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RESEARCH MEMORANDUM

A FLIGHT INVESTIGATION OF THE EFFECTS OF INCLINATION OF THE PRINCIPAL AXIS OF INERTIA ON THE DYNAMIC LATERAL STABILITY OF THE REPUBLIC XF-91 AIRPLANE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

A flight investigation has been conducted by the NACA High-Speed Flight Research Station at Edwards Air Force Base, Calif., in cooperation with the Republic Aviation Corp. to determine the effect that inclination of the principal axis of inertia as produced by varying the wing incidence angle has on dynamic lateral stability of the Republic XF-91 airplane.

It was found that, as indicated by theory, the time to damp to one-half amplitude increased with both an increase in incidence angle and an increase in altitude over the Mach number range tested. The damping decreased rapidly at incidence angles greater than 4°. As was expected, varying the wing incidence angle had a negligible effect on the period.

INTRODUCTION

Theoretical investigations and dynamic wind-tunnel tests (refs. 1 and 2) indicate that the product of inertia resulting from inclination of the principal longitudinal axis to the flight path should not be neglected in determining the lateral stability characteristics of an airplane. A minor change in the inclination of the principal axis may cause a large change in the stability of the airplane.

One method of determining the effect of the inclination of the principal axis on lateral stability for a full-scale airplane in flight is by testing an airplane such as the Republic XF-91. Variable incidence is incorporated in the wing of this airplane so that, as the wing incidence is varied, a change in the inclination of the principal axis is one of the aerodynamic changes that takes place. In cooperation with the Republic Aviation Corp., the NACA High-Speed Flight Research Station at Edwards Air Force Base, Calif., conducted an investigation with the XF-91 airplane to determine the effects of wing incidence on the dynamic lateral stability characteristics at incidence angles between -2.0° and 5.65° for an altitude range of 10,000 to 39,500 feet.

The values of the mass parameters for the flight test airplane were not available at the time of the tests, and, since comprehensive studies of the comparison between experimental data presented herein and predicted lateral stability characteristics of the XF-91 airplane have been published in references 3 and 4, no additional calculations were made for comparison with experimental data.

SYMBOLS

c	chord, ft
h_p	pressure altitude, ft
i_w	angle of incidence of wing-root-chord line with respect to longitudinal axis of airplane, deg
M	Mach number
P	period of lateral oscillation, sec
p	rolling angular velocity about X-axis, radians/sec
r	yawing angular velocity about Z-axis, radians/sec
$T_{1/2}$	time for amplitude of lateral oscillation to damp to one-half of original value, sec
t	time, sec
δ	control deflection measured perpendicular to hinge line, deg

Subscripts:

a	aileron
r	rudder
L	left

AIRPLANE AND INSTRUMENTATION

The XF-91 airplane is a single-place fighter-type airplane powered by a General Electric J47-GE-17 turbojet engine. The wing has a sweep angle of 40° at the 50-percent-chord line and has inverse taper and variable incidence. The wing incidence angle is variable in flight through a range from -2° to 5.65°. The physical characteristics of the airplane are given in table I and a three-view drawing and photographs are presented in figures 1 and 2, respectively.

The following quantities were recorded on NACA internal recording instruments which were synchronized by a common timer: rolling angular velocity, yawing angular velocity, left aileron deflection, and rudder deflection. Mach number, pressure altitude, and dynamic pressure were recorded on a photopanel.

TESTS, RESULTS, AND DISCUSSION

Flight Data

The period and damping of the lateral oscillations were determined from oscillations produced by abrupt rudder kicks. The tests were made in the clean configuration at altitudes of 10,000, 20,000, and 30,000 feet, and between 35,500 and 39,500 feet. The data obtained above 35,500 feet have been grouped together and presented for an average altitude of 37,500 feet. Wing incidence angles of -2°, 2°, 4°, and 5.65° were tested at all altitudes except that 5.65° was not used at 10,000 feet and 4° incidence was not used at 37,500 feet.

Examples of time histories of lateral oscillations are shown in figure 3. During these flights there was no mechanical stop to lock the controls and the aileron and rudder both moved slightly during the runs.

The time to damp to half amplitude of the lateral oscillation as measured in the tests is presented in figure 4 as a variation with Mach number for wing incidence angles of -2°, 2°, 4°, and 5.65° at altitudes of 10,000, 20,000, 30,000, and 37,500 feet. In general, it is believed that scatter in the data was caused by the controls not being fixed. It is evident from figure 4 that, for the Mach number and altitude range tested, the time required to damp to half amplitude increases with increasing wing incidence as indicated by theory (refs. 1 and 2). The decrease in damping between 4° and 5.65° is greater than that caused by corresponding changes at lower incidence. The time to damp to half amplitude decreases with increasing Mach number up to a Mach number of approximately 0.7 to 0.8, depending on the altitude, and tends to increase at higher Mach numbers. This trend is characteristic of all wing incidence angles tested.

The effect of changing the wing incidence angle on the period of the lateral oscillation is shown in figure 5 by the variation of the period with Mach number for all altitudes and incidence angles tested. As is indicated in reference 1, changes in the wing incidence angle have no appreciable effect on the period of the lateral oscillation. The changes in the period with altitude and Mach number are those that would be expected from the corresponding change in dynamic pressure.

CONCLUSIONS

An investigation of the dynamic lateral stability of the Republic XF-91 airplane has indicated the following conclusions:

1. As is predicted by theory, the time to damp to one-half amplitude of the lateral oscillation increased with both an increase in wing incidence angle and an increase in altitude over the Mach number range tested. For wing incidence angles greater than 4°, an increase in wing incidence produced a larger decrease in stability than for a similar incidence change at lower wing incidence angles.

2. The change in wing incidence angle had a negligible effect on the period of the lateral oscillation.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 15, 1953.

REFERENCES

1. McKinney, Marion O., Jr., and Drake, Hubert M.: Correlation of Experimental and Calculated Effects of Product of Inertia on Lateral Stability. NACA TN 1370, 1947.

2. Sternfield, Leonard: Effect of Product of Inertia on Lateral Stability. NACA TN 1193, 1947.

3. Heinle, Donovan R., and McNeill, Walter E.: Correlation of Predicted and Experimental Lateral Oscillation Characteristics for Several Airplanes. NACA RM A52J06, 1952.

4. Jaquet, Byron M., and Fletcher, H. S.: Lateral Oscillatory Characteristics of the Republic F-91 Airplane Calculated by Using Low-Speed Experimental Static and Rotary Derivatives. NACA RM L53G01, 1953.

