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RESEARCH MEMORANDUM

for the

U. S. Air Force

FREE-SPINNING AND RECOVERY CHARACTERISTICS OF A 1/36-SCALE MODEL OF THE REPUBLIC F-105B AIRPLANE

COORD. NO. AF-AM-83

By James S. Bowman, Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

OCT 9 1957

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/36-scale model of the Republic F-105B airplane to determine the spin and recovery characteristics.

Model test results indicated that even optimum control technique, full movement of rudder against the spin and of ailerons with the spin (stick right in a right spin), will be inadequate to insure satisfactory recovery; optimum control technique should be accompanied by extension of both canard surfaces (access doors) available on the airplane. It is important that the canard surfaces be extended fully to the horizontal position to be effective for recovery.

The minimum size parachute required to insure satisfactory recovery in an emergency by parachute action alone was indicated to be 24 feet in diameter (laid out flat) with a drag coefficient of 0.673 (based on the laid-out-flat diameter) and a towline length of 45 feet. A 21-foot-diameter parachute with a drag coefficient of 0.55 was tested in conjunction with deflection of the canard surfaces and was found inadequate.

INTRODUCTION

The spin investigation of a 1/36-scale model of the Republic F-105B airplane was initiated in the Wright Air Development Center vertical wind tunnel. However, during the course of the spin-test program, the WADC vertical wind tunnel became inoperative and required remodeling. As a result, the U. S. Air Force requested that an investigation be conducted in the Langley 20-foot free-spinning tunnel on a 1/36-scale model to determine the spin and recovery characteristics of the Republic F-105B airplane.

The present investigation included tests to determine the effect of the engine gyroscopic moments, the effects of aileron movements, and the effect of various emergency spin-recovery parachutes on recovery characteristics. All tests were conducted for erect spins and for the normal gross-weight loading with a center-of-gravity position of 28.8 percent mean aerodynamic chord.

An appendix is included which presents a general description of the model testing technique, the precision with which model test results and mass characteristics were determined, variations of model mass characteristics occurring during tests, and a general comparison between model and airplane results.

SYMBOLS

b — wing span, ft

S — wing area, sq ft

$\bar{c}$ — mean aerodynamic chord, ft

$x/\bar{c}$ — 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)

m — mass of airplane, slugs

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

ρ air density, slug/cu ft

μ relative density of airplane, $\frac{m}{\rho Sb}$

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ angle between span axis and horizontal, deg

V full-scale true rate of descent, ft/sec

Ω full-scale angular velocity about spin axis, rps

MODEL AND TEST CONDITIONS

The 1/36-scale model of the Republic F-105B airplane previously tested in the WADC spin tunnel was used in the present investigation. A three-view drawing of the model as tested is shown in figure 1.

For tests made simulating engine on, the angular momentum of the rotating parts for idle speed of the full-scale Pratt & Whitney J-75 engine (15,000 slug-ft^2/sec) was simulated by rotating a flywheel with a small direct-current motor powered by small silver-cell batteries. The flywheel was located in the model so that the axis of the angular momentum was parallel to the longitudinal axis of the airplane.

Except for brief tests conducted to determine the effect of the nose-landing gear extended, spin tests were conducted with the model in the clean condition.

The airplane is equipped with canard-type access doors on each side of the fuselage near the nose, the door on the right-hand side being the larger of the two as shown in figure 2. The model program was extended to evaluate the possible use of these access doors (henceforth referred to as canards) as emergency recovery devices.

The emergency spin-recovery parachute tests were conducted with stable flat-type parachutes made of 400 porosity material. The parachute point of attachment was at the top rear of the fuselage.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 25,000 feet (ρ = 0.001065 slug/cu ft). The dimensional characteristics of the airplane are presented in table I. The mass characteristics of the airplane and the loading tested on the model are presented in table II. The maximum control deflections (measured perpendicular to the hinge lines) used on the model during tests were:

Rudder, deg:
- Right 32
- Left 32

Horizontal tail:
- Trailing edge up, deg 25
- Trailing edge down, deg 7

Ailerons, deg:
- Up 20
- Down 20

Upper-surface spoiler, deg:
- Up 50
- Down 0

RESULTS AND DISCUSSION

The model test results are presented in charts 1 to 4 and in table III. The model data are presented in terms of full-scale values for the airplane at an altitude of 25,000 feet.

The model as received from Wright Air Development Center had been extensively tested, and asymmetric spin results were obtained possibly because of its relatively poor condition. This was evidenced by the fact that it would not spin in one direction. It was felt, however, that the corresponding airplane would probably be capable of the entire range of the results obtained on the model.

For the spins obtained, ailerons indicated some effectiveness in terminating the spin, but even use of optimum control technique (based on test results of similarly loaded models), which is movement of the rudder to full against the spin and the ailerons to full with the spin, was indicated to be inadequate in insuring satisfactory recoveries; use of the canards on the nose of the model in conjunction with the optimum

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control movement was necessary to obtain good recoveries (charts 1 to 4). The optimum control technique, therefore, must be accompanied by extension of the canard surfaces available on the airplane to insure satisfactory recoveries. As indicated in reference 1, the extended canard on the inboard side (right side in a right spin) is probably the effective canard surface in assisting recovery. Simultaneously actuated canard surfaces were used in this instance so that the pilot would not inadvertently open the wrong canard. The results, although not presented in chart form, indicated that the canard surfaces should be extended fully to the horizontal position to be effective for recovery.

