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TECHNICAL MEMORANDUM

REPORT

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FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/30-SCALE MODEL OF A TWIN-JET SWEPT-WING FIGHTER AIRPLANE

CLEARANCE NO. N5154

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

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON DEC 1960

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TECHNICAL MEMORANDUM SX-446

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FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/30-SCALE MODEL OF A TWIN-JET SWEPT-WING FIGHTER AIRPLANE*

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SUMMARY

An investigation has been made in the Langley 20-foot free-spinning tunnel to determine the erect and inverted spin and recovery characteristics of a 1/30-scale dynamic model of a twin-jet swept-wing fighter airplane.

The model results indicate that the optimum erect spin recovery technique determined (simultaneous rudder reversal to full against the spin and aileron deflection to full with the spin) will provide satisfactory recovery from steep-type spins obtained on the airplane. It is considered that the airplane will not readily enter flat-type spins, also indicated as possible by the model tests, but developed-spin conditions should be avoided inasmuch as the optimum recovery procedure may not provide satisfactory recovery if the airplane encounters a flat-type developed spin. Satisfactory recovery from inverted spins will be obtained on the airplane by neutralization of all controls. A 30-foot-diameter (laid-out-flat) stable tail parachute having a drag coefficient of 0.67 and a towline length of 27.5 feet will be satisfactory for emergency spin recovery.

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*Title, Unclassified.

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INTRODUCTION

An investigation has been made in the Langley 20-foot free-spinning tunnel to determine the spin and spin-recovery characteristics of a 1/30-scale dynamic model of a twin-jet, swept-wing, all-weather fighter airplane, the F4H-1.

The erect and inverted spin and recovery characteristics were investigated for the combat loading. The size of a spin-recovery tail parachute required in case of emergency was determined.

In addition, an evaluation has been made herein of possible Reynolds number and spin-tunnel technique effects and a brief discussion is included of results of parallel tests made on 0.13-scale radio-controlled models dropped from a helicopter.

SYMBOLS

C_D parachute drag coefficient

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

[redacted] mb^2 [redacted]tia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

[redacted]

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

V full-scale true rate of descent, fps

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

Ω full-scale angular velocity about spin axis, rps

MODEL AND TESTING TECHNIQUES

The 1/30-scale model of the McDonnell F4H-1 airplane was furnished by the Department of the Navy and was prepared for testing by the Langley Research Center of the National Aeronautics and Space Administration. A three-view drawing of the model as tested is shown in figure 1. A photograph of the model is shown in figure 2. Figure 3 is a sketch showing the dimensions and location of strakes added to the nose for some of the tests. The strake identifications were assigned by the manufacturer. Several strake configurations were tested and are indicated in the chart presenting these results. The dimensional characteristics of the airplane are presented in table I.

The lateral control system of the airplane includes spoilers as well as trailing-edge ailerons. Experience has indicated that spoilers on the upper surface of the wing are ineffective for control during developed spins, so the model was equipped only with ailerons. An evaluation of spoiler-type lateral controls on a spinning model is reported in reference 1.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 25,000 feet ($\rho = 0.001065$ slug/cu ft). The mass characteristics for the loadings of the airplane and for the loading tested on the model are presented in table II. A remote-control mechanism was installed in the model to actuate the controls and sufficient torque was applied to the controls to reverse them fully and rapidly for the recovery attempts. Controls were set with an accuracy of $\pm 1^{\circ}$.

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

Rudder deflection, deg:	
Right	30
Left	30
Horizontal tail deflection for longitudinal control (trailing edge), deg:	
Up	21
Down	9
Horizontal tail deflection for lateral control (as investigated on model, trailing edge), deg:	
Up	70
Down	15
Aileron deflection, deg:	
Up	0
Down	30

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning control configuration (longitudinal control full up, lateral controls neutral, and rudder full with the spin) and for various other lateral and longitudinal control 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 longitudinal control, or by rapid full reversal of the rudder simultaneously with deflection of 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 (ref. 2). 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 longitudinal control 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 reversing the rudder to two-thirds against the spin and moving the longitudinal control to either neutral or two-thirds down, or by simultaneously reversing the rudder to two-thirds against the spin and moving the ailerons to two-thirds with the spin. The control configuration and manipulation used 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.

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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 past experience as determined from spin-recovery data of full-scale airplanes that are available for comparison with corresponding model test results.

General descriptions of model testing techniques, methods of interpreting test results, and correlation between model and airplane results are presented in reference 2.

Model spin-recovery information as presented in the charts includes the following notation: For recovery attempts for which the model did not recover within 10 turns, the recovery was recorded as ∞. When a model recovered without control movement (controls maintained with the spin), the results were recorded as "no spin."

RESULTS AND DISCUSSION

The results of tests with the model loaded to simulate the combat loading (loading 2 in table II) are presented on charts 1 and 2 and in table III. Spins to the pilot's right and left were similar, and the data are arbitrarily presented in terms of right spins.

