RESEARCH MEMORANDUM

ROLLING PERFORMANCE OF THE REPUBLIC YF-84F AIRPLANE

AS MEASURED IN FLIGHT

By John B. McKay

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Edwards, Calif.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

A flight investigation of the Republic YF-84F airplane has been conducted by the Republic Aviation Corp. in conjunction with the National Advisory Committee for Aeronautics to determine the rolling performance at Mach numbers between 0.35 and 0.95 at approximate altitudes of 10,000, 25,000, and 40,000 feet. Abrupt rudder-fixed aileron rolls were made utilizing from one-third to maximum aileron deflection.

It was found that, at an altitude of 10,000 feet, the wing-tip helix angle per degree total aileron deflection decreased from a value of 0.0031 to a value of 0.0011 as Mach number increased from 0.60 to 0.92. At 40,000 feet, the effectiveness decreased from a value of 0.0022 to a value of 0.0019 between Mach numbers of 0.68 and 0.95. The results show that at constant dynamic pressure the aileron effectiveness decreases with increasing Mach number over the range of dynamic pressure where comparable data were available. The magnitude of this decrease is less at the higher values of dynamic pressures.

Data obtained from tests utilizing either a 30:1 boost ratio system or an irreversible system show little difference in the time required to obtain a bank angle of 90°.

INTRODUCTION

The NACA has participated with the Republic Aviation Corp. in a joint investigation of the aileron effectiveness of the original version of the YF-84F airplane before spoilers were incorporated. The aileron characteristics were determined at altitudes of approximately 10,000, 25,000, and 40,000 feet. The Mach number range covered by the tests varied with altitude. At 10,000 feet Mach number varied from 0.35 to 0.93; at an altitude of 25,000 feet, Mach number varied from 0.50 to 0.93; and at 40,000 feet, the Mach number variation was from 0.67 to 0.95.

SYMBOLS

b	wing span, ft
h_p	pressure altitude, ft
M	Mach number
M.A.C.	mean aerodynamic chord, ft
p	rolling angular velocity, radians/sec, or deg/sec
$pb/2V$	wing-tip helix angle, radians
q	dynamic pressure, lb/sq ft
T_{90°	time to bank 90°, sec
t	time, sec
V	true airspeed, ft/sec
α	airplane angle of attack, deg
δ_a	aileron deflection (perpendicular to hinge line), deg

Subscripts:

a	aileron
T	total
max	maximum

AIRPLANE AND INSTRUMENTATION

The YF-84F airplane is a jet-propelled single-place midwing monoplane powered by a Wright YJ65-W-1 axial-flow turbojet engine. The wing is swept back 40° at the 25-percent-chord line, and has a taper ratio of 0.579. The thickness ratio is 10 percent, normal to the plane reference line which is the 25-percent-chord line. A three-view drawing and photographs of the airplane are shown as figures 1 and 2, respectively. Details of the wing and aileron are shown as figure 3(a). Figure 3(b) shows a schematic detail of the aileron linkage and boost installation. Both the 30:1 boost ratio system and the irreversible boost system used during the test employed the same control system. Any change in the control system to convert from the 30:1 boost ratio system to the irreversible boost ratio system was made in the aileron boost cylinder assembly, the aileron linkage and location of the boost valve remaining the same regardless of the boost system used. In table I are presented the physical characteristics of the airplane.

The ailerons are of the internal-sealed balance type, and have a maximum travel from 18° up to 18° down. The contour of the aileron is a continuation of the wing airfoil section. Since this paper presents the original roll capability of the YF-84F airplane with only the plain flap ailerons, it might be emphasized that spoilers were incorporated on later blocks of production F-84F airplanes to increase the rolling effectiveness after the deficiency in rate of roll was recognized.

Aileron positions were measured on both left and right ailerons by means of control position transmitters. Standard NACA recording instruments recorded rolling angular velocity, three components of acceleration, and left and right aileron angles. Dynamic pressure, pressure altitude, and Mach number were recorded on a photopanel. All records were synchronized by a common timer.

PROCEDURE AND TEST CONDITIONS

Data were obtained during abrupt rudder-fixed aileron rolls at test altitudes of approximately 10,000, 25,000, and 40,000 feet. The rolls were made at various Mach numbers between 0.35 and 0.93 at h_p = 10,000 feet; from $M = 0.50$ to $M = 0.93$ at h_p = 25,000 feet; and from $M = 0.67$ to $M = 0.95$ at h_p = 40,000 feet. A chain stop was installed in the cockpit to aid the pilot in holding a constant control deflection until maximum rolling velocity was reached.

Four of the eight flights were made with the aileron controls employing an irreversible boost system having no feedback to the control system. During the remaining four flights, duplicate tests were made employing a 30:1 boost ratio system on the aileron controls. Only data obtained from tests utilizing an irreversible boost system are presented except where a comparison is made of the two systems of the time required to reach a bank angle of 90°.

RESULTS AND DISCUSSION

Time histories of typical aileron rolls at various altitudes from which values of $pb/2V$ were obtained are presented in figure 4.

Figure 5 shows the variation of wing-tip helix angle $pb/2V$ with change in total aileron deflection δ_{a_T} over the Mach number range at each of the three altitudes. The data of figure 5 indicate that the variation of $pb/2V$ with δ_{a_T} is slightly nonlinear at a test altitude of approximately 10,000 feet. At altitudes of approximately 25,000 and 40,000 feet, the variation of $pb/2V$ with δ_{a_T} becomes more nonlinear with an increase in Mach number.

Figure 6 presents the variation of rolling velocity with Mach number over the Mach number range covered at the three test altitudes. The rolling velocities are based on a change in total aileron deflection of 20°. The data show a gradual increase in rolling velocity with increase of Mach number to a maximum between Mach numbers of 0.68 and 0.82, depending on altitude. At higher Mach numbers, there is a decrease in rolling velocity, starting earliest at the lowest altitudes. The rolling velocity attained a maximum value of about 156° per second at 25,000 feet at $M = 0.81$.

The variation of aileron effectiveness $pb/2V/\delta_{a_T}$ with Mach number at the three test altitudes is shown in figure 7. Values of $pb/2V/\delta_{a_T}$ were obtained by dividing the maximum values of $pb/2V$ at a given Mach number by the corresponding total change in aileron deflection. The data indicate that the values of $pb/2V/\delta_{a_T}$ remain initially constant at the lower Mach numbers with the highest effectiveness at the lowest altitude. At higher Mach numbers, there is a decrease in effectiveness, starting earliest at the lowest altitudes. At an altitude of 10,000 feet, the data indicate a decrease in aileron effectiveness from a value of 0.0031 at $M = 0.60$ to a value of 0.0011 at $M = 0.92$. When the altitude is increased from 10,000 feet to 40,000 feet, the loss in aileron effectiveness decreases from a value of 0.0022 to a value of 0.0019 between $M = 0.68$ and $M = 0.95$.

Figure 8 shows the variation of wing-tip helix angle per degree aileron deflection with dynamic pressure at $M = 0.35$, 0.50, 0.60, 0.68, 0.72, 0.82, and 0.92. The curves were obtained from cross plots of figure 7. These data indicate that at constant values of dynamic pressure the aileron effectiveness decreases with increasing Mach number, and the magnitude of this decrease is less at the higher values of dynamic pressure. The data presented in figure 8 indicate that Mach number effects and aeroelastic effects are about equally significant in contributing toward the decrease in aileron effectiveness at the lower test altitudes. There are insufficient data to determine the aileron reversal speed but it appears to be at a value of dynamic pressure greater than 1,000 pounds per square foot.

Figure 9 shows the variation of wing-tip helix angle $\frac{pb}{2V} \times \frac{\Delta\delta_{a_{T_{max}}}}{\Delta\delta_{a_T}}$ with dynamic pressure for the three test altitudes covered. The data were extrapolated to represent a change in total aileron angle equivalent to 36° (full aileron travel). This is not strictly correct because of the nonlinearities shown in figure 5 but it is felt to be a reasonable approximation. It is evident from this figure that the aileron power thus extrapolated would satisfy the Air Force specification given in reference 1 up to a dynamic pressure of about 600 pounds per square foot.

It has been suggested in reference 2 that a more reasonable requirement for satisfactory aileron power might be to require sufficient aileron power to bank 90° in 1 second. The time required for the YF-84F to bank 90° at the three test altitudes is shown in figure 10. The data shown are for full deflection of the control stick, but do not necessarily represent a constant aileron deflection over the Mach number range because of the variation of control system stretch with variations of dynamic pressure.

The data indicate that the time required to reach 90° decreases to a minimum value between 1 and $1\frac{1}{4}$ seconds at about $M = 0.63$, 0.73, and 0.80 at altitudes of 10,000, 25,000, and 40,000 feet, respectively. Above these Mach numbers, the time required to reach 90° increases with increasing Mach number. At altitudes above 10,000 feet, the time required to reach 90° at the higher Mach numbers is less than that required at 10,000 feet.

It might be noted here that, although the airplane satisfies the Air Force specification over a large portion of the flight range, pilots feel that the rate of roll is too low for fighter-type aircraft. (See ref. 3.) This feeling may be associated with the excessive time required to reach 90° bank as shown in figure 10.