Test results indicated that the angular momentum of the rotating jet engine will not affect the spin and recovery characteristics appreciably.

Brief tests were conducted on the model to determine the effectiveness of upper-surface slotted spoilers, at one time considered as a possible replacement for the ailerons on the airplane. The results indicated that spoilers offered little assistance in terminating the spin. The addition of an undersurface deflector in conjunction with the upper-surface slotted spoilers offered little or no additional assistance in terminating the spin. These results are not presented in chart form.

Brief tests conducted to determine the effects of the extended nose gear (results not presented) indicated that the airplane spin and recovery characteristics would not change appreciably with the nose gear in the extended position.

Parachute Tests

The results of the tests performed to determine the minimum size parachute required to insure satisfactory recovery in an emergency are presented in table III. Also presented in table III are tests conducted for a 21-foot-diameter parachute used in conjunction with the canards for recovery. The towline attachment point was at the upper part of the tail cone. (See fig. 1.)

Test results indicated that a 24-foot-diameter parachute with a drag coefficient of 0.673 (based on the laid-out-flat diameter) and a towline length of 45 feet is required to insure satisfactory recovery by parachute action alone. It should be noted, however, that if a parachute with a different drag coefficient is used, a corresponding adjustment in the parachute diameter will be required. At the request of the manufacturer, recoveries were attempted by using a 21-foot-diameter parachute with a drag coefficient of 0.55 and a towline length of 45 feet simultaneously with extended canards. The test results indicated that this was inadequate for satisfactory recoveries.

SUMMARY OF RESULTS

Based on analysis of spin tests of a 1/36-scale model of the Republic F-105B airplane, the following conclusions regarding the spin and recovery characteristics of the F-105B airplane at an altitude of 25,000 feet are made:

1. Although the airplane may not spin for some conditions, developed spins will be possible from which recovery may be difficult. Optimum control technique for recovery will be movement of the rudder to full against the spin and the ailerons to full with the spin, but this will be inadequate to insure satisfactory recoveries for all conditions; for satisfactory recoveries, optimum control technique should be accompanied by extension of both canard surfaces (access doors) available on the airplane. It is important that the canard surfaces be extended fully to the horizontal position to be effective for recovery.

2. The minimum size parachute required to insure satisfactory recoveries in an emergency is 24 feet in diameter (laid out flat) with a drag coefficient of 0.673 (based on the laid-out-flat diameter) and a towline length of 45 feet.

3. A 21-foot-diameter parachute with a drag coefficient of 0.55 and a towline length of 45 feet used simultaneously with extended canards was inadequate to give satisfactory recoveries.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 12, 1957.

James S. Bowman, Jr.
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Approved:
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APPENDIX

MODEL TESTING TECHNIQUE AND PRECISION

Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. The mechanism moves the controls rapidly from the position for the steady spin to the position being investigated in the recovery attempt. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 2.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning-control configuration (horizontal-tail trailing edge full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and horizontal-tail combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and horizontal tail, or by rapid full reversal of the rudder simultaneously with moving ailerons to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model (refs. 3, 4, and 5). Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the horizontal tail is set at either full up or two-thirds of its full-up deflection and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which may be either against the spin (stick left in a right spin) or with the spin depending primarily on the mass characteristics of the particular model. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin, and movement of the horizontal tail to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and stick movement to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin," with the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. Recovery characteristics of a model are generally considered satisfactory if recovery attempted from the criterion spin in any of the manners previously described is accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

For recovery attempts in which a model strikes the safety net while it was still in a spin, the recovery is recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as > 3. A > 3-turn recovery, however, does not necessarily indicate an improvement over a > 7-turn recovery. A recovery of ten or more turns is indicated as ∞.

For spin-recovery parachute tests, the minimum size tail parachute required to effect recovery within $2\frac{1}{4}$ turns from the criterion spin is determined. The parachute is opened for the recovery attempts by actuating the remote-control mechanism and the rudder is held with the spin so that recovery is due to the parachute action alone. The folded spin-recovery parachute is placed on the model in such a position that it does not seriously influence the established spin. A rubber band holds the packed parachute to the model and when released allows the parachute to be blown free of the model. On full-scale parachute installations it is desirable to mount the parachute pack within the airplane structure, if possible, and it is recommended that a mechanism be employed for positive ejection of the parachute.

Precision

Results determined in free-spinning-tunnel tests are believed to be true values given by models within the following limits:

α, deg	± 1
ϕ, deg	± 1
V, percent	± 5
Ω, percent	± 2
Turns for recovery obtained from motion-picture records	$\pm\frac{1}{4}$
Turns for recovery obtained visually	$\pm\frac{1}{2}$

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls are set with an accuracy of ±1°.

Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the Republic F-105B model varied from the true scaled-down values within the following limits:

Weight, percent	0 to 1 high
Center-of-gravity location, percent $\bar{c}$	0 to 2.8 rearward
Angular momentum, percent	12 high to 12 low
Moments of inertia:	
I_X, percent	3 high to 27 high
I_Y, percent	5 high to 9 high
I_Z, percent	3 high to 8 high

Comparison Between Model and Airplane Results

Comparison between model and full-scale results in reference 6 indicated that model tests accurately predicted full-scale recovery characteristics approximately 90 percent of the time and that, for the remaining 10 percent of the time, the model results were of value in predicting some of the details of the full-scale spins, such as motions in the developed spin and proper recovery techniques. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 6 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models, although the higher rate of descent was found to be generally associated with the smaller angle of attack, regardless of whether it was for the model or airplane.

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TABLE I

DIMENSIONAL CHARACTERISTICS OF THE REPUBLIC F-105B AIRPLANE

Overall length, ft	63.11
Wing:	
Area, sq ft	385.0
Span, ft	35
Root chord (theoretical), ft	15
Tip chord, ft	7
Airfoil section:	
Wing station 80 in. (streamwise)	NACA 65A005.5
Tip (streamwise)	NACA 65A003.7
Mean aerodynamic chord, ft	11.485
Leading edge of root chord to leading edge $\bar{c}$, in.	102.75
Sweepback at 0.25-chord line, deg	45
Incidence, deg	0
Aspect ratio	3.182
Dihedral, deg	-3.5
Taper ratio	2.14
Ailerons:	
Span, percent wing span	30
Horizontal-tail surfaces:	
Total area, sq ft	95.8
Span, ft	17.4
Airfoil section:	
Root	NACA 65A006
Tip	NACA 65A004
Sweepback at 0.25-chord line, deg	45
Vertical-tail surfaces:	
Total area, sq ft (above water line 38)	63.25
Rudder area, sq ft	11.39
Span, ft	13.08
Airfoil section:	
Water line 38	NACA 65A006
Tip	NACA 65A004

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TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR A LOADING POSSIBLE ON THE REPUBLIC F-105B AND FOR A LOADING TESTED ON THE 1/36-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, at		Moments of inertia, slug-feet^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	Altitude, 25,000 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 values											
Normal gross weight	33,324	0.288	0.055	32.30	72.13	14,137	187,403	198,013	$-1,366 \times 10^{-4}$	-84×10^{-4}	$1,450 \times 10^{-4}$
Model values											
Normal gross weight	33,318	0.288	0.008	32.27	72.06	14,574	197,693	203,131	$-1,446 \times 10^{-4}$	-43×10^{-4}	$1,489 \times 10^{-4}$

TABLE III

SPIN-RECOVERY-PARACHUTE DATA OBTAINED WITH A 1/36-SCALE MODEL OF THE REPUBLIC F-105B AIRPLANE

[Normal gross-weight loading with center of gravity at 28.8 percent $\bar{c}$; rudder fixed full with the spin and recovery attempted by parachute action alone, unless otherwise indicated, developed-spin data presented for rudder-full-with spins]

Parachute diameter, ft	Drag coefficient	Towline length, ft	Shroud line length, ft	Control settings		V, ft/sec	α, deg	Ω, rps	Simulated spin direction	Engine speed simulated as indicated	Recovery by	Turns for recovery
				Ailerons	Horizontal-tail trailing edge, deg							
22.5	0.670	45	30.4	$\frac{1}{3}$ against	$16\frac{2}{3}$ up	296	[a] 56, 77	0.23	Right	Idle engine speed simulated	Parachute	>4
24	.673	45	32.4	$\frac{1}{3}$ against	$16\frac{2}{3}$ up	313	66	.18	Left	Idle engine speed simulated	Parachute	1, $1\frac{1}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$
24	.673	45	32.4	$\frac{1}{3}$ against	$16\frac{2}{3}$ up	296	[a] 56, 77	.23	Right	Idle engine speed simulated	Parachute	$1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2
24	.673	45	32.4	$\frac{1}{3}$ against	$16\frac{2}{3}$ up	296	70	.22	Right	Zero engine speed simulated	Parachute	1, $1\frac{1}{4}$, $1\frac{1}{2}$, 2
21	.55	45	21.0	$\frac{1}{3}$ against	$16\frac{2}{3}$ up	296	70	.22	Right	Zero engine speed simulated	Parachute and canards[b]	$2\frac{1}{4}$, 4, 4, >5

[a]Oscillatory spin, range of values given.