TABLE I.- PHYSICAL CHARACTERISTICS OF REPUBLIC XF-91 AIRPLANE

Wing:	
Airfoil section	Republic R-4, 40-1710-1.0
Area, sq ft	320.0
Span, ft	31.225
Aspect ratio	3.07
Taper ratio	1.626
Root chord (airplane center line), in.	95.0
Tip chord, in.	154.5
Mean aerodynamic chord, in.	127.1
Sweepback of 50-percent-chord line, deg	40.0
Geometric twist, deg	0
Dihedral, deg	-5.0
Incidence angle, deg	Variable from -2 to 6
Rotation point, percent root chord	89.5
Slats (type)	
Leading edge	Full span
Flaps (type)	
Trailing edge	Plain partial span
Ailerons:	
Type	Internal sealed 30.2-percent balance
Area (one), sq ft	19.14
Span, in.	73.5
Sweepback angle of aileron hinge line, deg	42.5
Ratio aileron area to wing area	0.12
Travel, deg	-19 to 16
Vertical tail:	
Airfoil section	Republic R-4, 40-010X (Mod.)
Area, sq ft	48.4
Span, in.	117
Aspect ratio	1.99
Taper ratio	0.44
Sweepback at 25-percent-chord line, deg	33.0
Rudder area, sq ft	9.7
Horizontal tail:	
Airfoil section	Republic R-4, 40-010
Area, sq ft	69.8
Span, in.	204
Aspect ratio	3.98
Taper ratio	1.00
Sweepback at 25-percent-chord line, deg	40.0
Elevator area (total), sq ft	19.3
Elevator tab area, sq ft	1.03
Stabilizer area, sq ft	50.5

TABLE I.- PHYSICAL CHARACTERISTICS OF REPUBLIC XF-91 AIRPLANE - Concluded

Fuselage:	
Length, ft	43.33
Frontal area (including canopy), sq ft	24.2
Fineness ratio (Twice length/Maximum width plus height)	8.4
Canopy frontal area, sq ft	2.2
Power plant	General Electric J47-GE-17
Weight:	
Gross weight, lb	19,500
Empty weight, lb	15,900
Center-of-gravity position, percent M.A.C.	20 to 22.6

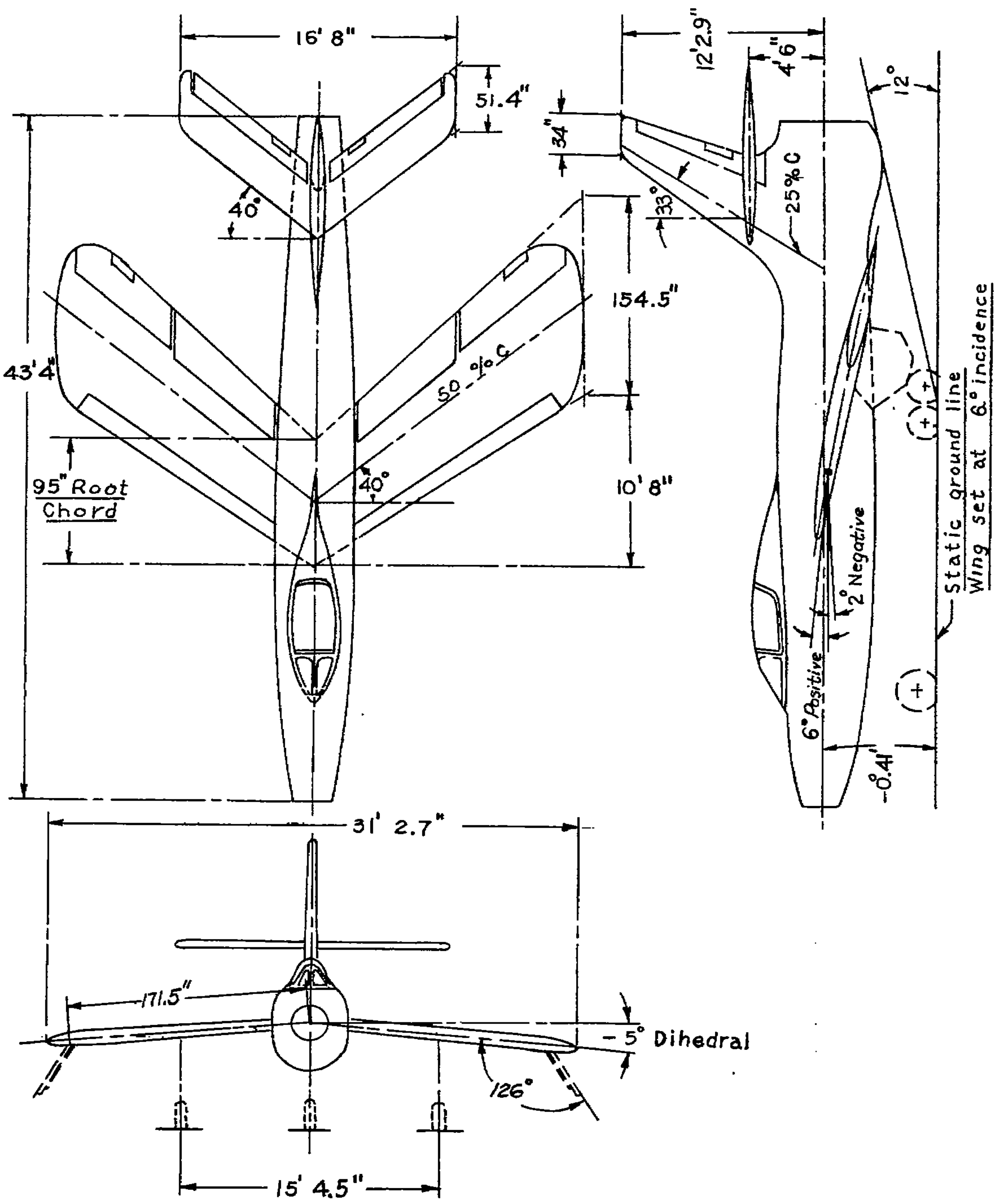
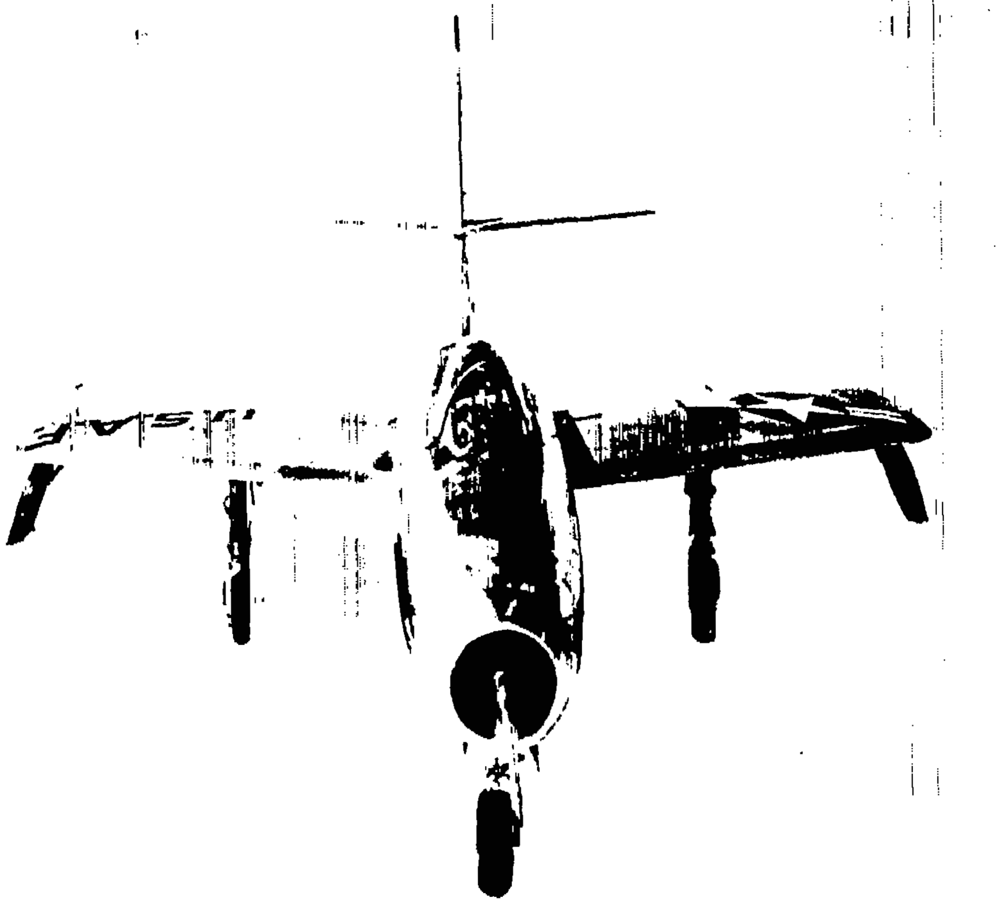


