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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FREE-SPINNING-TUNNEL INVESTIGATION OF A $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE

TED NO. NACA DE 340

By Theodore Berman

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FREE-SPINNING-TUNNEL INVESTIGATION OF A $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane to determine its spin and recovery characteristics. The investigation included erect and inverted spins for both the straight-wing and swept-wing configurations. Tests to determine the optimum size spin-recovery parachutes and the rudder forces required for recovery were also made.

The results indicated that in the straight-wing configuration, satisfactory recoveries of the airplane will be obtained from erect and inverted spins by rudder reversal alone. In the swept-wing configuration recoveries will be unsatisfactory from erect spins. Unsweeping the wings during the spin and reversal of the rudder, however, will lead to eventual recovery. The test results also indicated that, if existing small ailerons are made deflectable through large angles, satisfactory recoveries will be obtained from erect spins in the swept-wing configuration by simultaneous movement of the rudder to against the spin and movement of the ailerons to with the spin. Normal-size ailerons deflected through a normal range would also be effective. Satisfactory recoveries by rudder reversal will be obtained from inverted spins in the swept-wing configuration. In the straight-wing configuration a 14.2-foot tail parachute or a 5.0-foot wing-tip parachute opened on the outer wing tip will effect satisfactory recovery of the airplane by parachute action alone; a 30.0-foot tail parachute or a 10.0-foot wing-tip parachute will be

required for the swept-wing configuration. The forces required to fully reverse the rudder should be within the capabilities of the pilot.

INTRODUCTION

In accordance with the request of the Bureau of Aeronautics, Department of the Navy, tests were performed in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane. This airplane is a single-place, variable-sweep, high-wing, jet-propelled fighter. The angle of sweepback of the wing can be varied in flight from the take-off and landing position of $12\frac{1}{2}^\circ$ to the high-speed position of $42\frac{1}{2}^\circ$. The extremes of the variation of sweepback, $12\frac{1}{2}^\circ$ and $42\frac{1}{2}^\circ$, are referred to as the straight wing and swept wing, respectively. The airplane design incorporated spoilers for lateral control.

The erect and inverted spin and recovery characteristics of the model were determined for a range of loadings with the straight and swept wings. Tests to determine the minimum parachute size required for satisfactory emergency recovery and to determine the rudder forces required for recovery were also made. In an attempt to improve recovery characteristics in the swept-wing configuration, the spoilers were replaced by ailerons. Brief tests were also made with the tail lengthened

SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing or elevator chord at any station along span
M.G.C.	mean geometric chord
x/M.G.C.	ratio of distance of center of gravity rearward of leading edge of mean geometric chord to mean geometric chord
z/M.G.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 foot
μ	relative density of airplane $\left(\frac{m}{\rho Sb}\right)$
α	angle between fuselage reference line and vertical (approx. 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 approx. 3°.)
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 was furnished by the Bureau of Aeronautics, Department of the Navy. The horizontal tail was rebuilt at the Langley Laboratory according to a revised design furnished by Grumman. Three-view drawings of the model as tested with straight and swept wings are shown as figures 1 and 2, respectively. Photographs showing the model in the straight-wing configuration, the swept-wing configuration, and with the spoilers deflected are shown in figures 3, 4, and 5, respectively. A drawing showing ailerons installed on the model is presented as figure 6. Dimensional characteristics of the airplane are presented in table I. The tail-damping power factor was computed by the method described in reference 1.

Lateral control of the XF10F-1 in normal flight is achieved through use of spoilers that extend equally above and below the wing. After the tests had started, Grumman representatives informed Langley staff members that lateral-control trimmers were on the airplane for use in the landing condition but that they could be rigged for use as ailerons in all flight conditions.

Longitudinal control of the XF10F-1 is achieved by use of a horizontal tail consisting of two triangular planes mounted on a boom. The forward and smaller plane is called the bow plane and is moved directly by the stick. The bow plane also includes a controllable tab. The rear plane is called the stabilizer and is fixed rigidly to the boom which is free to float. The floating position of the stabilizer is influenced by the position of the bow plane. The tab on the stabilizer is linked to move with equal but opposite angular deflections to the stabilizer. For the model, three bow planes, one each at full up, neutral, and full down, and three stabilizers, one each at full up, neutral, and full down, with the tab deflected with equal and opposite deflections were constructed. These planes were interchangeable so that each bow plane could be tested with each stabilizer. The bow-plane tab was fixed at neutral for the tests because it was felt that due to its small size it would have little effect on spin characteristics.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 25,000 feet (ρ = 0.001065 slug/cu ft) for the straight-wing configuration. It was necessary to increase the simulated altitude to 30,000 feet (ρ = 0.000889 slug/cu ft) for the swept-wing portion of the investigation in order to ballast the model properly. A remote-control mechanism was installed in the model to actuate the controls for the recovery attempts and to open the parachutes for the tail-parachute and wing-tip-parachute tests. Sufficient moments were exerted on the controls to reverse them fully and rapidly for the recovery attempts.

The model parachutes used were of the flat circular type, made of nylon, and had a drag coefficient of approximately 0.65 (based upon the canopy area measured with the parachute spread out flat).

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 2 except that the models are launched by hand with spinning rotation rather than being launched by a spindle. After a number of turns in the established spin, recovery is attempted by moving one or more controls. After recovery the model dives into a safety net. A photograph of the model during a spin is shown in figure 7.

The spin data presented were obtained and converted to corresponding full-scale values by methods described in reference 2. The turns for recovery are measured from the time the controls are moved, or the parachute is opened, to the time the spin rotation ceases and the model dives into the net. For the spins which had a rate of descent in excess of that which can readily be attained in the tunnel, the rate of descent was recorded as greater than the velocity at the time the model hit the safety net, for example, >300. For these tests, the recovery was attempted before the model reached its final steeper attitude and while the model was still descending in the tunnel. Such results are conservative; that is, recoveries will not be as fast as when the model is in the final steeper attitude. For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was 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 does not necessarily indicate an improvement over a >7-turn recovery. For recovery attempts in which the model did not recover, the recovery was recorded as ∞. When the model recovered without control movement, with the controls with the spin, the result was recorded as "no spin."

Spin-tunnel tests are usually made to determine the spin and recovery characteristics of the model at the normal spinning control configuration (stick full back and laterally neutral and rudder full with the spin) and at various other stick positions including zero and maximum deflections. Recovery is generally attempted by rapid full rudder reversal. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For this type of test, the ailerons are generally displaced one-third of full deflection in the direction conducive to slower recovery and the elevator is at two-thirds up or full up. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin. If this technique is ineffective, recovery is also attempted by simultaneous rudder and elevator movement or by simultaneous rudder and aileron movement. This control configuration and movement is referred to as the "criterion spin." Recovery characteristics of the model are considered satisfactory if recovery from this criterion spin requires $2\frac{1}{4}$ turns or less. 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 the XF10F-1 this criterion spin could not conveniently be used because of the unusual control system, and therefore recovery characteristics were judged by examination of the test results for indications of the effects of control deviations from the normal control configuration for spinning.

Testing techniques for parachute tests were similar to those described in reference 3. A parachute was considered satisfactory if it terminated the spin in $2\frac{1}{4}$ turns or less. For the tail-parachute tests, the towline length selected was based on the data of reference 3 and attachment points above and below the jet exhaust were investigated. The parachute was packed on the right side of the fuselage for right spins. Wing-tip parachutes were attached to the outer wing tip with the towline length generally adjusted so that the parachute could not reach the horizontal tail. In every case the folded parachute was placed on the fuselage or wing in such a position that it did not seriously influence the established spin before the parachute was opened. For full-scale parachute installations, it is felt that positive means of ejection should be provided. For the model tests, the rudder was held with the spin during recovery so that the recovery was due entirely to the effect of opening the parachute.

In order to estimate the rudder-pedal forces necessary to effect satisfactory recovery on the full-scale airplane, the tension in the rubber band that pulls the rudder of the model against the spin was adjusted to represent known hinge-moment values about the rudder hinge line. A series of recovery tests was then made, the tension in the rubber band being systematically lowered, until the turns for recovery began to increase. The value of the model hinge moment at this point was then converted to the corresponding full-scale rudder-pedal force at the equivalent altitude at which the tests were made.

PRECISION

The model test results presented are believed to be true values given by the model within the following limits:

α, degrees	± 1
ϕ, degrees	± 1
V, percent	± 5
Ω, percent	± 2

Turns for recovery:

From motion-picture records	$\pm 1/4$
From visual observation	$\pm 1/2$

The preceding limits may have been exceeded for some of the spins in which it was 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.

Comparison between model and full-scale results (reference 4) indicates that model tests satisfactorily predicted full-scale recovery characteristics approximately 90 percent of the time and, 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 and the relative effects of the controls on recovery. The airplanes generally spun at an angle of attack closer to 45° than did the model and at a higher altitude loss per turn than indicated by the model results. The rate of descent was found to be associated with the angle of attack; when the model spun at a smaller angle of attack than the airplane, model results indicated a greater rate of descent than the airplane rate of descent.

