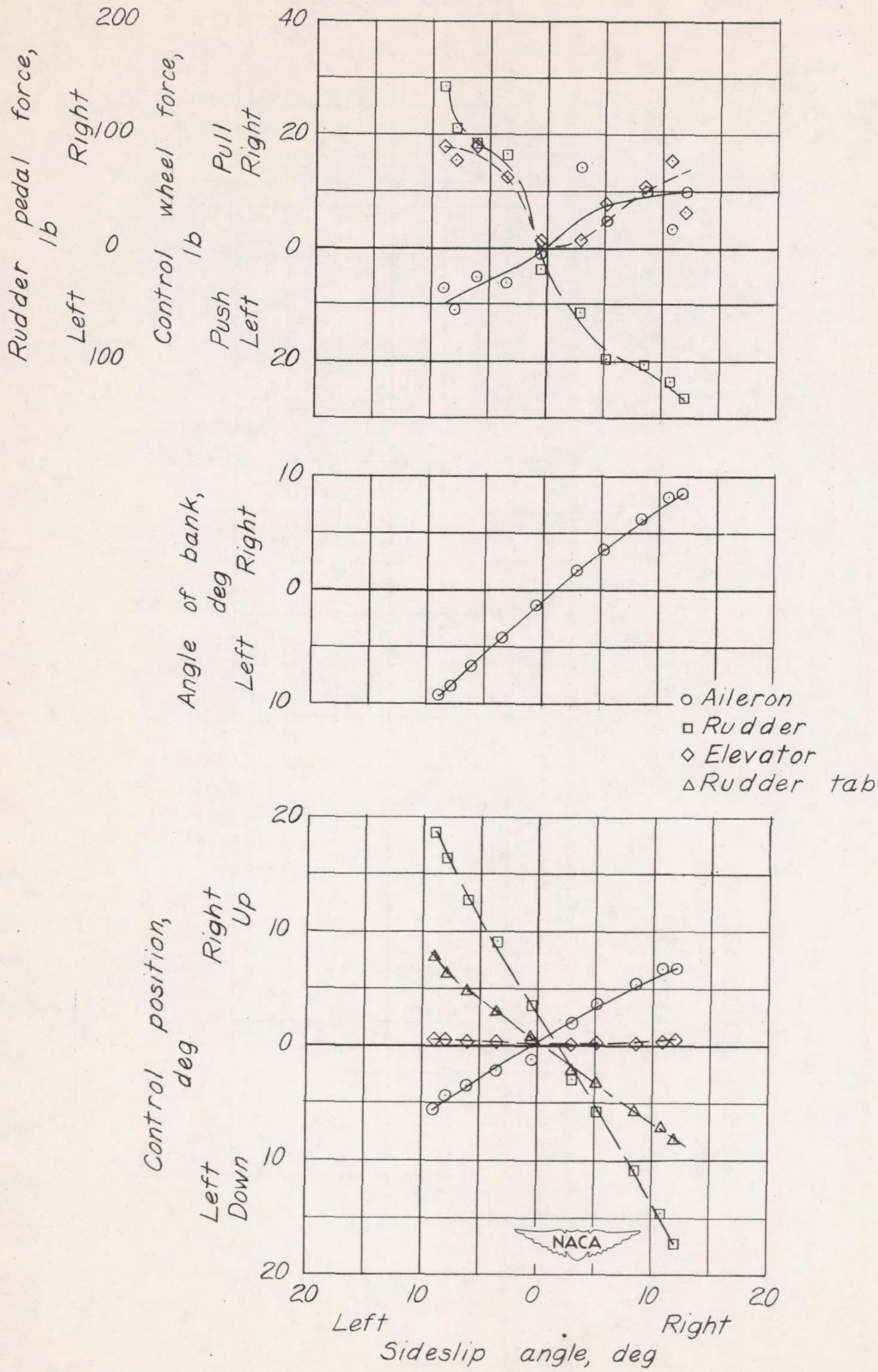
(d) 225 miles per hour.

Figure 10.– Concluded.



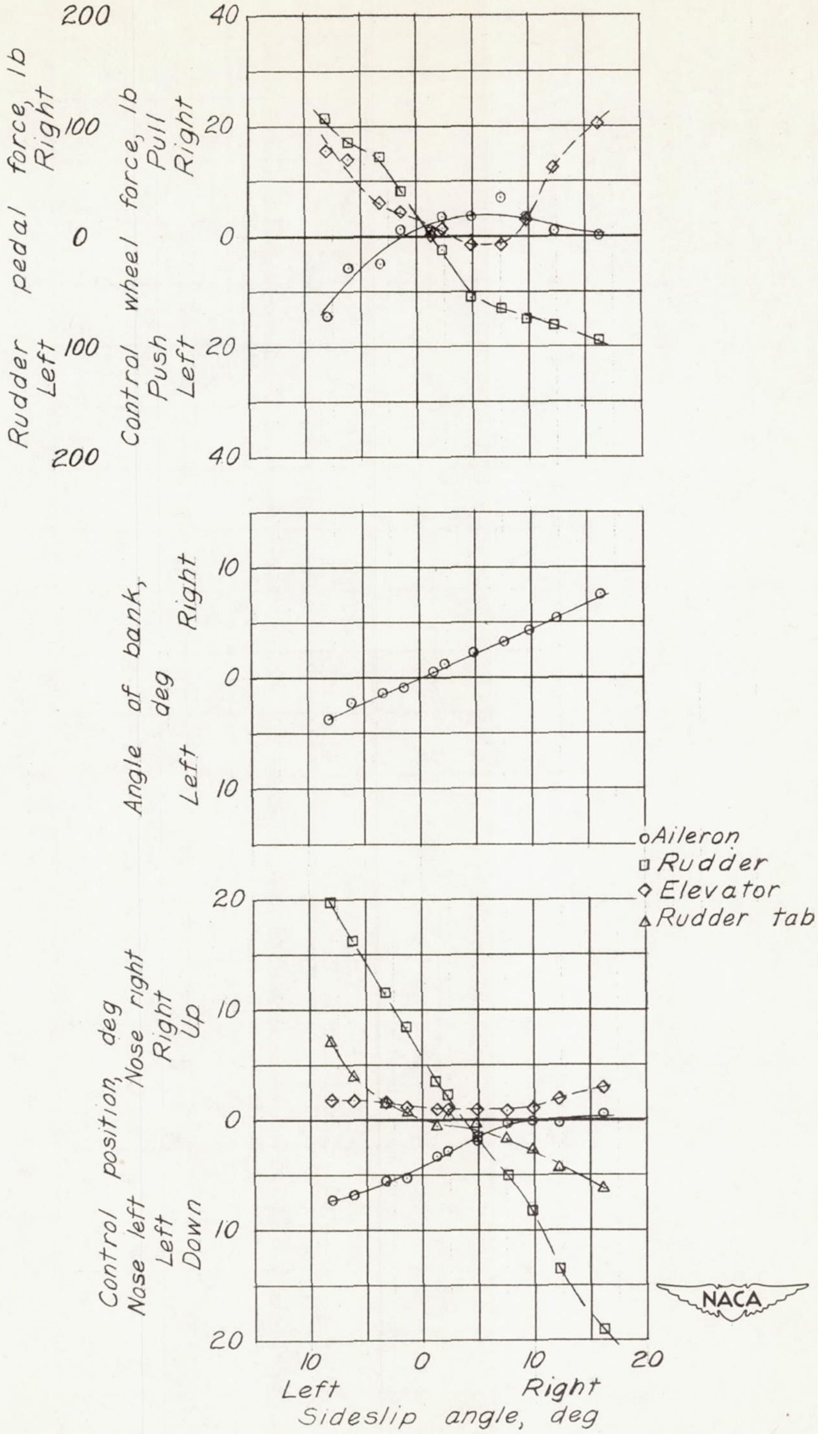
(a) 120 miles per hour.

Figure 11.– Sideslip characteristics. C–54D airplane; flaps 20°; gear down; power 20 in.; 2550 rpm.



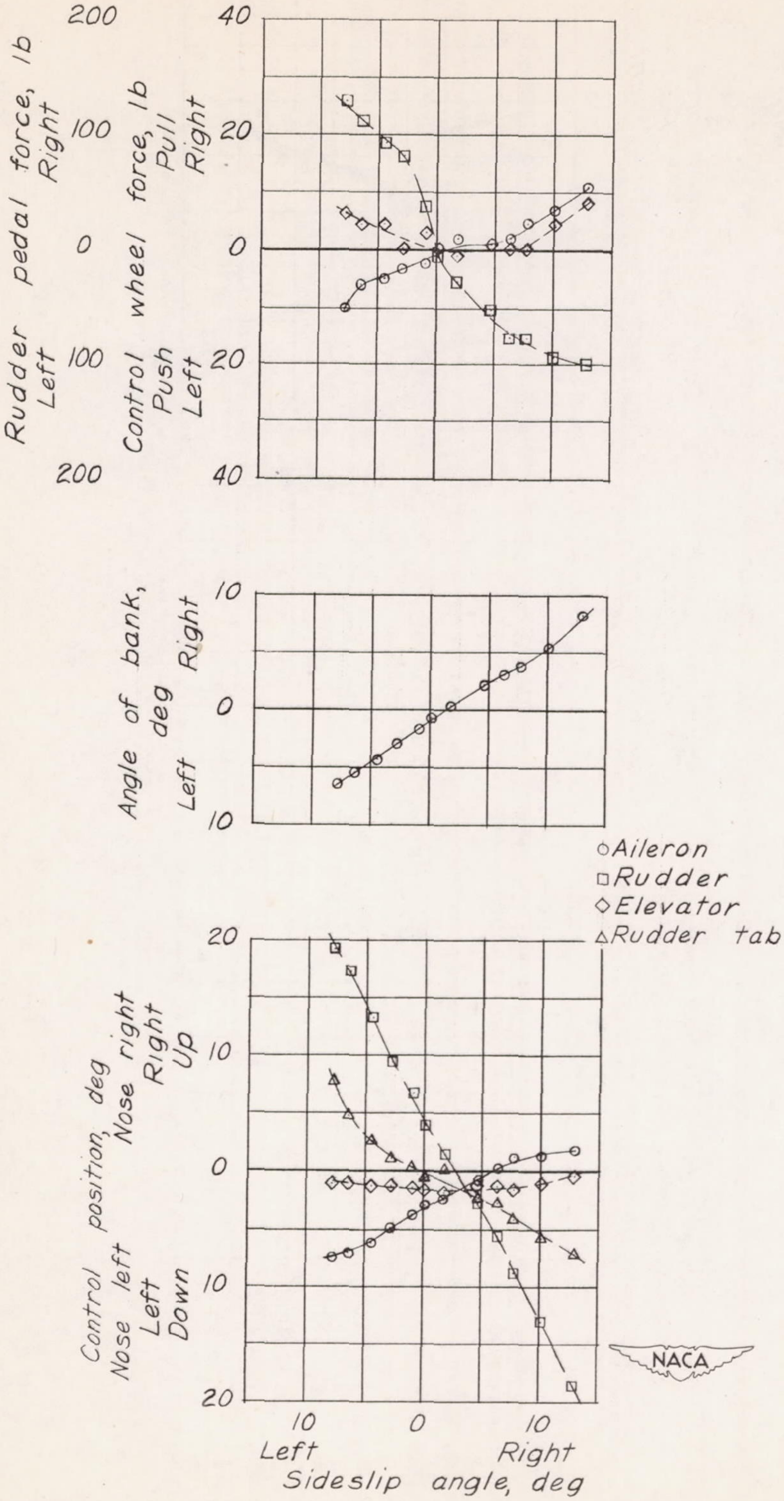
(b) 140 miles per hour.

Figure 11.- Concluded.



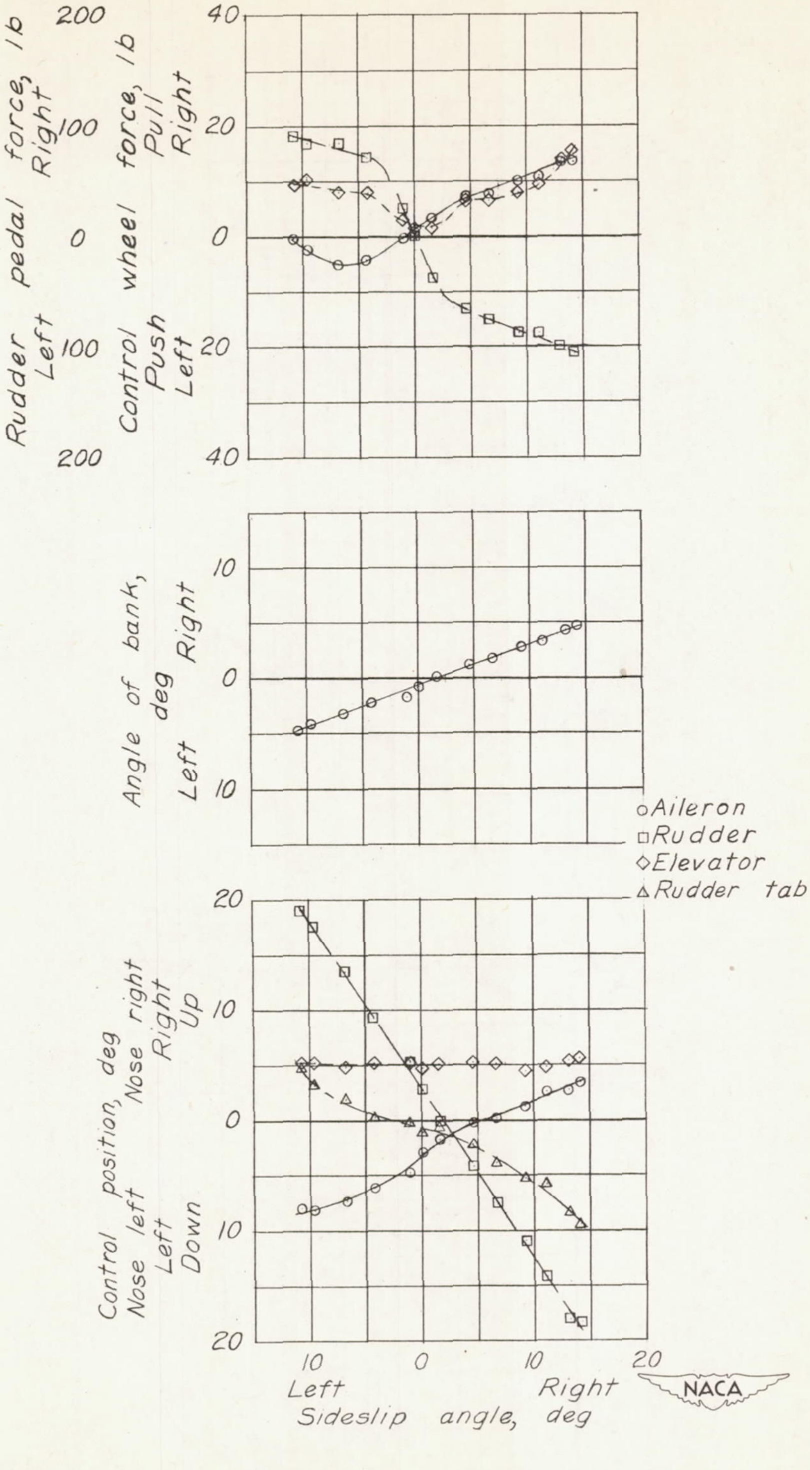
(a) 100 miles per hour.

Figure 12.- Sideslip characteristics. C-54D airplane; flaps and gear down; normal rated power.



