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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

SUPPLEMENTARY FREE-SPINNING-TUNNEL INVESTIGATION OF A $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE SWEPT-WING CONFIGURATION WITH SLATS EXTENDED

TED NO. NACA DE 340

By Theodore Berman and Walter J. Klinar

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
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SUMMARY

A supplementary investigation has been conducted in the Langley 20-foot free-spinning tunnel of a $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane to determine what effect full-span slats would have on the spin-recovery characteristics of the swept-wing version of the XF10F-1 airplane, which had previously been indicated as possessing undesirable spin-recovery characteristics without slats. The effects of extended nose-wheel doors and of fairing the air-duct inlets were also determined.

The results indicated that, with slats fully extended, satisfactory recovery could be obtained by rudder reversal provided it was accompanied by movement of the trimmer ailerons to full with the spin (only up-going spoiler operative). Extension of the nose-wheel doors or fairing of the air-duct inlets did not improve the recovery characteristics.

INTRODUCTION

A spin-tunnel investigation conducted on a $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane reported in reference 1 had indicated that recovery characteristics would be satisfactory for the straight-wing configuration but unsatisfactory for the swept-wing configuration. Subsequent to completion of this investigation, information supplied by the contractor indicated that the XF10F-1 airplane was to be equipped with full-span slats, and, inasmuch as analysis indicated a possible favorable effect of slats for the XF10F-1 design, supplementary model tests were performed for the swept-wing version to evaluate their effect.

SYMBOLS

b wing span, feet

S wing area, square feet

$\bar{c}$ mean geometric chord, feet

$\frac{x}{\bar{c}}$ ratio of distance of center of gravity rearward of leading edge of mean geometric chord to mean geometric chord

$\frac{z}{\bar{c}}$ ratio of distance between center of gravity and fuselage reference line to mean geometric chord (positive when center of gravity is below fuselage reference line)

m mass of airplane, slugs

I_X, I_Y, I_Z moments of inertia about X, Y, and Z body axes, respectively, slug-feet^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, slugs per cubic feet

μ relative density of airplane $\left(\frac{m}{\rho Sb}\right)$

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

φ angle between span axis and horizontal, degrees

V full-scale true rate of descent, feet per second

Ω full-scale angular velocity about spin axis, revolutions per second

σ helix angle, angle between flight path and vertical, degrees (For the tests of this model, the average absolute value of the helix angle was approximately 2°.)

β approximate angle of sideslip at center of gravity, degrees (Sideslip is inward when inner wing is down by an amount greater than the helix angle.)

APPARATUS AND METHODS

Model

The $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane used in the investigation reported in reference 1 was used in the present investigation. A three-view drawing of the model in the swept-wing configuration is shown in figure 1. A sketch showing the extended nose-wheel doors and the faired air-duct inlets investigated is presented in figure 2. Dimensional characteristics of the airplane are presented in table I. The tail-damping-power factor was computed by the method described in reference 2.

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 recovery attempts.

Technique and Precision

The tests were performed in the Langley 20-foot free-spinning tunnel. The testing technique applied and methods for determining the spin data were essentially the same as those reported in reference 1.

The precision of the test results and the limits of accuracy of the mass characteristics of the model for the present tests were within the limits presented in reference 1.

TEST CONDITION

The mass characteristics and inertia parameters for the loading investigated on the model and for the comparable airplane loading are shown in table II. All tests were conducted with the cockpit closed and the flaps and landing gear retracted.

The following maximum control deflections (identical to those used in the investigation reported in reference 1) were used in the tests:

Rudder, degrees	20 right, 20 left
Bow plane, degrees	+10, -20
Stabilizer, degrees	+3, -8

The maximum deflections of the lateral-control trimmers (called trimmer ailerons hereinafter) used for this investigation were the normal deflections of 20° up and 15° down. For a few of the tests the trimmer ailerons were set at two-thirds of their full deflection. Inasmuch as a curve of control deflection against lateral stick position was not available, the variation was arbitrarily taken as linear. Slight deviations from linearity would not be expected to alter the results obtained.

The maximum control deflections of the rudder and the trimmer ailerons are given perpendicular to the hinge lines of the control surfaces.

