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NACA

RESEARCH MEMORANDUM

STALL CHARACTERISTICS OBTAINED FROM FLIGHT 10 OF NORTHROP X-4 NO. 2 AIRPLANE (USAF NO. 46-677)

By Melvin Sadoff and Thomas R. Sisk

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Moffett Field, Calif.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
February 27, 1950

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

STALL CHARACTERISTICS OBTAINED FROM FLIG[redacted] OF NORTHROP X-4 NO. 2 AIRPLANE (USAF NO. 46-[redacted]

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ON [redacted]

SUMMARY

NACA instrumentation has been installed in the X-4 airplanes to obtain stability and control data during the acceptance tests conducted by the Northrop Aircraft Corporation. This report presents data obtained on the stalling characteristics of the airplane in the clean and gear-down configurations. The center of gravity was located at approximately 18 percent of the mean aerodynamic chord during the tests.

The results indicated that the airplane was not completely stalled when stall was gradually approached during nominally unaccelerated flight but that it was completely stalled during a more abruptly approached stall in accelerated flight. The stall in accelerated flight was relatively mild, and this was attributed to the nature of the variation of lift with angle of attack for the 0010-64 airfoil section, the plan form of the wing, and to the fact that the initial sideslip at the stall produced (as shown by wind-tunnel tests of a model of the airplane) a more symmetrical stall pattern.

INTRODUCTION

The X-4 airplane was constructed by the Northrop Company to provide the Air Force, the Navy, and the NACA with a research vehicle for obtaining stability and control information at high subsonic Mach numbers on an airplane having no horizontal tail.

Several reports have been published presenting limited stability and control information on this airplane. Reference 1 presents some longitudinal-stability data, stick fixed, with the center of gravity located at about 22 percent of the mean aerodynamic chord. References 2 and 3 include information on a poorly damped directional oscillation and on the lateral- and directional-stability characteristics, respectively. Reference 4 presents stability data with the center of gravity located at about 19.5 percent of the mean aerodynamic chord; in addition, lateral oscillation characteristics and dive-brake effectiveness data are also included.

To provide data on the stalling characteristics of this airplane prior to accelerated stability tests, flight 10 was made on the X-4 No. 2 airplane on September 30, 1949.

SYMBOLS

V_i	indicated airspeed, miles per hour
A_Z	normal acceleration factor (the ratio of the net aerodynamic force along the airplane Z axis to the weight of the airplane)
M	Mach number
q	dynamic pressure, pounds per square foot
F	stick force, pounds
S	wing area, square feet
W	airplane weight, pounds
α	angle of attack, degrees
β	sideslip angle, positive to the right, degrees
δ_e	elevon angle, positive downward, degrees
$\frac{\delta_{e_L} + \delta_{e_R}}{2}$	effective longitudinal control angle, degrees
C_N	airplane normal-force coefficient (WA_Z/qS)
F/q	stick-force factor, feet squared

Subscripts

L	left elevon
R	right elevon

AIRPLANE

The Northrop X-4 research airplane has a vertical tail but no horizontal tail. It is powered by two modified Westinghouse J-30-WE-7-9 engines and is designed for flight research in the high subsonic speed range. Photographs of the X-4 No. 1 airplane, which is identical to the test airplane, are presented in figure 1 and a three-view drawing is included as figure 2. The physical characteristics of the test airplane are listed in table I.

INSTRUMENTATION AND TEST PROCEDURE

Standard NACA instruments were used to record the altitude; airspeed; normal, transverse, and longitudinal acceleration; sideslip angle; right and left elevon positions; rudder position; yawing and rolling velocities; stick force; and elevon and rudder hinge moments as a function of time. In addition, the normal acceleration, altitude, airspeed, right and left elevon positions, and the rudder position were telemetered to a ground station. All the internal records were correlated by a common timer. Because of the uncertainty regarding the validity of the absolute magnitudes of the hinge-moment data, these quantities are not included in this report.

The airspeed and altitude recorders are connected to the airspeed head on the vertical fin. This installation has not been calibrated.

The test procedure was the same for all the stalls and consisted of a straight and level approach using no corrective rudder or lateral control until the stall occurred. Four gradual stall maneuvers were made in nominally unaccelerated flight at a pressure altitude of about 17,000 feet with the engine speed set at about 11,000 rpm. Two of these stall maneuvers were in the clean configuration and two were in the gear-down configuration. In addition, one abrupt stall was made in accelerated flight in the clean configuration at a pressure altitude of about 17,000 feet with the engine speed set at 13,000 rpm. The Reynolds numbers for these stalls based on the mean aerodynamic chord varied from 8.69×10^6 to 9.84×10^6.

RESULTS AND DISCUSSION

Typical time histories of the motion of the airplane and controls during the stall maneuvers are presented in figure 3.

The time histories of the gradual stall maneuvers in nominally unaccelerated flight (figs. 3(a) and 3(b)) show that as stall was approached the right wing dropped mildly and slight buffeting occurred. However, the pilot commented that the right wing dropped sharply with no warning. Recovery was easily and rapidly effected by the use of small down-elevon angles.

The time history of the abrupt stall in accelerated flight (fig. 3(c)) indicates fairly rapid right roll at the stall and moderate buffeting, although the stall is regarded as being relatively mild. The buffeting persisted throughout the recovery. The pilot commented that the characteristics in the abrupt stall were similar to those in the gradual stall, with the exception that noticeable buffeting, which was considered as a positive warning, occurred just prior to the actual stall. Recovery of the abrupt stall was rapid and complete following the use of down-elevon deflection.

From consideration of the time-history records and other data, it appears that the airplane was not completely stalled in the gradual stall maneuvers. The buffeting was milder than would be expected at complete stall. The velocity of roll-off at the stall was so mild as to fall, as indicated in reference 5, in the category of a stall warning rather than a stall. A maximum value of C_N of but about 0.71 was obtained in the gradual stall maneuvers; whereas a value of C_N of about 0.77 was obtained in tests of the X-4 No. 1 airplane reported upon in reference 4.

A comparison of the maximum values of normal-force coefficient obtained in flight with the values of $C_{L_{max}}$ obtained from three-dimensional and two-dimensional wind-tunnel tests (references 6 and 7, respectively) is presented in figure 4. The gradual stall values are considerably lower than the values obtained from wind-tunnel tests even though the wind-tunnel values of Reynolds number were considerably lower in general. However, since the wind-tunnel values were for zero elevon angle and the flight values were for elevons deflected about -15°, the discrepancy is not as large as it would appear. The -15° elevon deflection corresponds to a ΔC_N of about -0.08. Thus for zero elevon deflection the flight values of $C_{N_{max}}$ would be about 0.79. This value is still considerably below the wind-tunnel values that are indicated in figure 4 for flight Reynolds numbers, although it is above the value of about 0.60 at which, as indicated in figure 5 obtained from reference 8, separated flow occurred on the outboard portion of the right wing of the model during the wind-tunnel tests. It is believed, however, that the effect of separation on lateral trim and stability would not be apparent in actual flight until C_N was somewhat higher than 0.60, because of the higher Reynolds numbers of the flight tests. The value of $C_{N_{max}}$ which could be obtained in flight would no doubt depend upon the pilot's ability to hold wings level by use of the controls after initial separation occurred over part of the wing.

The more abrupt stall (fig. 3(c)) was believed to be complete since the roll-off was pronounced, and increasing up-elevon at the stall had no effect in increasing $C_{N_{max}}$ above about 0.85. As shown in figure 4, the value of $C_{N_{max}}$ obtained in the abrupt stall is in better agreement with the wind-tunnel values, although this comparison also is not strictly valid because of the difference in elevon deflection and because of the effect on the flight value of $C_{N_{max}}$ of the relatively rapid change in angle of attack as the stall was approached. The effect of this latter factor in the gradual stalls is probably very small.

