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TECHNICAL MEMORANDUM

SX-196

for the

Bureau of Aeronautics, Department of the Navy

FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/25-SCALE MODEL OF THE CHANCE VOUGHT F8U-1P AIRPLANE

TED NO. NASA AD-3137

By James S. Bowman, Jr., and Frederick M. Healy

Langley Research Center
Langley Field, Va.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON SEP 25 1959

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CONFIDENTIAL

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SUMMARY

An investigation has been made in the Langley 20-foot free-spinning tunnel on a 1/25-scale dynamic model to determine the spin and recovery characteristics of the Chance Vought F8U-1P airplane. Results indicated that the F8U-1P airplane would have spin-recovery characteristics similar to the XF8U-1 design, a model of which was tested and the results of the tests reported in NACA Research Memorandum SL56L31b. The results indicate that some modification in the design, or some special technique for recovery, is required in order to insure satisfactory recovery from fully developed erect spins. The recommended recovery technique for the F8U-1P will be full rudder reversal and movement of ailerons full with the spin (stick right in a right spin) with full deflection of the wing leading-edge flap.

Inverted spins will be difficult to obtain and any inverted spin obtained should be readily terminated by full rudder reversal to oppose the yawing rotation and neutralization of the longitudinal and lateral controls.

In an emergency, the same size parachute recommended for the XF8U-1 airplane will be adequate for termination of the spin: a stable parachute 17.7 feet in diameter (projected) with a drag coefficient of 1.14 (based on projected diameter) and a towline length of 36.5 feet.

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*Title, Unclassified.

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SERVICE REPORT

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, an investigation has been made in the Langley 20-foot free-spinning tunnel of the spin and spin-recovery characteristics of a 1/25-scale model of the Chance Vought F8U-1P airplane. Figure 1 is a three-view drawing of the model as tested. The F8U-1P model is similar to the XF8U-1 model previously tested in the spin tunnel (ref. 1) except that the lower fuselage forebody cross section has been modified to accommodate the camera installation. Figure 2 illustrates the nature of the modification. Spin-tunnel tests on a 1/25-scale model of the XF8U-1 airplane indicated that both a flat rapidly rotating spin and a steeper slower oscillatory spin were possible (ref. 1). Subsequently, however, static force tests at high angles of attack and tests of a 1/9-scale dynamic radio-controlled model (ref. 2) of a similar design indicated that the flat fast spin was a result of low Reynolds number. The present investigation was undertaken because references 3 and 4 indicated that the F8U-1P cross-sectional shape was such that a propelling pro-spin yawing moment would prevail on the fuselage nose at angles of attack of 70° or higher for both model and airplane Reynolds numbers and that a flat rapidly rotating spin as well as a steeper slower spin would likely be possible on the corresponding airplane.

The erect and inverted spin and recovery characteristics of the model were determined with the model loaded to simulate the basic flight design gross weight (center of gravity at 23.9 percent $\bar{c}$) of the airplane. Erect-spin tests were also made with the center of gravity at 31.9 percent $\bar{c}$. The influence of the gyroscopic moments of the rotating engine components on erect spins and recoveries was investigated. Brief tests were also made with a spin-recovery parachute housing simulated on the model. A spin-recovery tail parachute to effect satisfactory spin recovery in an emergency was also investigated.

SYMBOLS

b	wing span, ft
C_Y	side-force coefficient, $\dfrac{F_Y}{\frac{1}{2}\rho(V')^2 S}$
$\bar{c}$	mean aerodynamic chord, ft
F_Y	side force, lb

[redacted]

I_X, I_Y, I_Z	moments of inertia about X-, Y-, and Z-body axes, respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
l	fuselage depth at wing root leading edge, ft
m	mass of airplane, slugs
R	Reynolds number (based on fuselage depth at wing root leading edge), $\frac{V'l}{\nu}$
S	wing area, sq ft
V	full-scale true rate of descent, ft/sec
V'	absolute velocity, ft/sec
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg
α'	absolute angle of attack, deg
β	sideslip angle, deg
μ	relative density of airplane, $\frac{m}{\rho Sb}$

[redacted]

ν	kinematic viscosity of air, standard condition, ft^2/sec
ρ	air density, slugs/cu ft
ϕ	angle between span axis and horizontal, deg
Ω	full-scale angular velocity about spin axis, rps

MODEL AND TESTING TECHNIQUES

The 1/25-scale model of the Chance Vought F8U-1P airplane was constructed at the Langley Research Center of the National Aeronautics and Space Administration. The dimensional characteristics of the airplane are presented in table I. The mass characteristics for the loadings of the airplane and for the loadings tested on the model are presented in table II. The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 30,000 feet (ρ = 0.000889 slug/cu ft).