Several of the flights were made with the aileron controls utilizing a 30:1 boost ratio system. Although no change in rolling effectiveness of the YF-84F airplane was expected with the 30:1 boost system as compared to that of the irreversible boost system, it was felt that the difference in control forces needed to actuate the two systems might delay the aileron response to such an extent that the time to reach a bank angle of 90° would differ between identical airplanes using the different boost systems. Figure 11 compares the two systems from the standpoint of the time required to reach a bank angle of 90°. This comparison shows little difference in the time required to obtain a bank angle of 90°, regardless of the type of boost system used.

CONCLUSIONS

From the measurements of rolling performance in flight of the Republic YF-84F airplane, the following conclusions have been drawn:

1. The aileron effectiveness decreases from a value of 0.0031 to a value of 0.0011 at an altitude of 10,000 feet as the Mach number increased from 0.60 to 0.92. When the altitude is increased from 10,000 feet to 40,000 feet, the aileron effectiveness decreases from a value of 0.0022 to a value of 0.0019 between Mach numbers of 0.68 and 0.95.

2. Over the range of dynamic pressures where comparable data were available, the aileron effectiveness decreases with increasing Mach number, and the magnitude of this decrease is less at the higher values of dynamic pressure.

3. Except for small differences in the time required to obtain a bank angle of 90°, identical results were obtained from tests employing the irreversible boost system and the 30:1 boost ratio system.

High-Speed Flight Station,
National Advisory Committee for Aeronautics,
Edwards, Calif., July 2, 1954.

REFERENCES

1. Anon: Flying Qualities of Piloted Airplanes. U. S. Air Force Specifications No. 1815-B, June 1, 1948.

2. Williams, W. C., and Crossfield, A. S.: Handling Qualities of High-Speed Airplanes. NACA RM L52A08, 1952.

3. Cole, John W., and Collins, Harold E.: Phase II Flight Tests of the YF-84F Airplane, USAF No. 49-2430. Memo. Rep. No. MCRFT-2331, Air Materiel Command, Flight Test Div., U. S. Air Force, Mar. 8, 1951.

TABLE I

PHYSICAL CHARACTERISTICS OF REPUBLIC YF-84F AIRPLANE

Wing:	
Airfoil section	NACA 64A010
Area, sq ft	324.7
Span, ft	33.58
Mean aerodynamic chord, in.	120.6
Root chord (airplane center line), in.	148.56
Tip chord, in.	86.04
Aspect ratio	3.47
Taper ratio	0.579
Geometric twist, deg	0
Cathedral, deg	-3.5
Sweep at 0.25 chord, deg	40
Tip chord inclination, deg	1.5
Incidence angle, deg	1.5
Slats (type):	
Leading edge	Partial span, drooped
Flaps (type):	
Trailing edge	Partial span, plain
Ailerons:	
Type	Internal sealed, aerodynamic and static balance
Area (one), aft of hinge line, sq ft	13.46
Travel, deg:	
Up	18 ± 1/2
Down	18 ± 1/2
Area left aileron tab, sq ft	0.58
Vertical tail:	
Airfoil section	NACA 64A011
Area, sq ft	35.0
Sweep at 0.25 chord, deg	40
Fin normal setting (on fuselage center line), deg	0
Fin travel, deg	Fixed
Rudder area, sq ft	6.75
Rudder travel, deg:	
Right	$23\frac{1}{2} \pm \frac{1}{2}$
Left	$23\frac{1}{2} \pm \frac{1}{2}$

TABLE I - Concluded

PHYSICAL CHARACTERISTICS OF REPUBLIC YF-84F AIRPLANE

Horizontal tail:	
Airfoil section	NACA 64A009
Area, sq ft	55.8
Span, ft	14.2
Sweep at 0.25 chord, deg	40
Elevator area (total), sq ft	14.8
Elevator travel, deg:	
Up	$27\frac{1}{2} \pm \frac{1}{2}$
Down	12 ± 1/2
Stabilizer area, sq ft	41.0
Stabilizer travel, deg:	
Up	$3\frac{3}{4} \pm \frac{1}{4}$
Down	$8\frac{3}{4} \pm \frac{1}{4}$
Fuselage:	
Width, ft	4.16
Length, ft	38.42
Height (top of canopy to bottom of fairing), ft	7.41
Fineness ratio (2 times length/maximum width plus height)	6.65
Power plant	YJ65-W-1
Rated thrust, lb	7,000
Airplane weight, lb:	
Empty weight	11,718.6
Useful load	5,618.4
Gross weight	17,320

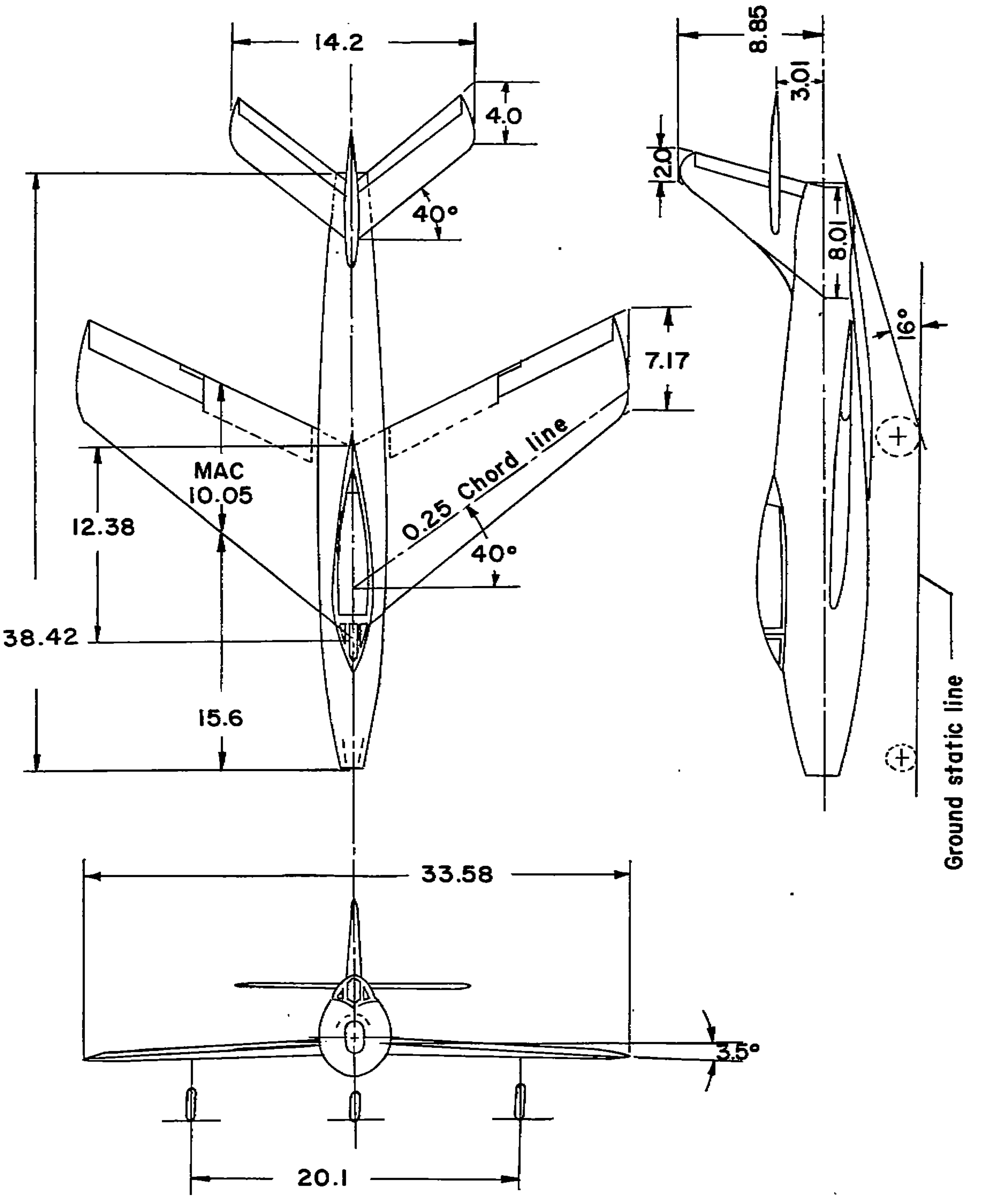


Figure 1.- Three-view drawing of Republic YF-84F airplane. All dimensions in feet.

