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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

FREE-SPINNING-TUNNEL TESTS OF A $\frac{1}{24}$ - SCALE MODEL OF THE GRUMMAN XF9F-2 AIRPLANE - TED NO. NACA DE 317

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation of the spin and recovery characteristics of a $\frac{1}{24}$-scale model of the Grumman XF9F-2 airplane has been conducted in the Langley 20-foot free-spinning tunnel. The effects of control settings and movements on the erect and inverted spin and recovery characteristics of the model in the flight loading were determined. The investigation also included spin-recovery-parachute, pilot-escape, and rudder-pedal-force tests.

The recovery characteristics of the model were satisfactory for all configurations tested. Spins for the normal control configuration were oscillatory in roll and yaw. Deflecting the leading-edge flaps or the dive brakes did not change the spin and recovery characteristics of the model noticeably. A 10.0-foot tail parachute or a 6.0-foot wing-tip parachute (drag coefficient of 0.75) was found to be effective for recoveries from demonstration spins. The rudder forces in the spin appeared to be within the capabilities of the pilot.

INTRODUCTION

In accordance with the request of the Bureau of Aeronautics, Navy Department, tests were performed in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a $\frac{1}{24}$-scale model of the Grumman XF9F-2 airplane. This airplane is a single-place single-engine mid-wing jet-propelled fighter.

The erect and inverted spin and recovery characteristics of the model were determined for the flight loading. The effect of depressing the wing leading-edge flaps and the effect of opening the dive brakes were investigated. Tests were also made to determine the minimum parachute size for emergency recovery, the rudder-pedal force necessary to effect satisfactory recovery, and the procedure to follow if it becomes necessary for the pilot to leave the airplane during a spin.

SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing or elevator chord at any station along span
$\bar{c}$	mean aerodynamic chord, feet
$x/\bar{c}$	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 thrust line to mean aerodynamic chord (positive when center of gravity is below thrust 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 $\left(m/\rho Sb\right)$
α	angle between thrust 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, rps

APPARATUS AND METHODS

Model

The $\frac{1}{24}$-scale model of the Grumman XF9F-2 airplane was furnished by the Bureau of Aeronautics, Navy Department, and was checked for dimensional accuracy and prepared for testing by the Langley Laboratory. A three-view drawing of the model as tested is shown in figure 1. A photograph of the model in the clean condition is shown in figure 2. Sketches of the leading-edge flaps and dive brakes are shown in figures 3 and 4, respectively. The dimensional characteristics of the model as tested are given in table I. The tail-damping power factor was computed by the method given in reference 1.

The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 20,000 feet (ρ = 0.001267 slug/cu ft). A remote-control mechanism was installed in the model to actuate the controls or open the parachute for recovery tests and also to release the pilot for the emergency escape tests. Sufficient moments were exerted on the control surfaces during recovery tests to reverse the controls fully and rapidly.

A $\frac{1}{24}$-scale pilot model was built and ballasted at the Langley Laboratory to represent the pilot and parachute (200 lb) at 20,000 feet for the pilot-escape tests.

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 for the Langley 15-foot free-spinning tunnel, except that the models are launched by hand with spinning rotation rather than launched by spindle into the vertically rising air stream. After a number of turns in the established spin, recovery is attempted by moving one or more controls by means of the remote-control mechanism. After recovery the model dives into a safety net. The model is retrieved, the controls reset, and the model is then ready for the next spin. A photograph of the model during a spin is shown in figure 5.

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, greater than 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 greater than 3. A greater than 3-turn recovery does not necessarily indicate an improvement over a greater than 7-turn recovery. 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 (elevator full-up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations 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 these tests, the ailerons are set at one-third of the full deflection and the elevator is set at two-thirds of its full-up deflection. Recovery is attempted by rapidly reversing the rudder from full with the spin to two-thirds against the spin. 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 by rudder reversal or a combination of rudder and elevator reversal. 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.

The testing technique for determining the optimum size of, and the towline length for, spin-recovery parachutes is described in detail in reference 3. For the tail-parachute tests the parachute pack and towline were attached to the model below the horizontal tail near the rear of the vertical fin and on the inboard side. Wing-tip parachutes were attached to the outer wing tip. When the parachute was attached to the wing tip, the towline length was so adjusted that the parachute would just clear 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 steady spin before the parachute was opened. For a full-scale-wing-parachute installation it is advisable that the parachute be packed within the wing. Full-scale-parachute installations should be provided with positive means of ejection. For the current tests, the rudder was held with the spin during recovery so that the recovery was due entirely to the effect of opening the parachute. Nylon parachutes having a drag coefficient of approximately 0.75 (based on the canopy area measured with the parachute spread out flat) were used for the spin-recovery-parachute tests.

For tests to determine from which side of the spinning airplane it would be best for the pilot to make an emergency escape, the pilot model is usually released from the inboard and outboard side of the fuselage at the cockpit for both steep and flat spinning attitudes and the path it follows is noted.

The full-scale rudder-pedal force necessary to move the rudder for recovery in a spin was determined from model tests. For these tests, tension in the rubber band which pulls the model rudder against the spin was adjusted to represent a known value of hinge moment about the rudder hinge line and recovery tests were run. The tension was reduced systematically until the turns for recovery began to increase. The model rudder hinge moment at this point was converted to corresponding full-scale rudder-pedal force at the equivalent altitude at which the tests were run.

Precision

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

V, percent . . . . ± 5

Turns for recovery . . . . $\begin{cases} \pm\frac{1}{4} \text{ from motion-picture records} \\ \pm\frac{1}{2} \text{ from visual observation} \end{cases}$

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 (references 2 and 4) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. In general, the models spun at a somewhat smaller angle of attack, at a somewhat higher rate of descent, and at from 5° to 10° more outward sideslip than did the airplanes. The comparison made in reference 4 for 20 airplanes showed that approximately 80 percent of the models predicted satisfactorily the number of turns required for recovery from the spin for the corresponding airplanes and that approximately 10 percent overestimated and approximately 10 percent underestimated the number of turns required.

Little can be stated about the precision of the pilot-escape tests because no comparable airplane data are available. It is felt, however, that if the pilot model is observed to clear all parts of the model by a large margin after being released from both steep and flat spinning attitudes, then the tests indicate that the pilot will be able to escape during a spin.

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 XF9F-2 model varied from the true scaled-down values within the following limits:

Weight, percent		3 high to 4 high
Center-of-gravity location, percent $\bar{c}$		1 rearward to 1 rearward
Moments of inertia	I_X, percent	3 high to 8 high
	I_Y, percent	0 to 3 high
	I_Z, percent	2 high to 3 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 within an accuracy of $\pm 1^{\circ}$.

Test Conditions

The mass characteristics and inertia parameters for loadings possible on the airplane and for the loading of the model during tests are shown in table II and plotted in figure 6. As discussed in reference 5, figure 6 can be used as an aid in predicting the relative effectiveness of the controls on the recovery characteristics of the model.