A remote-control mechanism was installed in the model to actuate the controls for the recovery attempts. Sufficient torque was applied to the controls for the recovery attempts to reverse them fully and rapidly. Controls were set with an accuracy of ±1°.

The angular momentum of the rotating components of the full-scale engine was simulated by rotating a flywheel with a small battery-powered motor. The flywheel was located in the model so that the axis of rotation was parallel to the longitudinal axis of the airplane. Tests were made with and without the flywheel rotating.

The following normal maximum control deflections (measured perpendicular to the control hinge lines) were used during the test program:

Rudder, deg:
- Right 6
- Left 6

Horizontal tail (trailing edge), deg:
- Up 30
- Down 10

Ailerons, deg:
- Up 15
- Down 15

General descriptions of model testing techniques, methods of interpreting test results, and correlation between model and airplane results are presented in reference 3.

Model spin-recovery information as presented in chart 1 includes the following notation: For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as greater than the number of turns from the time the controls are moved to the time the model strikes the net, as >3. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin."

RESULTS AND DISCUSSION

Erect Spins

<u>Basic flight design gross weight</u>.- The results of tests with the model loaded to simulate the basic flight design gross weight (loading 1 in table II) are presented in chart 1. Inasmuch as the results for spins to the right and to the left indicated no significant effects of model asymmetry, the data are arbitrarily presented in terms of right spins.

Recoveries from erect spins of the model were generally attempted by simultaneous reversal of the rudder to full against the spin, and movement of the ailerons to full with the spin (stick to the right in a right spin). Selection of this procedure as the normal control recovery technique was based on the results of XF8U-1 model tests reported in reference 1 and on the effectiveness of control techniques in terminating spins of airplanes having various conditions of mass distribution as discussed in detail in reference 3.

The spins in which the ailerons were either neutral or against the spin during the developed phase of the spin exhibited two spinning conditions - a flat rapidly rotating spin and a steeper more oscillatory spin; in some instances, also, an additional condition in which the model would not remain in a developed spin was also obtainable. When the ailerons were maintained full with the launching rotation, the model would not spin. The criterion spin configuration indicated that model recoveries could range from satisfactory to unsatisfactory. Based on the model results obtained, it is considered that satisfactory airplane recoveries may not always be obtained by the normal control recovery technique (rapid rudder reversal to full against the spin and movement of the ailerons to full with the spin). During airplane recovery attempts the stick should be maintained full back, inasmuch as the model results indicate that faster rates of rotation at forward stick positions make recovery more difficult. When recovery appears imminent, the stick should be moved forward to prevent entry into a secondary spin in the opposite direction. To insure satisfactory recovery characteristics for the airplane, modifications to the design similar to those recommended for the XF8U-1 in reference 1 are necessary. A special control technique (discussed later) should provide satisfactory recovery from at least the steep-type spins.

Other conditions.- Erect spin and recovery characteristics of the model were investigated with the center of gravity moved from 23.9 percent $\bar{c}$ (loading 1 in table II) to 31.9 percent $\bar{c}$ (loading 4 in table II). Tests were made with the angular momentum of the rotating components of the engine at idle rpm simulated by a flywheel mounted in the model. Clockwise and counterclockwise rotations of the flywheel were investigated in both right and left erect spins. Brief tests were made with a spin-recovery parachute housing simulated on the model (fig. 1). No significant variations in the spin and recovery characteristics of the model as reported for the basic flight design gross weight were observed for any of these conditions.