Because it is impracticable to ballast the model exactly and because of the inadvertent damage to the model during tests, the measured weight and mass distribution of the XF10F-1 model varied from the true scaled-down values within the following limits:

Weight, percent	0 to 1 low
Center-of-gravity location, percent $\bar{c}$	0 to 1 forward

Moments of inertia:

I_X, percent	9 low to 6 high
I_Y, percent	3 low to 7 high
I_Z, percent	5 low to 6 high

The accuracy of measuring weights and mass distribution 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 were set with an accuracy of $\pm 1^{\circ}$.

TEST CONDITIONS

The mass characteristics and inertia parameters for loadings possible on the airplane and for the loadings tested with the model are shown in table II.

The maximum control deflections used in the tests were:

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

The spoilers were tested in the fully deflected condition and for a few tests the spoilers were at one-half of full deflection.

Normal-size ailerons of an arbitrary design were installed on the model and the lateral-control trimmers were also installed and used as small ailerons. The maximum deflections used in the aileron tests were:

Normal ailerons, degrees	15 up, 15 down
Small ailerons, degrees	40 up, 40 down

All control deflections were measured in a plane perpendicular to the hinge line.

RESULTS AND DISCUSSION

Straight Wing

The results of tests with the straight wing installed are presented in charts 1 to 3 and table III. The model results were somewhat different to the right and to the left and this difference varied during the course of the tests. The results indicated satisfactory recovery characteristics, however, in both directions and only the results obtained in the conservative direction are presented. The data are arbitrarily presented in terms of right spins.

Erect spins.- The data presented in chart 1 were obtained from erect spins of the model in the loading with the wing fuel and ammunition removed (loading 1 in table II). The results show that recoveries were satisfactory by rudder reversal alone for all control configurations tested. When the spoilers were set full against the spin (stick left in a right spin), the model either did not spin or spun steeply. When spoilers were undeflected or deflected full with the spin, the model spun at a moderately steep attitude. Variation of the tail planes in pitch caused no appreciable change in the spin and recovery characteristics of the model. In the course of tests, it was noted that if the tail planes were rolled approximately 3° or more with the outboard (left in a right spin) tip down, unsatisfactory recoveries were obtained. The airplane tail should therefore be correctly alined in order to avoid this condition.

The data presented in chart 2 show that adding wing fuel and ammunition (loading 2 in table II) caused little change in recovery characteristics for the various control configurations.

Inverted spins.- The data presented in chart 3 were obtained from inverted spins of the model in loading 2. The order used for presenting the data for inverted spins is different from that used for erect spins. For inverted spins, "controls crossed" for the established spin (right rudder pedal forward and stick to the pilot's left) is presented to the right of the chart and positive incidence of the tail surfaces (with respect to the airplane) is presented at the top. When the controls are crossed in the established spin, the spoilers aid the rolling motion.

The model spun inverted when the rudder was with the rotation only when both tail planes were at a negative incidence and the spoilers were either undeflected or deflected against the direction of rotation (relative to the pilot). Recoveries were rapid by reversal of the rudder alone from the spins that were obtained.

Swept Wing

The results of tests with the swept wing installed are presented in charts 4 to 7 and table III.

Erect spins.- Although the model appeared to be symmetrical, left spins were steep with rapid recoveries, whereas right spins were moderately flat and oscillatory and recoveries were very poor. The test results could be made symmetrical by altering the shape of the fuselage nose slightly. When this was done, only the flat, oscillatory spins with poor recoveries could be obtained in both directions. Accordingly, the results of the right spins (conservative direction) are presented although it is recognized that a steep spin with rapid recovery may also be possible for the airplane. The results presented in chart 4 for erect spins of the model in the loading with the wing fuel and ammunition removed (loading 4 in table II) indicated very poor recovery characteristics by rudder reversal alone. Variation of the spoilers and tail planes resulted in very little change in the spin characteristics and the model would not recover from any control configuration.

Previously published data (reference 5) had indicated that sweeping the wing back should either have little effect or a favorable effect on recoveries depending on whether the tail design is inherently good or bad, respectively, as regards spin recovery. Differences in design and loading for the high-wing XF10F-1 airplane and the model reported in reference 5 probably account for the different effect of sweep obtained on the XF10F-1 model. A thorough explanation of the effects of sweep on spin recovery is as yet unavailable.

On the basis of the results obtained on the swept-wing version of the XF10F-1 model, it appears that intentional spinning of the XF10F-1 airplane should be prohibited when it is flown in the swept-wing configuration. If a spin is entered inadvertently in the swept-wing configuration, unsweeping the wing and reversal of the rudder should lead to eventual recovery. Unsweeping the wing will require 3 to 4 turns of the spin (based on a maximum time of 10 seconds as provided by Grumman representatives). There will also probably be an additional time delay for the air flow about the tail to adjust itself to correspond to straight wing conditions. After straight-wing conditions are established, recovery should be satisfactory. Thus, the entire procedure may require somewhat more than six turns but, inasmuch as the airplane is intended to fly with the swept wing only at high operational altitudes, the loss of altitude involved may be tolerable.

Modifications were made to the tail of the model in an attempt to improve the rudder effectiveness. Lengthening the fuselage of the model so that the empennage was moved back 2 inches (corresponding to a 5-foot extension on the airplane) resulted in the rudder still being ineffective in causing recovery. Moving the rudder down until it was directly behind the jet exhaust on the lengthened fuselage in an attempt to remove the rudder from the wake of the wing did not improve the recovery characteristics. These data are not presented in chart form. On the basis of these test results, it appears that modifying the tail to enable satisfactory recovery from spins with the wing sweepback maintained will require extensive alterations to the airplane.

Because recent spin-tunnel experience has shown that ailerons are extremely effective in aiding spin recovery of swept-wing designs at high negative values of the inertia yawing-moment parameter, the XF10F-1 model was modified by the addition of ailerons (fig. 6) and the results of subsequent tests are shown in charts 5 and 6. These results indicate that movement of the ailerons to with the spin in conjunction with rudder movement to against the spin was very beneficial for spin recovery. This control movement resulted in the model going into either a dive or an aileron roll. Although not shown in the charts, the tests also indicated that neutralization of the ailerons during the aileron roll caused the model to stop rotating. With the normal ailerons, deflections of $\pm 15^{\circ}$

were sufficient to cause satisfactory recoveries but with the smaller ailerons deflections of $\pm 40^{\circ}$ were necessary. These results indicated that the ailerons were more effective than the spoilers in providing a rolling moment which led to recovery.

Inverted spins.- The results of inverted spins of the model in the swept-wing configuration are presented in chart 7. These results indicated that the model recovery characteristics were satisfactory by rudder reversal alone. The results also indicated that neutralization of the rudder was sufficient to effect recoveries. Although not tested, it is felt that neutralization of the rudder would have been equally as effective in causing recoveries from any inverted spins in the straight-wing condition based on the similarity of the inverted spins obtained for the straight- and swept-wing configuration.

Spin-Recovery Parachutes

The results of spin-recovery parachute tests are presented in table III. In the straight-wing configuration, a 14.2-foot tail parachute was indicated to be necessary for satisfactory recovery by parachute action alone but for the swept-wing configuration a 30.0-foot tail parachute was required. Towline length was varied from 0 to 65 feet for the swept-wing configuration and had little effect. Although not shown in table III, towline attachment points both above and below the jet exhaust were tested but no appreciable difference was indicated.

A 5.0-foot wing-tip parachute was indicated to be necessary for satisfactory recovery by parachute action alone in the straight-wing configuration but a parachute 10.0 feet in diameter was required in the swept-wing configuration. In the straight-wing configuration, a towline short enough to clear the tail surfaces, 17.5 feet, was satisfactory. In the swept-wing configuration, a towline 7.3 feet long was necessary. This towline length was such that the parachute might foul on the tail. Film records showed that when the wing-tip parachute was blown clear of the tail by the air stream, it remained clear of the tail and was effective in terminating the spin. These results indicate that for a full-scale installation a method of positive ejection of the parachute would be required to enable the parachute to clear the tail of the airplane and prevent fouling.

The model parachutes tested had values of drag coefficient of approximately 0.65. If a parachute with a different drag coefficient is used on the airplane, a corresponding adjustment will be required in parachute size.

The parachutes used in this investigation were flat-type parachutes which are unstable. If the full-scale parachute installation is to be tested in level flight before spins are attempted, flat-type parachutes may cause violent pitching and yawing gyrations. Use of stable-type parachutes, described in reference 6, will eliminate this possibility.

Because of the large size parachutes required for the XF10F-1 excessively high shock loads may be encountered when the parachutes are opened. A recent spin-tunnel investigation reported in reference 7 indicates that a shock absorber may be used to eliminate the opening shock load without affecting the effectiveness of the parachute in causing recovery.