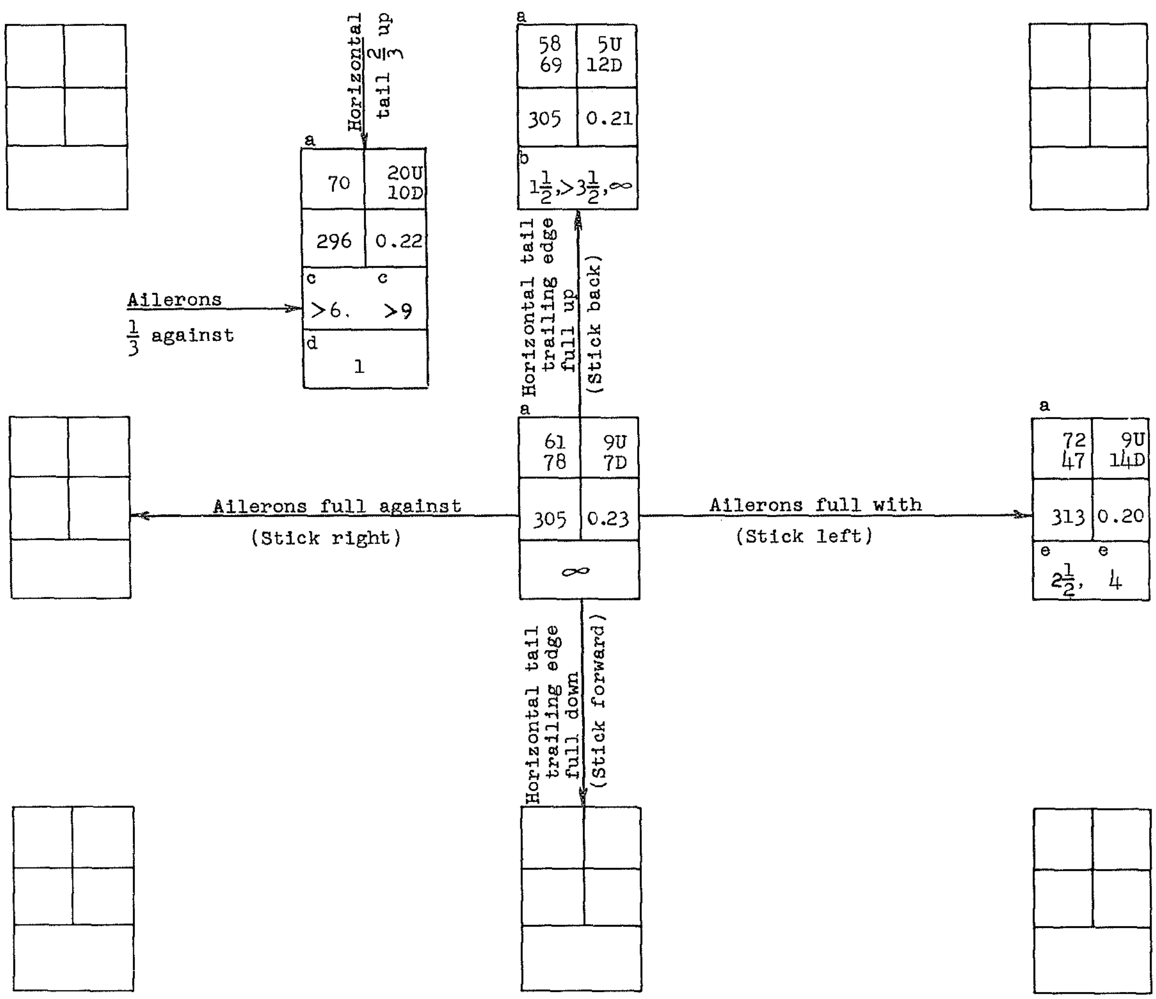
[b]Recovery attempted by opening parachute and simultaneously extending the canards.

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Direction	Loading (see table II)		Angular momentum of jet engine not simulated
F-105B	Erect	Simulated left spin	Normal gross weight loading		
Slats	Flaps		Center-of-gravity position	Altitude	
			28.8 percent c̄	25,000 ft	

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



[a]Oscillatory spin, average or range of values given.

[b]Model recovered in a glide.

[c]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin.

[d]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin and extending the canards.

[e]Model recovered in a dive rolling with the ailerons.