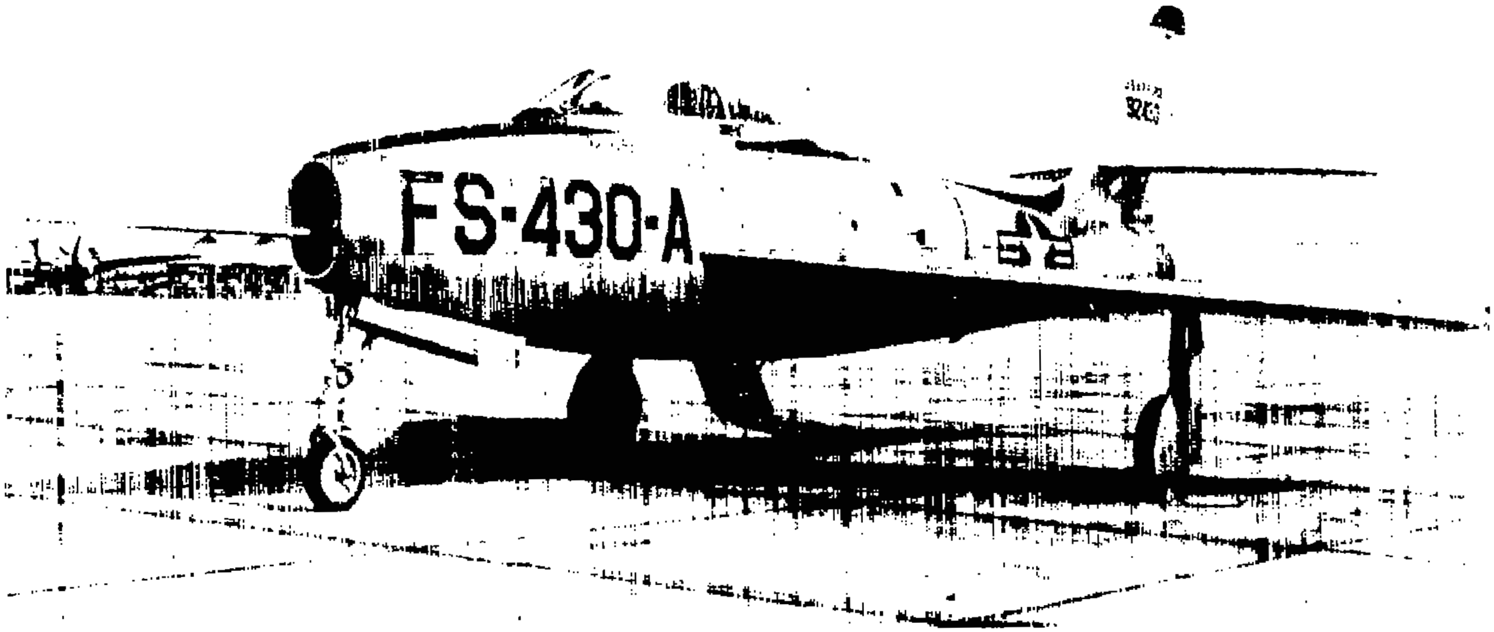
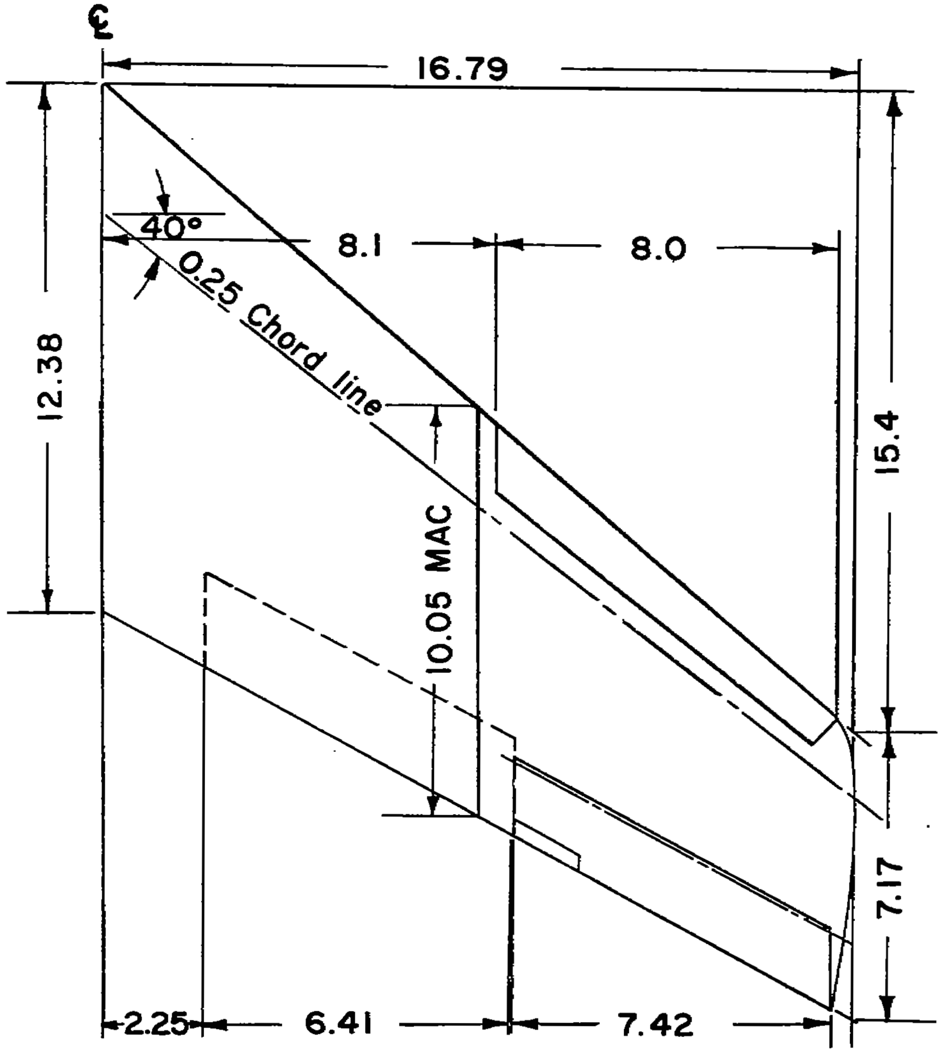
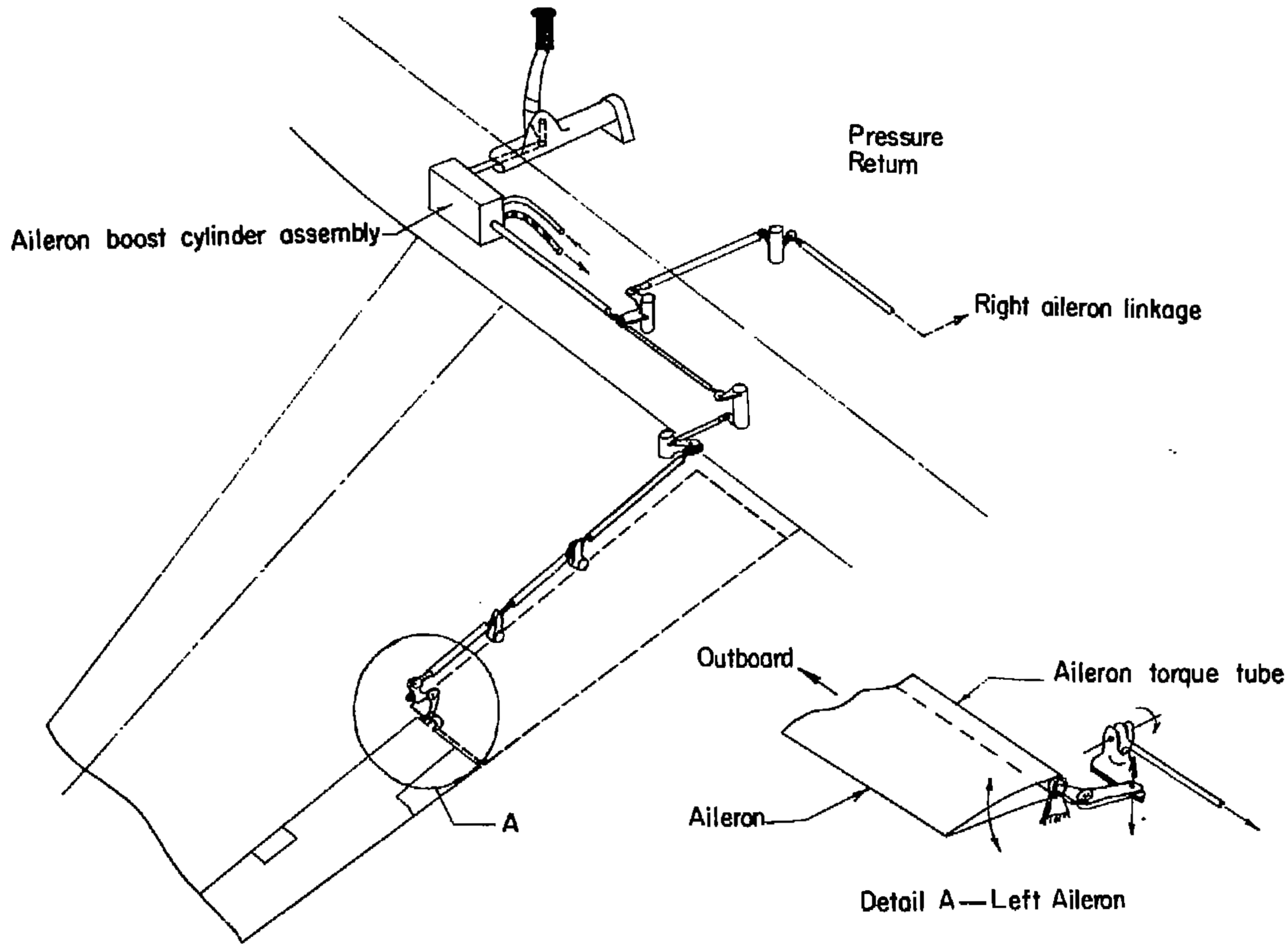