The maximum control deflections used in the tests were:

Rudder, degrees	30 right 30 left
Elevator, degrees	35 up 10 down
Ailerons, degrees	20 up 15 down
Leading-edge flaps, degrees	25 down

Intermediate control deflections used were:

Rudder, two-thirds deflected, degrees	20
Elevator, two-thirds up, degrees	$23\frac{1}{3}$
Ailerons, one-third deflected, degrees	$6\frac{2}{3}$ up 5 down
Ailerons, one-half deflected, degrees	10 up $7\frac{1}{2}$ down

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented in charts 1 to 4 and in table III. The model data are presented in terms of the full-scale values for the airplane at a test altitude of 20,000 feet. Unless otherwise stated, all tests were performed with the model in the clean condition (cockpit closed, flaps neutral, and landing gear retracted). Results for right and left spins were quite similar and results for right spins only are arbitrarily presented in the charts.

Flight Loading

Erect spins.- The results of erect spin tests of the model in the flight loading (loading point 1 in table II and fig. 6) are shown in chart 1. For the normal control configuration for spinning, the model spins were steep and oscillatory in roll and yaw; recoveries were rapid by rudder reversal.

In general, setting ailerons with the spin affected the spin and recovery characteristics only little. Setting ailerons full against the spin, however, increased the oscillatory nature of the spinning motion of the model until the model rolled over into an inverted attitude and started spinning in the opposite direction. The rudder, which originally was maintained with the erect right spin, was now with the inverted left spin. No spins were obtained for any elevator-down setting. After being launched erect, the model went into an inverted spin of its own accord for all aileron settings.

Based on the results presented on chart 1, it appears that, for optimum recovery technique for the corresponding airplane, the rudder reversal should be followed by moving the elevator to neutral and maintaining the ailerons neutral.

Inverted spins.- The results of the inverted-spin tests of the model in the flight loading are presented in chart 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 for a spin turning to the pilot's right) 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 ailerons aid the rolling motion; when the controls are together, the ailerons oppose the rolling motion. The angle of wing tilt ϕ on the chart is given as up or down relative to the ground.

The inverted spin-recovery characteristics of the model were satisfactory. Rapid recoveries were obtained by rudder reversal from all spins obtained. In the course of the tests it was noted that in some cases the model started to spin in the opposite direction after recovery and in some cases started to spin erect. Based on these results it is believed that the optimum recovery technique will be rudder reversal followed by stick neutralization.

Leading-edge flaps.– The results of erect spins with the wing leading-edge flaps deflected down 25° are shown in chart 3. Spin and recovery characteristics were satisfactory and were similar to results obtained for the corresponding clean-condition spins.

Dive brakes.– Chart 4 shows the results of extending the dive brakes on the spin and recovery characteristics of the model. The recovery characteristics were satisfactory and no appreciable changes in the spin or recovery characteristics due to deflecting the dive brakes were noted.

Mass Changes and Center-of-Gravity Movement

Inasmuch as all the loadings and center-of-gravity locations, which are listed as possible for this airplane in the mass information received from the manufacturer, are only slightly different from the loading and center-of-gravity location tested, it is felt that the results obtained with the model in the flight loading would apply to all possible loadings and center-of-gravity locations indicated for this airplane.

Spin-Recovery Parachutes

The results of spin-recovery-parachute tests are presented in table III. A tail parachute 10.0 feet in diameter with a towline 24.0 feet long effected satisfactory recovery of the airplane by parachute action alone. Satisfactory recoveries were also obtained by opening a 6.0-foot-diameter parachute attached to the outer wing tip with a 7.8-foot towline.

The model parachutes as tested had values of drag coefficient of approximately 0.75. If a parachute with a different drag coefficient is used on the airplane, a corresponding adjustment will be required in parachute size.

Pilot-Escape Tests

As previously indicated, pilot-escape tests are usually made from both typical steep and typical flat spinning attitudes, but inasmuch as only steep spins were obtained on this model, in some instances the pilot was released soon after the model was launched and while it was still in a flat attitude due to the launching rotation.

When released from the typical steep spin of this model, the pilot model was observed to clear all parts of the model when leaving from the inboard side; but when leaving from the outboard side, it appeared to either strike or come very close to the outboard wing. When released from the flat spinning attitude the pilot apparently cleared the model by a fairly large margin from the outboard side, but appeared to clear the model from the inboard side by only a moderate amount.

Based on these results it appears that to insure safe egress from the XF9F-2 airplane, it may be necessary that the pilot be jettisoned. If no jettisoning equipment is available, it appears that the pilot will stand the best chance of getting out of the spinning airplane from the inboard side.

Landing Condition

The landing condition was not tested on this model inasmuch as current Navy specifications require this type of airplane to demonstrate satisfactory recoveries in the landing condition from only 1-turn spins. At the end of 1 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 available full-scale results to determine the effect of flaps and landing gear indicates that the XF9F-2 airplane will probably recover satisfactorily from an incipient spin in the landing condition, although recoveries from fully developed spins may be unsatisfactory. Therefore, in order to avoid entering a fully developed spin, it is recommended that the flaps be neutralized and recovery attempted immediately upon inadvertently entering a spin in the landing condition.

Rudder 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 was previously mentioned, sufficient force was applied to the controls to move them fully and rapidly for all tests. Sufficient force must be applied to the airplane controls to move them in a similar manner in order for the model and airplane results to be comparable.

A few tests were performed with the model in the flight loading in which the forces applied to the rudder in order to effect a satisfactory recovery were measured. The results indicated that the full-scale pedal force would be within the capabilities of the pilot. The pedal force was found to be light and was calculated to be of the order of 100 pounds or less. Because of lack of detail in the rudder balance of the model, of inertia mass-balance effects, and of scale effect, this result is only a qualitative indication of the actual forces that may be experienced.

Recommended Recovery Technique

Based on the results obtained with the model, the following recommendation is made as to recovery technique for all loading, and erect and inverted spins of the airplane: the rudder should be reversed briskly from full with the spin to full against the spin followed approximately 1/2 turn later by movement of the stick to neutral (laterally and longitudinally); care should be exercised to avoid excessive rates of acceleration in the recovery dive.

CONCLUSIONS

Based on the results of spin tests of a $\frac{1}{24}$-scale model of the Grumman XF9F-2 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane at a spin altitude of 20,000 feet have been drawn:

1. Spins will be oscillatory in roll and yaw, and rapid recovery will be obtained by normal recovery technique.

2. Deflecting the leading-edge flaps or the dive brakes will cause no appreciable change in spin and recovery characteristics.

3. A 10.0-foot-diameter tail parachute with a towline of 24.0 feet or a 6.0-foot-diameter parachute with a 7.8-foot towline opened on the outer wing tip will be satisfactory for emergency recoveries from spins. These sizes are based on a drag coefficient of 0.75 for the laid-out-flat surface area.

4. If a spin is inadvertently entered in the landing condition, the landing flaps should be neutralized and recovery attempted immediately.