Special recovery technique.- Model spin tests conducted on the XF8U-1 (ref. 1) indicated that the extension of canard surfaces on the nose of the airplane would provide satisfactory recoveries from either the flat or the steeper type of spins when used in conjunction with the optimum control technique. However, during the airplane spin demonstration (ref. 5) in which only steep-type spins were obtained, the contractor elected to utilize full (landing) wing leading-edge-flap deflection in conjunction with the optimum control manipulation. Satisfactory recovery characteristics have been indicated from steep-type spins of the XF8U-1 by using this control technique. It should be pointed out, however, that, based on the data presented in reference 1, this control technique would not be sufficient to provide satisfactory recoveries from the flat-type spin. However, in the absence of the recommended canard modification, full (landing) deflection of the leading-edge flaps (as used on the XF8U-1) in conjunction with the previously specified recovery technique (simultaneous rudder reversal to full against the spin and aileron movement to full with the spin) is recommended in attempting recovery from erect spins of the airplane.

Inverted Spins

The results of inverted spin tests with the model loaded to simulate the basic flight design gross weight (loading 1 in table II) indicated that the model would not enter a developed inverted spin for any condition of control-surface settings investigated. Based on the model tests, it appears that the F8U-1P airplane would be difficult to spin inverted. In the event that an inverted spin is encountered with the airplane, recovery should be satisfactory by the method recommended for the XF8U-1 in reference 1 - that is, full reversal of the rudder to oppose the yawing rotation and neutralization of the longitudinal and lateral controls.

Spin-Recovery Parachute Tests

Brief tests utilizing the spin-recovery parachute that was found to be satisfactory for the XF8U-1 of reference 1 were conducted. Results of these tests indicate that the same parachute would provide satisfactory spin recovery for the F8U-1P airplane during emergencies in spin demonstrations. These tests were conducted for the basic flight design gross weight (loading 1 in table II). The towline was attached to the bottom of the extreme rearward point of the fuselage. The rudder was maintained full with the spin during the recovery attempts. The parachute was a 17.7-foot-diameter (projected) stable parachute with a drag coefficient of 1.14 (based on projected area). The shroud lines were 37.5 feet long and the towline length was 36.5 feet. Another size stable tail parachute giving equivalent drag could also be used for satisfactory recovery.

Effects of Reynolds Number and Tunnel Testing Technique

Reynolds number and tunnel testing technique may have considerable effect on the spin-recovery results of some contemporary fighter design models tested in the spin tunnel. Experience has indicated, as pointed out in references 3 and 4, that the part of the fuselage forward of the wing (hereinafter referred to as the nose) can introduce autorotative or antirotative moments, depending on the cross-sectional shape of the nose and on the Reynolds number.

The technique used in testing the models in the spin tunnel (ref. 3) involves launching the models in a flat attitude with rotation. This technique provides favorable conditions for the model to find a possible flat spin as well as a steeper spin. The corresponding airplane, on the other hand, may be capable of simulating such an entry only as a result of a violent maneuver, a pitch-up, or a directional divergence. However, as a general case, the airplane enters the spin from a low-angle-of-attack, no-rotation condition from which it is difficult to increase the rotational rate to the fast flat spinning condition.

In order to evaluate better the current model spin results, static force tests were made on a 1/9-scale model of the F8U-1P nose (in the presence of the rest of the fuselage). The force tests were made in the Langley 300-MPH 7- by 10-foot tunnel for a range of Reynolds numbers to represent both the model and airplane. The results of these tests for the spinning angle-of-attack range of the model are presented in figure 3 as the variation of side-force coefficient with sideslip for a range of

Reynolds numbers. As indicated in figure 3, the F8U-1P nose design is expected to have little or no Reynolds number effect. The side force on the nose through the spinning angle-of-attack range indicates that an antirotative or damping moment is produced on the nose of both the spin model and the airplane for angles of attack up to 60°. However, from 70° and up, an autorotative or propelling moment is indicated as possible on both the spin model and the airplane.

It appears, therefore, from the foregoing discussion that the two types of spins obtainable on the model are also possible on the F8U-1P airplane, but it is expected that the steeper type would be most likely to be obtained unless some violent maneuver leading to pitch-up and directional divergence should occur on the F8U-1P configuration. It is recommended that intentional spins be avoided with the F8U-1P airplane inasmuch as there is no assurance that even the special technique of utilizing full wing leading-edge-flap deflection will be effective if the spin should develop to the flat phase. In the event of an inadvertent spin or a violent maneuver likely to induce a spin, recovery should be initiated immediately to minimize the possibility of entering the flatter type of spin.

