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RESEARCH MEMORANDUM

FLIGHT MEASUREMENTS WITH THE DOUGLAS D-558-II (BuAero No. 37974) RESEARCH AIRPLANE

LOW-SPEED STALLING AND LIFT CHARACTERISTICS

By W. H. Stillwell, J. V. Wilmerding, and
R. A. Champine

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
September 5, 1950

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FLIGHT MEASUREMENTS WITH THE DOUGLAS D-558-II (BuAero No. 37974) RESEARCH AIRPLANE

LOW-SPEED STALLING AND LIFT CHARACTERISTICS

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SUMMARY

The low-speed stalling and lift characteristics of the D-558-II airplane were measured in a series of 1 g stalls in four different airplane configurations.

With the slats locked closed and the flaps up or down, the airplane was unstable at angles of attack greater than about 9°. With the flaps up this corresponds to a normal-force coefficient of about 0.8 and with the flaps down, about 1.07. Because of this instability, the airplane tended to pitch to high angles of attack; at these high angles of attack, violent rolling and yawing motions sometimes occurred. In one case with the flaps down and the slats locked the airplane went into a spin after pitching up to high angles of attack. The pilots considered the stalling characteristics of the airplane with the slats locked to be very objectionable. No data are presented in this paper on the stalling characteristics in maneuvering flight, but the pilots considered the longitudinal instability particularly objectionable in maneuvering flight.

With the slats unlocked and the flaps up or down the airplane was unstable at angles of attack greater than about 23°. Uncontrolled-for rolling and yawing motions due to stalling were present when the airplane was unstable in the high angle-of-attack range. With the slats unlocked and the flaps and landing gear up or down, there was adequate stall warning in the form of buffeting and lateral oscillations of the airplane. With the slats locked, slight buffeting of the airplane occurred at a normal-force coefficient slightly less than the normal-force coefficient at which the airplane became longitudinally unstable.

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With the flaps up and the slats locked, the highest normal-force coefficient obtained was 1.13 at an angle of attack of about 17.5°. The highest normal-force coefficient obtained with the flaps up and the slats unlocked was 1.46 at an angle of attack of 36°, and in the angle-of-attack range from 23° to 30° the normal-force coefficient had a substantially constant value of 1.32.

At the lower angles of attack with the slats locked or unlocked deflecting the flaps produced an increment in normal-force coefficient at a given angle of attack of about 0.26.

The highest normal-force coefficient obtained with the flaps down and the slats locked or unlocked was about 1.65. This value was attained at an angle of attack of about 35.5° with the slats locked and at an angle of attack of about 38° with the slats unlocked. However, in the angle-of-attack range from 12° to 32° considerably greater normal-force coefficients were obtained with the slats unlocked than with the slats locked.

INTRODUCTION

The National Advisory Committee for Aeronautics is conducting a flight research program utilizing the Douglas D-558-II (BuAero No. 37974) research airplane at the NACA High-Speed Flight Research Station at Edwards Air Force Base, Calif. The D-558-II airplanes were designed for flight research in the transonic speed range and were procured for the NACA by the Bureau of Aeronautics of the Navy Department. The flight research program currently being conducted with the BuAero No. 37974 airplane consists of determining the stability and control characteristics and the aerodynamic loads acting on the wing and horizontal tail from the stalling speed up to a maximum Mach number of about 0.90. The results of an investigation made to determine the low-speed stalling and lift characteristics of the airplane are presented in this paper. The data presented were obtained in 1 g stalls in four different airplane configurations. References 1 to 4 present results which have been obtained during the present flight research program on other aerodynamic characteristics of the D-558-II airplane.

AIRPLANE

The Douglas D-558-II airplanes have sweptback wing and tail surfaces and were designed for combination turbojet and rocket power. The airplane being used in the present investigation (BuAero No. 37974) does not have the rocket engine installed. This airplane is powered only by

a J-34-WE-40 turbojet engine which exhausts out of the bottom of the fuselage between the wing and the tail. Photographs of the airplane are shown in figures 1 and 2 and a three-view drawing is shown in figure 3. Pertinent airplane dimensions and characteristics are listed in table I.

Both slats and fences are incorporated on the wing of the airplane. The wing slats can be locked in the closed position or they can be unlocked. When the slats are unlocked, the slat position is a function of the angle of attack of the airplane. Also, the slats on the left and right wings are interconnected and therefore, at any time, have the same position. A section view of the slat and the forward portion of the wing showing the motion of the slat with respect to the wing is shown in figure 4.

The airplane is equipped with an adjustable stabilizer but there is no method provided for trimming out aileron- or rudder-control forces. No aerodynamic balance or control-force booster system is used on any of the controls. Hydraulic dampers are installed on all control surfaces to aid in the prevention of control-surface flutter. Dive brakes are located on the rear portion of the fuselage.

The variations of aileron and elevator position with control-wheel position are shown in figures 5 and 6 and the variation of rudder position with right rudder pedal position is shown in figure 7. The friction in the control systems as measured on the ground under no load is shown in figures 8, 9, and 10. The friction measurements were obtained by measuring the control position and the control force as the controls were deflected slowly. The rate of control deflection was sufficiently low so that the control force resulting from the hydraulic dampers in the control system was negligible.

SYMBOLS

V_c calibrated indicated airspeeds, miles per hour

n normal acceleration gravitational units

C_{N_A} airplane normal-force coefficient

α angle of attack, degrees

δ_e elevator position, degrees

δ_a total aileron position, degrees

δ_r rudder position, degrees

F_e elevator control force, pounds

F_a aileron control force, pounds

F_r rudder control force, pounds

p rolling velocity, radians per second

q pitching velocity, radians per second

r yawing velocity, radians per second

d_s slat position, inches

INSTRUMENTATION

Standard NACA recording instruments were installed in the airplane to measure the following quantities:

Airspeed
Altitude
Elevator and aileron wheel forces
Rudder pedal force
Normal, longitudinal, and transverse accelerations
Rolling, pitching, and yawing velocities
Angle of attack
Stabilizer, elevator, rudder, left and right aileron, and slat position

Strain gages were installed in the airplane to measure wing and tail loads. The strain-gage deflections were recorded on an oscillograph. All instruments were synchronized by means of a common timer.

A free-swiveling airspeed head was used to measure both static and total pressure. This airspeed head was mounted on a boom 7 feet forward of the nose of the airplane. A vane which was used to measure angle of attack was mounted below the same boom $4\frac{1}{2}$ feet forward of the nose of the airplane. (See fig. 1.) The airspeed system was calibrated by the fly-by method at indicated airspeeds down to 225 miles per hour. The static-pressure error at this speed was 3.5 percent of the impact pressure above the free-stream static pressure. Most of the data presented in this paper are for indicated airspeeds less than 225 miles per hour. For these airspeeds the static-pressure error which was present at 225 miles per hour has been applied to the data.

The left and right aileron positions were measured on bell cranks about 1 foot forward of the ailerons. The stabilizer, rudder, and elevator positions were measured on the control surfaces. The elevator positions presented were measured with respect to the stabilizer; the stabilizer position was measured with respect to the fuselage center line. All control positions were measured perpendicular to the control hinge line.

Photographs of tufts on the left and right wings were obtained with two 16-millimeter gun cameras which were mounted near the top of the vertical tail.

TESTS, RESULTS, AND DISCUSSION

The low-speed stalling and lift characteristics of the D-558-II airplane were measured in a series of 1 g stalls in four different airplane configurations:

(a) Landing gear up, flaps up, inlet-duct flaps closed, slats locked
(b) Landing gear up, flaps up, inlet-duct flaps closed, slats unlocked
(c) Landing gear down, flaps down, inlet-duct flaps open, slats locked
(d) Landing gear down, flaps down, inlet-duct flaps open, slats unlocked

The stalls were made with the engine set at idle thrust. The location of the center of gravity of the airplane during the stalls was between 26.1 and 26.7 percent of the mean aerodynamic chord. The data were obtained in an altitude range from 26,000 to 13,000 feet.

Stalling Characteristics

Flaps up, landing gear up, inlet-duct flaps closed, slats locked.- A time history of a stall in this configuration is presented in figure 11(a). Presented in figure 11(b) are photographs of tufts on the wing at various times during the stall. The black lines on the wing are parallel to the airplane center line and are located at intervals of 25 percent of the semispan of the exposed wings. The times listed in figure 11(b) correspond to the times of figure 11(a). The run was started at an indicated airspeed of about 230 miles per hour and the minimum speed reached was about 142 miles per hour. A lateral oscillation, which was predominantly a rolling motion, persisted throughout the run. The data indicate that the airplane became longitudinally unstable

at a normal-force coefficient of 0.8 and an angle of attack of about 9° which, for 1 g flight, corresponds to an airspeed of about 165 miles per hour. When the airplane became unstable the pilot was required to use large down-elevator deflections to control the pitching. In figure 11(a) at times between 50 and 53 seconds, the elevator was moved from 5° up to 3° down but the angle of attack increased from 11° to 18.2°. The highest normal-force coefficient reached was 1.13 at an angle of attack of about 17.5°.

The pilot objected to the characteristics of the airplane near the stall in this configuration because of the tendency for the airplane to pitch up abruptly. In some cases, particularly in maneuvering flight, the pilot did not check the pitch up as soon as in the run presented in figure 11(a). In these cases the angle of attack increased very rapidly and when the high angles of attack were reached the airplane performed violent rolling and yawing motions.

Inspection of the tuft pictures of figure 11(b) shows that separation first occurs on the right wing between the 50- and 75-percent semispan stations. At the same time there is a marked outflow on both wings outboard of the wing fences. As the angle of attack increases, the separation spreads over both the left and right wings and at the highest angle of attack reached, 18.2°, the entire wing appears to be stalled.

Flaps up, landing gear up, inlet-duct flaps closed, slats unlocked.- A time history of a stall in this airplane configuration is presented as figure 12(a) and tuft pictures at various times during the stall are shown in figure 12(b). The approach to the stall was started at about 200 miles per hour and the minimum speed reached was about 122 miles per hour. At times between 24 and 29 seconds (in the speed range from 155 to 140 miles per hour), the data indicate that the airplane was slightly unstable longitudinally since the up-elevator deflection required for trim decreased as the angle of attack and normal-force coefficient increased. The pilots did not have any serious objections to the slight instability present in this speed range. From 140 miles per hour down to a speed slightly above the minimum speed reached (122 miles per hour), the airplane was stable longitudinally. Near the minimum speed or at the higher angles of attack (23° to 28.5°) the data indicate that the airplane was again unstable. At 42.5 seconds the elevator was quickly moved down but between 42.5 and 43.5 seconds the angle of attack increased from 26° to 28.5°. A rolling and yawing motion was present when the airplane was unstable at the high angles of attack. These motions were objectionable to the pilots and were much more noticeable than the longitudinal instability. Recovery from the stall was accomplished by moving the elevator down.

The tuft pictures of figure 12(b) show the wing first stalls between the fuselage and the 50 percent wing semispan. At the same time

there is outflow over the outer part of the wing panel. As the angle of attack increases, the stall spreads outboard over both wings. The tuft pictures for the time 43 seconds in figure 11(b), (the slats-locked configuration), are for about the same angle of attack and airplane normal-force coefficient as the tuft pictures of the time 20 seconds in figure 12(b). Comparison of these tuft pictures indicates that the slats are effective in delaying separation since at 43 seconds in figure 11(b) the tufts show an appreciable separation but at 20 seconds in figure 12(b) the flow appears to be smooth.

The stall presented in figure 13 shows the same characteristics as that in figure 12(a), except that recovery was made after the airplane had reached a higher angle of attack. (The range of the angle-of-attack recorder was exceeded at 38°.) The approach to the stall was started at 190 miles per hour and recovery was made at 122 miles per hour. At the higher angles of attack the airplane was longitudinally unstable. At times between 70 and 72 seconds the elevator is moved down, but at the same time the angle of attack increases rapidly. Also at times between 72 and 75 seconds when the elevator is being moved up, the angle of attack is leading rather than lagging the elevator motion. The highest normal-force coefficient reached was 1.47 at an angle of attack of about 36°. Recovery from the stall was accomplished by moving the elevator down. The longitudinal instability which occurred in this airplane configuration at angles of attack greater than about 23° was not nearly so objectionable to the pilots as the instability which occurred in the slats-locked configuration previously discussed. With the slats locked the instability occurred at a much lower normal-force coefficient or angle of attack and the pitch-up was more rapid.

Flaps down, landing gear down, inlet-duct flaps open, slats locked.- Figure 14(a) presents a time history of a stall approach in this airplane configuration. The tuft pictures are presented as figure 14(b). The stall approach was started as an indicated airspeed of about 200 miles per hour and the minimum speed reached was about 142 miles per hour. As will be shown in a later time history, figure 15, considerably lower speeds and higher angles of attack have been reached in this airplane configuration in other runs, and therefore in the time history presented as figure 14(a) the airplane was not completely stalled. The tuft pictures of figure 14(b) also show that the wing of the airplane was only partially stalled at the highest angles of attack reached. A rolling oscillation of small amplitude was present throughout most of the run. The airplane was neutrally stable or slightly unstable longitudinally in the speed range from about 150 to 142 miles per hour. Inspection of the tuft pictures shows that stalling first occurred on the flaps. The tuft pictures at 47, 49, and 52 seconds show parts of the left and right wings to be alternately stalled and unstalled. The alternate stalling and unstalling of the wings appear to be associated with the rolling motion. When the airplane is rolling to the left at 47 and 52 seconds,

part of the left wing is stalled; when the airplane is rolling to the right at 49 seconds, a part of the right wing is stalled.

Figure 15 presents a time history of a stall approach and stall in the same airplane configuration during which much higher angles of attack were reached. The data show that at about 140 miles per hour (time 26.5 seconds) the airplane becomes very unstable longitudinally. In the time interval between 26.5 and 32.5 seconds the elevator was moved from 3.5° up to 12.5° down and during the same time the angle of attack increased from about 9° to 33°. The airplane experienced quite high rolling velocities at the higher angles of attack. A rolling velocity of about 1.2 radians per second to the right first occurred followed by a roll to the left. During the left roll the recording instruments were inadvertently turned off. After the rolling oscillation occurred the airplane went into a spin. The pilot was unable to effect recovery from the spin with the flaps and landing gear extended, but when the flaps and landing gear were retracted recovery was accomplished with the ailerons and rudder held against the spin.