Erect Spins

Basic model.- As indicated in chart 1, two types of developed spins were obtained during the tests of the model. Developed spins of the flatter type were possible throughout the range of control deflections; these spins were characterized by a high rate of rotation, generally 0.5 revolution per second (full-scale) or higher. For this flat-type spin, control-surface deflections during the spin and for recovery had relatively little effect on the spin. The other type of developed spins were steeper and more oscillatory. These spins would persist only when the longitudinal control was full up and the lateral controls were either neutral or against the spin. At any other control setting the steep spin would not persist and the model recovered without control application (indicated as "no spin" on the charts).

Satisfactory recovery was obtained from the steep spins in the normal spinning control configuration (longitudinal control full up, lateral controls neutral, and rudder full with the spin) by simultaneous rudder reversal to full against the spin and deflection of ailerons to full with

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the spin (stick right in a right spin). This spin-recovery technique will be satisfactory and is recommended as the optimum control movement for recovery from the steeper-type spins of the airplane. This technique was, however, inadequate for recovery from the flat-type spins.

It should be noted that the optimum control technique for recovery calls for holding stick full back for the initial recovery control manipulation. It is felt that special mention should be made concerning use of the longitudinal control, since the wrong impression may be obtained by observing the results of chart 2 at face value. As pointed out previously, the steep spin was obtained only for stick-back positions. However, this does not mean that after the spin is developed, the stick-forward position will be effective for recovery. As pointed out in reference 2, stick-forward positions for mass loadings similar to those of the full-scale airplane, in general, cause the spin to increase in rate of rotation. Some brief tests were conducted on the spin model in the tunnel to determine the effects of forward motion of the stick on both the flat and steep developed spins (results not presented in charts). When the stick was moved forward for the flat spin, there was no difference in the model spinning characteristics. When the stick was moved forward for the steep spin, the model continued spinning up to 11 turns before the model entered a dive. These results indicate that movement of the stick forward for either spinning condition is not advisable. In addition, since forward stick positions would tend to increase the spin rate, the possibility of the airplane going into the flat spin may be made even easier. It is recommended therefore, that the stick be held full back as part of the recovery control technique, thereby assuring a slower spin rate from which recovery is easier than from a higher spin rate. At some point when recovery is imminent, the stick should be moved forward to avoid the possibility of entering another spin. The exact time and sequence of the stick-forward movement will have to be obtained from tests on the airplane.

Effect of nose strakes.- In an effort to obtain satisfactory recovery from the rapidly rotating flat-type spins, the effect of extending strakes on the nose of the model in conjunction with flight control surface application was evaluated. The size and locations of the strakes investigated are shown in figure 3. Chart 2 includes results in which recovery was attempted by reversing rudder to against the spin, deflecting ailerons to with the spin, and extending strakes on one and on both sides of the nose of the model. As indicated in the chart, the strakes had an anti-spin effect, but satisfactory recovery was still not obtained for any of the strake configurations investigated.

Effect of modifications.- The influence of various modifications on the spin and recovery characteristics of the model was briefly investigated during the test program. These results are not presented in chart form. Tests were made in which the leading-edge flaps were deflected,

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the speed brakes were extended, the missile rack was extended, or the infrared seeker was installed. These components are shown in figure 1. None of these conditions appreciably affected the model spin characteristics. Techniques used to supplement the primary flight controls for recovery attempts from the flat-type spin included extending large panels representing the refrigeration equipment compartment doors of the airplane, differential deflection of the horizontal tail, extending a slat on the outboard side of the nose, and deflecting the trailing-edge flaps in conjunction with the ailerons. The results of the tests indicate that an antispin effect was provided by differential deflection of the tail surfaces, but consistently satisfactory recoveries were not obtained even by extreme (85°) differential deflections of the horizontal tail. The other devices mentioned were ineffective for recovery from the flat spin.

Gyroscopic effects of engine rotation.- The angular momentum of the rotating components of the engines at 7,500 rpm was simulated by a flywheel installed in the model. Rotation of the flywheel was simulated for both left and right spins. The results (not presented in chart form) indicate that there was little significant influence on the spin and recovery characteristics of the model for either direction.

Inverted Spins

Brief tests of model inverted spins indicated that the spins were steep and in many cases a developed spin was not obtained. The results of the inverted spin tests (not presented in chart form) indicate that satisfactory recovery was obtained by rudder neutralization. It is recommended that recovery from inverted spins encountered by the airplane be attempted by neutralization of all controls.

Spin-Recovery Parachute Tests

The results of spin-recovery tail-parachute tests are presented in table III. Flat-type stable parachutes were used throughout the investigation. Canopy dimensions indicate the laid-out-flat diameter, and drag coefficients are based on laid-out-flat area. The table indicates that a stable parachute 30 feet in diameter having a drag coefficient of 0.676 and a 27.5-foot towline will insure recovery by parachute action alone from any possible spinning condition which may be encountered by the airplane. If a parachute with a different drag coefficient is used, a corresponding adjustment in canopy size will be required.