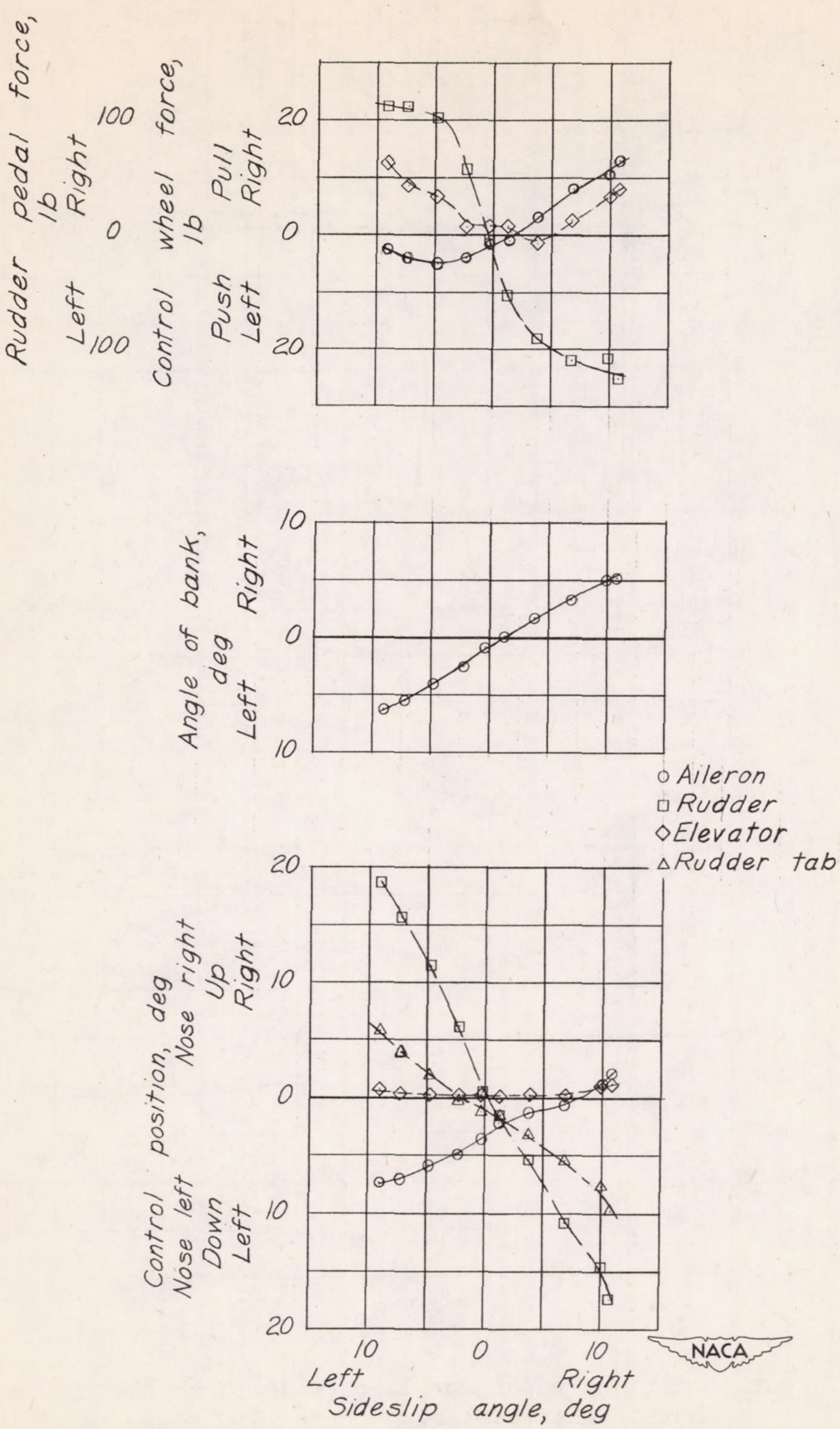
(b) 120 miles per hour.

Figure 12.– Concluded.



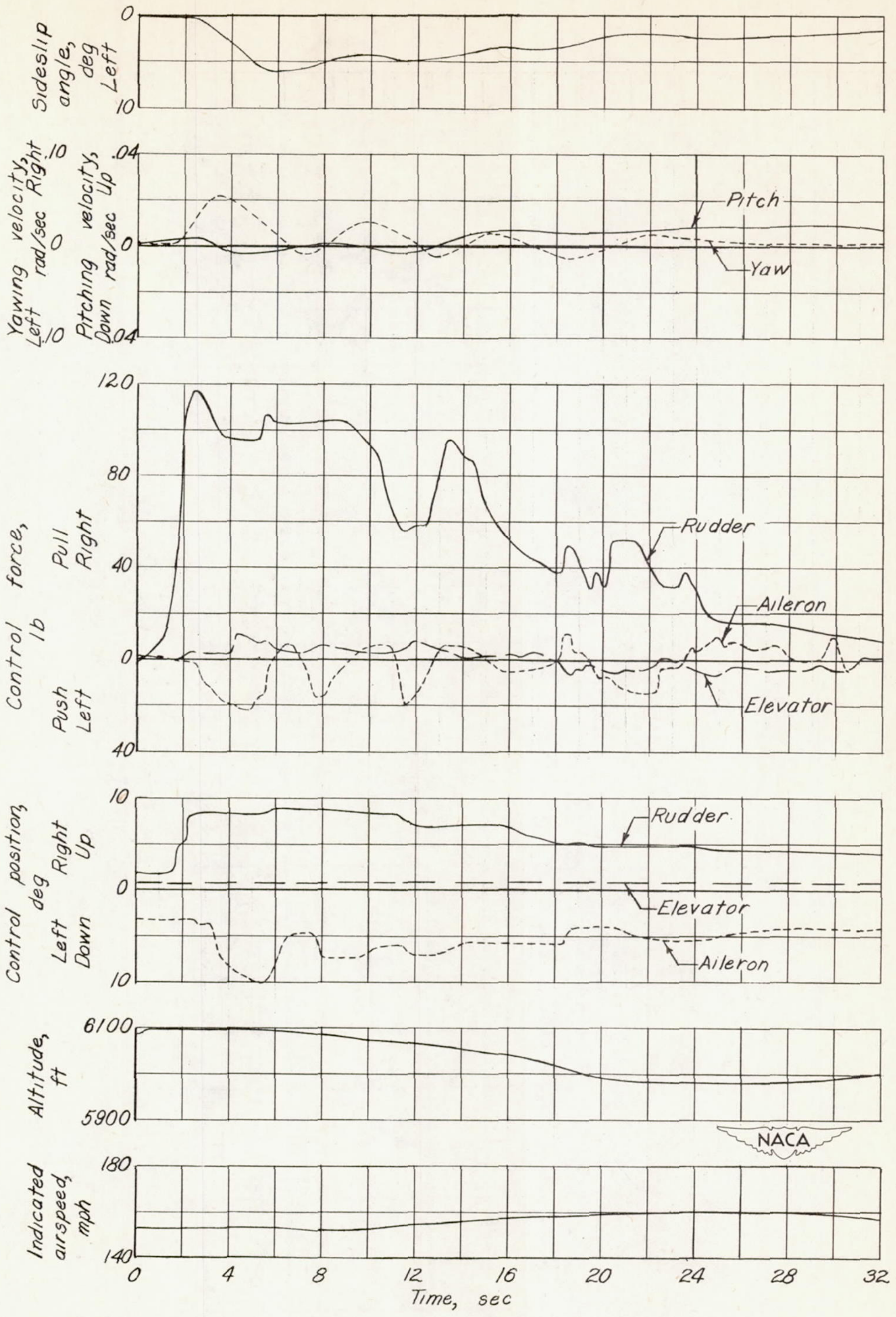
(a) 100 miles per hour.

Figure 13.- Sideslip characteristics. C-54D airplane; flaps and gear down; power off.



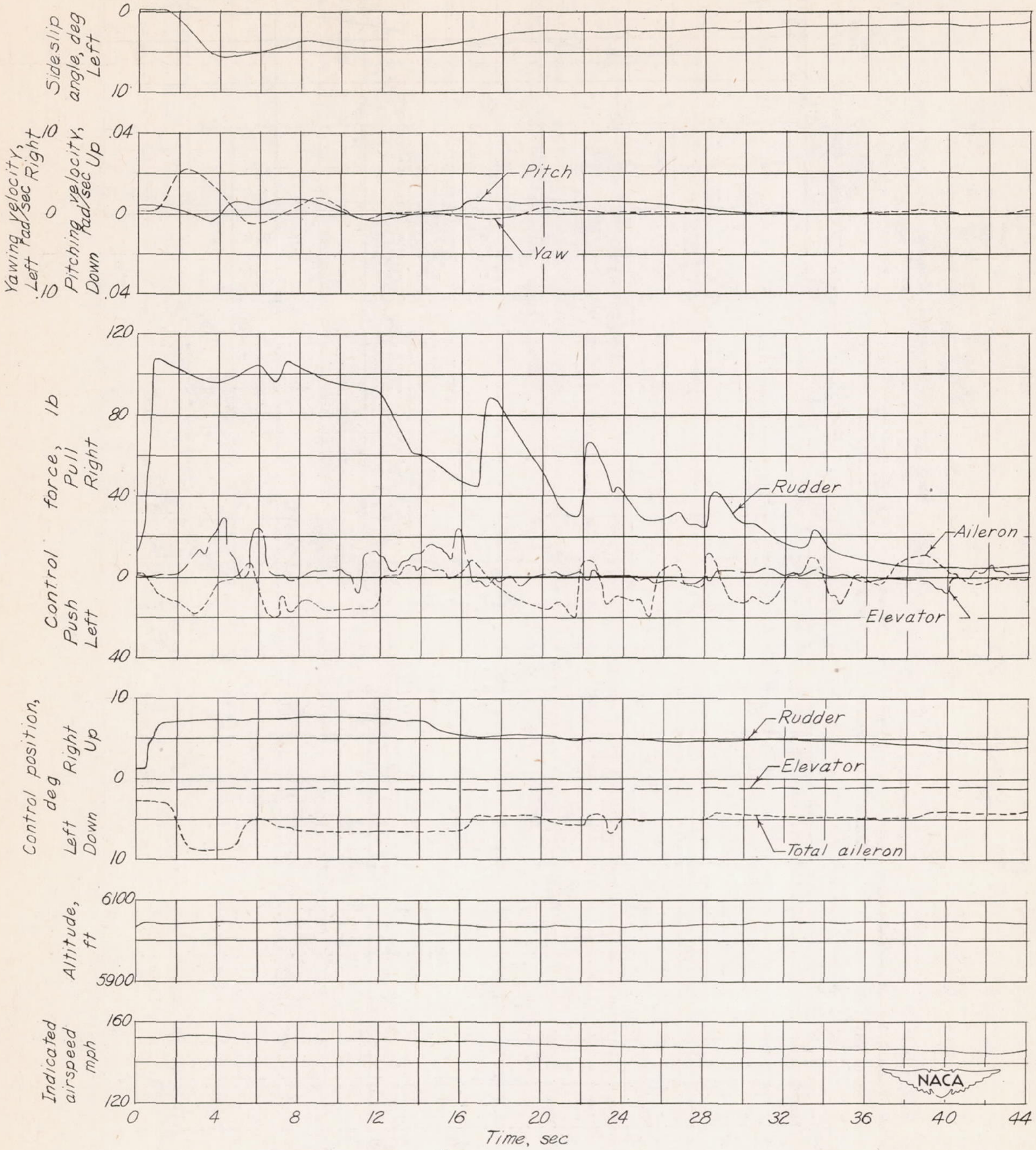
(b) 120 miles per hour.

Figure 13.– Concluded.



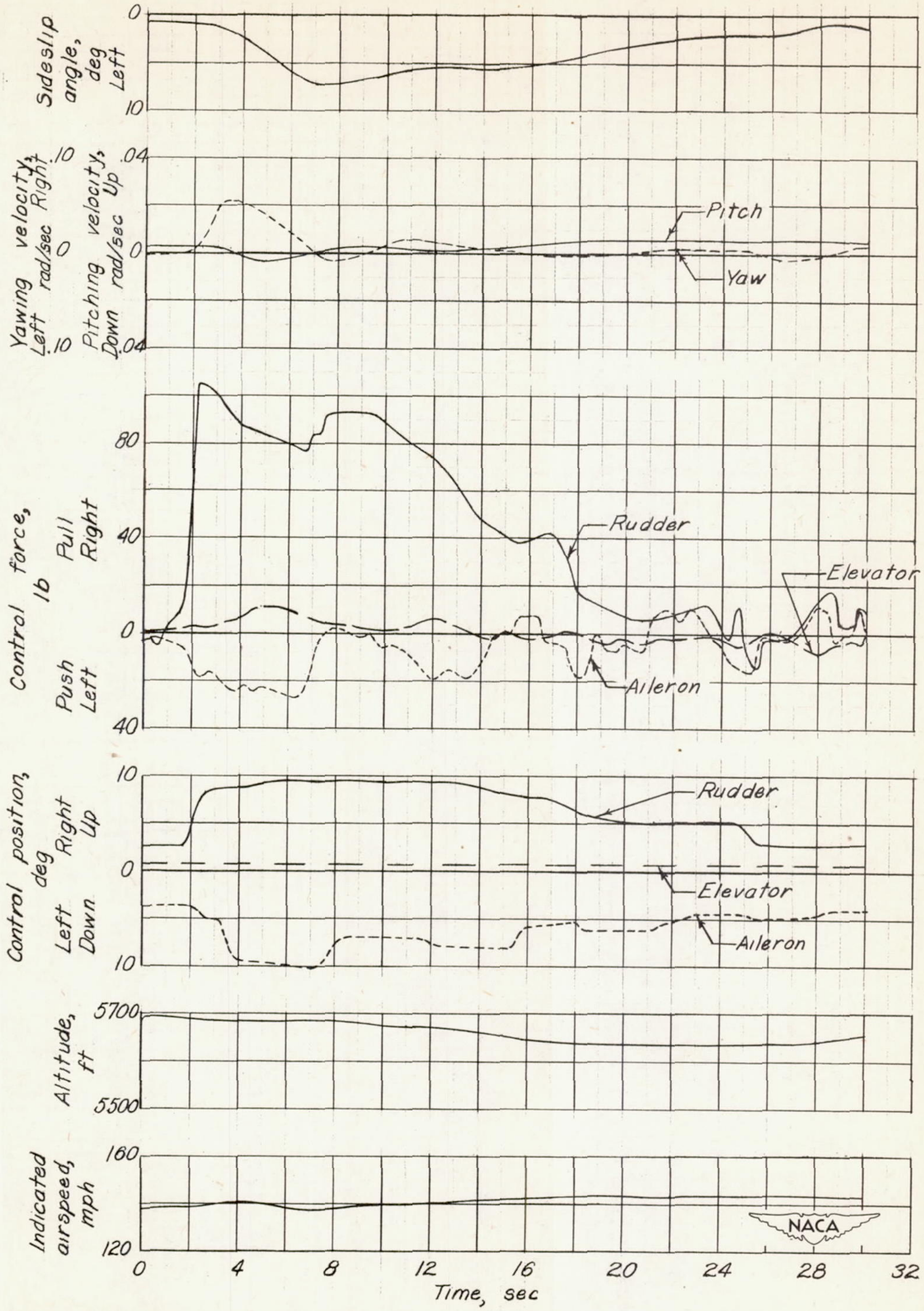
(a) Clean condition; power for level flight; no attempt made to control altitude; right turn; 150 miles per hour.

Figure 14.– Time histories of 10° heading changes holding the wings level. C-54D airplane.



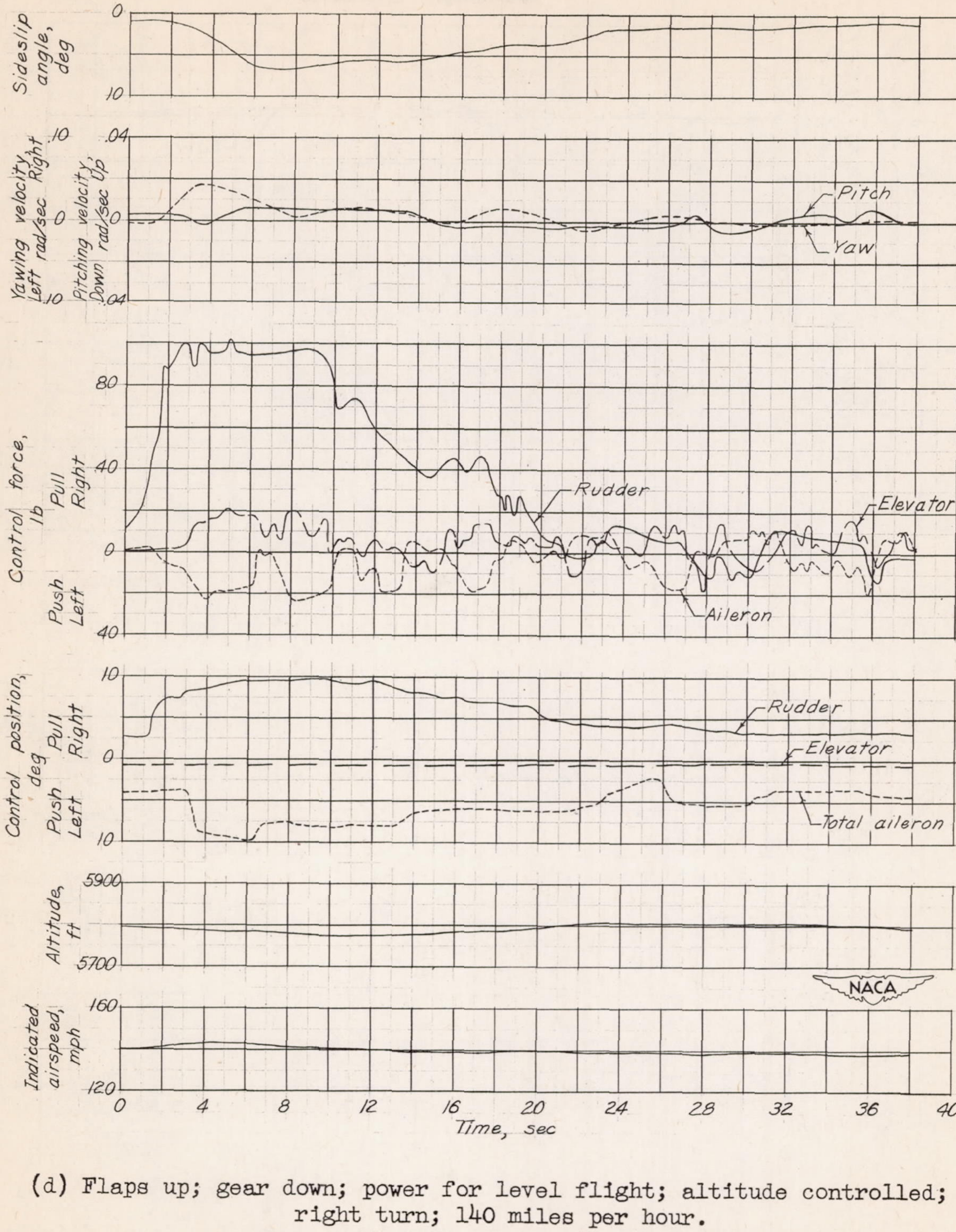
(b) Clean condition; power for level flight; altitude controlled; right turn; 150 miles per hour.

