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# RESEARCH MEMORANDUM

## FLIGHT DETERMINATION OF THE LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF THE BELL X-5 RESEARCH AIRPLANE AT 58.7° SWEEPBACK

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

May 26, 1955

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RESEARCH MEMORANDUM

# FLIGHT DETERMINATION OF THE LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF THE BELL X-5 RESEARCH AIRPLANE AT 58.7° SWEEPBACK

By Thomas W. Finch

## SUMMARY

The Bell X-5 research airplane has been primarily tested at 58.7° sweepback during the program to determine the characteristics of a variable-sweep fighter airplane at transonic speeds. Limited stability and control characteristics at 58.7° sweepback have been previously discussed with the presentation of the boundary for reduction of static longitudinal stability at 40,000 feet for Mach numbers up to 0.98. This paper presents the stability and control characteristics in the stable lift range up to Mach numbers near 1.0 at an altitude of 40,000 feet and to slightly lower Mach numbers at altitudes of 25,000 feet and 15,000 feet.

The high values of the apparent stability parameter $d\delta_e/dC_{N_A}$ and stick force gradient $dF_e/dn$ (minimum of -15 and 17, respectively) approximately doubled from low to moderate lifts. At moderate lifts the values of $d\delta_e/dC_{N_A}$ and $dF_e/dn$ increased about 4 and 7 times, respectively, over a Mach number range of 0.64 to 1.01. Calculations indicated that the rapid increase in $d\delta_e/dC_{N_A}$ near Mach numbers of about 0.90 was attributable to a reduction in the elevator effectiveness parameter $C_{m_{\delta_e}}$. At moderate lifts for a Mach number range of about 0.90 to 1.01 the apparent stability parameter $di_t/dC_{N_A}$ increased about 3 times from a nearly constant value below a Mach number of 0.90.

The relative elevator-stabilizer effectiveness parameter $di_t/d\delta_e$ decreased from about 0.35 to 0.25 as the Mach number increased from 0.68 to 1.0.

A threefold increase in dynamic pressure caused $d\delta_e/dC_{N_A}$ and $dF_e/dn$ to increase appreciably.

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Although the dynamic characteristics were influenced by cross-coupling between lateral and longitudinal motions, the short period longitudinal oscillation was well damped.

Comparisons with wind-tunnel results showed reasonably good agreement except for control effectiveness at high Mach numbers.

## INTRODUCTION

The Bell X-5 research airplane was obtained for the National Advisory Committee for Aeronautics by the U. S. Air Force as part of the joint Air Force-Navy-NACA high-speed flight research program to investigate the characteristics of a variable-sweep fighter-type airplane at transonic speeds. The tests to date have been performed primarily at 58.7° sweepback. Published data can be found in references 1 to 6.

Early in the research program as the flight characteristics at 58.7° sweepback were being investigated, a reduction of static longitudinal stability, or pitch-up, was encountered which severely limited the stable range for maneuvering flight. The boundary for stability reduction and flight characteristics at high lifts for Mach numbers up to 0.98 were discussed in reference 3. One attempt was made to reduce the severity of the pitch-up by modifying the wing leading-edge fillet similar to a modification tested in reference 7; however, the results of reference 4 indicate the fix was ineffective.

This paper primarily discusses the longitudinal stability and control characteristics in the stable lift range at an altitude of 40,000 feet for Mach numbers up to about 1.0 and at altitudes of 25,000 feet and 15,000 feet for slightly lower Mach numbers. Stalling characteristics are not included.

## SYMBOLS

$C_{N_A}$ airplane normal-force coefficient, $\frac{nW}{qS}$

$C_{m_\alpha}$ rate of change of airplane pitching-moment coefficient with angle of attack, $deg^{-1}$

$C_{m_{\delta_e}}$ elevator effectiveness parameter, $deg^{-1}$

| | |
|---|---|
| $\frac{d\delta_e}{dC_{N_A}}$ | rate of change of elevator deflection with airplane normal-force coefficient, deg |
| $\frac{di_t}{dC_{N_A}}$ | rate of change of stabilizer deflection with airplane normal-force coefficient, deg |
| $\frac{di_t}{d\delta_e}$ | relative elevator-stabilizer control effectiveness parameter |
| $\frac{d\delta_e}{dn}$ | rate of change of elevator deflection with normal acceleration, deg/g |
| $\frac{dC_{N_A}}{d\alpha}$ | normal-force curve slope, $deg^{-1}$ |
| $\frac{dF_e}{dn}$ | rate of change of elevator stick force with normal acceleration, lb/g |
| $\frac{dC_m}{dC_L}$ | static longitudinal stability parameter |
| $F_e$ | elevator stick force, lb |
| $g$ | acceleration due to gravity, $ft/sec^2$ |
| $h_p$ | pressure altitude, ft |
| $I_Y$ | moment of inertia about Y-axis, $slug\text{-}ft^2$ |
| $i_t$ | angle of tail incidence measured from line parallel to longitudinal axis of airplane, (positive when leading edge of stabilizer up), deg |
| $M$ | Mach number |
| $n$ | normal acceleration, g units |
| $P$ | period of longitudinal oscillation, sec |
| $q$ | dynamic pressure, lb/sq ft |
| $S$ | wing area, sq ft |

$T_{1/2}$ time to damp to half amplitude of longitudinal oscillation, sec

$t$ time, sec

$V_c$ calibrated airspeed, mph

$W$ airplane weight, lb

$\alpha$ angle of attack, measured from thrust axis of airplane, deg

$\beta$ angle of sideslip, deg

$\delta_e$ root elevator control deflection, deg

$\dot{\theta}$ pitching velocity, radians/sec

$\dot{\psi}$ yawing velocity, radians/sec

$\dot{\phi}$ rolling velocity, radians/sec

Subscript:

max maximum

## DESCRIPTION OF AIRPLANE

The Bell X-5 airplane is a transonic research airplane incorporating a wing which has sweepback variable in flight between 20° and 58.7°. It is a single-place fighter-type airplane powered by an Allison J35-A-17 turbojet engine. A three-view drawing of the airplane with 58.7° sweepback is given in figure 1. A photograph is presented in figure 2. The airplane physical characteristics are given in table I. The longitudinal control system is composed of an unboosted elevator control with a 20.8 percent overhang balance. In addition a motor-driven stabilizer is used for trim and to supplement the elevator control. The friction in the elevator control system is very light, on the order of ±0.5 pound.

## INSTRUMENTATION AND ACCURACY

The following quantities pertinent to this investigation were recorded on NACA internal recording instruments synchronized by a common timer:

Airspeed
Altitude
Normal acceleration
Angle of attack and angle of sideslip

Root and tip elevator deflections
Stabilizer deflection
Elevator stick force
Pitching velocity
Rolling velocity
Yawing velocity
Wing sweep angle

An NACA type A-6 total pressure head was mounted on a nose boom shown in figure 1. The position error of the head was calibrated in flight and the accuracy of Mach number obtained from the airspeed calibration is within ±0.01. The maximum error in the determination of the airplane normal-force coefficient is about ±0.03. The angle of attack was measured by a vane located on the same nose boom and the data are presented uncorrected for boom bending, vane floating angle, pitching velocity, and upwash.

## TESTS

The tests were conducted in the clean configuration with the center-of-gravity position at about 45 percent of the mean aerodynamic chord up to Mach numbers near 1.0 at 40,000 feet and to slightly lower Mach numbers at altitudes of 25,000 feet and 15,000 feet.

Longitudinal elevator-pulse data were obtained near trim lift for 1 g flight up to Mach numbers of about 0.97 at altitudes of 40,000 feet and 25,000 feet. Limited data were obtained at 15,000 feet. The trim data presented for altitudes near 40,000 feet were obtained in level flight up to the drag rise at $M = 0.93$ (ref. 5) and in shallow dives at higher Mach numbers. Limited trim data were also obtained at test altitudes of 25,000 feet and 15,000 feet. All trim runs were made at 100 percent rpm.

Accelerated flight data were obtained at constant rpm during gradual push-down pull-up maneuvers performed with the elevator over the lift range at 40,000 feet up to Mach numbers near 1.0 and for low lifts during wind-up turns at altitudes of 25,000 feet and 15,000 feet for Mach numbers up to 0.96 and 0.92, respectively. Gradual pull-ups were performed with the stabilizer control for moderate and high lifts at 40,000 feet up to about $M = 1.0$.

## RESULTS AND DISCUSSION

### General Comments

The stability regions encountered during the flight testing of the Bell X-5 airplane at 58.7° are evident in the typical accelerated maneuver presented in figure 3. As the airplane traverses the lift range, the stability increases from a nearly constant value at low lifts (region A) to a larger value at moderate lifts (region B). As lift is further increased an abrupt reduction in stability is encountered resulting in a pitch-up, sometimes to $C_{N_{A_{max}}}$. As discussed in reference 3, the pitch-up was rendered more objectionable to the pilot by the occurrence of directional divergence and aileron overbalance. The boundaries for $C_{N_{A_{max}}}$ presented in reference 6 and peak $C_{N_A}$ reached at higher Mach numbers are shown in figure 4. The boundary for the reduction in stability dividing the lift regime of the airplane into a stable and a pitch-up region is also presented in figure 4. This boundary was presented and discussed in reference 3 for Mach numbers up to 0.98. At higher Mach numbers insufficient control was available to establish the boundary. The gradual increase in stability from region A to region B occurs in a $C_{N_A}$ range represented by a cross-hatched area in figure 4. This $C_{N_A}$ range corresponds to an angle-of-attack range of about 2°. Wind-tunnel results of reference 8 indicated that a similar change in stability through about the same incremental angle of attack was caused by an increase in the wing-fuselage contribution to stability. Unpublished flight measurements of wing loads and horizontal-tail loads data also indicate a similar change in stability.

The normal-force-coefficient variations for 1 g flight at an average test weight of 8,800 pounds are also shown in figure 4 for altitudes of 40,000, 25,000, and 15,000 feet. It may be seen that any data obtained near trim lifts at 40,000 feet may be influenced by changing stability, whereas data obtained near trim lifts at the lower test altitudes are within a constant stability region.

It should also be noted that, because of the general unsteady behavior of the airplane resulting from coupling of the longitudinal and lateral motions, there is more scatter in the data than might normally be expected.