Figure 1.- Three-view drawing of the Republic XF-91 airplane.



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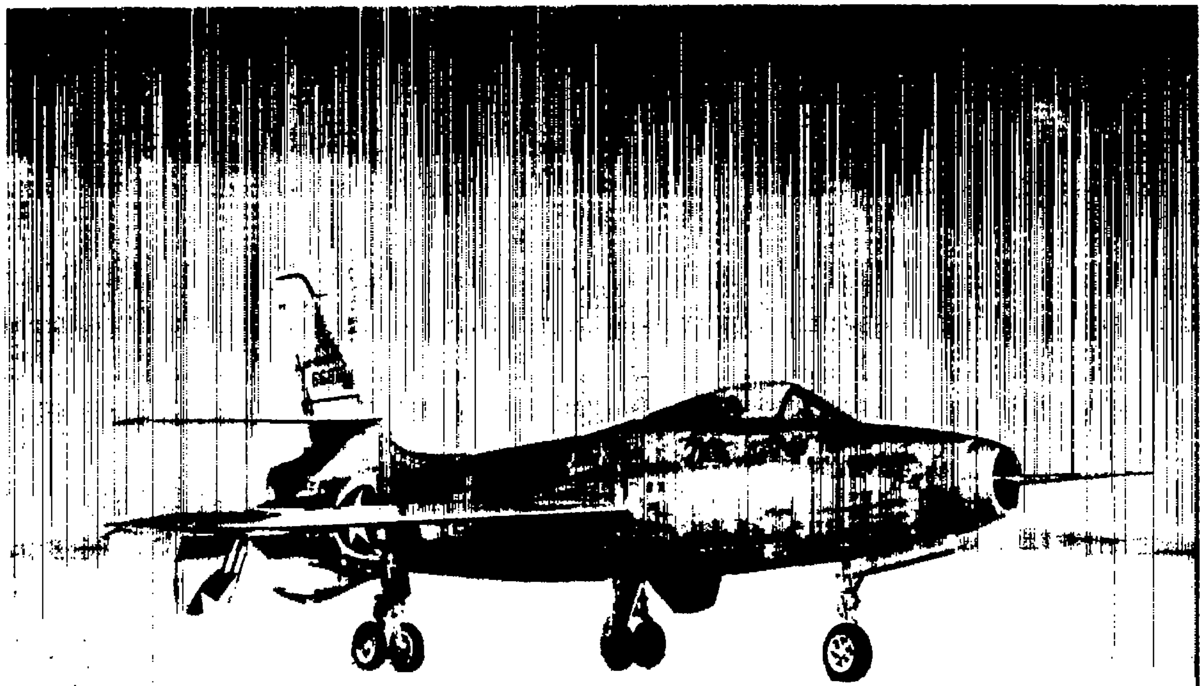
(a) Overhead front view.

Figure 2.- Photographs of the XF-91 airplane.