Variation of Loading

Spin-tunnel experience indicates that the spin and recovery characteristics of the XF10F-1 would not vary appreciably from the results presented herein within the range of loadings indicated as possible on the airplane and accordingly no other loadings were tested.

Pilot Escape

Data in reference 8 indicate that for airplane designs in which the cockpit is forward of the leading edge of the wing, as it is for the XF10F-1, pilot escape from either side of the cockpit is hazardous but that the pilot has a somewhat better chance of avoiding injury if he leaves from the outboard side (left side in a right spin). In order to insure safe escape an ejection seat would be necessary.

Landing Condition

The landing condition was not investigated on this model inasmuch as current Navy specifications require this type of airplane to demonstrate satisfactory recoveries in the landing condition from only one-turn spins. At the end of one turn, the airplane will probably still be in an incipient spin from which recoveries are more readily obtained than from fully developed spins.

An analysis of model tests to determine the effect of landing flaps and landing gear (reference 9) indicates that although the XF10F-1 with the straight or swept wing will probably recover satisfactorily from an incipient spin in the landing condition, recoveries from fully developed spins will probably be unsatisfactory. If a spin is inadvertently entered in the landing condition, the flaps and landing gear should be retracted and recovery attempted immediately.

Control Forces

The discussion of the results so far has been based on control effectiveness alone without regard to the forces required to move the controls. As previously mentioned, sufficient force was applied to the controls to move them fully and rapidly. The airplane controls should be moved in a similar manner in order for the model and airplane results to be comparable. As previously indicated a few tests were made for the straight-wing configuration to determine the maximum pedal forces required to move the rudder for recovery. The results indicated (based on a rudder-pedal travel of 8 in.) that a rudder-pedal force of the order of 280 pounds would be required which should be within the capabilities of a pilot. In the swept-wing configuration, the rudder-pedal forces would probably be less in the flatter spin and somewhat higher if the steeper spin is obtained.

CONCLUSIONS AND RECOMMENDATIONS

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 at a spin test altitude of 25,000 to 30,000 feet:

1. For the straight-wing configuration, recovery characteristics will be satisfactory by rudder reversal alone from erect and inverted spins. The position of the spoilers and horizontal tail surfaces will not appreciably affect recoveries.

2. For the swept-wing configuration recovery characteristics will be unsatisfactory. If a spin is inadvertently entered in the swept-wing configuration, measures to unsweep the wing should be applied immediately and the rudder should be reversed to full against the spin.

3. Satisfactory recoveries will be obtained in the swept-wing configuration by deflecting the existing small ailerons through large angles, or normal-size ailerons through a normal range if the recovery technique of simultaneous movement of the rudder to against the spin and movement of the ailerons to with the spin is used.

4. Recoveries from inverted spins in the swept-wing configuration will be satisfactory by rudder reversal alone.

5. In the straight-wing configuration a 14.2-foot tail parachute or a 5.0-foot wing-tip parachute opened on the outer wing tip will effect satisfactory recovery of the airplane by parachute action alone; a 30.0-foot tail parachute or a 10.0-foot wing-tip parachute will be required for the swept-wing configuration.

6. The forces required to fully reverse the rudder should be within the capabilities of the pilot.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF $\frac{1}{30}$-SCALE MODEL

OF GRUMMAN XF10F-1 AIRPLANE

Length over-all, ft	55.3
Normal center-of-gravity location (straight), percent M.G.C.	30.1
Normal center-of-gravity location (swept wing), percent M.G.C.	23.6
Straight wing:	
Span, ft	50.0
Area, sq ft	450.0
Sweepback at c/4, deg	12.5
Incidence, deg	0
Dihedral, deg	-6.5
Section	NACA 64_1A009
Aspect ratio	5.5
Mean geometric chord, ft	9.6
Leading edge of M.G.C. rearward of leading edge of root chord, ft	3.1
Swept wing:	
Span, ft	36.7
Area, sq ft	450.0
Sweepback of c/4, 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 M.G.C. rearward of leading edge of root chord, ft	8.4
Spoilers:	
Height, in	7.0
Span, percent b/2 (swept wing)	40.0
Span, percent b/2 (straight wing)	36.6
Chordwise location forward of trailing edge of swept wing (constant), ft	4.0
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 including tab, sq ft	5.9
Apex angle of bow plane, deg	53.2
Distance from normal center of gravity to bow plane hinge line, ft	15.6
Total 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 (straight wing)	0.002993
Tail-damping-power factor (swept wing)	0.007596
Side area moment factor	0.49

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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS TESTED WITH $\frac{1}{30}$- SCALE MODEL OF GRUMMAN XF10F-1 AIRPLANE

[Model values converted to corresponding full-scale values; moments of inertia are given about center of gravity]

No.	Loading	Weight (lb)	Center-of-gravity location		Relative density, μ			Moments of inertia (slug-feet^2)			Mass parameters		
			x/M.G.C.	z/M.G.C.	Sea level	25,000 feet	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	Straight wing, no wing fuel, no ammunition	26,185	0.301	-0.029	15.1	33.7	40.4	26,078	70,504	84,453	-218×10^{-4}	-69×10^{-4}	287×10^{-4}
2	Straight wing, wing fuel and ammunition	30,000	0.301	-0.052	17.3	38.7	46.3	35,683	72,618	95,284	-158	-97	256
3	Swept wing, wing fuel and ammunition	30,000	0.236	-0.047	23.6	53.1	63.6	23,581	76,310	86,568	-421	-82	503
4	Swept wing, no wing fuel, no ammunition	26,185	0.234	-0.025	20.7	46.3	55.5	17,810	73,528	79,022	-509	-50	559
	Model values												
1	Straight wing, no wing fuel, no ammunition	26,693	0.301	-0.028	15.5	34.6	41.4	26,467	71,686	84,490	-218×10^{-4}	-62×10^{-4}	280×10^{-4}
2	Straight wing, wing fuel and ammunition	29,760	0.302	-0.057	17.3	38.5	46.2	37,693	77,609	100,744	-173	-100	273
4	Swept wing, no wing fuel, no ammunition	26,680	0.229	-0.025	21.1	47.1	56.4	16,313	72,901	76,083	-508	-29	537

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TABLE III.- SPIN-RECOVERY-PARACHUTE DATA OBTAINED WITH $\frac{1}{30}$-SCALE MODEL

OF GRUMMAN XF10F-1 AIRPLANE

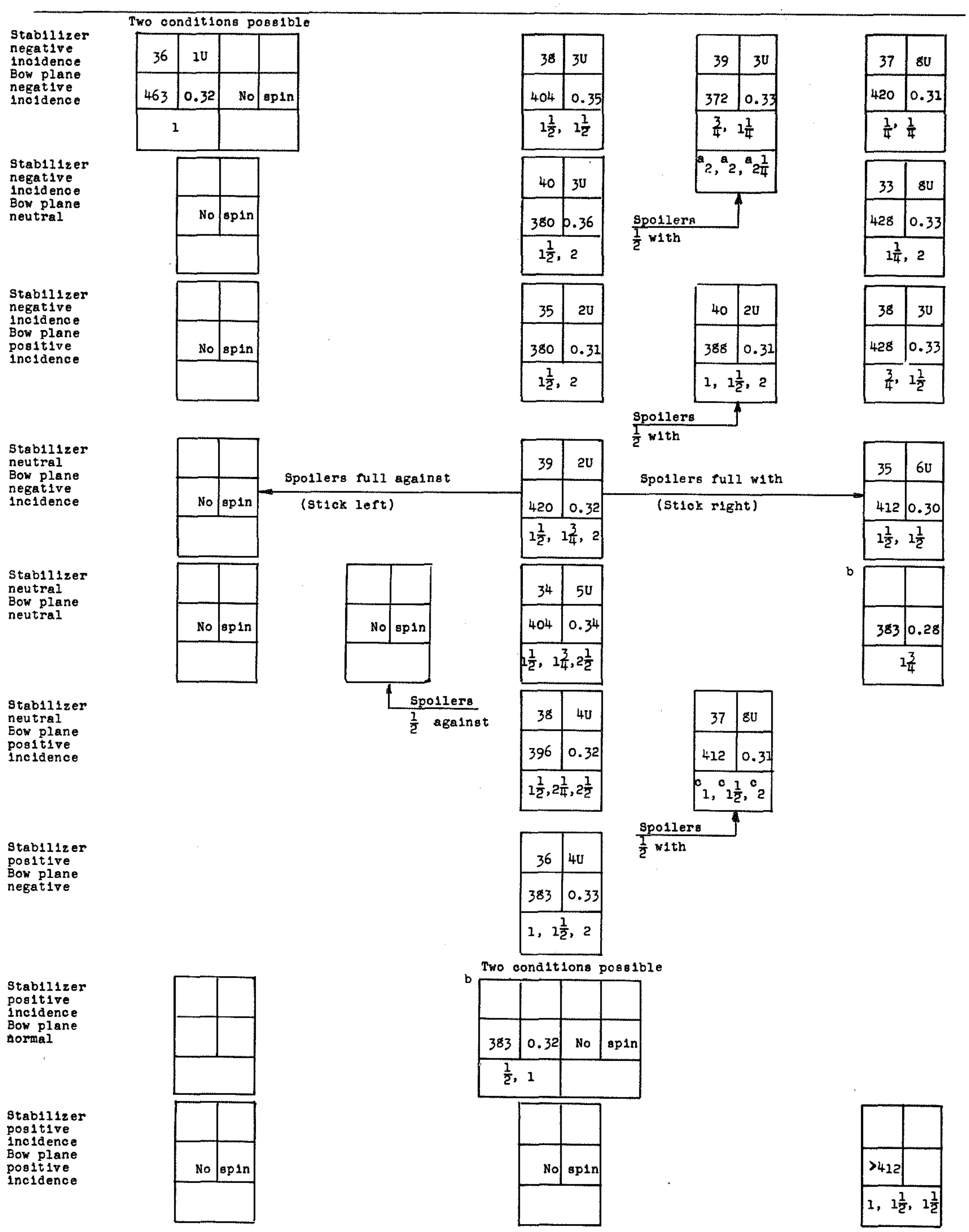
[Rudder full with the spin; model values converted to corresponding full-scale values; C_D of parachutes 0.65; right erect spins]

