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# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

## FREE-SPINNING TUNNEL INVESTIGATION OF A $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE


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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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# FREE-SPINNING TUNNEL INVESTIGATION OF A $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE

By Jack H. Wilson

## SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane. The effects of control settings and movement upon the erect spin and recovery characteristics of the model were determined for the take-off condition and for the condition with full wing-tip fuel tanks installed. Brief tests were also conducted to determine the effect of deflecting the speed brakes and to determine the effect of moving the center of gravity forward of normal. The investigation also included inverted spin tests and tests to determine the parachute size required for emergency spin recovery.

For the take-off or combat loadings either an extremely steep spin was obtained from which recoveries were rapid or an oscillatory motion was obtained with the oscillation becoming so violent that the model would oscillate out of the spin. Extending the speed brakes or moving the center of gravity 5 percent forward of normal had little effect on the spin or spin-recovery characteristics. When the full wing-tip fuel tanks were installed, steep spins were obtained and recoveries by full reversal of the rudder and movement of the elevator down were satisfactory.

Recoveries from inverted spins by reversal of the rudder were rapid.

Either a 16.7-foot tail or a 10-foot wing-tip spin-recovery parachute (drag coefficients 0.63 and 0.72, respectively) was indicated to be an effective emergency spin-recovery device for demonstration spins.

[redacted]

## INTRODUCTION

In accordance with a request by 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 $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane. The F2H-3 is an unswept-wing, duel-jet, single-place, low-wing fighter.

The erect and inverted spin and recovery characteristics of the model were determined for the clean condition. The effects of speed brakes and of moving the center of gravity forward of normal were also determined. Fully loaded wing-tip tanks were investigated on the model and tests to determine the required size of emergency spin-recovery tail and wing-tip parachutes were also performed. Two simulated spin-test altitudes were investigated.

## SYMBOLS

| | |
|---|---|
| $b$ | wing span, feet |
| $S$ | wing area, square feet |
| $\bar{c}$ | 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 fuselage reference line to mean aerodynamic 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

$\rho$ air density, slugs per cubic foot

$\mu$ relative density of airplane $(m/\rho Sb)$

$\alpha$ angle between fuselage reference line and vertical (approx. equal to absolute value of angle of attack at plane of symmetry), degrees

$\phi$ angle between span axis and horizontal, degrees

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

$\Omega$ full-scale angular velocity about spin axis, revolutions per second

## APPARATUS AND METHODS

The $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane was furnished by the Bureau of Aeronautics, Navy Department, and was checked for dimensional accuracy and prepared for testing by the Langley Aeronautical Laboratory. A three-view drawing of the model with wing-tip tanks installed is shown in figure 1. Photographs of the model in the clean condition are shown in figure 2. Figure 3 is a photograph of the model with speed brakes installed. The dimensional characteristics of the airplane are given in table I.

For the greater portion of the tests, the model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho$ = 0.001496 slug/cu ft). Brief tests were also conducted with the model ballasted to simulate the airplane at a test altitude of 25,000 feet ($\rho$ = 0.001065 slug/cu ft). A remote-control mechanism was installed in the model to actuate the controls or open the parachute for recovery tests. Sufficient moments were exerted on the control surfaces during recovery tests to reverse the controls fully and rapidly.

## WIND TUNNEL AND TESTING TECHNIQUE

The model tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in

reference 1 for the Langley 15-foot free-spinning tunnel, except that the model-launching technique has been changed. With the controls set in the desired position, the model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, recovery is attempted by moving one or more of the controls by means of a remote-control mechanism. After recovery, the model dives into a safety net.

The data presented were determined by methods described in reference 1 and have been converted to corresponding full-scale values. 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. Recovery in two turns or less has been adopted as the criterion for a satisfactory spin recovery for the model. 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, as >330. 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, and such results are considered conservative. For recovery attempts in which the model struck the 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 >2.