The relative mildness of the abrupt stall is probably due to the nature of the variation of lift with angle of attack for the 0010-64 airfoil section, the plan form of the wing, and to the effect of sideslip on the stalling characteristics. The lift curves for the 0010-64 airfoil section and for a 1/4-scale model of the X-4 airplane are shown in figure 6 for several values of Mach number. Even though breakdown of flow first occurs at the tip sections of a swept-back wing, the use of airfoil sections and plan forms which maintain their lift beyond initial separation tends to reduce the magnitude of the rolling and pitching moments that are applied. Also, during roll-off at the stall sideslip occurs which reduces the asymmetry causing the roll. The effect of sideslip on the separated flow conditions over the wing is shown in figure 5.

The stick-fixed and stick-free longitudinal-stability characteristics near the stall are presented in figures 7 and 8, respectively. The data were obtained in steady straight flight with the exception of the point at $C_{N_{max}}$ for the abrupt stall. The stick-fixed data indicate an apparent increase in stability as the normal-force coefficient is increased. This increase in stability which persists to values of C_N approaching the stall is a desirable characteristic, since it reduces the danger of inadvertent stalling. The corresponding stick-free characteristics (fig. 8) show positive and nearly constant stability up to values of C_N approaching those at the stall.

Although elevon hinge-moment data are not presented because of the uncertainty regarding the absolute magnitudes, the data showed that the right-elevon hinge-moment variation with C_N was similar to that of the longitudinal control.

In summary, it may be noted that the stalling characteristics, as measured in flight, were in general agreement with the stalling characteristics predicted from wind-tunnel tests.

CONCLUSIONS

The results of stall tests, as determined from flight 10 on the X-4 No. 2 airplane, and a comparison of these results with wind-tunnel measurements led to the following conclusions:

1. The gradual stall maneuvers, made at indicated airspeeds of about 140 miles per hour at approximately a pressure altitude of 17,000 feet, corresponding to maximum values of normal-force coefficient of 0.71, were incomplete stalls. The abrupt stall to about an A_Z of 1.60, made at an indicated airspeed of about 165 miles per hour and a pressure altitude of about 17,000 feet, was believed to be complete. The maximum normal-force coefficient in this case was 0.85.

2. The maximum normal-force coefficient obtained in the abrupt stall compared favorably with the wind-tunnel values. Those values obtained in the gradual stall maneuvers were considerably lower than

comparable wind-tunnel values. This discrepancy was believed due to the fact that these stall maneuvers were not complete stalls. Conceivably, higher values of normal-force coefficient could have been obtained by using corrective control to maintain wings-level flight.

3. The relative mildness of the abrupt stall was traced to the flat-top type of lift-curve characteristic of the 0010-64 airfoil section, the plan form used, and to the effect of sideslip on the stalling characteristics.

4. The stick-fixed longitudinal-stability data near the stall indicated an apparent increase in stability over that existing at low normal-force coefficients. This increase was considered desirable, since it reduced the danger of inadvertent stalling. The stick-free stability was positive and nearly constant over the C_N range.

Ames Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Moffett Field, Calif.

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2. Williams, Walter C.: Results Obtained From Second Flight of X-4 Airplane (A.F. No. 46-676). NACA RM L9F21, 1949.

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4. Valentine, George M.: Stability and Control Data Obtained From Fourth and Fifth Flights of the Northrop X-4 Airplane (A.F. No. 46-676). NACA RM L9G25a, 1949.

5. Anderson, Seth B.: Correlation of Pilot Opinion of Stall Warning with Flight Measurements of Various Factors Which Produce the Warning. NACA TN 1868, 1949.

6. Preliminary Report on High-Speed Wind-Tunnel Tests of a 1/4-Scale Reflection Plane Model of the Northrop XS-4 Airplane. Rep. No. 69, Southern Calif. Cooperative Wind Tunnel, Calif. Inst. Tech., Pasadena, Calif., Oct. 28, 1948.

7. Polentz, Perry P.: Comparison of the Aerodynamic Characteristics of the NACA 0010 and 0010-64 Airfoil Sections at High Subsonic Mach Numbers. NACA RM A9G19, 1949.

8. Pass, H. R., and Hayes, B. R.: Wind-Tunnel Tests of a 1/4-Scale Model of the Northrop XS-4 Airplane. Rep. No. A WT 46, Northrop Aviation Corp., 1947.

TABLE I.- PHYSICAL CHARACTERISTICS OF X-4 AIRPLANE

Engines (two)	Westinghouse J-30-WE-7-9
Rating (each) static thrust at sea level, pounds	1600
Airplane weight, pounds	
Maximum (238 gal fuel)	7786
Minimum (10 gal fuel trapped)	6406
Wing loading, pounds per square foot	
Maximum	38.9
Minimum	32.0
Center-of-gravity travel (flight 10), percent M.A.C.	
Gear down, full load	19.35
Gear down, empty	16.65
Gear up, full load	19.05
Gear up, empty	16.25
Height, over-all, feet	14.83
Length, over-all, feet	23.25
Wing	
Area, square feet	200
Span, feet	26.83
Airfoil section	0010-64
Mean aerodynamic chord, feet	7.81
Aspect ratio	3.6
Root chord, feet	10.25
Tip chord, feet	4.67
Taper ratio	2.2:1
Sweepback (leading edge), degrees	41.57
Dihedral (chord plane), degrees	0
Wing flaps (split)	
Area, square feet	16.7
Span, feet	8.92
Chord, percent wing chord	25
Travel, degrees	30

TABLE I.– CONCLUDED

Dive brake dimensions as flaps	
Travel, degrees	±60
Elevons	
Area (total), square feet	17.20
Span (2 elevons), feet	15.45
Chord, percent wing chord	20
Movement, degrees	
Up	35
Down	20
Operation	Hydraulic with electrical emergency
Vertical tail	
Area, square feet	16
Height, feet	5.96
Rudder	
Area, square feet	4.1
Span, feet	4.3
Travel, degrees	±30
Operation	Direct

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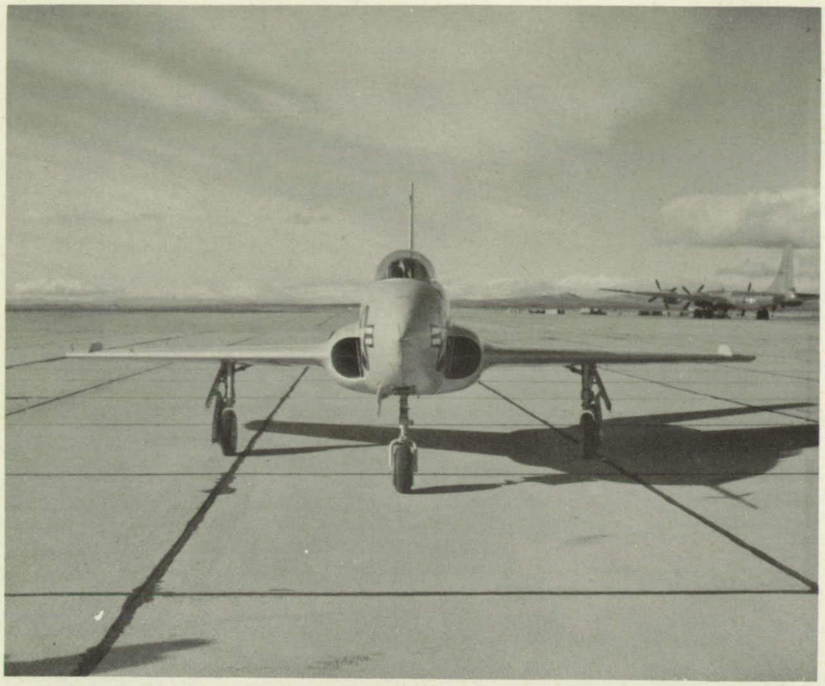

(a) Front view.