Loading	Parachute diameter (ft)	Towline length (ft)	Spoilers	Bow plane	Stabilizer	Turns for recovery
Straight wing - towline attached below jet exhaust						
Tail parachutes						
No wing fuel, no ammunition	10.5	30.0	1/2 with	Negative incidence	Negative incidence	4, 6
	10.5	50.0	↓	↓	↓	3, $5\frac{1}{2}$
	12.5	30.0	↓	↓	↓	4, $4\frac{1}{2}$
	14.2	30.0	↓	↓	↓	$\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$, 2
	15.0	30.0	↓	↓	↓	$\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$
Wing-tip parachutes						
No wing fuel, no ammunition	5.0	17.5	1/2 with	Negative incidence	Negative incidence	$\frac{3}{4}$, 1, 1, $1\frac{1}{4}$
	7.5	12.8	↓	↓	↓	$\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$
Swept wing - towline attached above jet exhaust						
Tail parachutes						
No wing fuel, no ammunition	15.0	30.0	Neutral	Negative incidence	Negative incidence	5, >7
	17.5	30.0	↓	↓	↓	$\frac{1}{4}$, $\frac{1}{2}$, 8, ∞
	20.0	30.0	↓	↓	↓	$\frac{1}{2}$, 1, 1, 2, 6
	30.0	0	↓	↓	↓	$\frac{3}{4}$, $\frac{3}{4}$, $\frac{3}{4}$, 1
	30.0	30.0	↓	↓	↓	$\frac{1}{2}$, 1, $1\frac{3}{4}$
	30.0	65.0	↓	↓	↓	$\frac{1}{2}$, $\frac{1}{2}$, $1\frac{1}{4}$, $1\frac{1}{2}$
Wing-tip parachutes						
No wing fuel, no ammunition	7.5	6.5	Neutral	Negative incidence	Negative incidence	2, ∞, ∞
	10.0	3.8	↓	↓	↓	$\frac{1}{2}$, $1\frac{3}{4}$, 3
	10.0	7.3	↓	↓	↓	$\frac{1}{2}$, $\frac{3}{4}$, [a]>3
	10.5	.25	↓	↓	↓	2, >3

[a]Parachute fouled on tail.

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE STRAIGHT-WING CONFIGURATION AND IN THE NO-WING-FUEL, NO-AMMUNITION LOADING

[Loading 1 in table II; flaps neutral; cockpit closed; 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]



[a]Recovery attempted by reversing rudder from full with to $\frac{2}{3}$ against the spin.

[b]Wandering spins. Complete steady spin data could not be obtained.

[c]Visual estimate.

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE STRAIGHT-WING CONFIGURATION AND IN THE FULLY-LOADED CONDITION

[Loading 2 in table II; flaps neutral; cockpit closed; 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]

	Spoilers against (Stick left)		Spoilers with (Stick right)
Stabilizer negative incidence Bow plane negative incidence	[a] >412 $\frac{1}{2}$, 1, 2	34, 6U 416, 0.32 $1\frac{1}{2}$, $2\frac{1}{4}$ [b]$1\frac{1}{2}$, [b]2	33, 6U 411, 0.33 $1\frac{1}{4}$, $1\frac{1}{2}$
Stabilizer negative incidence Bow plane neutral	No spin	37, 4U 420, 0.34 1, 1	28, 9U 444, 0.31 [c]1, [c]2
Stabilizer negative incidence Bow plane positive incidence	No spin	Two conditions possible No spin 33, 6U 428, 0.34 $1\frac{1}{4}$, $1\frac{1}{2}$	30, 8U 451, 0.32 $2\frac{1}{4}$, $2\frac{1}{2}$
Stabilizer neutral Bow plane negative incidence	No spin	Two conditions possible No spin 29, 4U 416, 0.33 $\frac{1}{2}$, $\frac{3}{4}$, 2	27, 8U 436, 0.32 $1\frac{3}{4}$, $2\frac{1}{4}$
Stabilizer neutral Bow plane neutral	No spin	35, 5U 451, 0.34 $1\frac{1}{4}$, 2	31, 9U 440, 0.31 $1\frac{1}{4}$, 2
Stabilizer neutral Bow plane positive incidence	Two conditions possible 33, 2U 459, 0.32 1, $1\frac{1}{2}$ No spin	31, 5U 436, 0.33 $1\frac{1}{4}$, [c]$1\frac{3}{4}$	29, 8U 444, 0.32 1, $1\frac{3}{4}$, $2\frac{1}{2}$
Stabilizer positive incidence Bow plane neutral	35, 3U 459, 0.35 $1\frac{1}{2}$, $1\frac{1}{2}$	35, 3U 475, 0.34 $1\frac{1}{4}$, 2	
Stabilizer positive incidence Bow plane positive incidence	31, 1U 436, 0.32 $\frac{1}{2}$, $1\frac{1}{2}$	Two conditions possible No spin 32, 4U 451, 0.33 $1\frac{1}{2}$, 2	29, 6U 436, 0.31 $1\frac{1}{2}$, 2

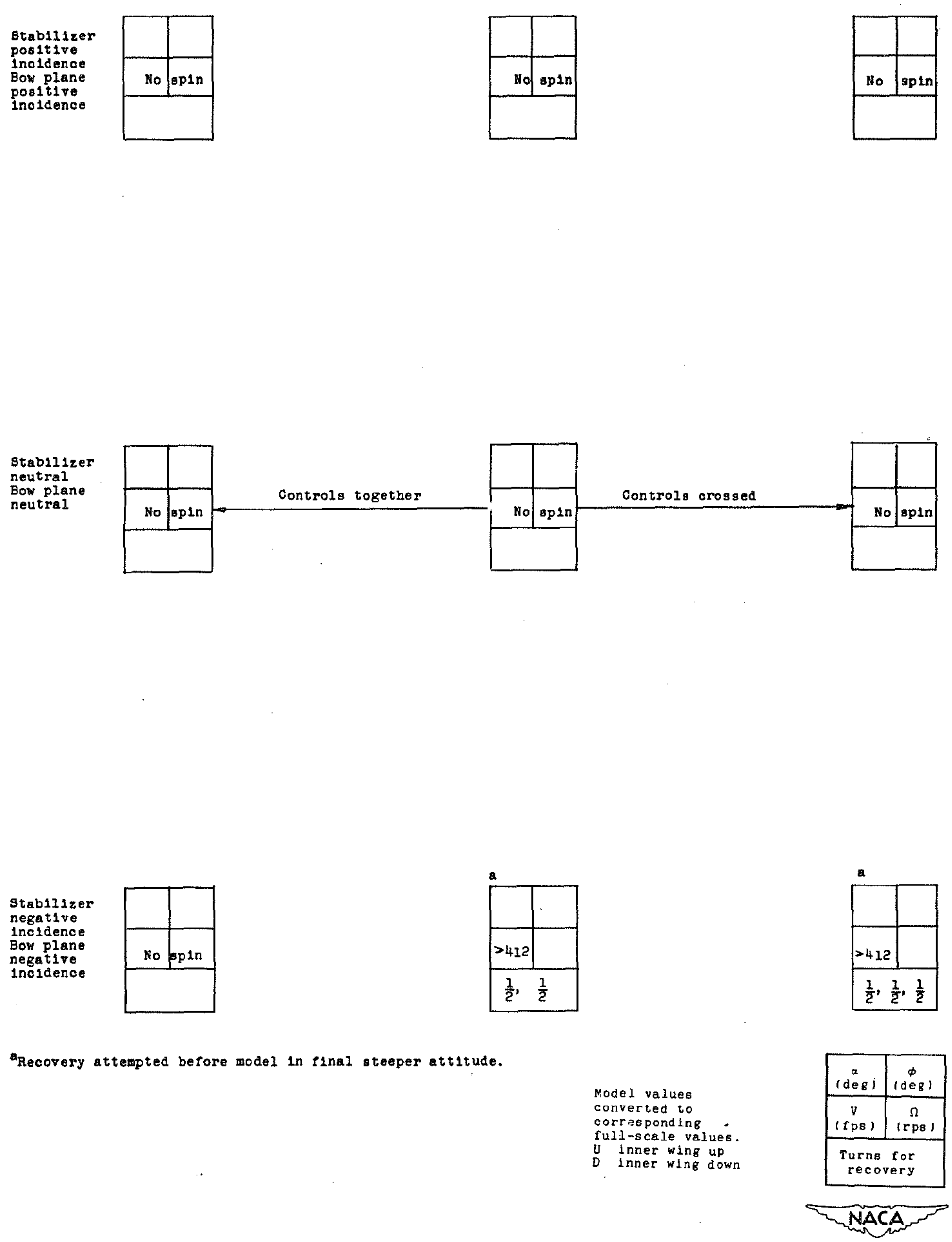
[a]Recovery attempted before model in final steeper attitude
[b]Recovery attempted by reversing rudder from full with to $\frac{2}{3}$ against the spin.
[c]Visual estimate.

