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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/28-SCALE MODEL OF THE NORTH AMERICAN FJ-4 AIRPLANE WITH EXTERNAL FUEL TANKS

TED NO. NACA AD 3112

By Frederick M. Healy

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SUMMARY

A supplementary investigation to determine the effect of external fuel tanks on the spin and recovery characteristics of a 1/28-scale model of the North American FJ-4 airplane has been conducted in the Langley 20-foot free-spinning tunnel. The model had been extensively tested previously (NACA Research Memorandum SL58A29) and therefore only brief tests were made to evaluate the effect of tank installation.

Erect spin tests of the model indicate that flat-type spins are more prevalent with 200-gallon external fuel tanks than with tanks not installed. The recovery technique determined for spins without tanks, rudder reversal to full against the spin accompanied by simultaneous movement of ailerons to full with the spin, is recommended for spins encountered with external tanks installed. If inverted spins are encountered with external tanks installed, the tanks should be jettisoned and recovery attempted by rudder reversal to full against the spin with ailerons maintained at neutral.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, a supplementary investigation has been made of the spin and spin-recovery

*Title, Unclassified.

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characteristics of a 1/28-scale model of the North American FJ-4 airplane previously tested in the Langley 20-foot free-spinning tunnel and reported in reference 1. The North American FJ-4 is a jet-propelled, low swept-wing, single-seat fighter airplane.

The effects of installing full 200-gallon external fuel tanks on the erect and inverted spin and recovery characteristics of the model were investigated.

SYMBOLS

b	wing span, ft
$\bar{c}$	mean aerodynamic chord, in.
$x/\bar{c}$	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
S	wing area, sq ft
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, $\frac{m}{\rho S b}$

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 TESTING TECHNIQUES

The 1/28-scale model of the North American FJ-4 airplane furnished by the Bureau of Aeronautics, Department of the Navy, was prepared for supplementary tests by the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model as tested with external fuel tanks installed is shown in figure 1. The dimensional characteristics of the airplane are presented in table I.

As indicated in reference 1, the longitudinal control system of the North American FJ-4 airplane includes both a controllable horizontal stabilizer and elevators. The elevators remain undeflected until the leading edge of the stabilizer is deflected 4° downward; at the maximum stabilizer deflection of 14° (leading edge down), the trailing edge of the elevators are deflected 15° upward (relative to the stabilizer). The rate of deflection of the elevators with respect to the deflection rate of stabilizer is approximately linear.

The mass characteristics for the loadings of the airplane and for the loading tested on the model are presented in table II. For these tests the model was again 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 exerted on the controls for the recovery attempts to reverse them fully and rapidly.

The following normal maximum control deflections used on the model during the tests (measured perpendicular to the hinge lines) were the same as those for the original tests:

Rudder deflection, deg . . . . 27.5 right; 27.5 left
Elevator deflection (with respect to horizontal tail), deg . . . . 15 up

Horizontal-tail deflection, deg	14 leading edge down 6 leading edge up
Aileron deflections, deg	20 up; 15 down

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

The following techniques are included in the presentation of the data on the charts:

For spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as greater than the velocity at the time the model hit the safety net; for example, >300 feet per second, full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude. For recovery attempts in which the 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. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin."

PRECISION

Results obtained from 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	± 1
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 $\pm 1^{\circ}$.

RESULTS AND DISCUSSION

The results of the model tests are presented in charts 1 and 2. Spins to the pilot's right and left were similar, and the data are arbitrarily presented in terms of right spins.