## Static Stability and Control Characteristics

Trim data.- The variations of elevator deflection, elevator stick force, and normal-force coefficient with Mach number obtained from representative speed runs near 1 g are presented in figure 5 for a range of stabilizer deflections of $-1.4^{\circ}$ to $-3.15^{\circ}$ at an altitude of approximately 40,000 feet. In general the data at the various stabilizer deflections show similar trends over the Mach number range, indicating that ample elevator control power is available to trim the airplane. The stick-force variations show the same general trends as shown by the elevator control. The forces measured over the Mach number range were on the order of 35 pounds push to 25 pounds pull and were considered moderate by the pilot.

Because of the variations in altitude, weight, and normal acceleration, each group of data covered a slightly different $C_{N_A}$ range. These data were corrected to the same 1 g variation at 40,000 feet for an average test weight of 8,800 pounds by using the values of $d\delta_e/dC_{N_A}$ presented later, and are replotted in figure 6. These data show a more systematic variation than the uncorrected data, indicating a stable variation with Mach number up to the characteristic nose-down or unstable trim variation occurring near a Mach number of 0.93. By cross-plotting the elevator trim data, a 1 g trim variation of the stabilizer control with $\delta_e = 0^{\circ}$ was obtained as shown in figure 6. About $2^{\circ}$ of stabilizer was required for trim over a Mach number range of 0.61 to 0.98; and, as expected from the greater effectiveness of the stabilizer, the trim variation with Mach number was more gradual.

Altitude effects on trim.- The variation of elevator deflection required for 1 g trim is presented in figure 7 as a function of Mach number and calibrated airspeed for altitudes of 40,000, 25,000, and 15,000 feet at a stabilizer deflection of $-1.5^{\circ}$. The trim variations at 40,000 feet and 25,000 feet are approximately those expected in the Mach number range for stable trim; however, the effect of altitude is evident in the trim variation at 15,000 feet as Mach number increases. At calibrated airspeeds low enough to avoid compressibility effects for all test altitudes $(V_c < 300 \text{ mph})$ altitude has no appreciable effect on trim. A stable break in the trim curve at higher speeds is characteristic of all test altitudes but is most evident at about $V_c = 400$ mph for 25,000 feet. The unstable trim variation starts at about $M = 0.93$ for altitudes of 40,000 feet and 25,000 feet and at about $M = 0.91$ for 15,000 feet. (Corresponding values of $V_c$ are about 360, 460, and 540 mph, respectively.) The effects of altitude on control characteristics are discussed in detail later in this paper.

Power effects.- The side view of the Bell X-5 airplane in figure 1 shows that engine thrust would induce a positive pitching moment about the center of gravity. The effect on trim at 1 g due to a change in power from 100 percent rpm to idle rpm (79 percent) is shown in figure 8. At 40,000 feet an additional up-elevator deflection of about $1.5^{\circ}$ is necessary to offset the loss of power for a Mach number range of 0.64 to 0.92. For a similar Mach number range at 15,000 feet the additional up elevator required was in excess of $2^{\circ}$. Calculations indicate that the direct thrust effects would account only for about half the additional elevator required. The remainder may be attributed to the jet effects on the flow at the tail.

Limited maneuvering data obtained with idle power indicate that the effects of power in accelerated flight would be negligible.

Maneuvering control effectiveness.- Figure 9 presents the variations with Mach number of the apparent stability parameters, $d\delta_e/dC_{N_A}$ and $di_t/dC_{N_A}$, and the relative elevator-stabilizer effectiveness $di_t/d\delta_e$ measured in gradual pull-up maneuvers at altitudes near 40,000 feet. The slopes of the variations of $\delta_e$ and $i_t$ with $C_{N_A}$ were measured in the $C_{N_A}$ range below the boundary for the reduction in stability shown in figure 3. The value of $d\delta_e/dC_{N_A}$ in region A rapidly increases from a nearly constant value of -17 below $M = 0.92$ to about -50 at $M = 0.98$. An increase in apparent stability by a factor of about 1.3 to 2.3 (depending on Mach number) is evident in region B with $d\delta_e/dC_{N_A}$ gradually increasing from -26 at $M = 0.64$ to -38 at $M = 0.92$ followed by a rapid increase to -100 near $M = 1.01$.

To avoid lateral motions induced by gyroscopic coupling, the push-down pull-up maneuver between trim lifts at 1 g and about zero lift and the pull-up maneuver between trim lifts at 1 g and high lifts were usually performed separately. The pilot was not expected to notice the change in stability when performing separate maneuvers since the change occurred near 1 g at 40,000 feet; however, when maneuvers were performed continuously over the entire lift range to enable the pilot to define the change in stability, he was still unable to notice the change.

The variation of $di_t/dC_{N_A}$ is available for region B only. With the elevator deflection near $0^{\circ}$ the value of $di_t/dC_{N_A}$ was approximately -9 for a Mach number range of 0.68 to 0.90 and rapidly increased to about -25 near $M = 1.01$.

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Below Mach numbers of about $M = 0.92$ the pilot was equally aware of both the high values of apparent stability $\left(d\delta_e/dC_{N_A}\right)$ and stick-force gradient; however, at higher Mach numbers he was primarily aware of the rapid increase in $d\delta_e/dC_{N_A}$. Although there is a complete lack of feel in stabilizer maneuvers (the stabilizer is actuated by a switch on the stick), the pilot was aware of the rapid increase in apparent stability $\left(di_t/dC_{N_A}\right)$ at higher Mach numbers and considered it objectionable.

The variation of $di_t/d\delta_e$ obtained from $d\delta_e/dC_{N_A}$ and $di_t/dC_{N_A}$ is presented for region B. The value of $di_t/d\delta_e$ generally decreases from about 0.35 to 0.23 for a Mach number range of 0.68 to 1.0.

Maneuvering elevator force characteristics.- The stick-force gradients are very high for all conditions, as shown in figure 10 by the variation of $dF_e/dn$ with Mach number at 40,000 feet. In region A the value of $dF_e/dn$ rapidly increases from a nearly constant value of 16 below $M = 0.92$ to 60 at $M = 0.98$. The stick-force gradients increase by a factor of 1.7 to 2.9 (depending on Mach number) in region B with $dF_e/dn$ gradually increasing from about 30 to 50 for a Mach number range of 0.64 to 0.92 and rapidly increasing to about 200 near $M = 1.01$. As would be expected, the pilot strongly objected to the unreasonably high stick-force gradients. He was generally not aware of the change in gradients between regions A and B, as indicated in the previous section.

Normal-force-curve slope.- The variation of $dC_{N_A}/d\alpha$ with Mach number for 40,000 feet is presented in figure 11. The measured slope in region A gradually increases from 0.04 at $M = 0.67$ to 0.051 at $M = 0.98$. In region B the slope is nearly constant at 0.054 for a Mach number range of 0.67 to 0.90 and gradually decreases to 0.05 at $M = 1.01$. The wind-tunnel lift-curve slope from reference 8 measured at low lifts is in reasonably good agreement with the flight variation in region A.

Altitude effects on maneuvering characteristics.- The effect of altitude on the maneuvering characteristics is shown in figure 12 which presents the variations of $d\delta_e/dC_{N_A}$, $dF_e/dn$, $d\delta_e/dn$, and $dC_{N_A}/d\alpha$ with Mach number. Data are presented for region A at altitudes of 40,000, 25,000, and 15,000 feet where the dynamic pressure ratio is on the order of 1, 2, and 3, respectively. Although the values of $d\delta_e/dC_{N_A}$ and $dF_e/dn$ might be expected to be on the same order for all altitudes tested,


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the values of $d\delta_e/dC_{N_A}$ measured at 15,000 feet were on the order of 50 to 100 percent higher, depending on Mach number, than the values measured at 40,000 feet.

Although elevator force data were available only up to $M = 0.78$ at 15,000 feet, the value of $dF_e/dn$ was on the order of 75 percent greater than the measured value at 40,000 feet. The variations of $d\delta_e/dn$ were not directly proportional to changes in dynamic pressure because of the aforementioned dependence of $d\delta_e/dC_{N_A}$ on altitude. It may be noted that at the lower test altitudes the normal-force-curve slope was slightly higher for a given Mach number.

Several possibilities have been investigated to determine the reasons for the altitude effects shown. The combined effects of pitching acceleration, damping, and aeroelasticity of the wing, fuselage, and tail would account for about 25 to 30 percent of the difference between the values of $d\delta_e/dC_{N_A}$ measured at altitudes of 40,000 feet and 15,000 feet. The discrepancy may be exaggerated, considering the different flight techniques used in obtaining the data and the general unsteady behavior of the airplane resulting from the coupling of longitudinal and lateral motions. Scatter in the basic data resulting from the differing flight techniques and airplane behavior are evident in figure 12.

Analysis of Mach number effects on $d\delta_e/dC_{N_A}$.- A brief analysis may be made with the aid of figure 13 to determine the reasons for the rapid increase in apparent stability at Mach numbers near 0.90. Because the elevator pulse data at 40,000 feet were obtained in a lift region characterized by changing stability, the analysis was made by using data obtained at 25,000 feet. The variations with Mach number of $C_{m_\alpha}$, $dC_m/dC_L$, $C_{m_{\delta_e}}$, and $d\delta_e/dC_{N_A}$ are presented in figure 13 for low lifts at 25,000 feet. By using the pulse data obtained at 25,000 feet the variation of $C_{m_\alpha}$ was determined by the expression:

$$C_{m_\alpha} = -\frac{I_Y}{qSc}\left[\left(\frac{2\pi}{P}\right)^2 + \left(\frac{0.693}{T_{1/2}}\right)^2\right]$$

The static longitudinal stability parameter $dC_m/dC_L$ was determined from $C_{m_\alpha}$ and the lift-curve slope at 25,000 feet. The expression $C_{m_{\delta_e}} = dC_m/dC_L \big/ d\delta_e/dC_L$ indicates that, with nearly constant stability

over the Mach number range of 0.62 to 0.96 as evidenced by the variation of $dC_m/dC_L$, the rapid increase in $d\delta_e/dC_{N_A}$ above $M = 0.89$ must be attributable to a reduction in $C_{m_{\delta_e}}$.

A comparison of flight data with wind-tunnel results (fig. 13) indicates that the general trend with Mach number is the same, although the tunnel data, corrected to the center-of-gravity position of the airplane, exhibit about 3 percent less stability than flight results. The more gradual increase in the wind-tunnel variation of $d\delta_e/dC_L$ about 0.05 in Mach number above the abrupt increase in the flight variations is primarily caused by the nearly constant control effectiveness in the wind tunnel $\left(C_{m_{\delta_e}}\right.$ decreases very gradually above $\left.M = 0.96\right)$ as compared to an abrupt decrease in flight near $M = 0.89$.