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	

CHART 3.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE STRAIGHT-WING CONFIGURATION AND IN THE NO-WING-FUEL, NO-AMMUNITION LOADING

[Loading 1 in table II; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); spins to pilot's left]



[a]Recovery attempted before model in final steeper attitude.

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE SWEPT-WING CONFIGURATION AND IN THE NO-WING-FUEL, NO-AMMUNITION LOADING

[Loading 4 in table II; flaps neutral; cockpit closed; 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]

Stabilizer negative incidence
Bow plane negative incidence

[a] 81 37	42U 25D	[a] 75 38	35U 35D	[a] 72 35	37U 20D
App 347	0.26	352	0.30	352	0.37
∞, ∞		∞, ∞		>3, ∞	

Stabilizer negative incidence
Bow plane neutral

[a] 70 45	22U 20D	[a] 75 30	40U 20D	[a] 72 45	32U 25D
347	0.28	347	0.30	352	0.29
∞, ∞		∞, ∞		∞, ∞	

Stabilizer negative incidence
Bow plane positive incidence

[a] 75 45	30U 18D	[a] 75 40	35U 25D	[a] 75 35	28U 20D
356	0.37	356	0.30	356	0.30
∞, ∞		>3, ∞		∞, ∞	

Stabilizer neutral
Bow plane neutral

Spoilers against (Stick left)				Spoilers with (Stick right)	
[a] 75 50	35U 23D	[a] 70 30	35U 15D	[a] 75 43	35U 25D
372	0.30	372	0.30	365	0.26
∞, ∞		>6, ∞		>3, ∞	

Stabilizer positive incidence
Bow plane neutral incidence

[a] 75 28	38U 18D	[a] 75 32	30U 28D	[a] 73 35	35U 20D
372	0.28	372	0.26	356	0.26
∞, ∞		>6, ∞		>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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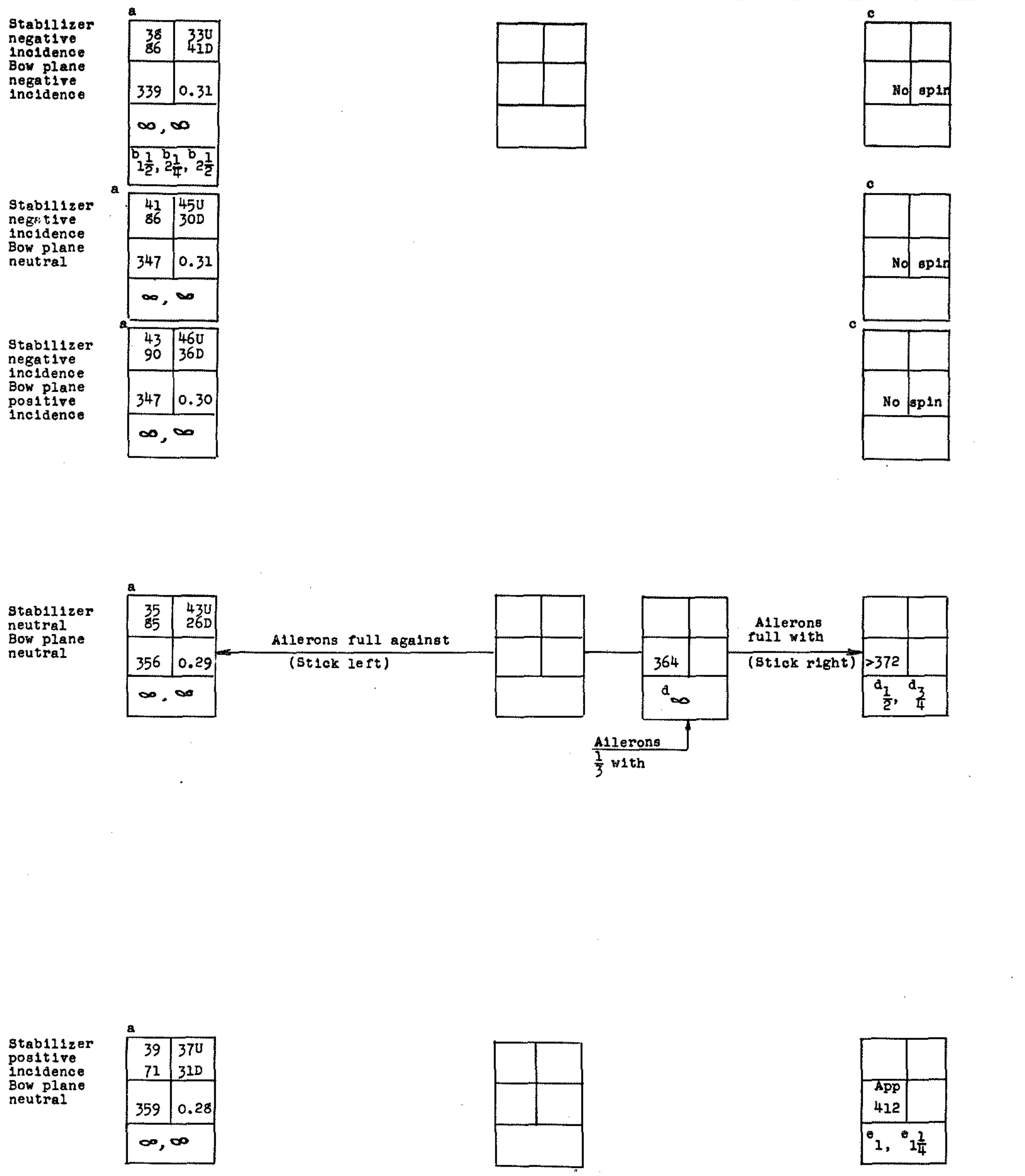
CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE SWEPT-WING CONFIGURATION AND IN THE NO-WING-FUEL, NO-AMMUNITION LOADING WITH THE NORMAL AILERONS INSTALLED

[Loading 4 in table II; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal unless otherwise indicated (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]



[a]Spin oscillatory in roll and yaw. Range of values or average value given.
[b]Recovery attempted by simultaneous movement of the rudder to full against the spin and the ailerons to full with the spin.
[c]Model went into an aileron roll.
[d]Visual observation.
[e]After rudder reversal the model went into an aileron roll.

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	

CHART 6.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE SWEPT-WING CONFIGURATION AND IN THE NO-WING-FUEL, NO-AMMUNITION LOADING WITH THE SMALLER AILERONS INSTALLED

[Loading 4 in table II; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]

Stabilizer negative incidence Bow plane negative incidence

	Ailerons neutral [a]	Ailerons 15° with [a]	Ailerons 20° with [a]	Ailerons 25° with [a]	Ailerons 30° with [a]	Ailerons 40° with [b]
α (deg)	32 75	25 72	30 73	27 71	28 64	
φ (deg)	38U 27D	29U 18D	25U 19D	27U 14D	26U 10D	
V (fps)	353	355	363	363	363	No
Ω (rps)	0.29	0.29	0.30	0.30	0.29	spin
Turns for recovery	∞	∞	∞, ∞	3, $3\frac{1}{2}$, $6\frac{1}{4}$	$2\frac{3}{4}$, $3\frac{1}{4}$	