Figure 14.– Continued.



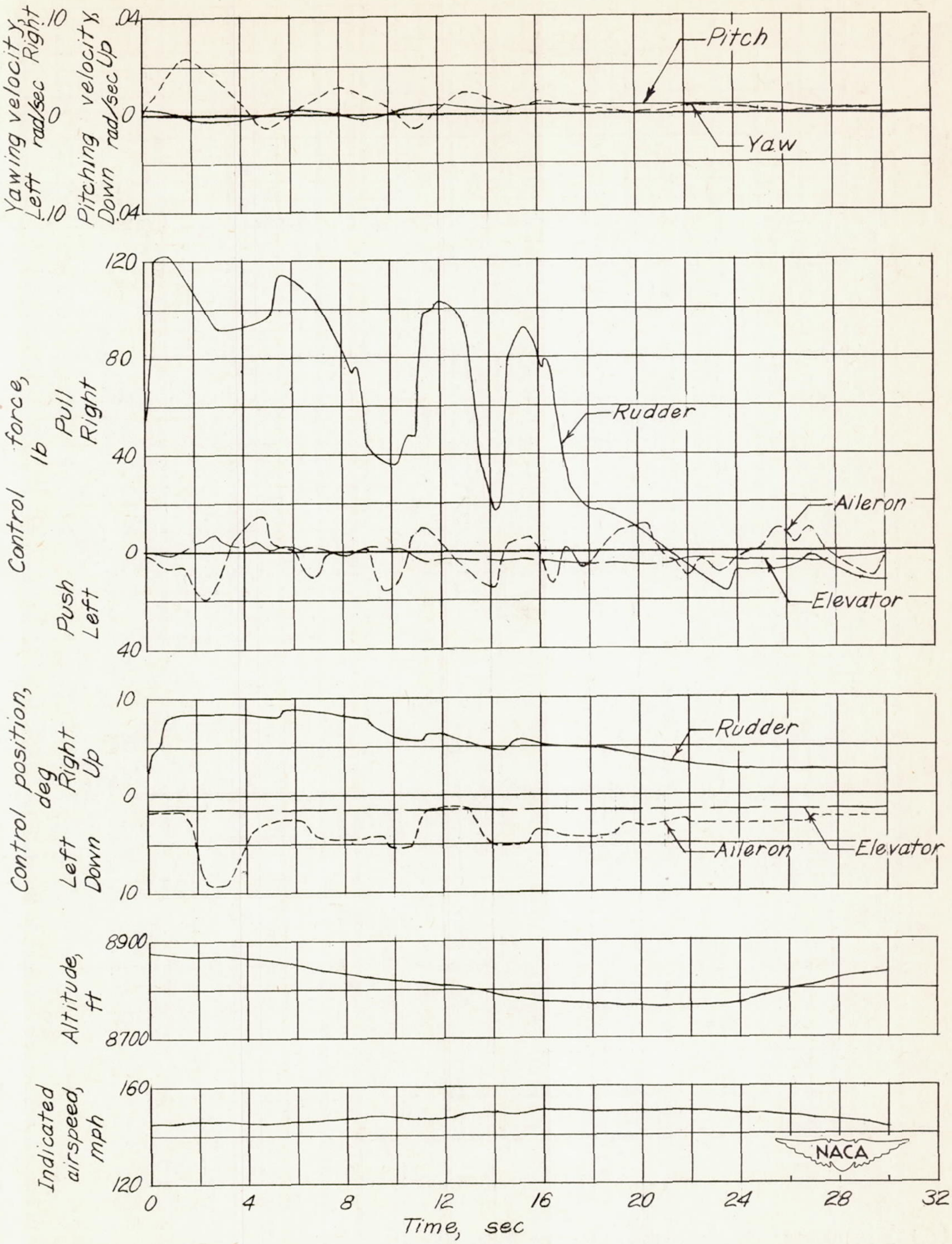
(c) Flaps up; gear down; power for level flight; no attempt to control altitude; right turn; 140 miles per hour.

Figure 14.– Continued.



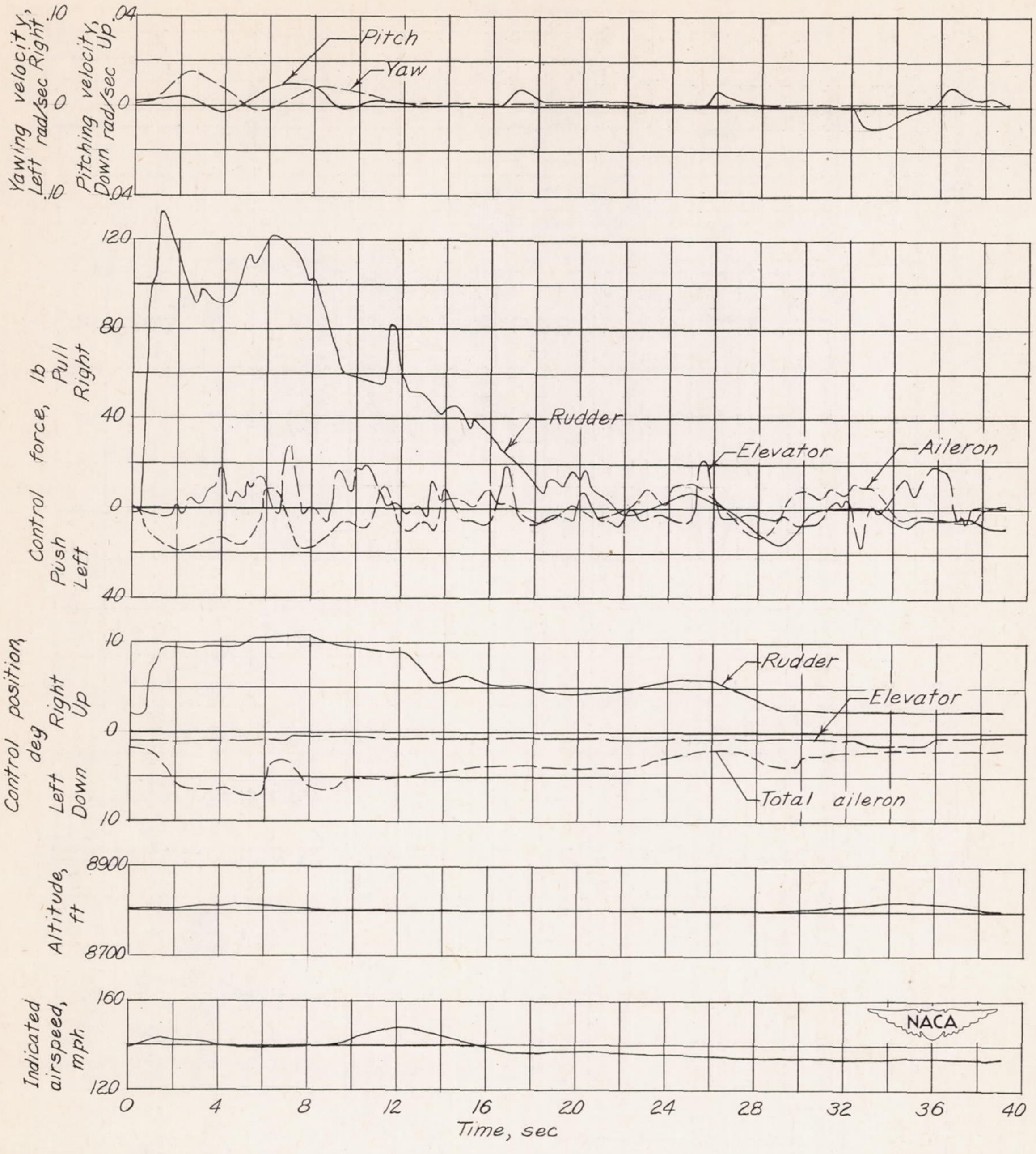
(d) Flaps up; gear down; power for level flight; altitude controlled; right turn; 140 miles per hour.

Figure 14.– Continued.



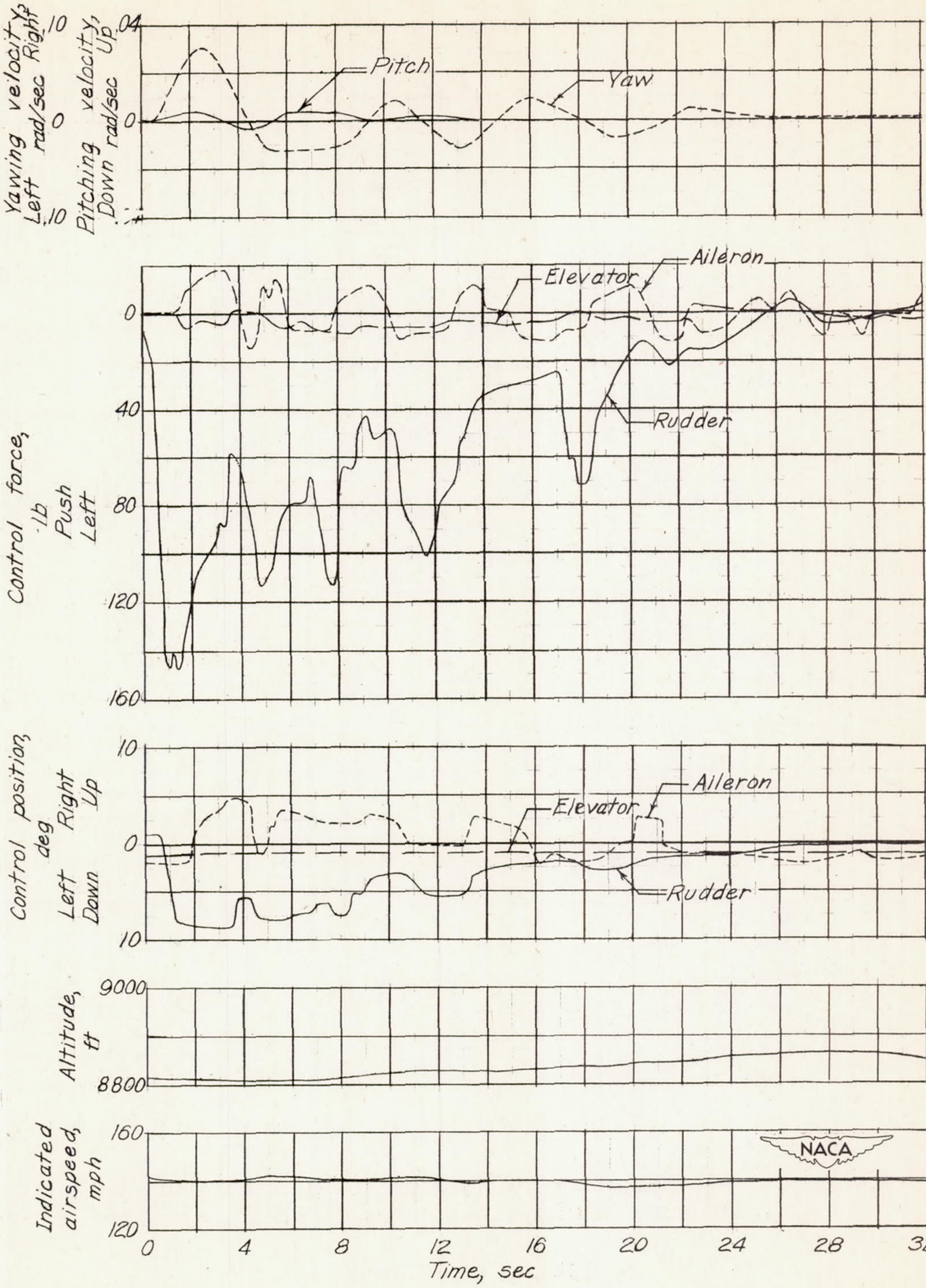
(e) Approach condition; flaps 20°; gear down; power for level flight; no attempt to control altitude; right turn; 140 miles per hour.

Figure 14.– Continued.



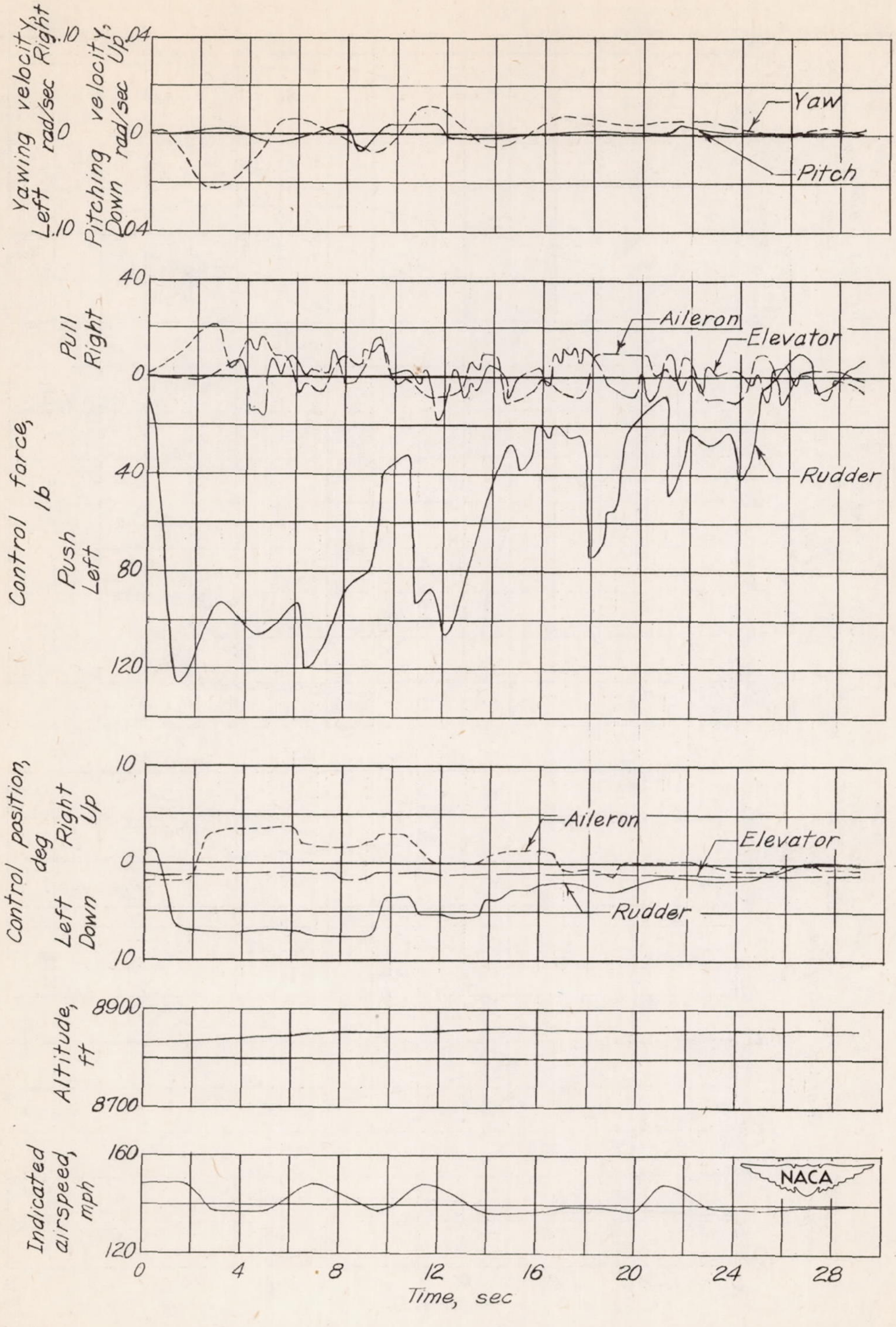
(f) Approach condition; flaps 20°; gear down; power for level flight; altitude controlled; right turn; 140 miles per hour.

Figure 14.– Continued.