SUMMARY OF RESULTS

From a free-spinning tunnel investigation of a 1/25-scale model of the Chance Vought F8U-1P airplane, the following results are considered applicable to the spin and recovery characteristics of the airplane at 30,000 feet:

1. Two types of erect spins are possible with the ailerons neutral or against the spin: a flat rapidly rotating spin, and a steeper more oscillatory spin. Satisfactory recovery may sometimes not be possible from either type of spin even by the normal control recovery manipulation (simultaneous rudder reversal to full against the spin and movement of ailerons to full with the spin) and some airplane modification appears necessary to insure satisfactory recovery from all developed spins that are obtainable on this design. As an alternative, the special technique employed for the XF8U-1 airplane (full deflection of wing leading-edge flap in conjunction with the normal control technique) may be effective for insuring recovery. It is recommended that the spin not be allowed to develop fully on this airplane and that recovery control technique be utilized as soon as a spin is indicated.

2. Center-of-gravity movement from 23.9 percent $\bar{c}$ to 31.9 percent $\bar{c}$, gyroscopic moments of the rotating components of the engine, or installation of the spin-recovery parachute housing on the lower rear fuselage

had little significant influence on the erect spin and recovery characteristics of the airplane.

3. Inverted spins are difficult to obtain. The recommended recovery procedure if an inverted spin is encountered is full reversal of the rudder to oppose the yawing rotation and neutralization of the other controls.

4. For satisfactory emergency spin recovery during demonstration flights the 17.7-foot-diameter (projected) stable tail parachute with a drag coefficient of 1.14 (based on projected area), 37.5-foot shroud lines, and a 36.5-foot towline previously utilized for the XF8U-1 airplane is adequate.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., August 28, 1959.

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TABLE I

DIMENSIONAL CHARACTERISTICS OF THE CHANCE VOUGHT F8U-1P AIRPLANE

Overall length, ft	54.23
Wing:	
Span, ft	35.67
Area (including chord-extension), sq ft	385.33
Root chord, in.	202.00
Tip chord (not including chord-extension), in.	49.95
Tip chord (including chord-extension), in.	55.93
Mean aerodynamic chord, in.	141.40
Distance from leading edge of $\bar{c}$ rearward of leading edge of root chord, in.	92.20
Aspect ratio (area including chord-extension)	3.30
Taper ratio (not including chord-extension)	0.25
Taper ratio (including chord-extension)	0.28
Dihedral, deg	-5
Incidence, deg	-1
Sweepback at quarter-chord, deg	42
Airfoil section:	
Root	NACA 65A006
Tip	NACA 65A005
Ailerons:	
Total area (rearward of hinge line), sq ft	83.12
Span of one aileron, percent b/2	38.55
Horizontal tail:	
Span, ft	18.09
Area, sq ft	93.45
Sweepback at quarter-chord, deg	45
Root chord, in.	108.05
Tip chord, in.	15.96
Aspect ratio	3.53
Dihedral, deg	5.42
Airfoil section:	
Root	Modified NACA 65A006
Tip	Modified NACA 65A004
Vertical tail:	
Height, ft	12.08
Total area (including dorsal), sq ft	115.95
Rudder area (rearward of hinge line), sq ft	12.56
Sweepback at quarter-chord, deg	45
Root chord (31 in. above fuselage reference line), in.	133.00
Tip chord, in.	41.00
Aspect ratio	1.26
Airfoil section:	
Root (65 in. above fuselage reference line)	Modified NACA 65A005.3
Tip	Modified NACA 65A004

[redacted]

TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE CHANCE VOUGHT F8U-1P AIRPLANE AND FOR LOADINGS TESTED ON THE 1/25-SCALE MODEL

[Values given are full scale, and moments of inertia are given about the center of gravity]