## Longitudinal Dynamic Stability

A typical example of the short-period longitudinal oscillation resulting from an abrupt elevator pulse is shown in figure 14. It may be noted that because of gyroscopic coupling effects caused by the engine, a lateral-directional oscillation is produced almost simultaneously with the longitudinal oscillation.

The period and time to damp to half-amplitude of the short-period longitudinal oscillation are presented in figure 15. At 40,000 feet the oscillation was fairly heavily damped with $T_{1/2} = 1.0$ second at $M = 0.56$ and decreasing to 0.5 second at $M = 0.98$. The period gradually decreased from 1.9 to 1.6 seconds over the same Mach number range. It may be noted that the oscillation damps to half-amplitude in less than one-half cycle at Mach numbers above 0.60. The measured variation of the period with Mach number may be attributed partly to the fact that at 40,000 feet the pulse data were obtained in or near a lift region characterized by changing stability.

Limited measurements made at an altitude of 25,000 feet are also presented in figure 15. The Mach number variation of the period reflects the general trend of the variation at 40,000 feet and the magnitudes are about those expected for the difference in altitude. Damping improves with a decrease in altitude; oscillation at 15,000 feet is deadbeat.

## CONCLUSIONS

From the results obtained during the flight investigation of the Bell X-5 research airplane at 58.7° sweepback at altitudes of 40,000, 25,000, and 15,000 feet, it may be concluded that:

1. Elevator trim changes were small and stick forces required were moderate throughout the Mach number range at 40,000 feet. Power changes had a minor effect on trim.

2. The high values of apparent stability $d\delta_e/dC_{N_A}$ and stick-force gradient $dF_e/dn$ (minimum of -15 and 17, respectively,) approximately doubled from low to moderate lifts. At moderate lifts the value of $d\delta_e/dC_{N_A}$ increased about 4 times and $dF_e/dn$ increased about 7 times as Mach number increased from 0.64 to 1.01.

3. Calculations indicated that, with nearly constant stability over the Mach number range, the rapid increase in apparent stability $d\delta_e/dC_{N_A}$ at Mach numbers near 0.90 must be attributable to a reduction in control effectiveness $C_{m_{\delta_e}}$.

4. The value of apparent stability $di_t/dC_{N_A}$ for moderate lifts rapidly increased from a nearly constant value of -9 below a Mach number of 0.90 to -25 at a Mach number of 1.01. The relative elevator-stabilizer effectiveness $di_t/d\delta_e$ decreased from about 0.35 to 0.25 as the Mach number increased from 0.68 to 1.0.

5. The normal-force-curve slope $dC_{N_A}/d\alpha$ at 40,000 feet was nearly constant at 0.054 for moderate lifts but decreased by as much as one-fourth at low lifts and at low Mach numbers.

6. A three-fold increase in dynamic pressure caused an appreciable increase in apparent stability $d\delta_e/dC_{N_A}$ and stick-force gradient $dF_e/dn$.

7. Although the dynamic characteristics were influenced by cross-coupling, the short-period longitudinal oscillation was well damped.

8. Comparisons made with wind-tunnel results showed reasonably good agreement except for control effectiveness at high Mach numbers.

High-Speed Flight Station,
National Advisory Committee for Aeronautics,
Edwards, Calif., February 25, 1955.

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TABLE I.- PHYSICAL CHARACTERISTICS OF BELL X-5 AIRPLANE

| | |
|---|---|
| Airplane: | |
| Weight, lb: | |
| Full fuel | 10,006 |
| Less fuel | 7,894 |
| Power plant: | |
| Axial-flow turbojet engine | J35-A-17 |
| Guaranteed rated thrust at 7800 rpm and static sea level conditions, lb | 4,900 |
| Center-of-gravity position, percent M.A.C.: | |
| Sweep angle, deg | 58.7 |
| Full fuel | 45.0 |
| Less fuel | 45.5 |
| Overall height, ft | 12.2 |
| Overall length, ft | 33.6 |
| Moment of inertia about Y-axis, slug-ft$^2$: | |
| Full fuel | 9,495 |
| Less fuel | 8,040 |
| Wing: | |
| Airfoil section (perpendicular to 38.02 percent chord line): | |
| Pivot point | NACA $64_{(10)}$A011 |
| Tip | NACA $64_{(08)}$A008.28 |
| Sweep angle at 0.25 chord, deg | 58.7 |
| Area, sq ft | 183.7 |
| Span, ft | 20.1 |
| Span between equivalent tips, ft | 19.3 |
| Aspect ratio | 2.2 |
| Taper ratio | 0.411 |
| Mean aerodynamic chord, ft | 9.95 |
| Location of leading edge of M.A.C., fuselage station | 101.2 |
| Incidence root chord, deg | 0 |
| Dihedral, deg | 0 |
| Geometric twist, deg | 0 |
| Wing flaps (split): | |
| Area, sq ft | 15.9 |
| Span, parallel to hinge center line, ft | 6.53 |
| Chord, parallel to line of symmetry at 20° sweepback in.: | |
| Root | 30.8 |
| Tip | 19.2 |
| Travel, deg | 60 |
| Slats (leading edge divided): | |
| Area, sq ft | 14.6 |
| Span, parallel to leading edge, ft | 10.3 |
| Chord, perpendicular to leading edge, in.: | |
| Root | 11.1 |
| Tip | 6.6 |
| Travel, percent wing chord: | |
| Forward | 10 |
| Down | 5 |
| Aileron (45 percent internal-seal pressure balance): | |
| Area (each aileron behind hinge line), sq ft | 3.62 |
| Span parallel to hinge center line, ft | 5.15 |
| Travel, deg | ±15 |
| Chord, percent wing chord | 19.7 |
| Moment area rearward of hinge line (total), in.$^3$ | 4,380 |

TABLE I.- PHYSICAL CHARACTERISTICS OF BELL X-5 AIRPLANE - Concluded

| | |
|---|---|
| Horizontal tail: | |
| Airfoil section (parallel to fuselage center line) . . . | NACA 65A006 |
| Area (including area covered by fuselage), sq ft . . . . . | 31.5 |
| Span, ft . . . . . | 9.56 |
| Aspect ratio . . . . . | 2.9 |
| Taper ratio . . . . . | 0.371 |
| Sweep angle at 0.25 percent chord, deg . . . . . | 45 |
| Mean aerodynamic chord, in. . . . . | 42.8 |
| Position of 0.25 M.A.C., fuselage station . . . . . | 355.6 |
| Stabilizer travel, (power actuated), deg: | |
| Leading edge up . . . . . | 4.5 |
| Leading edge down . . . . . | 7.5 |
| Elevator (20.8 percent overhang balance, 31.5 percent elevator span): | |
| Area rearward of hinge line, sq ft . . . . . | 6.9 |
| Travel from stabilizer, deg: | |
| Up . . . . . | 25 |
| Down . . . . . | 20 |
| Chord, percent horizontal tail chord . . . . . | 30 |
| Moment area rearward of hinge line (total), in.$^3$ . . . . . | 4,200 |
| Vertical tail: | |
| Airfoil section (parallel to rear fuselage center line) . . . . . | NACA 65A006 |
| Area, (above rear fuselage center line), sq ft . . . . . | 25.8 |
| Span, perpendicular to rear fuselage center line, ft . . . . . | 6.17 |
| Aspect ratio . . . . . | 1.47 |
| Sweep angle of leading edge, deg . . . . . | 46.6 |
| Fin: | |
| Area, sq ft . . . . . | 24.8 |
| Rudder (23.1 percent overhang balance, 26.3 percent middle span): | |
| Area rearward of hinge line, sq ft . . . . . | 4.7 |
| Span, ft . . . . . | 4.43 |
| Travel, deg . . . . . | ±35 |
| Chord, percent horizontal-tail chord . . . . . | 22.7 |
| Moment area rearward of hinge line, in.$^3$ . . . . . | 3,585 |