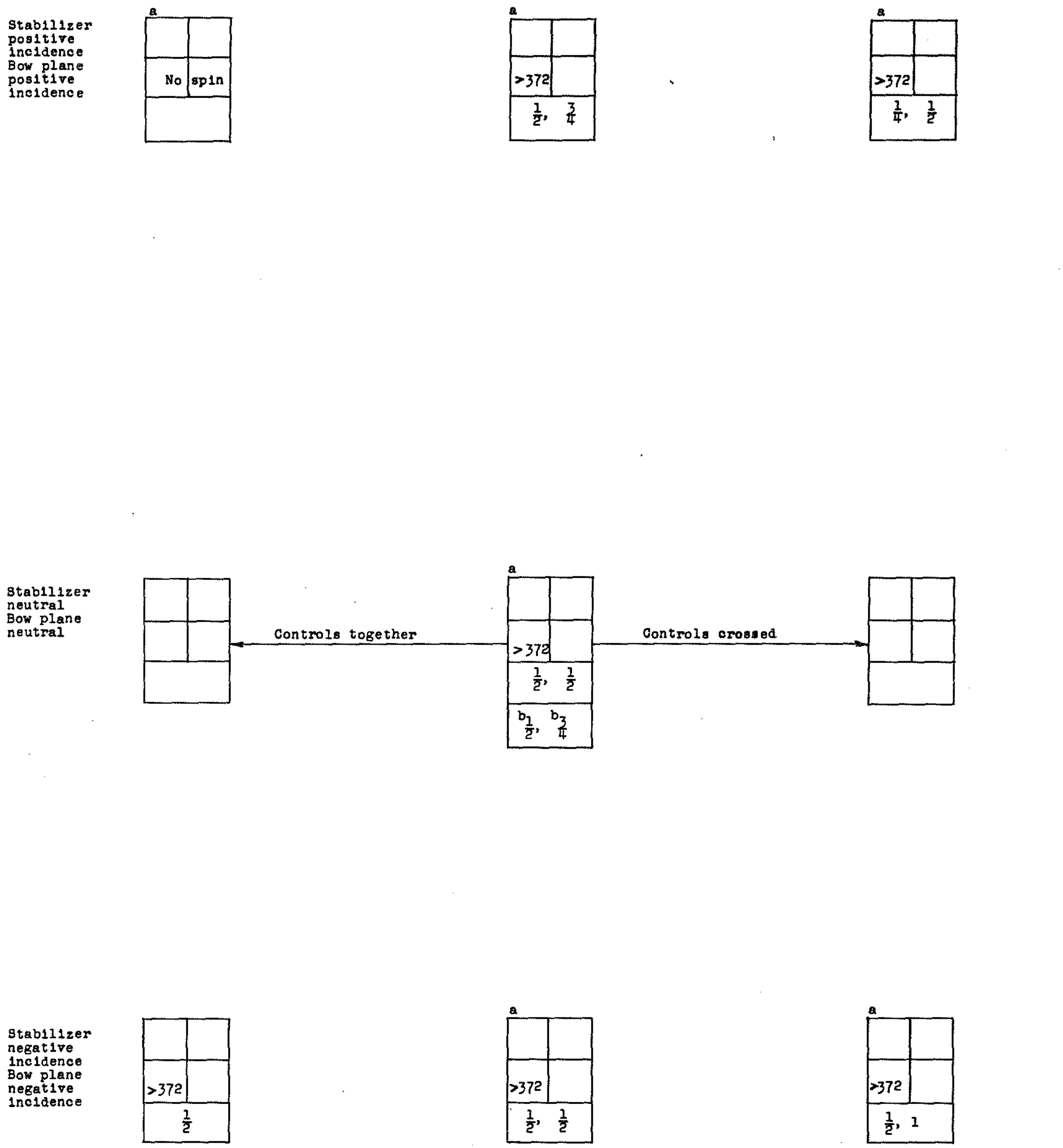
[a]Spin oscillatory in roll and yaw. Range of values or average value given.
[b]Model went into an aileron roll.

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

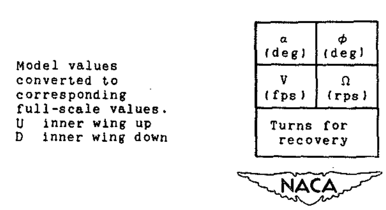
α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 7.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XF10F-1 AIRPLANE IN THE SWEPT-WING CONFIGURATION AND IN THE NO-WING-FUEL, NO-AMMUNITION LOADING

[Loading 4 in table II; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from, and steady-spin data presented for, rudder-with spins); spins to pilot's left]



[a]Recovery attempted before model in final steeper attitude.
[b]Recovery attempted by neutralizing rudder.



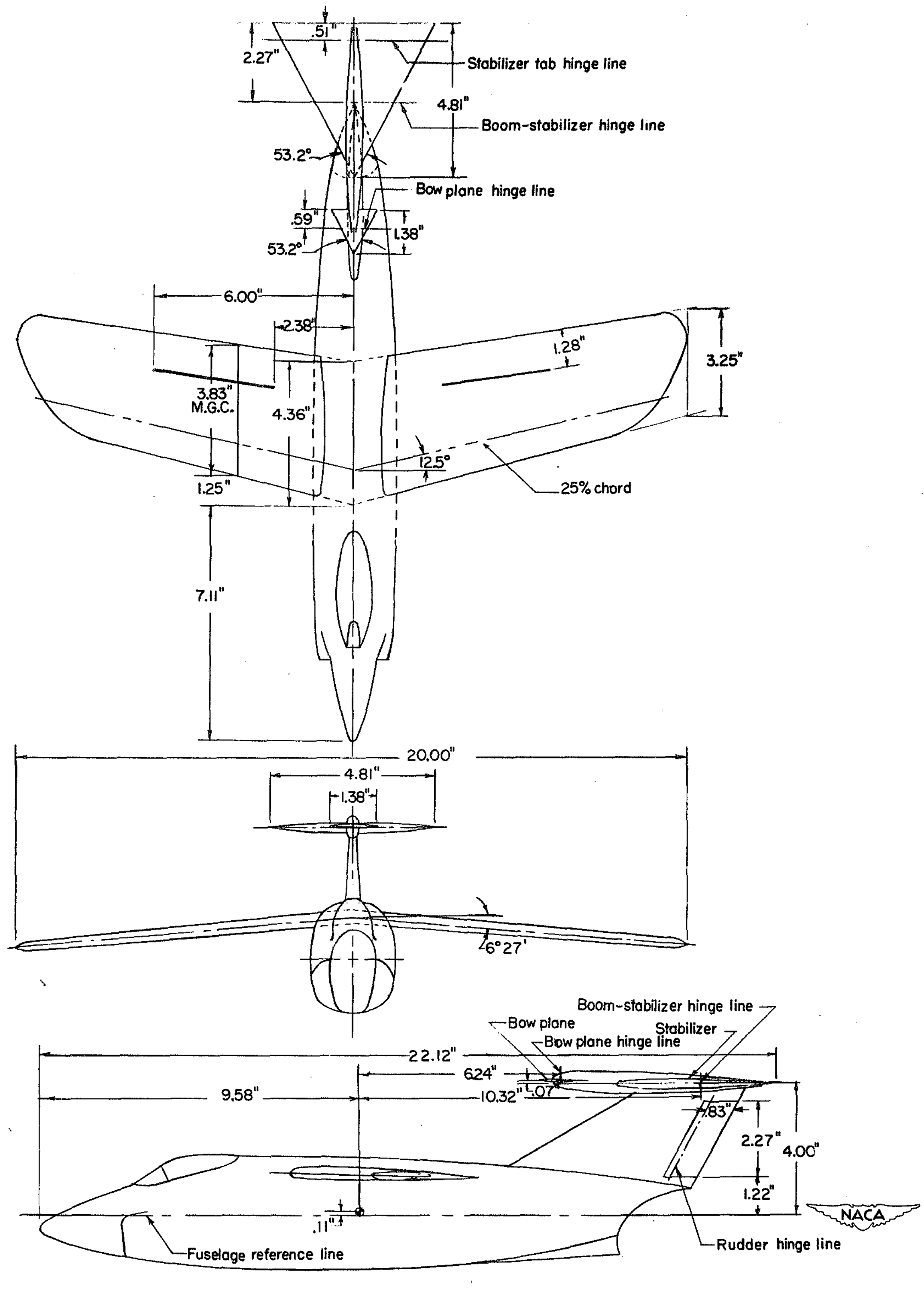


Figure 1.- Three-view drawing of the $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane as tested in the straight-wing configuration. Center of gravity is for no wing fuel, no ammunition loading.