The pilots considered the stalling characteristics of the airplane in this configuration very objectionable because of the rapid pitch-up which occurred when the airplane became longitudinally unstable and because of the large rolling motions and the possibility of the airplane's spinning. With the slats locked and the flaps and landing gear either up or down, slight buffeting of the airplane occurred at a normal-force coefficient slightly less than the normal-force coefficient at which the airplane became longitudinally unstable. If the pilot initiates recovery when the airplane buffeting occurs or at the first indication of the instability, the violent uncontrolled-for motions can be avoided.

Flaps down, landing gear down, inlet-duct flaps open, slats open.- A time history of a stall approach in this airplane configuration is shown in figure 16(a) and the corresponding tuft pictures are presented in figure 16(b). The run was started at an indicated airspeed of 195 miles per hour and the minimum speed reached was 114 miles per hour. At the higher speeds the airplane performs a Dutch roll oscillation which damps out as the speed is decreased. This has been noted in many flights with the D-558-II airplane. With the flaps down at indicated speeds greater than about 190 miles per hour the pilots have not been able to make precision maneuvers with the airplane because of the poor damping of the Dutch roll oscillations; at speeds between about 150 and 190 miles per hour, the Dutch roll characteristics have not been nearly as troublesome.

The data indicate that the airplane is longitudinally stable in this configuration at indicated airspeeds greater than approximately 140 miles per hour. In the airspeed range from 140 to 130 miles per hour

the airplane has approximately neutral longitudinal stability and at indicated airspeeds less than 130 miles per hour the airplane is very stable longitudinally. The highest angle of attack reached in this run was about 22° and the normal-force coefficient at this angle of attack is 1.50. A rolling and yawing oscillation occurred at the higher angles of attack but the airplane motions during the oscillation were mild.

Figure 16(b) shows that stalling first occurs on the flaps as was also the case with the slats locked (fig. 14(b)). As the angle of attack increases the slats appear to be quite effective in preventing separation as most of the stalling occurs over the inboard 50 percent of the exposed wing semispan. There is considerable outflow over the outer portions of the wing but the flow does not appear to be separated as it is inboard.

A time history of a stall in which considerably higher angles of attack were reached than in the time history presented as figure 16(a) is shown in figure 17. Inspection of figure 17 shows that the airplane is unstable at angles of attack greater than about 23°. At times between 72 and 75 seconds the elevator is moved from 13.5° up to 0.5° down but at the same time the angle of attack increases from 25.5° to 38°. A rolling and yawing motion involving rolling velocities of the order of 1 radian per second occurred at the high angles of attack. These motions were objectionable to the pilots and were more noticeable than the longitudinal instability. Recovery from the stall was accomplished by moving the elevator down.

With the slats unlocked and the flaps and landing gear up or down, there is adequate stall warning in the form of buffeting and lateral oscillations of the airplane.

Lift Characteristics

From some of the runs previously presented as time histories of stalls, the variation of airplane normal-force coefficient with angle of attack was determined for the four different airplane configurations previously discussed. These data are presented in figures 18(a) for the flaps-up configurations and in 18(b) for the flaps-down configurations. The variation of slat position with angle of attack is also presented in figure 18.

At the lower normal-force coefficients, with the flaps up or down, unlocking the slats had no appreciable effect on the angle of attack required to produce a given normal-force coefficient. With the flaps up and the slats locked, the highest normal-force coefficient reached was about 1.13 at an angle of attack of about 18°. With the flaps up and the slats unlocked, the highest normal-force coefficient reached was

about 1.46 at an angle of attack of 36°. In the angle-of-attack range from about 23° to 30° the normal-force coefficient has a substantially constant value of 1.32. At the higher angles of attack, the lift coefficient would be considerably lower than the normal-force coefficient because of the large inclination of the normal-force vector with respect to the lift vector.

With the flaps down and the slats locked or unlocked (fig. 18(b)) the highest normal-force coefficient reached was about 1.65. This value of normal-force coefficient was reached at an angle of attack of 35.5° with the slats locked and 38° with the slats unlocked. However, in the angle-of-attack range from 12° to 32°, considerably higher normal-force coefficients can be reached at a given angle of attack with the slats unlocked than locked. For example, at an angle of attack of 25° the normal-force coefficient is about 1.5 with the slats unlocked and 1.25 with the slats locked.

In order to show more clearly the effect of flap deflection on the lift characteristics the data of figure 18 have been replotted in figure 19. Figure 19(a) is for the slats-locked configuration and figure 19(b) is for the slats-unlocked configuration. At the lower angles of attack, with the slats locked or unlocked, deflecting the flaps will produce an increment in normal-force coefficient of about 0.26. With the slats locked at an angle of attack of 17°, the normal-force coefficient has approximately the same value, 1.13, with the flaps up or down. With the slats unlocked the flaps produce an appreciable increment in normal-force coefficient throughout the angle-of-attack range.

CONCLUDING REMARKS

The low-speed stalling and lift characteristics of the D-558-II airplane were measured in a series of 1 g stalls in four different airplane configurations.

With the slats locked closed and the flaps up or down the airplane was unstable at angles of attack greater than about 9°. With the flaps up, this corresponds to a normal-force coefficient of about 0.8 and with the flaps down, about 1.07. Because of this instability the airplane tended to pitch to high angles of attack; at these high angles of attack violent rolling and yawing motions sometimes occurred. In one case with the flaps down and the slats locked the airplane went into a spin after pitching up to high angles of attack. The pilots considered the stalling characteristics of the airplane with the slats locked to be very objectionable. No data are presented in this paper on the stalling characteristics in maneuvering flight but the pilots considered the longitudinal instability particularly objectionable in maneuvering flight.

With the slats unlocked and the flaps up or down the airplane was unstable at angles of attack greater than about 23°. Uncontrolled-for rolling and yawing motions due to stalling were present when the airplane was unstable in the high angle-of-attack range. With the slats unlocked and the flaps and landing gear up or down, there was adequate stall warning in the form of buffeting and lateral oscillations of the airplane. With the slats locked, slight buffeting of the airplane occurred at a normal-force coefficient slightly less than the normal-force coefficient at which the airplane became longitudinally unstable.

With the flaps up and the slats locked the highest normal-force coefficient obtained was 1.13 at an angle of attack of about 17.5°. The highest normal-force coefficient obtained with the flaps up and the slats unlocked was 1.46 at an angle of attack of 36° and in the angle-of-attack range from 23° to 30° the normal-force coefficient had a substantially constant value of 1.32.

At the lower angles of attack with the slats locked or unlocked, deflecting the flaps produced an increment in normal-force coefficient at a given angle of attack of about 0.26.

The highest normal-force coefficient obtained with the flaps down and the slats locked or unlocked was about 1.65. This value was attained at an angle of attack of about 35.5° with the slats locked and at an angle of attack of about 38° with the slats unlocked. However, in the angle-of-attack range from 12° to 32° considerably greater normal-force coefficients were obtained with the slats unlocked than with the slats locked.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va.

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TABLE I

DIMENSIONS AND CHARACTERISTICS OF THE

DOUGLAS D-558-II AIRPLANE

Wing:	
Root airfoil section (normal to 0.30 chord)	NACA 63-010
Tip airfoil section (normal to 0.30 chord)	NACA 63_1-012
Total area, sq ft	175.0
Span, ft	25.0
Mean aerodynamic chord, in.	87.3
Root chord (parallel to plane of symmetry), in.	108.5
Tip chord (parallel to plane of symmetry), in.	61.2
Taper ratio	0.565
Aspect ratio	3.570
Sweep at 0.30 chord, deg	35.0
Incidence at fuselage center line, deg	3.0
Dihedral, deg	-3.0
Geometric twist, deg	0
Total aileron area (aft of hinge), sq ft	9.8
Aileron span, perpendicular to plane of symmetry, in.	66
Aileron travel (each), deg	±15
Total flap area, sq ft	12.58
Flap travel, deg	50
Horizontal tail:	
Root airfoil section (normal to 0.30 chord)	NACA 63-010
Tip airfoil section (normal to 0.30 chord)	NACA 63-010
Area (including fuselage) sq ft	39.9
Span, in.	143.6
Mean aerodynamic chord, in.	41.75
Root chord (parallel to plane of symmetry) in.	53.6
Tip chord (parallel to plane of symmetry) in.	26.8
Taper ratio	0.50
Aspect ratio	3.59
Sweep at 0.30 chord line, deg	40.0
Dihedral, deg	0
Elevator area, sq ft	9.4
Elevator travel, deg	25 up 15 down
Stabilizer travel, deg	4 L.E. up 5 L.E. down

TABLE I

DIMENSIONS AND CHARACTERISTICS OF THE

DOUGLAS D-558-II AIRPLANE - Concluded

Vertical tail:	
Airfoil section (parallel to fuselage center line)	NACA 63-010
Area, sq ft	36.6
Height from fuselage center line, in.	98.0
Root chord (parallel to fuselage center line), in.	146.0
Tip chord (parallel to fuselage center line), in.	44.0
Sweep angle at 0.30 chord, deg	49.0
Rudder area (aft of hinge line), sq ft	6.15
Rudder travel, deg	±25
Fuselage:	
Length, ft	42.0
Maximum diameter, in.	60.0
Fineness ratio	8.40
Speed-retarder area, sq ft	5.25
Power plant	J-34-WE-40 2 jatos for take-off
Airplane weight (full fuel), lb	10,645
Airplane weight (no fuel), lb	9,085
Airplane weight (full fuel and 2 jatos), lb	11,060
Center-of-gravity locations:	
Full fuel (gear down), percent mean aerodynamic chord	25.3
Full fuel (gear up), percent mean aerodynamic chord	25.8
No fuel (gear down), percent mean aerodynamic chord	26.8
No fuel (gear up), percent mean aerodynamic chord	27.5
Full fuel and 2 jatos (gear down), percent mean aerodynamic chord	29.2

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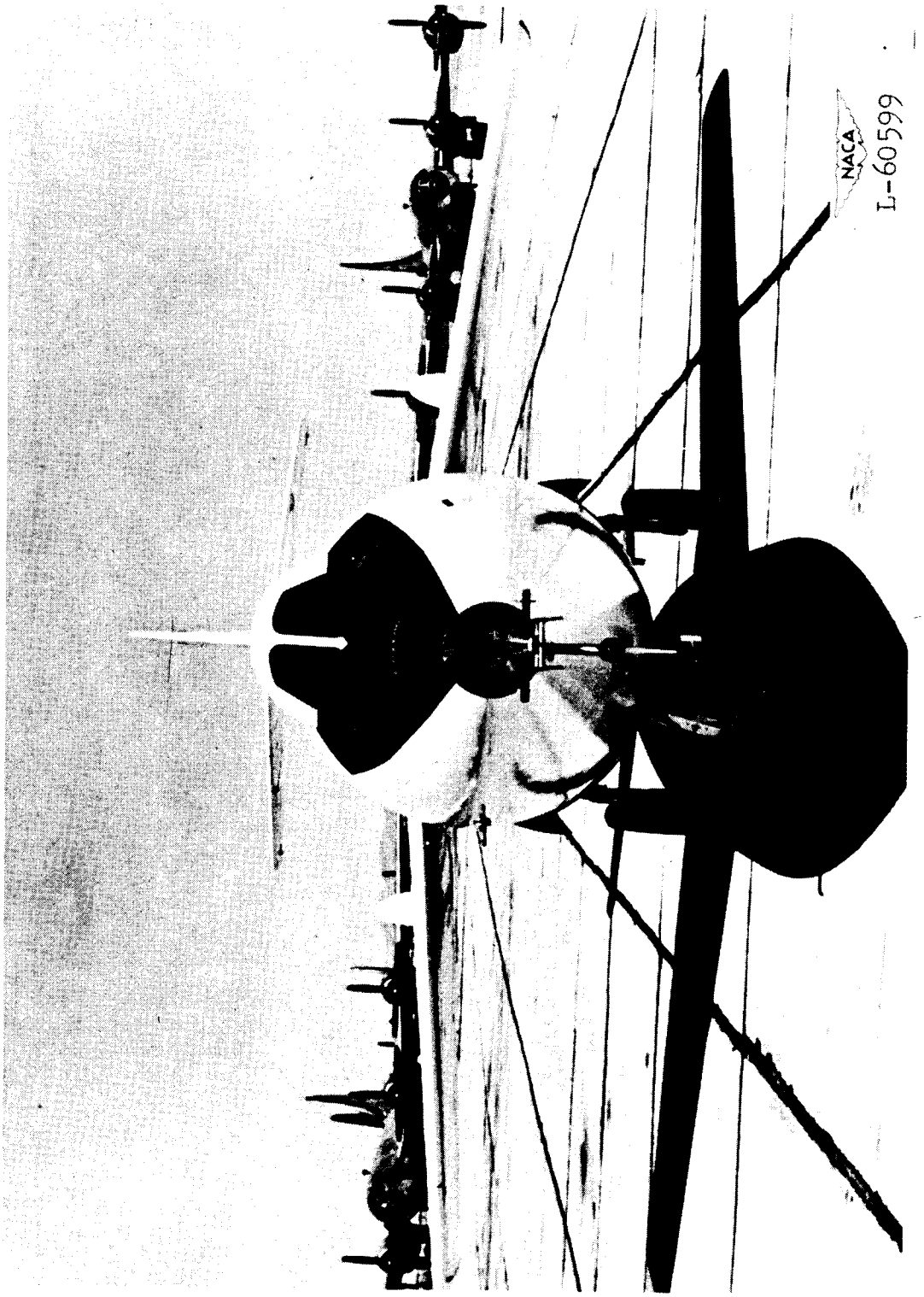

Figure 1.- Front view of Douglas D-558-II (BuAero No. 37974) research airplane.