RESULTS AND DISCUSSION

The spin data for the model with slats retracted, as presented in reference 1, are shown in chart 1 for comparison purposes. The results of the present investigation are shown in charts 2 to 4. For the present investigation, check spins with slats retracted revealed that both right and left spins were now similar to the flat spins that were originally obtained to the right for the original investigation (reference 1). The results of spins with slats extended were also quite similar to the right and left; and the results of the present investigation are arbitrarily presented in terms of right spins.

Effect of extending both slats.- Comparison of charts 1 and 2 indicates the effects on the spin of extending the slats. As is shown on the charts, fully extending the slats reduced the amplitude of the oscillations encountered in the spin and had a somewhat favorable effect on the normal control configuration for spinning (rudder with the spin, elevator up, and ailerons neutral) in that satisfactory as well as unsatisfactory recoveries could be obtained by reversal of the rudder. As is shown on chart 2, changing the incidence of the horizontal tail planes or deflecting the spoilers with or against the spin had little effect on the spins, and, although satisfactory recoveries are not recorded for all control configurations, it is felt that if sufficient attempts had been made, satisfactory as well as unsatisfactory recoveries would probably have been obtained for all control configurations. It should be noted that for slats retracted (chart 1) only unsatisfactory recoveries were originally obtainable. The satisfactory and unsatisfactory recoveries observed with the slats extended were found to be influenced by slight inadvertent changes in the roll attitude of the horizontal tail surfaces of the model, and it is believed that both satisfactory and unsatisfactory recoveries may be obtainable on the corresponding airplane. On this basis the spin-recovery characteristics of the swept-wing version of the XF10F-1 airplane with slats extended utilizing only spoilers for lateral control are still considered unsatisfactory.

Effect of deflecting the trimmer ailerons, slats extended.- As had been indicated in reference 1, satisfactory recoveries could be obtained on the swept-wing version of the model with slats retracted by simultaneous reversal of the rudder and deflection of the trimmer ailerons to $\pm 40^{\circ}$ with the spin (left trimmer 40° down and right trimmer 40° up in a right spin), the spoilers remaining at neutral. Inasmuch as extending the slats had indicated a somewhat favorable effect, tests were conducted with the slats fully extended and the trimmer ailerons deflected with the spin to determine if extension of the slats would reduce the trimmer-aileron deflection with the spin required for recovery. The results of these tests are presented on chart 3.

As is shown on the chart, when the spoilers were at neutral, deflecting the trimmer ailerons to only $\pm 10^{\circ}$ with the spin (left 10° down and right 10° up in a right spin) resulted in satisfactory recoveries by reversal of the rudder. Deflecting the spoilers with the spin in combination with the trimmer ailerons reduced the effectiveness of the trimmers, however, and with both spoilers and trimmers operative the full trimmer deflection (20° up and 15° down) had to be employed to obtain satisfactory recoveries when the spoilers were deflected full with the spin.

Although the trimmer ailerons were designed for operation in the landing condition on only the straight-wing version of the XF10F-1 airplane, it was learned from the contractor that the trimmer ailerons could also be made operative for the swept-wing configuration. It was also learned that, when the normal lateral-control linkage for the XF10F-1 is used and the trimmer ailerons are operative, only the upgoing spoiler deflects. Accordingly, this combination of lateral-control movements was investigated. Results of these tests (presented on chart 3) indicate that, with the trimmer ailerons and only the up-going spoiler operative, satisfactory recoveries could be obtained by deflection of the stick laterally with the spin and simultaneous reversal of the rudder against the spin even though only two-thirds deflections of these controls were used, when the slats were fully extended. Thus it appears from these tests that the down-going spoiler had an adverse effect on recoveries when both spoiler and trimmer ailerons were deflected with the spin. Thus, the control linkage which provides for deflecting only the up-going spoiler when trimmer ailerons are operated is desirable from the standpoint of recovery.