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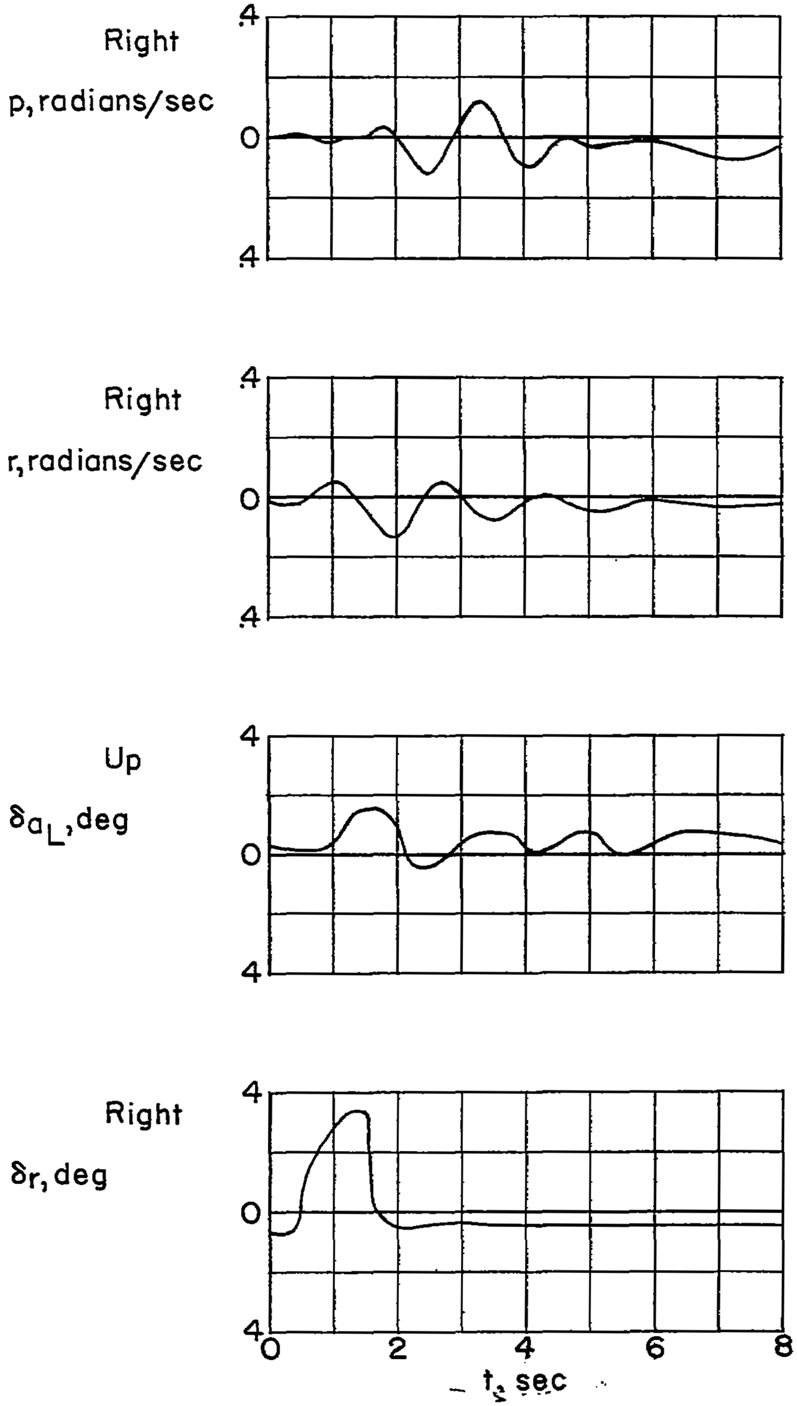
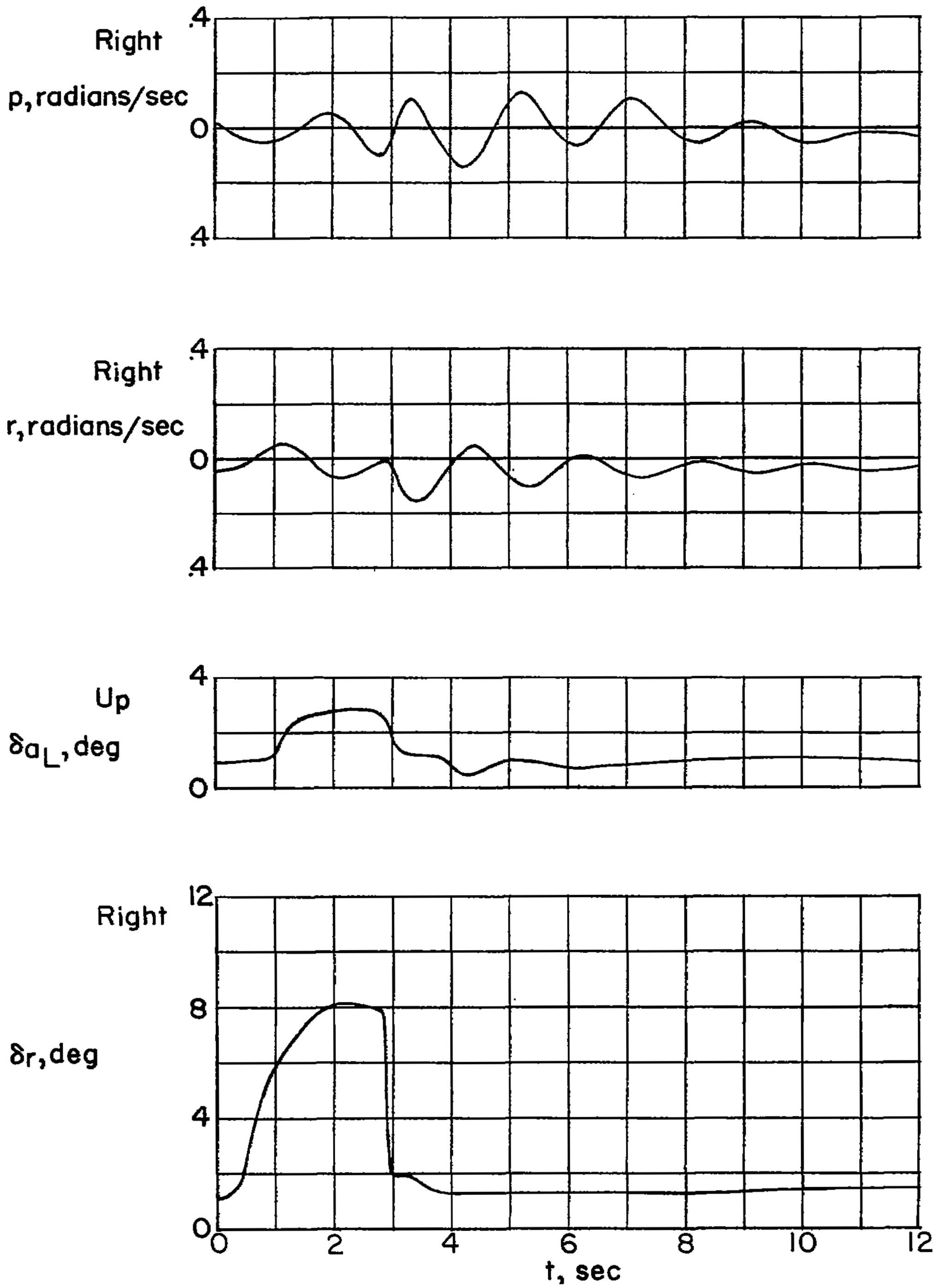
(b) One-quarter front view.

Figure 2.- Concluded.