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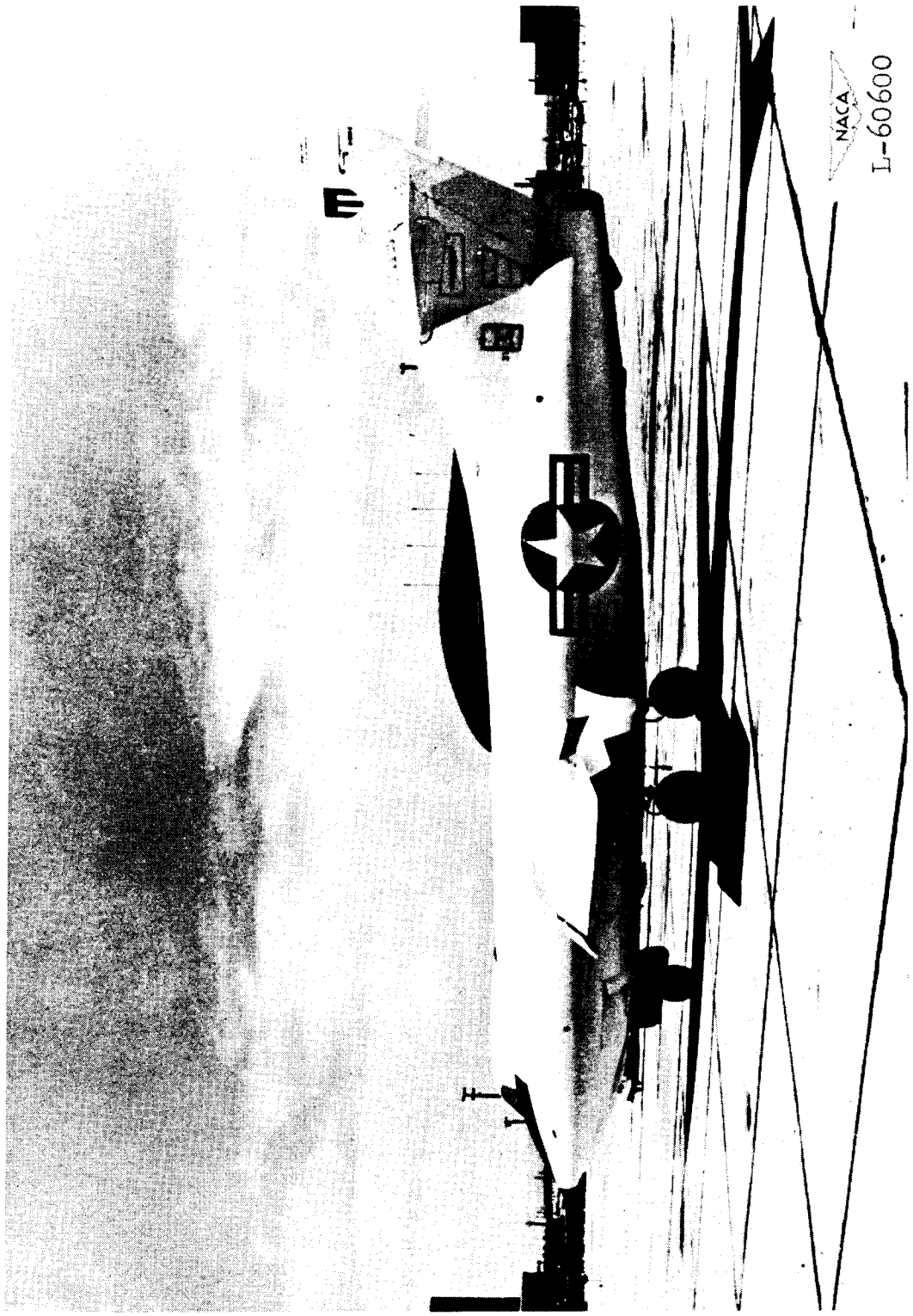


Figure 2.- Three-quarter rear view of Douglas D-558-II (BuAero No. 37974) research airplane.

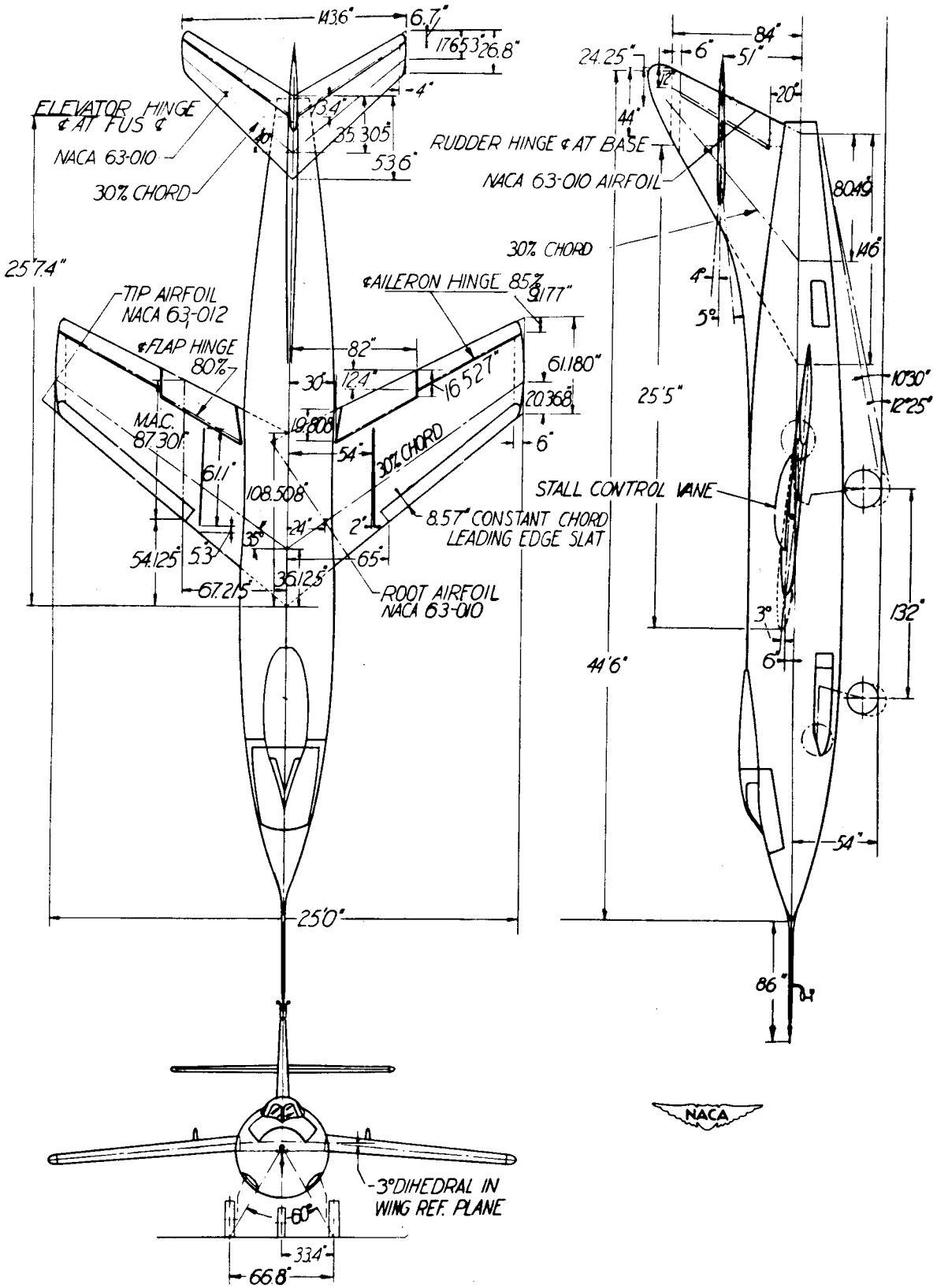


Figure 3.- Three-view drawing of the Douglas D-558-II (BuAero No. 37974) research airplane.

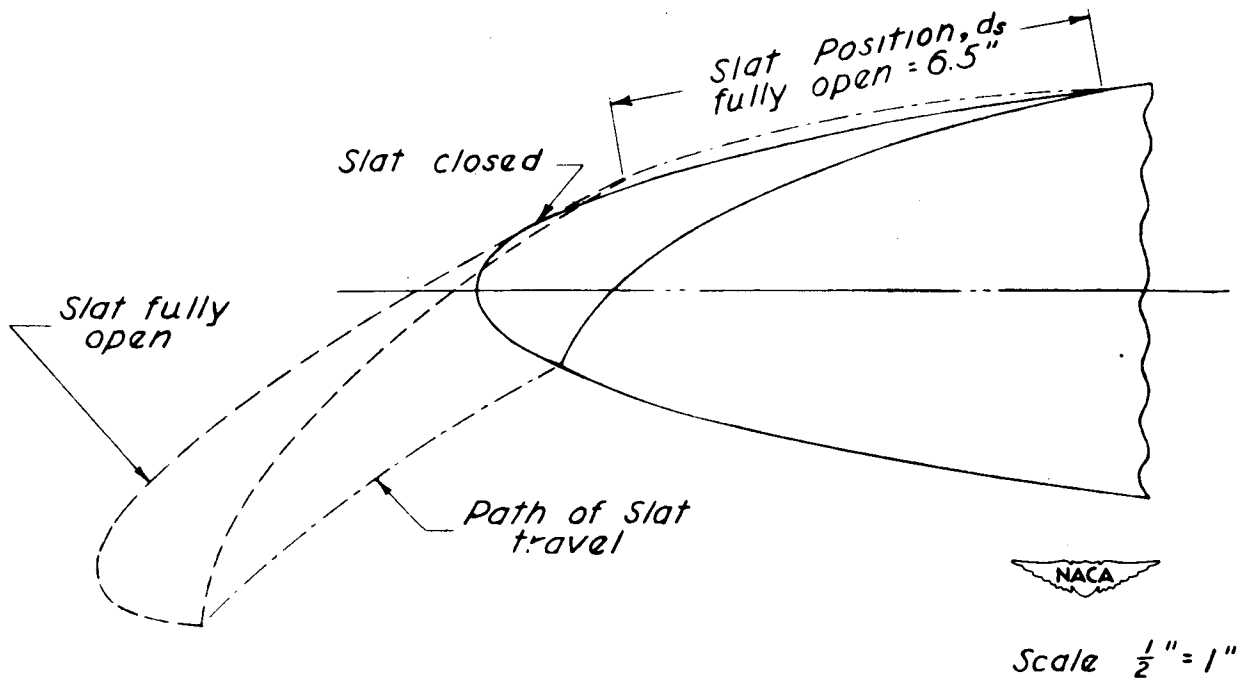


Figure 4.- Section of wing slat of Douglas D-558-II (BuAero No. 37974) research airplane perpendicular to leading edge of wing.

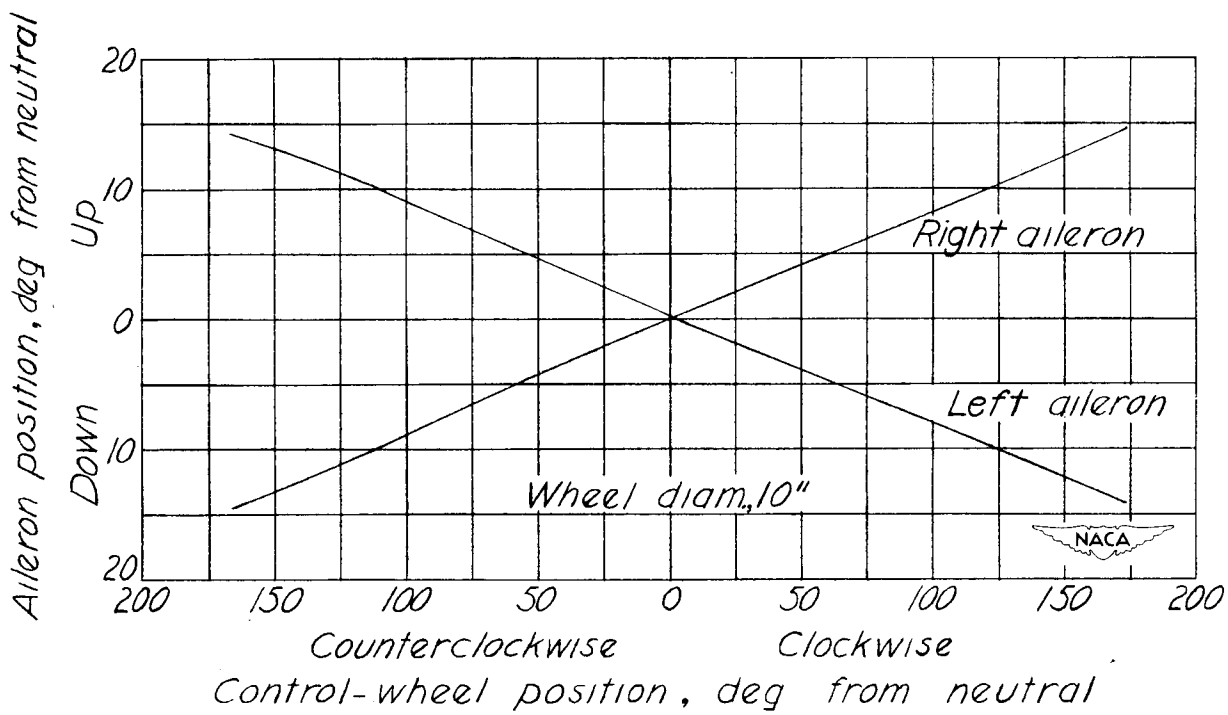


Figure 5.- Variation of left and right aileron positions with control-wheel position. No load on system.