5. The pedal force necessary to move the rudder to effect satisfactory recovery from a spin will be within the physical capability of the pilot.

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4. Seidman, Oscar, and Neihouse, A. I.: Comparison of Free-Spinning Wind-Tunnel Results with Corresponding Full-Scale Spin Results. NACA MR, Dec. 7, 1938.

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TABLE I.– DIMENSIONAL CHARACTERISTICS OF

GRUMMAN XF9F-2 AIRPLANE

Length, over all, ft	37.67
Weight, flight loading, lb	11,000
Center-of-gravity location, percent $\bar{c}$	23
Wing:	
Span	35.25
Area, sq ft	250
Section	NACA 64_1-A012
L. E. wing at root to elevator hinge, ft	20.5
Incidence, deg	0
Dihedral, deg	4
Aspect ratio	4.97
Leading edge of $\bar{c}$ rearward of L. E. of wing, in.	7.5
Mean aerodynamic chord, in.	89.4
Sweepback at 27 percent c, deg	0
Ailerons:	
Span, ft	5.8
Area aft hinge line, sq ft	18.08
Hinge line, percent c	71.7
Horizontal tail:	
Span, ft	16.2
Total area, sq ft	60
Elevator area aft hinge line, sq ft	18.48
Incidence, deg	0
Vertical tail:	
Total area, sq ft	34.89
Total rudder area aft hinge line, sq ft	5.92
Tail-damping ratio	0.05218
Unshielded rudder-volume coefficient	0.01374
Tail-damping power factor	0.000717

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TABLE II.– MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING CONDITIONS POSSIBLE ON GRUMMAN XF9F-2 AIRPLANE AND FOR LOADING TESTED ON $\frac{1}{24}$-SCALE MODEL

[Model values converted to corresponding full-scale values; moments of inertia given about c.g.]

Number (Same as fig. 4)	Loading	Weight (lb)	μ, sea level	μ, 20,000 ft	Center-of-gravity location		Moments of inertia (slug-ft^2)			Mass parameters		
					$x/\bar{c}$	$z/\bar{c}$	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	Take-off	12,600	18.7	35.1	0.247	0.002	4312	17,308	20,354	-267×10^{-4}	-63×10^{-4}	330×10^{-4}
2	Flight	11,000	16.3	30.6	.230	.017	4242	17,415	20,472	-310	-72	382
3	Landing full ammunition	9,600	14.2	26.7	.0261	.034	4101	16,889	19,923	-345	-82	427
Model values												
1	Flight	11,380	16.9	31.7	0.238	0.034	4462	17,699	20,938	-301×10^{-4}	-74×10^{-4}	375×10^{-4}

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TABLE III.– SPIN-RECOVERY-PARACHUTE DATA OBTAINED WITH

$\frac{1}{24}$–SCALE MODEL OF GRUMMAN XF9F-2 AIRPLANE

[Loading point 1 on table II and fig. 4; rudder fixed full with the spin; model values converted to corresponding full-scale values; C_D of parachutes 0.75; right erect spins]

Parachute diameter (ft)	Towline length (ft)	Ailerons	Elevator	Turns for recovery
Tail parachutes				
10.0	24.0	Neutral	Full up	1/2, 1/2, 1, 1
8.0	24.0	Neutral	Full up	1/2, 3/4, $1\frac{1}{2}$, >3
6.0	24.0	Neutral	Full up	3/4, $2\frac{1}{4}$, >$2\frac{1}{2}$, >3
Wing-tip parachutes				
8.0	4.4	Neutral	Full up	3/4, 3/4, 1
6.0	7.8	Neutral	Full up	3/4, 1, 1
4.0	11.8	Neutral	Full up	>$2\frac{1}{2}$, >$2\frac{3}{4}$, >$3\frac{1}{2}$

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CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE GRUMMAN XF9F-2 AIRPLANE IN THE FLIGHT LOADING

[Loading point 1 on table II and figure 4; 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]

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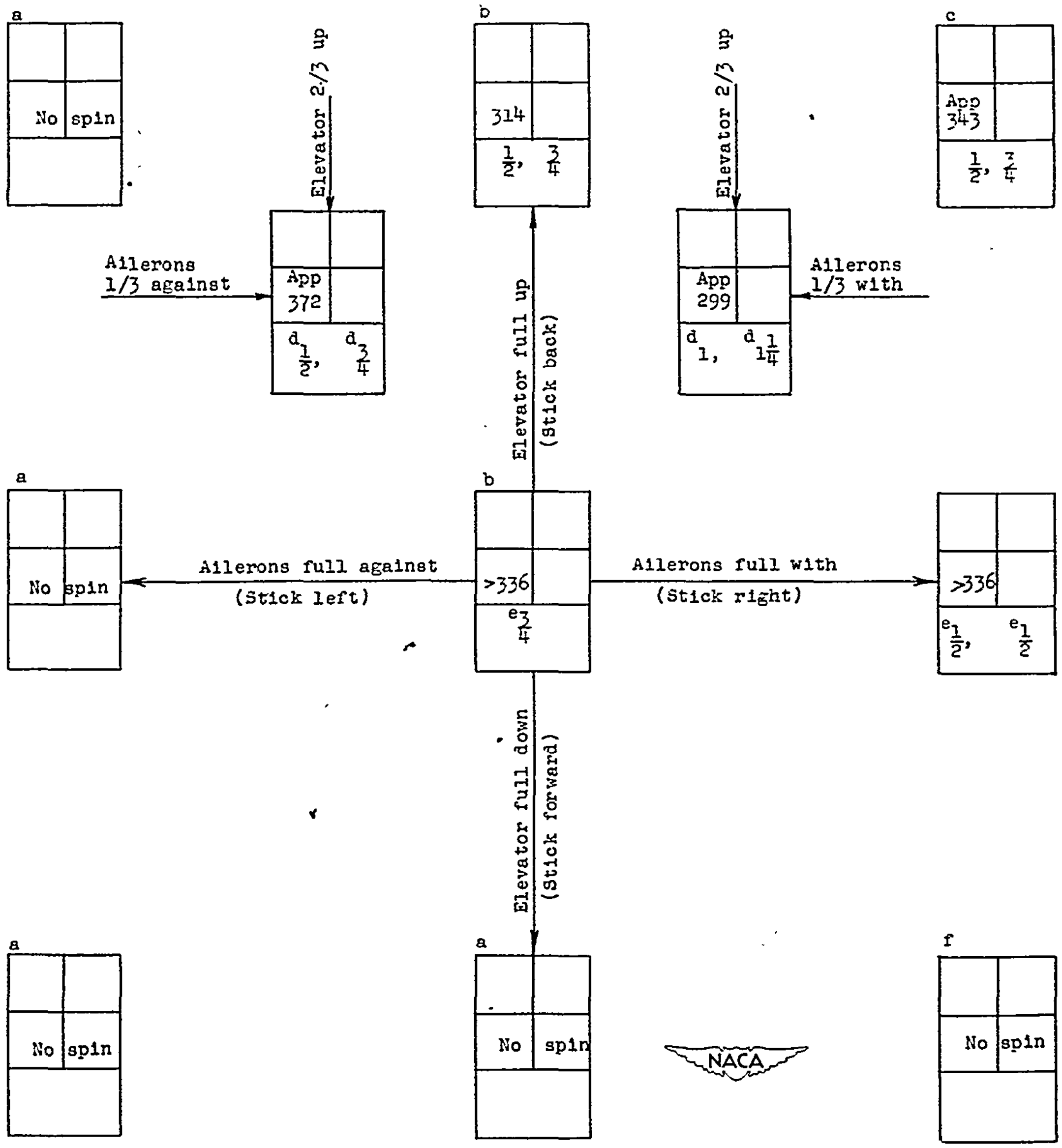