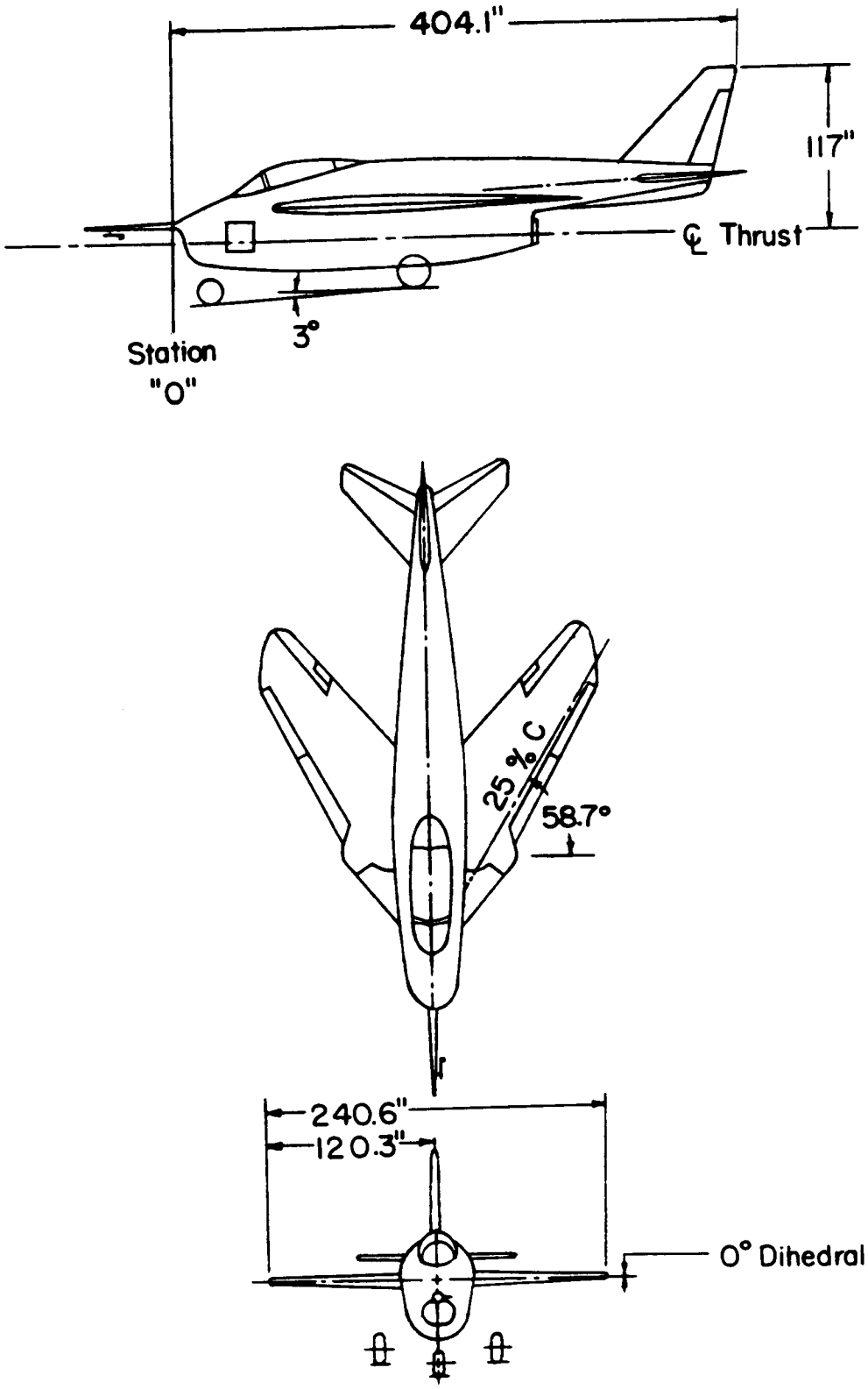


Figure 1.- Three-view drawing of the Bell X-5 research airplane at 58.7° sweepback.

Figure 2.- Photograph of the Bell X-5 research airplane at 58.7° sweepback. L-87906

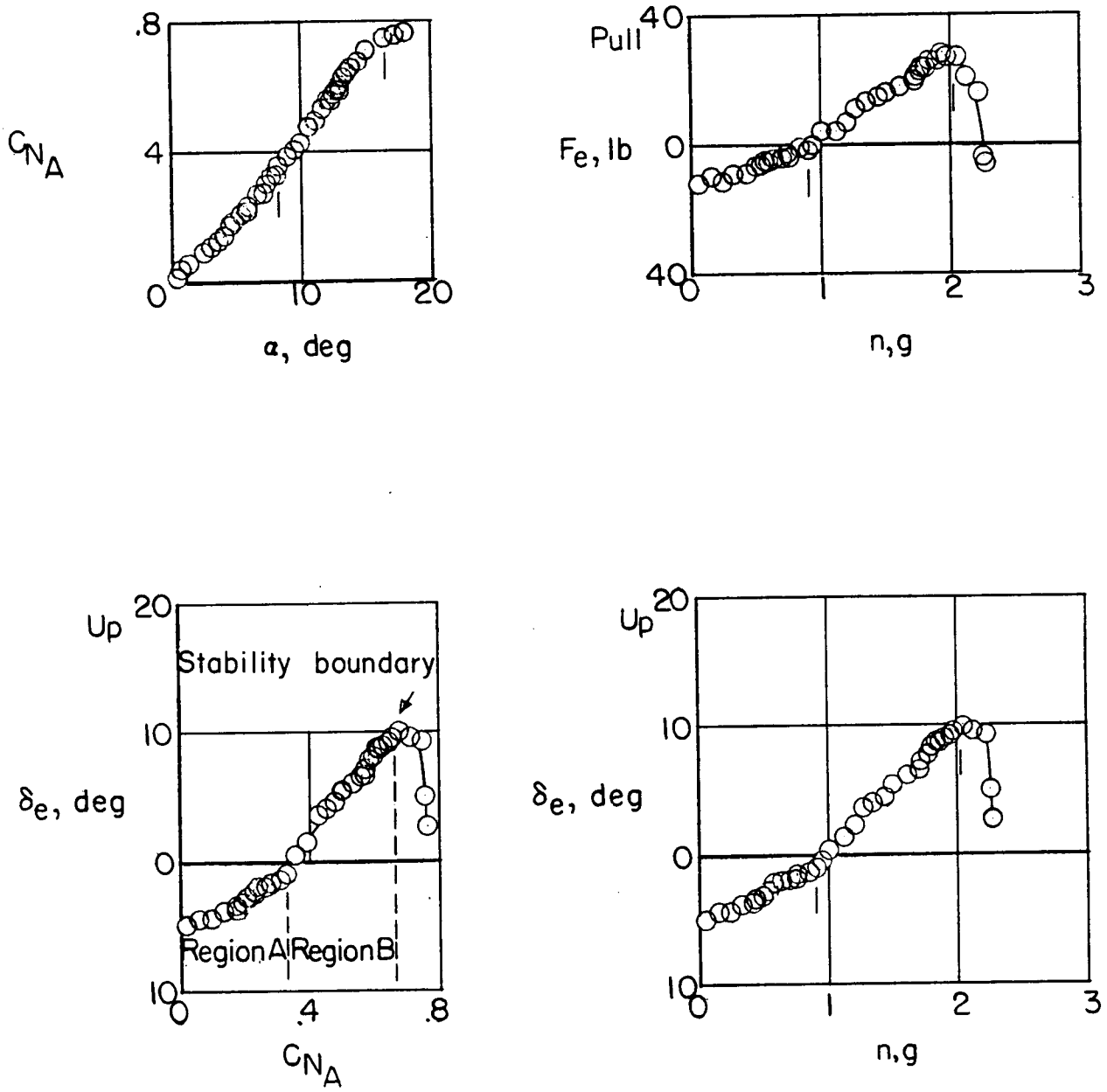


Figure 3.- Variation of several stability and control parameters during a gradual accelerated maneuver. M = 0.73; $h_p$ = 40,500 feet.

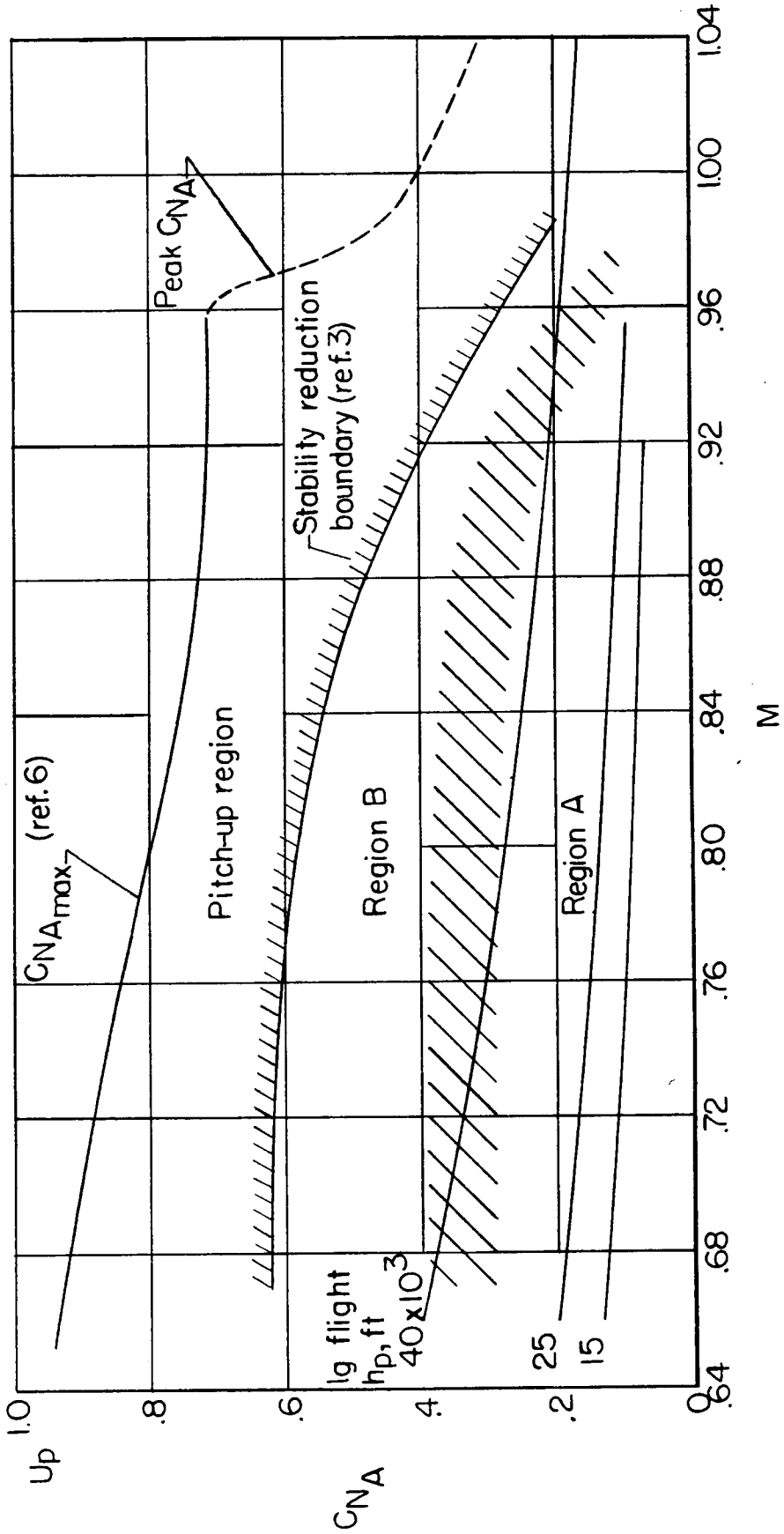


Figure 4.- Test limits and stability regions of the Bell X-5 research airplane at 58.7° sweepback.