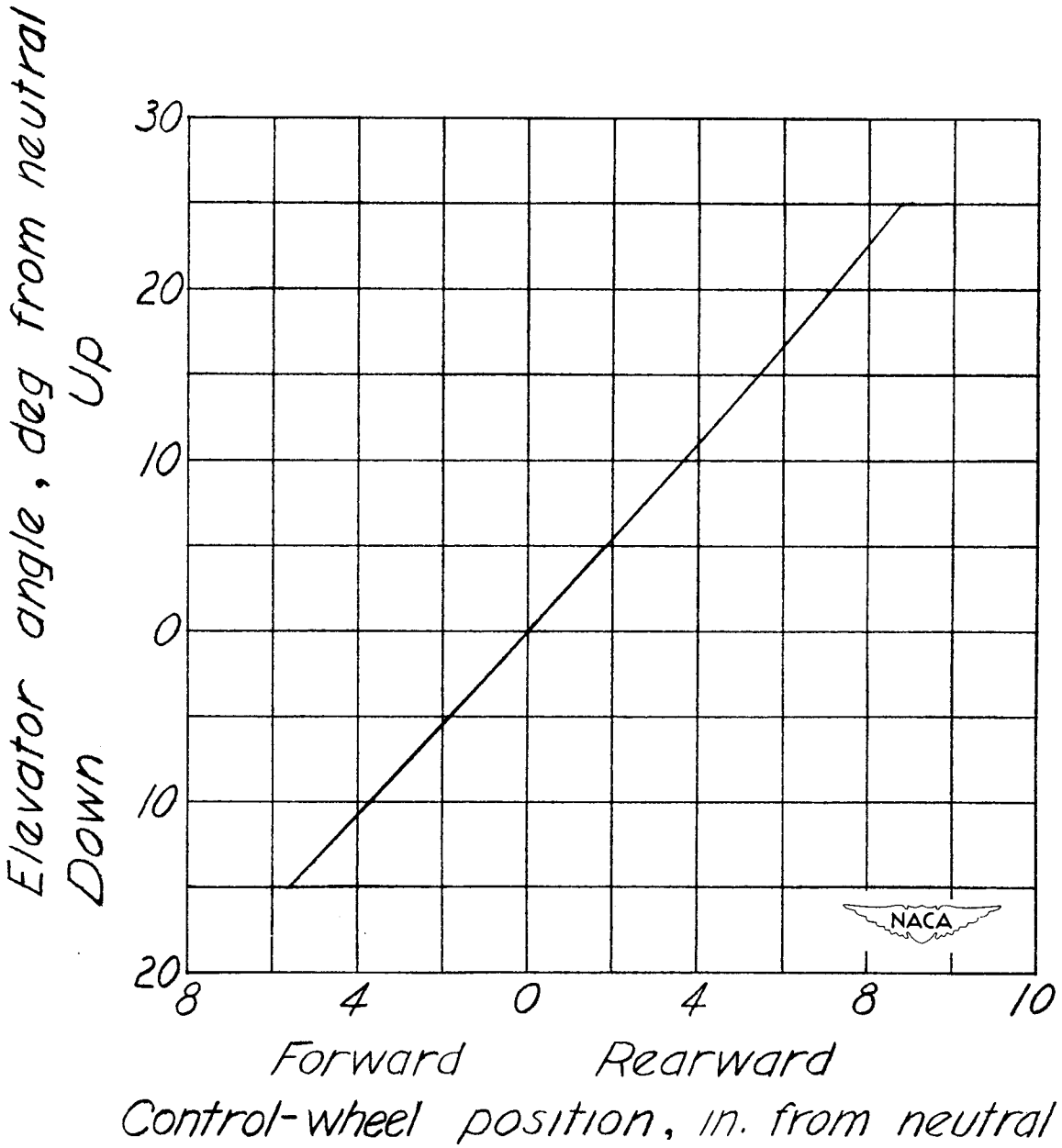


Figure 6.- Variation of elevator position with control-wheel position. No load on system.

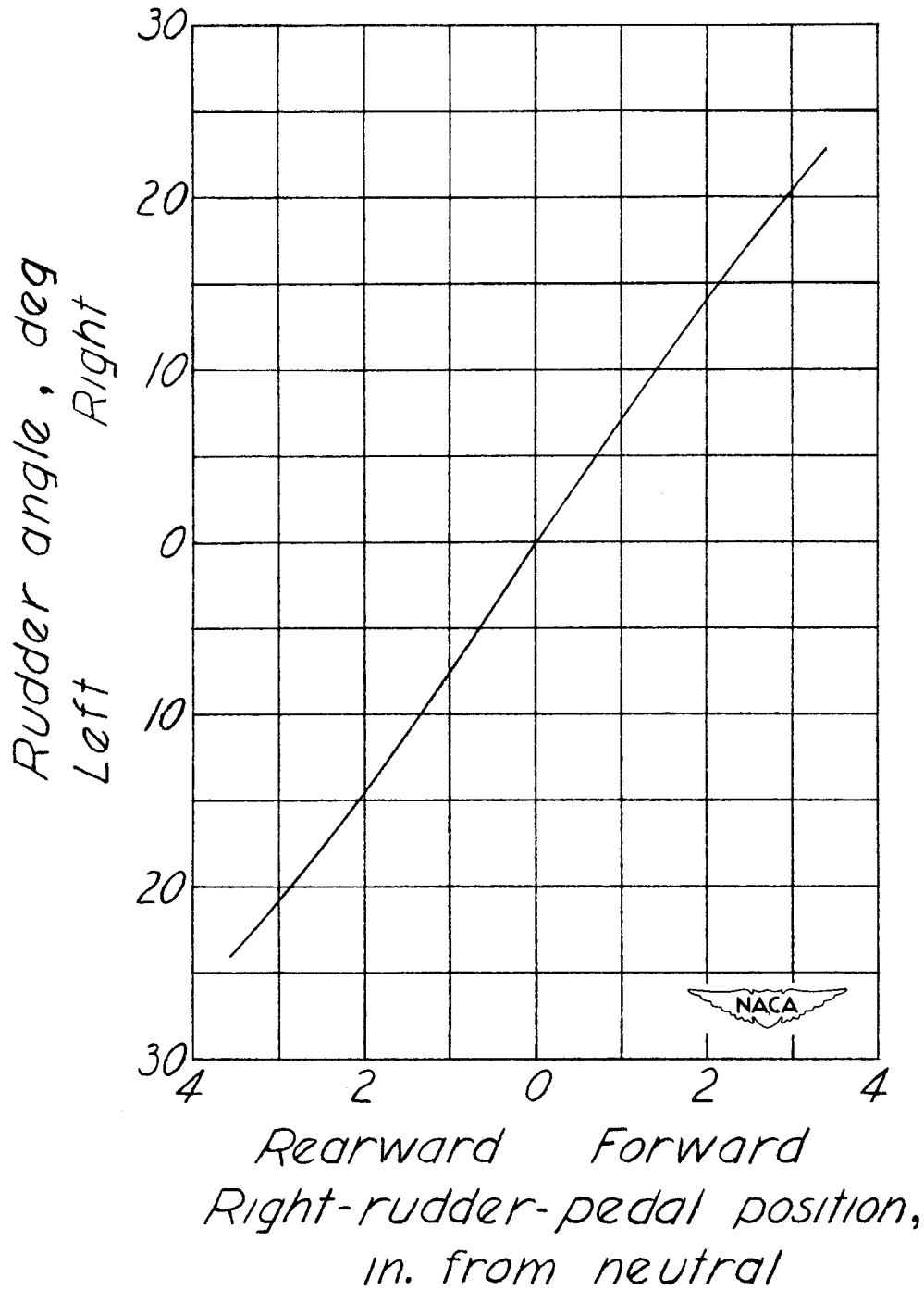


Figure 7.- Variation of rudder position with right-rudder-pedal position. No load on system.

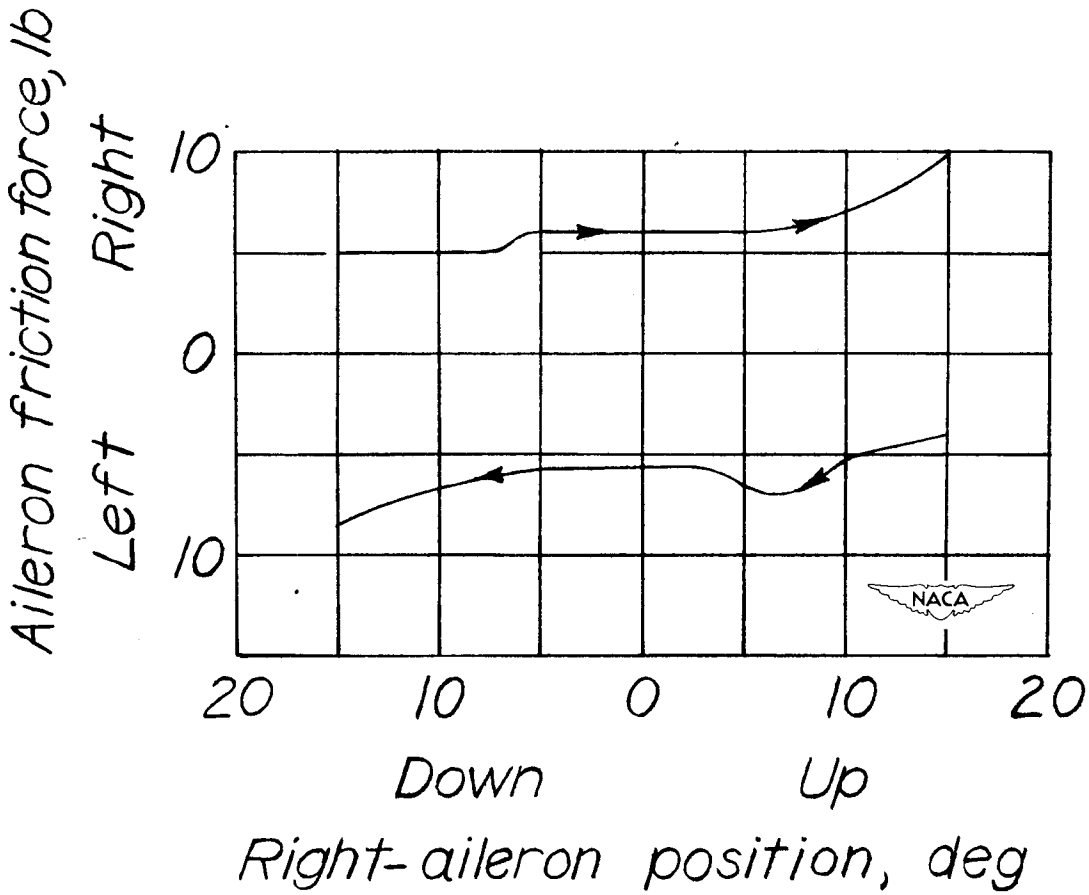


Figure 8.- Aileron-control force required to deflect ailerons on the ground under no load.

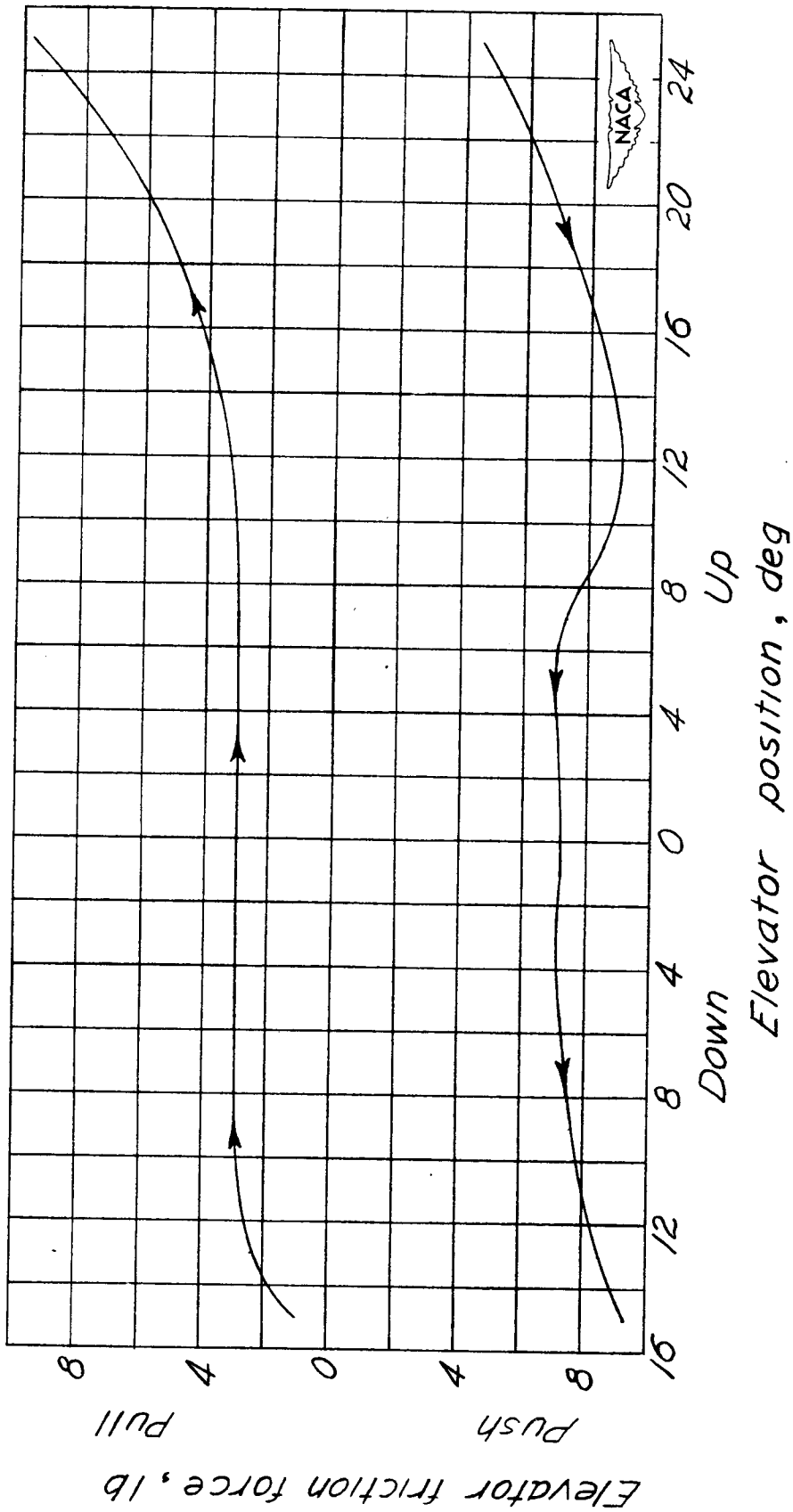


Figure 9.- Elevator-control force required to deflect elevator on the ground under no load.