Spin-tunnel tests are made to determine the spin and recovery characteristics of the model for 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 either by rapid full rudder reversal alone or by simultaneous rapid full rudder and elevator reversal. Tests are also performed to evaluate the possible adverse effects on recovery of small control deviations from the normal control configuration for spinning. For these tests, the ailerons are set at one-third of the full deflection in the direction of the slower recoveries and the elevator is set at full up or at two-thirds of its full-up deflection, whichever will cause slower recoveries. Recovery is attempted either by rapid rudder reversal alone from full with the spin to two-thirds against the spin or by simultaneous rapid rudder reversal from full with the spin to two-thirds against the spin and movement of the elevator down. 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 spin-recovery parachute tests, the minimum size parachute required to effect recovery within $2\frac{1}{4}$ turns after the packed parachute

was opened was selected as the parachute required for satisfactory termination of the spin. The towline length used on the spin-recovery tail parachutes was selected on the basis of the data presented in reference 2. For the tail parachute tests, the parachute pack and towline were attached to the model at the rear of the fuselage below the horizontal tail on the inboard side of the fuselage (right side of the fuselage in a right spin). Wing-tip parachutes were attached to the outer wing tip (left wing tip in a right spin). When the parachute was attached to the wing tip, the towline length was so adjusted that the parachute could not be fouled by the horizontal tail. Tests were also made with a very short towline for the wing-tip parachute. It is recommended that, for full-scale wing-parachute installation, the parachute be packed within the airplane structure if possible; all parachutes should be provided with a positive means of ejection. For the tests, the controls were not moved during recovery so that recovery was due entirely to the effect of opening the parachute. Flat-type silk parachutes which had a drag coefficient of approximately 0.72 for the wing-tip parachutes and 0.63 for the tail parachutes (based upon the canopy area measured with the parachute spread out flat on a flat surface) were used for the spin-recovery parachute tests.

## PRECISION

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

| | |
|---|---|
| $\alpha$, degrees . . . . . | $\pm 1$ |
| $\phi$, degrees . . . . . | $\pm 1$ |
| V, percent . . . . . | $\pm 5$ |
| $\Omega$, percent . . . . . | $\pm 2$ |
| Turn for recovery: | |
| Motion-picture records . . . . . | $\pm\frac{1}{4}$ |
| Visual estimate . . . . . | $\pm\frac{1}{2}$ |

The preceding limits may have been exceeded for a large portion 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 3) indicates that model tests satisfactorily predicted full-scale recovery characteristics approximately 90 percent of the time and for the ramining 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 effectiveness of the controls on the recovery characteristics. The airplane generally spun at an angle of attack closer to 45° than did the model and had a greater altitude loss per revolution than did the model. The comparison presented in reference 3 also indicated that generally the model's inner wing was tilted less downward and that the corresponding airplane spun at a greater or lower rate of rotation, depending on whether the tail-damping ratio was greater or less than 0.02, than the model.

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

| | |
|---|---|
| Weight, percent . . . . . | 1 low to 1 high |
| Longitudinal center-of-gravity location, percent $\bar{c}$ . . . . . | 1 rearward to 2 forward |
| Moments of inertia: | |
| $I_X$, percent . . . . . | 5 low to 6 high |
| $I_Y$, percent . . . . . | 7 low to 4 high |
| $I_Z$, percent . . . . . | 5 low to 4 high |

The accuracy of measuring the weight and mass distribution of the model is believed to be within the following limits:

| | |
|---|---|
| Weight, percent . . . . . | ±1 |
| Center-of-gravity location, percent $\bar{c}$ . . . . . | ±1 |
| Moments of inertia, percent . . . . . | ±5 |

The controls were set with an accuracy of ±1°.

## TEST CONDITIONS

Tests were made to determine the erect spin and recovery characteristics of the model in the clean condition for normal and forward center-of-gravity positions. The effect of the installation of speed brakes and of full external wing-tip fuel tanks was also determined. The inverted spin and recovery characteristics were obtained for the clean condition and normal center-of-gravity position.

The mass characteristics and inertia parameters for loadings possible on the airplane and for the loadings tested on the model are shown

in table II. The model was ballasted according to the original mass information reveived from McDonnell. Subsequent to the ballasting of the model, revised mass data were received for the F2H-3 airplane but, inasmuch as the mass and mass distribution were not appreciably changed from the original data received, the model was not reballasted. The results of the investigation presented herein are considered applicable for either the original or revised mass data given in table II.