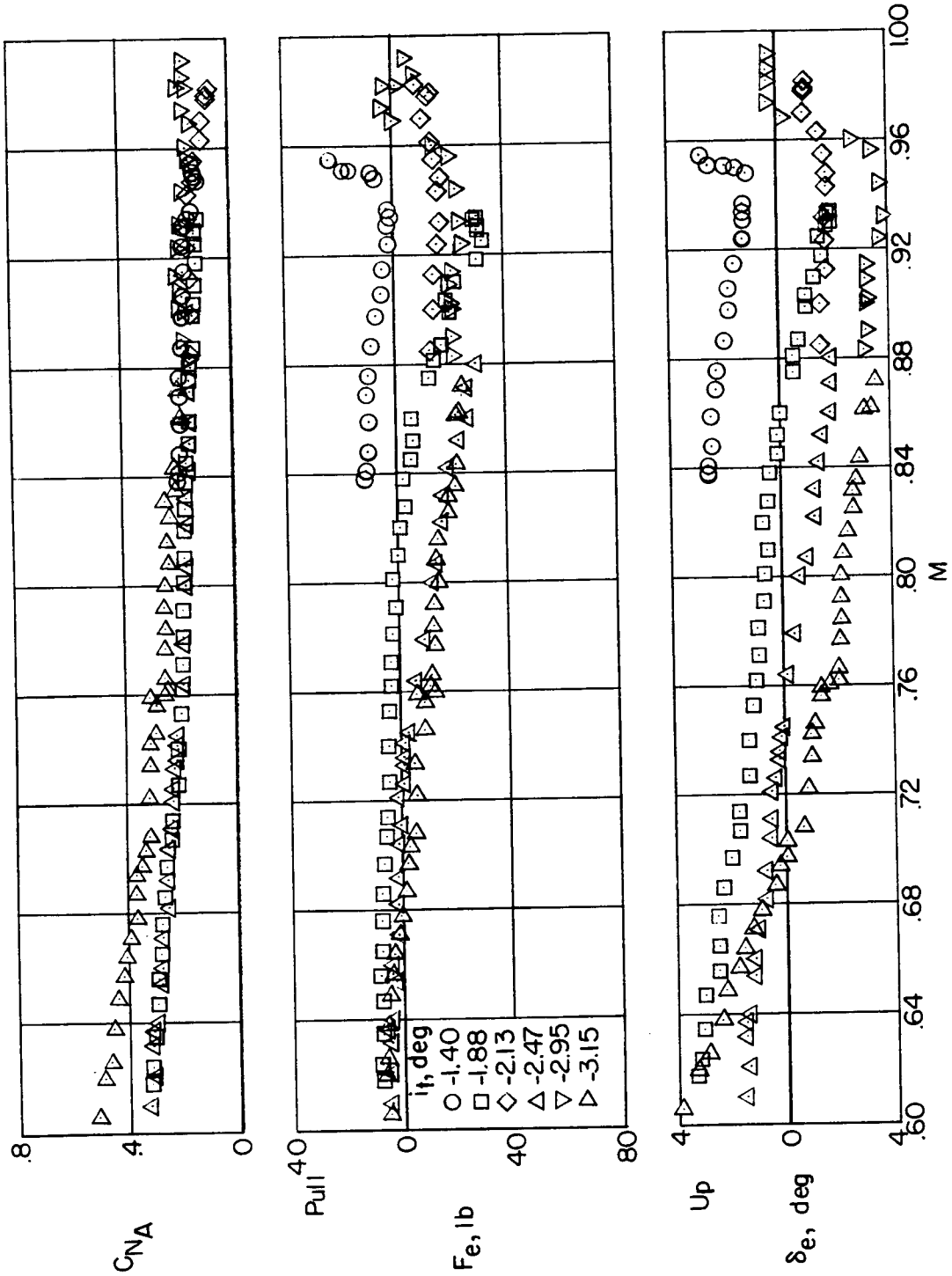


Figure 5.- Variation of elevator deflection, elevator stick force, and normal-force coefficient with Mach number for several stabilizer deflections. $h_p \approx 40,000$ feet.

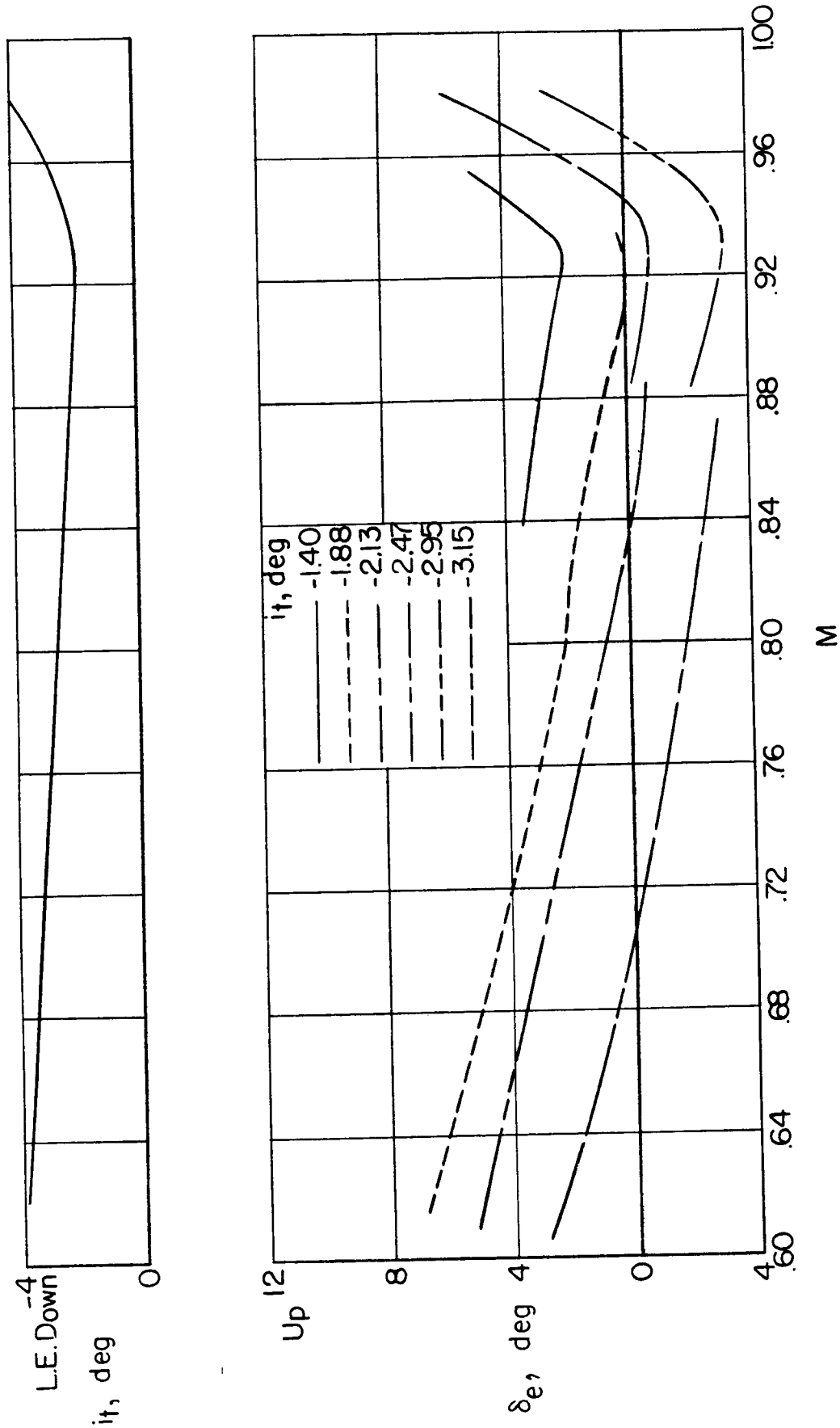


Figure 6.- Elevator and stabilizer deflections required for 1 g trim. $h_p$ = 40,000 feet; W = 8,800 pounds.

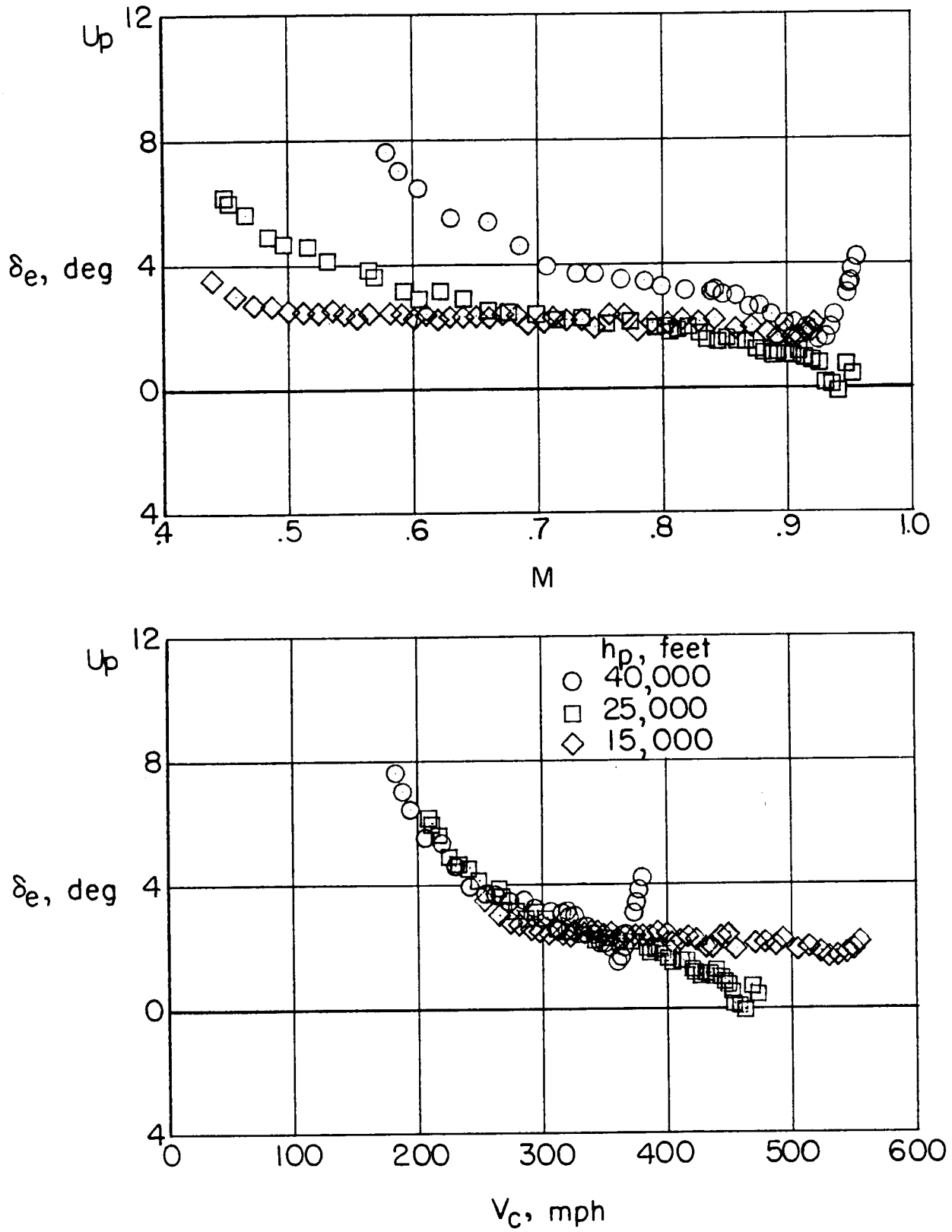


Figure 7.- Effect of altitude and dynamic pressure on elevator deflection required for 1 g trim. W = 8,800 pounds; $i_t = -1.5^{\circ}$.