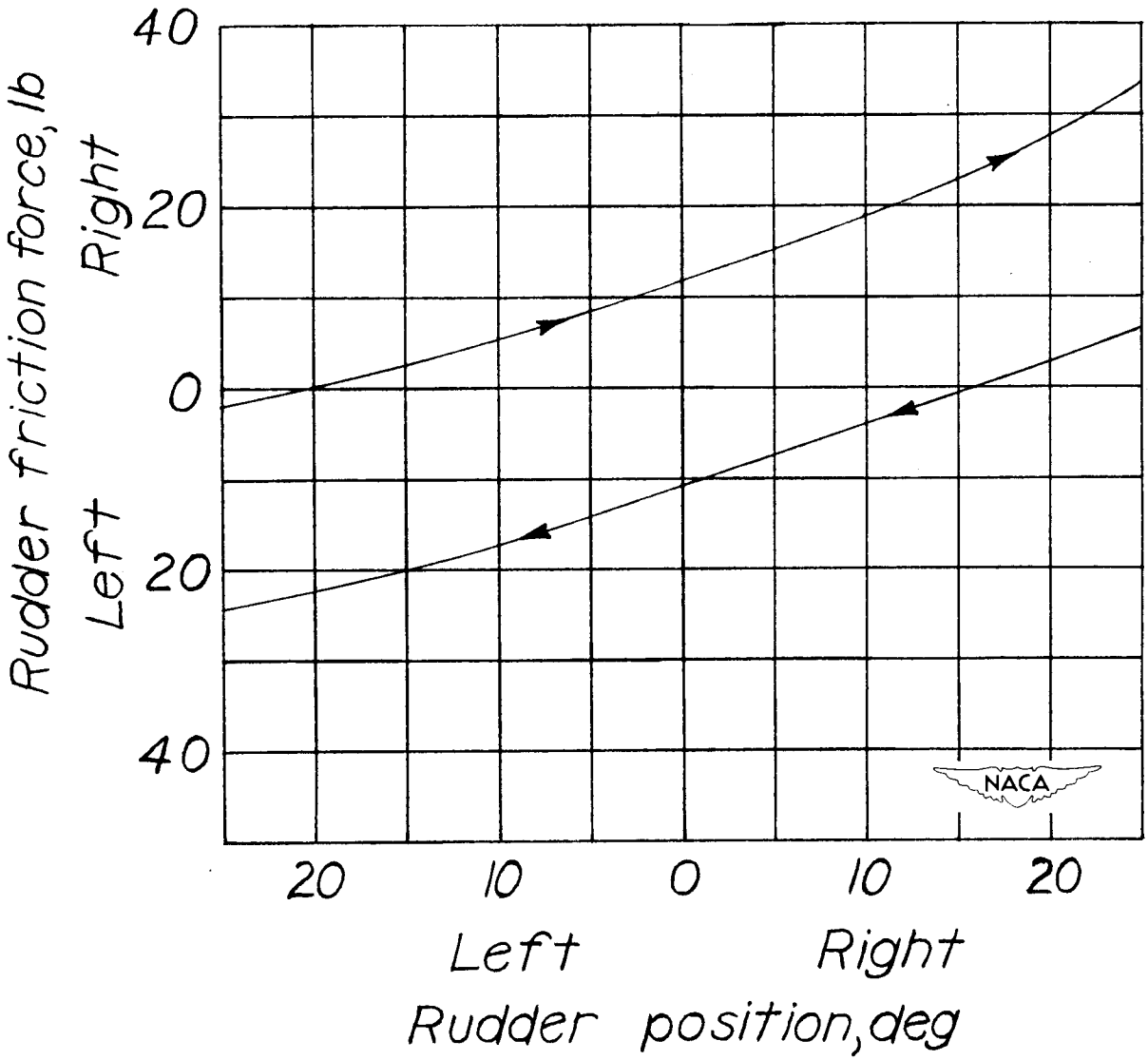
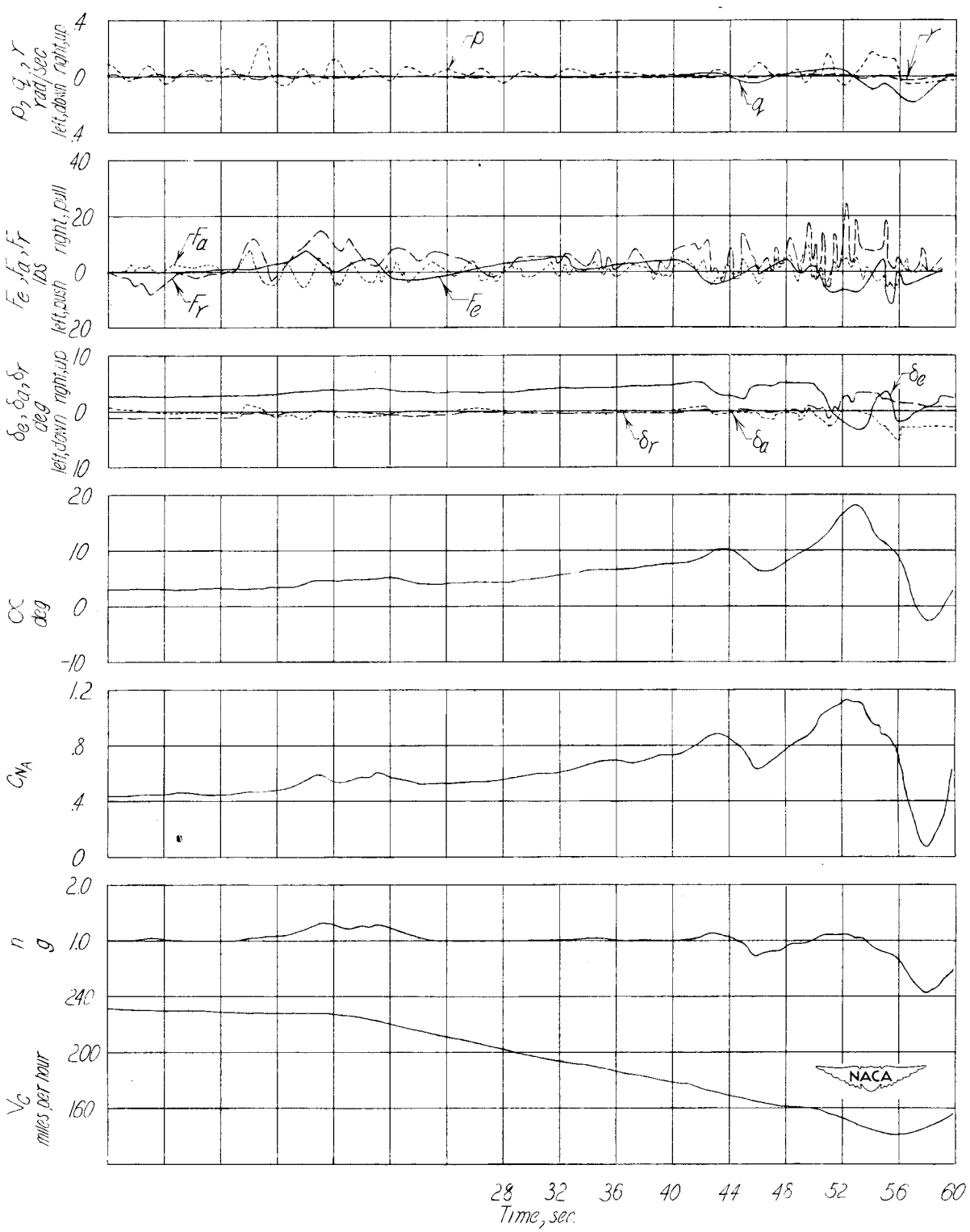
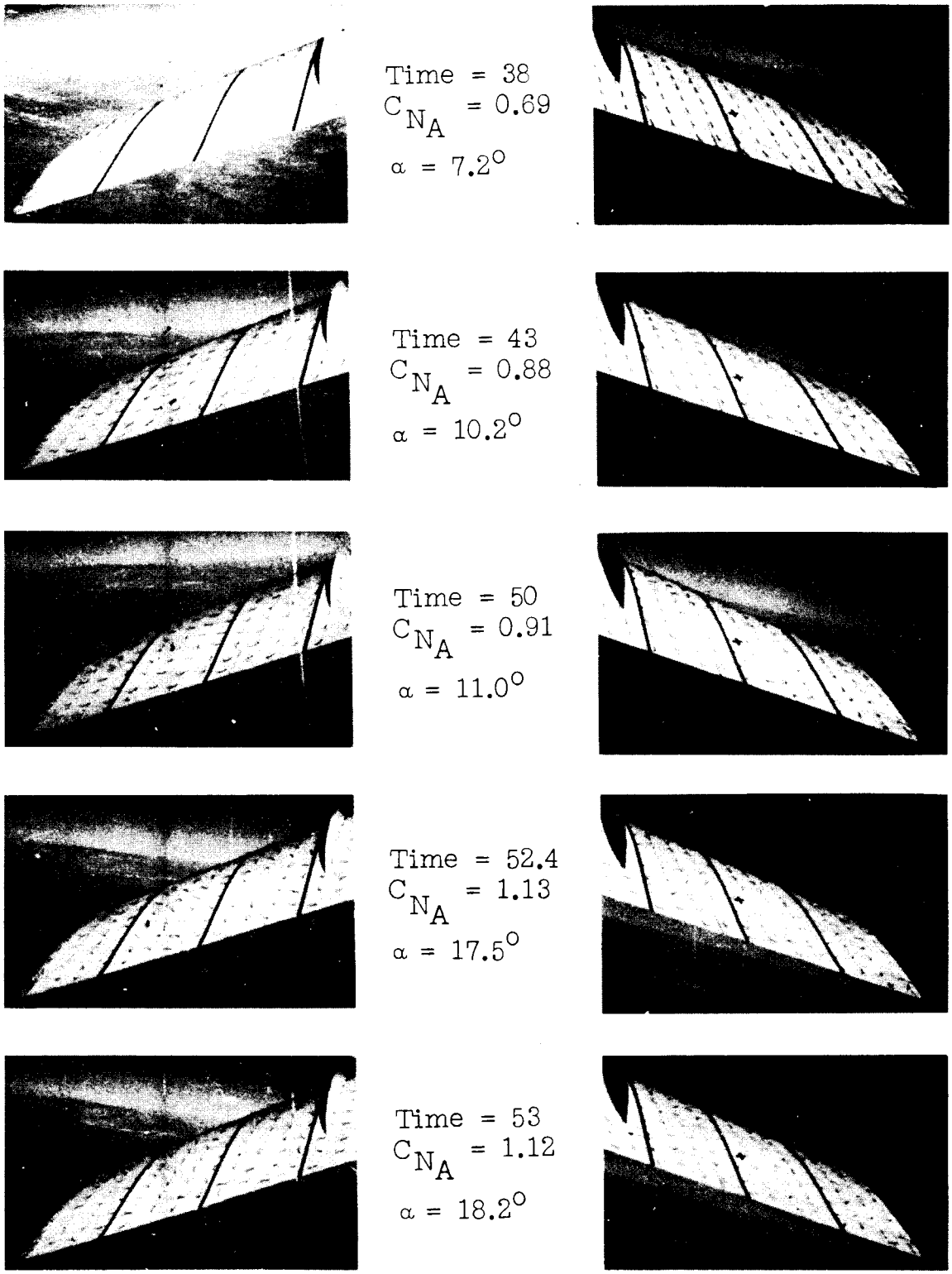


Figure 10.- Rudder-control force required to deflect rudder on the ground under no load.



(a) Time history.

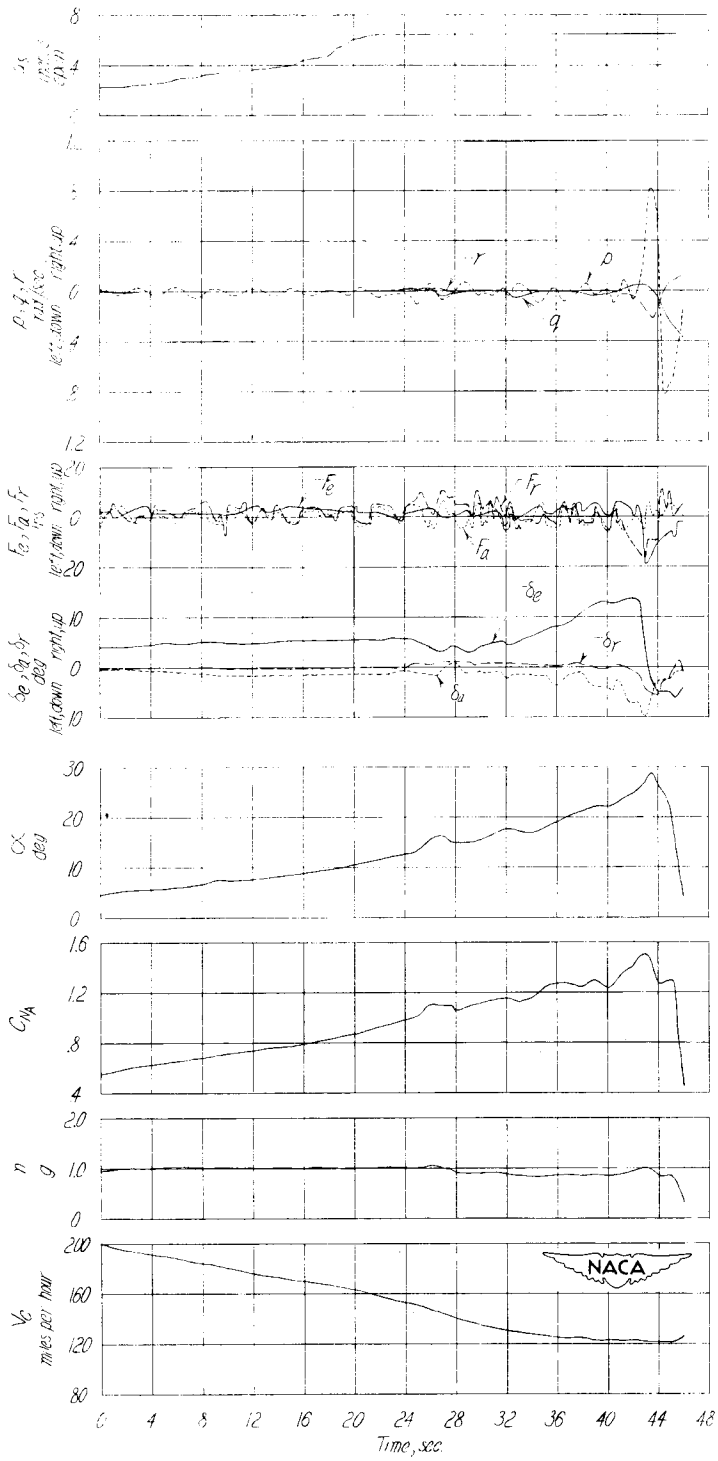
Figure 11.- Stall data for the Douglas D-558-II (BuAero No. 37974) research airplane. Flaps up; landing gear up; slats locked; inlet-duct flaps closed; stabilizer setting 1.95°; center of gravity at 26.5 percent mean aerodynamic chord.