Erect Spins

The results of tests with full 200-gallon external fuel tanks installed are presented in chart 1, together with results for a corresponding wing-heavy loading from reference 1. Additional tests, not presented in chart form, with empty tanks installed and with equivalent weights substituted to determine the aerodynamic effect of the tanks showed no significant difference in spin and recovery characteristics. The results with full external tanks are generally similar to the results without tanks from reference 1, except that in the tests without tanks two types of spin were obtained, a flat spin with unsatisfactory recovery characteristics and a steep spin from which satisfactory recoveries were obtained. The present brief tests showed only the flatter-type spin. The increased prevalence of flat spins may possibly be attributable to a slight increase in angular velocity in the tests with external tanks. On the basis of the criterion spins (ref. 2), the erect-spin recovery characteristics of the model with tanks are considered unsatisfactory. However, the optimum control technique determined in reference 1 (rudder full against and ailerons full with the spin) is recommended for the airplane with tanks installed inasmuch as it appears that recoveries, at least from any steep spins encountered, should be obtainable by this method. Spin tests of the airplane conducted to date with and without external tanks have resulted in only the steeper-type spins from which satisfactory recoveries were obtained. Recovery techniques used during airplane spin tests were rudder full against the spin and lateral and longitudinal neutralization of the stick for tests with and without external stores. In addition, rudder reversal to two-thirds against the spin followed by brisk forward stick displacement was used for tests without stores. Reference 2 discusses the influence of such factors as scale effect and tunnel technique in causing differences which occasionally occur between model results and results obtained during the actual airplane spin tests.

Inverted Spins

The results of the inverted spin and recovery tests of the model are presented in chart 2. The order used for presenting the data for the inverted spins is different from that used for erect spins. Chart 2 incorporates two control-setting diagrams. For each diagram, "controls crossed" for the established spin (right rudder pedal forward and stick to the left of the pilot for a spin to the right of the pilot) is presented to the right of the chart and "stick back" is presented at the bottom. When the controls are crossed in the established spin, the lateral controls aid the rolling motion; when the controls are together, the lateral controls oppose the rolling motion. The angle ϕ and the elevator position in the chart are given as up or down relative to the ground.

The results of the inverted-spin tests with full 200-gallon external fuel tanks installed are presented in chart 2, together with results for a corresponding wing-heavy loading from reference 1. Additional tests, not presented in chart form, with empty tanks installed and with equivalent weights substituted to determine the aerodynamic effect of the tanks in inverted spins showed no significant difference in spin and recovery characteristics. The spins with full external tanks installed and the spins for a corresponding loading (from ref. 1) exhibit similar trends with respect to aileron setting but indicate adverse effects on recoveries for some of the control dispositions investigated. If inverted spins are encountered in this configuration, it is recommended that the external tanks be jettisoned, if possible, and recovery be attempted by rudder reversal to full against the spin with ailerons maintained at neutral.

SUMMARY OF RESULTS

From a free-spinning tunnel investigation of a 1/28-scale model of the North American FJ-4 airplane, the following summary is considered applicable to the spin and recovery characteristics of the airplane at 30,000 feet:

1. The optimum recovery technique for erect spins of the airplane with 200-gallon external fuel tanks installed is the same as that recommended when tanks were not installed; that is, simultaneous rudder reversal to full against the spin and aileron movement to full with the spin (stick full right in a right spin).

2. If inverted spins are encountered with 200-gallon external fuel tanks installed, the tanks should be jettisoned and recovery attempted by full rudder reversal to against the spin with ailerons maintained at neutral.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 23, 1958.

REFERENCES

1. Healy, Frederick M.: Free-Spinning-Tunnel Investigation of a 1/28-Scale Model of the North American FJ-4 Airplane - TED NO. NACA AD-3112. NACA RM SL58A29, Bur. Aero., 1958.