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SIGNIFICANCE OF RESULTS

Interpretation of spin-tunnel model test results may be affected by tunnel testing technique and Reynolds number, particularly for some modern high-speed designs. The tunnel testing technique, as pointed out in reference 2, involves launching the model by hand into the tunnel in a flat attitude with high rotation. In this technique, a flat spin would be more readily obtainable in the tunnel than would be likely for the airplane using flight spin-entry techniques. Therefore, in order to get a more realistic evaluation of the spin-entry characteristics, a 0.13-scale nonpowered radio-controlled model was dropped from a helicopter and flown into the spin (ref. 3). The radio-controlled model test results indicated that, although two types of spins are possible, the probability of the airplane entering the fast flat spin is somewhat remote and that the steep spin would likely be obtainable. In general, the fully developed spin and recovery characteristics obtained from the radio-control tests were in agreement with the model results obtained in the spin tunnel.

The shape of the fuselage forward of the leading edge of the wing may have considerable effect on the way in which a modern high-speed fighter airplane may spin. As pointed out in reference 2, the nose portion of the fuselage may be "damping" or "propelling" depending on the cross-section shape of the nose and the Reynolds number. In order to determine the Reynolds number effects of the design of this investigation, static force tests were made on models for a range of Reynolds numbers (ref. 4 and unpublished data). These force-test results indicated that the nose portion of the fuselage will be slightly damped at both model and full-scale Reynolds numbers. It is considered, therefore, that the spin-tunnel results obtained on the model were not affected by Reynolds number.

Recommended Recovery Procedure

Based on the results of this investigation and on results of reference 3, the recommended control manipulation technique for erect spin-type maneuvers encountered by the full-scale airplane is rudder reversal to full against the spin and simultaneous aileron deflection to full with the spin (stick right in a right spin) with the stick maintained full back until recovery appears imminent. It is considered that the airplane will not readily enter a flat spin, but inasmuch as the possibility exists, any developed spin condition should, as far as possible, be avoided. It is recommended that intentional spinning without emergency recovery devices not be attempted. Extreme caution should be exercised during flight near the stall region, and the pilot should be alert for, and immediately initiate recovery from, any possible incipient-spin

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maneuver encountered by movement of the rudder to oppose the rotation and deflection of the ailerons with the rotation (rudder left and stick right for right turn).

SUMMARY OF RESULTS

From a free-spinning tunnel investigation of a 1/30-scale dynamic model of a twin-jet swept-wing fighter airplane at a simulated test altitude of 25,000 feet, the following results are considered applicable to the spin and recovery characteristics of the corresponding airplane:

1. The optimum spin recovery control manipulation technique determined for this airplane is simultaneous rudder reversal to full against the spin and deflection of ailerons to full with the spin (stick right in a right spin). This procedure will provide satisfactory recovery from steep erect spins but will not be adequate if the airplane encounters a flat-type developed spin indicated as possible by the model results.

2. It is recommended that the spin not be allowed to develop fully on this airplane and that recovery be initiated as soon as a spin is indicated. Recovery should be attempted by full reversal of the rudder to against the spin and simultaneous deflection of the ailerons to full with the spin.

3. Satisfactory recovery from airplane inverted spins will be obtained by neutralization of all controls.

4. A 30-foot-diameter (laid-out-flat) stable tail parachute having a drag coefficient of 0.67 and a towline length of 27.5 feet will be satisfactory for emergency spin recovery.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., November 4, 1960.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF FULL-SCALE AIRPLANE

Overall length, ft	55.99
Wing:	
Span, ft	38.41
Area (theoretical), sq ft	530.00
Area (including leading-edge extension), sq ft	538.34
Root chord (center line of airplane), in.	282.00
Tip chord (theoretical tip), in.	47.00
Mean aerodynamic chord, $\bar{c}$, in.	192.50
Leading edge of $\bar{c}$ rearward of leading edge of root chord, in.	110.76
Aspect ratio	2.82
Taper ratio	0.167
Sweepback of 25 percent chord, deg	45.00
Dihedral (inboard base line 160.0), deg	0
Dihedral (outboard base line 160.0), deg	12.00
Incidence, deg	+1.00
Airfoil section:	
Root (center line of airplane)	Modified NACA 0006.4-64
Tip (theoretical)	Modified NACA 0003.0-64
Aileron:	
Area (one side) rearward of hinge line, sq ft	13.08
Span (one aileron) (from 44.5 percent b/2 to 67.0 percent b/2), ft	4.35 (22.5 percent b/2)
Inboard end chord (base line 103.24 in.), in.	37.81 (21.3 percent c)
Outboard end chord (base line 155.44 in.), in.	34.38 (27.6 percent c)
Horizontal tail:	
Area (in chord plane), sq ft	94.70
Movable area, sq ft	77.40
Span, ft	8.85
Aspect ratio	3.30
Taper ratio	0.20
Sweepback of 25 percent chord, deg	35.50
Dihedral, deg	-15.00
Root chord (at airplane center line), in.	107.00
Tip chord (theoretical), in.	21.40
Airfoil section:	
Root (airplane center line)	Modified NACA 0003.7-64
Tip (theoretical)	Modified NACA 0003.0-64
Vertical tail:	
Area (theoretical, above water line 66.5), sq ft	67.50
Span (water line 66.5 to water line 143), ft	6.375
Taper ratio	0.227
Root chord (water line 66.5), in.	207.15
Tip chord (water line 143), in.	47.10
Sweepback of 25 percent chord, deg	58.30
Airfoil section:	
Root (water line 66.5)	Modified NACA 0004.0-64
Tip (water line 143)	Modified NACA 0002.5-64
Rudder:	
Area (rearward of hinge line), sq ft	11.07
Hinge-line location, percent of water line chords	80.00