aExtremely oscillatory. Model oscillations increased in amplitude until model rolled over and went into inverted attitude.
bOscillatory in roll and yaw.
cWide radius spin with model oscillating in roll.
dRecovery attempted by reversing the rudder from full with to 2/3 against the spin.
eRecovery attempted before model reached its final steep attitude.
fModel attitude steepens until it passes into an inverted 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 2.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE GRUMMAN XF9F-2 AIRPLANE IN THE FLIGHT LOADING

[Loading point 1 on table II and figure 4; 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 right]

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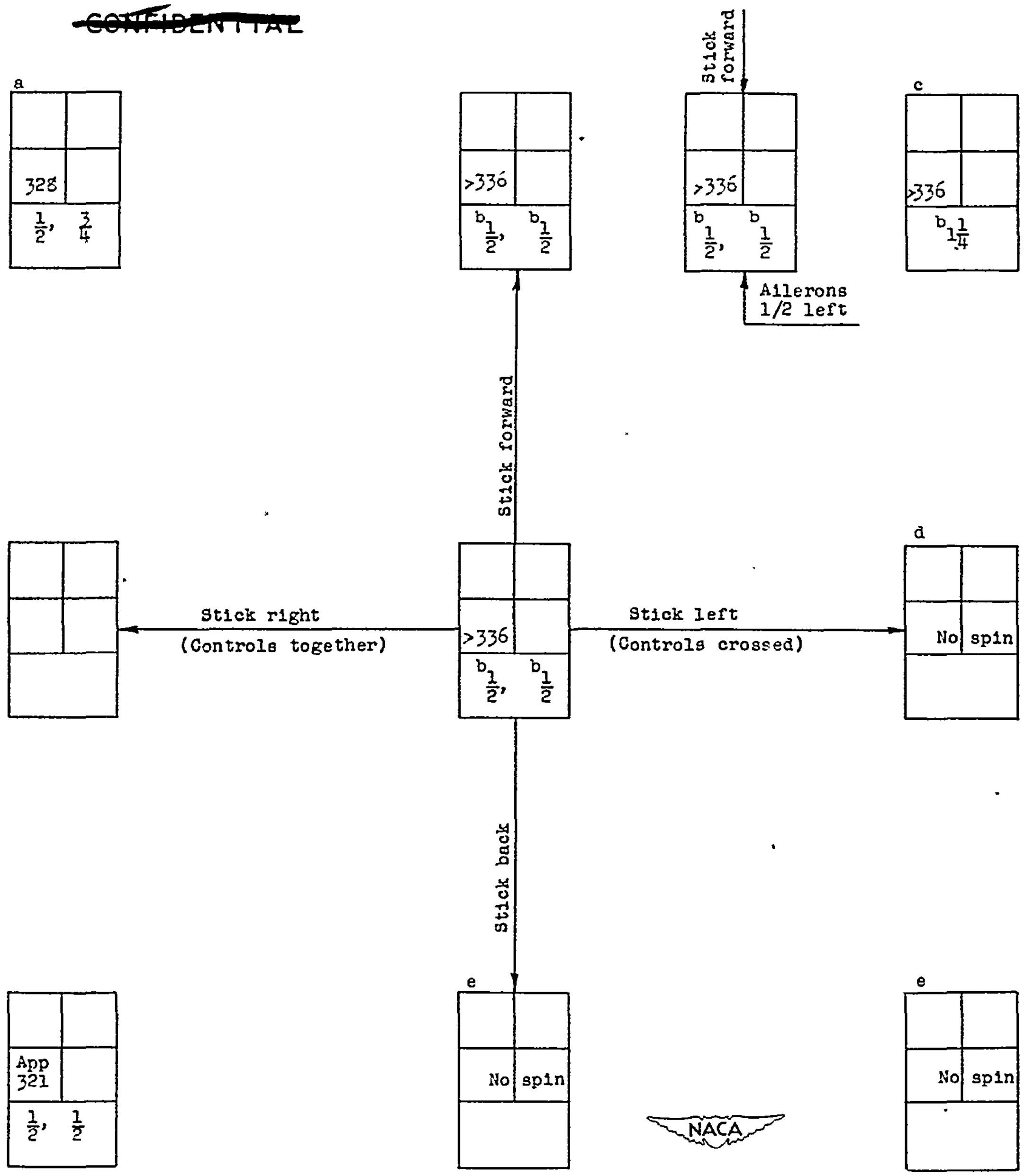

[a]Oscillatory and wandering spin. After recovery, spins inverted in opposite direction.
[b]Recovery attempted before model reached its final steep attitude.
[c]Model goes from inverted into an erect spin when recovery takes place.
[d]Model whips from inverted to erect spin periodically.
[e]Model recovers in an erect dive.

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 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE GRUMMAN XF9F-2 AIRPLANE WITH THE LEADING EDGE FLAPS DEFLECTED 25°

[Loading point 1 on table II and figure 4; trailing edge 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]