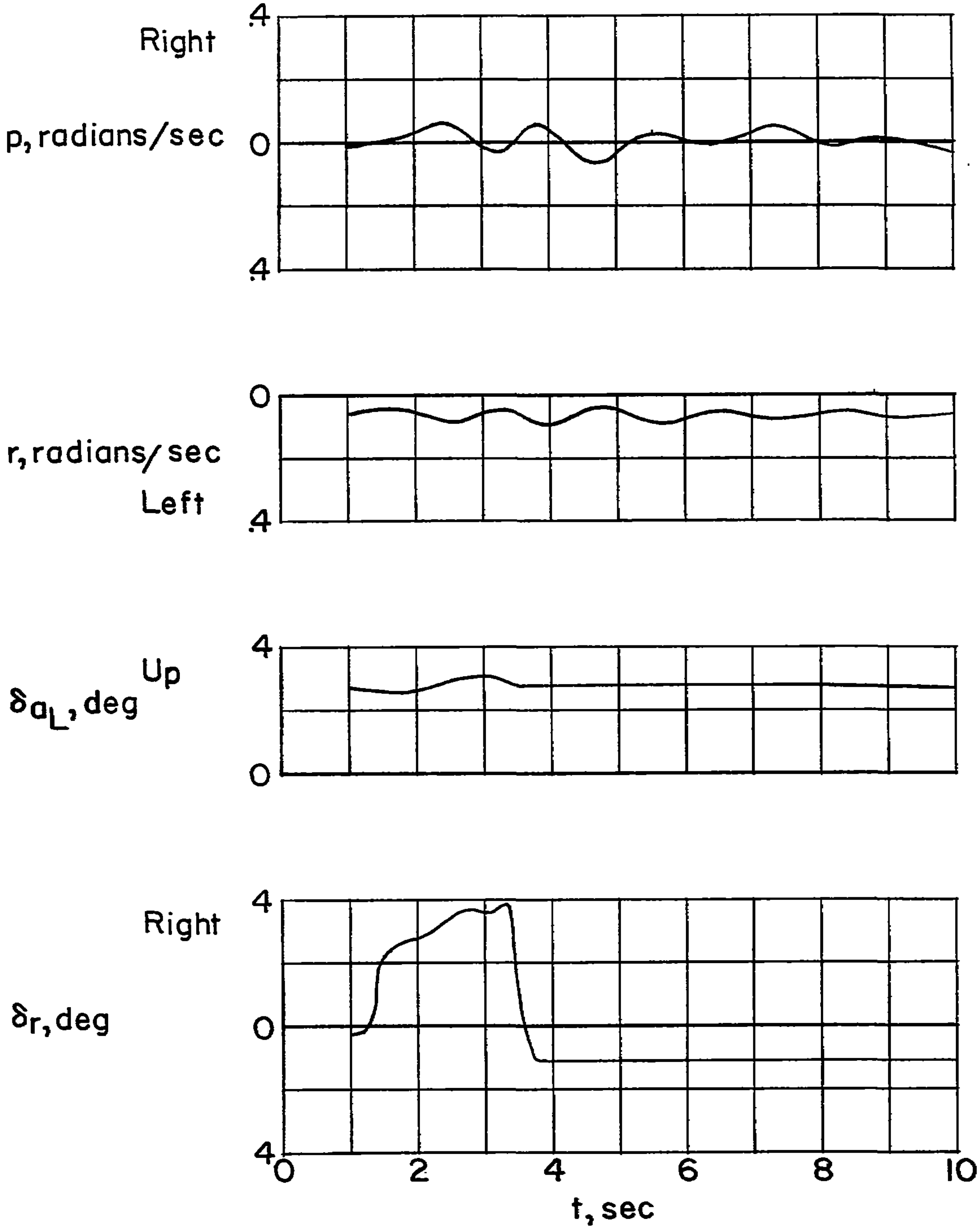
(a) $M = 0.69$; $i_w = -2^{\circ}$; $h_p = 10,000$ feet.

Figure 3.- Time histories of lateral oscillations.



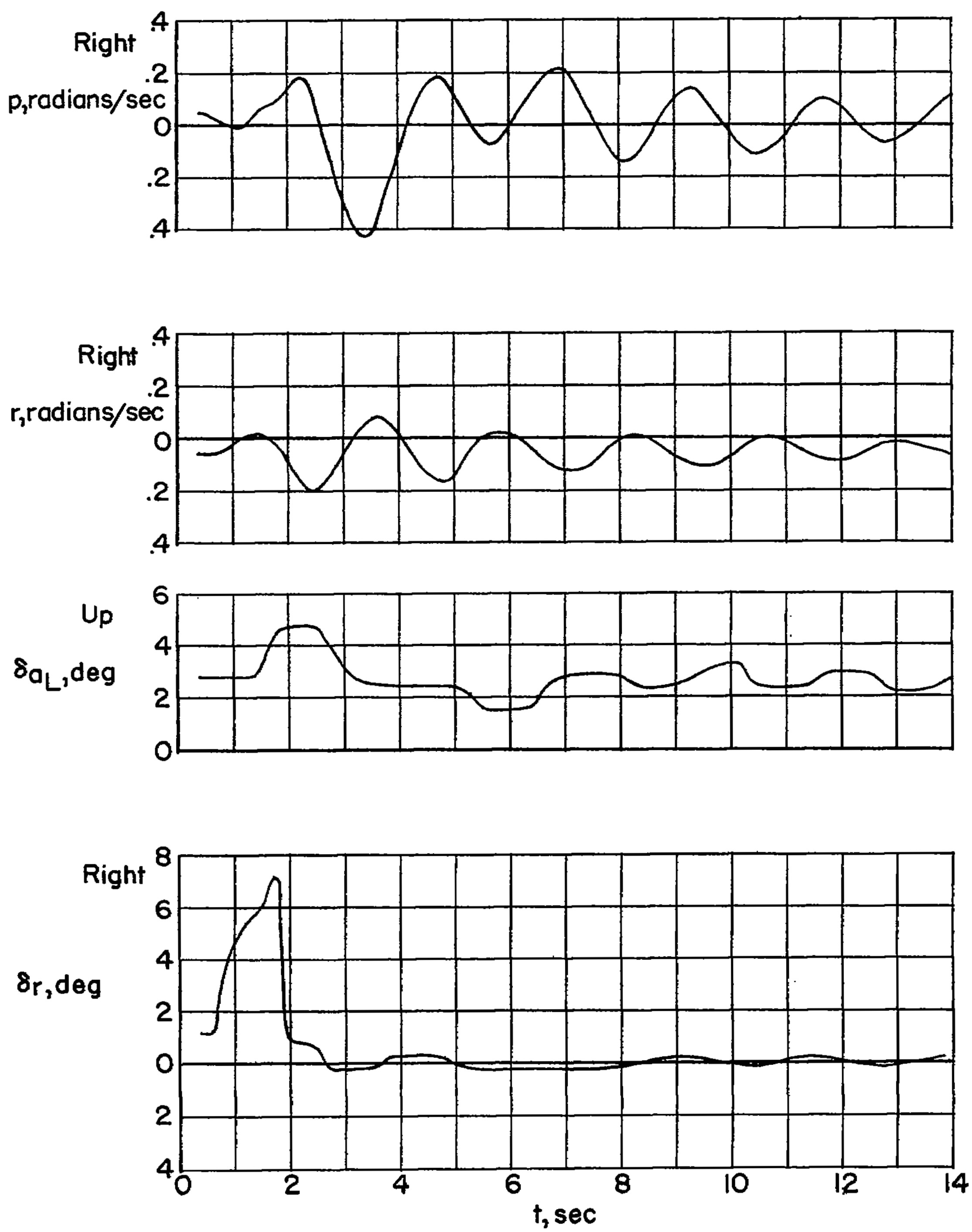
(b) $M = 0.69$; $i_w = 2^{\circ}$; $h_p = 20{,}000$ feet.