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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE FULL-SCALE AIRPLANE AND FOR THE LOADING USED FOR 1/30 SCALE MODEL TESTS

[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	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											
1: Take-off, gear up	39,839	0.326	0.0187	25.16	56.18	25,600	116,815	133,670	-500×10^{-4}	-92×10^{-4}	592×10^{-4}
2: Combat, gear up	34,473	.321	.0151	21.78	48.64	20,335	109,172	121,904	-562	-81	643
3: Landing, most forward center of gravity	28,900	.289	.0457	18.26	40.78	18,282	102,074	114,415	-633	-93	726
4: Most rearward center of gravity, gear up	39,830	.336	.0187	25.16	56.18	25,600	116,815	133,670	-500	-92	592
Model											
2: Combat	34,635	0.319	0.035	21.88	48.85	23,561	119,481	134,975	-605×10^{-4}	-98×10^{-4}	703×10^{-4}

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TABLE III.- SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH THE 1/30-SCALE MODEL OF FIGHTER AIRPLANE

[Model values converted to full-scale values]

Parachute diam., ft	Parachute drag coefficient, C_D	Towline length, ft	Rudder deflection, deg	Aileron deflection, deg	Horizontal tail deflection (trailing edge up), deg	α, deg	V, fps	Ω, rps	Turns for recovery	Remarks
					Flat erect spins					
22.5	0.637	32.5	30 with	10 against	14	77	259	0.48	$2\frac{1}{4}$, 3, 3, $>2\frac{1}{4}$	
22.5	0.637	32.5	30 with	10 against	14	77	262	0.46	$1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, 3	
25.0	0.627	32.5	30 with	10 against	14	77	262	0.47	$1\frac{3}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{4}$	
27.5	0.676	27.5	30 with	10 against	14	77	259	0.48	$1\frac{1}{2}$, $1\frac{3}{4}$, 2	
27.5	0.676	32.5	30 with	10 against	14	77	259	0.48	$1\frac{1}{2}$, $1\frac{3}{4}$, 2	
30.0	0.666	27.5	30 with	10 against	14	77	259	0.48	$1\frac{1}{2}$, $1\frac{3}{4}$, 2	
21.25	0.632	40.0	30 with to 20 against	10 against to 20 with	14	[a]81, 91	269	0.48	2, $2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{2}$	
22.50	0.624	40.0	30 with to 20 against	10 against to 20 with	14	[a]81, 91	269	0.48	$1\frac{3}{4}$, $1\frac{3}{4}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$	
					Steep erect spins					
17.5	0.653	32.5	30 with	10 against	14	67	270 to 310	0.27	1, $2\frac{1}{4}$, $2\frac{1}{4}$	
20.0	0.664	27.5	30 with	10 against	14	67	270 to 310	0.27	$1\frac{1}{4}$, $1\frac{3}{4}$, $2\frac{1}{4}$, $2\frac{1}{2}$, $>2\frac{1}{2}$	
20.0	0.664	32.5	30 with to 0	0	14	84	270 to 310	0.27	[b]1, $1\frac{1}{2}$, $1\frac{1}{2}$	
20.0	0.664	32.5	30 with	10 against	14	67	270 to 310	0.27	$\frac{3}{4}$, $1\frac{1}{2}$, 2, $>2\frac{1}{2}$	
					Inverted spins					
17.5	0.653	32.5	30 with	0	[c]9	[a]50, 66	310 to 335	(d)	$\frac{1}{2}$, 1, >3	Also "no spin" conditions
20.0	0.664	32.5	30 with	0	[c]9	[a]50, 66	310 to 335	(d)	$\frac{1}{4}$, $\frac{1}{2}$, $1\frac{1}{2}$, >2	Also "no spin" conditions
21.25	0.684	32.5	30 with	0	[c]9	[a]50, 66	310 to 335	(d)	$\frac{3}{4}$, 1, 2	

[a]Oscillatory spin range of values given.
[b]After short glide model starts turning again.
[c]Relative to the ground.
[d]Not available.

[redacted]