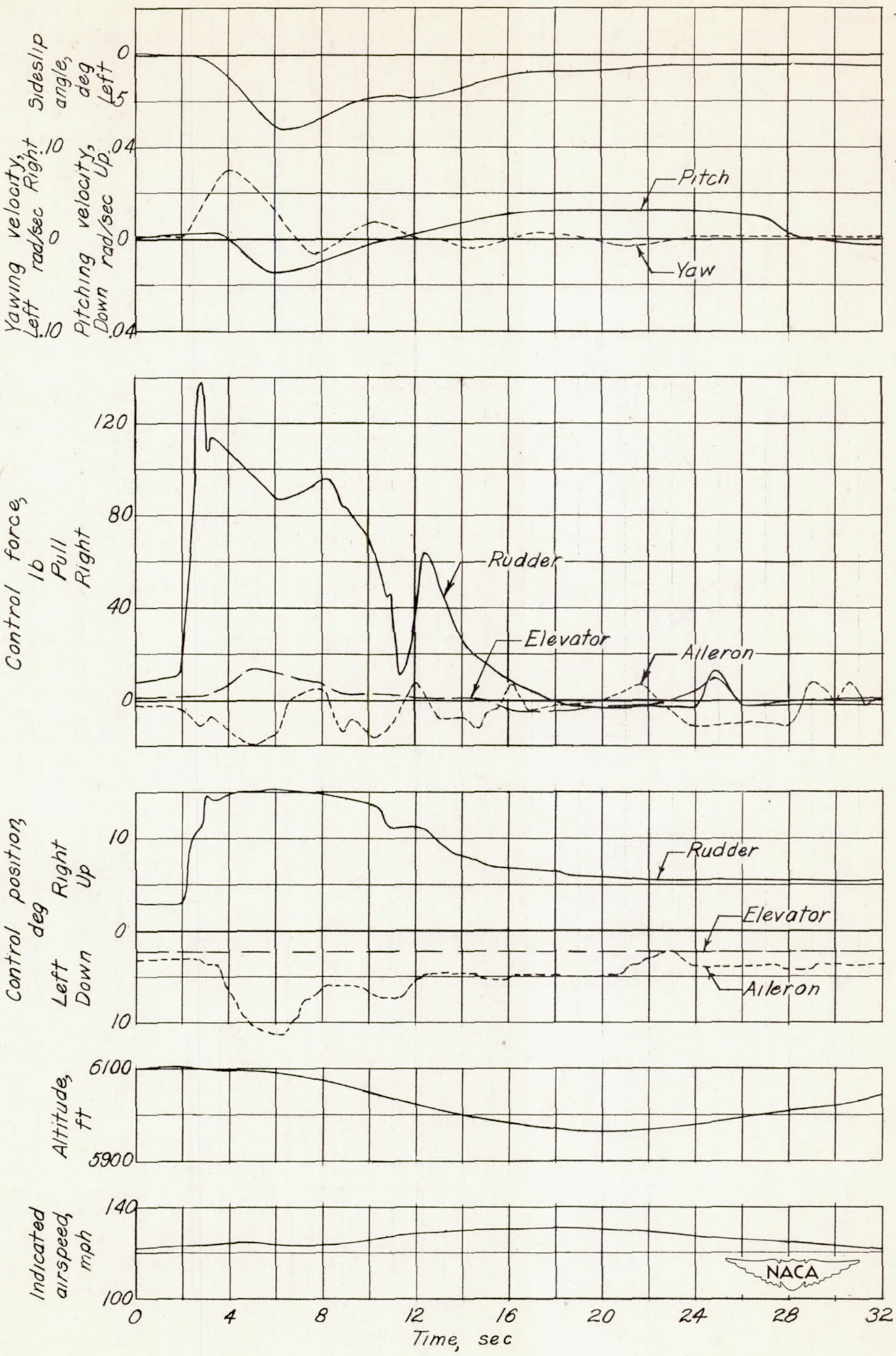
(g) Approach condition; flaps 20°; gear down; power for level flight; no attempt to control altitude; left turn; 140 miles per hour.

Figure 14.– Continued.



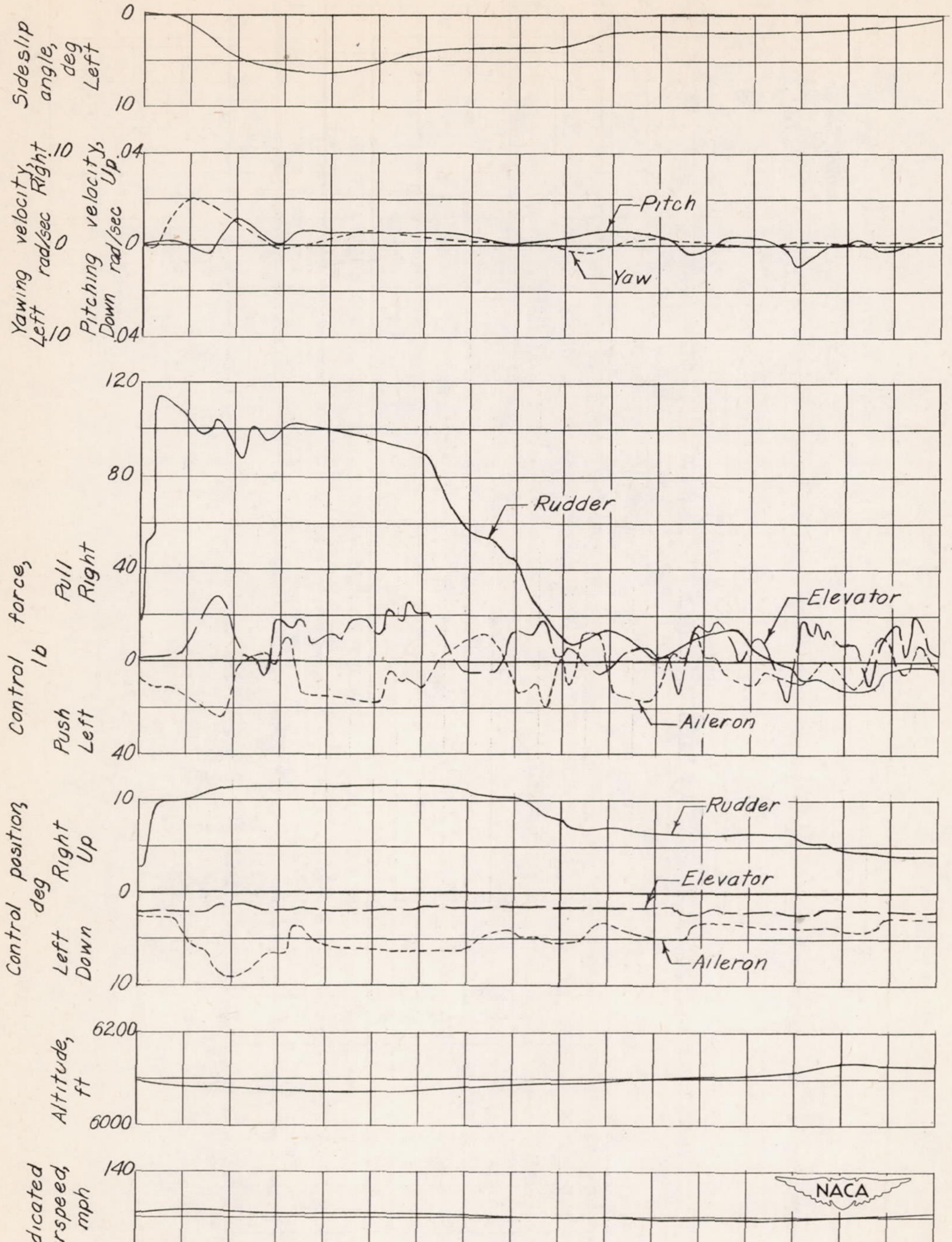
(h) Approach condition; flaps 20°; gear down; power for level flight; altitude controlled; left turn; 140 miles per hour.

Figure 14.– Continued.



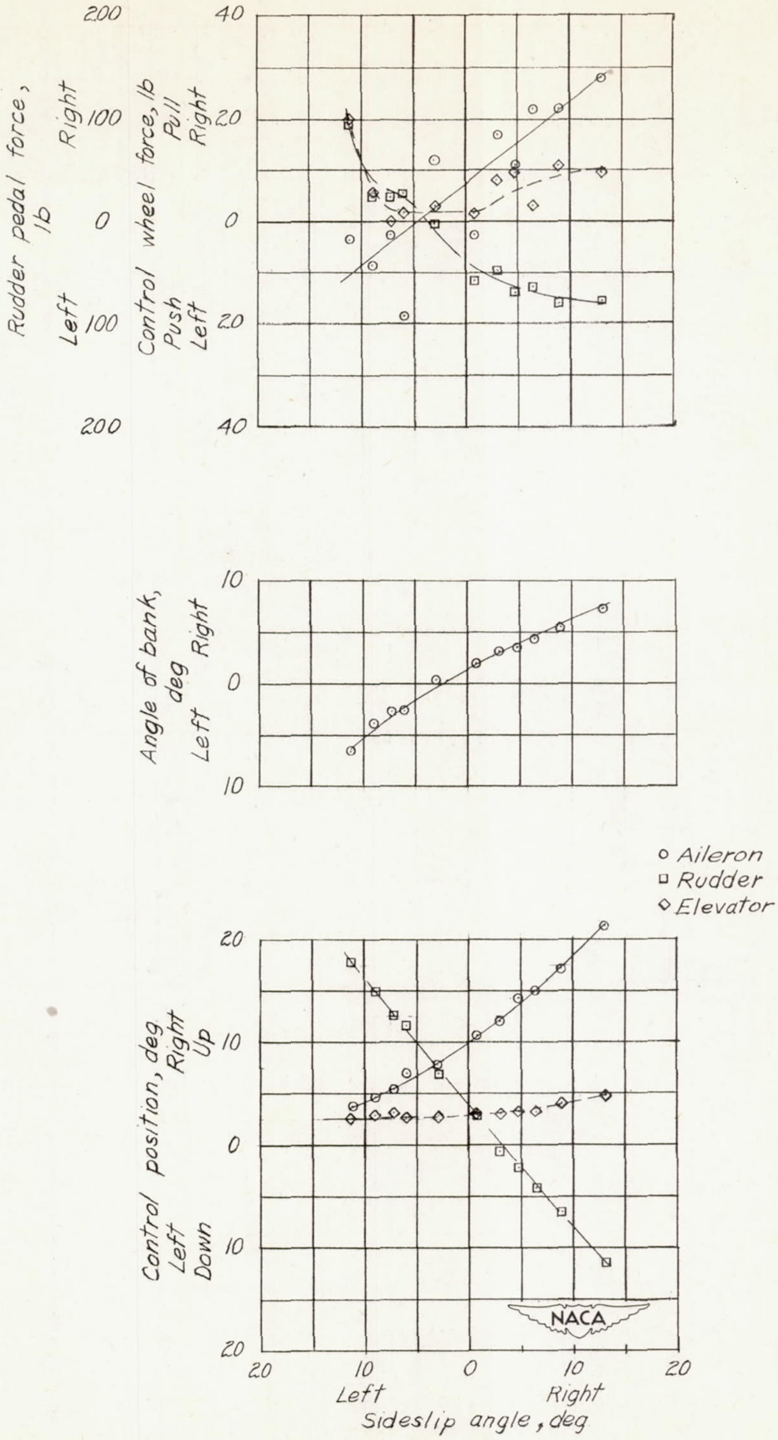
(i) Final approach condition; flaps full down; gear down; power for level flight; no attempt to control altitude; right turn; 120 miles per hour.

Figure 14.– Continued.



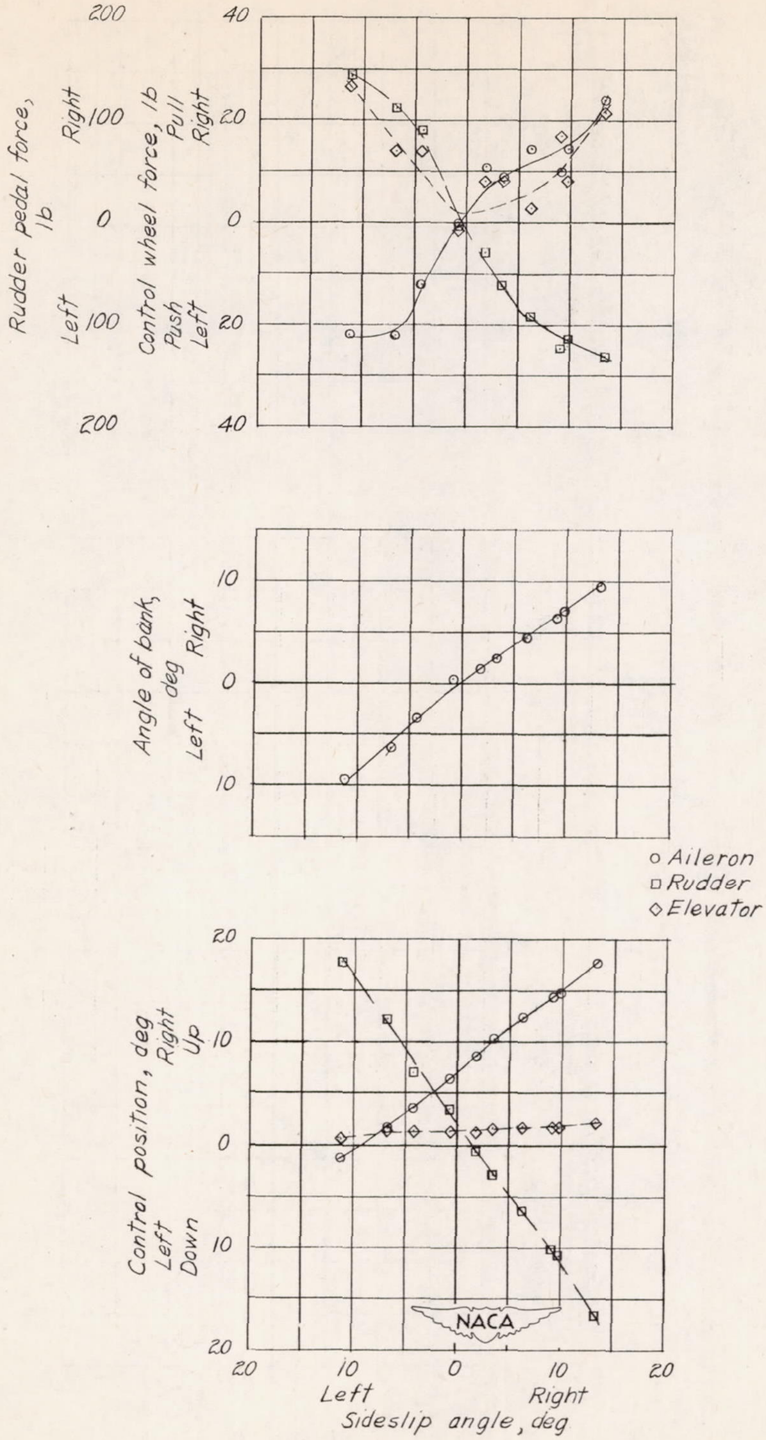
(j) Final approach condition; flaps full down; gear down; power for level flight; altitude controlled; right turn; 120 miles per hour.

Figure 14.– Concluded.



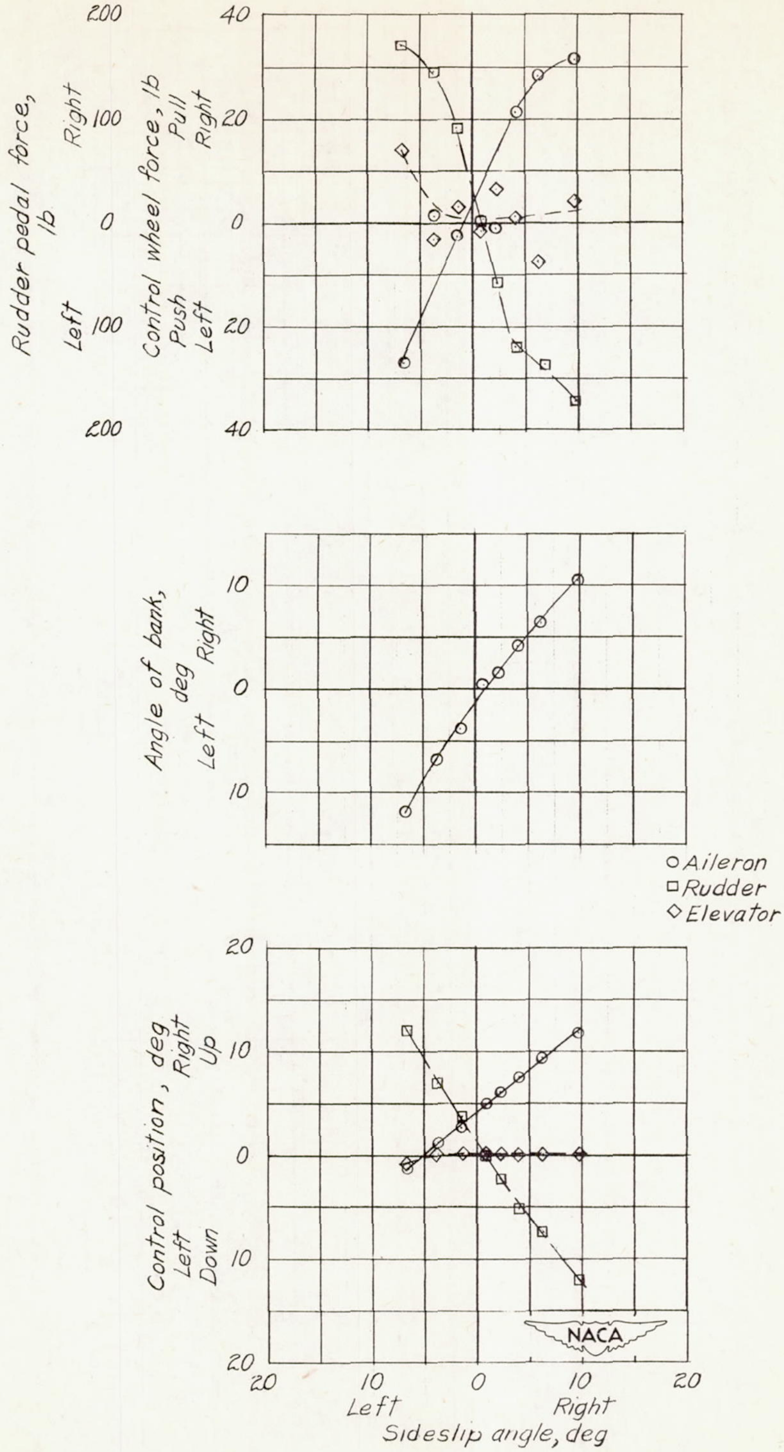
(a) 120 miles per hour.