Effect of extending the outboard or inboard slat.- Inasmuch as the results of reference 1 and the results of the present investigation had indicated a favorable effect on recoveries of a rolling moment into the spin (right rolling moment in a right spin), and inasmuch as a differential slat opening would be expected to provide a rolling moment during spins, the effects on the model's spin and spin-recovery characteristics of opening only the outboard slat (left slat in a right spin) or of opening the inboard slat (right slat in a right spin) were studied. The trimmer ailerons were maintained at neutral for these tests. As was anticipated, opening only the outboard slat (providing a rolling moment into the spin) had a favorable effect on recoveries, the model tending to resist spinning for nearly all settings of the horizontal tail planes when the spoilers were at neutral or against the spin. (See chart 4.) When the spoilers were deflected with the spin, however, the model spun and both satisfactory and unsatisfactory recoveries were obtained. As previously indicated this adverse effect may be attributed to the down-going spoiler.

Brief tests were conducted with only the inboard slat extended and the results of these tests, not presented in chart form, indicated that the spin and recoveries would be essentially the same as those presented on chart 1 for slats retracted.

Although extension of only the outboard slat during a spin produced a favorable effect on recoveries, proper differential operation of the slats on the part of the pilot may be difficult and confusing.

Effect of extending nose-wheel doors and of fairing the air-duct inlets.- At the request of the contractor, brief tests were conducted with the nose-wheel doors extended and with the air inlets faired to attempt to improve the model's spin-recovery characteristics. These tests were conducted with the slats either fully extended or fully retracted on the swept wing and with the trimmer ailerons inoperative. The results indicated that extending either a single or double nose-wheel door or installing large or small fairings on the air-duct inlets (fig. 2) would not improve the spin-recovery characteristics (results not presented in chart form).

Recommended recovery technique.- Satisfactory recoveries will be obtained for the swept-wing version of the XF10F-1 airplane provided slats are fully extended in the spin and rudder reversal is accompanied by simultaneous movement of the trimmer ailerons to full with the spin, the down-going spoiler remaining at neutral. Extension of the slats will have no discernible effect on the satisfactory recovery characteristics (reference 1) of the straight-wing version of the airplane.

CONCLUSIONS

Based on an investigation of a $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane, the following conclusions are made concerning the airplane spin and recovery characteristics of the swept-wing configuration at a spin-test altitude of 30,000 feet:

1. Extension of the slats will have a favorable effect on the spin-recovery characteristics but consistently satisfactory recoveries will not be obtained unless provision is made for deflecting the trimmer ailerons on the swept-wing configuration.

2. Satisfactory recoveries will be obtainable provided the slats are fully extended in the spin and rudder reversal is accompanied by simultaneous movement of the trimmer ailerons to full with the spin, the down-going spoiler remaining at neutral.

3. Extending the nose-wheel doors, or fairing the air-inlet ducts will not improve the spin-recovery characteristics.

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REFERENCES

1. Berman, Theodore: Free-Spinning-Tunnel Investigation of a $\frac{1}{30}$-Scale Model of the Grumman XF10F-1 Airplane - TED No. NACA DE 340. NACA RM SL50L14, Bur. Aero., 1950.

2. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN 1045, 1946.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE GRUMMAN XF10F-1

AIRPLANE IN THE SWEPT-WING CONFIGURATION

Length over all, ft	55.3
Normal center-of-gravity location, percent $\bar{c}$	23.4
Wing:	
Span, ft	36.7
Area, sq ft	450.0
Sweepback of one-quarter chord line, deg	42.5
Incidence, deg	0
Dihedral, deg	-5.0
Section	NACA 64_1A009
Aspect ratio	3.0
Mean geometric chord, ft	12.3
Leading edge of $\bar{c}$ rearward of leading edge of root chord, ft	8.4
Spoilers:	
Height, in	7.0
Span, percent b/2	40.0
Trimmer ailerons:	
Area rearward of hinge line, sq ft	15.0
Chord, ft	1.25
Vertical tail surfaces:	
Total area, sq ft	37.8
Total rudder area rearward of hinge line, sq ft	5.4
Horizontal tail surfaces:	
Bow-plane area, sq ft	5.9
Apex angle of bow plane, deg	53.2
Stabilizer area, sq ft	72.2
Apex angle of stabilizer, deg	53.2
Distance from normal center of gravity to stabilizer hinge line, ft	25.8
Tail-damping-power factor	0.007596

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADING TESTED ON THE MODEL AND FOR THE COMPARABLE AIRPLANE LOADING

[Model values converted to corresponding full-scale values]