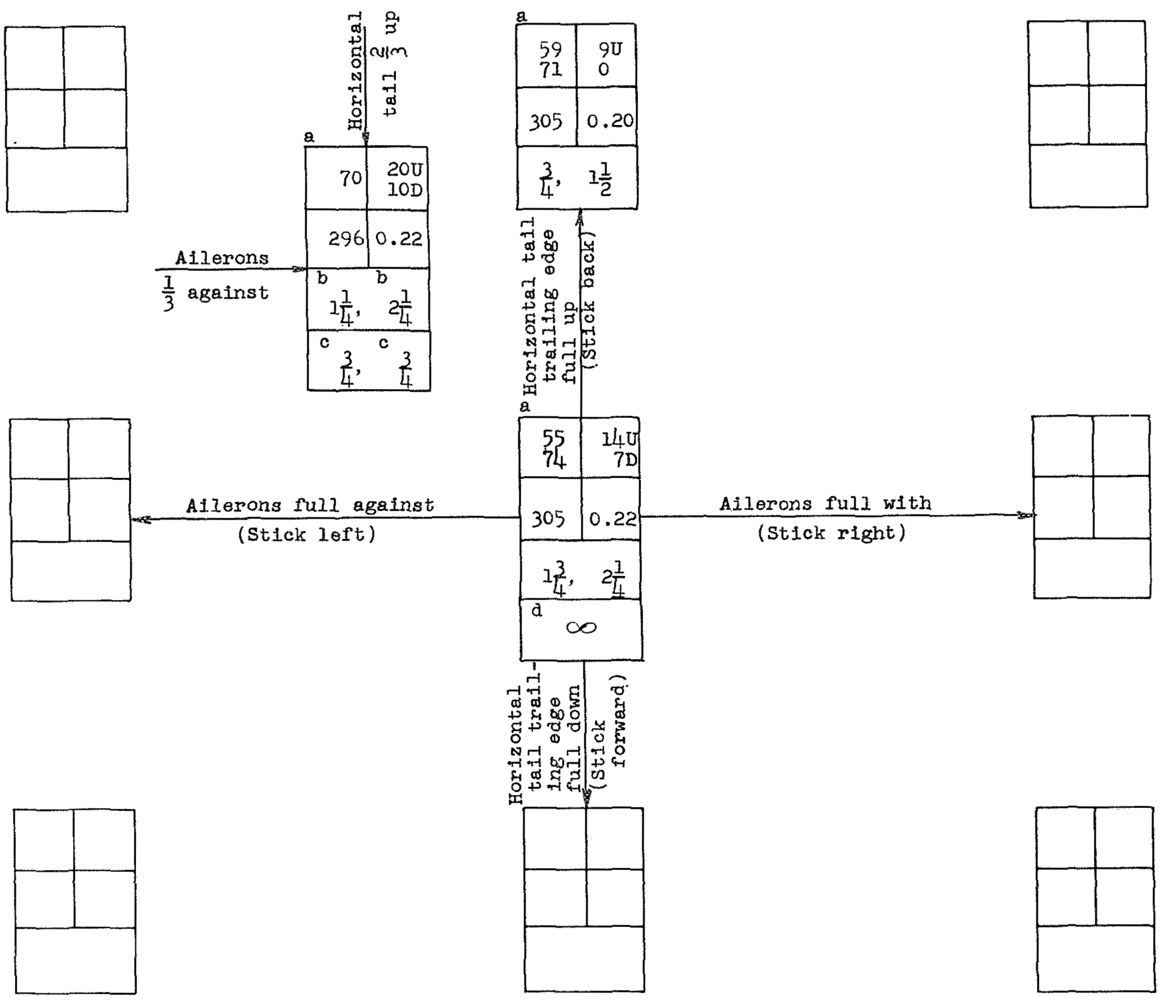
α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by rapid full rudder reversal and simultaneous extension of canards unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Direction	Loading (see table II)		Angular momentum of jet engine not simulated
F-105B	Erect		Normal gross weight loading		
Slats	Flaps	Simulated right spin	Center-of-gravity position 28.8 percent $\bar{c}$	Altitude 25,000 ft	

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



[a]Oscillatory spin, average or range of values given.

[b]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously extending canards.

[c]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin and extending the canards.

[d]Recovery attempted by extending canards only.

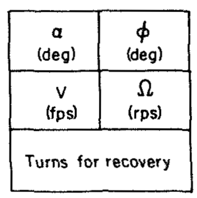
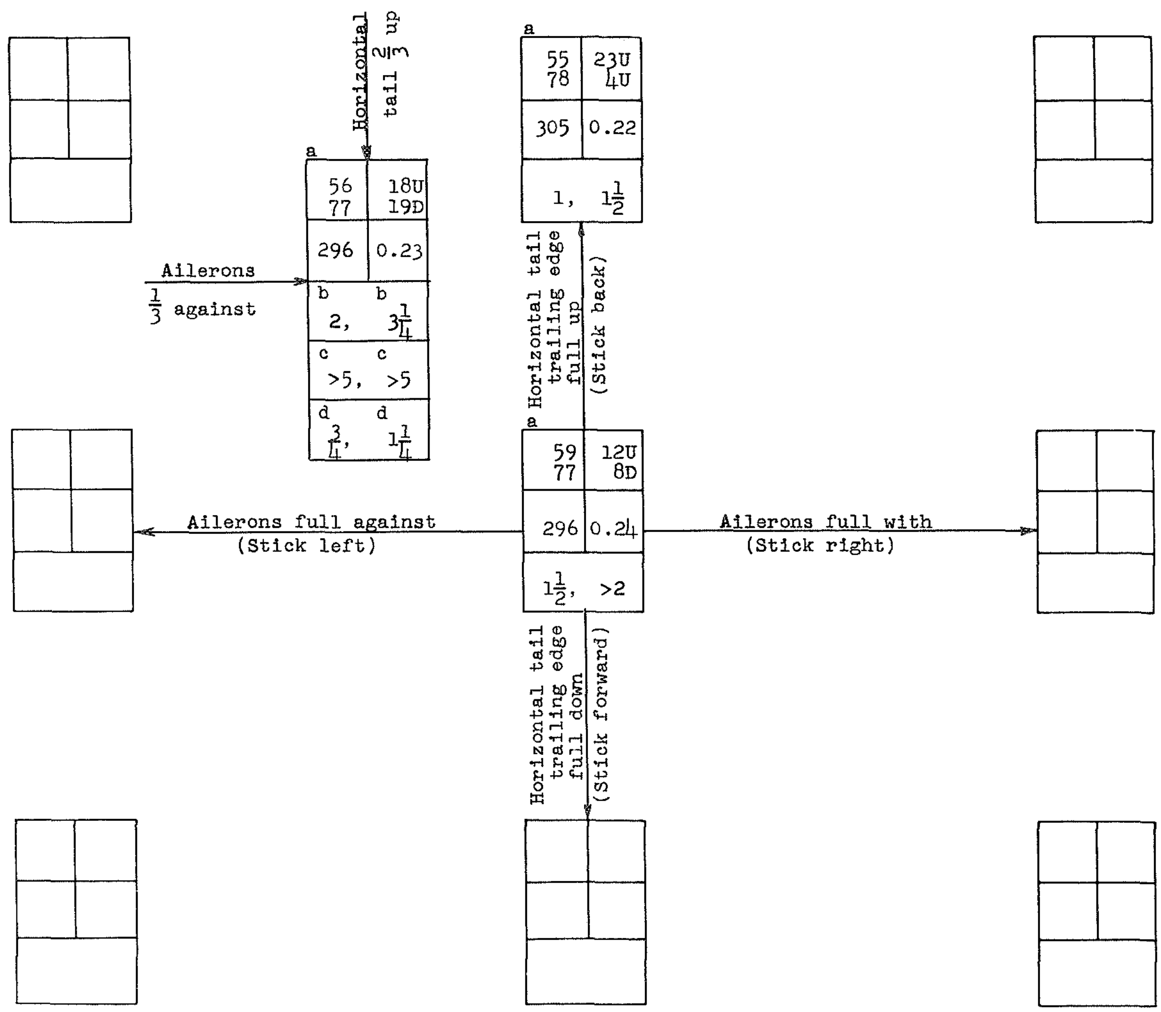


CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by rapid full rudder reversal and simultaneous extension of canards unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Direction	Loading (see table II)		Idle engine speed simulated
F-105B	Erect	Simulated right spin	Normal gross weight loading		
Slats	Flaps		Center-of-gravity position 28.8 percent $\bar{c}$	Altitude 25,000 ft	

Model values converted to full scale   U–inner wing up   D–inner wing down



[a]Oscillatory spin, range of values given.

[b]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously extending canards.

[c]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin.

[d]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin and extending canards.

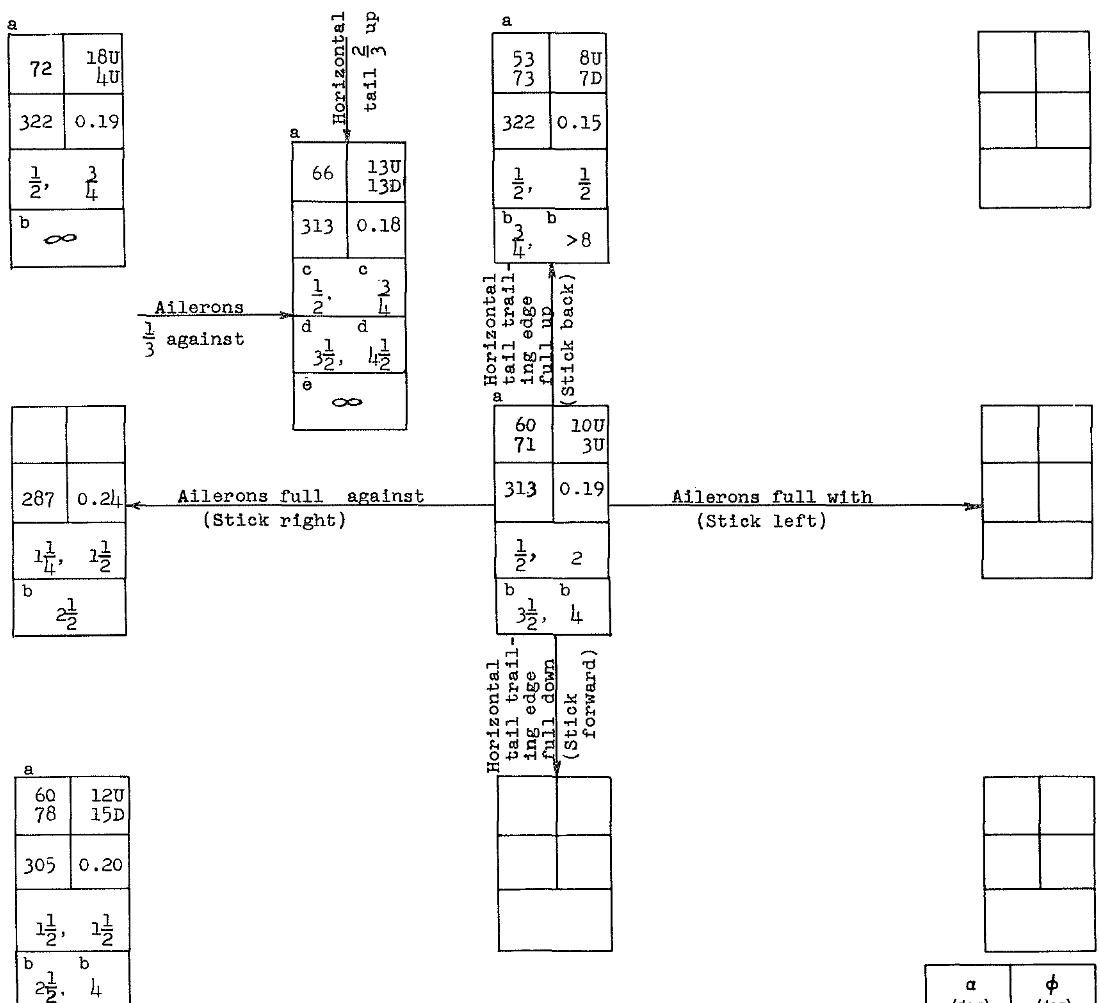
α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