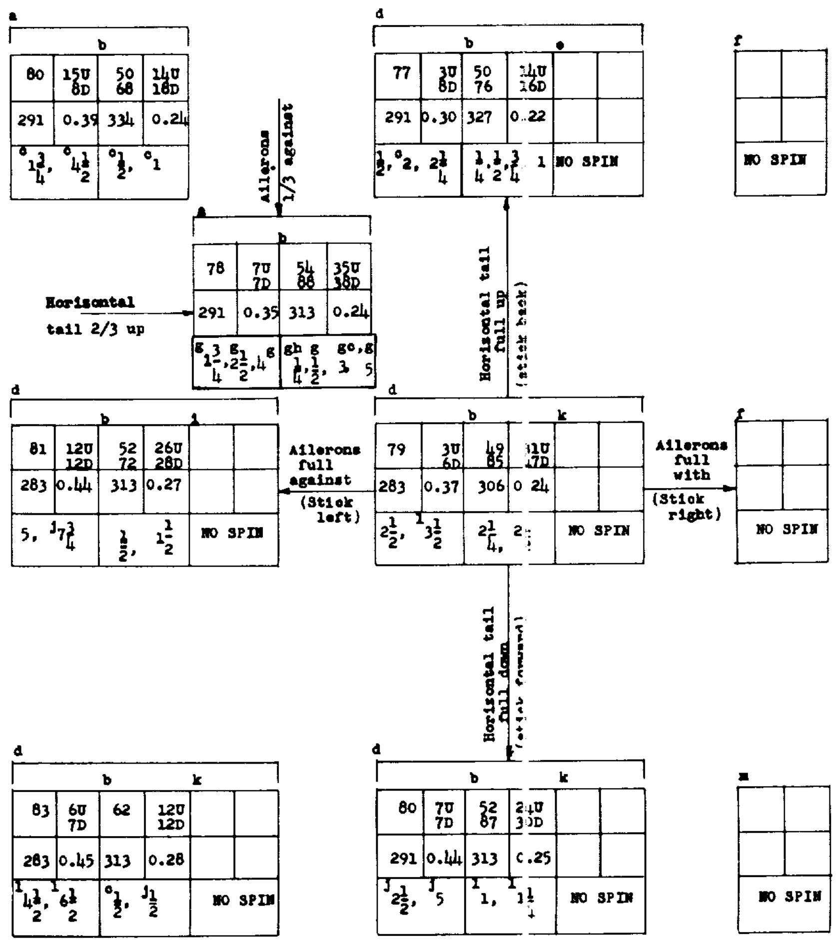
Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	30,000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane											
1 - Basic flight design gross weight	24,000	0.242	0.0262	22.80	60.97	11,215	89,501	95,540	-826×10^{-4}	-64×10^{-4}	890×10^{-4}
2 - Basic landing design gross weight	18,359	0.320	0.004	17.44	46.64	8,730	77,766	82,282	-952×10^{-4}	-62×10^{-4}	1014×10^{-4}
3 - Basic catapulting design gross weight	26,658	0.263	0.008	25.34	67.76	12,291	85,689	92,142	-697×10^{-4}	-61×10^{-4}	758×10^{-4}
Model											
1 - Basic flight design gross weight	24,059	0.239	0.017	22.87	61.15	11,303	90,308	95,648	-831×10^{-4}	-56×10^{-4}	887×10^{-4}
4 - Revised basic flight design gross weight (rearward center of gravity)	24,028	0.319	0.0085	22.83	61.05	10,869	86,090	91,978	-792×10^{-4}	-62×10^{-4}	854×10^{-4}

[redacted]

CHART 1.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by simultaneous reversal of rudder to full against the spin and movement of ailerons to full with the spin unless otherwise indicated (recovery attempted from, and developed spin data presented for, rudder full with spins)]

Airplane: F6U-1P	Attitude: Erect	Spin direction: Right	Loading (see table II) 1; Basic flight design gross weight	
	Altitude: 30,000 ft		Desired center-of-gravity position: 23.9 percent $\bar{c}$	



α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

[a]Two conditions possible.
[b]Very oscillatory spin.
[c]After recovery, model entered a spin in the opposite direction.
[d]Three conditions possible.
[e]Model entered a short dive followed by a spin in the opposite direction.
[f]Model entered a glide.
[g]Recovery attempted by simultaneous reversal of rudder to 2/3 against the spin and movement of ailerons to 2/3 with the spin.
[h]After recovery, model turned in the opposite direction.
[i]Model rolled inverted and entered a glide.
[j]Model recovered in an inverted dive.
[k]Model entered a dive.
[l]After recovery, model entered an aileron roll.
[m]Model entered an inverted dive.