Loading	Weight (lb)	Center-of-Gravity location		Relative Density μ		Moments of Inertia (slug-feet^2)			Mass Parameters		
		$x/\bar{c}$	$z/\bar{c}$	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											
No Wing Fuel No Ammunition	26,185	0.234	-0.025	20.7	55.5	17,810	73,528	79,022	-509×10^{-4}	-50×10^{-4}	559×10^{-4}
Average Model Values											
No Wing Fuel No Ammunition	26,669	0.233	-.017	21.1	56.4	17,971	74,631	77,277	-508×10^{-4}	-23×10^{-4}	532×10^{-4}

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE SWEPT-WING MODEL WITH SLATS RETRACTED AND TRIMMER AILERONS NEUTRALIZED

[Recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]

	Spoilers against (Stick left)		Spoilers with (Stick right)
Stabilizer negative incidence Bow plane negative incidence	[a] α: 81, 37; φ: 42U, 25D; V: App 347; Ω: 0.26; Turns: ∞, ∞	[a] α: 75, 38; φ: 35U, 35D; V: 352; Ω: 0.30; Turns: ∞, ∞	[a] α: 72, 35; φ: 37U, 20D; V: 352; Ω: 0.37; Turns: >3, ∞
Stabilizer negative incidence Bow plane neutral	[a] α: 70, 45; φ: 22U, 20D; V: 347; Ω: 0.28; Turns: ∞, ∞	[a] α: 75, 30; φ: 40U, 20D; V: 347; Ω: 0.30; Turns: ∞, ∞	[a] α: 72, 45; φ: 32U, 25D; V: 352; Ω: 0.29; Turns: ∞, ∞
Stabilizer negative incidence Bow plane positive incidence	[a] α: 75, 45; φ: 30U, 18D; V: 356; Ω: 0.37; Turns: ∞, ∞	[a] α: 75, 40; φ: 35U, 25D; V: 356; Ω: 0.30; Turns: >3, ∞	[a] α: 75, 35; φ: 28U, 20D; V: 356; Ω: 0.30; Turns: ∞, ∞
Stabilizer neutral Bow plane neutral	[a] α: 75, 50; φ: 35U, 23D; V: 372; Ω: 0.30; Turns: ∞, ∞	[a] α: 70, 30; φ: 35U, 15D; V: 372; Ω: 0.30; Turns: >6, ∞	[a] α: 75, 43; φ: 35U, 25D; V: 365; Ω: 0.26; Turns: >3, ∞
Stabilizer positive incidence Bow plane neutral incidence	[a] α: 75, 28; φ: 38U, 18D; V: 372; Ω: 0.28; Turns: ∞, ∞	[a] α: 75, 32; φ: 30U, 28D; V: 372; Ω: 0.26; Turns: >6, ∞	[a] α: 73, 35; φ: 35U, 20D; V: 356; Ω: 0.26; Turns: >2, ∞

[a]Spin oscillatory in roll and yaw. Range of values or average value given.

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	

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CHART 2.– SPIN AND RECOVERY CHARACTERISTICS OF THE SWEPT-WING MODEL WITH SLATS FULLY EXTENDED AND TRIMMER AILERONS NEUTRALIZED

[Recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with- spins); right erect spins]