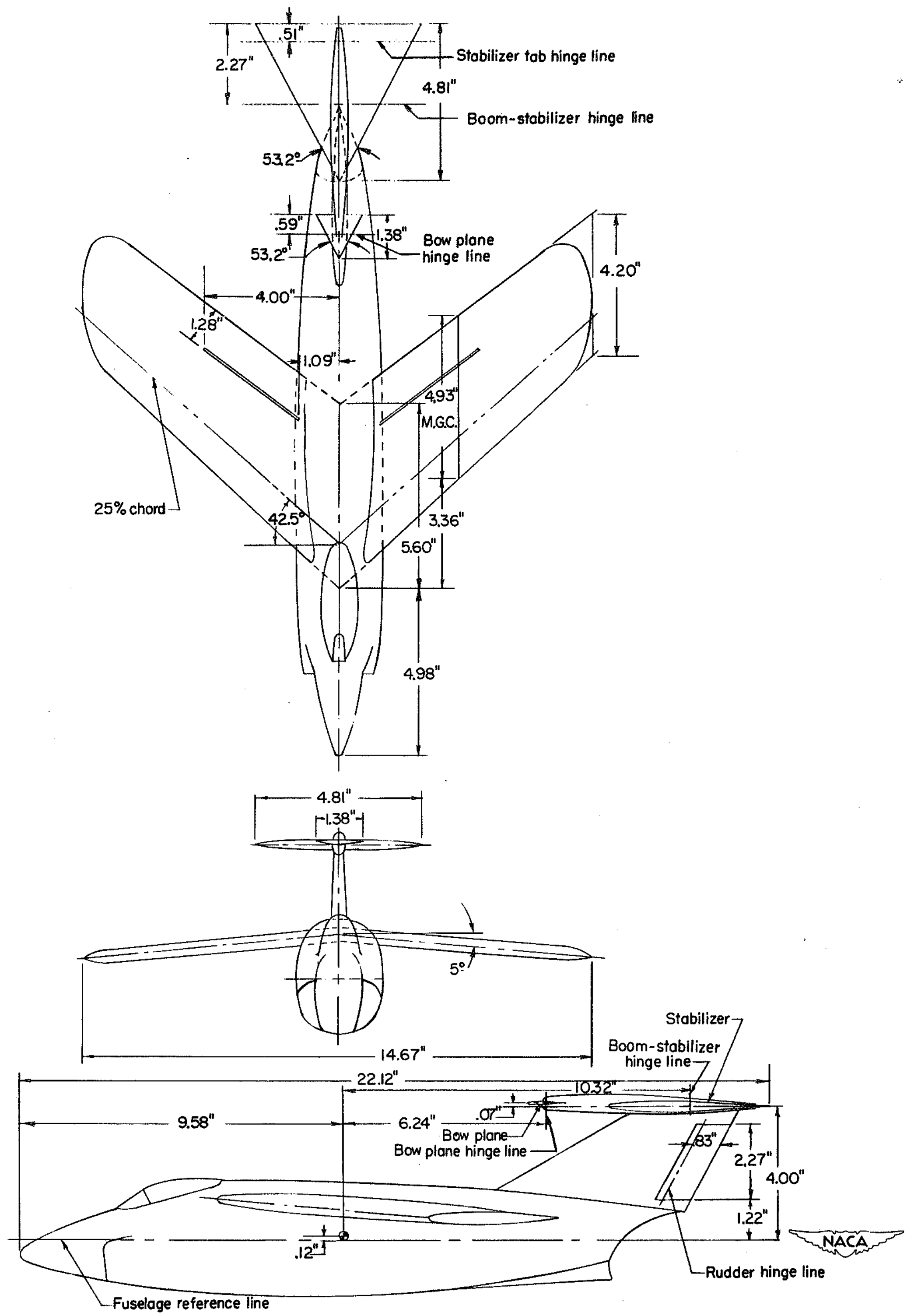


Figure 2.- Three-view drawing of the $\frac{1}{30}$- scale model of the Grumman XF10F-1 airplane as tested in the swept-wing configuration. Center of gravity is for no wing fuel, no ammunition loading.

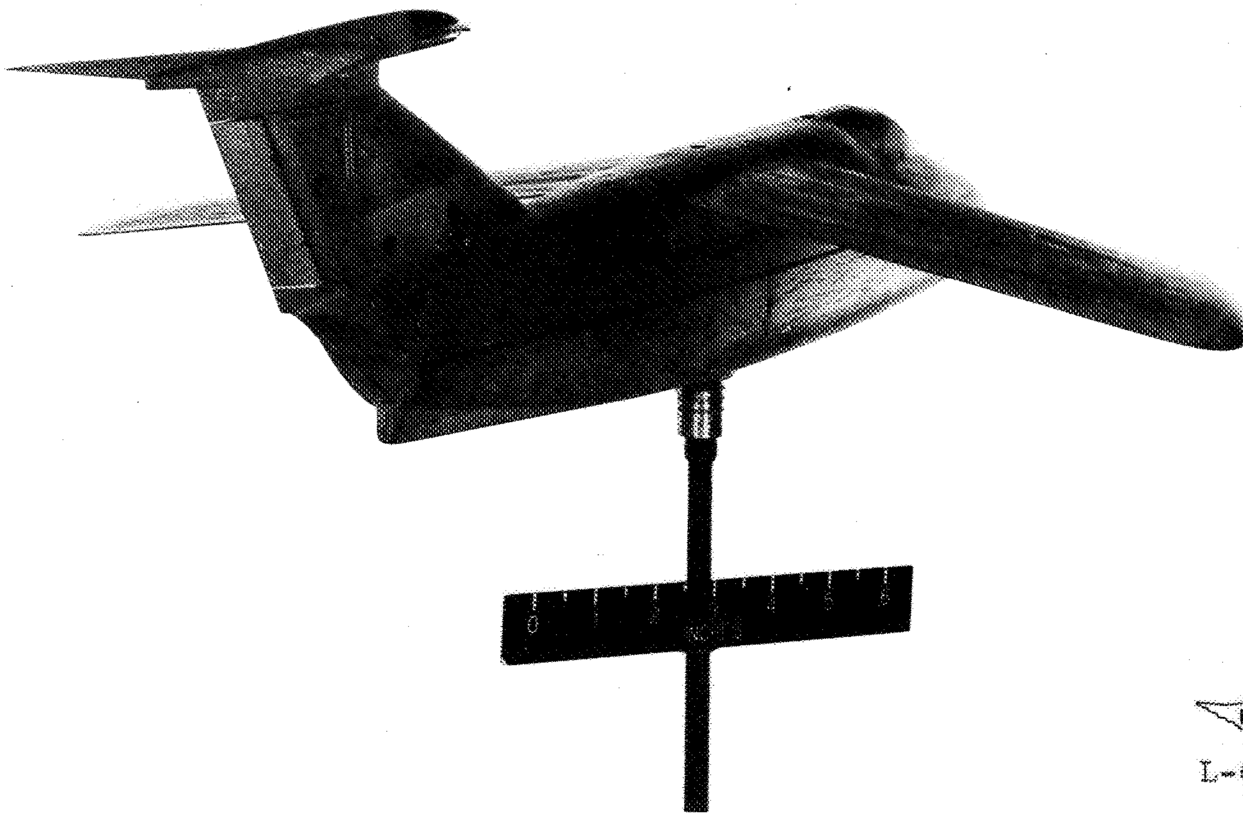


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Figure 3.- Photograph of the $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane in the straight-wing configuration.