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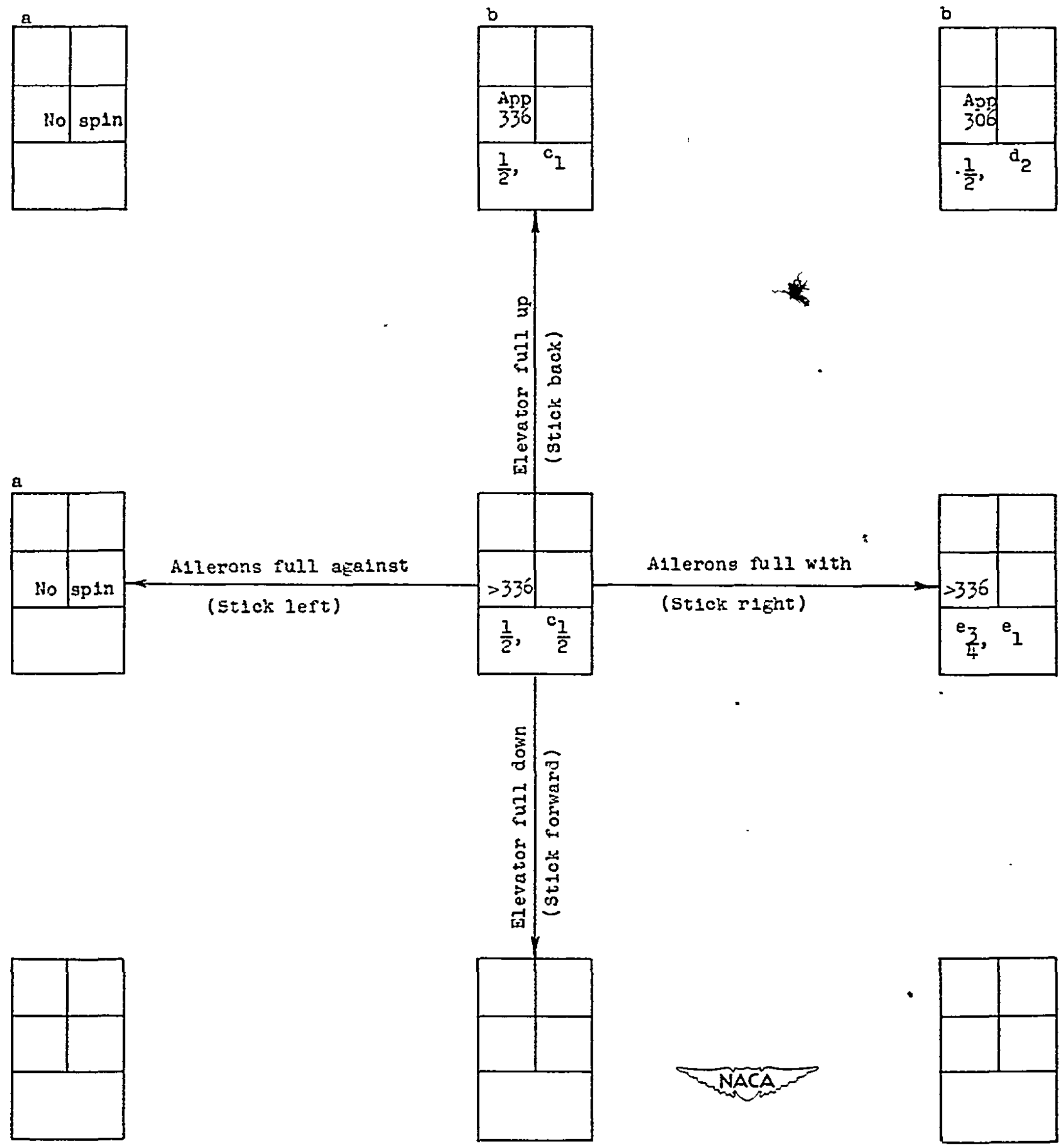

[a]Extremely oscillatory. Model oscillations increased in amplitude until model rolled over and went into an inverted attitude.
[b]Oscillatory in roll and yaw.
[c]Visual estimate.
[d]Model appeared to recover after 1/2 turn, then spun again 1-1/2 turns and recovered in a glide.
[e]Recovery attempted before model reached its final steep attitude. Model went immediately into inverted spin after recovery.

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	

[redacted]

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE GRUMMAN XF9F-2 AIRPLANE WITH THE DIVE BRAKES DEFLECTED

[Loading point 1 on table II and figure 4; 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]

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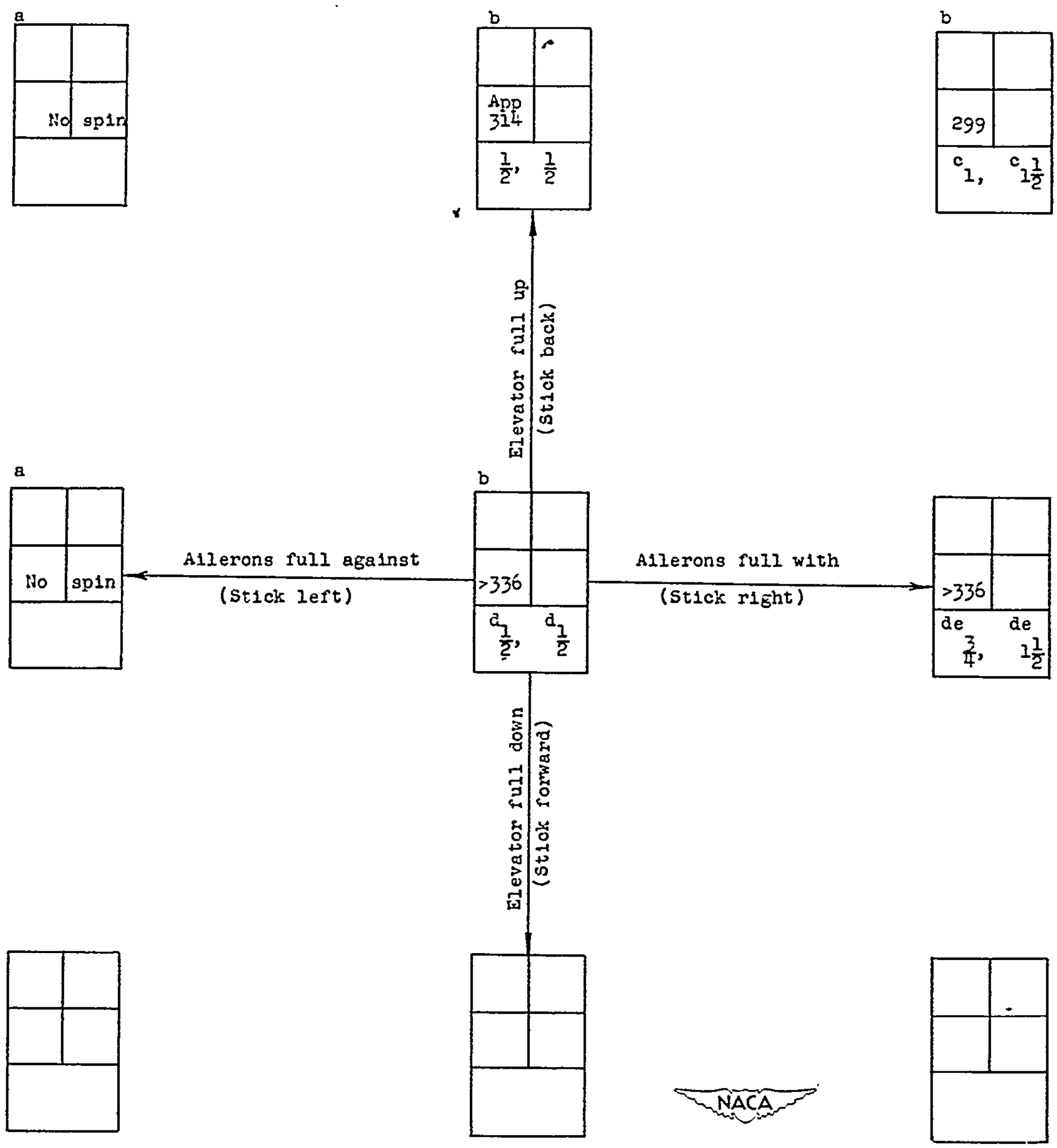