Figure 15.– Sideslip characteristics with asymmetric load. C-54D airplane; clean condition; normal rated power; right wing-tip gas tank empty.



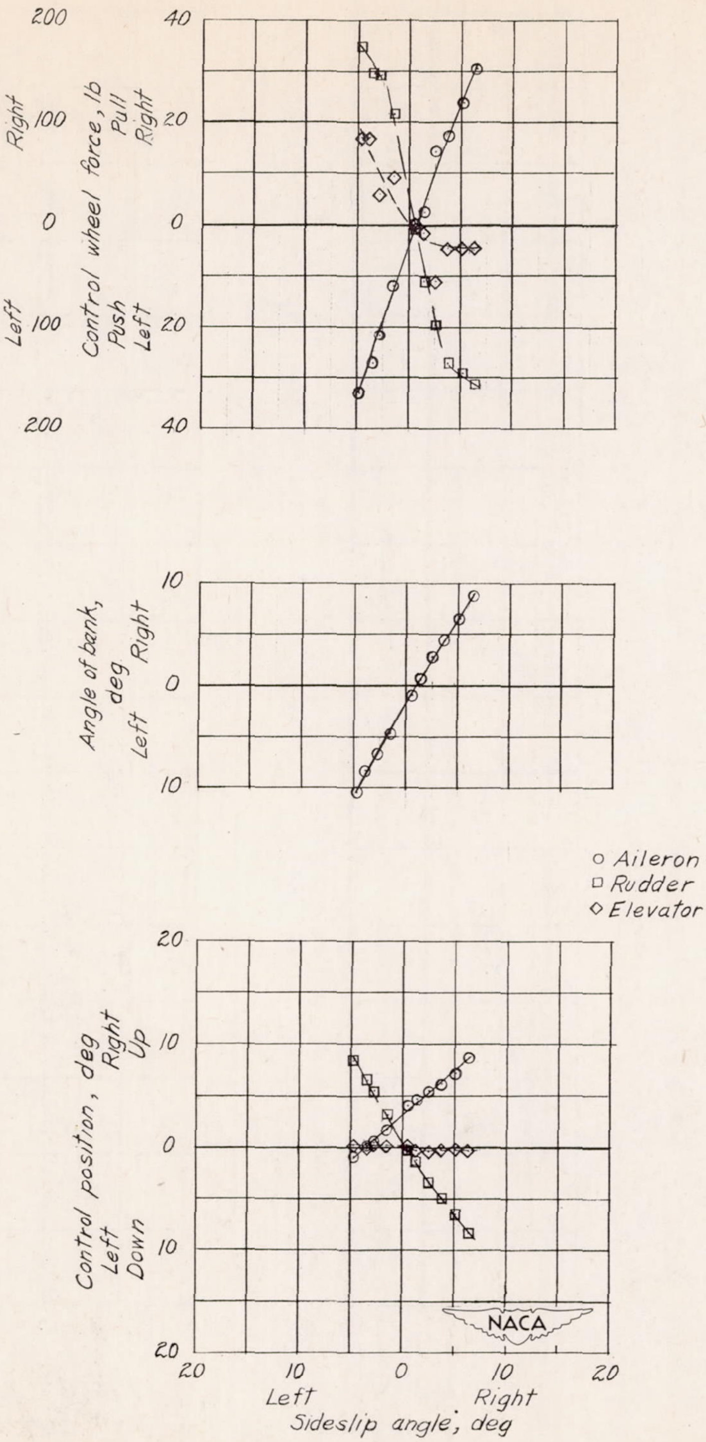
(b) 150 miles per hour.

Figure 15.– Continued.



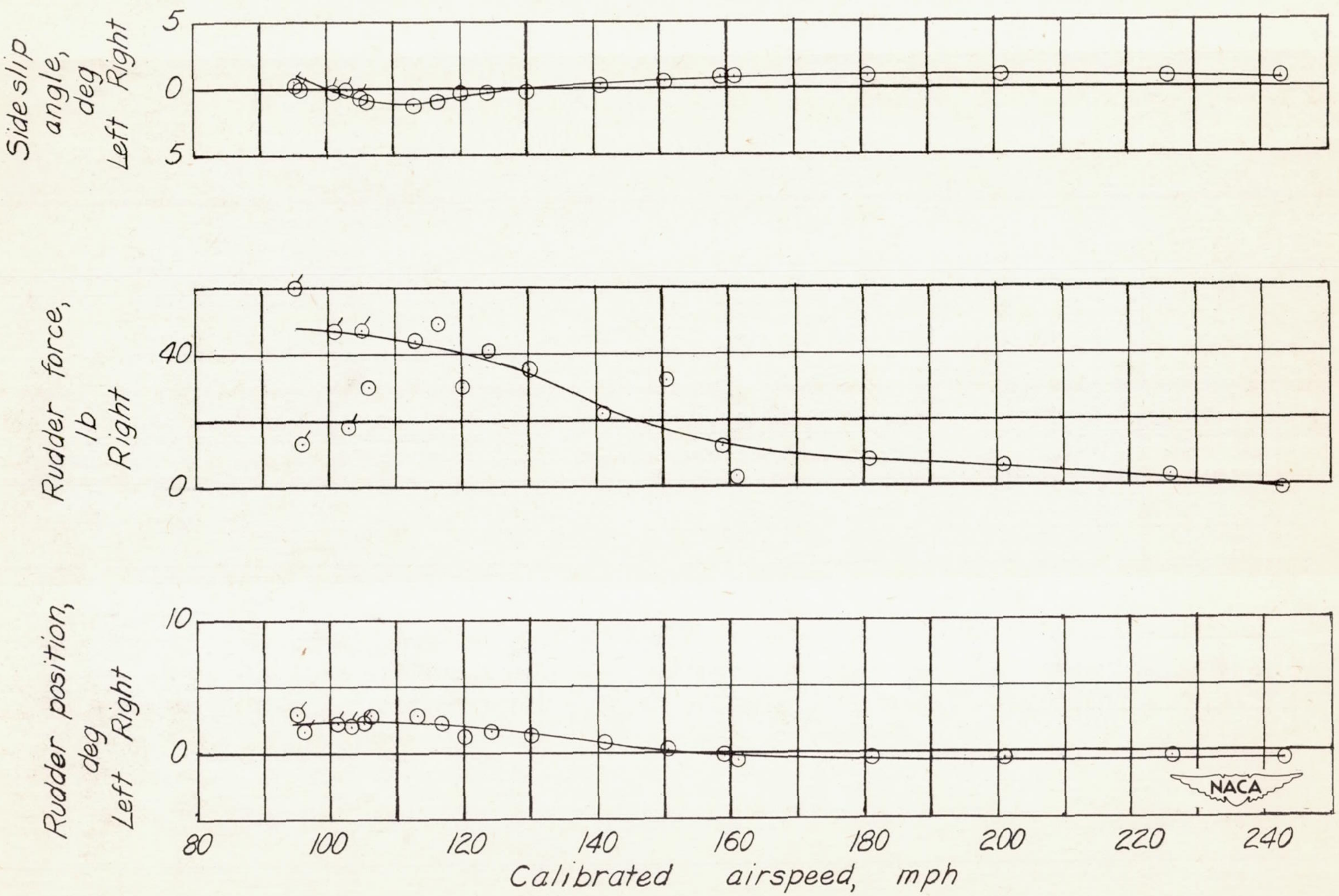
(c) 200 miles per hour.

Figure 15.– Continued.



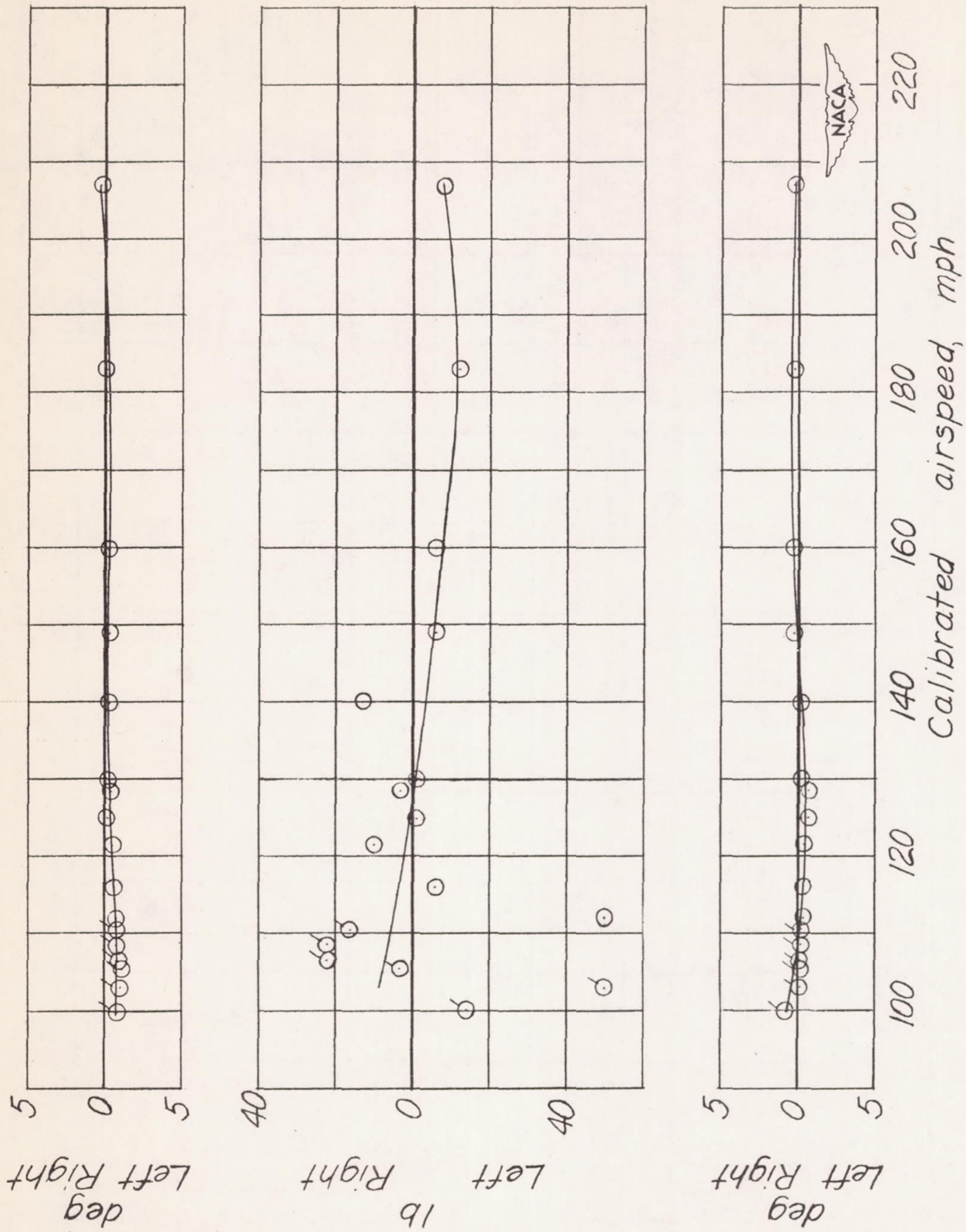
(d) 225 miles per hour.

Figure 15.– Concluded.



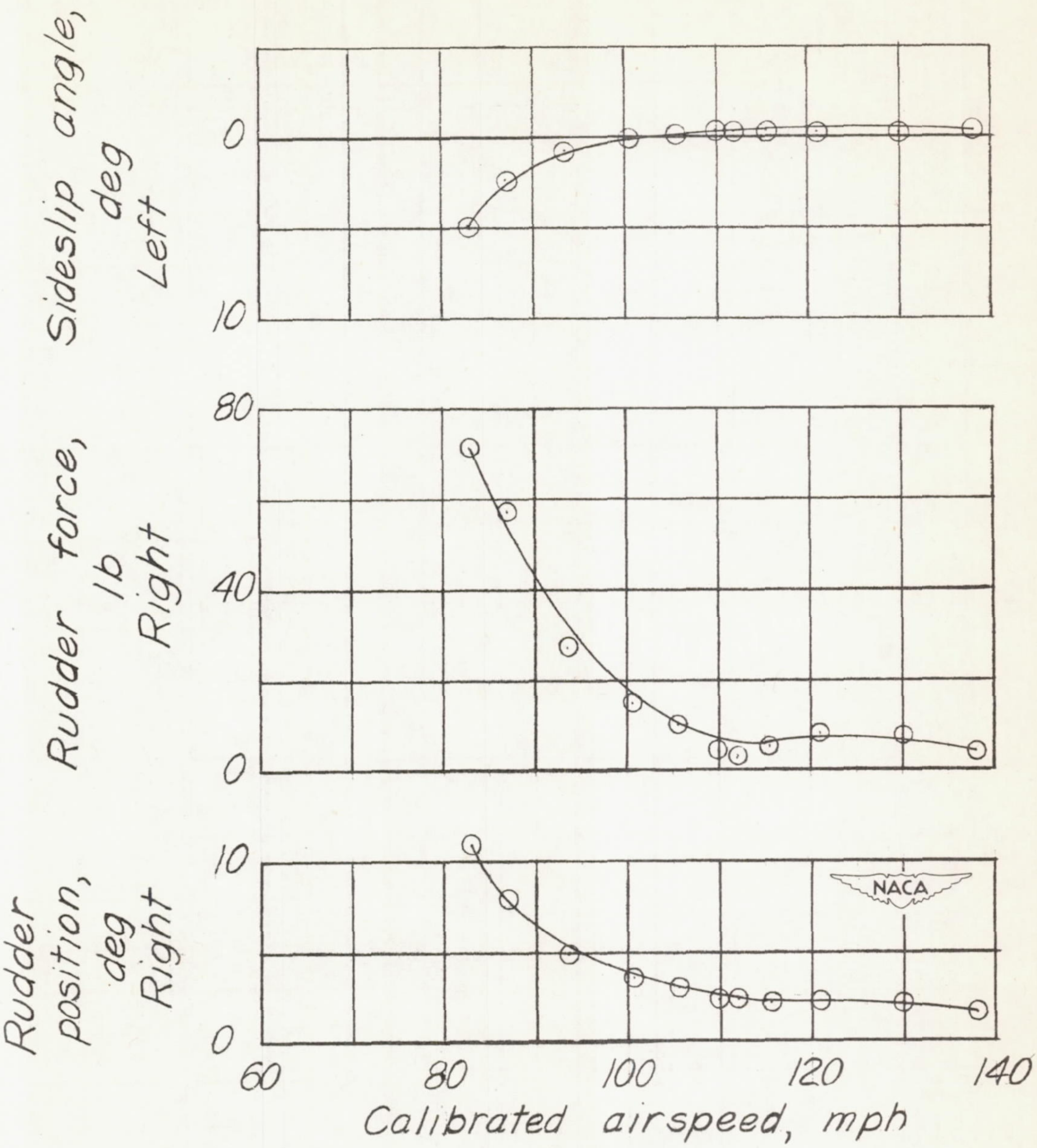
(a) Clean condition, normal rated power.

Figure 16.– Directional trim characteristics. C–54D airplane.