2. Neihouse, Anshal I., Klinar, Walter J., and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NACA RM L57F12, 1957.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE

NORTH AMERICAN FJ-4 AIRPLANE

Overall length, ft	37.68
Wing:	
Span, ft	39.11
Area, sq ft	338.66
Root chord, in.	160.51
Tip chord, in.	47.52
Mean aerodynamic chord, in.	114.42
Distance from leading-edge root chord to leading-edge mean aerodynamic chord, in.	78.67
Aspect ratio	4.5
Taper ratio	0.30
Sweepback of quarter-chord, deg	35
Dihedral, deg	3
Incidence, deg:	
Root	+1
Tip	-3
Airfoil section:	
Root	NACA 64A006 modified
Tip	NACA 64A006 modified
Ailerons:	
Total area, rearward of hinge line, sq ft	30.34
Span, each, percent b/2	36.40
Chord, inboard, in.	30.06
Chord, outboard, in.	21.29
Horizontal tail:	
Span, ft	13.16
Root chord, in.	61.33
Tip chord, in.	26.06
Sweepback of quarter-chord, deg	35
Dihedral, deg	0
Nose to leading edge of horizontal tail at root, ft	29.68
Airfoil section:	
Root	NACA 65A006
Tip	NACA 65A006 modified
Vertical tail:	
Span, fuselage reference line to equivalent tip, ft	8.55
Area, including dorsal, sq ft	9.09
Root chord, in.	76.50
Chord at equivalent tip, in.	20.072
Sweepback of quarter-chord, deg	35
Rudder area, rearward of hinge line, sq ft	5.26
Nose to leading edge of vertical tail at root, ft	27.33
Airfoil section:	
Root	NACA 65A006
Tip	NACA 65A006

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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE NORTH AMERICAN FJ-4 AIRPLANE AND FOR LOADINGS TESTED ON THE 1/28-SCALE MODEL

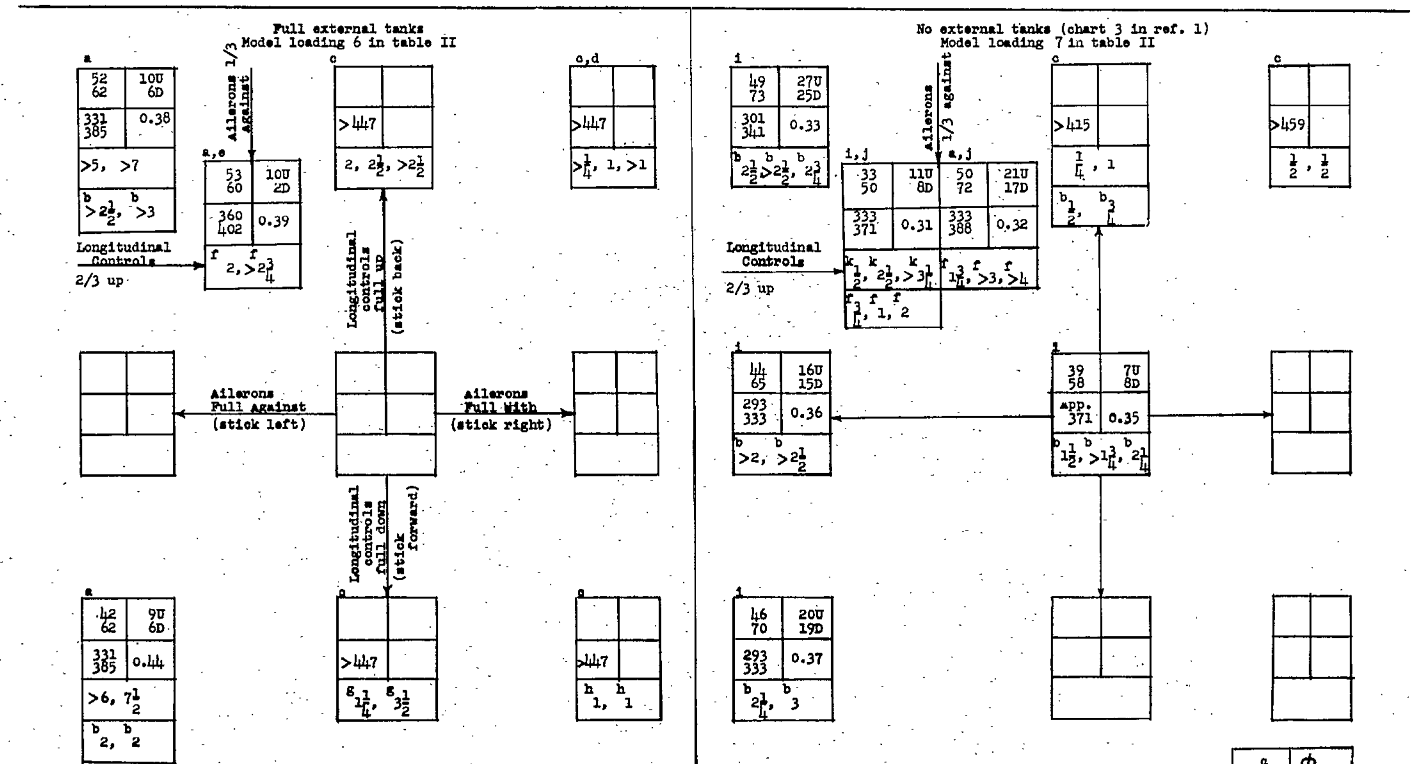
[Values given are full scale, and moments of inertia are given about the center of gravity]