[a]Extremely oscillatory. Model oscillations increased in amplitude until model rolled over and went into inverted attitude.
[b]Oscillatory in roll and yaw.
[c]Model recovers, glides short distance, and then goes into a turn with the ailerons.
[d]Recovery attempted before model reached its final steep attitude.
[e]After recovery, model goes immediately into inverted 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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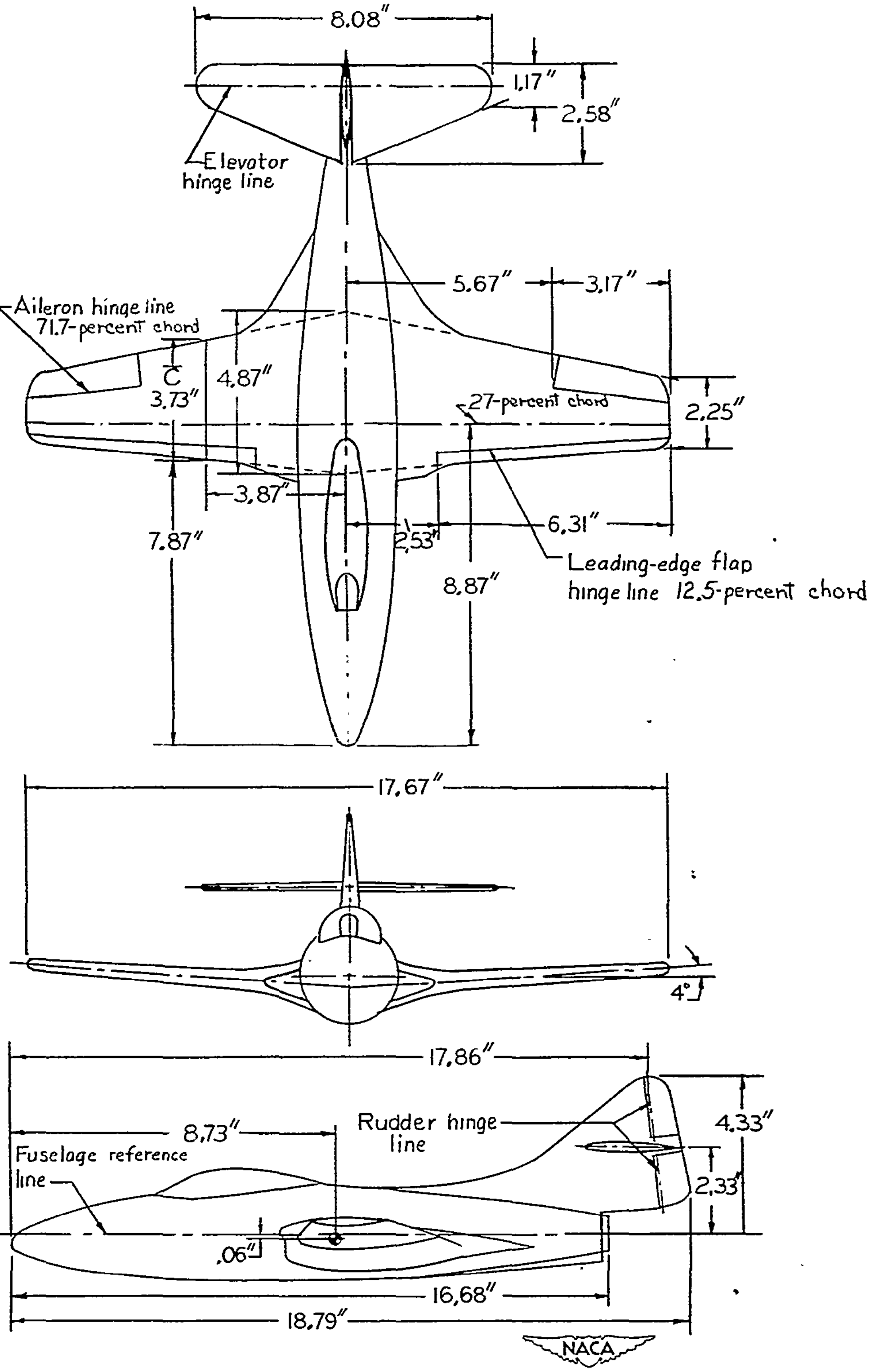

Figure 1.- Three-view drawing of the $\frac{1}{24}$-scale model of the Grumman XF9F-2 airplane as tested in the free-spinning tunnel. Center-of-gravity location is shown for flight loading.

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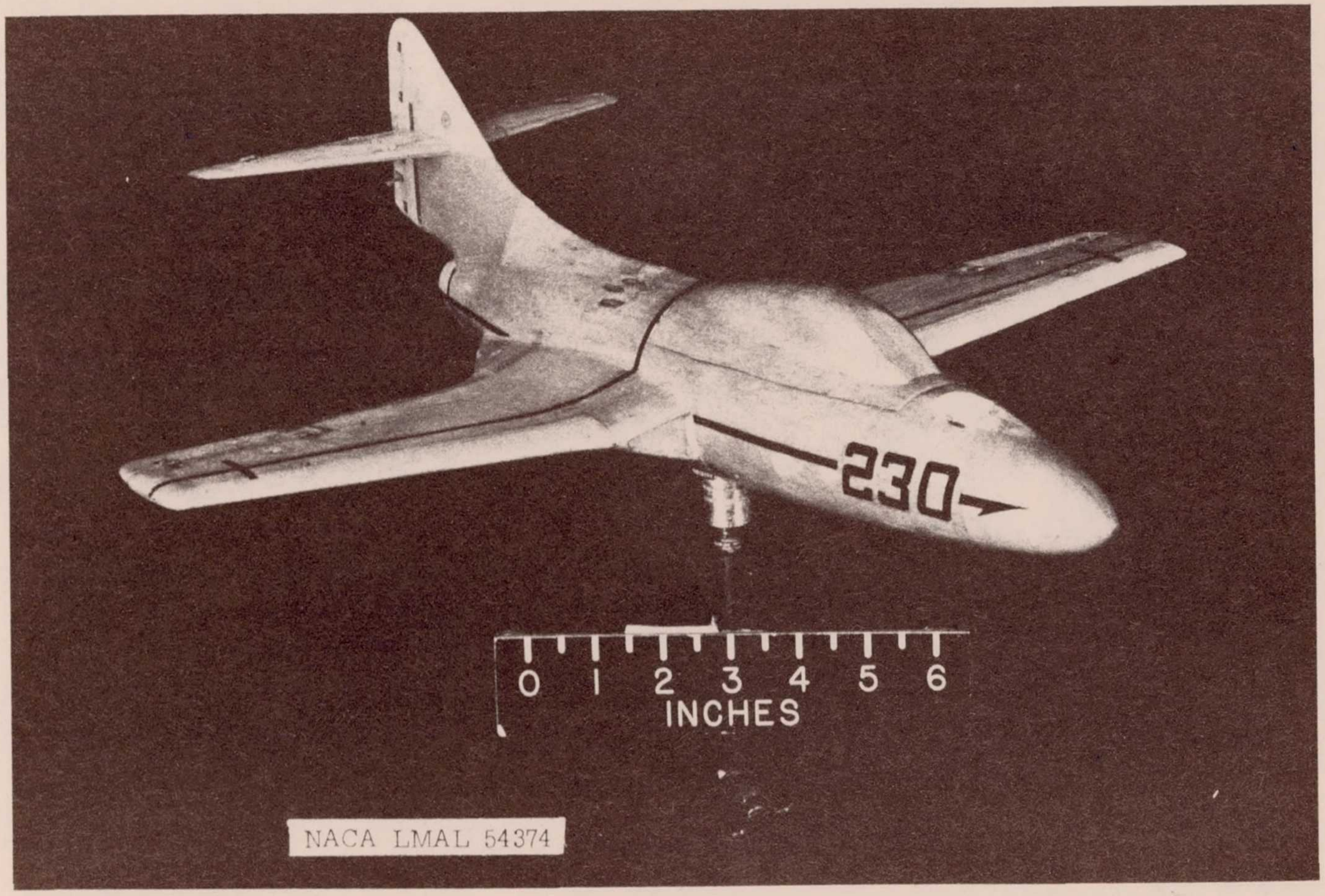