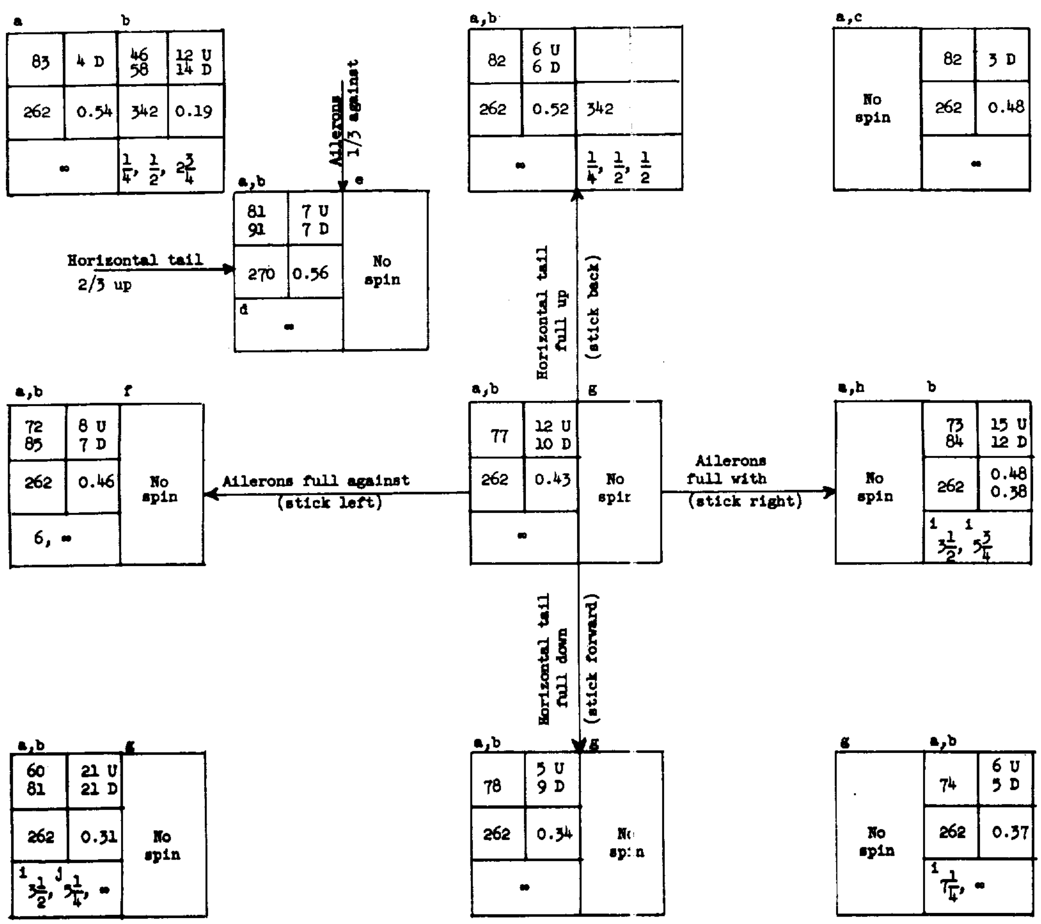
[redacted]

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by simultaneous rudder reversal 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	Attitude	Spin direction simulated	Loading (see table II)	
F4H-1	Erect	Right	Combat	
Slats	Altitude 25,000 ft		Desired center-of-gravity position 31.9 percent $\bar{c}$	

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



(a) Two conditions possible.
(b) Oscillatory spin, range or average values given.
(c) Model entered a glide.
(d) Recovery attempted by simultaneous reversal of rudder to 2/3 with the spin and movement of ailerons to 2/3 against the spin.
(e) Model entered a dive.
(f) Model spun flat for approximately 40 turns then entered a steep spin followed by an inverted dive.
(g) Model entered an inverted dive.
(h) Model spun steep for approximately 10 turns then entered a dive.
(i) Model recovered in an inverted dive.
(j) Model recovered in an erect dive.

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

[redacted]

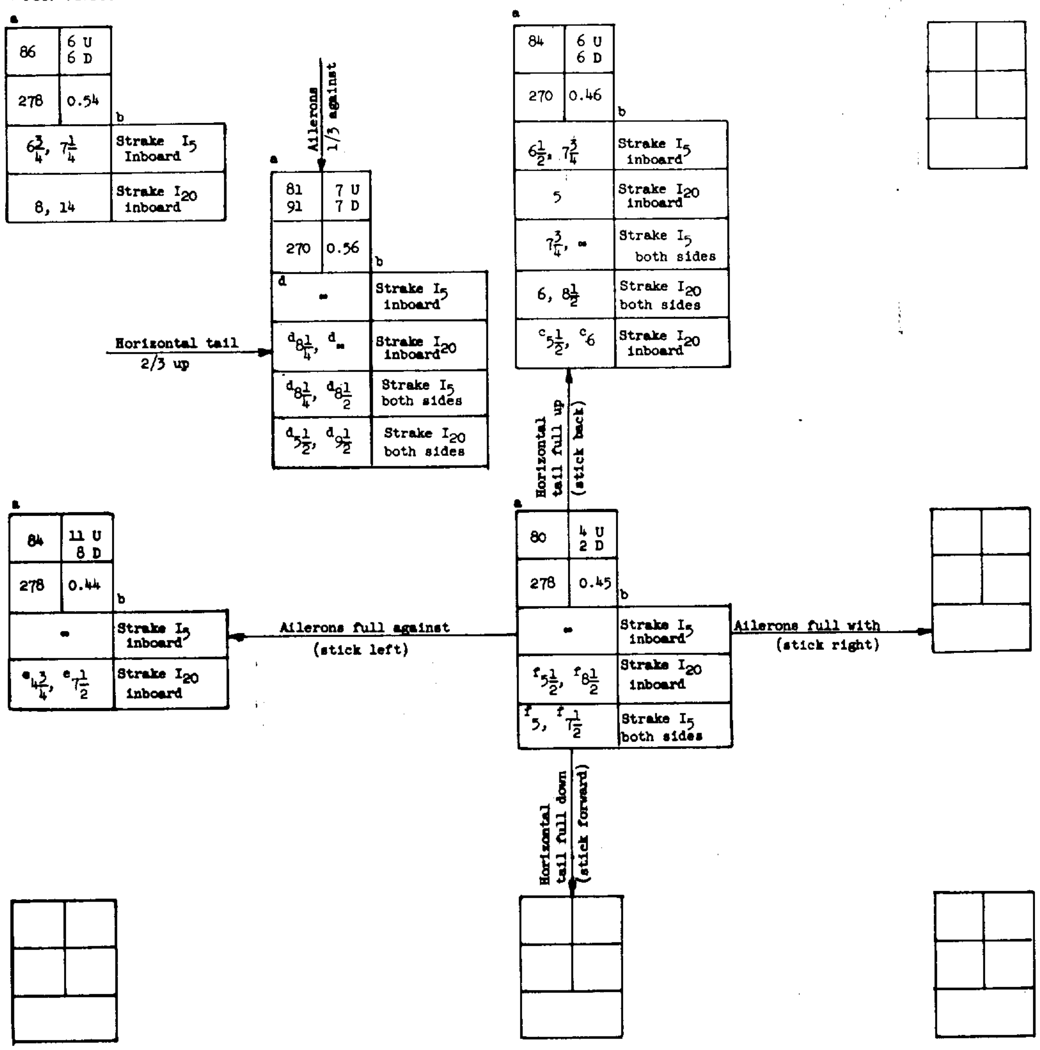
[redacted]