Figure 2.- Photograph of Republic YF-84F airplane. L-84926



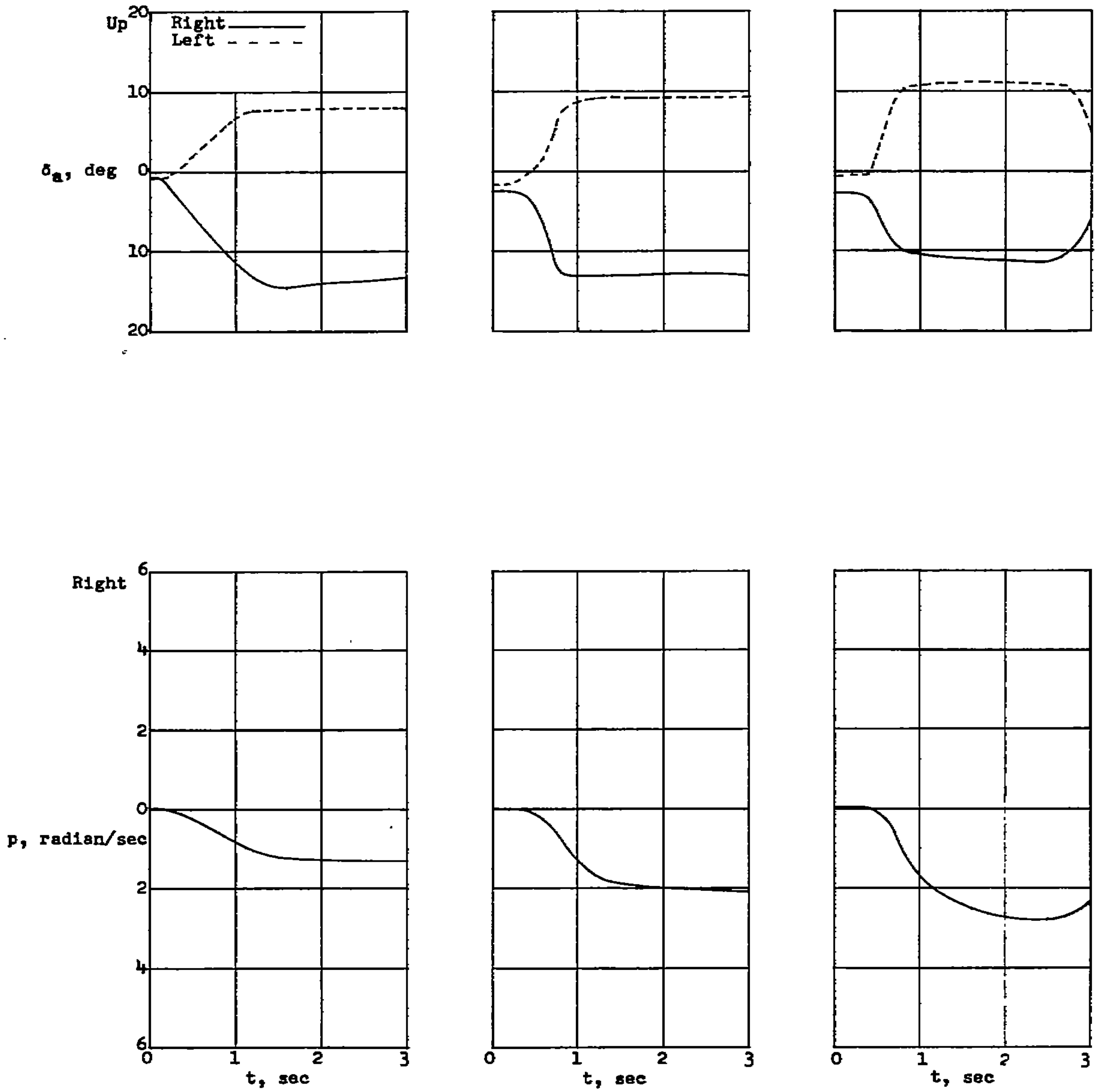
(a) Wing.

Figure 3.- Sketches of wing and aileron of Republic YF-84F airplane. Airfoil section, root and tip, NACA 64A010.



(b) Aileron installation.

Figure 3.- Concluded.

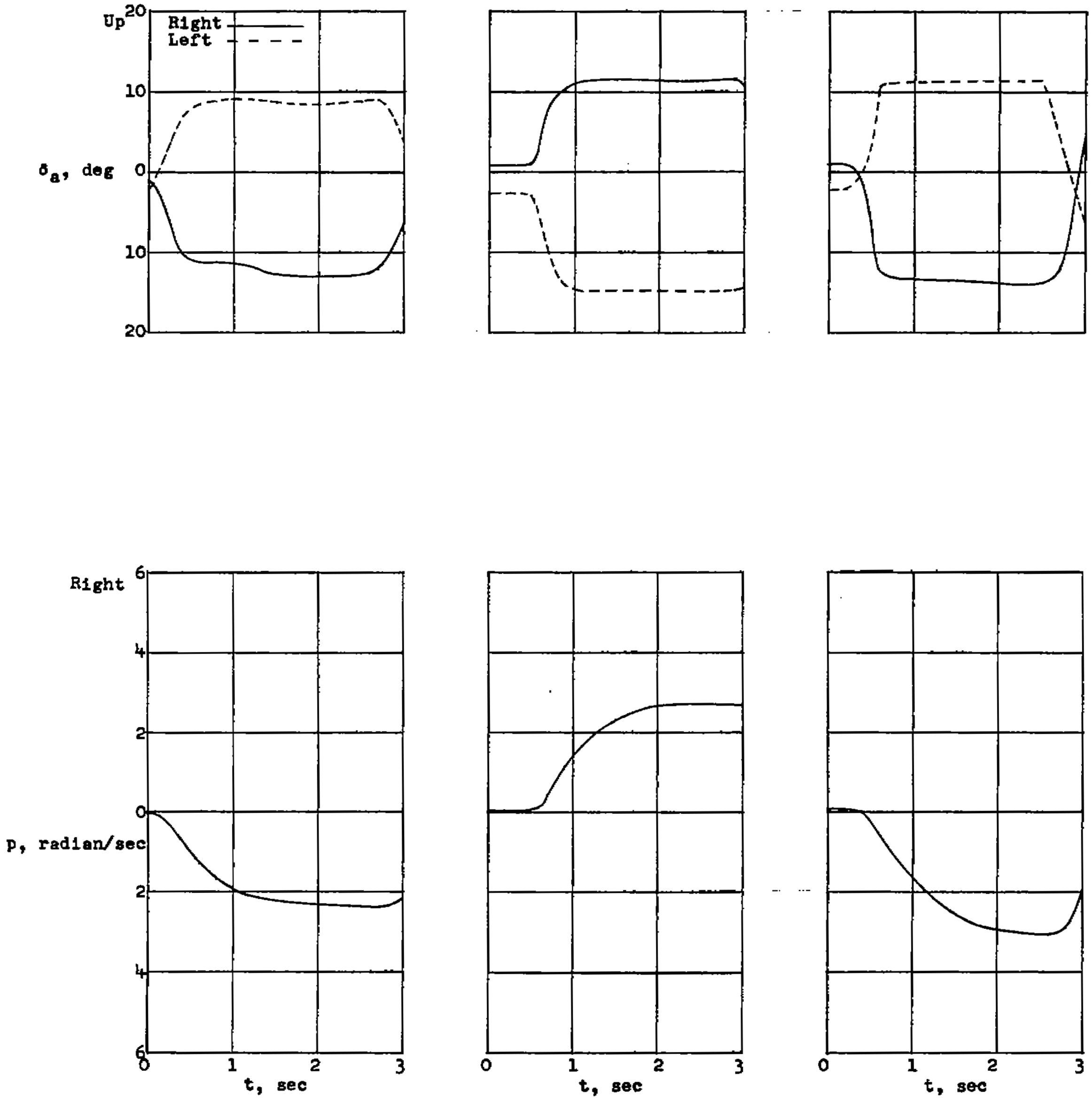


(a) $M = 0.92$; $h_p = 11,800$ ft.

(b) $M = 0.82$; $h_p = 13,300$ ft.

(c) $M = 0.62$; $h_p = 11,600$ ft.

Figure 4.- Time histories of aileron rolls used to determine $pb/2V$.