Figure 2.- Photograph of $\frac{1}{24}$-scale model of Grumman XF9F-2 airplane in the normal loading clean condition.

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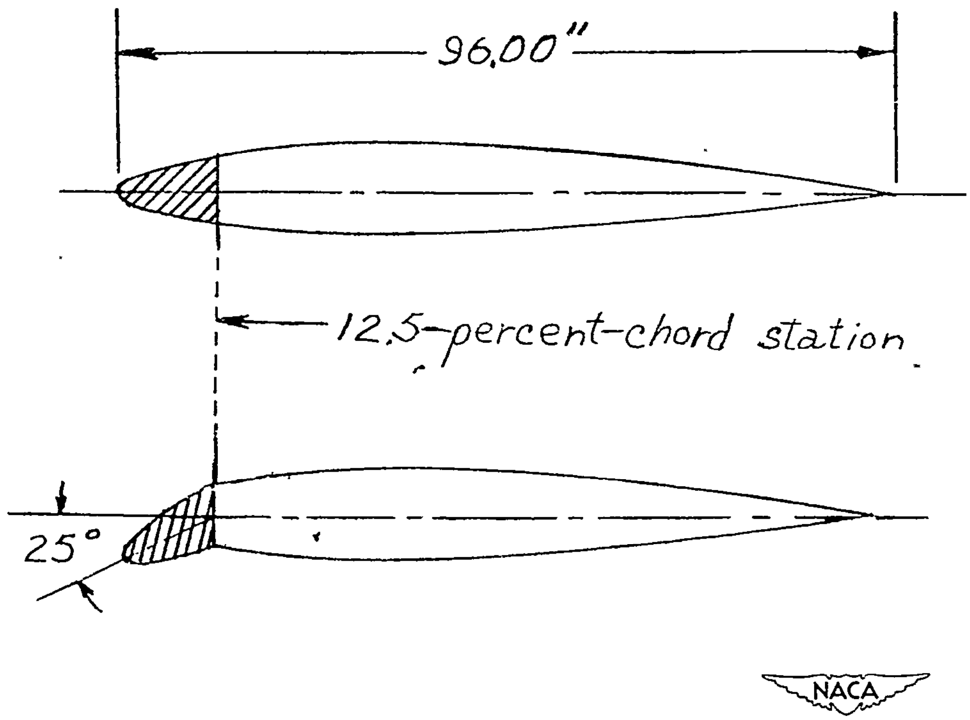

Figure 3.- Leading-edge flap positions tested on the $\frac{1}{24}$-scale model of the Grumman XF9F-2 airplane. Section shown is inboard end of flap. Dimensions are full-scale values.

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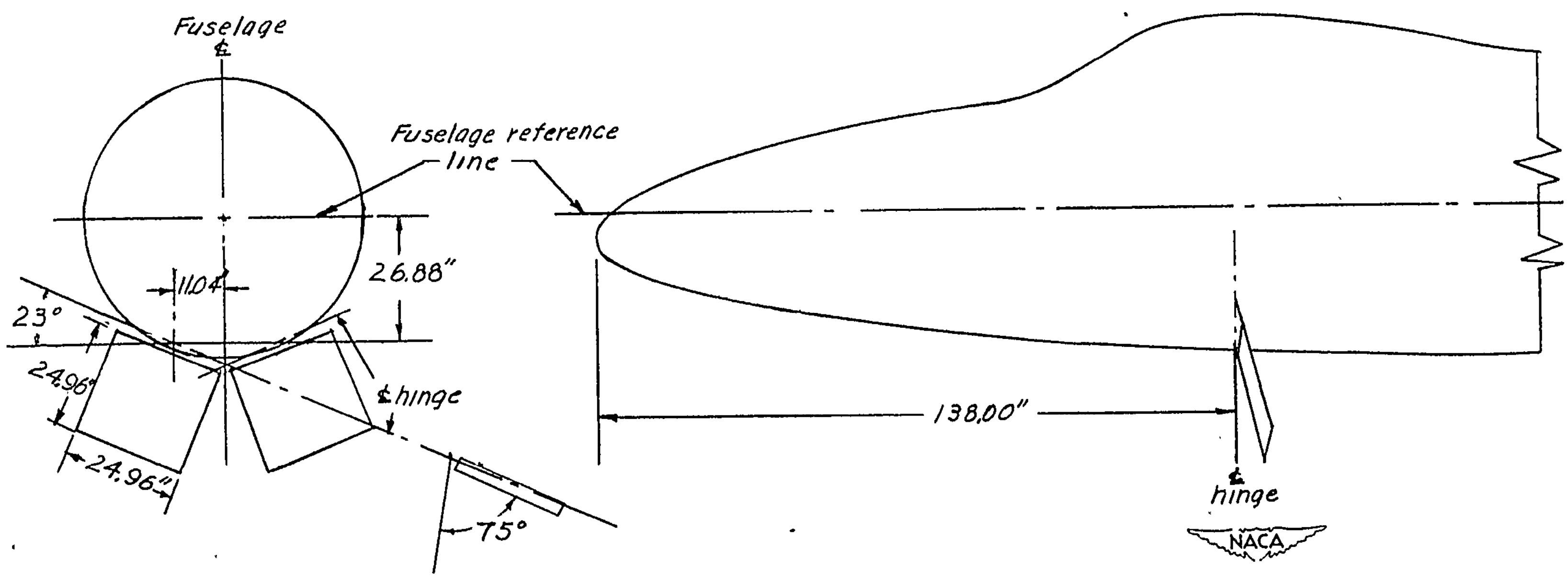

Figure 4.- Dive brakes in extended position as tested on the $\frac{1}{24}$-scale model of the Grumman XF9F-2 airplane. Dimensions are full-scale values.