Loading condition			Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
No.	Wing fuel	External tanks		$x/\bar{c}$	$z/\bar{c}$	Sea level	30,000 feet	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													
1	None	Off	15,809	0.228	--	15.59	41.68	11,307	26,422	35,110	-201×10^{-4}	-116×10^{-4}	317×10^{-4}
2	None	Empty	16,209	.229	--	15.97	42.70	12,374	26,557	36,165	-184	-125	309
3	None	Full	18,789	.226	--	18.54	49.58	19,186	27,913	42,730	- 98	-166	264
4	Full	Off	19,369	.250	--	19.11	51.10	14,923	26,244	38,590	-124	-134	258
5	Full	Empty	19,769	.252	--	19.49	52.12	15,986	26,364	39,758	-111	-143	254
6	Full	Full	22,769	.245	--	22.44	60.02	22,789	27,724	46,357	- 46	-172	218
Model values													
6	Full	Full	22,527	0.245	0.103	22.22	59.42	22,537	28,642	44,920	-57×10^{-4}	-152×10^{-4}	209×10^{-4}
7	Revised design combat gross weight (ref. 1)		17,573	.264	.074	17.33	46.35	18,297	25,446	40,633	-86	-182	268

[redacted]

CHART 1.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE FJ-4 MODEL

[Recovery attempted by rapid reversal of rudder to full against the spin except as indicated (recovery attempted from, and developed spin data presented for, rudder-full-with spins); right spins, external stores, and model loading as indicated]