The mass parameters for the loading conditions given in table II are plotted in figures 4 and 5. For unswept-wing airplanes, figure 4 can be used to determine whether the spins will be fairly steady or extremely oscillatory in roll and yaw (as associated with long-nose lengths and extreme loadings along the fuselage), reference 4. As discussed in reference 5, figure 5 can be used in predicting the relative effectiveness of the controls except when extreme rolling and yawing oscillations are obtained.

The tail-damping power factor of the F2H-3 was calculated by the method described in reference 6. The maximum control deflections used in the tests were:

| | |
|---|---|
| Rudder, degrees . . . . . | 20 right, 20 left |
| Elevator, degrees . . . . . | 15 up, 15 down |
| Ailerons, degrees . . . . . | 20 up, 20 down |

## RESULTS AND DISCUSSION

The results of the spin tests of the model are presented in charts 1 to 3 and in table III. Unless otherwise indicated, the model data are presented in terms of the full-scale values for the airplane at a test altitude of 15,000 feet. Preliminary tests of the model showed that recoveries from left and right spins were similar, and results are arbitrarily presented in terms of right spins.

### Erect Spins

Take-off and combat loadings.- The test results obtained with the F2H-3 model in the clean condition for the loading condition designated as the take-off loading (loading point 1 in table II and figs. 4 and 5) are presented in chart 1. Although no specific tests were conducted with the model balasted to simulate the combat loading (loading point 2 in table II and figs. 4 and 5), an examination of the mass and inertia data indicates that similar results should be obtained for the take-off or combat loadings or for any intermediate condition.

As shown in chart 1, with the ailerons set at neutral, two conditions were indicated as being possible: either the model would not spin or a steep spin was obtained.

For the steep spin, recoveries by rudder reversal were indicated to be rapid. For the "no spin" condition, the model oscillated in roll and yaw through a wide range of angles after the initial launching rotation was expended; during these oscillations reversal of the rudder during any phase of the oscillations quickly terminated this motion. If the rudder was not reversed during this oscillatory motion, the model eventually went into a left roll or into a glide with lift wing low (rudder maintained full right in a right spin). It is believed that, on the corresponding airplane, similar oscillations may be obtained during the incipient phase of the spin. Based on the model results, it appears that recovery of the corresponding airplane from any spin or oscillatory motion obtained should be satisfactory by normal-recovery technique (full reversal of the rudder followed 1/2 turn later by movement of the elevator down). Any rolling motion obtained on the airplane should be readily terminated by movement of ailerons to oppose this motion. With the ailerons set against the spin, the model would not spin but would go into a left roll after undergoing a series of extreme rolling and yawing oscillations. Setting the ailerons partially or fully with the spin resulted in steep spins when the elevator was or near full up, the model oscillating somewhat in roll and yaw and tending to whip or to glide out of the spin at times. With the elevator at neutral or down and the ailerons with the spin the model descended at a very steep attitude and may have been in an aileron roll. For all aileron-with spins, recovery by rudder reversal alone was rapid, the model either gliding out of the spin after rudder reversal or going into a steep inverted spin. In order to avoid entering an inverted spin, the stick and rudder pedals should be neutralized after the airplane has assumed a near-vertical attitude.

Brief tests made for the take-off loading with the speed brakes installed indicated that the nature of the spin and the spin-recovery characteristics were not affected by the speed brakes. The results of these tests are not presented in chart form.

Results of brief tests conducted with the center of gravity moved forward approximately 5 percent of normal for the take-off loading condition indicated that the spin and spin-recovery characteristics were essentially the same as those obtained with the center of gravity at its normal location (results not presented in chart form).