[redacted]

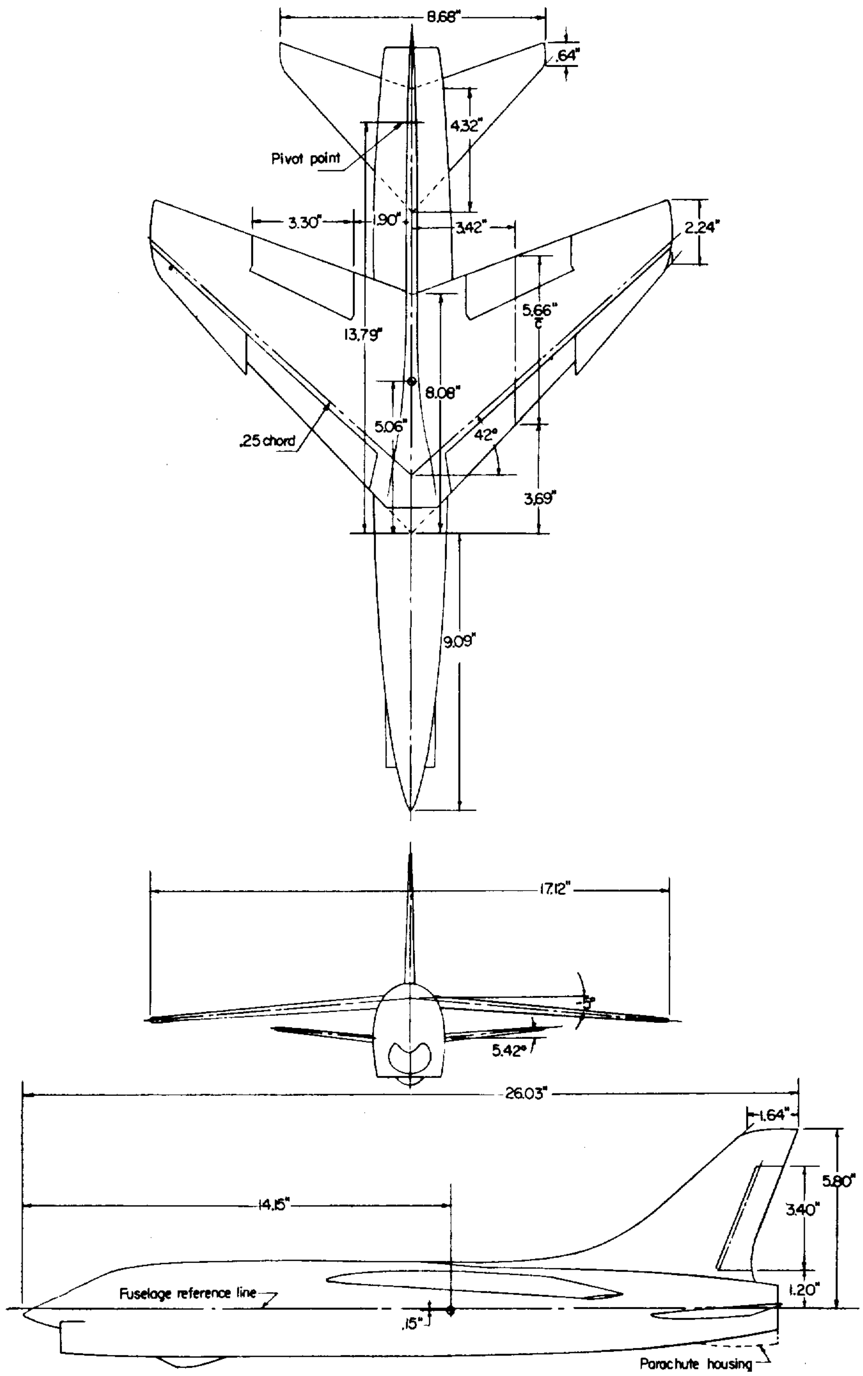


Figure 1.- Three-view drawing of the 1/25-scale model of the Chance Vought F8U-1P airplane. Center-of-gravity position indicated is for the basic flight design gross weight.