CHART 2.--SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

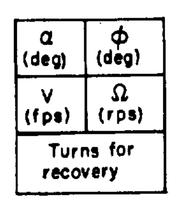
[Recovery attempted by simultaneous reversal of rudder to full against the spin, movement of ailerons to full with the spin, and extension of specified strake unless otherwise indicated (recovery attempted from, and developed spin data presented for, rudder-full-with spins), strakes are 7.5 in. (full-scale) below fuselage reference line.]

Airplane	Attitude	Spin direction	Loading 2 (see table II)
F4H-1	Erect	Right	Combat
Slots	Altitude 25,000 ft		Desired center-of-gravity location 31.9 percent $\bar{c}$

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



(a) Oscillatory spin, range or average values given.
(b) Strake extended for recovery attempts and side on which strake was extended.
(c) Recovery attempted by simultaneous reversal of rudder to full against the spin and extension of strake as indicated.
(d) Recovery attempted by simultaneous reversal of rudder to 2/3 against the spin, movement of ailerons to 2/3 with the spin, and extension of strake as indicated.
(e) Model recovered in an aileron roll.
(f) Model recovered in an inverted dive.



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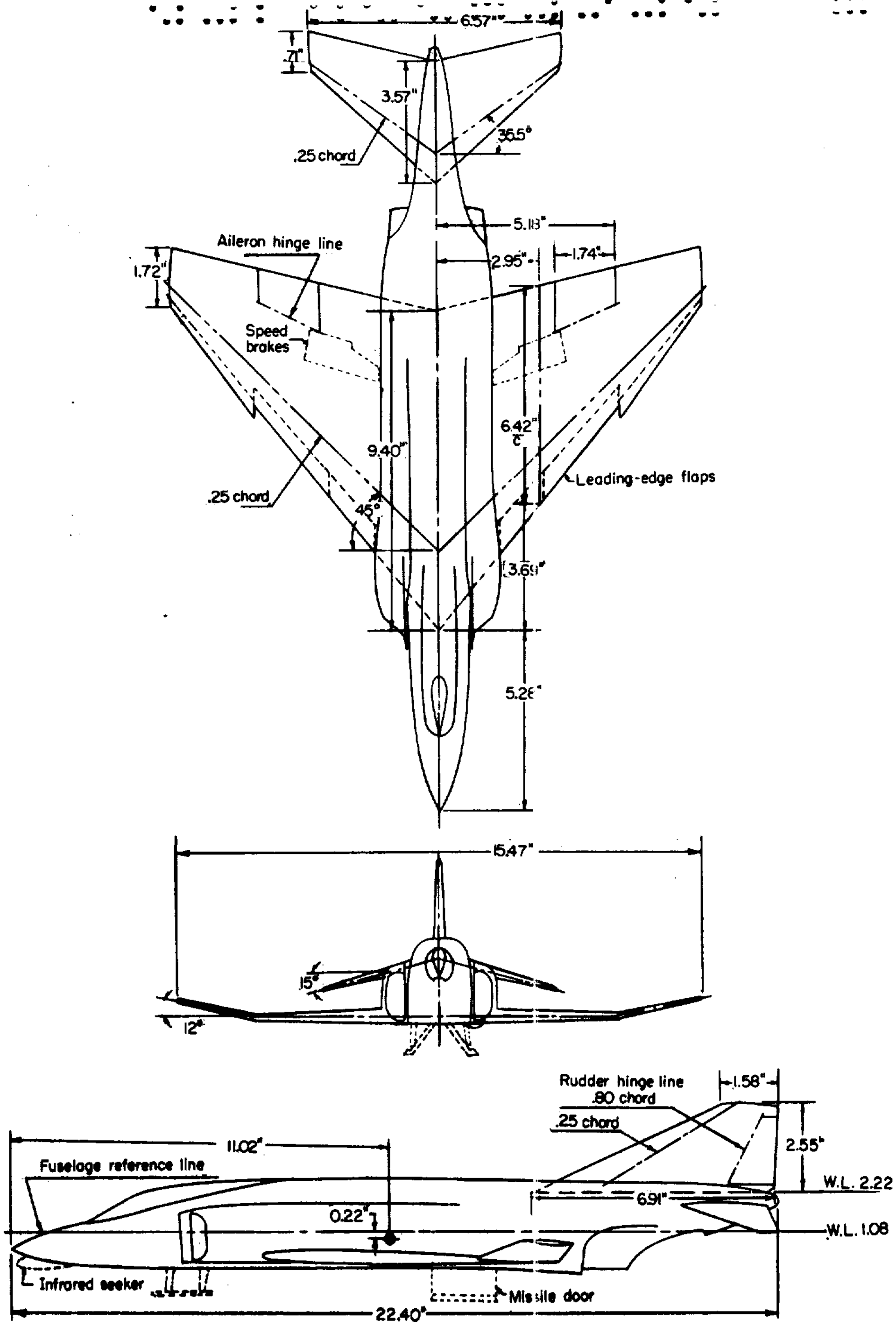