[redacted]

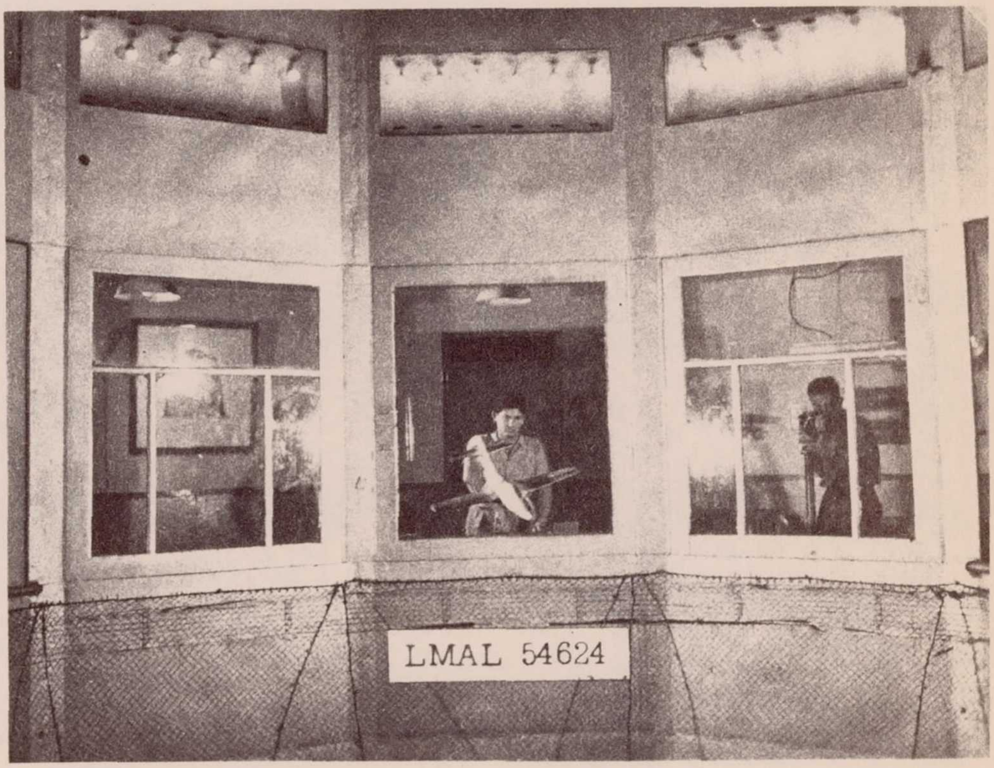

Figure 5.- Photograph of $\frac{1}{24}$-scale model of Grumman XF9F-2 airplane spinning in Langley 20-foot free-spinning tunnel.

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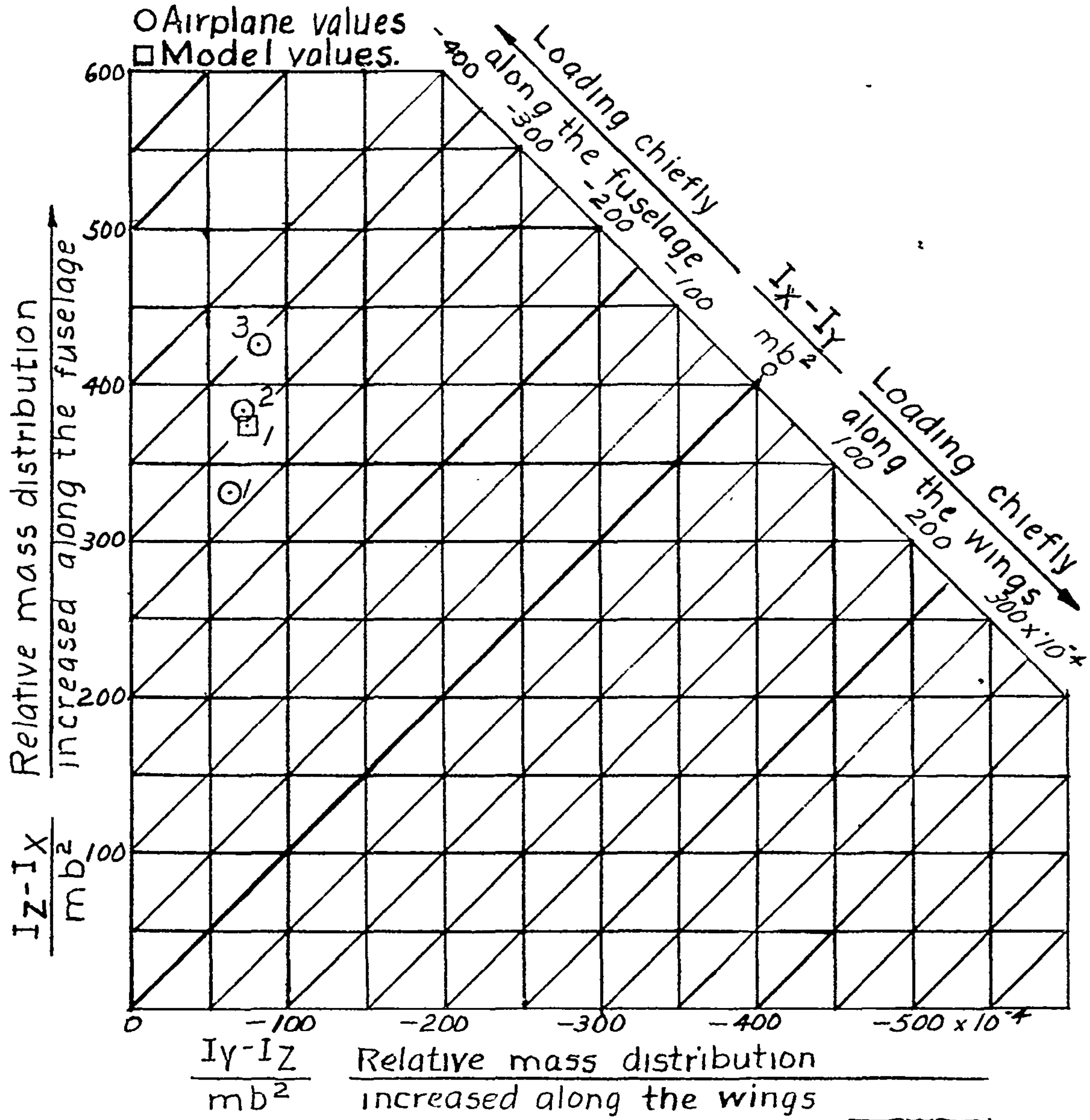

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Figure 6.- Mass parameters for loadings possible on the Grumman XF9F-2 airplane and for loadings tested on the $\frac{1}{24}$-scale model. (Points are for loadings listed in table II.)