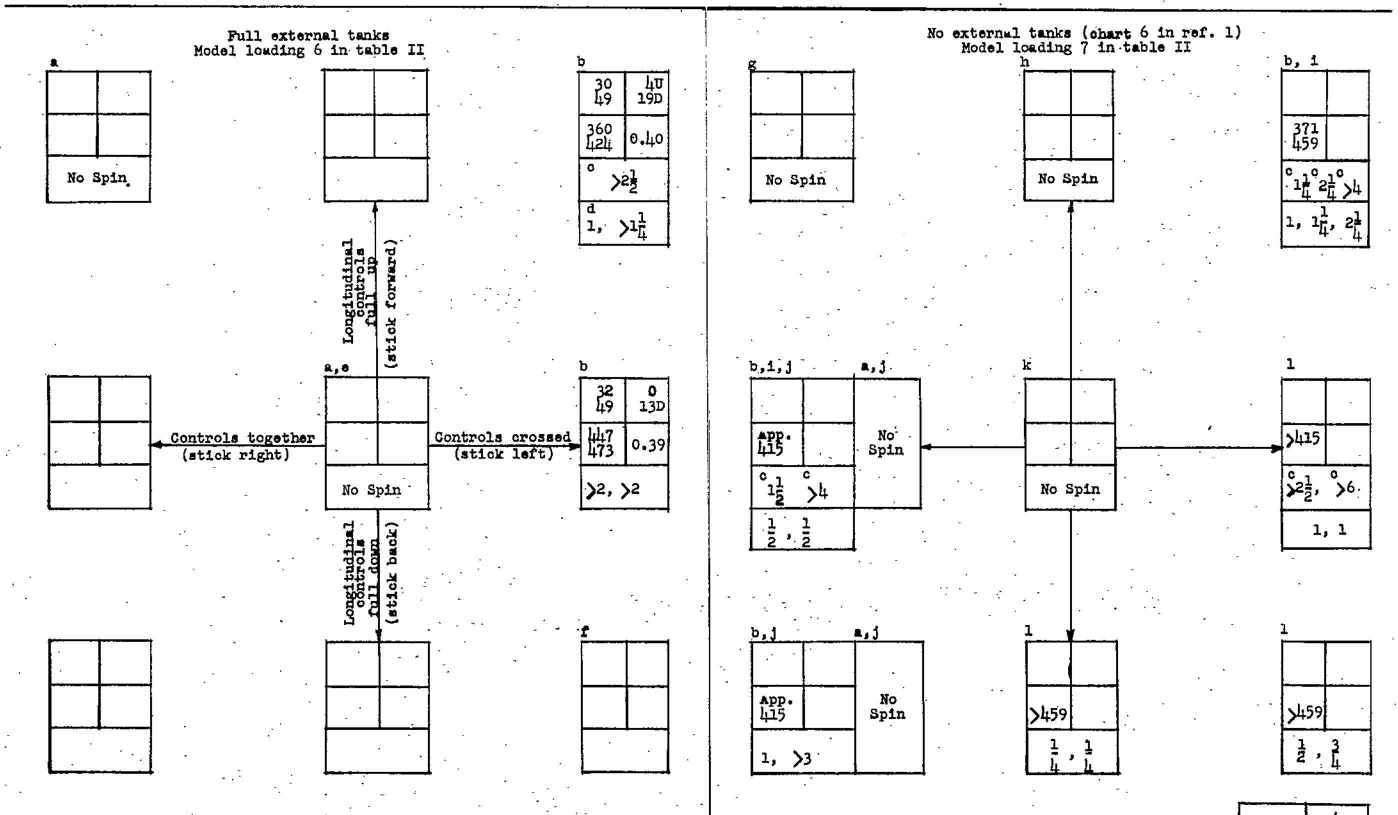
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

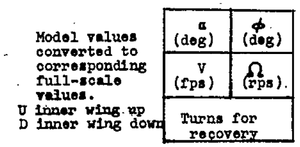
α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

[a]Oscillatory spin, range of values given
[b]Recovery attempted by simultaneous reversal of rudder to full against the spin and movement of ailerons to full with the spin
[c]Steep spin; recovery attempted before final attitude attained
[d]No spin condition also observed; model entered a glide
[e]Wandering spin
[f]Recovery attempted by simultaneous reversal of rudder to 2/3 against the spin and movement of ailerons to 2/3 with the spin
[g]Recovered in an inverted dive
[h]Recovered in an aileron roll
[i]Oscillatory and wandering spin, range or average values given
[j]Two conditions possible
[k]Recovery attempted by reversing rudder from full with to 2/3 against the spin

CHART 2.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE FJ-4 MODEL

[Recovery attempted by rapid reversal of rudder to full against the spin except as indicated (recovery attempted from, and developed spin data presented for, rudder-full-with spins); spins to pilot's right, external stores and model loading as indicated]





[a]Model entered an erect dive
[b]Oscillatory spin, range of values given
[c]Recovery attempted by rudder neutralization
[d]Recovered in an aileron roll
[e]Visual observation
[f]Model entered either a very steep spin or an aileron roll
[g]Model entered a spin to the pilot's left
[h]Model entered an inverted dive
[i]Whipping and wandering spin
[j]Two conditions possible
[k]Model entered a vertical dive
[l]Steep spin, recovery attempted before final attitude attained