Figure 3.- Continued.



(c) $M = 0.90$; $i_w = 4^{\circ}$; $h_p = 30,000$ feet.

Figure 3.- Continued.



(d) $M = 0.70$; $i_w = 5.65^\circ$; $h_p \approx 37{,}500$ feet.

Figure 3.- Concluded.

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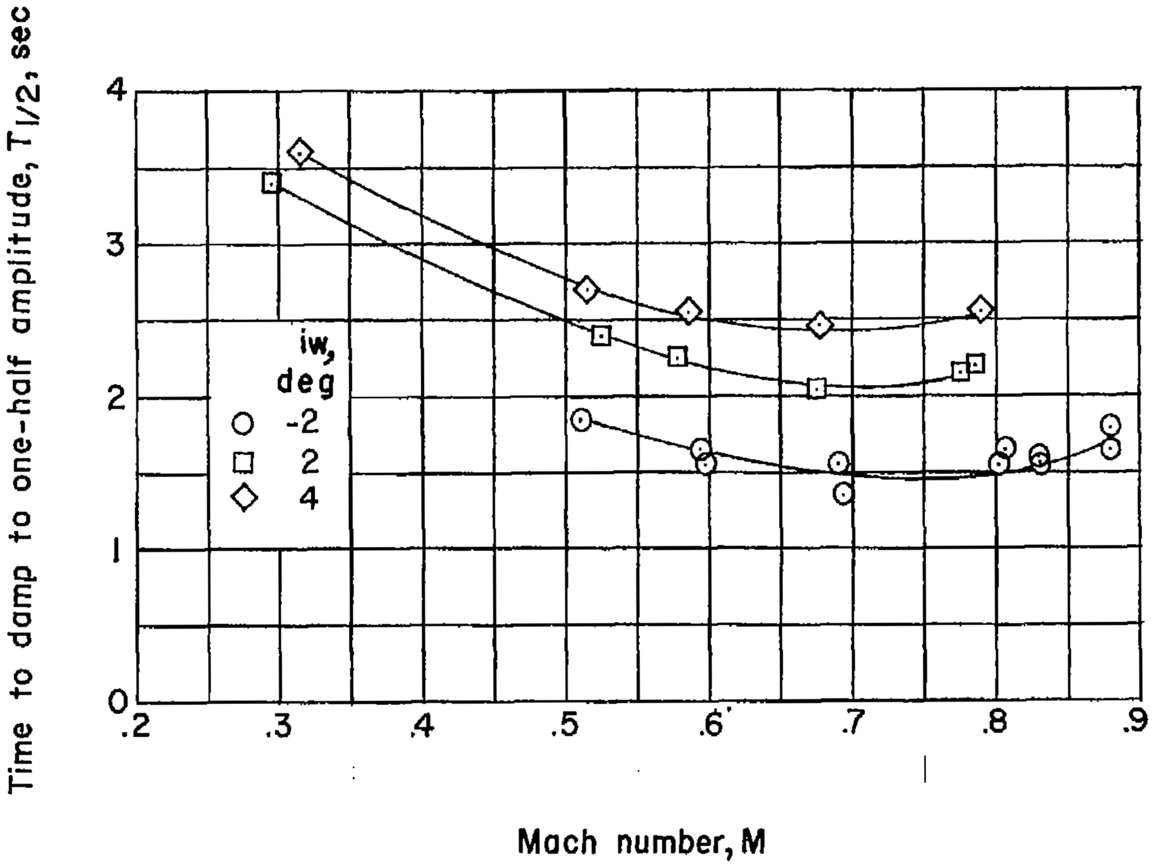

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(a) h_p = 10,000 feet.

Figure 4.- Variation of time to damp to one-half amplitude of the lateral oscillation with Mach number.

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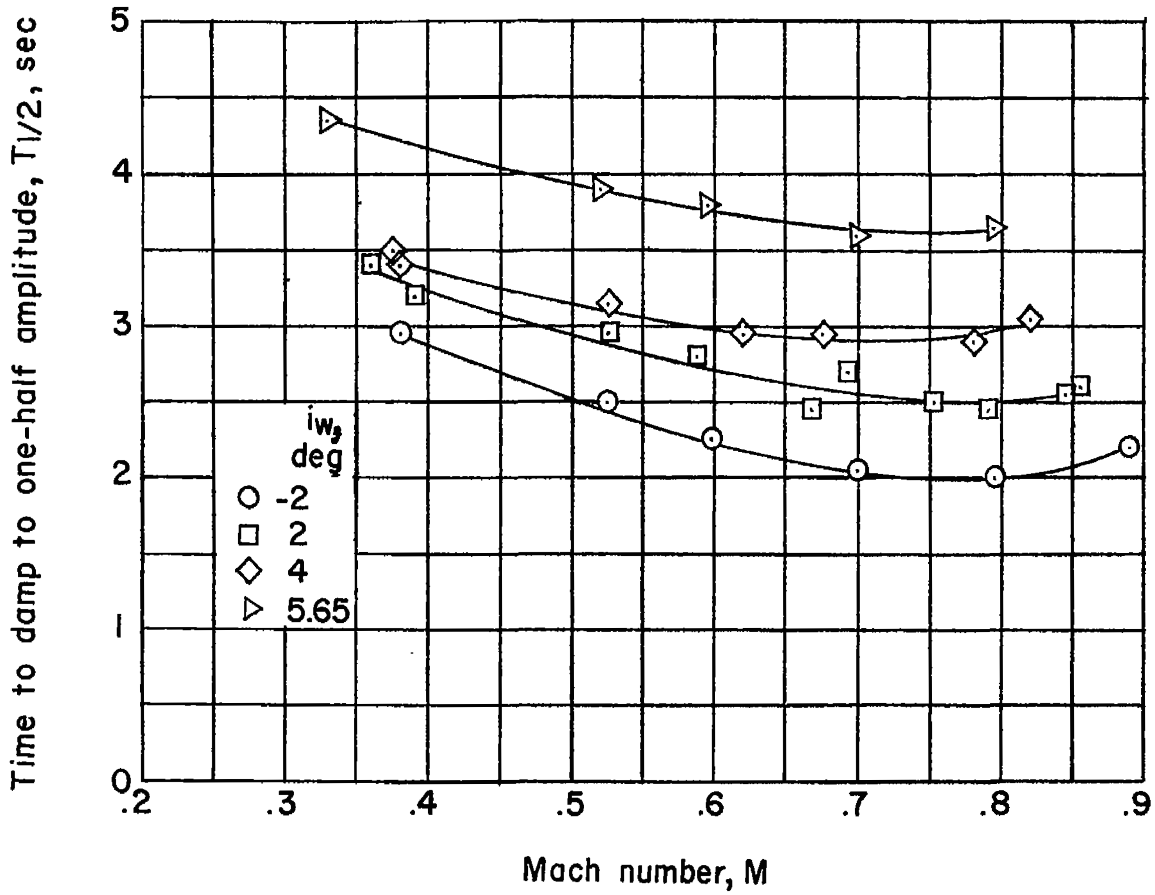