(b) Tuft pictures.

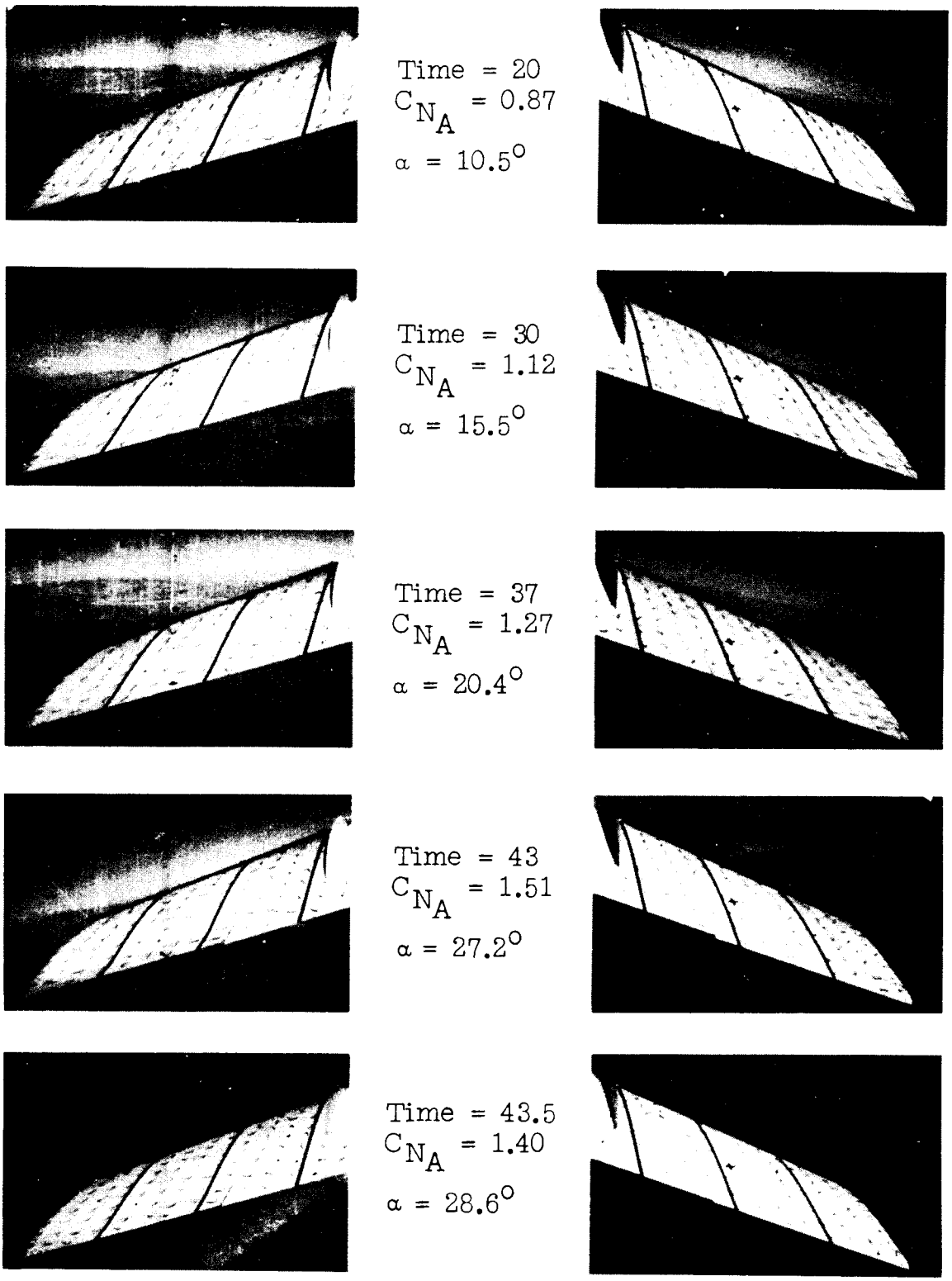
Figure 11.- Concluded.

L-64917



(a) Time history.

Figure 12.- Stall data for the Douglas D-558-II (BuAero No. 37974) research airplane. Flaps up; landing gear up; slats unlocked; inlet-duct flaps closed; stabilizer setting 1.95°; center of gravity at 26.6 percent mean aerodynamic chord.



(b) Tuft pictures.

Figure 12.- Concluded.

L-64918

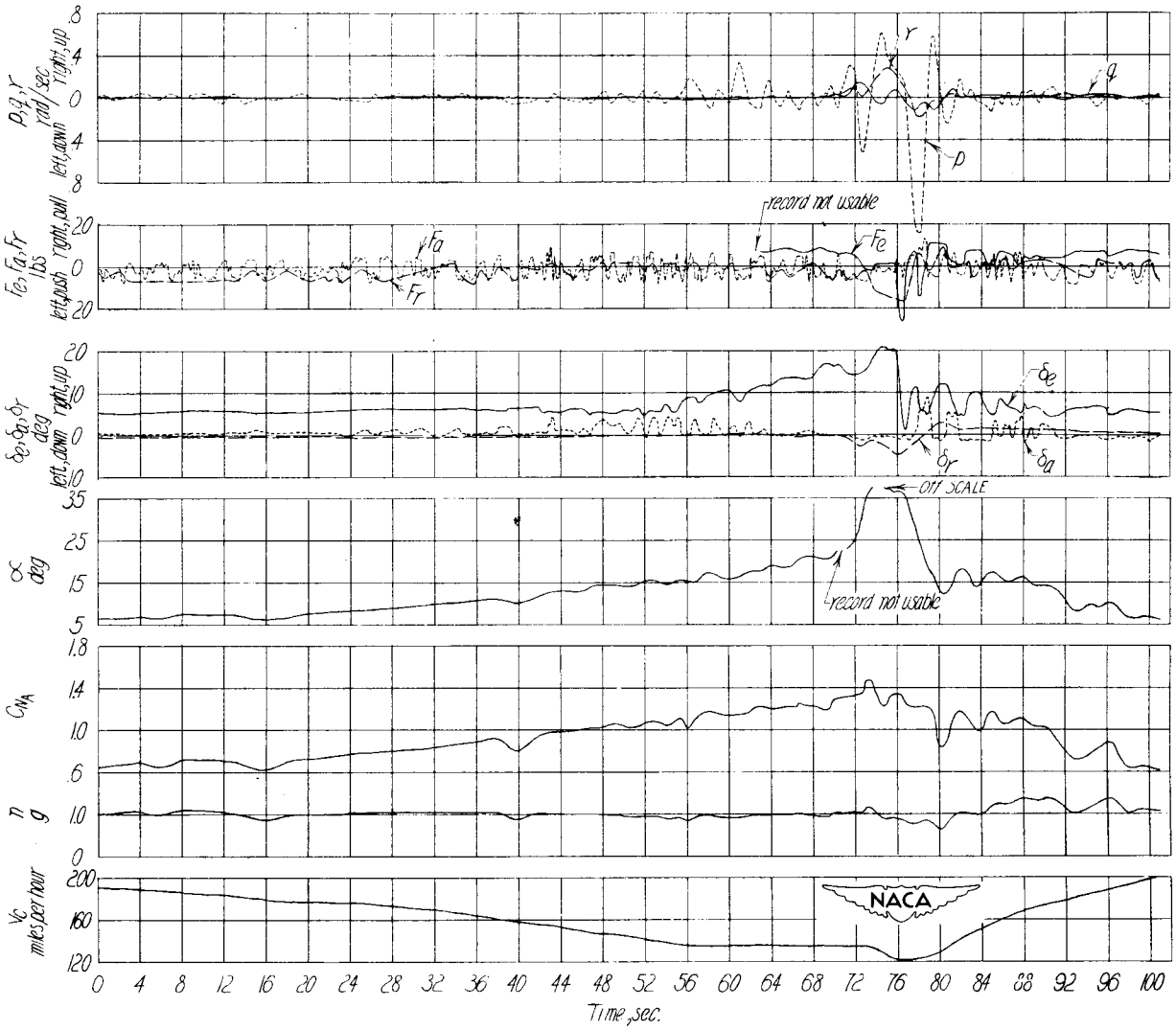
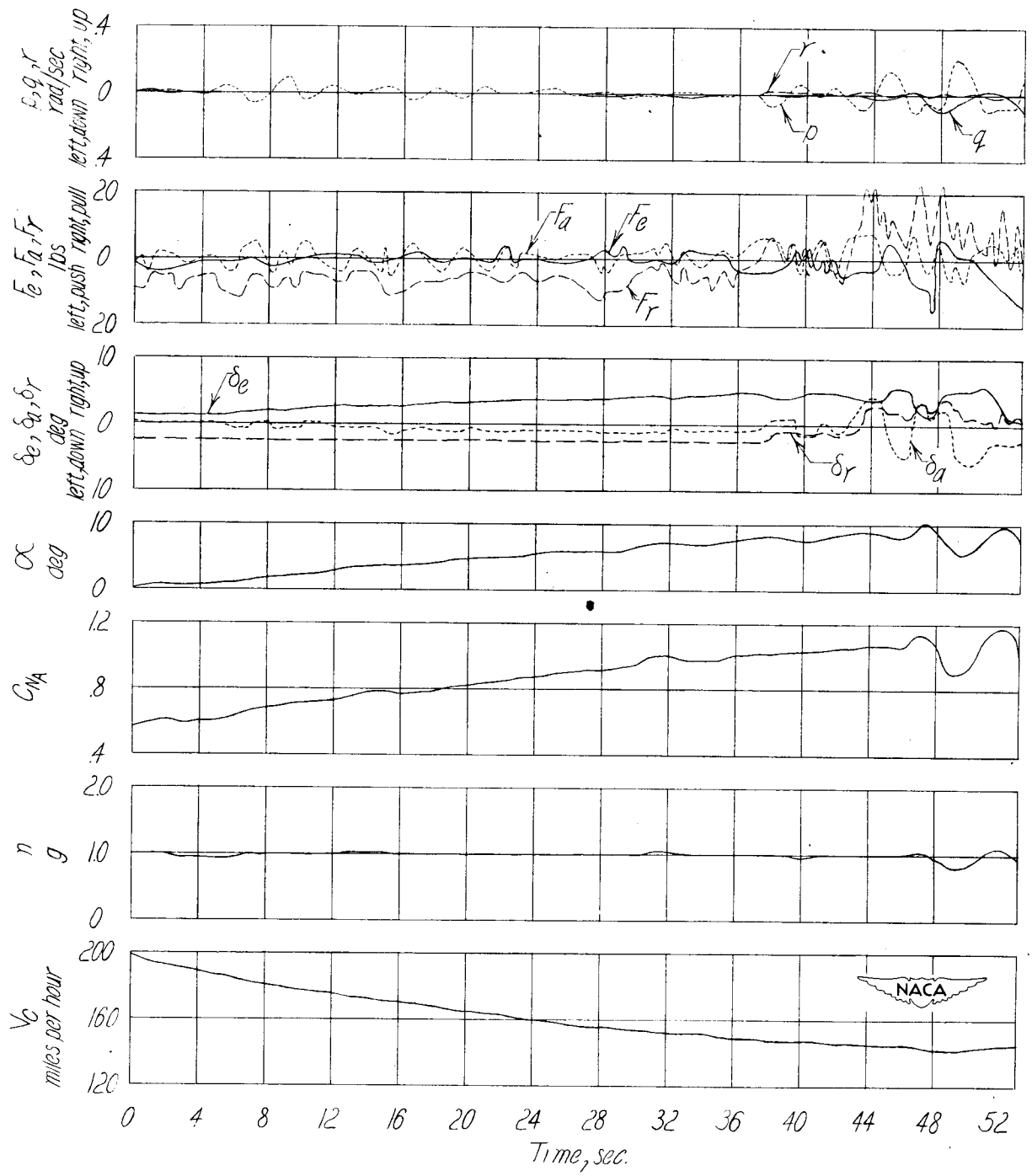
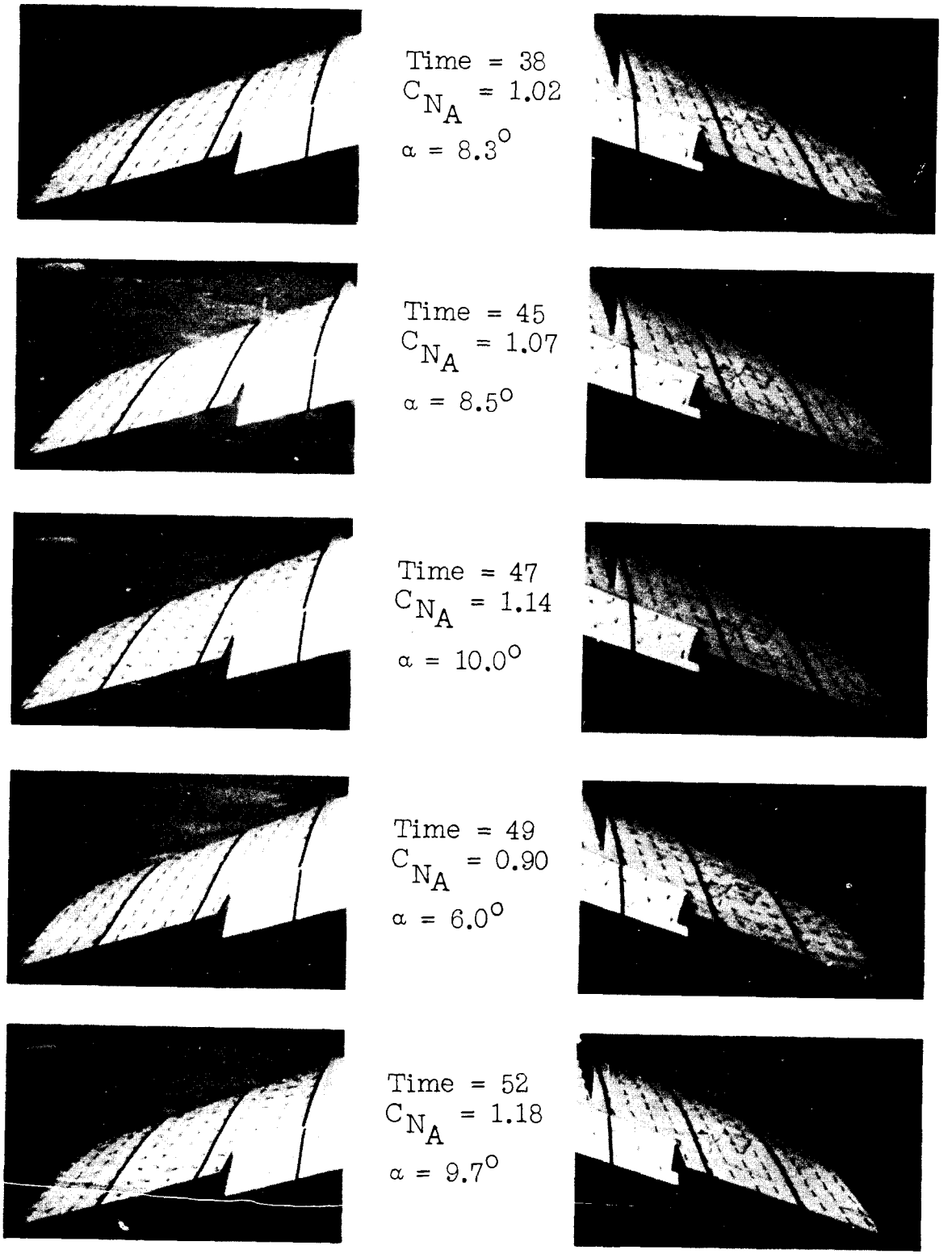