[redacted]

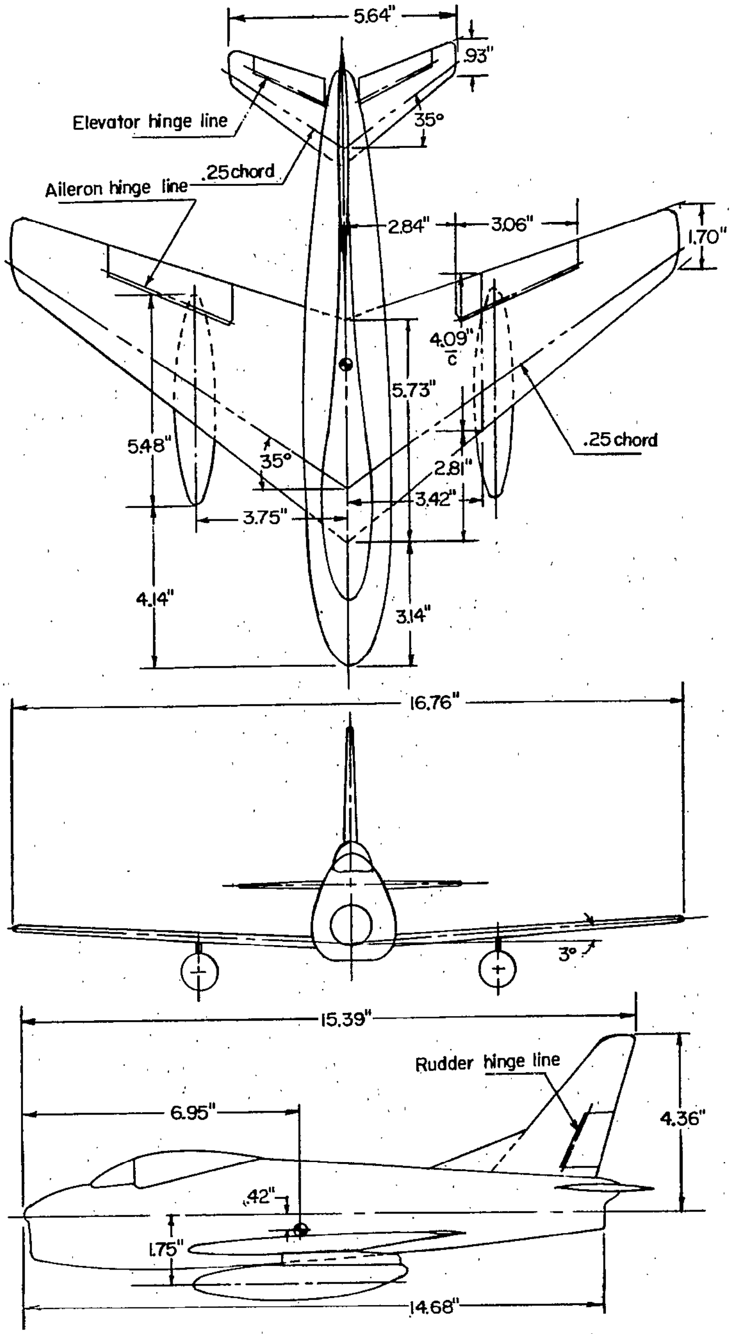


Figure 1.- Three-view drawing of the 1/28-scale model of the North American FJ-4 airplane with external fuel tanks. Center-of-gravity position indicated is for the loading with full wing fuel and full external tanks.

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ABSTRACT

Results of an investigation in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of the model are presented. Both erect and inverted spins were investigated with full 200-gallon external fuel tanks installed on the model.

INDEX HEADINGS

Stores - Airplane Components	1.7.1.1.5
Airplanes - Specific Types	1.7.1.2
Spinning	1.8.3
Mass and Gyroscopic Problems	1.8.6
Piloting Techniques	7.7

*Title, Unclassified.

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