(b) h_p = 20,000 feet.

Figure 4.- Continued.

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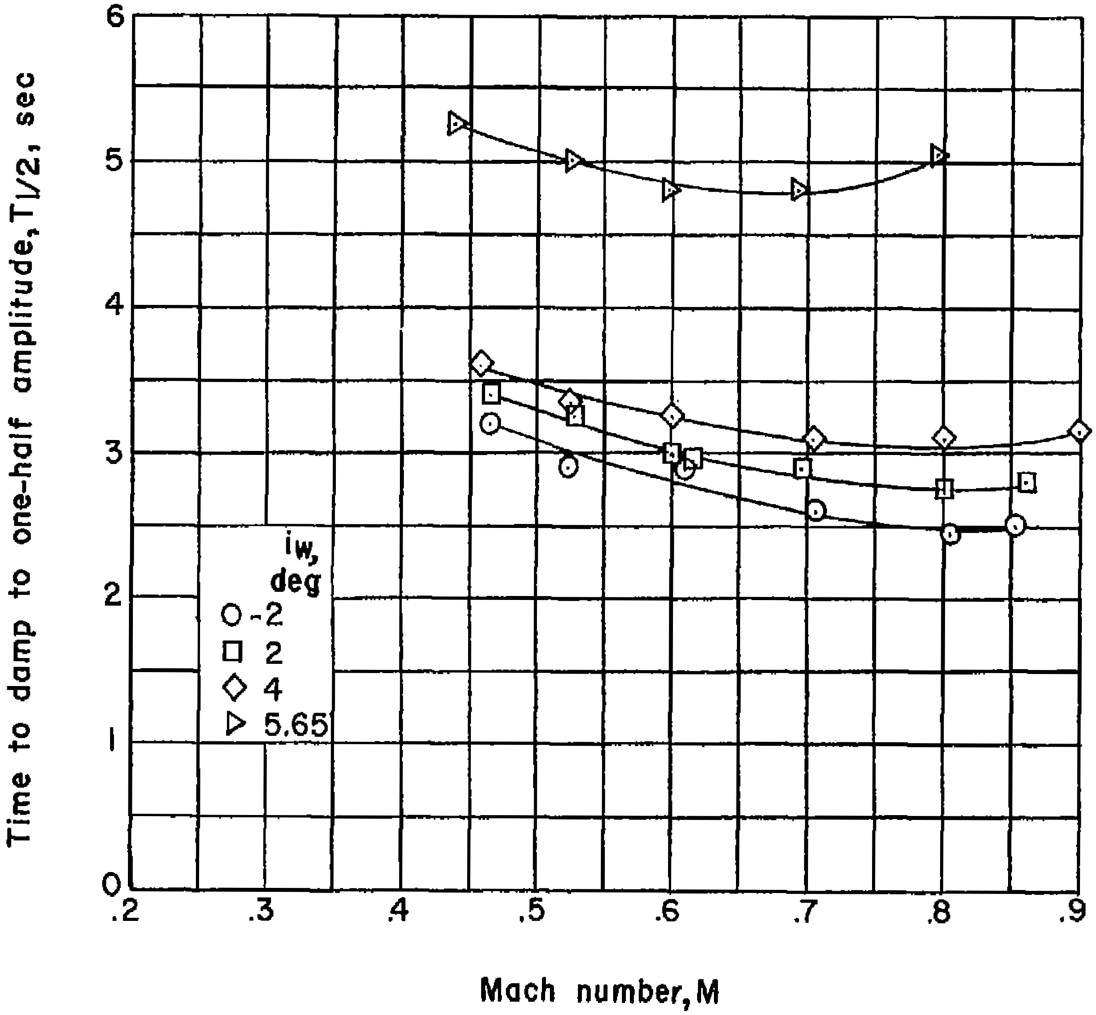
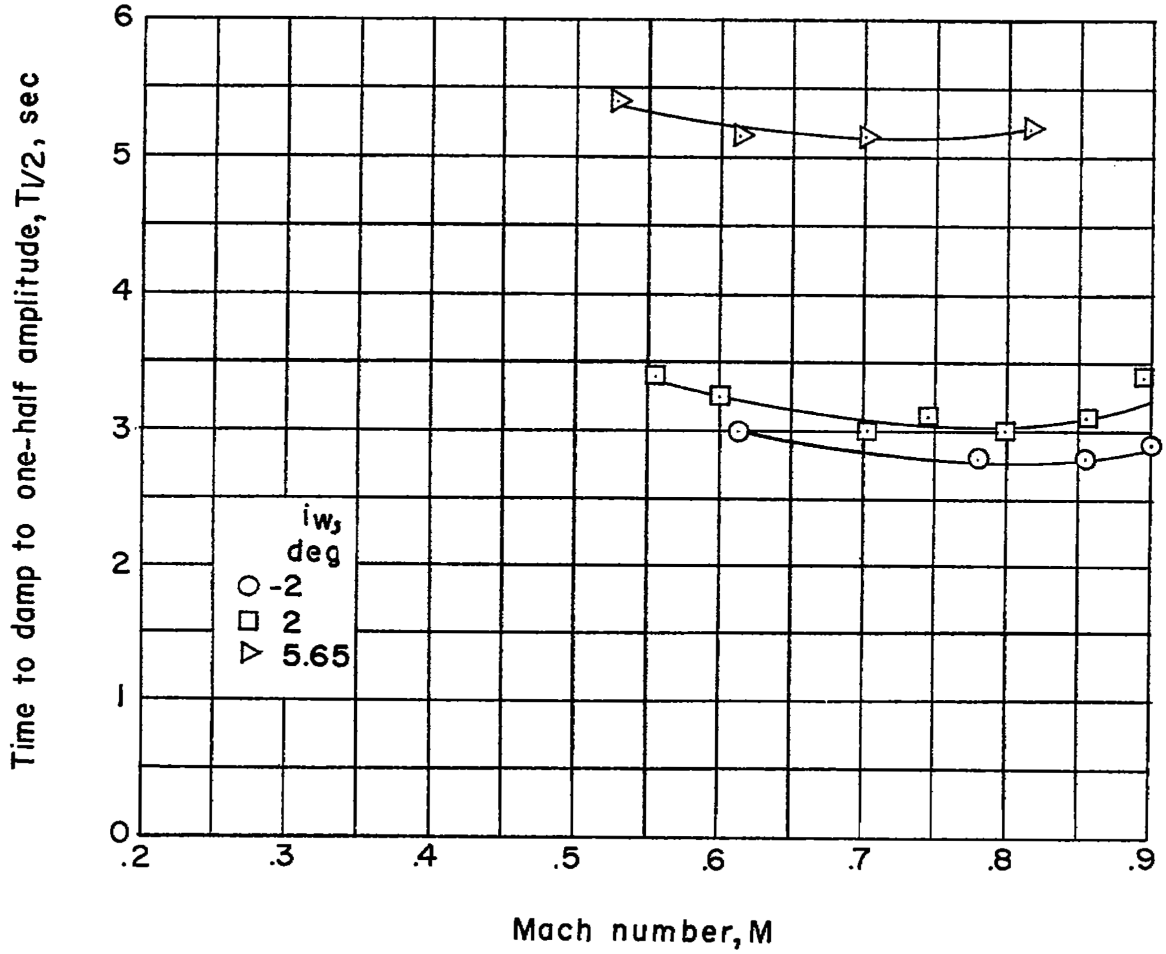