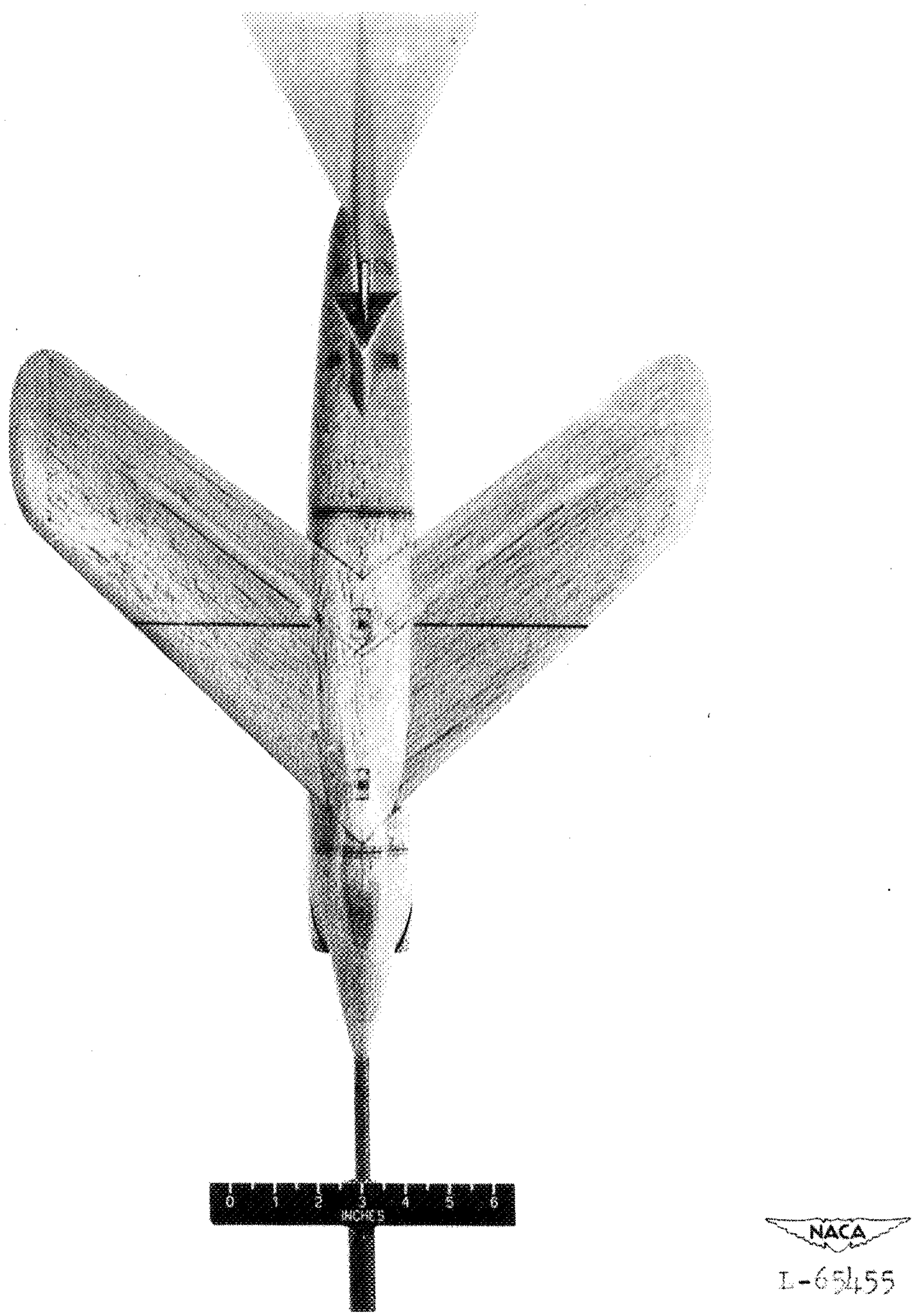

Figure 4.- Photograph of the $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane in the swept-wing configuration (top view).

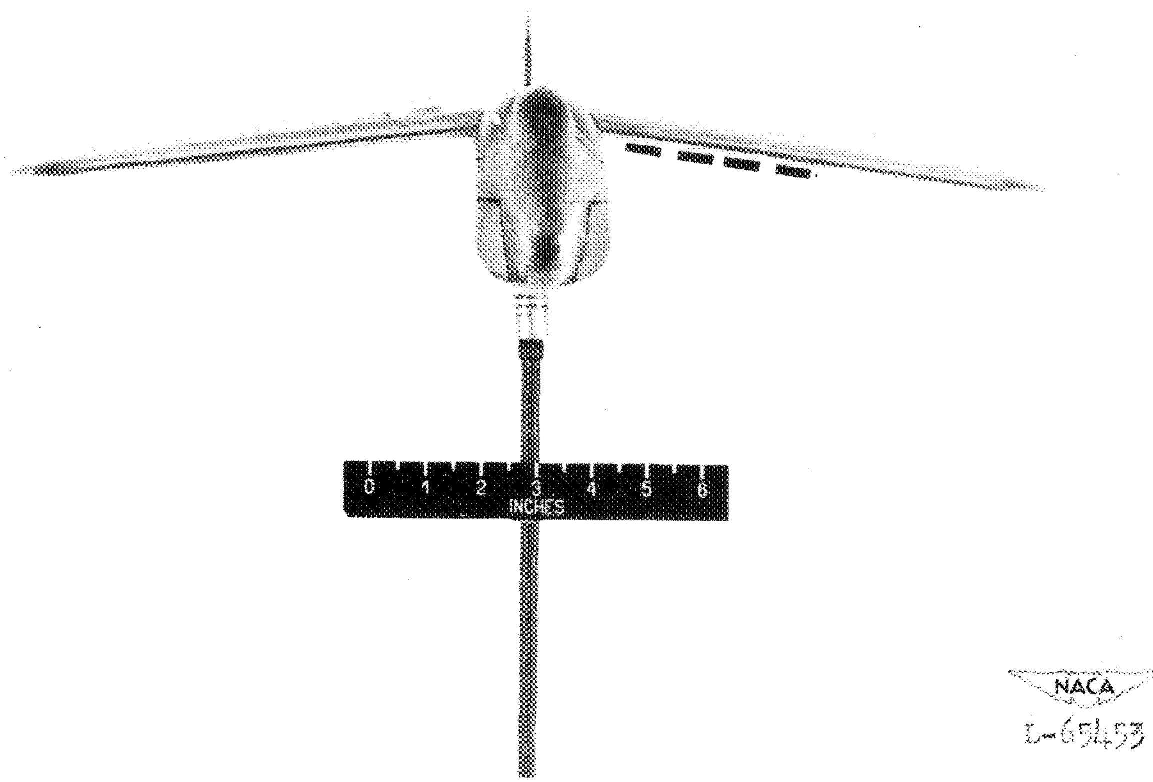

Figure 5.- Photograph of the $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane with the spoilers deflected.

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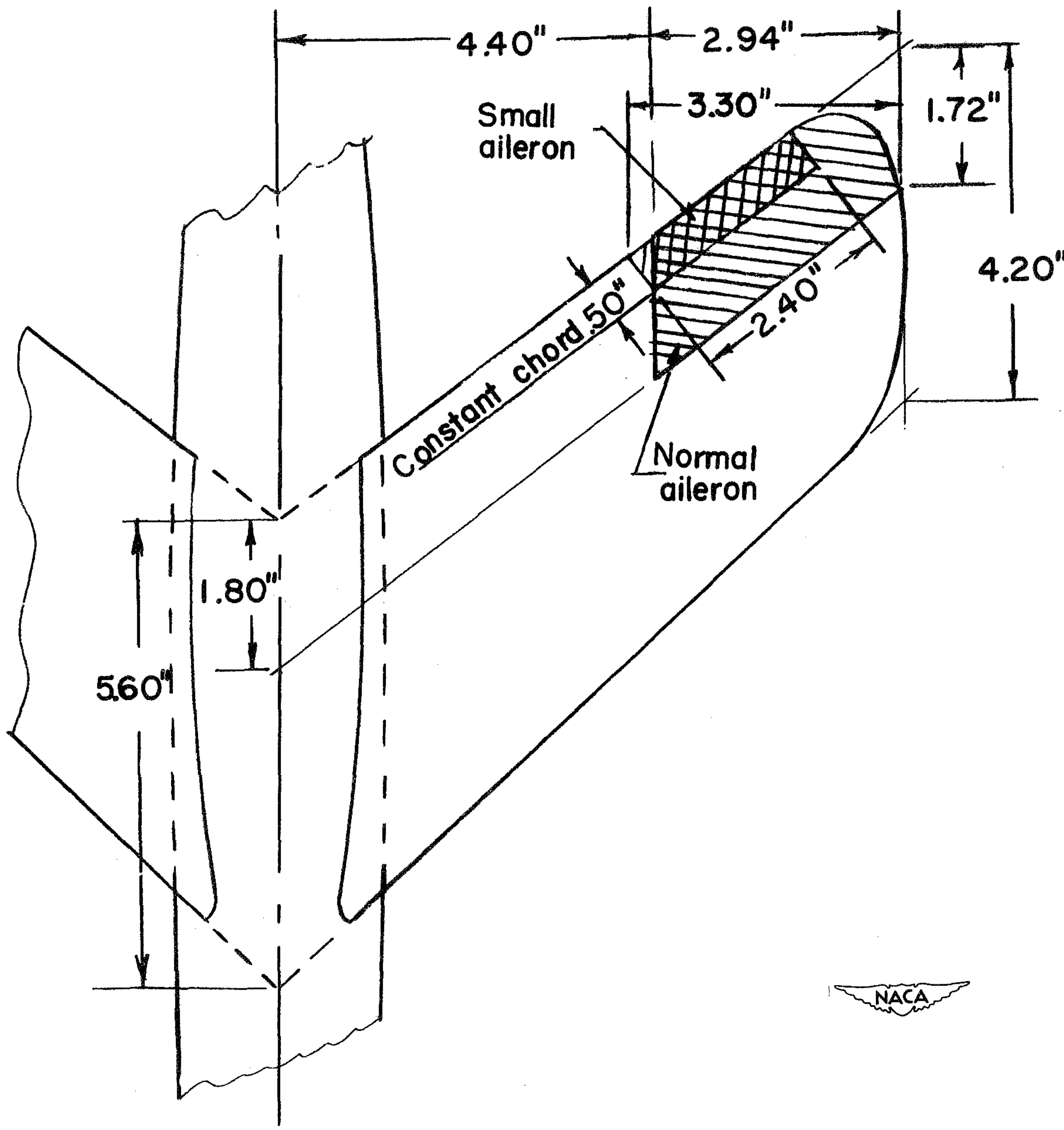

Figure 6.- Sketch of ailerons installed on the $\frac{1}{30}$ - scale model of the Grumman XF10F-1 airplane.

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Figure 7.- Photograph of the $\frac{1}{30}$-scale model of the Grumman XF10F-1 airplane spinning in the Langley spin tunnel.