Figure 13.- Time history of a stall with the Douglas D-558-II (BuAero No. 37974) research airplane. Flaps up; landing gear up; slats unlocked; inlet duct-flaps closed; stabilizer setting 1.72°; center of gravity at 26.7 percent mean aerodynamic chord.



(a) Time history.

Figure 14.- Stall data for the Douglas D-558-II (BuAero No. 37974) research airplane. Flaps down; landing gear down; slats locked; inlet-duct flaps open; stabilizer setting 2.2°; center of gravity at 26.1 percent mean aerodynamic chord.



(b) Tuft pictures.

Figure 14.- Concluded.

L-64919

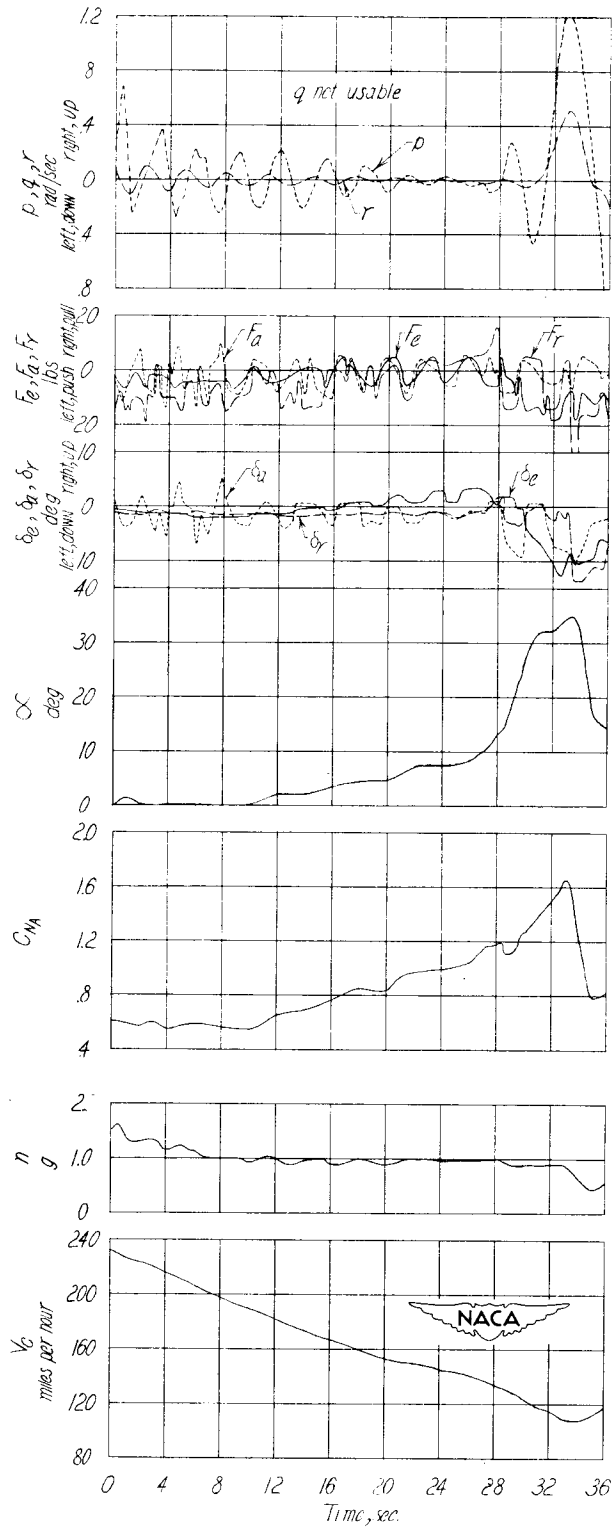
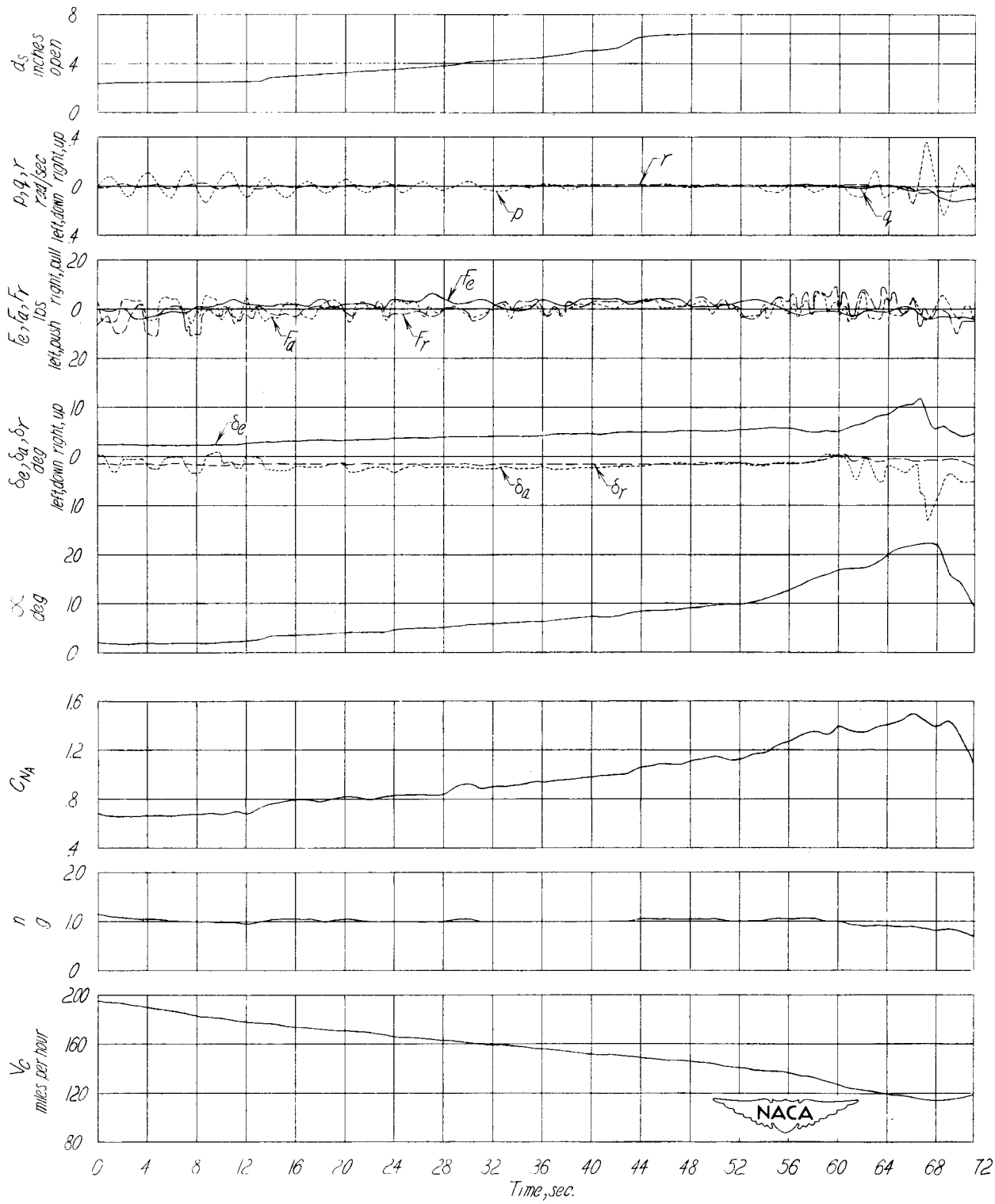
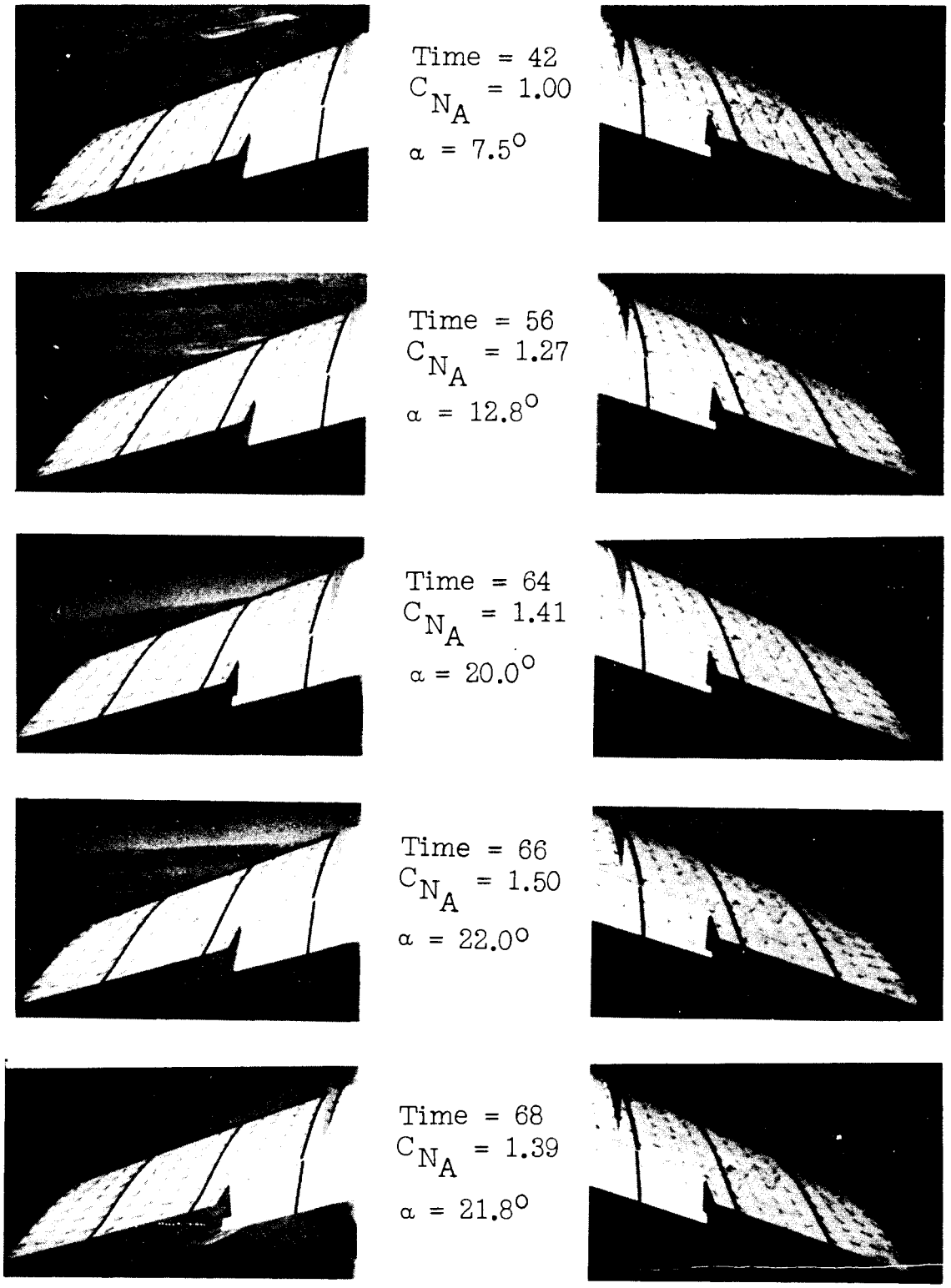


Figure 15.- Time history of a stall with the Douglas D-558-II (BuAero No. 37974) research airplane. Flaps down; landing gear down; slats locked; inlet-duct flaps open; stabilizer setting 0.7°; center of gravity at 26.6 percent mean aerodynamic chord.



(a) Time history.

Figure 16.- Stall data for the Douglas D-558-II (BuAero No. 37974) research airplane. Flaps down; landing gear down; slats unlocked; inlet-duct flaps open; stabilizer setting 2.2°; center of gravity at 26.2 percent mean aerodynamic chord.



(b) Tuft pictures.

Figure 16.- Concluded.