Wing-tip tanks on and full.- The results of spin tests of the model with wing-tip tanks on and full (loading point 4 in table II and figs. 4 and 5) are presented in chart 2. The model spins for all control configurations were very steep with the rate of descent of the model

exceeding the vertical velocity of the tunnel. As was anticipated for this loading condition of the model (reference 5), placing the ailerons against the spin and the elevator down had a favorable effect on recovery, whereas placing the ailerons with the spin retarded recoveries. The results of the model tests indicated that the recovery characteristics of the F2H-3 airplane for this loading condition will be satisfactory provided both rudder and elevator are reversed for recovery, regardless of the position of the ailerons.

Although not specifically investigated, it is not anticipated that any difficulty will be encountered in recovering from spins with wing-tip fuel partially or fully expended. If, however, a spin is entered with the wing-tip fuel tanks installed and recovery does not appear imminent after the normal manipulation of the controls (reversal of the rudder followed approximately 1/2 turn later by reversal of the elevator), it is recommended that the wing-tip fuel tanks be jettisoned and another recovery attempt be made. As indicated in reference 7, the jettisoned tanks should fall clear of the airplane.

Test altitude increased to 25,000 feet.- In order to determine if an increase in test altitude would have an adverse effect on the model's spin-recovery characteristics, the simulated test altitude of the model was raised from 15,000 to 25,000 feet. The results of these tests indicate that, for the take-off or combat loadings (loadings 1 and 2 in table II and figs. 4 and 5), the behavior of the airplane in spins should be essentially the same at 15,000 or 25,000 feet. No tests were conducted with the model ballasted to simulate the loading with wing-tanks installed at an altitude of 25,000 feet. As has been stated previously, if recovery does not appear imminent after normal use of the controls, it is recommended that the tanks be jettisoned and that recovery be reattempted.

Landing condition.- The landing condition was not investigated on this model inasmuch as current Navy specifications do not require airplanes to be spin-demonstrated in the landing condition. Analysis of full-scale and model tests on numerous designs to determine the effect of flaps and landing gear (reference 8) indicates that, although the F2H-3 airplane will probably recover satisfactorily from an incipient spin (1 turn or less), recoveries from fully developed spins in the landing configuration may be unsatisfactory. In order to avoid entering a fully developed spin, it is recommended that the flaps be neutralized and that recovery be attempted immediately upon inadvertently entering a spin in the landing condition.

Inverted spins.- The results of the inverted spin tests of the model in the take-off loading are presented in chart 3. 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 pilot's left for a spin 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 inverted spin, the ailerons aid the rolling motion; when the controls are together, the ailerons oppose the rolling motion.

The inverted spins were very steep, the rate of descent of the model exceeding the vertical velocity of the tunnel. Recoveries by rudder reversal from all control configurations were rapid.

Control forces.- The discussion of recovery characteristics so far has been based on control effectiveness alone without regard to the forces required to move the controls. As previously mentioned, for all tests sufficient force was applied to the controls to move them fully and rapidly. 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.

Calculations were made, based on the information presented in references 9 and 10, to determine the forces required to fully reverse the controls during spins. These calculations indicate that the rudder-pedal forces will probably be within the capabilities of the pilot, but that the force required to fully reverse the elevator might be excessive, indicating that some type of booster may be required to insure full reversal of the elevator.

Spin-recovery parachutes.- Spin-recovery parachutes were investigated on the model to determine the size parachute required for emergency recovery during demonstration spins. It was found that very large tail parachutes (of the order of 20 feet) were not capable of terminating the model's motion. Inasmuch as the model spins were very steep and the radius of the spin was observed to be small for the loading conditions investigated when spin-recovery tail parachutes were opened, it was noted that the parachute trailed nearly along the model's X-axis. It thus appears that the parachute contributed very little aerodynamic yawing moment opposing the model's rotation. If the airplane spins are generally similar to those indicated by the model results, it is believed that recovery should be readily obtainable without the aid of a parachute provided that the controls can be reversed. If, because of possible scale effects, the airplane spins somewhat flatter than the model, an emergency spin-recovery device may be required, however. After numerous attempts to obtain a flat spin on the model, it was found that placing a large fin at the rear of the fuselage off-set to give a pro-spin yawing moment and setting the controls beyond their maximum deflections led to a flat spin, angle of attack approximately 63°. Both outboard-wing-tip and tail parachute installations were investigated from this flat-spinning condition and the results of

these tests are presented in table III. Although these results are conservative, it is felt that the size parachutes determined from these tests should be effective as emergency spin recovery devices on the F2H-3 airplane.