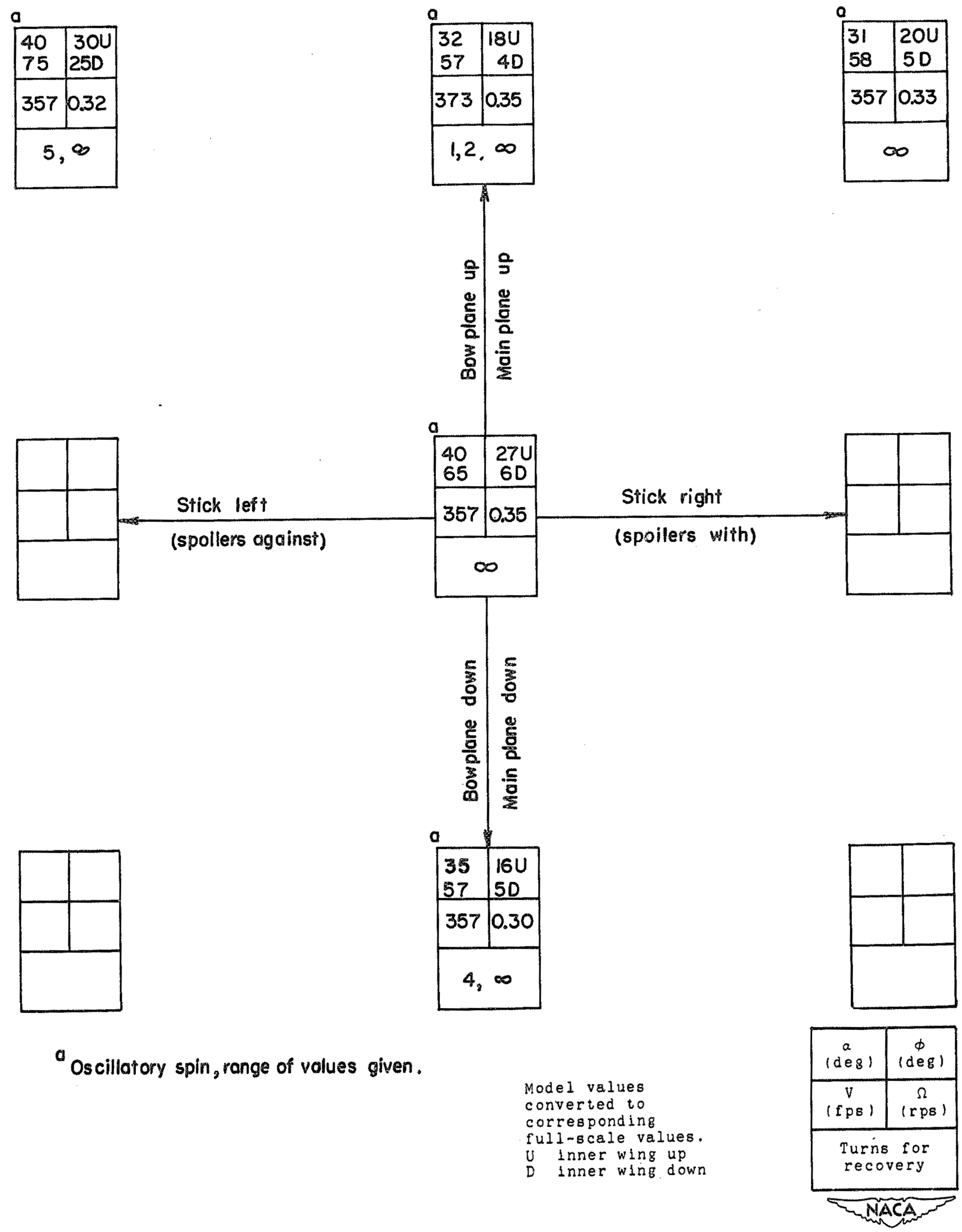

CHART 3.- EFFECT OF VARIOUS TRIMMER AILERON-SPOILER COMBINATIONS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE SWEPT-WING MODEL WITH SLATS FULLY EXTENDED.

[Bowplane and mainplane full up; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]

Spoiler position \ Trimmer aileron position	Neutral	±5°	±10°	$\frac{2}{3}$ with	Full with
Spoilers neutral	[a] α 32, 57; φ 18U, 4D V 373; Ω 0.35 [b]1, [b]2, ∞	[a] α 35, 52; φ 9U, 9D V 357; Ω 0.34 $\frac{3}{4}$, $1\frac{1}{2}$, ∞	[a] α 35, 55; φ 15U, 11D V 330; Ω 0.32 [b]$1\frac{1}{2}$, $1\frac{3}{4}$	No Spin	No Spin
Spoilers $\frac{1}{2}$ with	V 331; Ω 0.33 ∞	[a] α 40, 50; φ 10U, 0 V 349; Ω 0.36 ∞	V 349 ∞		
Spoilers full with	(no data)	[a] α 40, 48; φ 15U, 5D V 349; Ω 0.35 ∞		[a] α 40, 55; φ 12U, 1D V 397; Ω 0.36 ∞	α 44; φ 3U V 365; Ω 0.34 2, 2
Right spoiler full up; left spoiler neutral	[a] α 32, 47; φ 12U, 5D V 373; Ω 0.36 [c]$\frac{3}{4}$, [c]$1\frac{1}{2}$			[a,d] α 40, 60; φ 10U, 5D V 373; Ω 0.30 [e]$\frac{1}{2}$, [e]2	

[a] Oscillatory spin; range of values given.
[b] Visual estimate.
[c] Simultaneous reversal of rudder to $\frac{2}{3}$ of its full deflection against the spin and movement of trimmer ailerons to $\frac{2}{3}$ with the spin.
[d] A "No spin" condition also obtained.
[e] Rudder reversed to only $\frac{2}{3}$ of its full deflection against the spin.