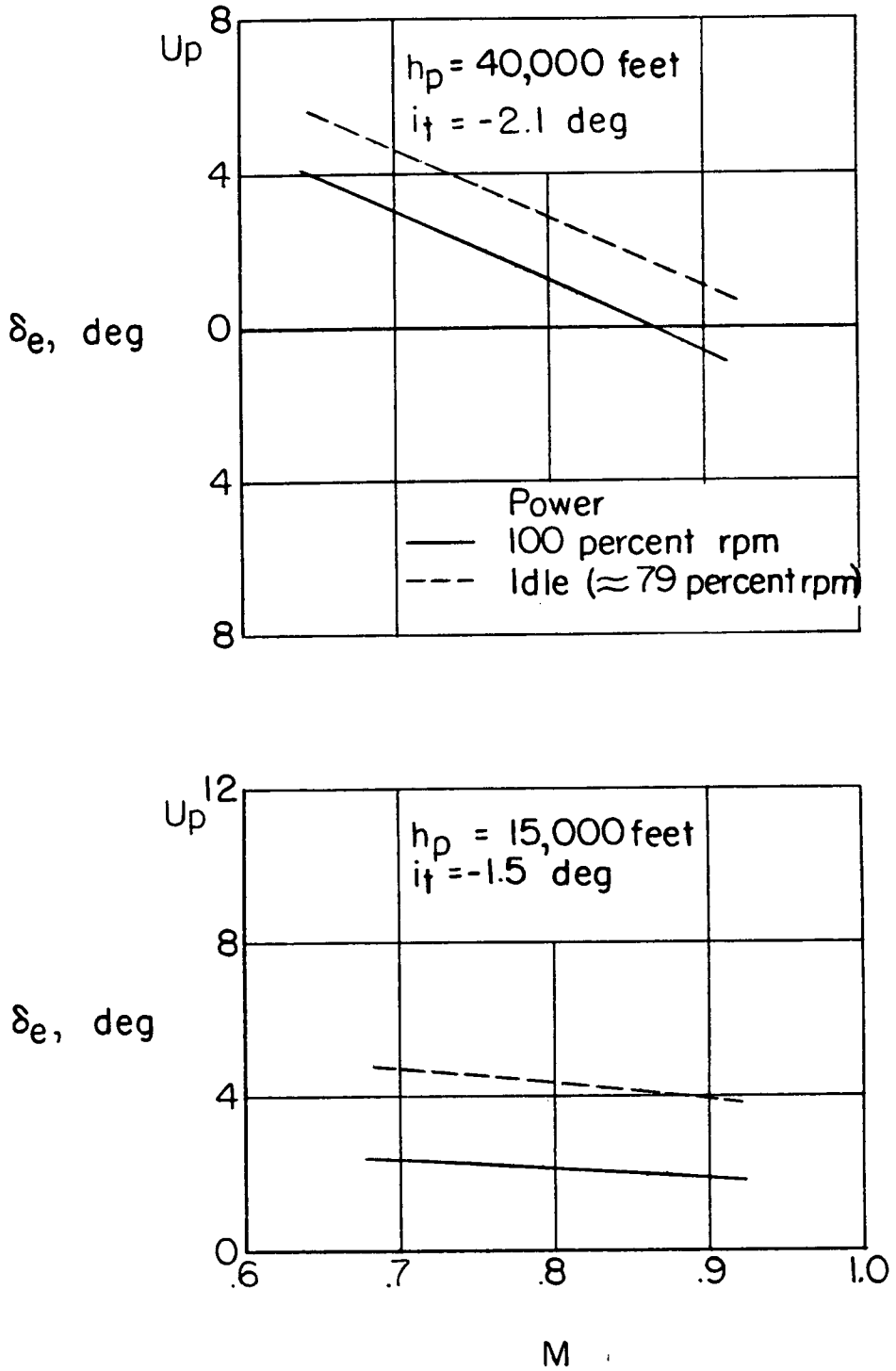


Figure 8.- Effect of power on 1g trim.

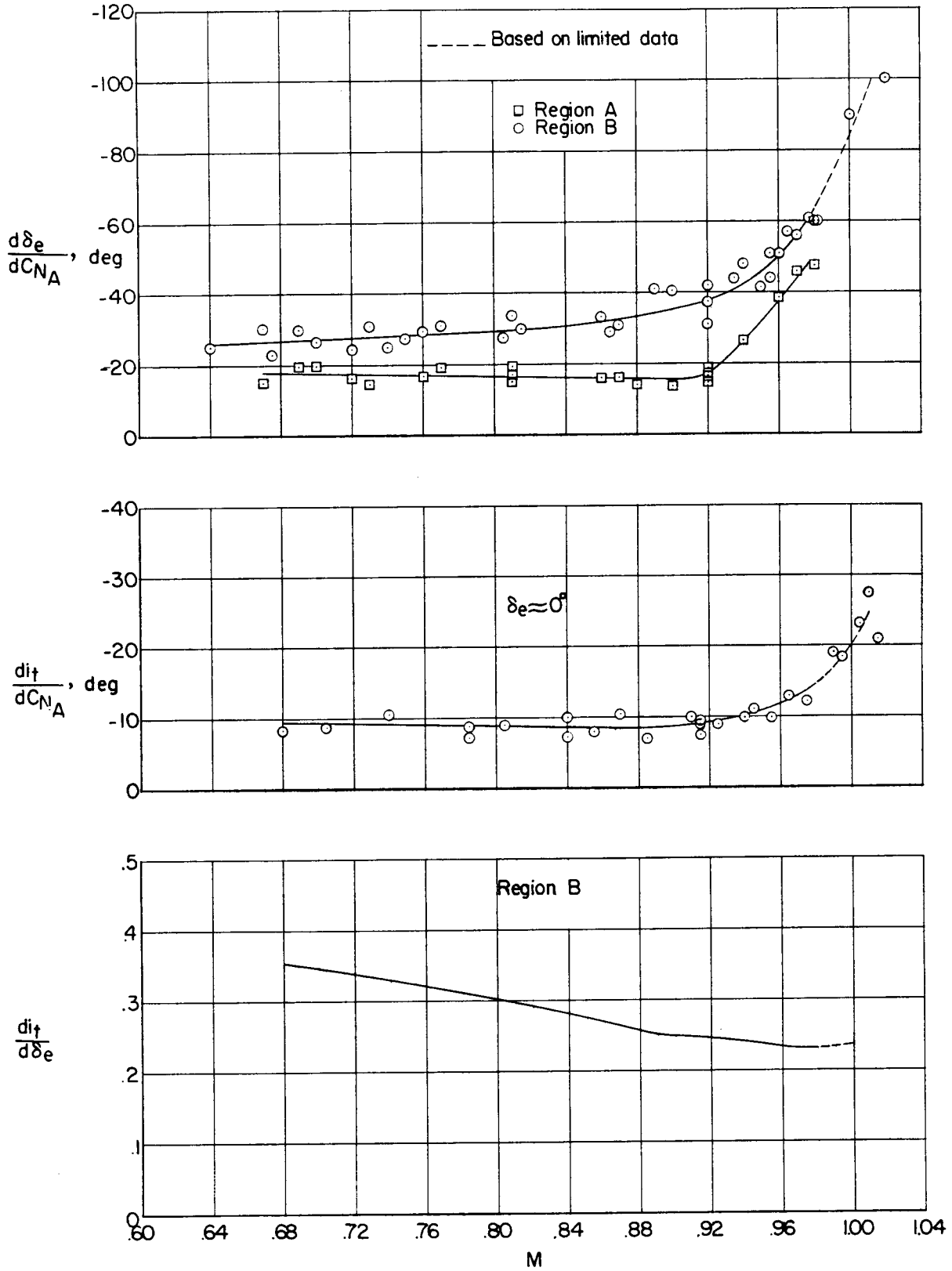


Figure 9.- Variation with Mach number of apparent stability parameters $d\delta_e/dC_{N_A}$ and $di_t/dC_{N_A}$, and relative elevator-stabilizer effectiveness $di_t/d\delta_e$.