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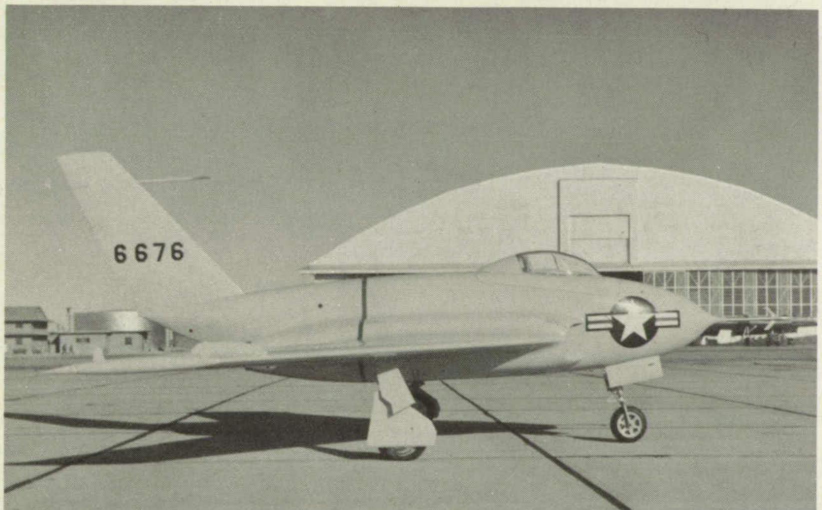

(b) Side view.

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Figure 1.- The Northrop X-4 Airplane.

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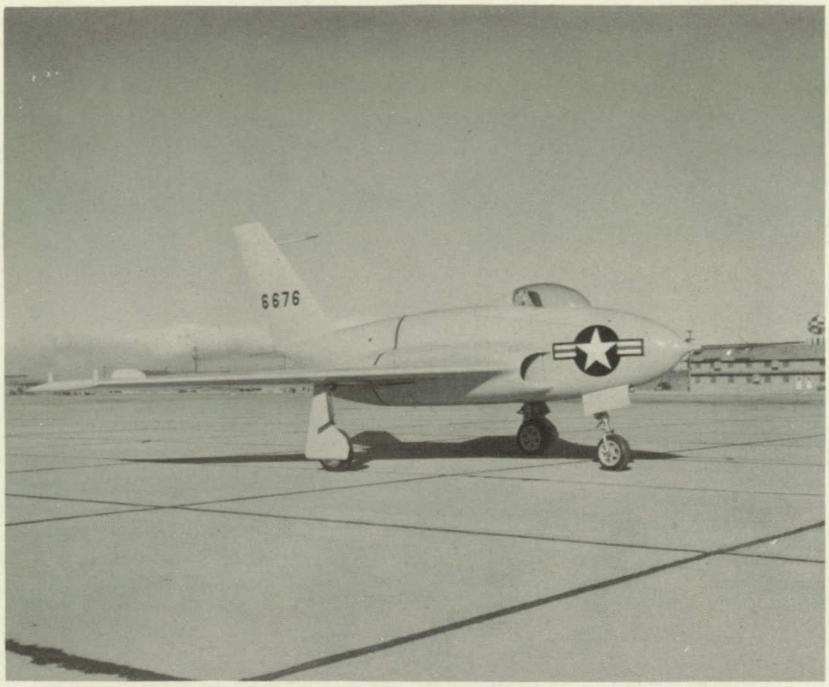

(c) Quarter front view. A-14773

(d) Three–quarter rear view. A-14774

Figure 1.– Continued.

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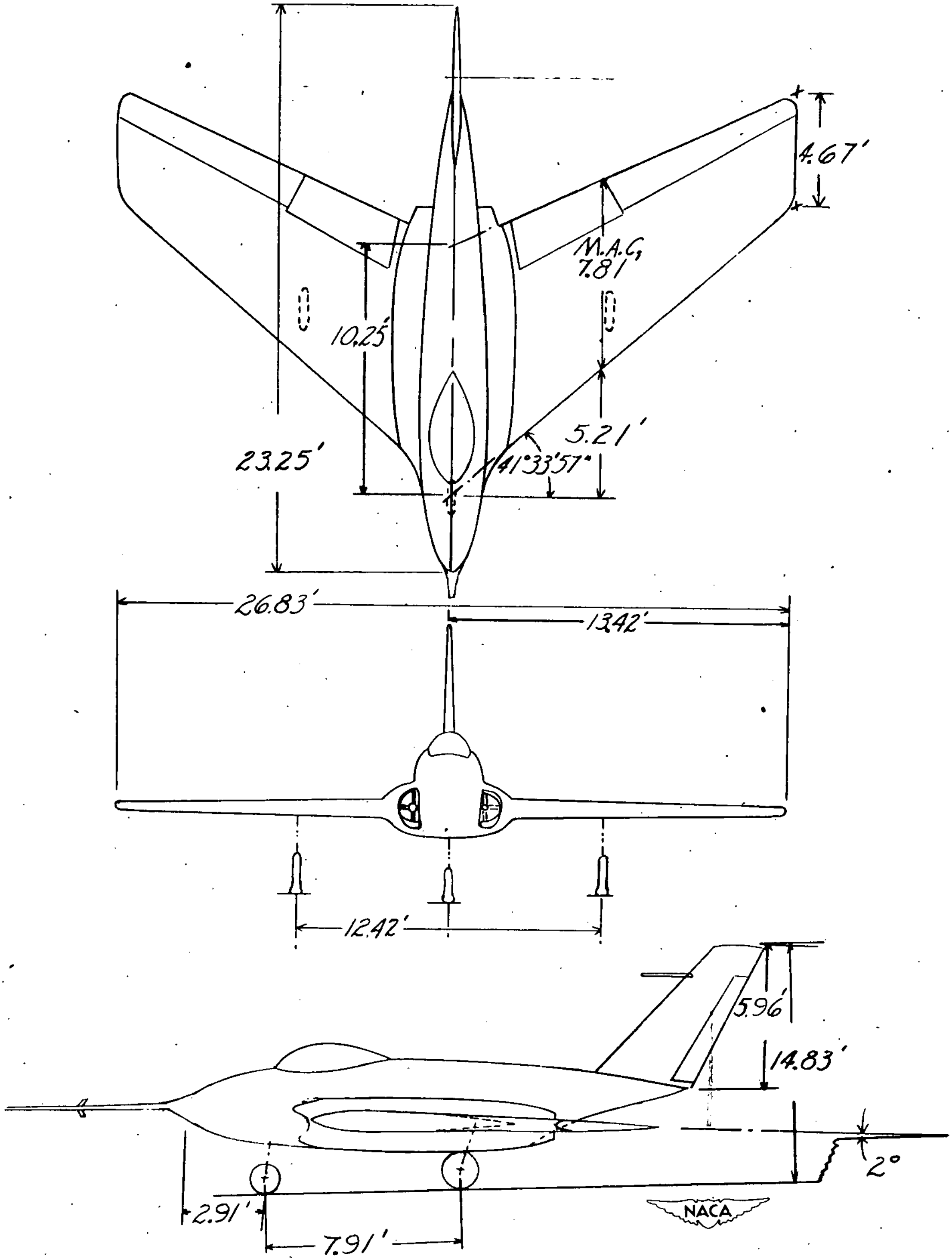

Figure 2.– Three-view drawing of X-4 Airplane.