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	

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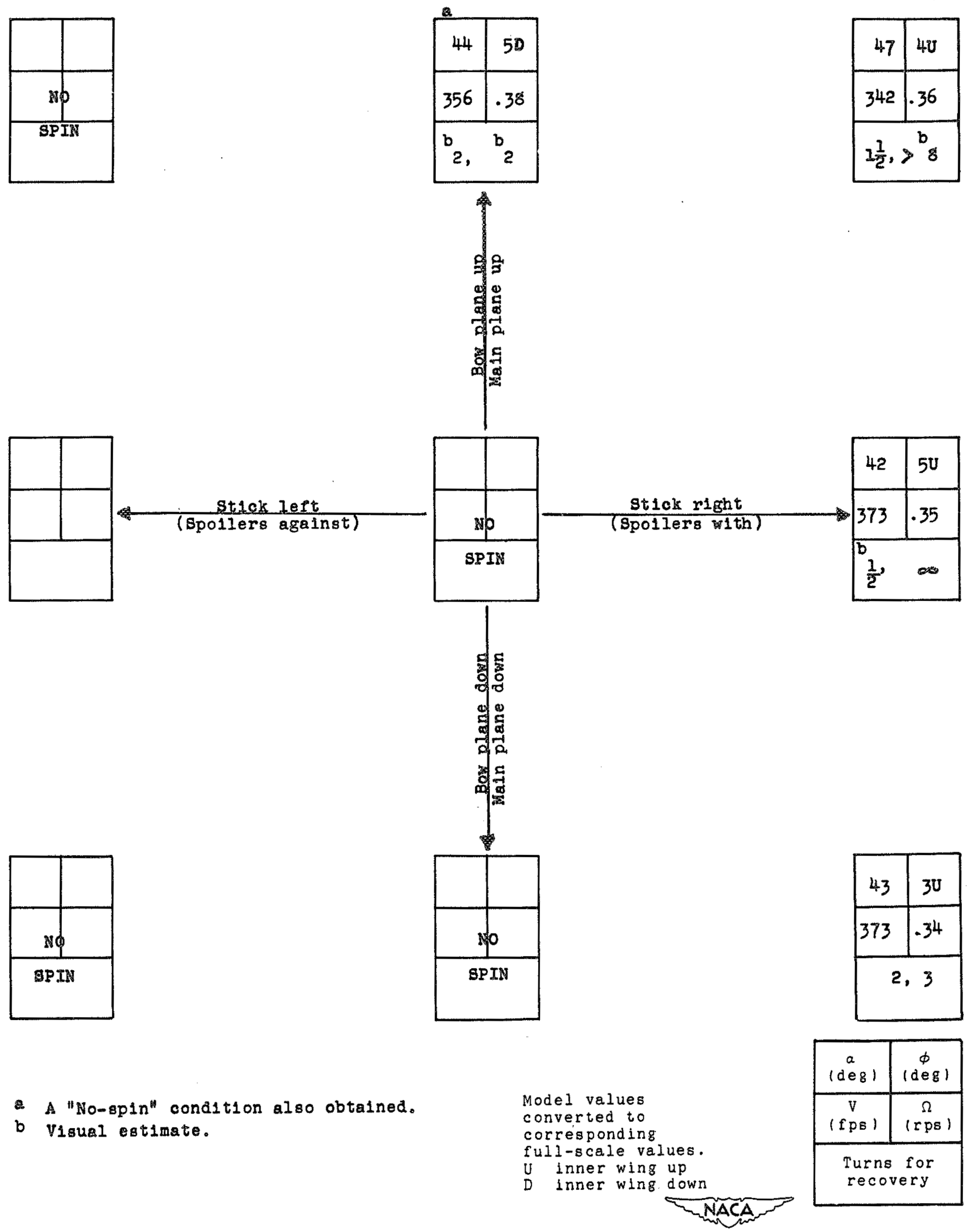
CHART 4.- EFFECT OF EXTENDING ONLY THE SLAT ON THE OUTBOARD WING (LEFT WING IN A RIGHT SPIN) ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE SWEPT-WING MODEL WITH TRIMMER AILERONS NEUTRALIZED

[Recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]



a A "No-spin" condition also obtained.
b Visual estimate.