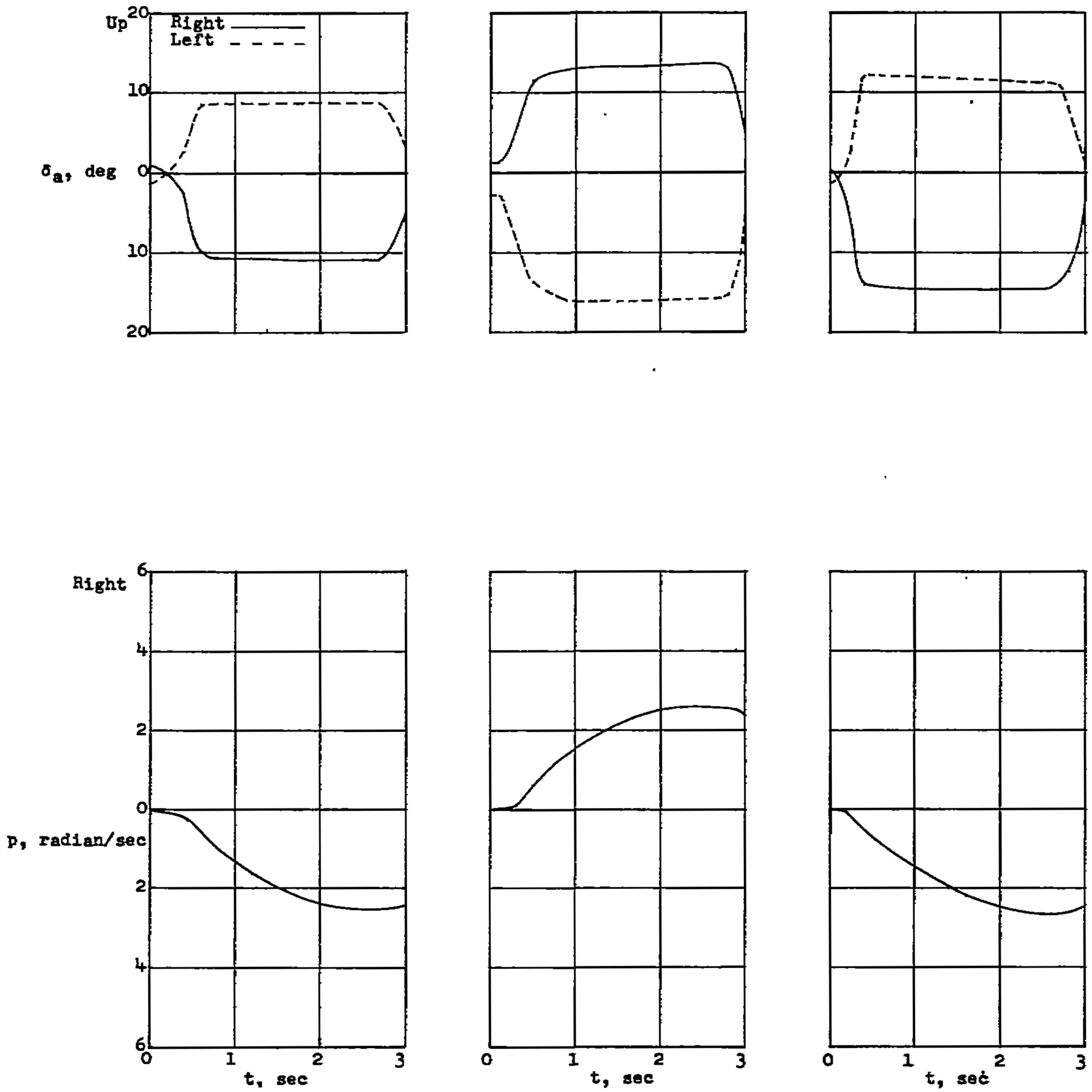


(d) M = 0.93; h_p = 25,800 ft.

(e) M = 0.82; h_p = 27,500 ft.

(f) M = 0.67; h_p = 25,800 ft.

Figure 4.- Continued.

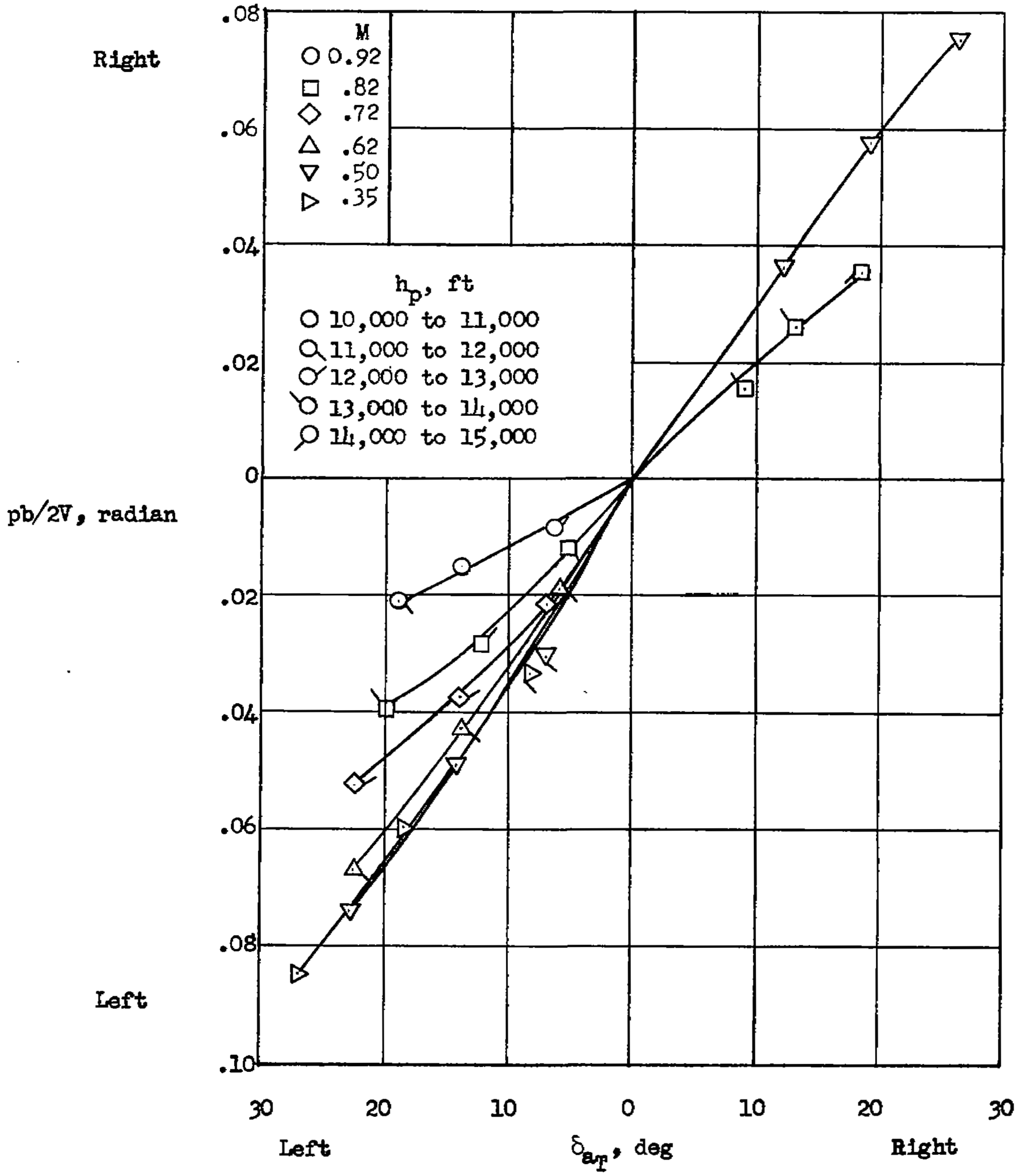


(g) $M = 0.95$; $h_p = 37{,}800$ ft.

(h) $M = 0.83$; $h_p = 40{,}000$ ft.

(i) $M = 0.67$; $h_p = 39{,}000$ ft.

Figure 4.- Concluded.



(a) $h_p \approx 10,000$ feet.

Figure 5.- Variation of wing-tip helix angle with change in total aileron deflection. YF-84F airplane.

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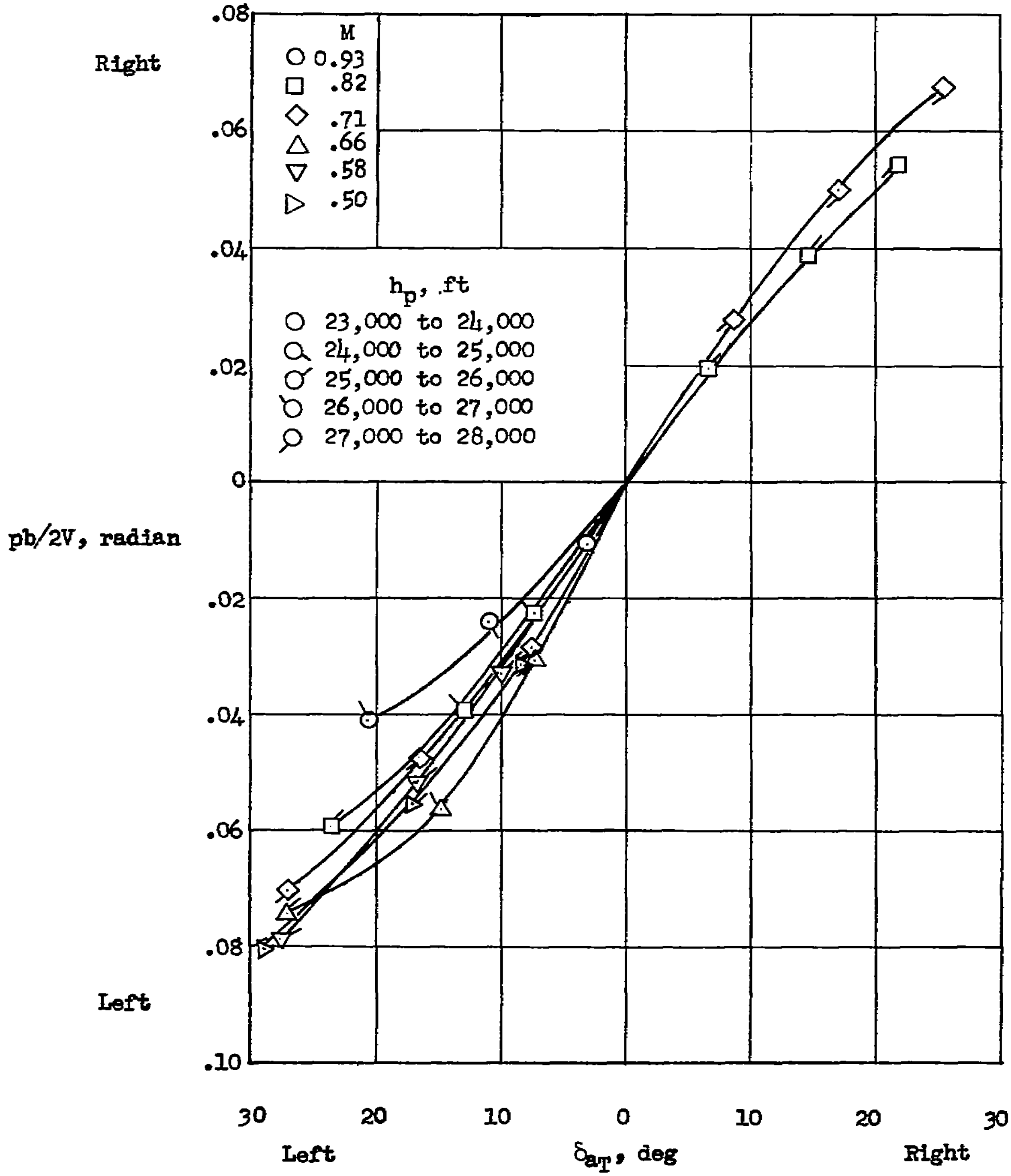

(b) $h_p \approx 25{,}000$ feet.