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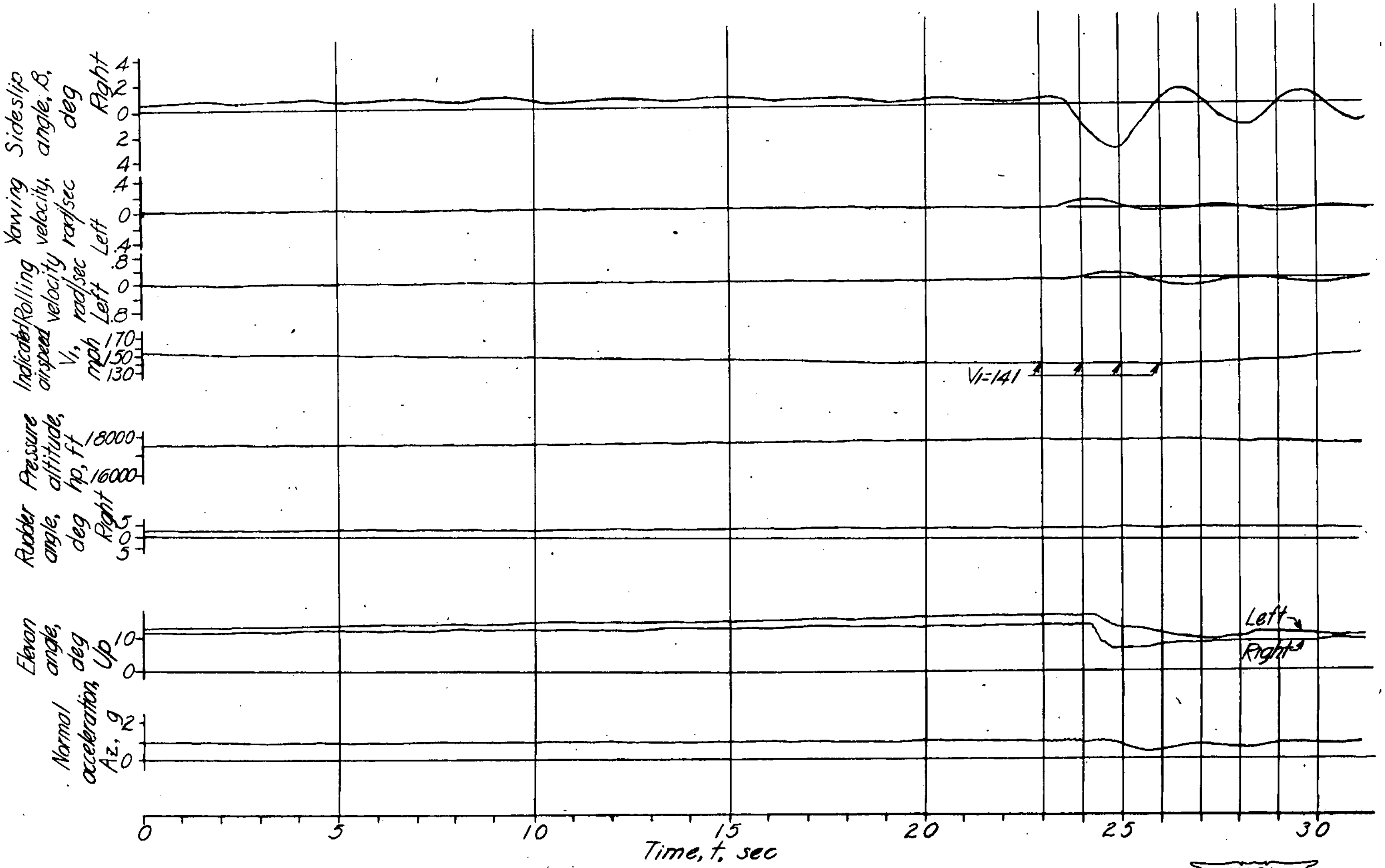

(a) Clean condition; 1 g stall; $R_{std} = 8.69 \times 10^6$.

Figure 3.- Time histories of stalls on Northrop X-4 Airplane.

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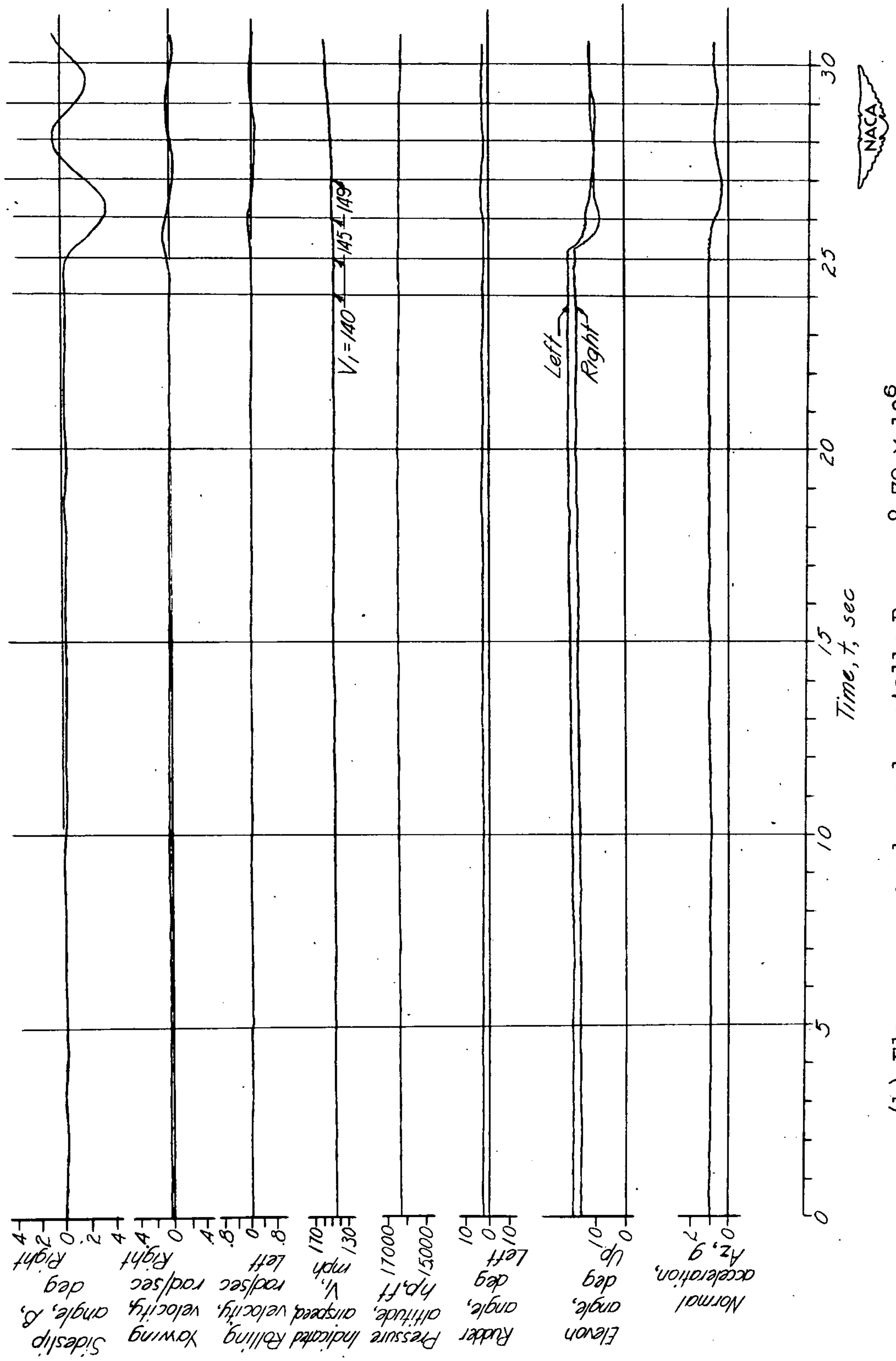

(b) Flaps up, gear down; 1 g stall; R_{std} = 8.79 × 10^6.

Figure 3.- Continued.