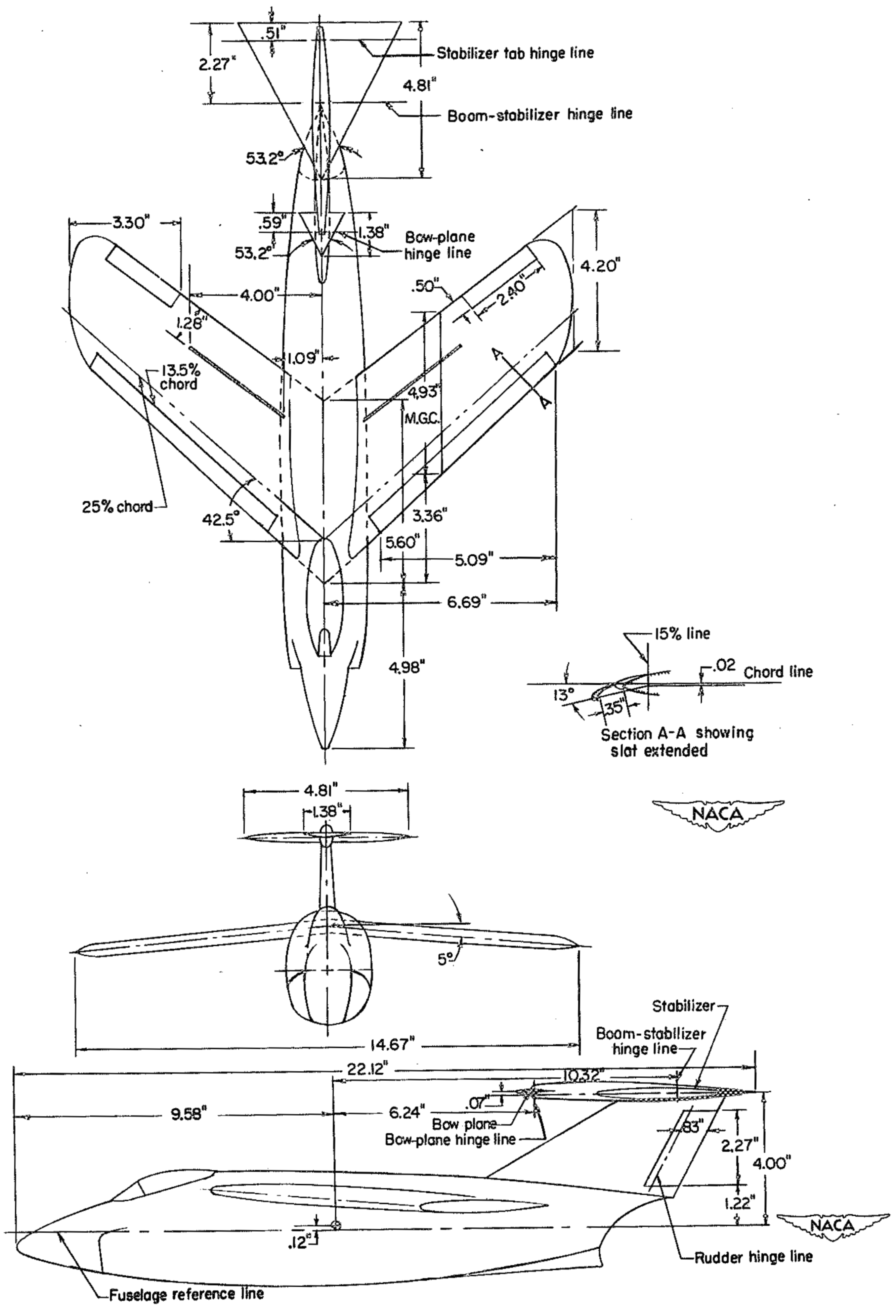


Figure 1.- Three-view drawing of the $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane as tested in the swept-wing configuration. Center of gravity is for no wing fuel, no ammunition loading.