(c) h_p = 30,000 feet.

Figure 4.- Continued.



(d) h_p = 37,500 feet.

Figure 4.- Concluded.

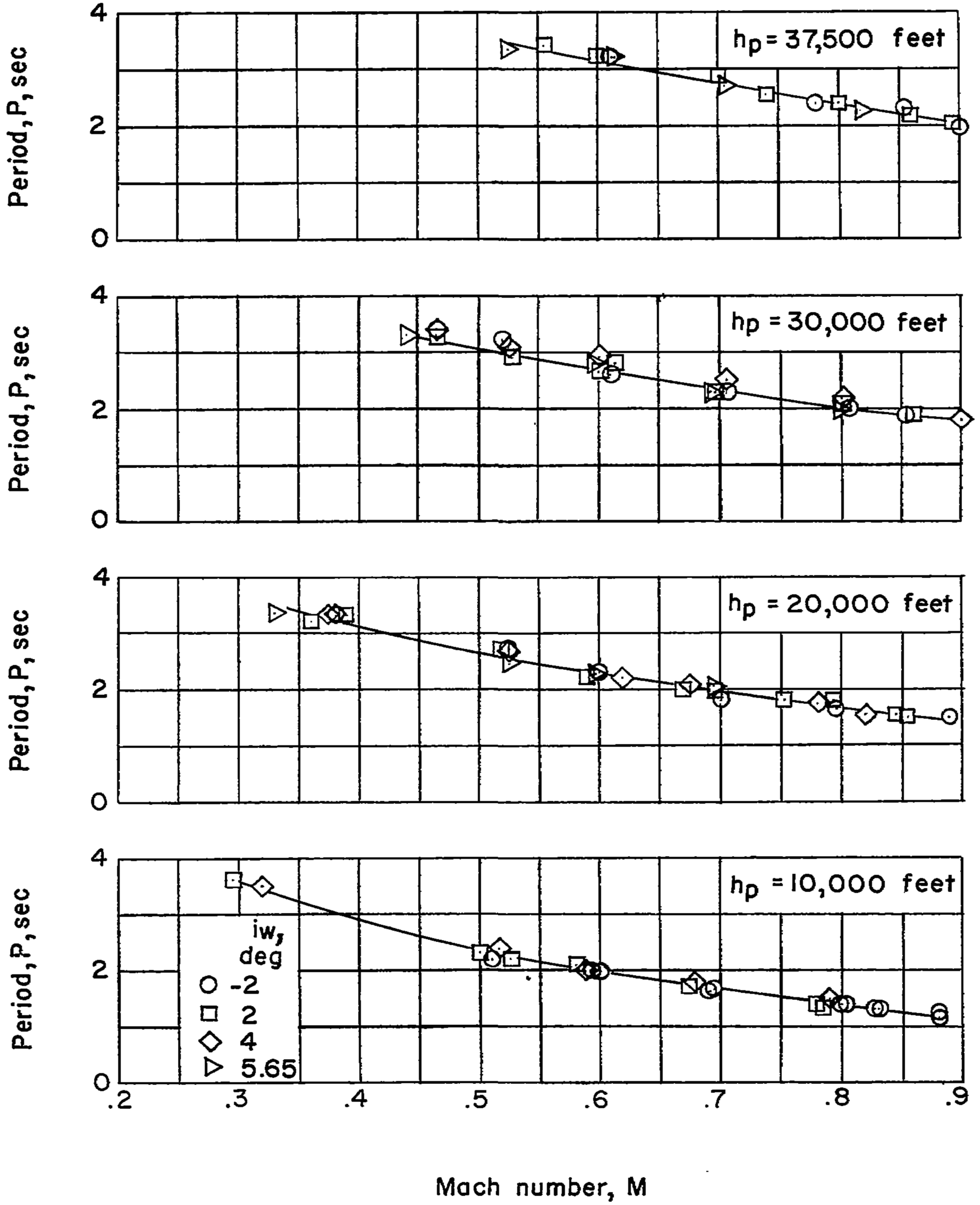


Figure 5.- Variation of period of the lateral oscillation with Mach number.

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