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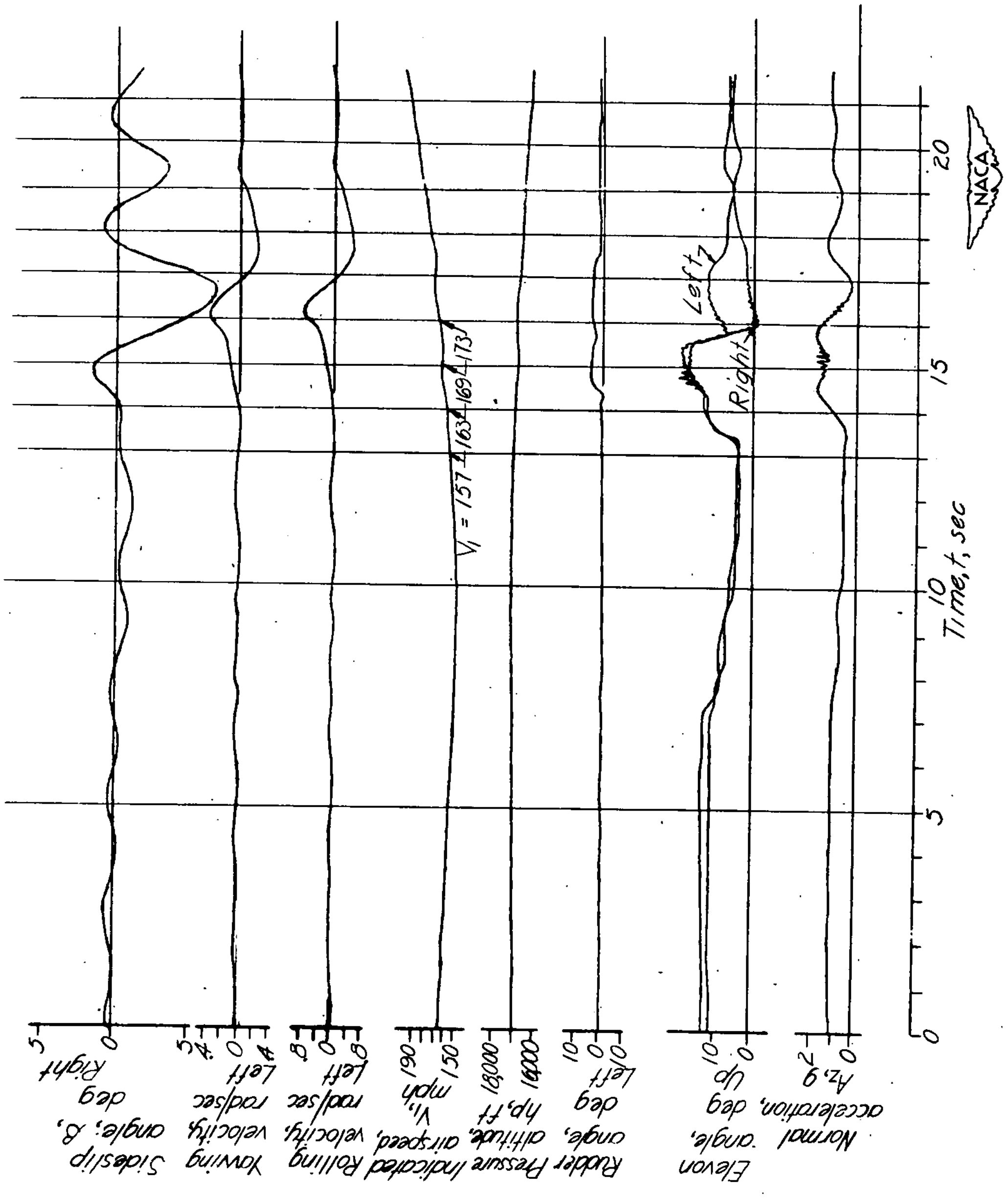

(c) Clean condition; stall at 1.60 g; $R_{std} = 9.84 \times 10^6$.

Figure 3.- Concluded.

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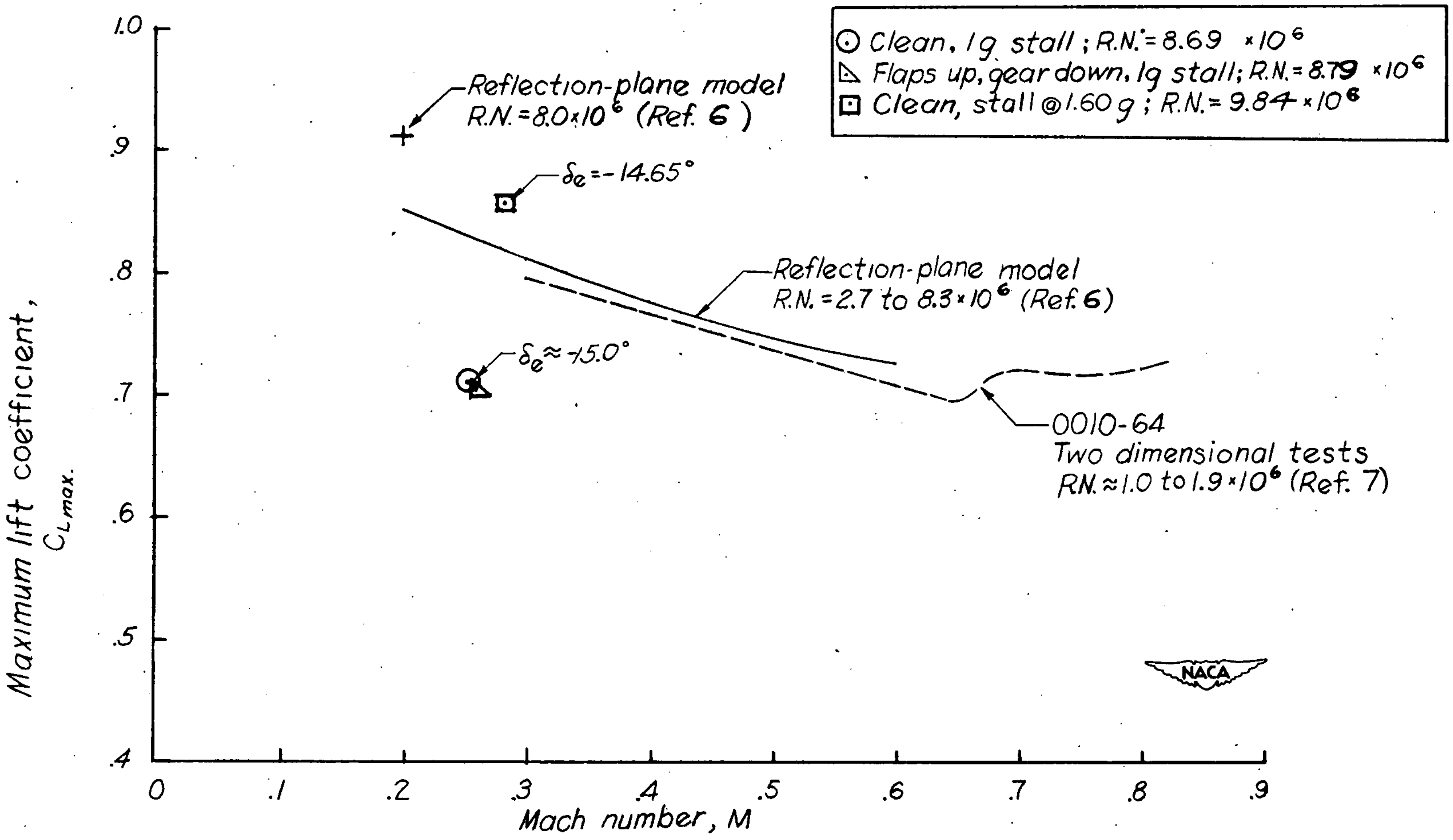
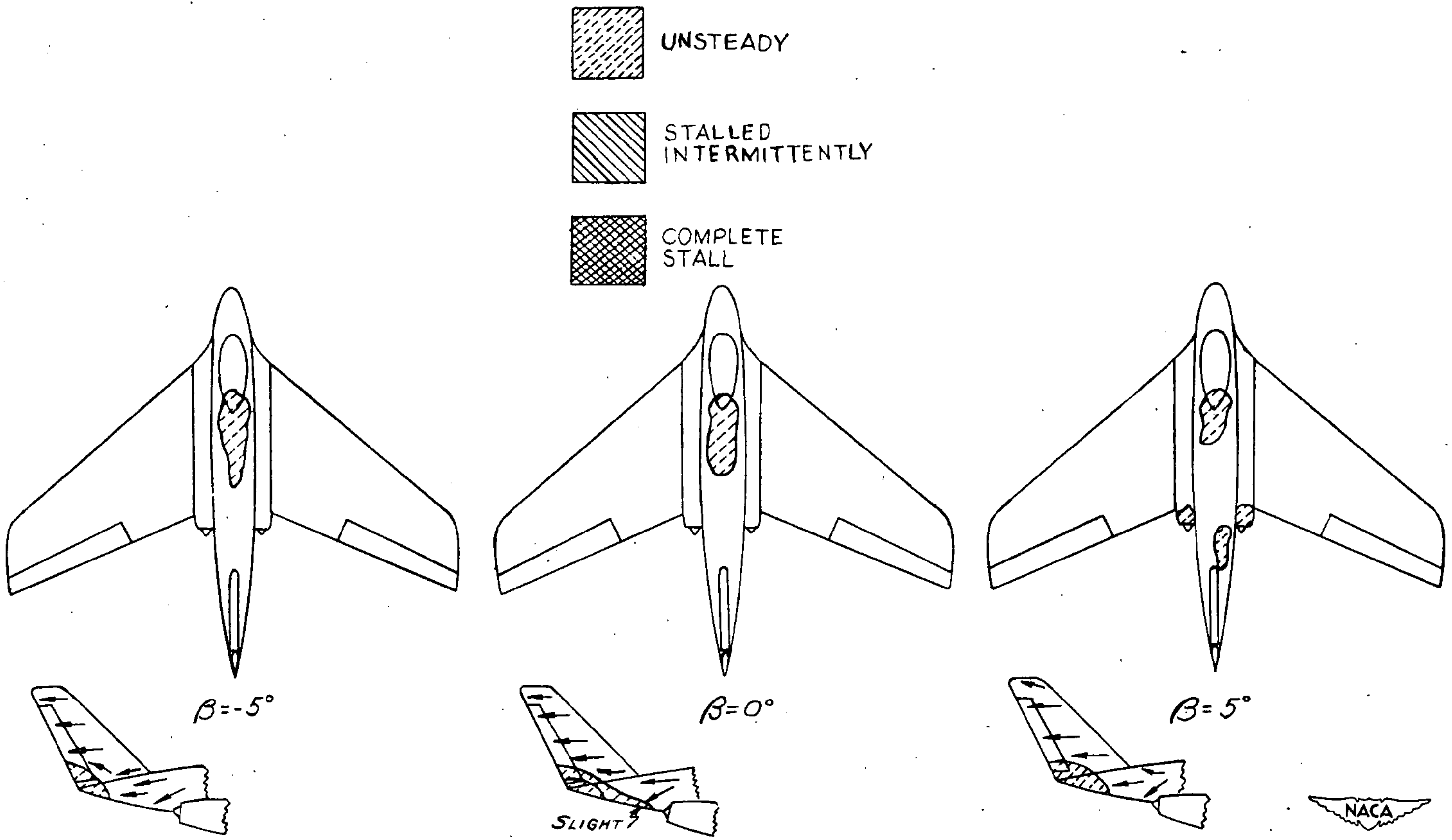