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

Airplane	Attitude	Direction	Loading (see table II)		Idle engine speed simulated
F-105B	Erect	Simulated left spin	Normal gross weight loading		
Slots	Flaps		Center-of-gravity position	Altitude	
			28.8 percent $\bar{c}$	25,000 ft	

Model values converted to full scale U–inner wing up D–inner wing down



[a]Oscillatory spin, average or range of value given.

[b]Recovery attempted by moving the ailerons to full with the spin and simultaneously extending canards.

[c]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin and extending canards.

[d]Recovery attempted by moving the ailerons to 2/3 with the spin and simultaneously extending the canards.

[e]Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin.

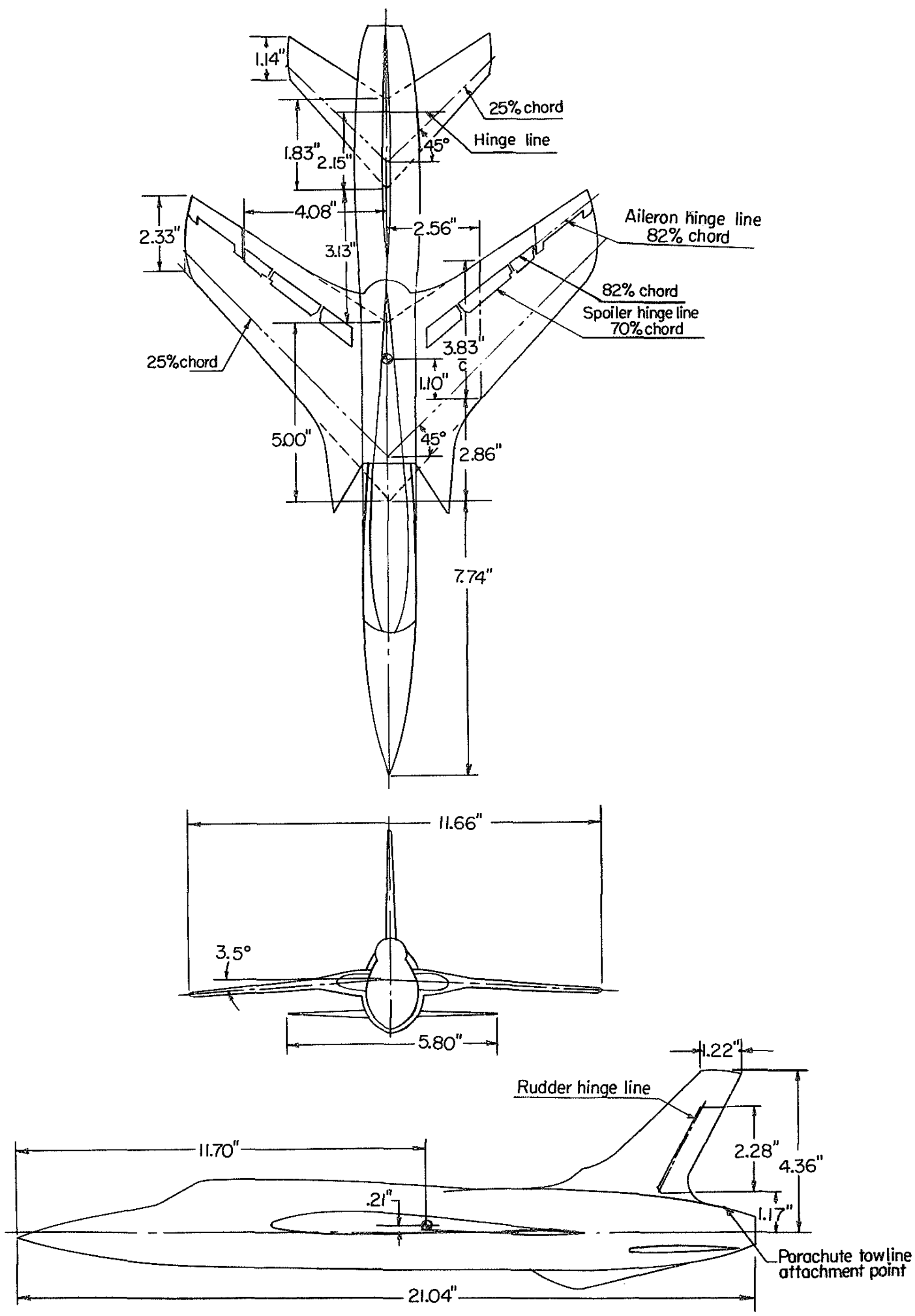


Figure 1.- Three-view drawing of the 1/36-scale model of the Republic F-105B airplane as tested in the Langley 20-foot free-spinning tunnel. Dimensions are model values in inches. Center-of-gravity position shown is 28.8 percent $\bar{c}$.