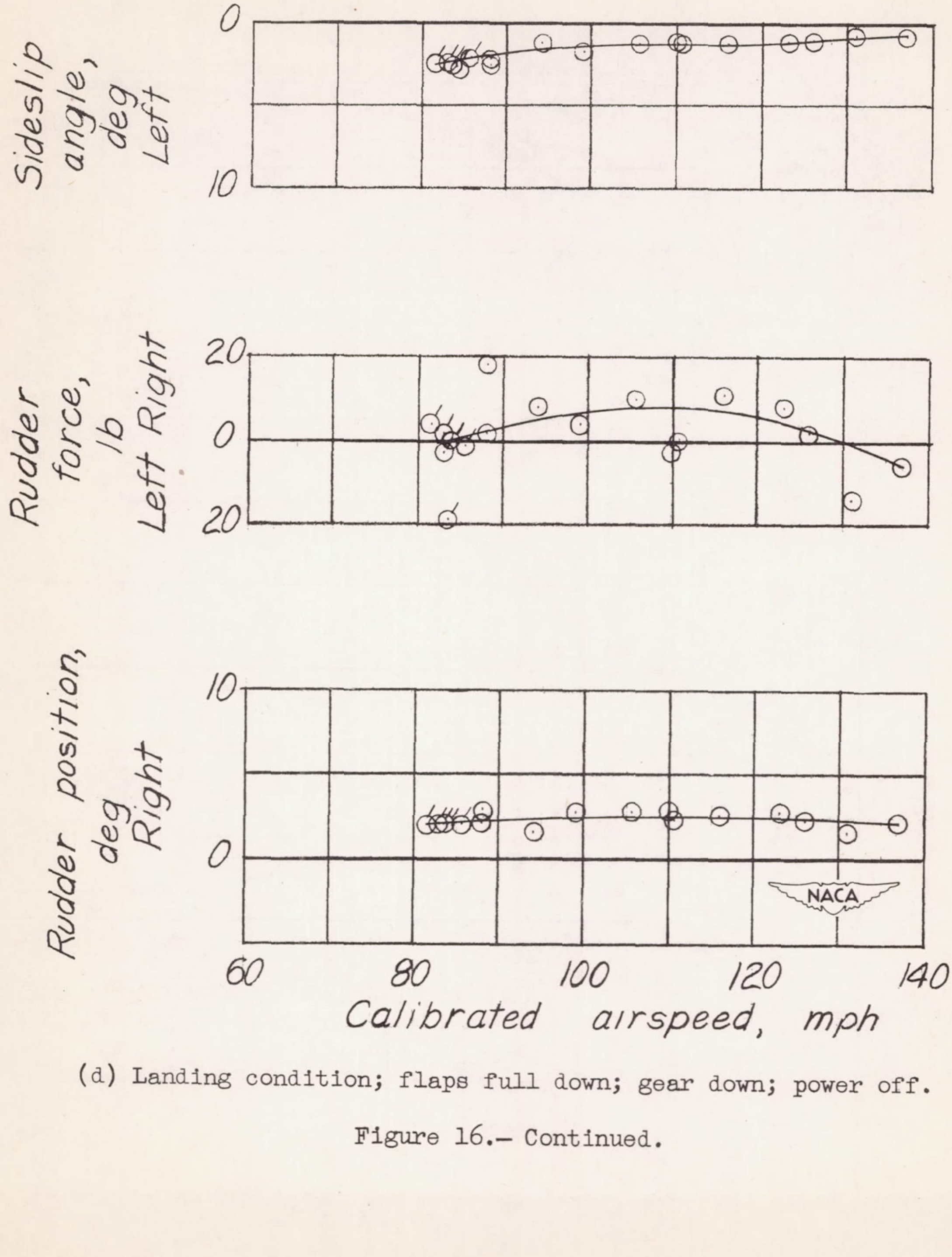
(b) Clean condition, power off.

Figure 16.- Continued.



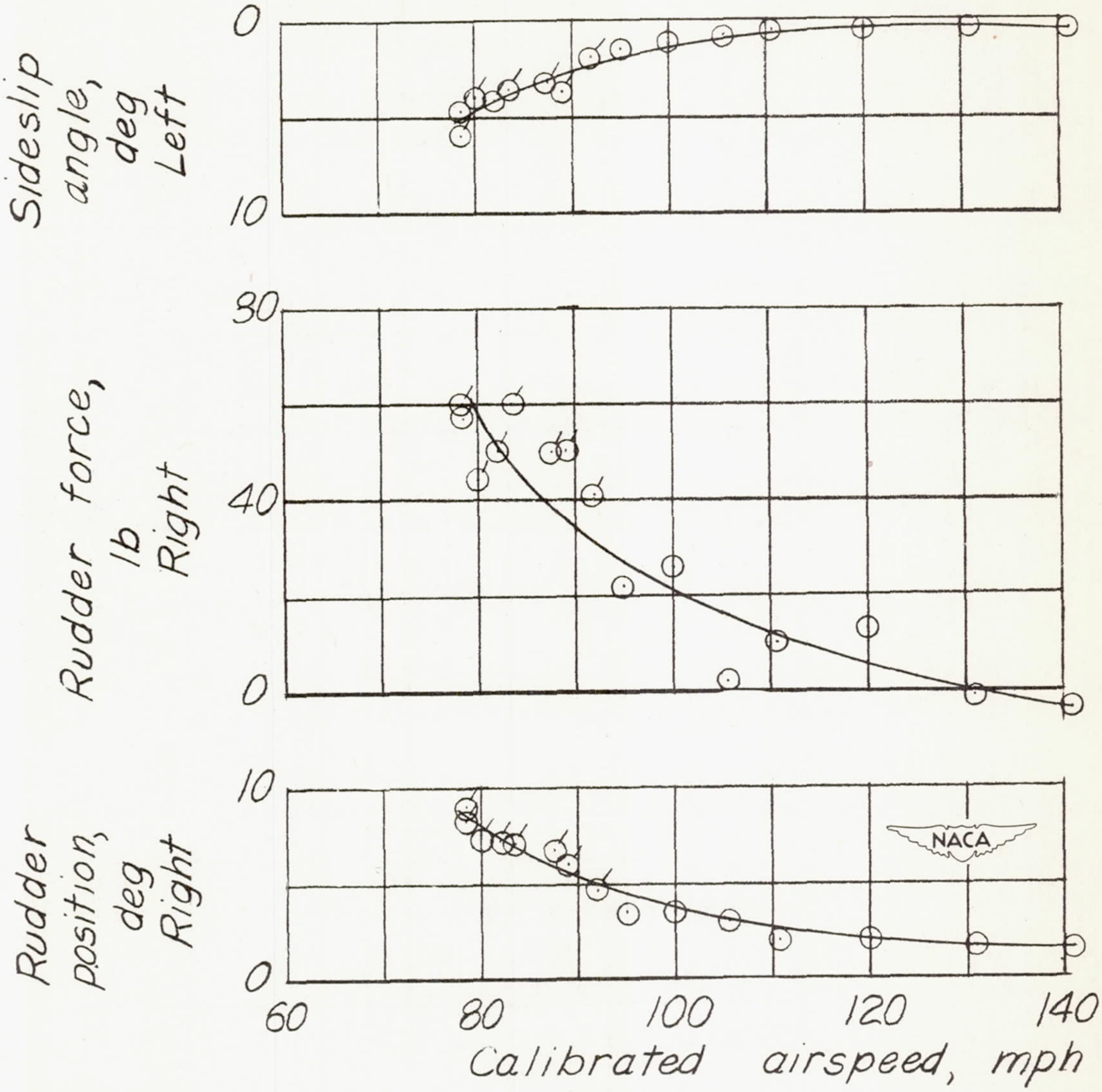
(c) Wave—off condition; flaps full down; gear down; normal rated power.

Figure 16.— Continued.



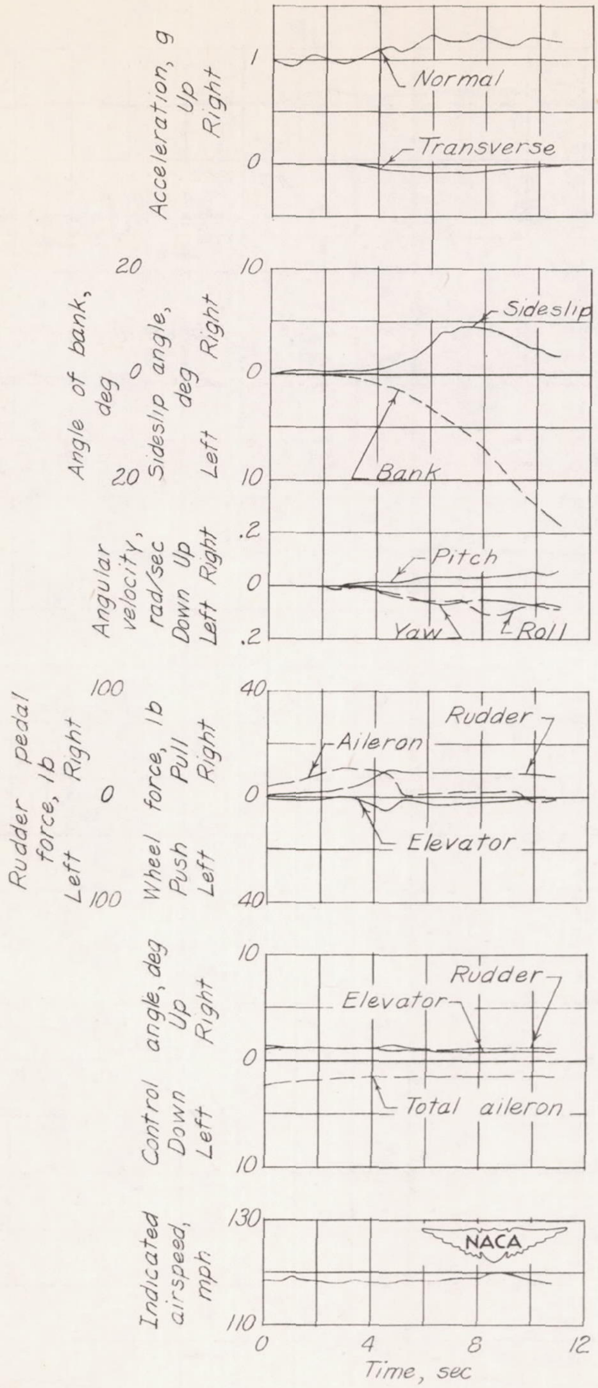
(d) Landing condition; flaps full down; gear down; power off.

Figure 16.- Continued.



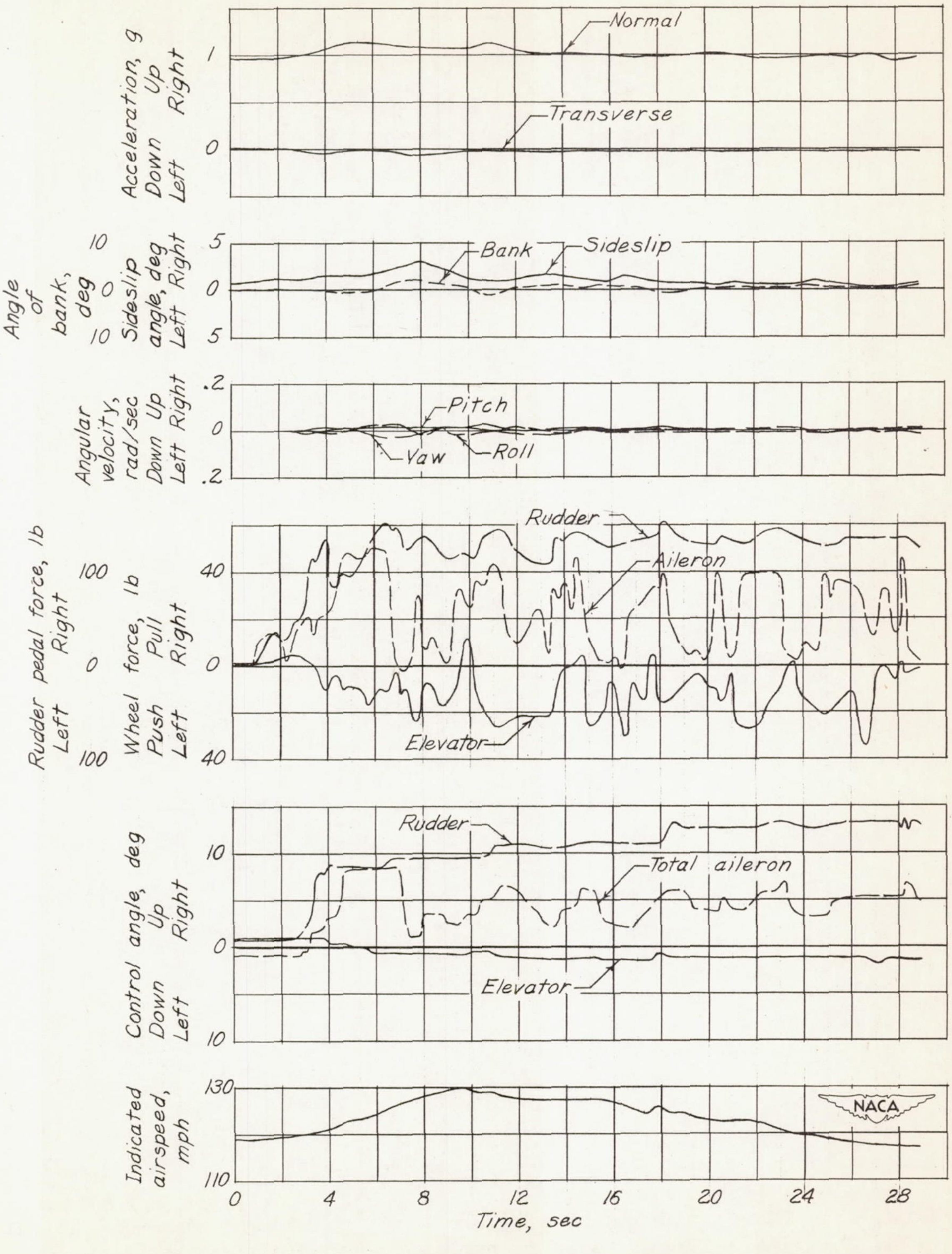
(e) Approach condition; flaps 20°; gear down; power 20 in. Hg, 2550 rpm.

Figure 16.– Concluded.



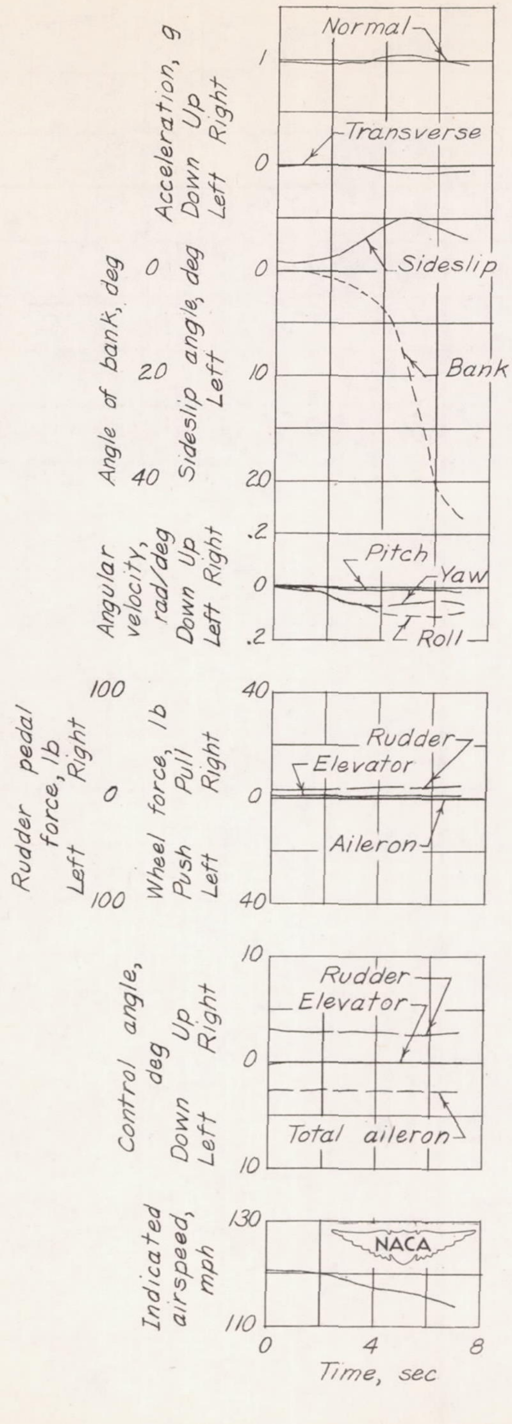
(a) No corrective control applied.

Figure 17.– Time histories of airplane motions during a wave-off in which No. 1 engine fails as power is applied. C-54D airplane; flaps full down; gear down; power initially off, but increased to 45 in. Hg during first three seconds.