The results of the model tests show that a tail parachute 16.7 feet in diameter, full-scale (measured laid out flat), will enable satisfactory recovery from the flat spin by parachute action alone. For the tail parachute tests a towline length of approximately 21 feet, full-scale, was used. Satisfactory recoveries were also indicated to be obtainable by opening a 10-foot diameter, full-scale (measured laid out flat), parachute attached to the outboard wing tip with towline lengths of approximately 7 feet or under.

The model parachutes as tested had values of drag coefficients of approximately 0.63 for the tail parachutes and approximately 0.72 for the wing-tip parachutes. If a parachute with a different drag coefficient is used on the airplane, a corresponding adjustment will be required in parachute size.

## CONCLUSIONS

Based upon the results of spin tests of a $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane, the following conclusions and recommendations regarding the spin and recovery characteristics of the airplane are made for a spin-test altitude up to 25,000 feet:

1. In the take-off or the combat loading of the airplane, either an extremely steep spin may be obtained from which recoveries will be rapid by normal use of the controls (full reversal of the rudder followed 1/2 turn later by movement of the elevator down) or the airplane may not spin. During an incipient phase of the spinning motion, extreme oscillations may be obtained, the oscillations becoming so violent that the airplane may roll or yaw out of the spin. If the rudder and elevator are moved for recovery during the oscillations, the motion will be terminated rapidly.

2. With full external wing-tip tanks installed the spins will be steep and recoveries will be satisfactory by normal use of the controls. If recovery does not appear imminent, however, after normal manipulation of the controls, it is recommended that the tanks be jettisoned and another attempt at recovery be made.

3. Satisfactory recoveries will be obtained from inverted spins by rapid full rudder reversal.

4. Moving the center of gravity forward of normal approximately 5 percent of the mean aerodynamic chord or extending the speed brakes will have little effect on the spin and recovery characteristics of the airplane.

5. For emergency recovery from demonstration spins, the use of a 16.7-foot-diameter (full-scale) flat-type tail parachute having a drag coefficient of approximately 0.63 with a towline length of approximately 21 feet or a 10-foot-diameter (full-scale) flat-type wing-tip parachute having a drag coefficient of approximately 0.72 with a towline length up to approximately 7 feet will terminate effectively any unexpected flat spin that might be obtained.

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fgs

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE

MCDONNELL F2H-3 AIRPLANE

| | |
|---|---|
| Over-all length, ft | 48.04 |
| Wing: | |
| Span, ft | 41.7 |
| Area, sq ft | 294.0 |
| Section, wing-fold | NACA $65_1$-212 |
| Incidence, deg | -0.5 |
| Aspect ratio | 5.9 |
| Dihedral, deg | 3.0 |
| Mean Aerodynamic Chord, in. | 88.4 |
| Leading edge of $\bar{c}$ aft of leading of root chord, in. | 0 |
| Ailerons: | |
| Mean chord rearward hinge line, ft | 1.24 |
| Span, percent b/2 | 32.8 |
| Horizontal tail surfaces: | |
| Total area, sq ft | 70.1 |
| Span, ft | 17.8 |
| Elevator area, aft hinge line, sq ft | 18.7 |
| Distance from $0.256\bar{c}$ to elevator hinge line, ft | 24.0 |
| Dihedral, deg | 10.0 |
| Vertical tail surfaces: | |
| Total area, sq ft | 39.9 |
| Rudder area aft hinge line, sq ft | 9.6 |
| Distance from $0.256\bar{c}$ to rudder hinge line, ft | 22.2 |
| Tail-damping power factor | 0.000145 |
| Tail-damping ratio | 0.0096 |
| Side-area moment factor | 0.6 |

[redacted]

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS POSSIBLE FOR THE McDONNELL F2H-3 AIRPLANE