Figure 4.– Comparison of $C_{L_{max}}$ obtained in flight on Northrop X-4 Airplane with values obtained from two-dimensional and three-dimensional wind-tunnel tests.



(a) $C_{L_{\beta=0}} = 0.13$.

Figure 5.– Stall progression on Northrop X-4 1/4-scale model; Reynolds number = 2.1×10^6 (reference 8).

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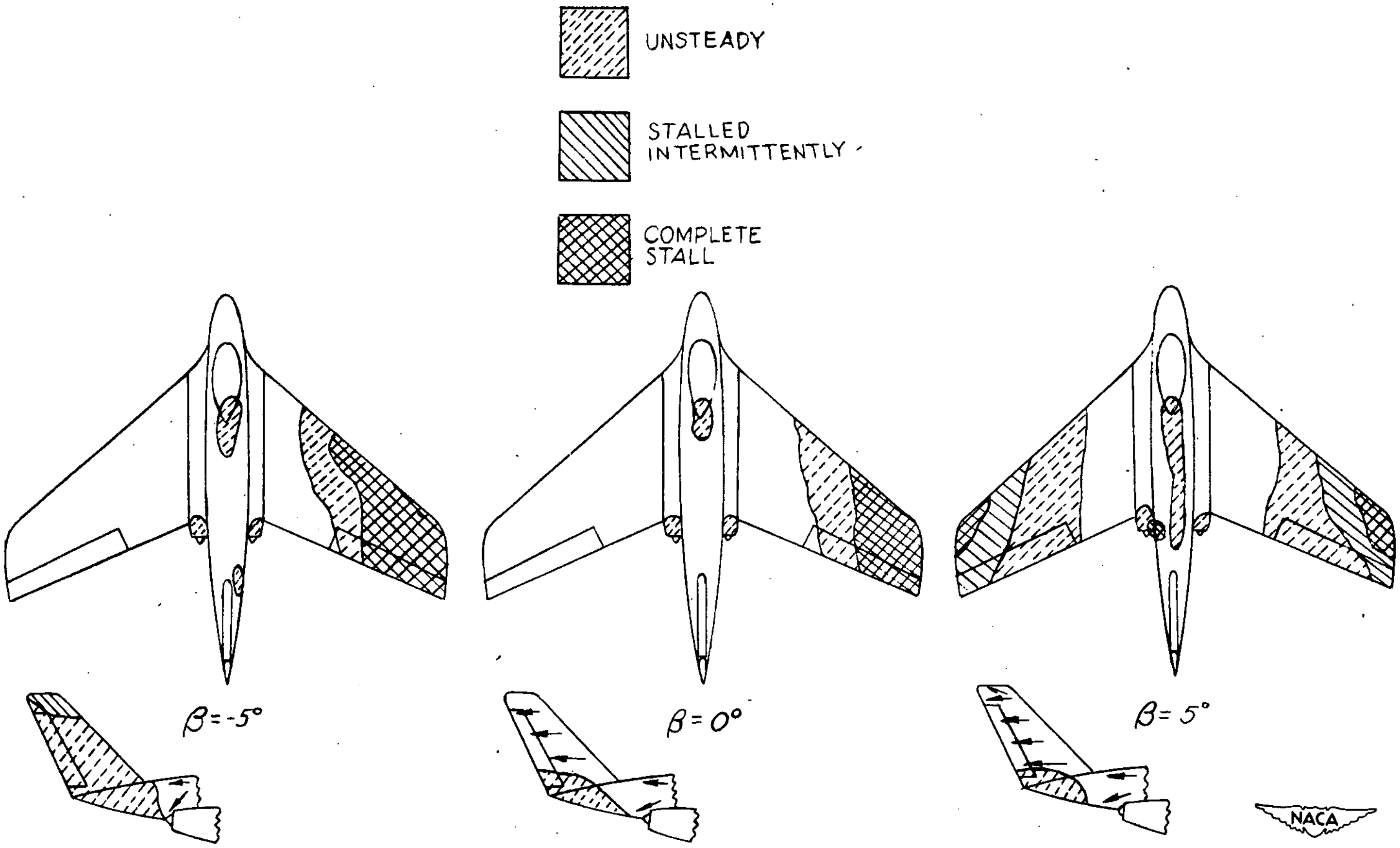

(b) $C_{L_{\beta=0}} = 0.61$.

Figure 5.- Continued.