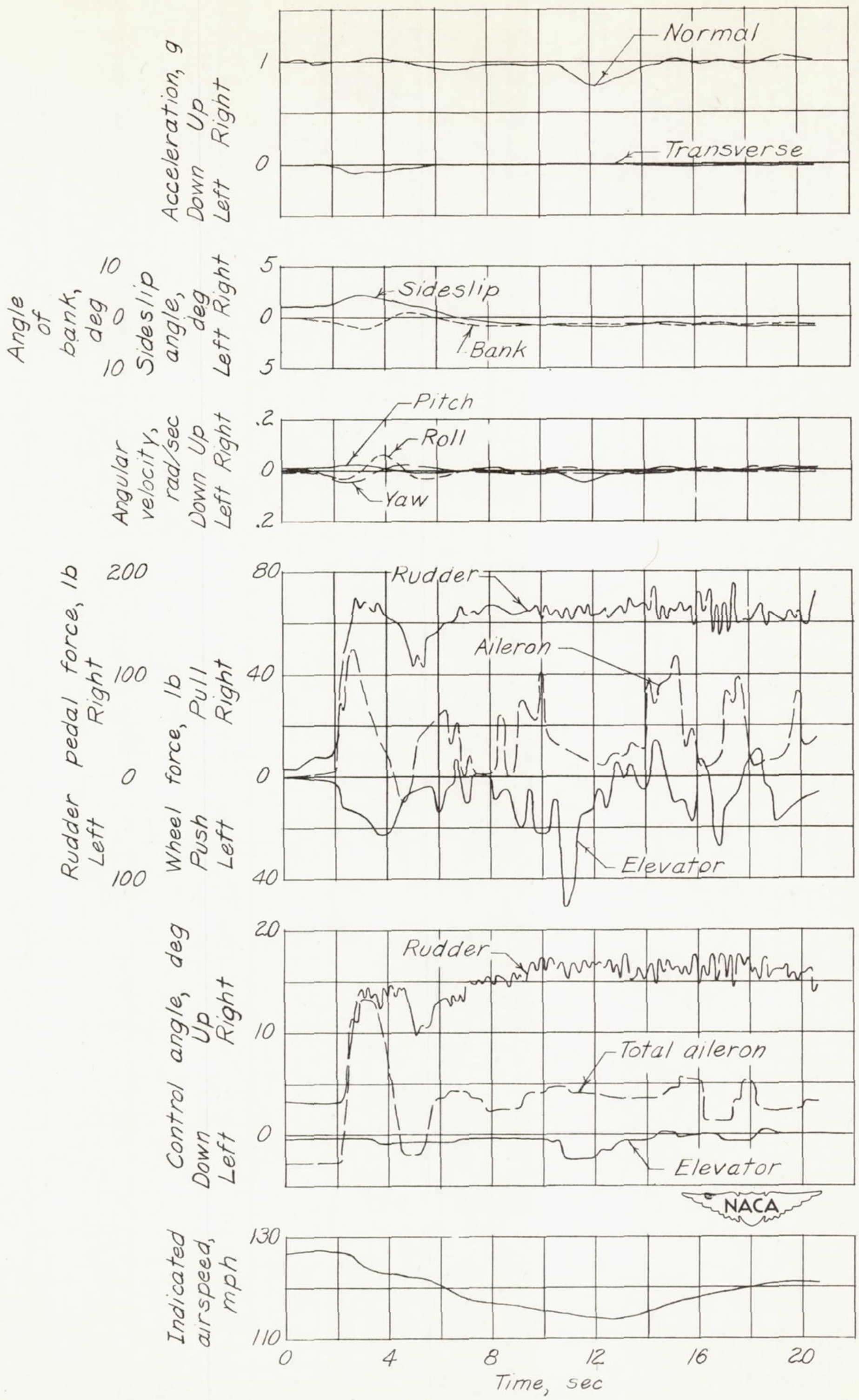
(b) Corrective control applied.

Figure 17.– Concluded.



(a) No corrective control applied. No. 1 engine fails at 0.7 second.

Figure 18.– Time histories of airplane motions during a simulated take-off in which No. 1 engine fails. C-54D airplane; flaps 20°; gear down; power 43 in. Hg; 2550 rpm; No. 1 engine cut to idling.



(b) Corrective control applied. No. 1 engine fails at 0.8 second.

Figure 18.– Concluded.

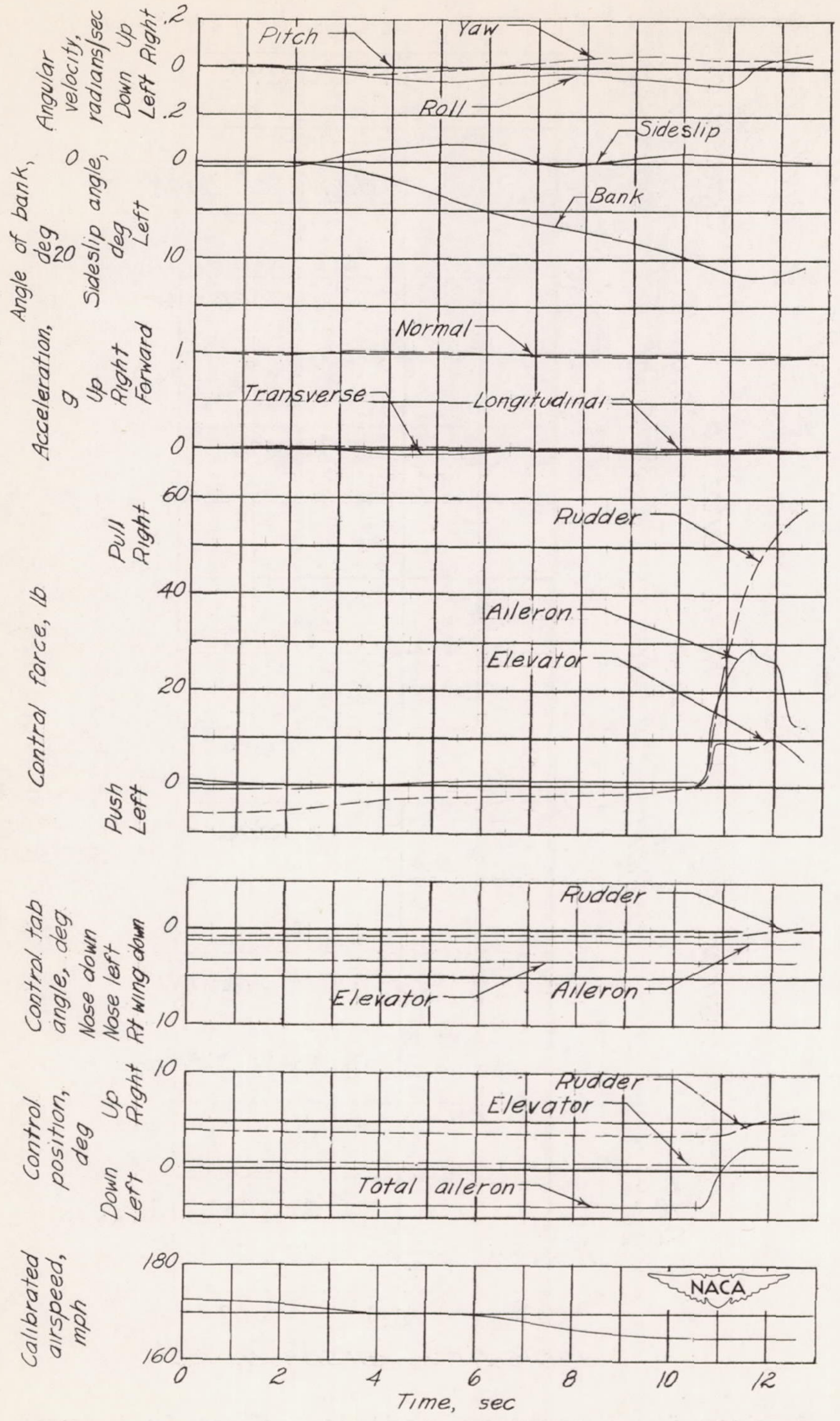
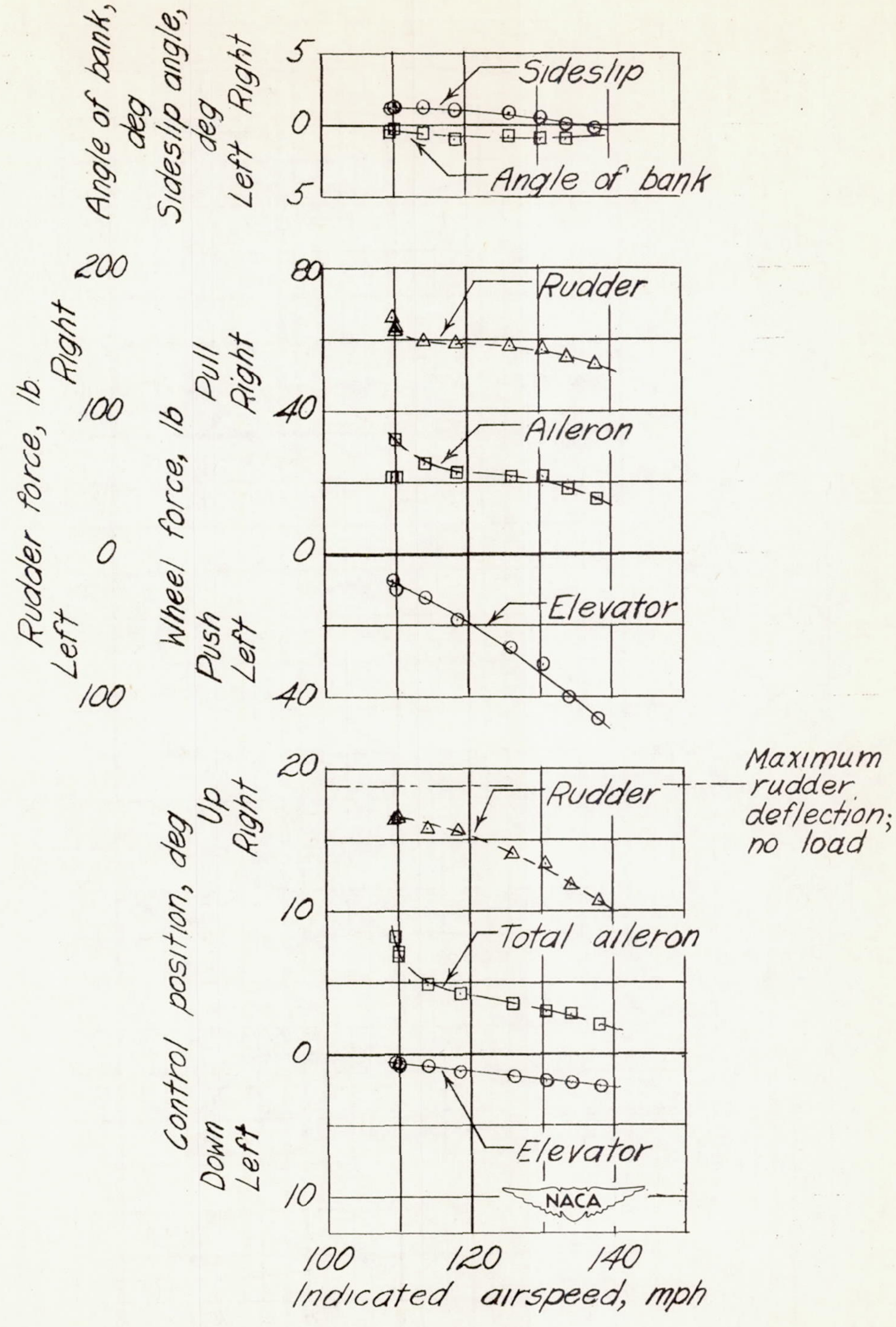
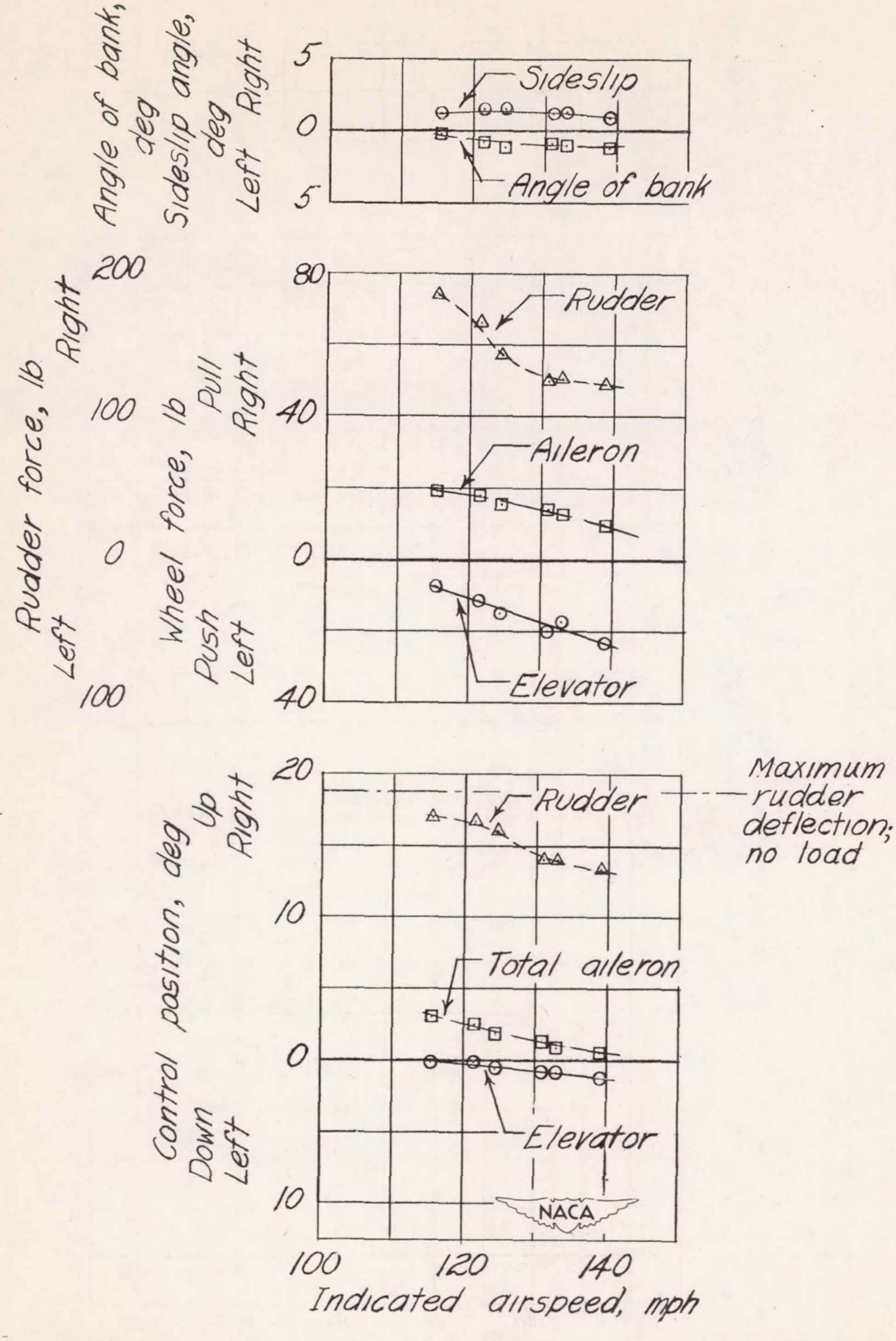


Figure 19.- Time history of airplane motions after loss of power on No. 1 engine in the cruise condition. C-54D airplane; clean power for level flight before No. 1 engine cut to idling at start of record; corrective control started at 10.5 seconds.



(a) Wave—off from final approach condition; flaps full down; gear down; No. 1 engine idling; No. 2, 3, and 4 engines 45 in. Hg; 2550 rpm. Trimmed for symmetrical power in approach condition.

Figure 20.— Lateral and longitudinal trim characteristics with asymmetric power. C—54D airplane.



(b) Take-off condition; flaps 20°; gear down; No. 1 engine idling; No. 2, 3, and 4 engines 45 in. Hg; 2550 rpm. Trimmed for symmetrical power in take-off condition.

Figure 20.- Concluded.

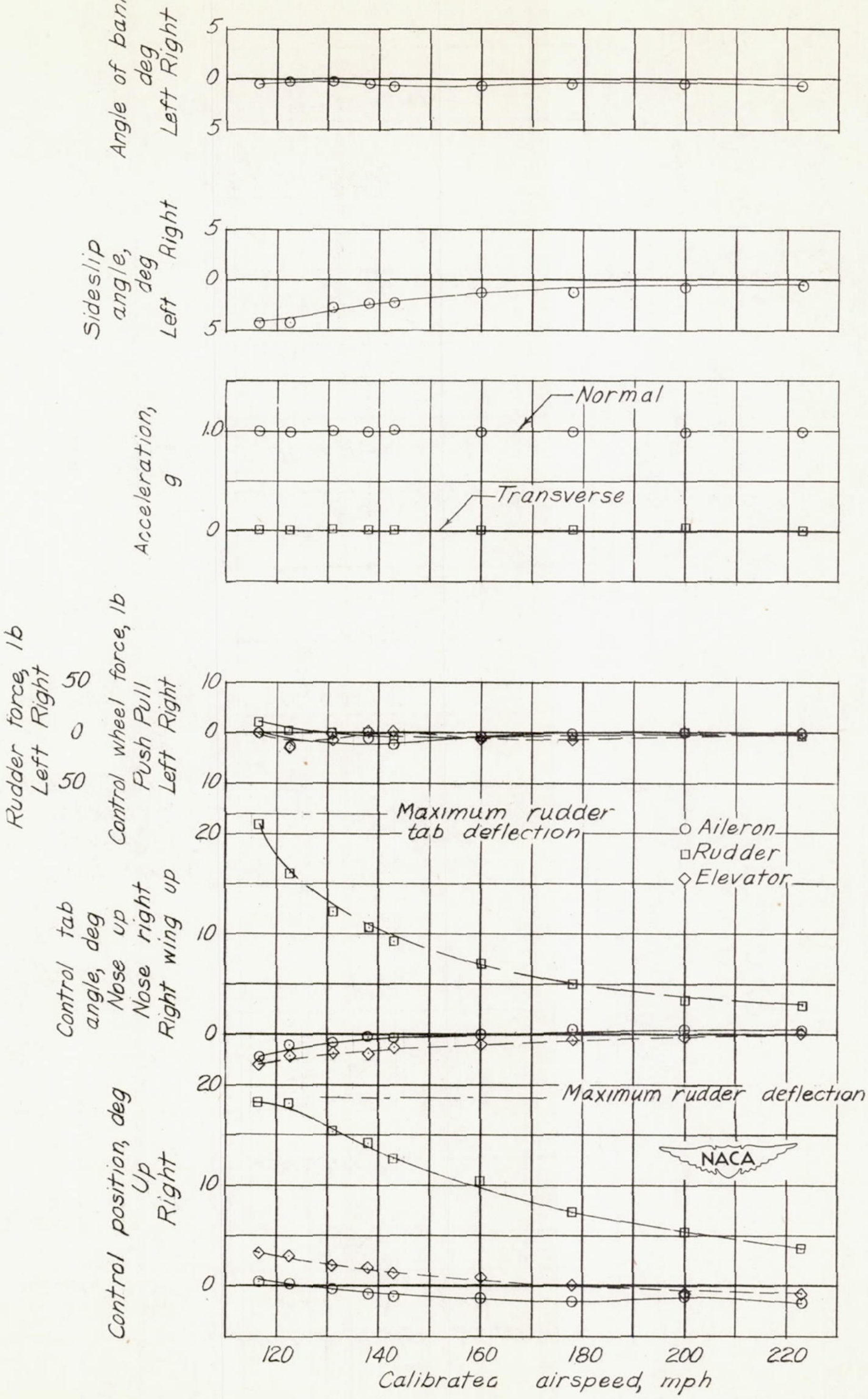


Figure 21.– Lateral and longitudinal trim characteristics with asymmetric power; trim with trim tabs; C-54D airplane. Clean condition; power; No. 1 engine idling; No. 2, 3, and 4 normal rated power.