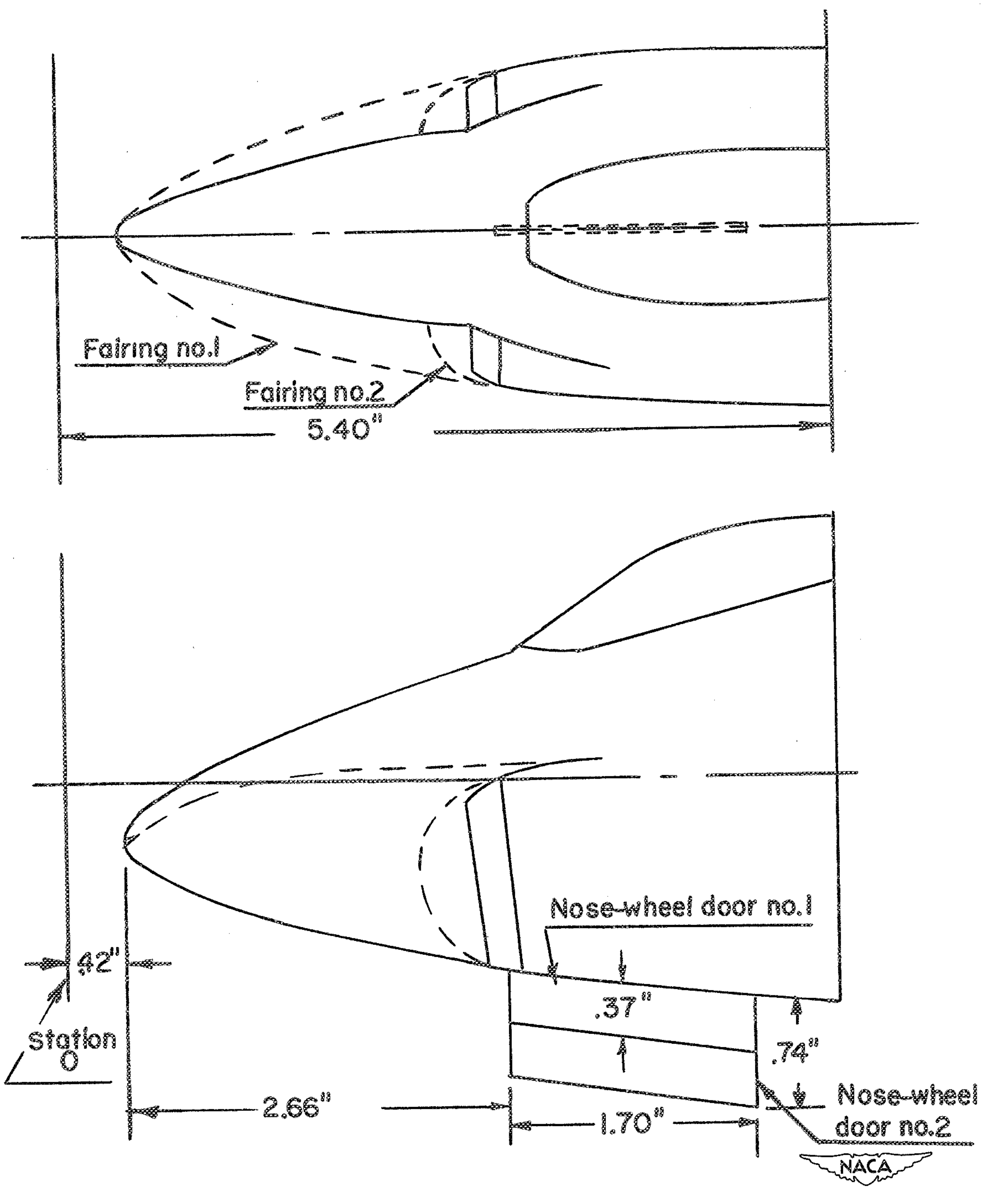


Figure 2.- Fuselage nose fairings and nose-wheel doors tested on the $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane. Dimensions are model scale.