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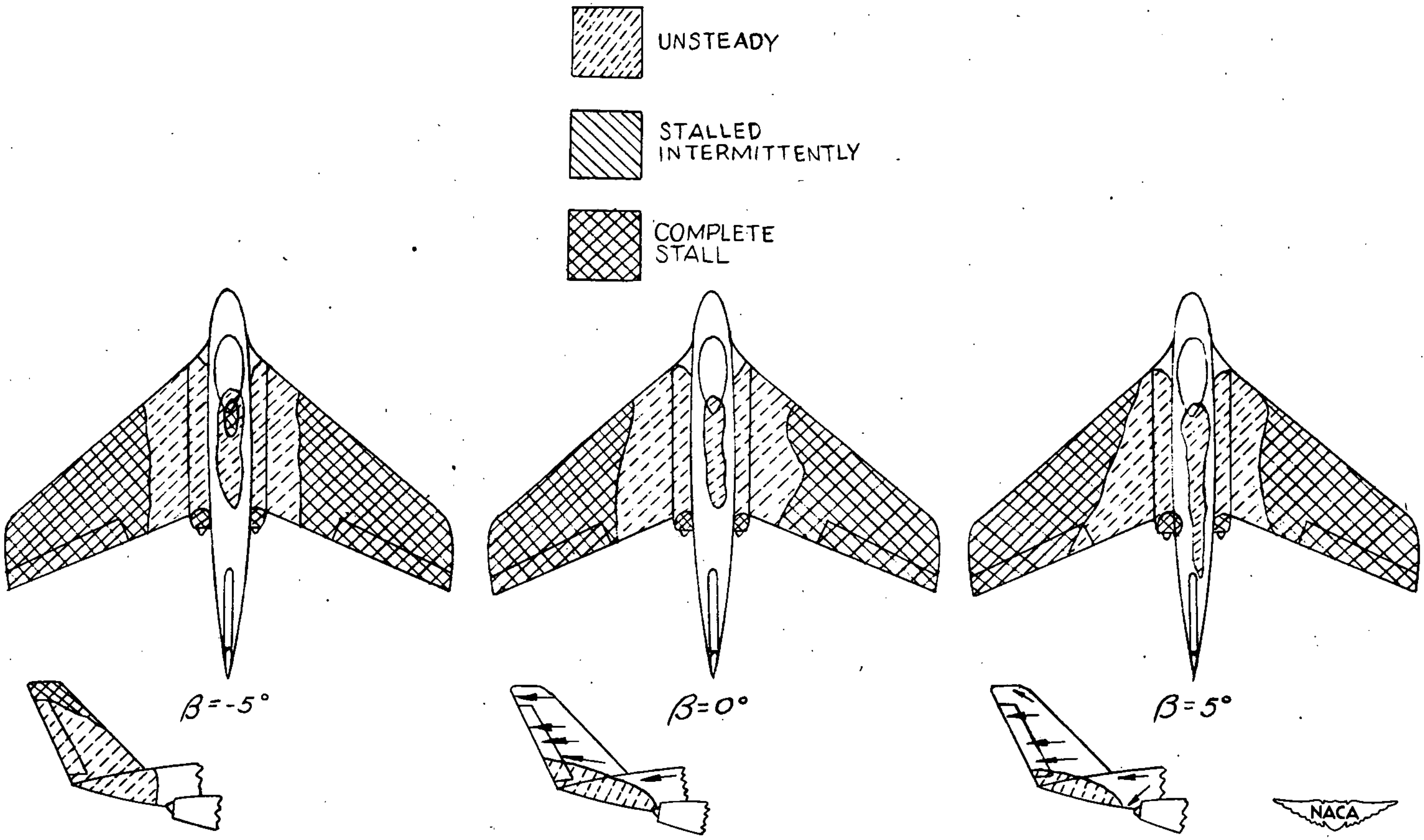

(c) $C_{L_{\beta=0}} = 0.86.$

Figure 5.– Concluded.

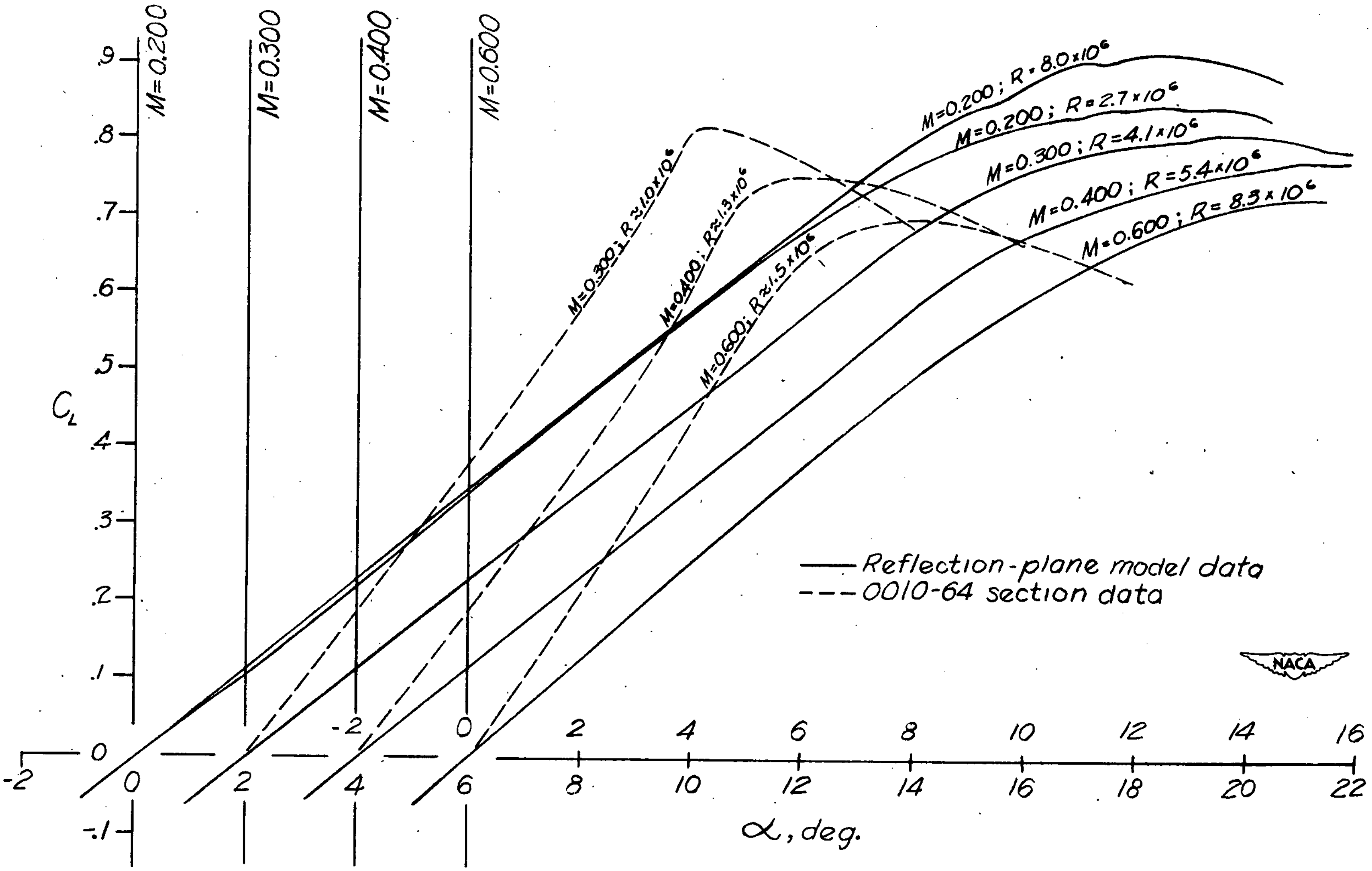

Figure 6.– Lift coefficient as a function of angle of attack at several Mach numbers. Reflection–plane model data (reference 6) and 0010–64 section data (reference 7).