Figure 5.- Continued.

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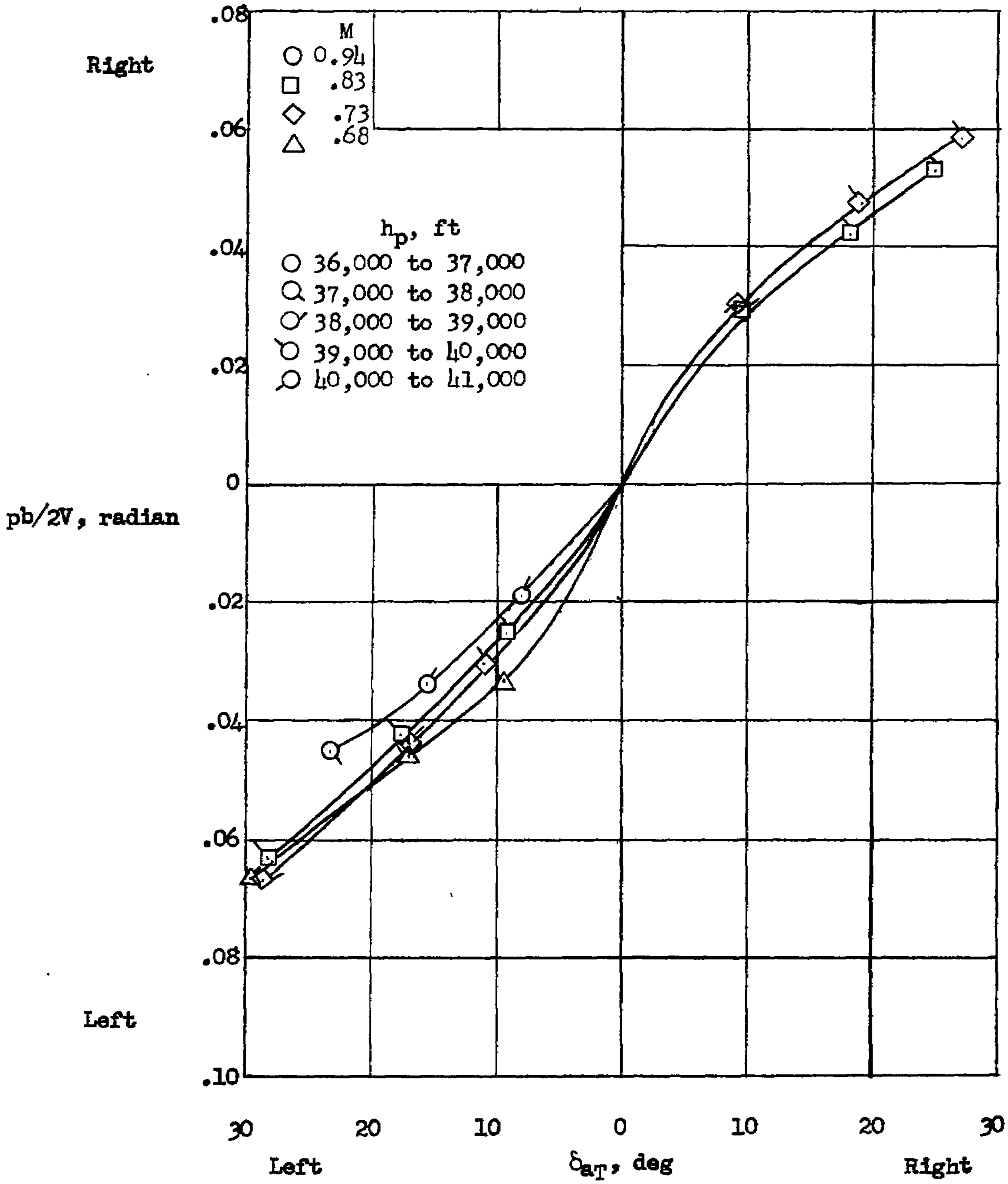

(c) $h_p \approx 40,000$ feet.

Figure 5.- Concluded.

[redacted]

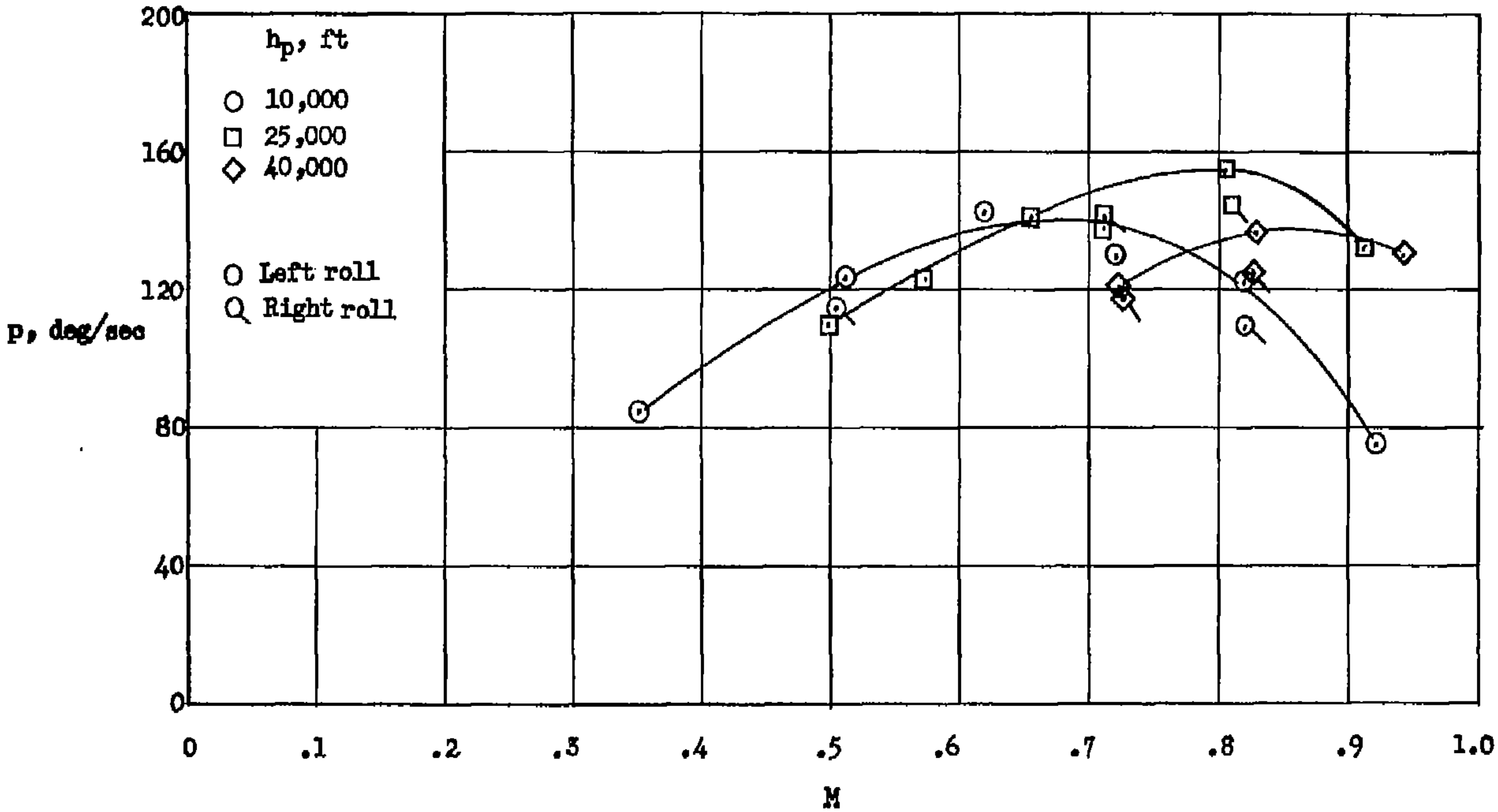

Figure 6.- Variation of rolling velocity with Mach number. YF-84F airplane.