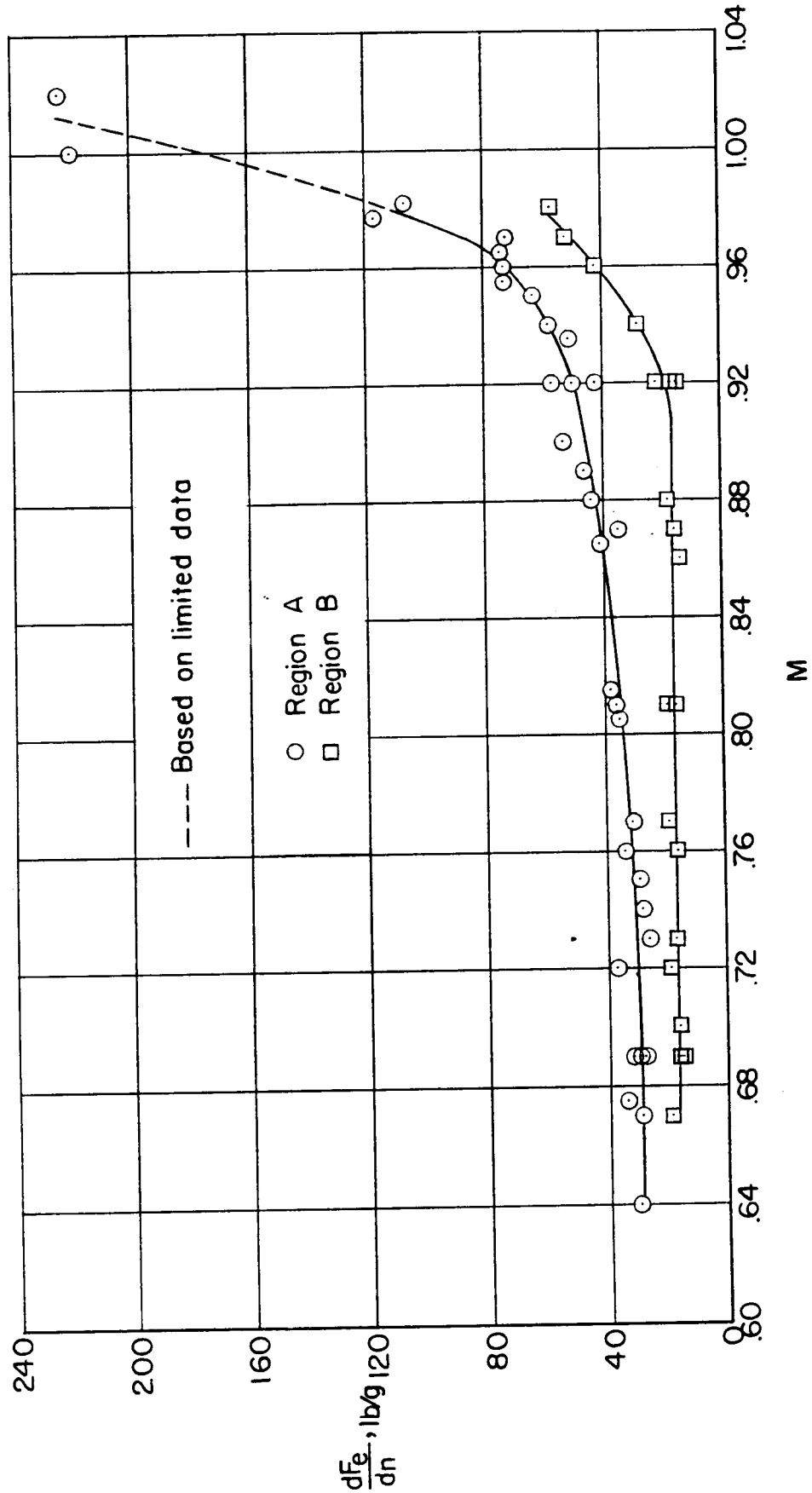


Figure 10.- Variation of elevator stick force per unit normal acceleration with Mach number for gradual elevator maneuvers. $h_p$ = 40,000 feet.

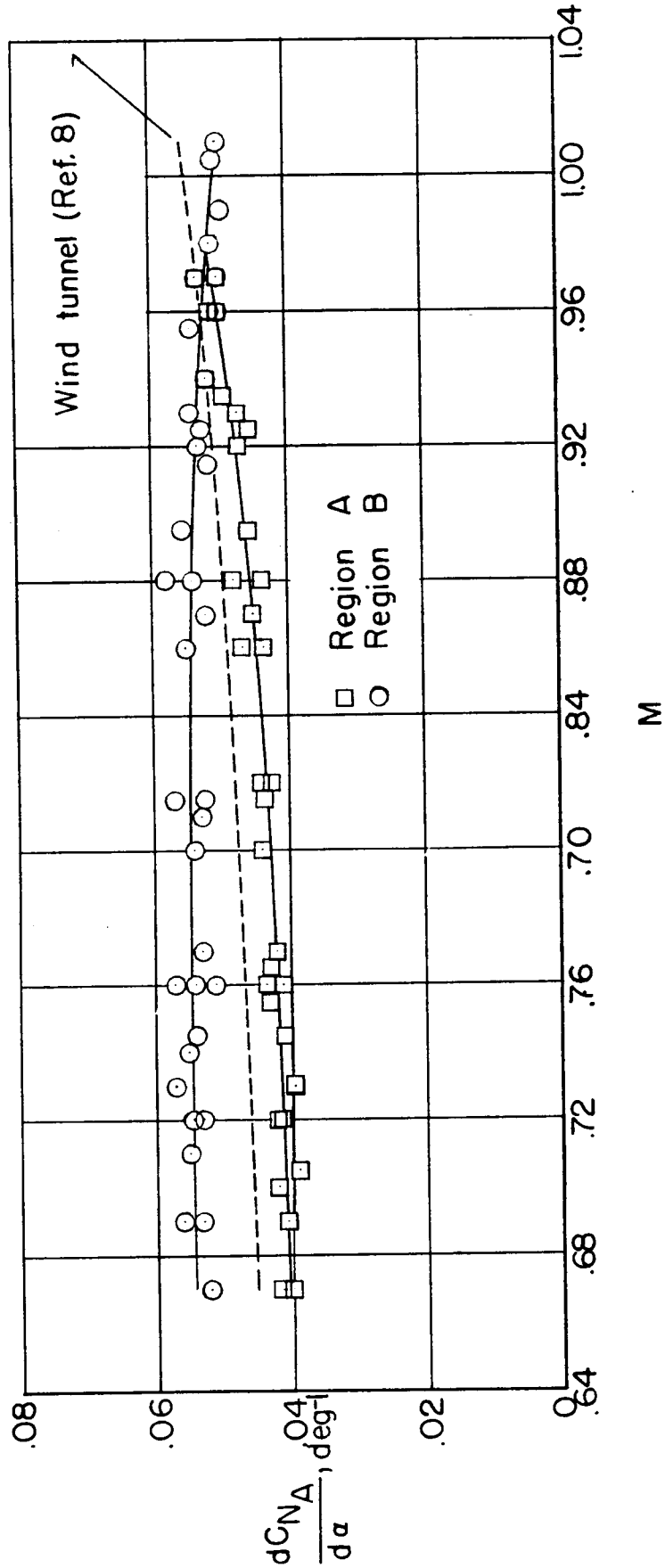


Figure 11.- Variation of the airplane normal-force-curve slope with Mach number. $h_p$ = 40,000 feet.

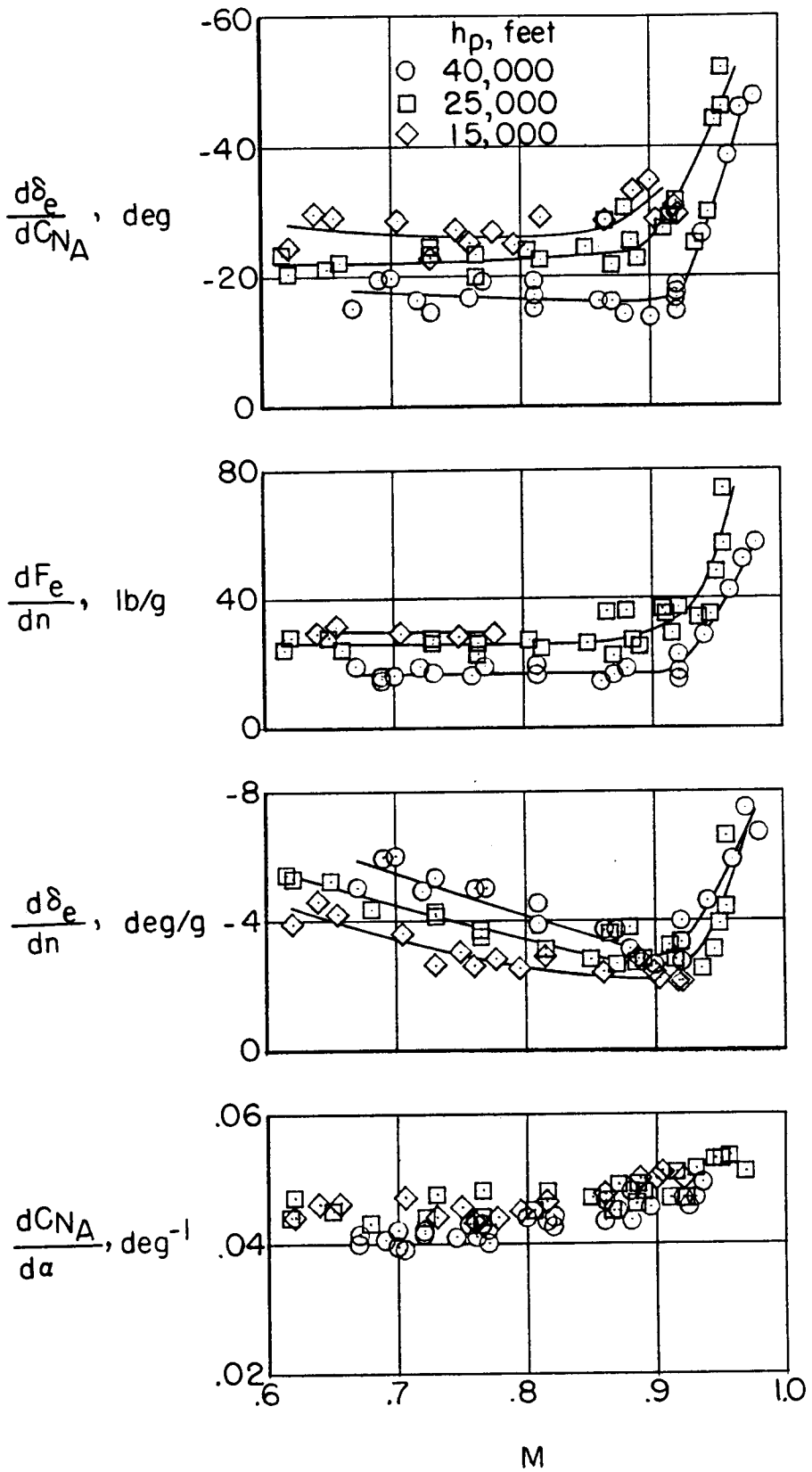


Figure 12.- Effect of altitude on several stability and control parameters.