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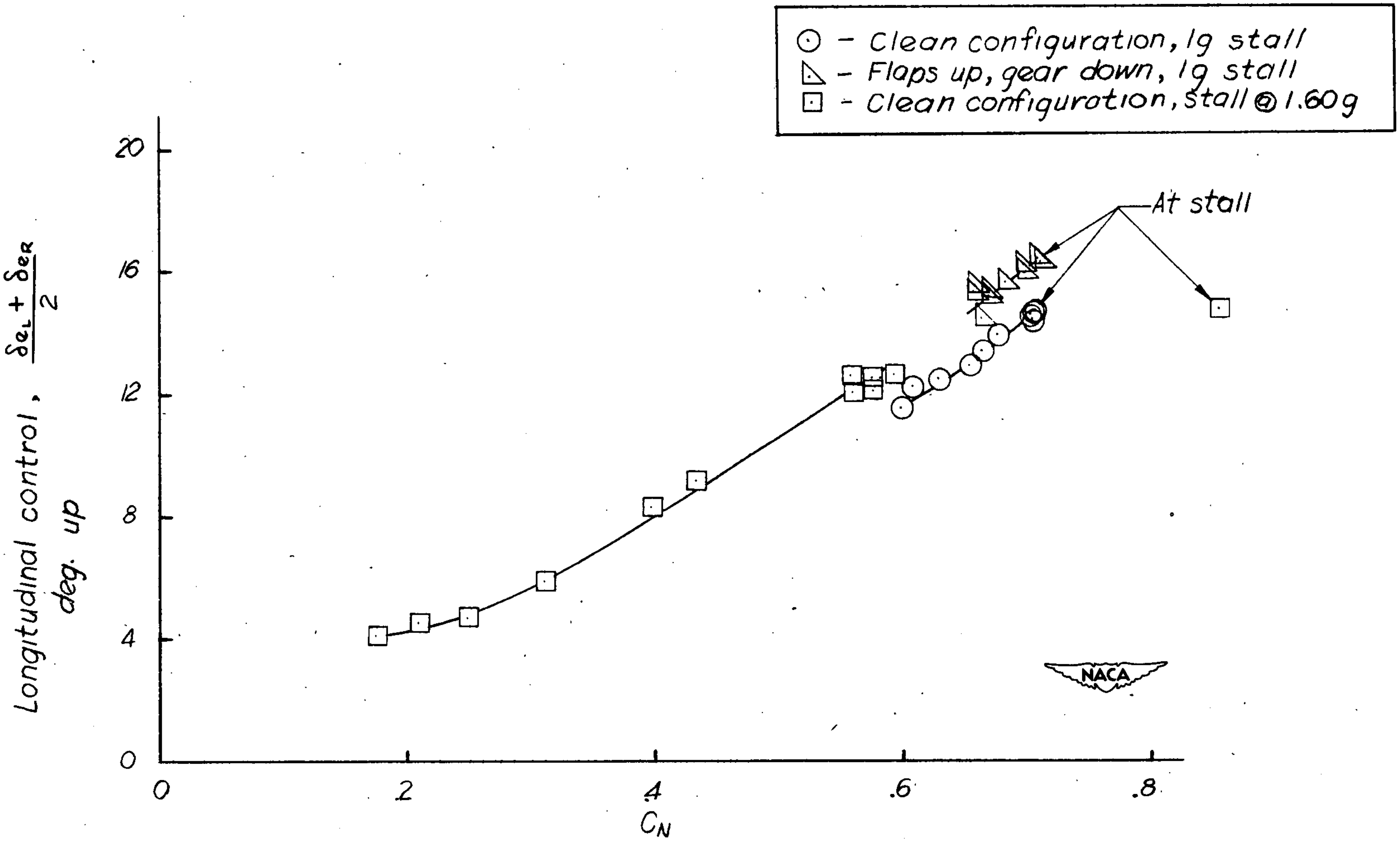

Figure 7.- Stick-fixed longitudinal-stability characteristics near the stall. Northrop X-4 Airplane.

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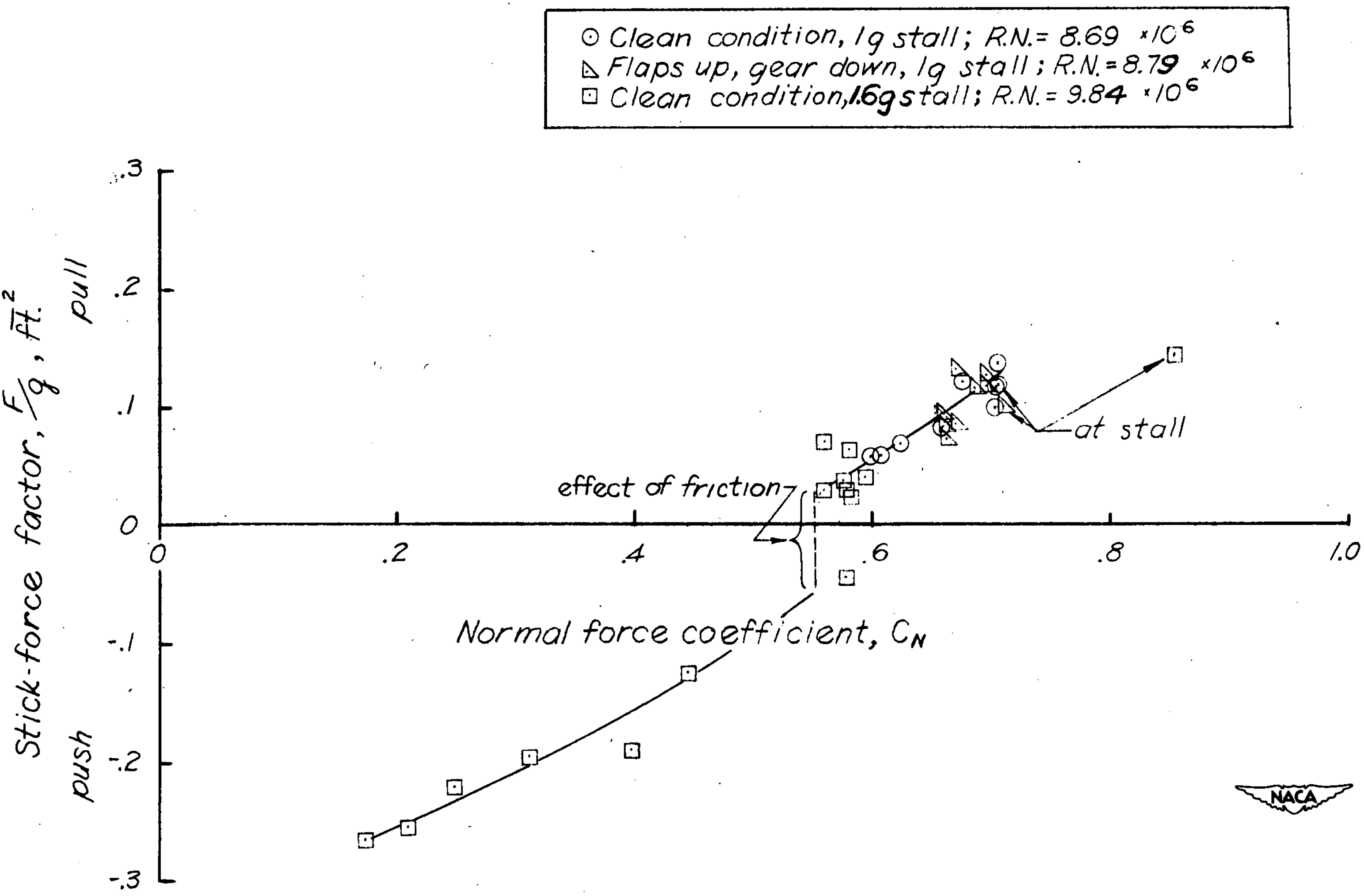

Figure 8.– Stick–free longitudinal–stability characteristics near stall.