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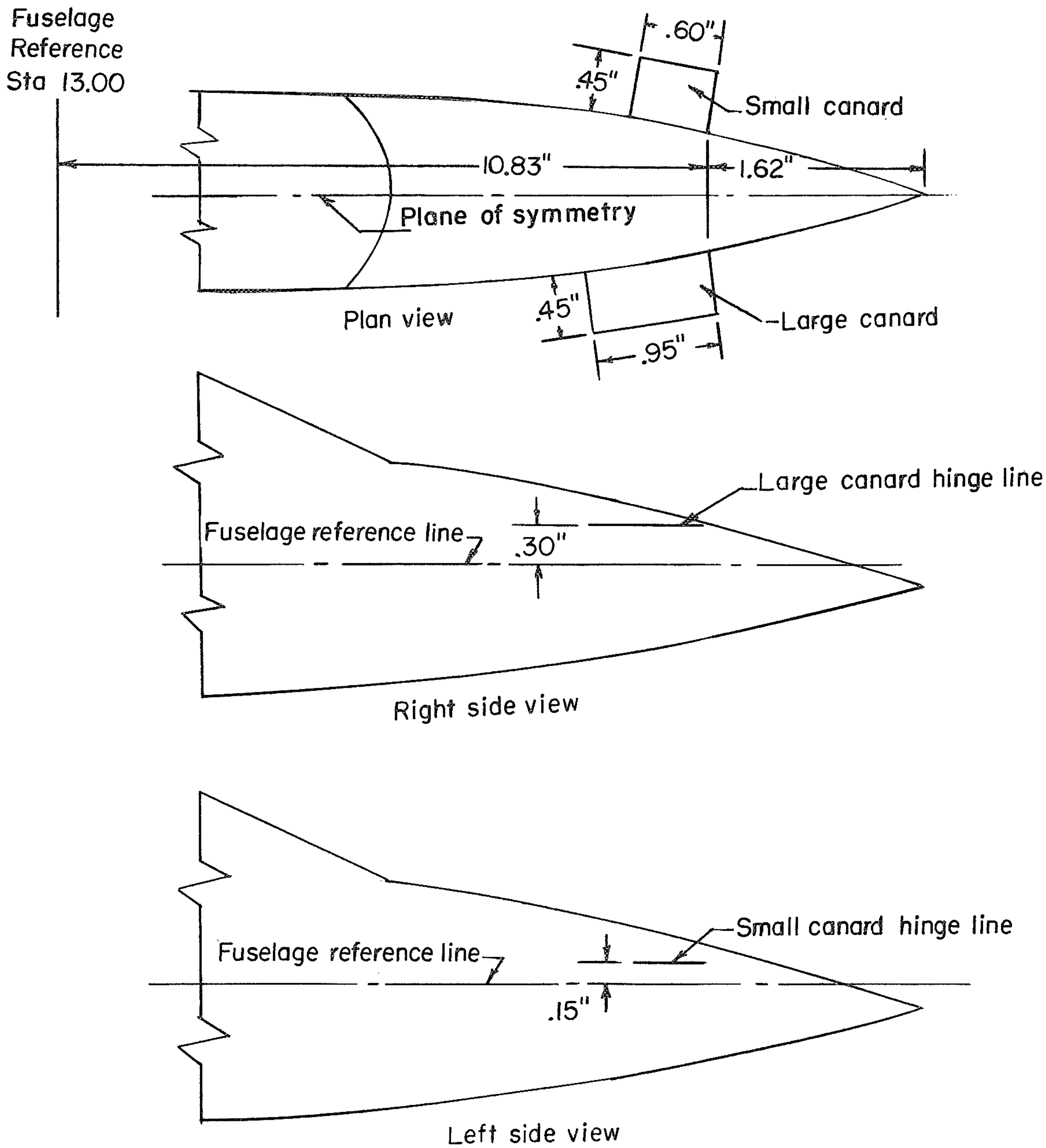

Figure 2.- Sketch showing position of canard-type access doors tested on a 1/36-scale model of the Republic F-105B airplane. Dimensions are model scale.

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ABSTRACT

An investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of an airplane model. Model test results indicated that even optimum control technique, full movement of rudder to against the spin and the ailerons to with the spin (stick right in a right spin), will be inadequate to insure satisfactory recovery on the airplane from a fully developed spin. For satisfactory recovery, optimum control technique must be accompanied by extension of canard surfaces (access doors) available on the airplane.

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