L-64920

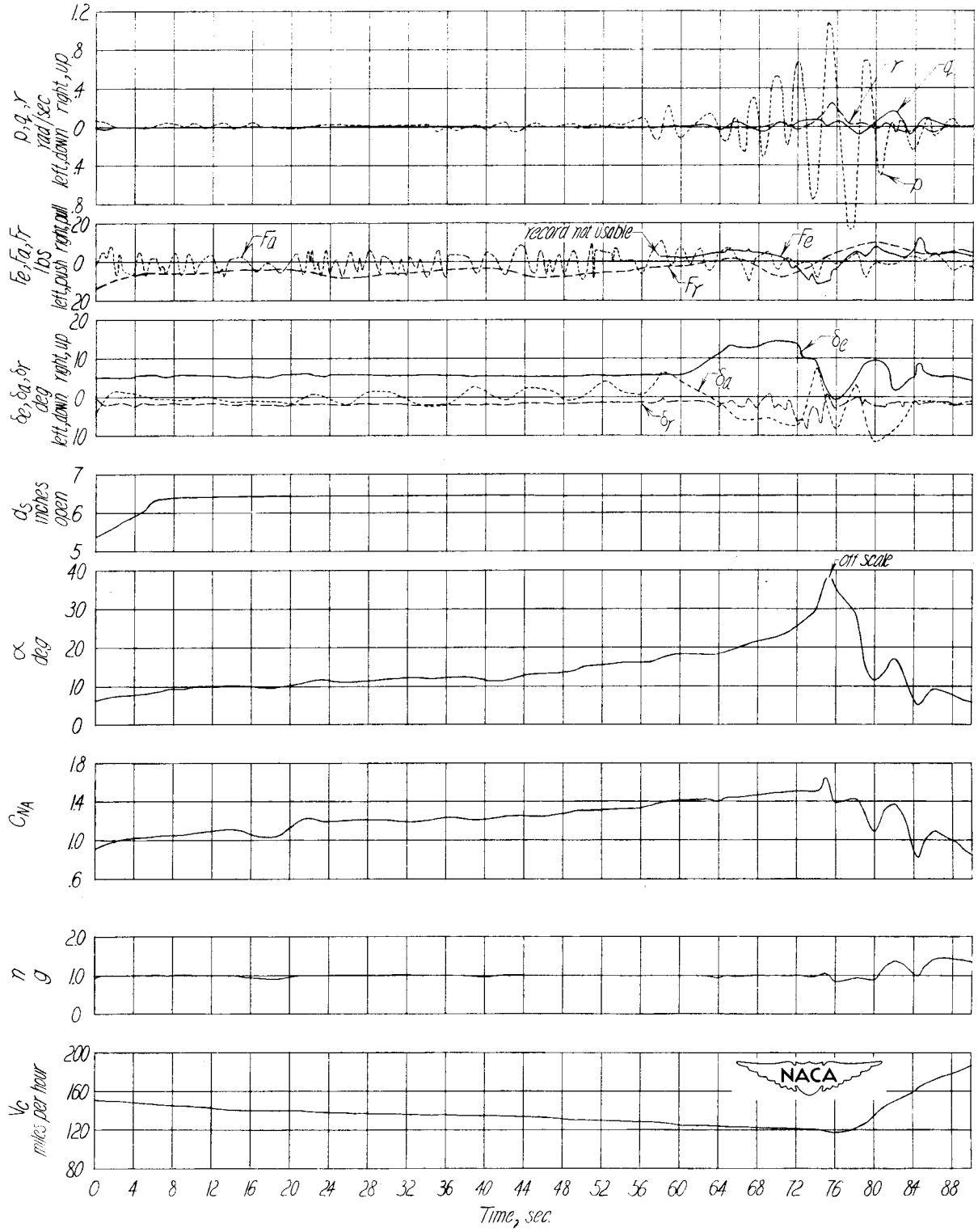
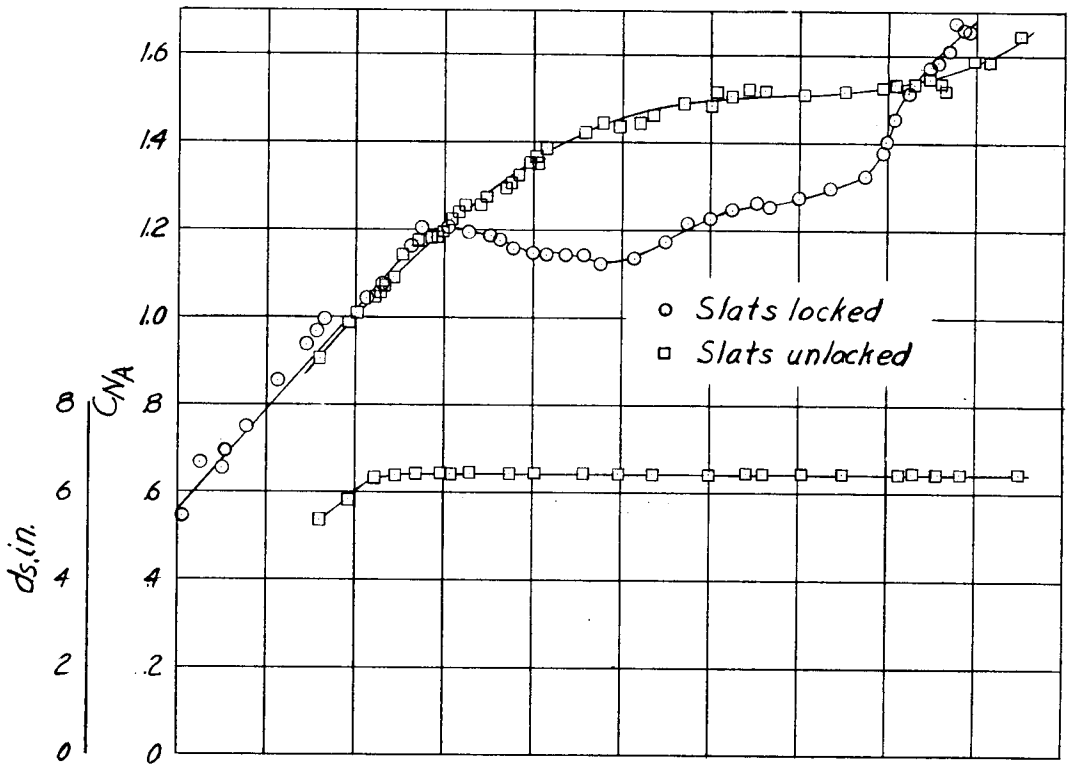
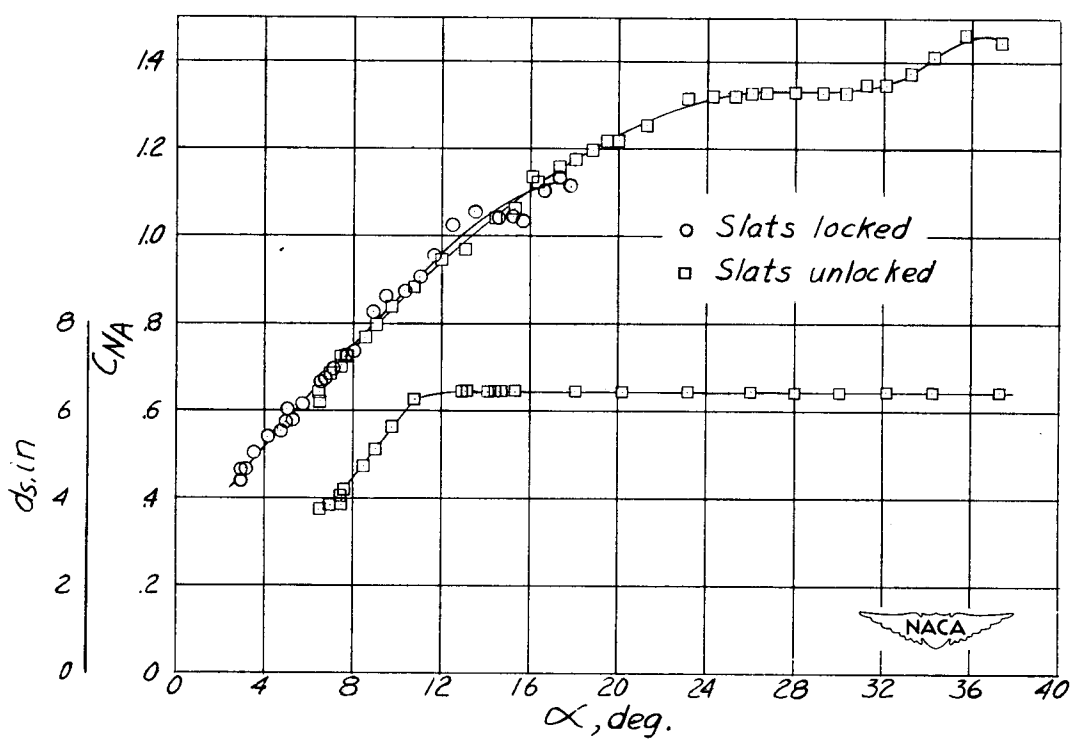


Figure 17.- Time history of a stall with the Douglas D-558-II (BuAero No. 37974) research airplane. Flaps down; landing gear down; slats unlocked; inlet-duct flaps open; stabilizer setting 1.72°; center of gravity at 26.3 percent mean aerodynamic chord.

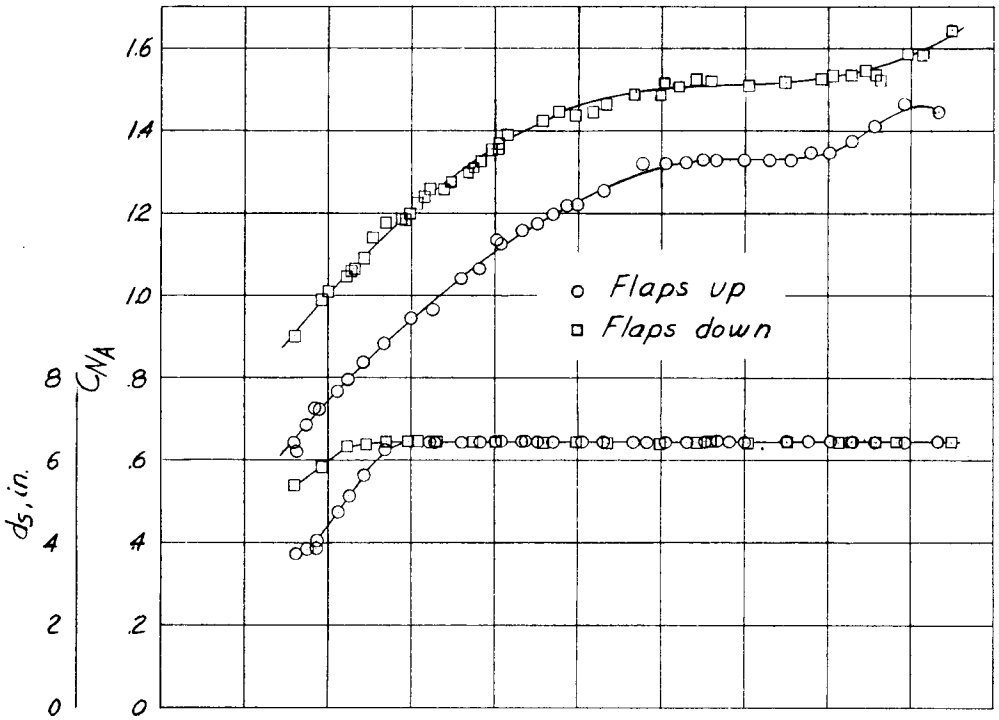


(b) Flaps down.

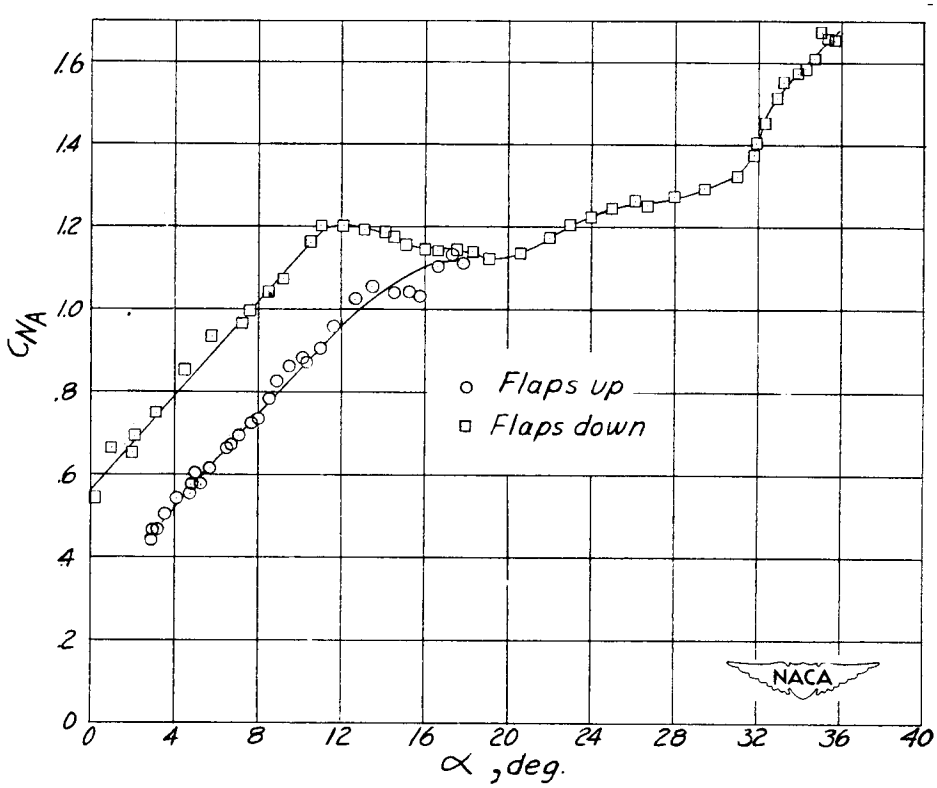


(a) Flaps up.

Figure 18.- Variation of airplane normal-force coefficient with angle of attack showing effect of slats.



(b) Slats unlocked.



(a) Slats locked.

Figure 19.- Variation of airplane normal-force coefficient with angle of attack showing effect of flaps.

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