[redacted]

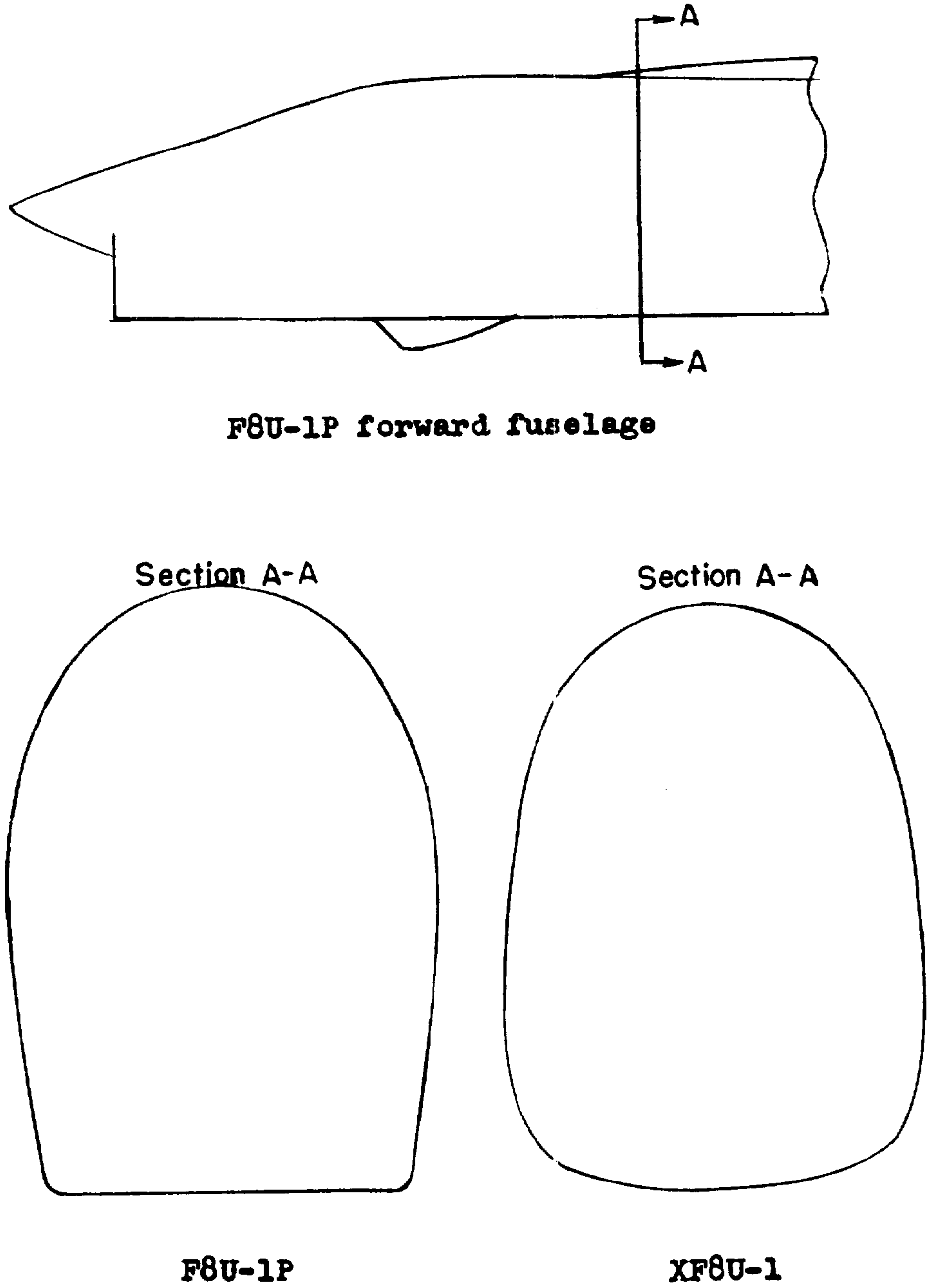


Figure 2.- Typical cross sections of the F8U-1P and XF8U-1 forward fuselages.