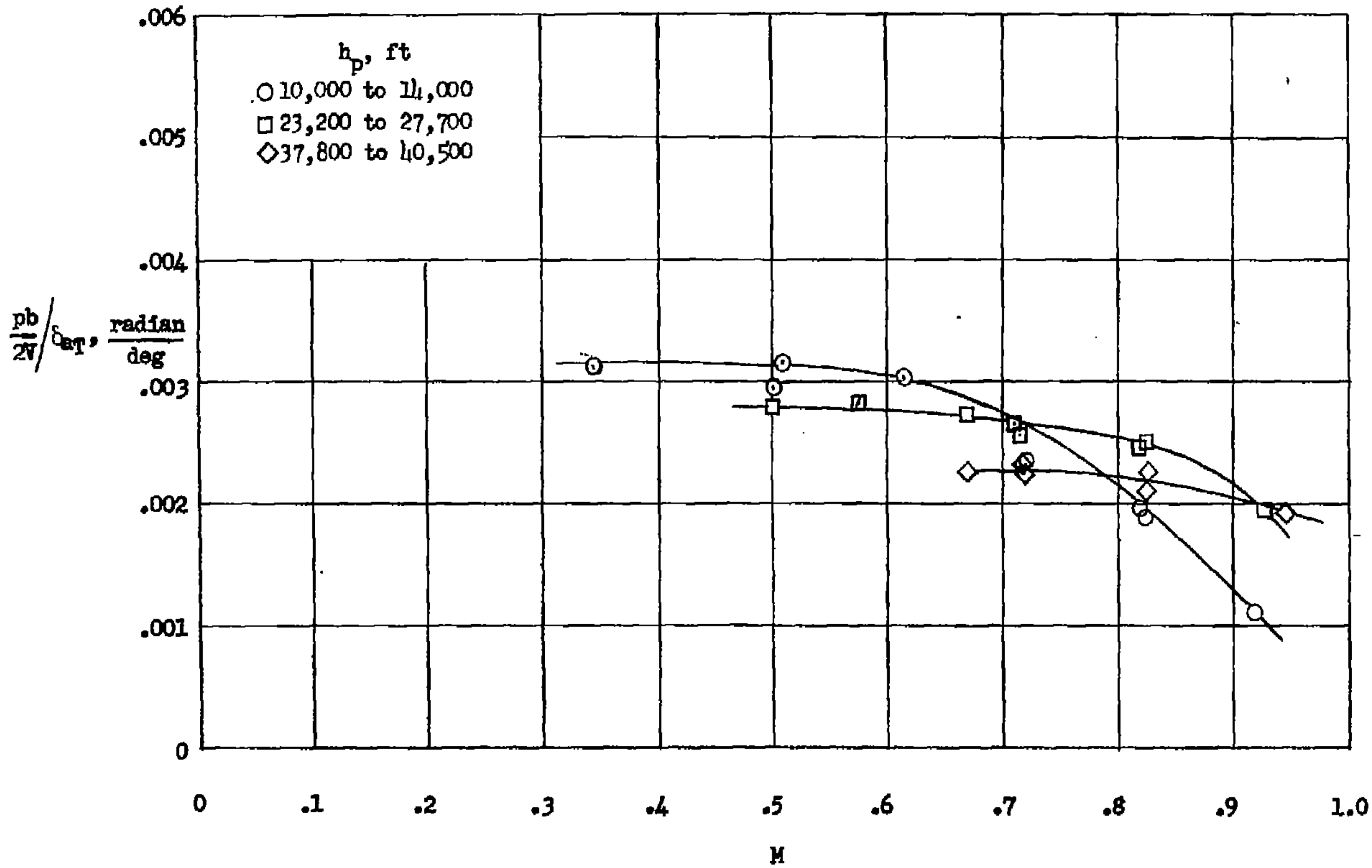

Figure 7.- Variation of wing-tip helix angle per degree total aileron deflection with Mach number. YF-84F airplane.

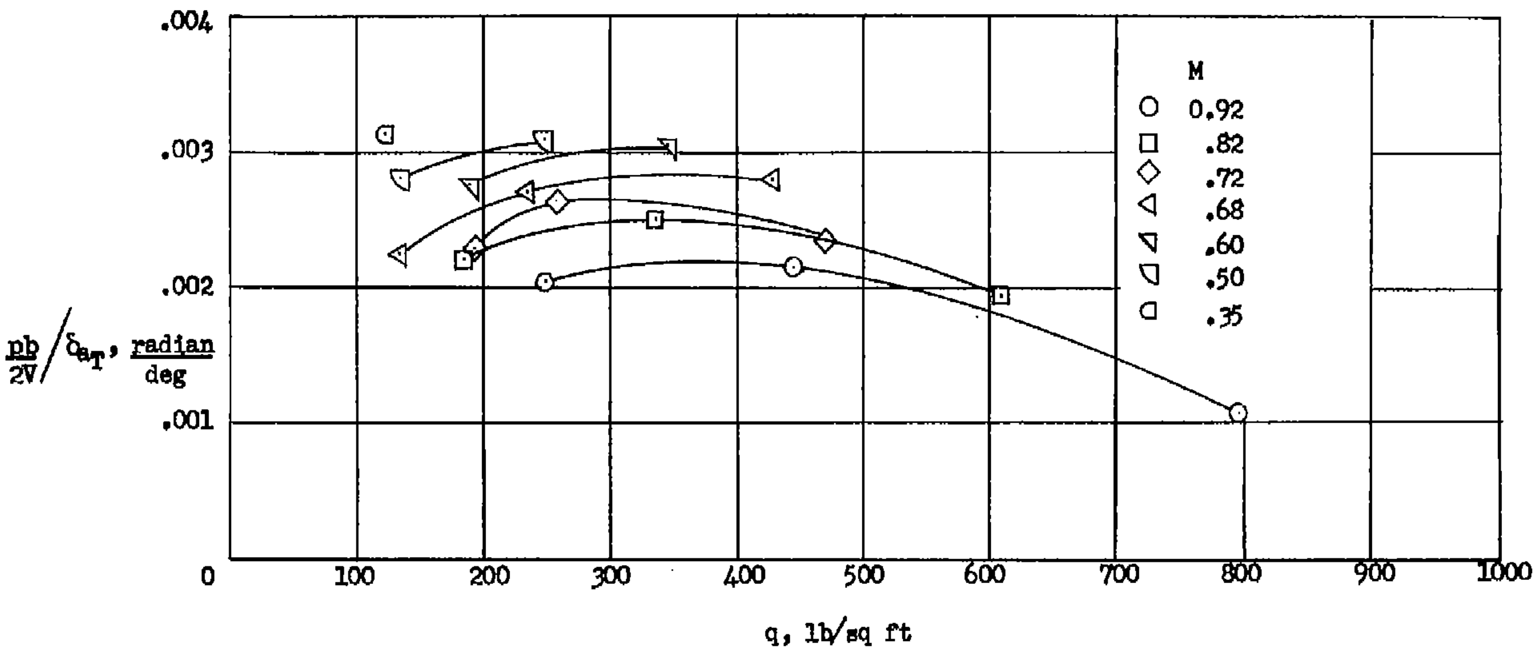

Figure 8.- Variation of wing-tip helix angle per degree total aileron deflection with dynamic pressure. YF-84F airplane.