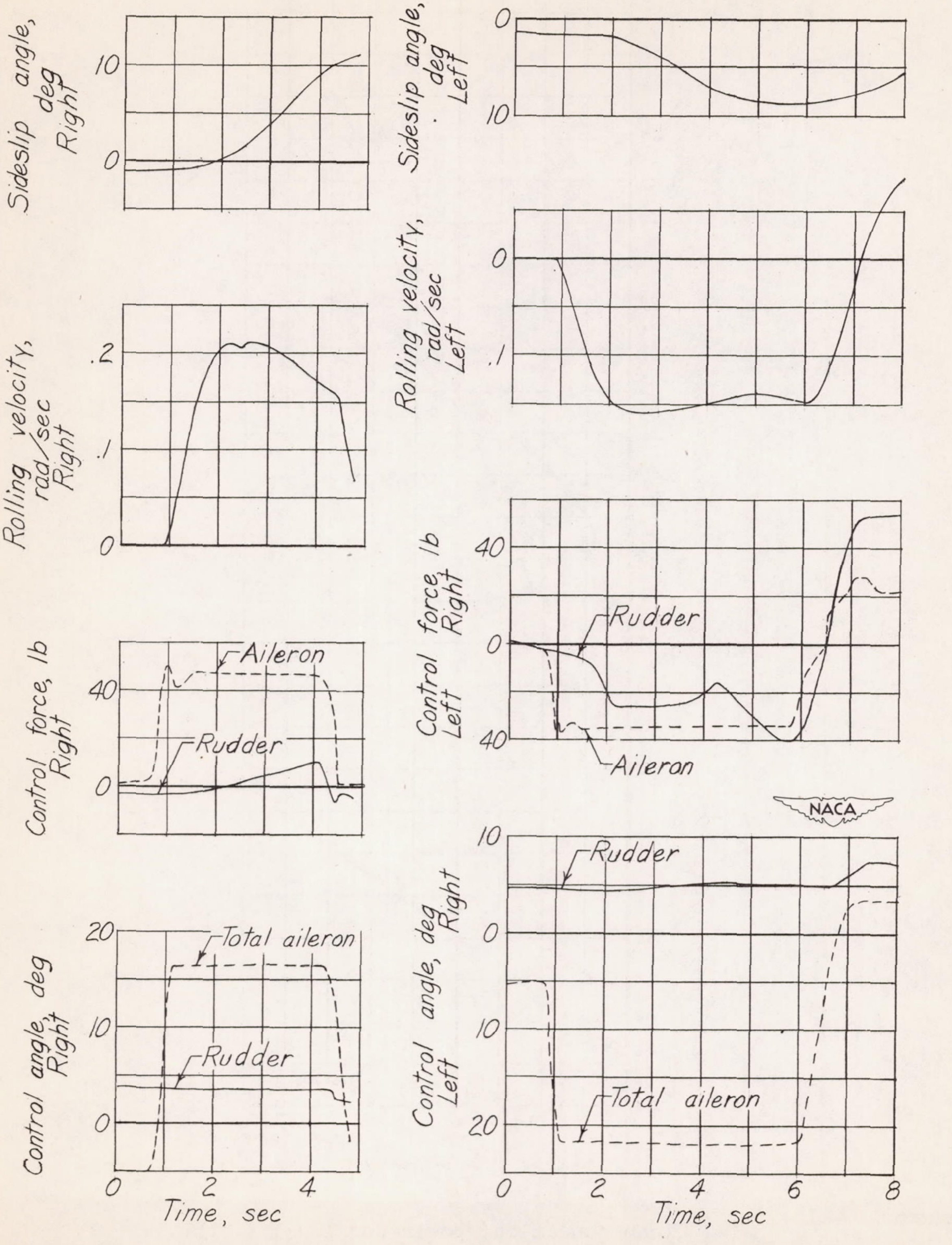
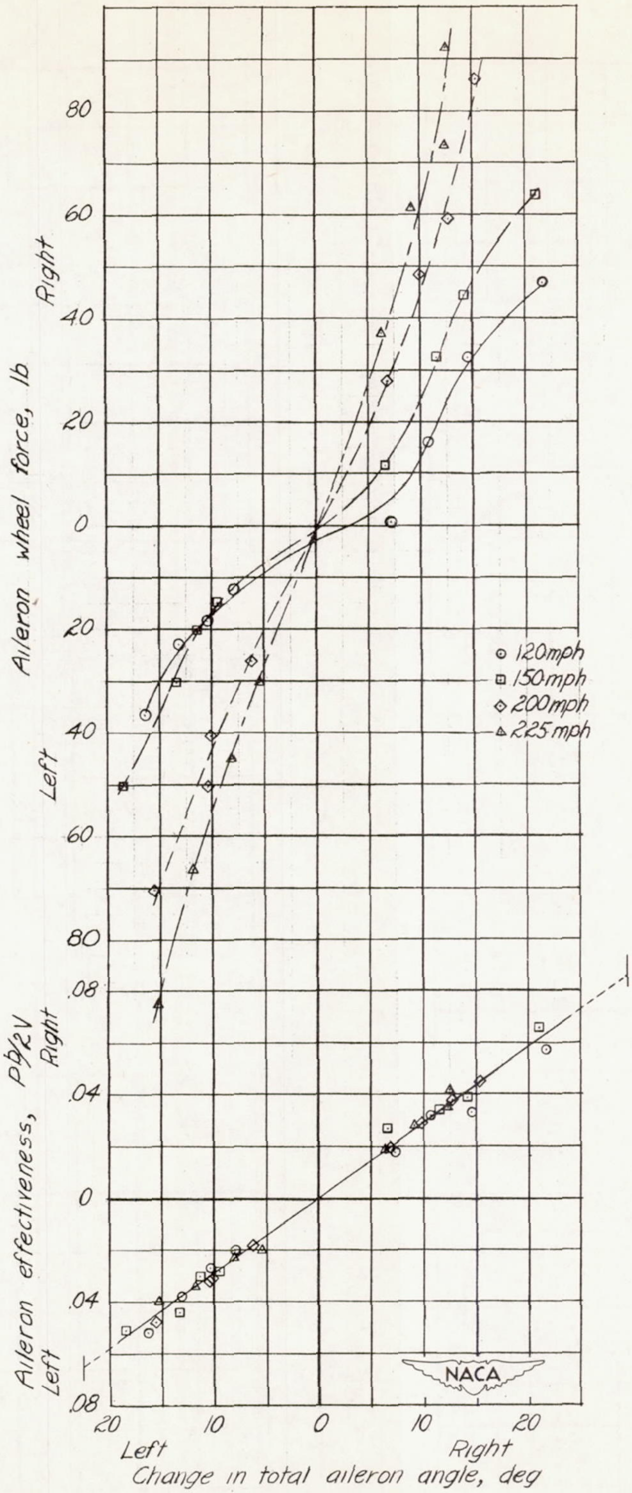
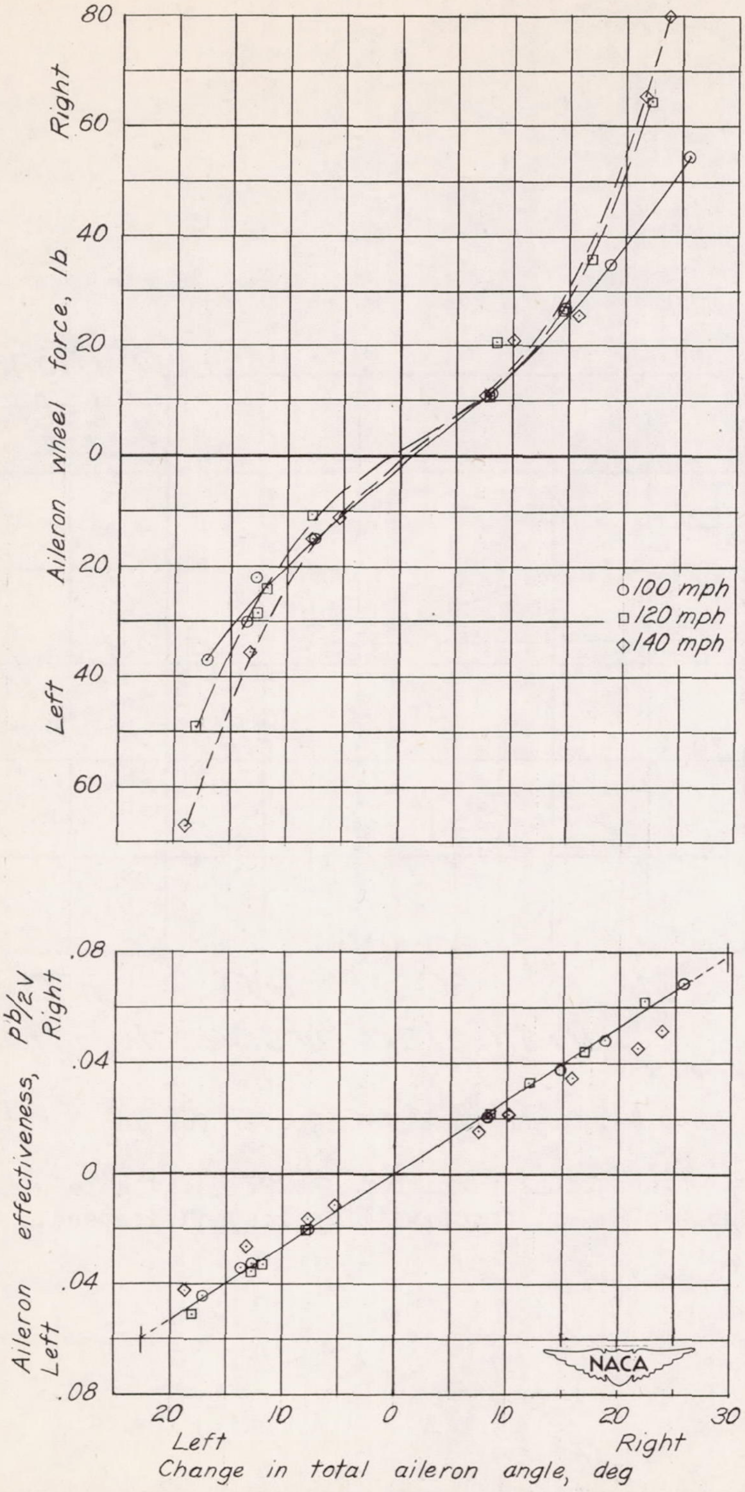


Figure 22.– Time histories of rudder fixed aileron rolls. C–54D airplane; clean condition; power for level flight; 120 miles per hour.



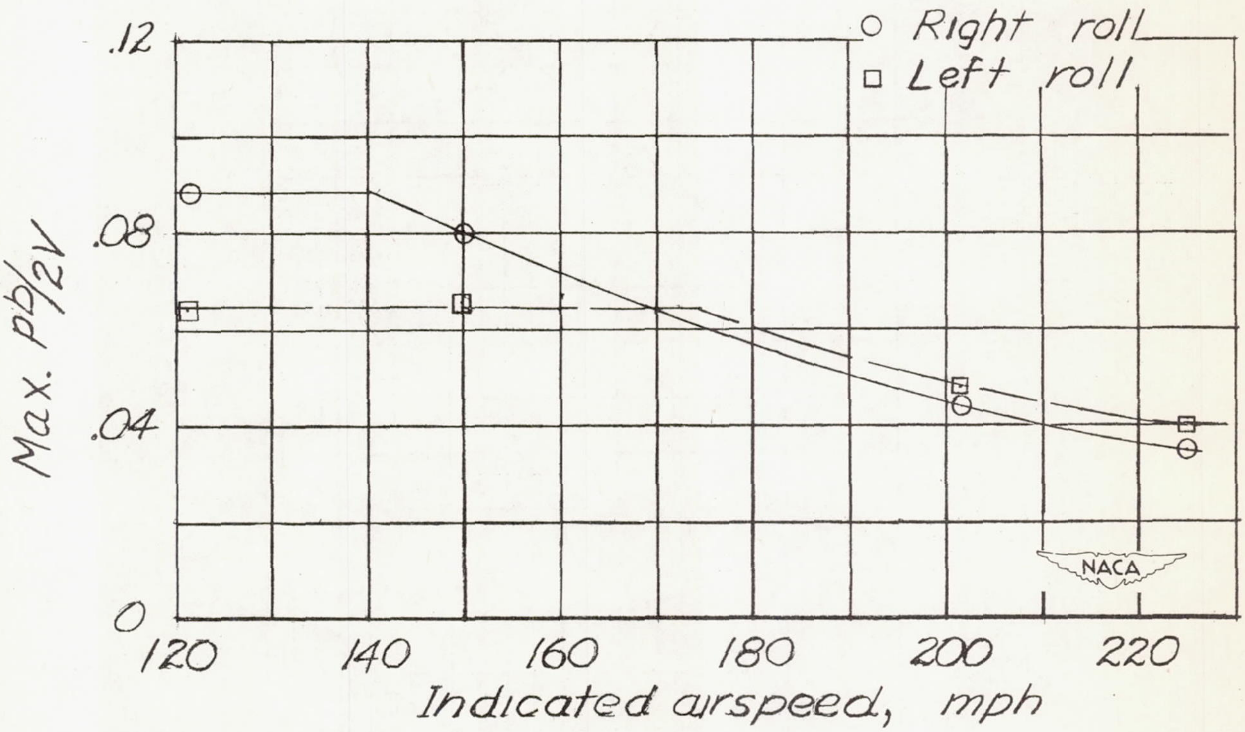
(a) Clean condition; power for level flight.

Figure 23.- Variation of aileron wheel force and aileron effectiveness parameter with change in total aileron angle at various speeds. C-54D airplane.



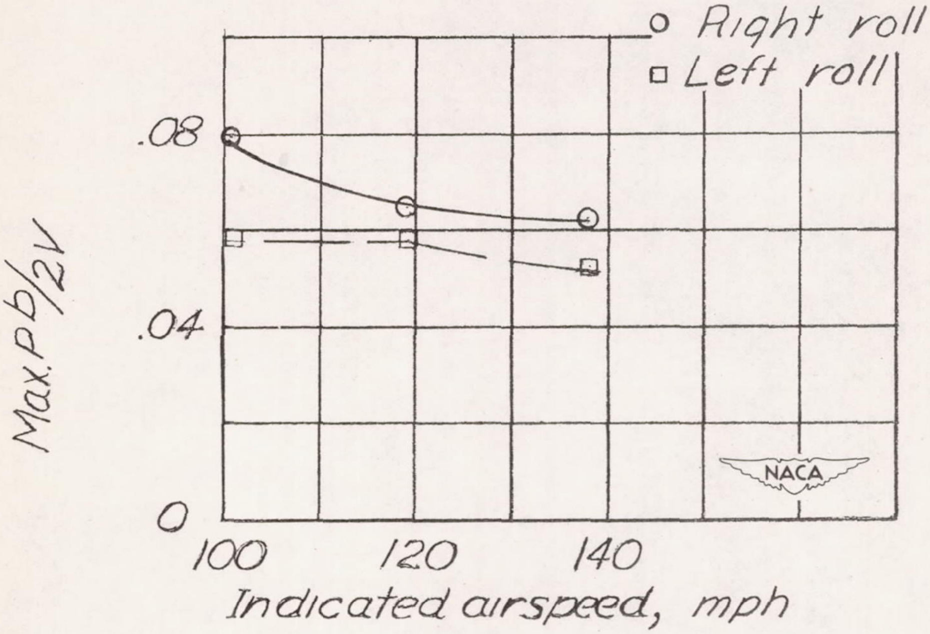
(b) Flaps and gear down; power for level flight.

Figure 23.– Concluded.



(a) Clean condition; power for level flight.

Figure 24.- Variation of maximum pb/2V available without exceeding 80 pounds of wheel force with indicated airspeed. C-54D airplane.



(b) Flaps and gear full down; power for level flight.

Figure 24.– Concluded.