Figure 1.- Three-view drawing of the model. (Center-of-gravity position indicated is for the combat loading.)

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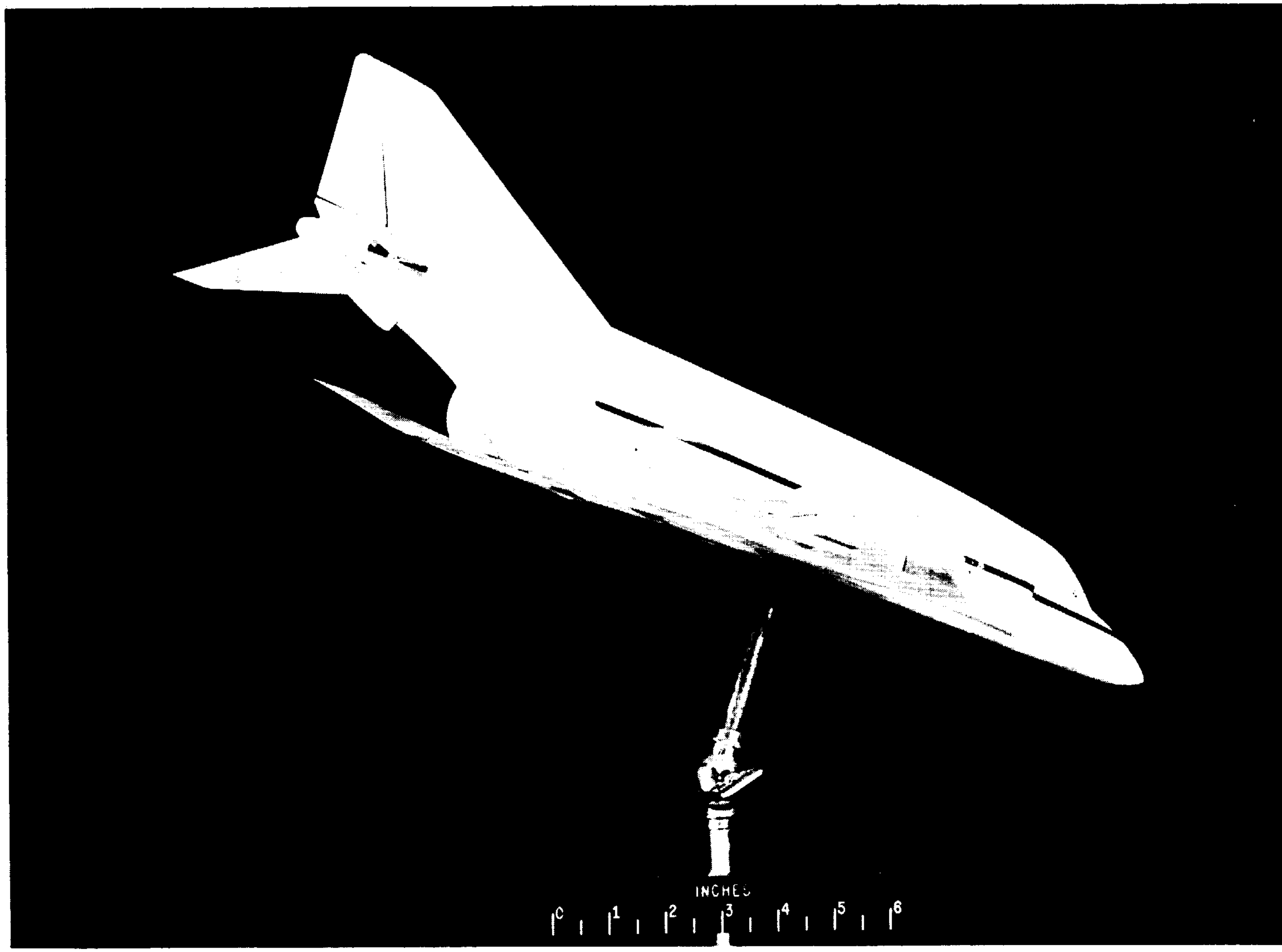

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Figure 2.- Photograph of the 1/30-scale model of twin-jet swept-wing fighter airplane.