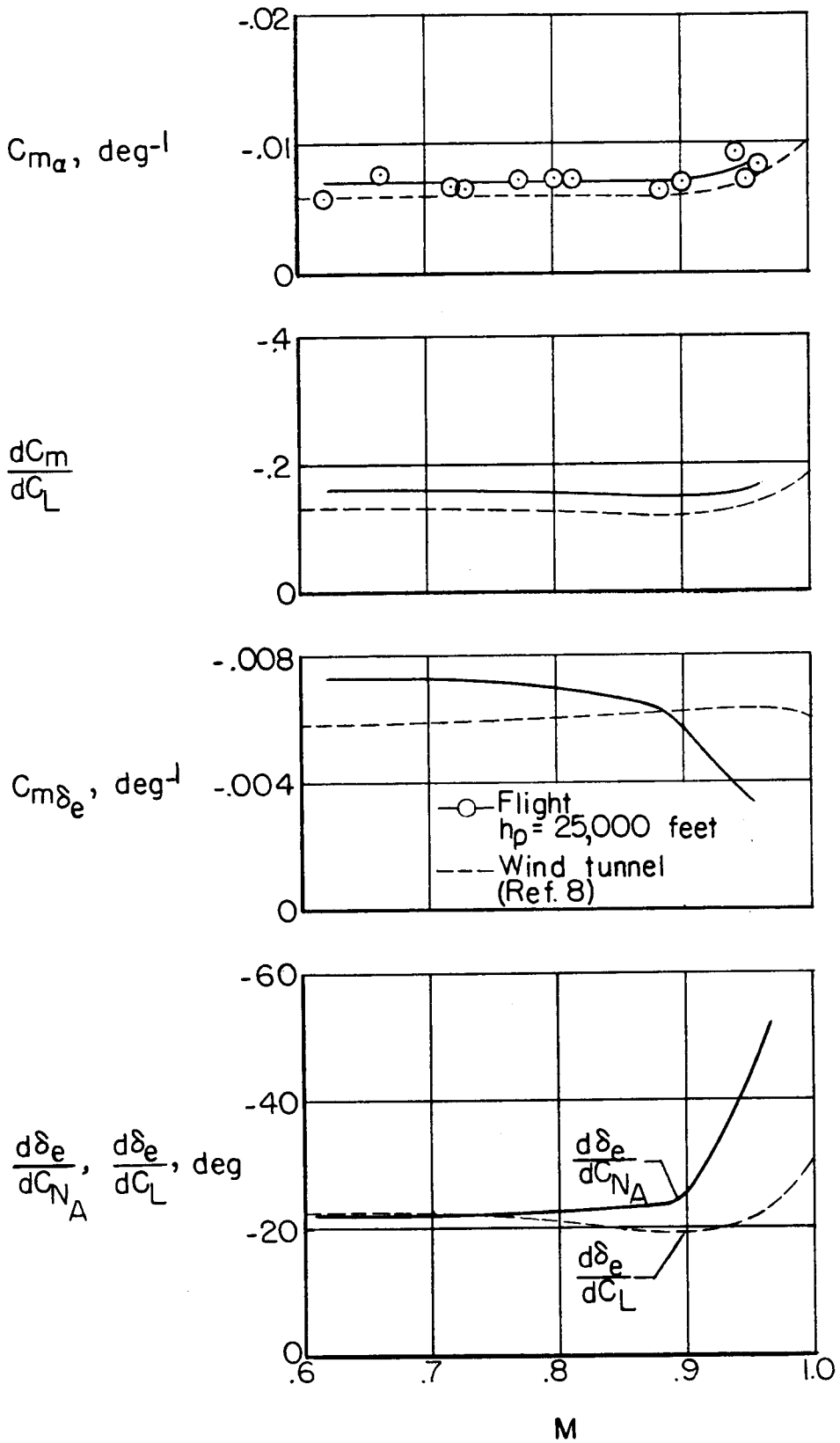


Figure 13.- Comparison of flight and wind-tunnel stability and control effectiveness parameters.

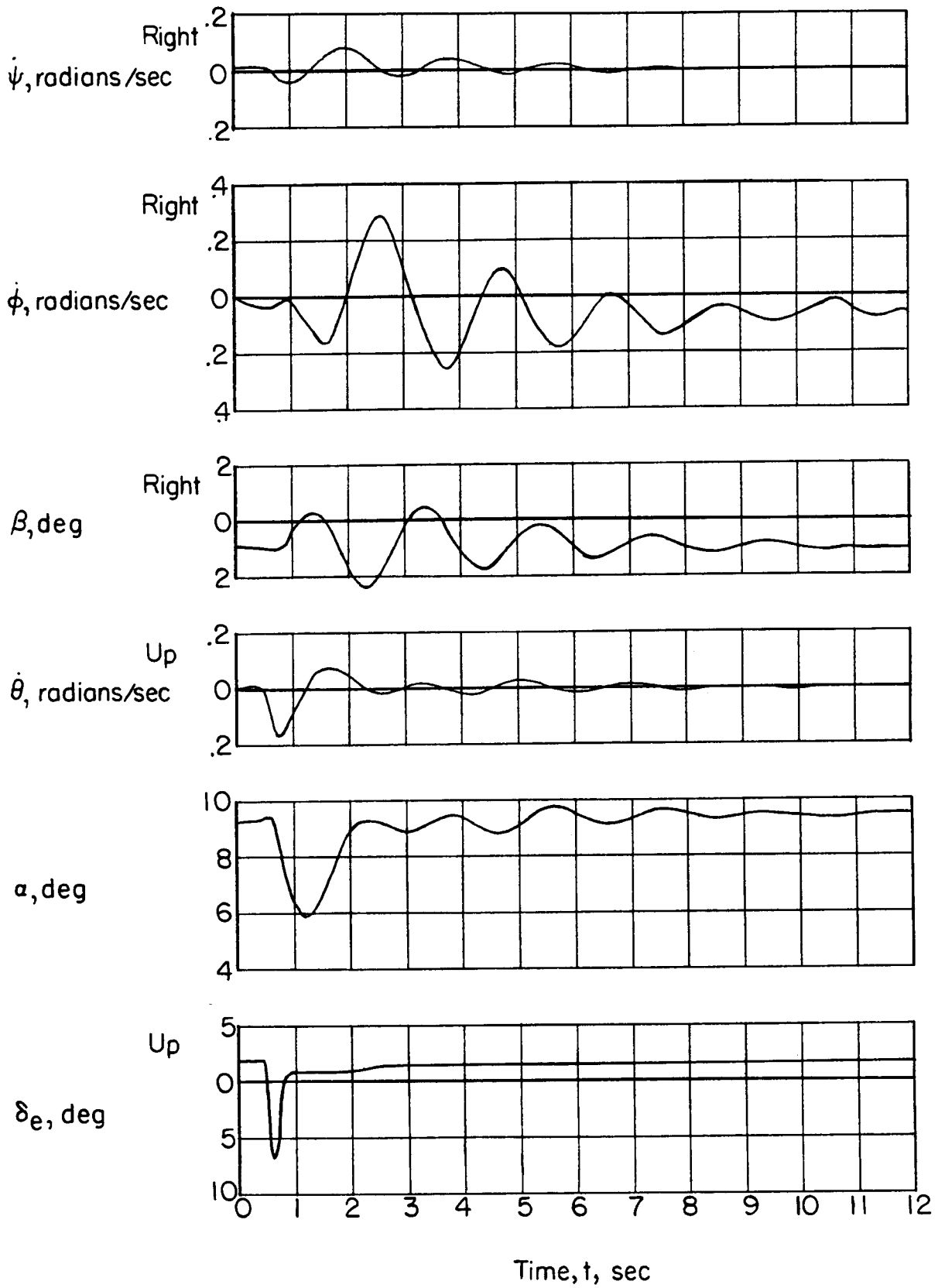


Figure 14.- Time history of the short-period longitudinal oscillation produced by an abrupt elevator pulse. M = 0.69; $h_p$ = 40,000 feet.

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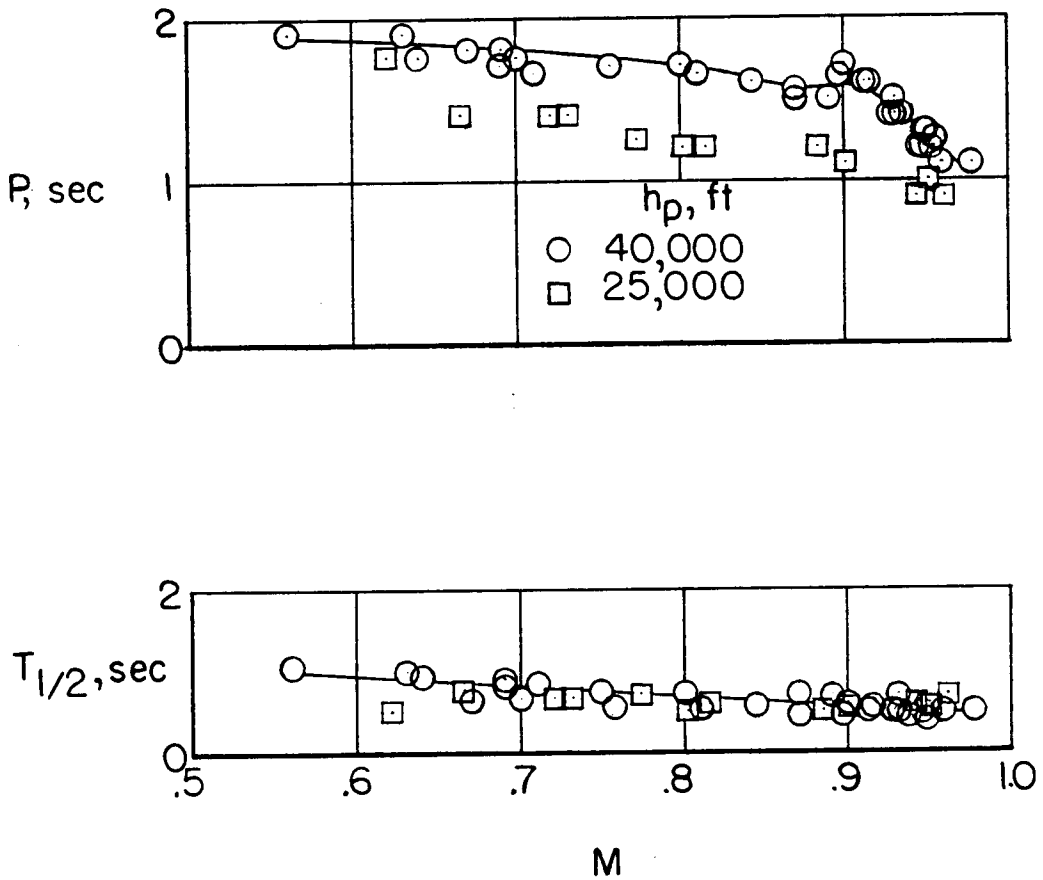


Figure 15.- Variation with Mach number of the period and time to damp to half-amplitude of the short-period longitudinal oscillation.

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