[Moments of inertia are about center of gravity]

| Number | Loading | Weight (lb) | $\mu$ | | Center-of-gravity location | | Moments of inertia (slug-ft$^2$) | | | Mass parameters | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sea level | 15,000 ft | $x/\bar{c}$ | $z/\bar{c}$ | $I_X$ | $I_Y$ | $I_Z$ | $\frac{I_X - I_Y}{mb^2}$ | $\frac{I_Y - I_Z}{mb^2}$ | $\frac{I_Z - I_X}{mb^2}$ |
| Original Airplane Values | | | | | | | | | | | | |
| 1 | Take-off (Clean condition) | 20,762 | 22.1 | 35.2 | 25.7 | 17.5 | 15,145 | 41,677 | 54,616 | $-237 \times 10^{-4}$ | $-116 \times 10^{-4}$ | $353 \times 10^{-4}$ |
| 2 | Combat (Clean condition) | 17,330 | 18.5 | 29.4 | 24.5 | 20.5 | 14,620 | 39,606 | 52,131 | -267 | -134 | 401 |
| 3 | Take-off plus empty tip-tanks (Estimated) | 21,165 | 22.6 | 35.8 | 25.7 | 19.8 | 20,976 | 41,775 | 60,526 | -182 | -164 | 346 |
| 4 | Take-off plus full tip-tanks (Estimated) | 22,782 | 24.3 | 38.6 | 25.6 | 17.7 | 44,579 | 42,124 | 84,496 | +20 | -345 | 325 |
| Revised Airplane Values | | | | | | | | | | | | |
| 1 | Take-off (Clean condition) | 20,762 | 22.1 | 35.2 | 25.4 | 17.5 | 14,335 | 44,122 | 55,490 | -266 | -102 | 368 |
| 2 | Combat (Clean condition) | 17,330 | 18.5 | 29.4 | 23.6 | 20.5 | 13,625 | 41,914 | 53,000 | -303 | -119 | 422 |
| 3 | Take-off plus empty tip-tanks (Estimated) | 21,165 | 22.6 | 35.8 | 25.3 | 19.8 | 20,157 | 44,210 | 61,399 | -211 | -151 | 362 |
| 4 | Take-off plus full tip-tanks (Estimated) | 22,782 | 24.3 | 38.6 | 25.2 | 17.7 | 43,769 | 44,569 | 85,370 | -7 | -332 | 339 |

[redacted]

TABLE III.- SPIN-RECOVERY-PARACHUTE DATA OBTAINED WITH A $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE

[Take-off loading (loading 1 in table II and fig. 5); rudder fixed full with the spin and recovery attempted by opening the parachute only; model values converted to corresponding full-scale values; right erect spins]

| Parachute diameter (ft) | Towline length (ft) | Ailerons | Elevator | V (fps) | α (deg) | Ω (rps) | Turns for recovery |
|---|---|---|---|---|---|---|---|
| Tail parachute $(C_D = 0.63)$ | | | | | | | |
| 15 | 20.7 | Right 30° down<br>Left 40° up | 35° Down | 233 | 63.0 | 0.34 | 2, ∞ |
| 16.7 | 20.7 | Right 30° down<br>Left 40° up | 35° Down | 233 | 63.0 | 0.34 | $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{3}{4}$ |
| 18.3 | 20.7 | Right 30° down<br>Left 40° up | 35° Down | 233 | 63.0 | 0.34 | $\frac{1}{4}$, $\frac{1}{4}$ |
| Outboard wing-tip parachute $(C_D = 0.72)$ | | | | | | | |
| 8.3 | 12.4 | Right 30° down<br>Left 40° up | 35° Down | 233 | 63.0 | 0.34 | $>2\frac{1}{4}$, $3\frac{1}{2}$ |
| 10 | 6.97 | Right 30° down<br>Left 40° up | 35° Down | 233 | 63.0 | 0.34 | $1\frac{1}{2}$, $1\frac{1}{2}$, 2, 2, |
| 10 | 1.0 | Right 30° down<br>Left 40° up | 35° Down | 233 | 63.0 | 0.34 | 1, 1, 1, $1\frac{3}{4}$ |