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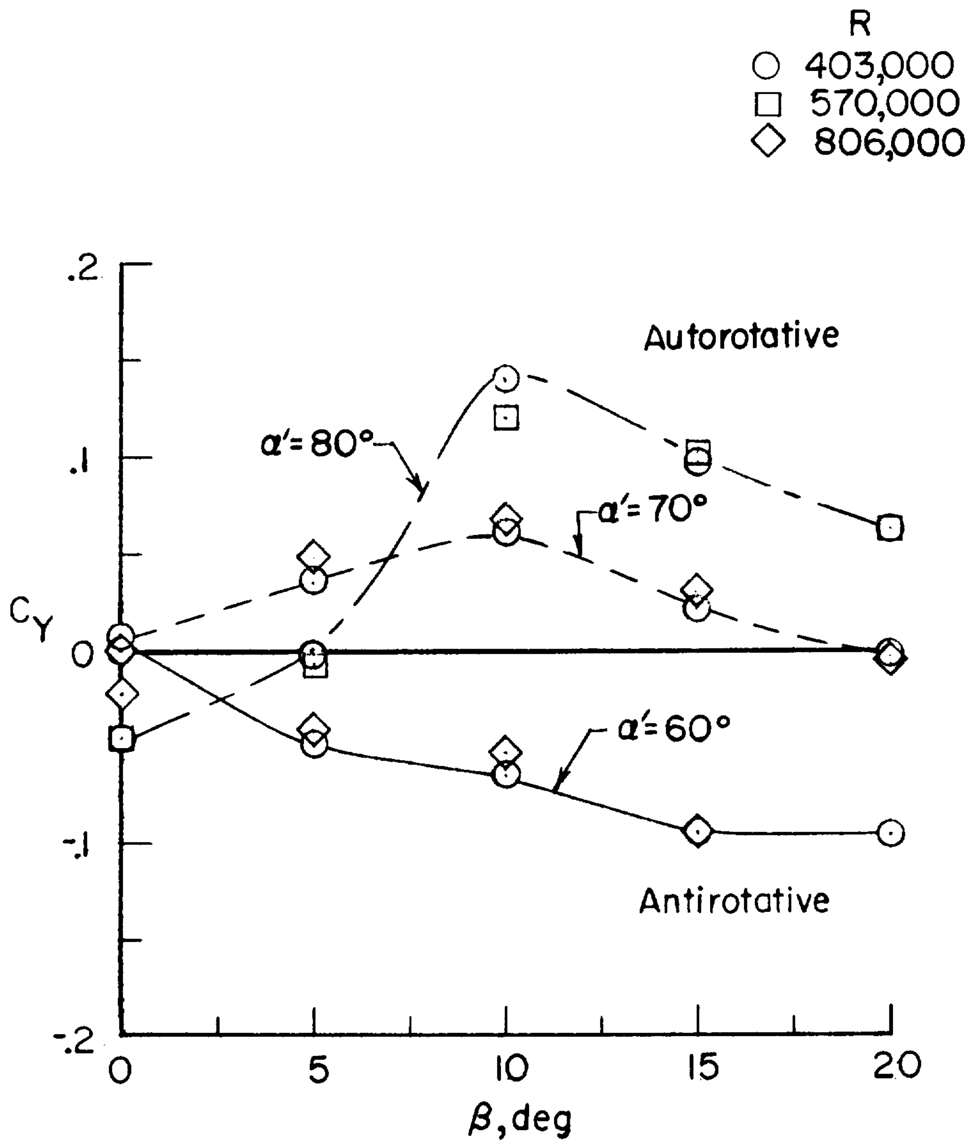

Figure 3.- Effect of Reynolds number and angle of attack on the autorotative tendencies of the F8U-1P fuselage (forward of wing-fuselage intersection).

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FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/25-SCALE MODEL OF THE CHANCE VOUGHT F8U-1P AIRPLANE*

TED NO. NASA AD-3137

By James S. Bowman, Jr., and Frederick M. Healy

ABSTRACT

Results of an investigation of a dynamic model in the Langley 20-foot free-spinning tunnel are presented. Erect and inverted developed spin and recovery characteristics were investigated. The size of stable tail parachute required for spin recovery in an emergency was determined.

INDEX HEADINGS

Airplanes - Specific Types	1.7.1.2
Spinning	1.8.3
Mass and Gyroscopic Problems	1.8.6
Parachutes	1.10
Piloting Techniques	7.7

*Title, Uncla[redacted]

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