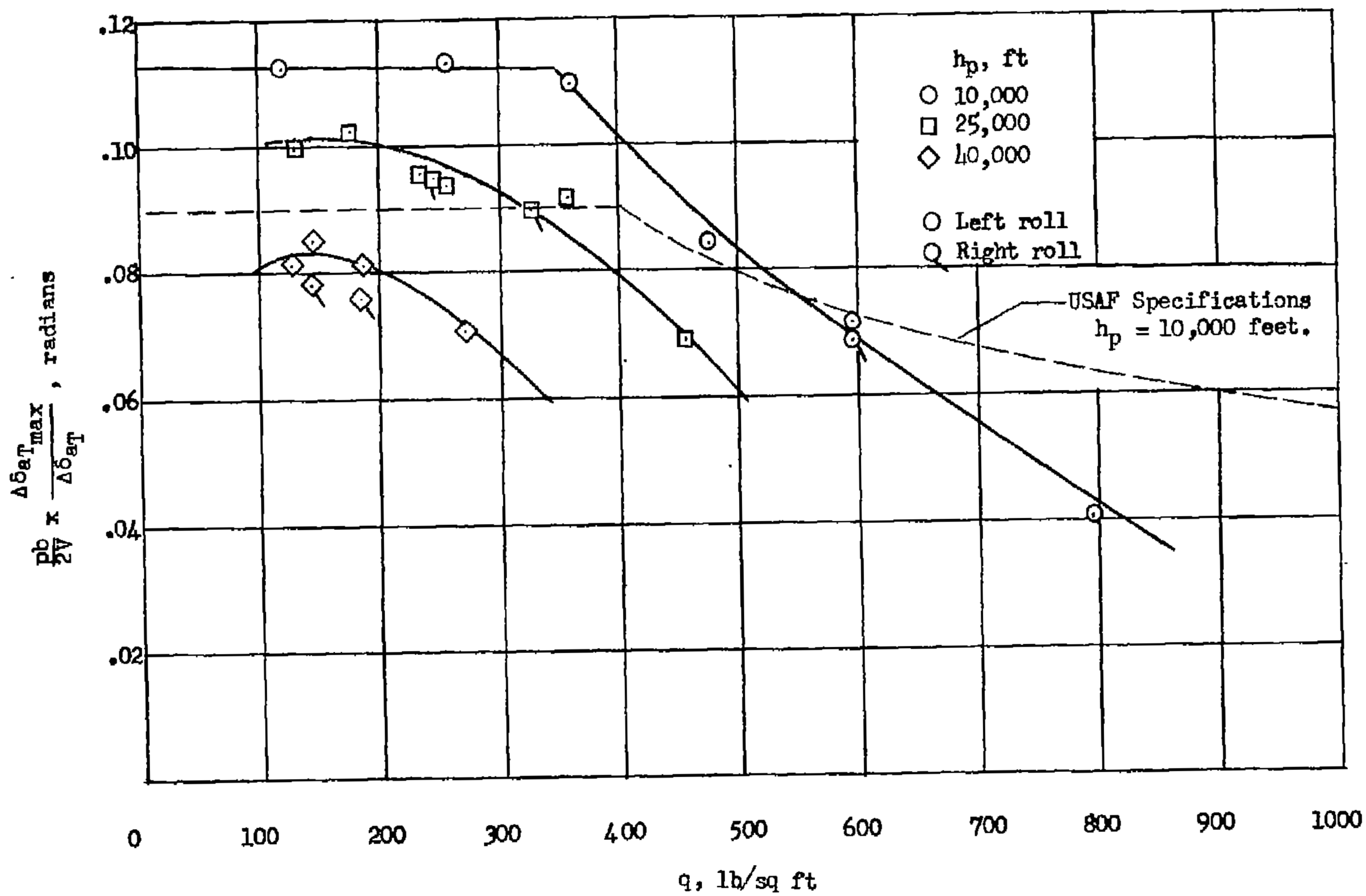

Figure 9.- Variation of wing-tip helix angle with dynamic pressure. (Maximum change in total aileron angle, 36°.) YF-84F airplane.

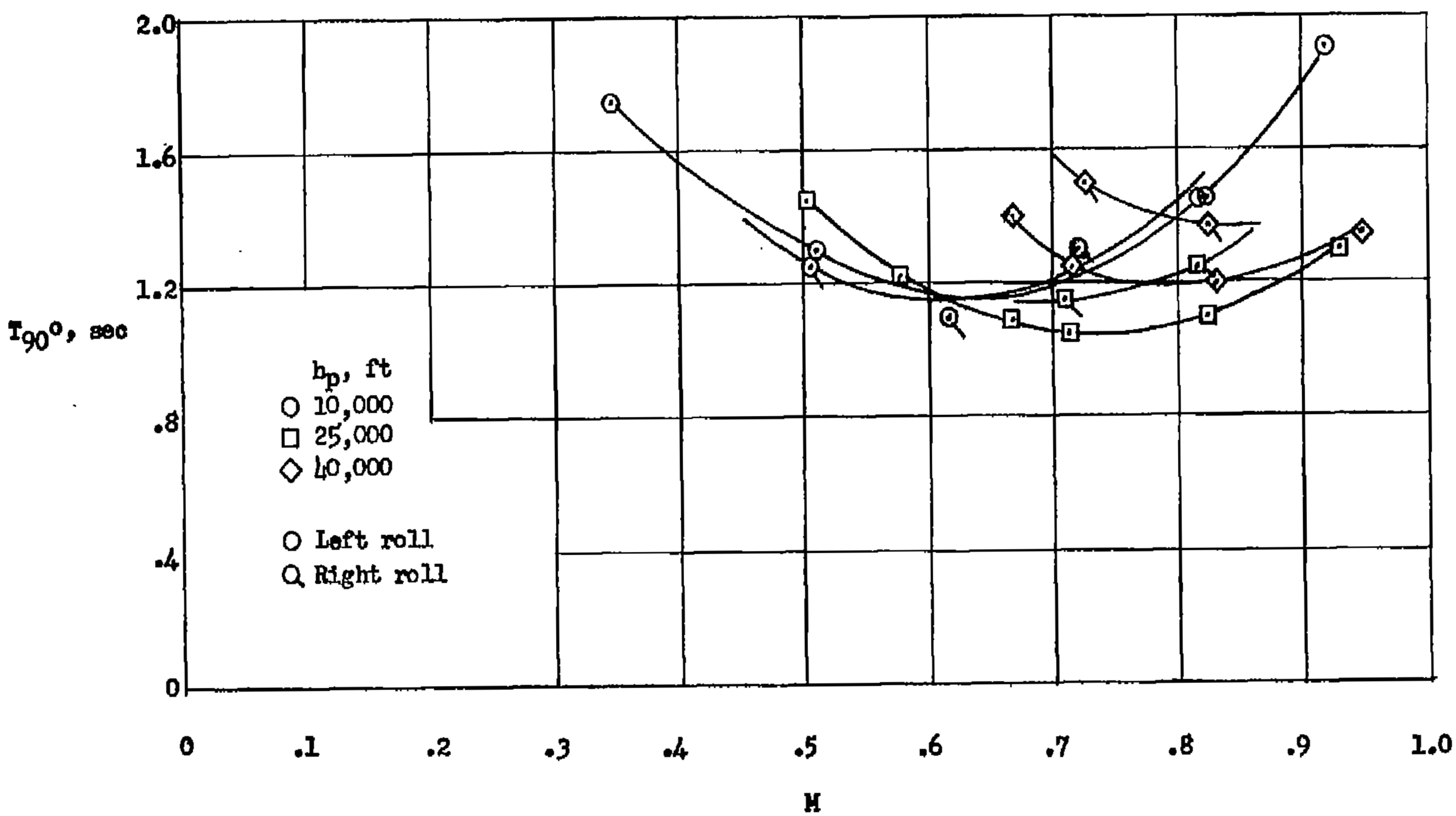

Figure 10.- Variation with Mach number of the time required to bank 90°. YF-84F airplane.

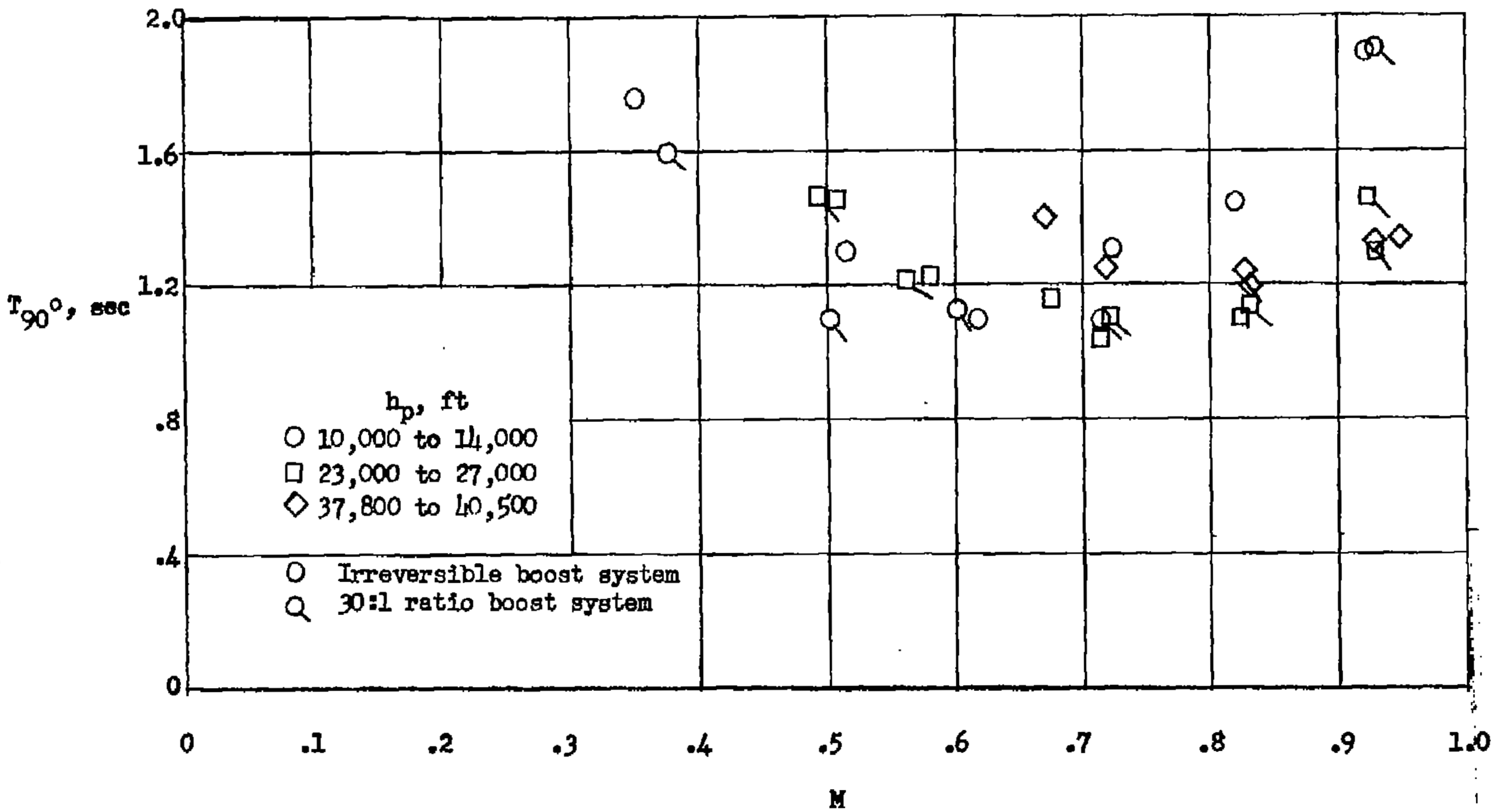

Figure 11.- Comparison of the time required to bank 90° of the irreversible boost system and the 30:1 ratio boost system. YF-84F airplane.

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