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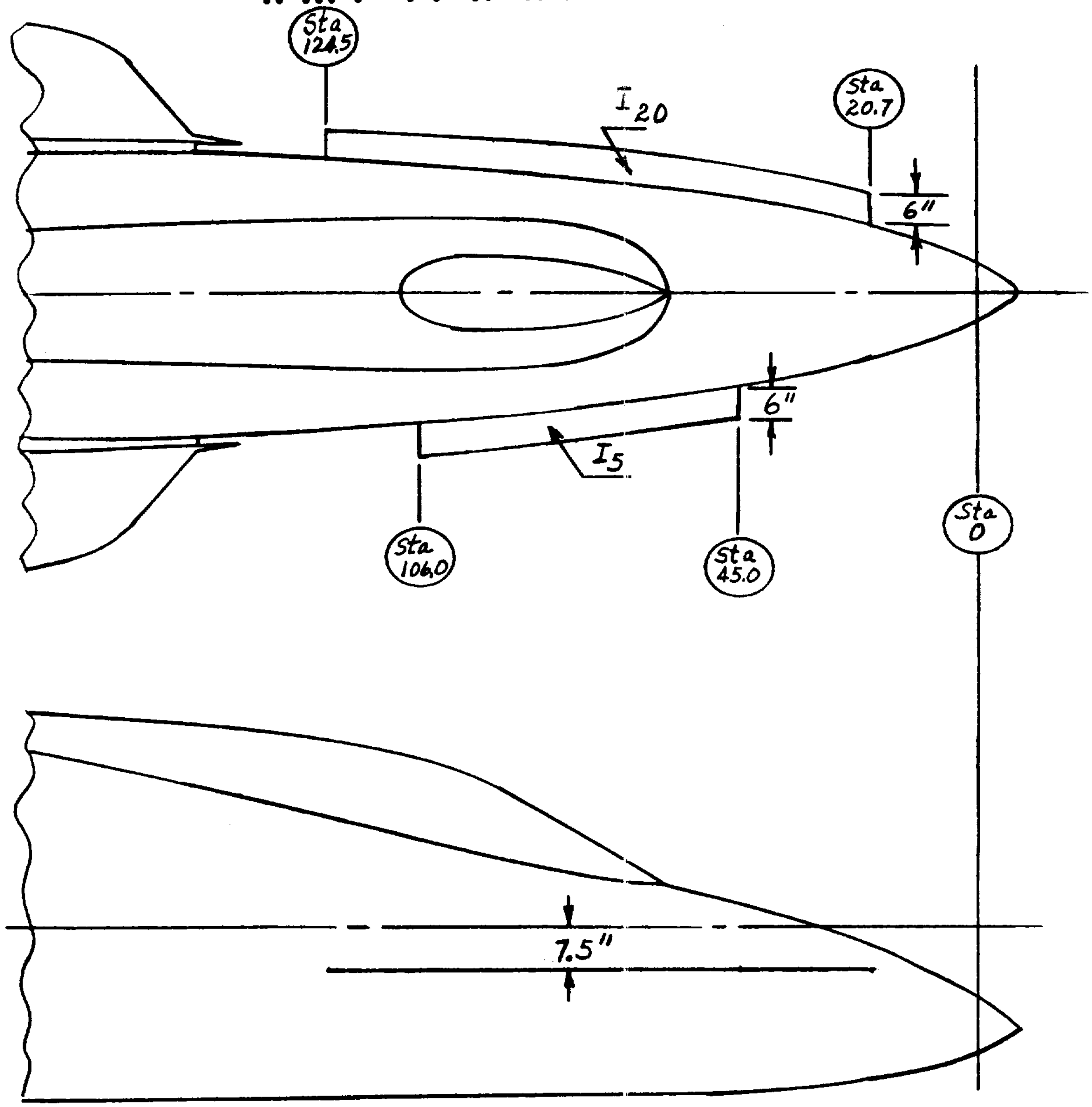

Figure 3.- Sketch showing size and location of strakes I_5 and I_{20}. Dimensions are inches, full-scale values.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM SX-446

for the

Bureau of Weapons

FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/30-SCALE MODEL OF A TWIN-JET SWEPT-WING FIGHTER AIRPLANE*

CLEARANCE NO. N5154

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

ABSTRACT

Results of an investigation of a dynamic model of the F4H-1 airplane in the Langley 20-foot free-spinning tunnel are presented. Erect and inverted developed-spin and recovery characteristics were investigated. The size of a stable tail parachute required for spin recovery in an emergency was determined.

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*Title, Unclassified

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