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CHART I.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE IN THE TAKE-OFF CONDITION

[Loading point 1 on table II and figure 5; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

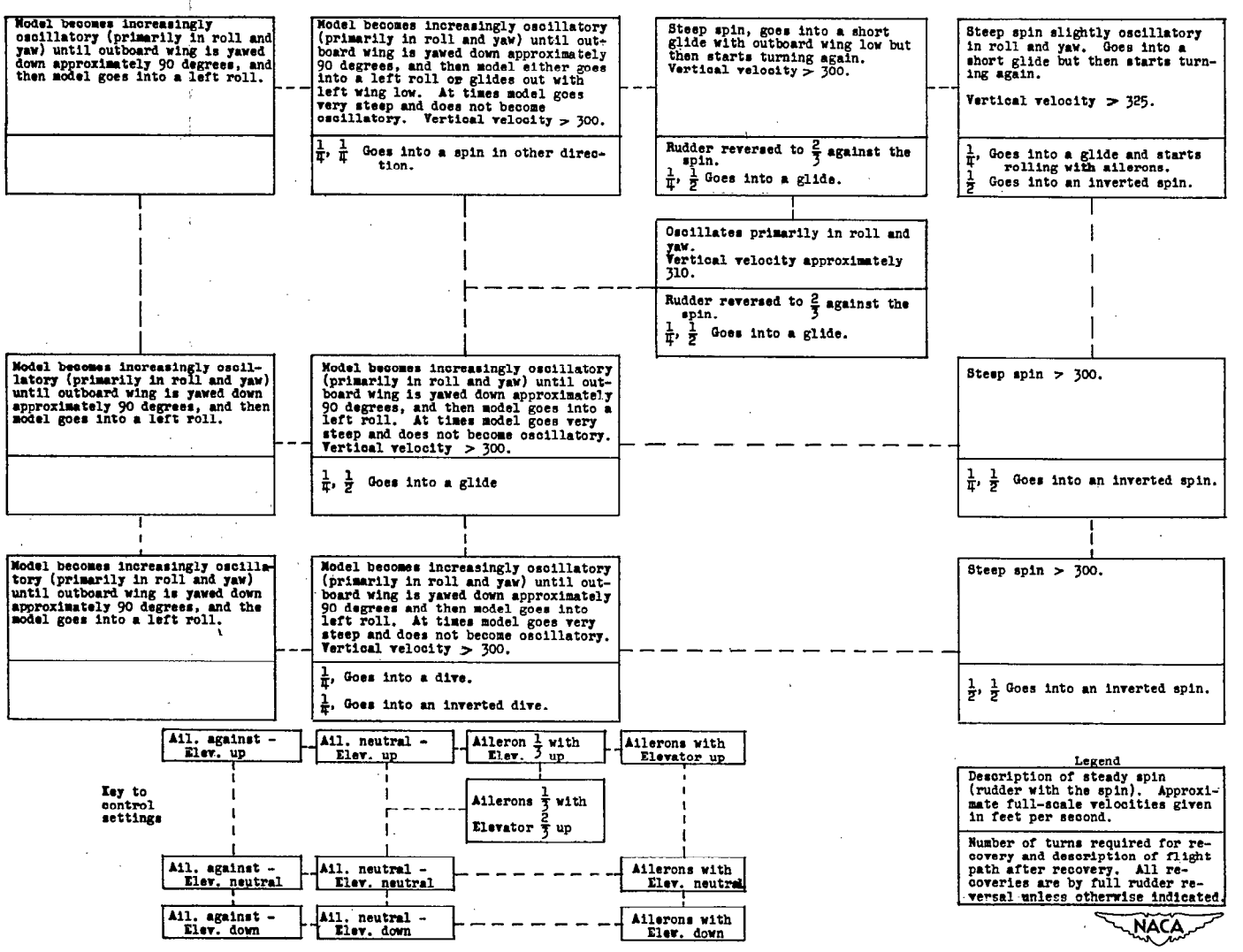
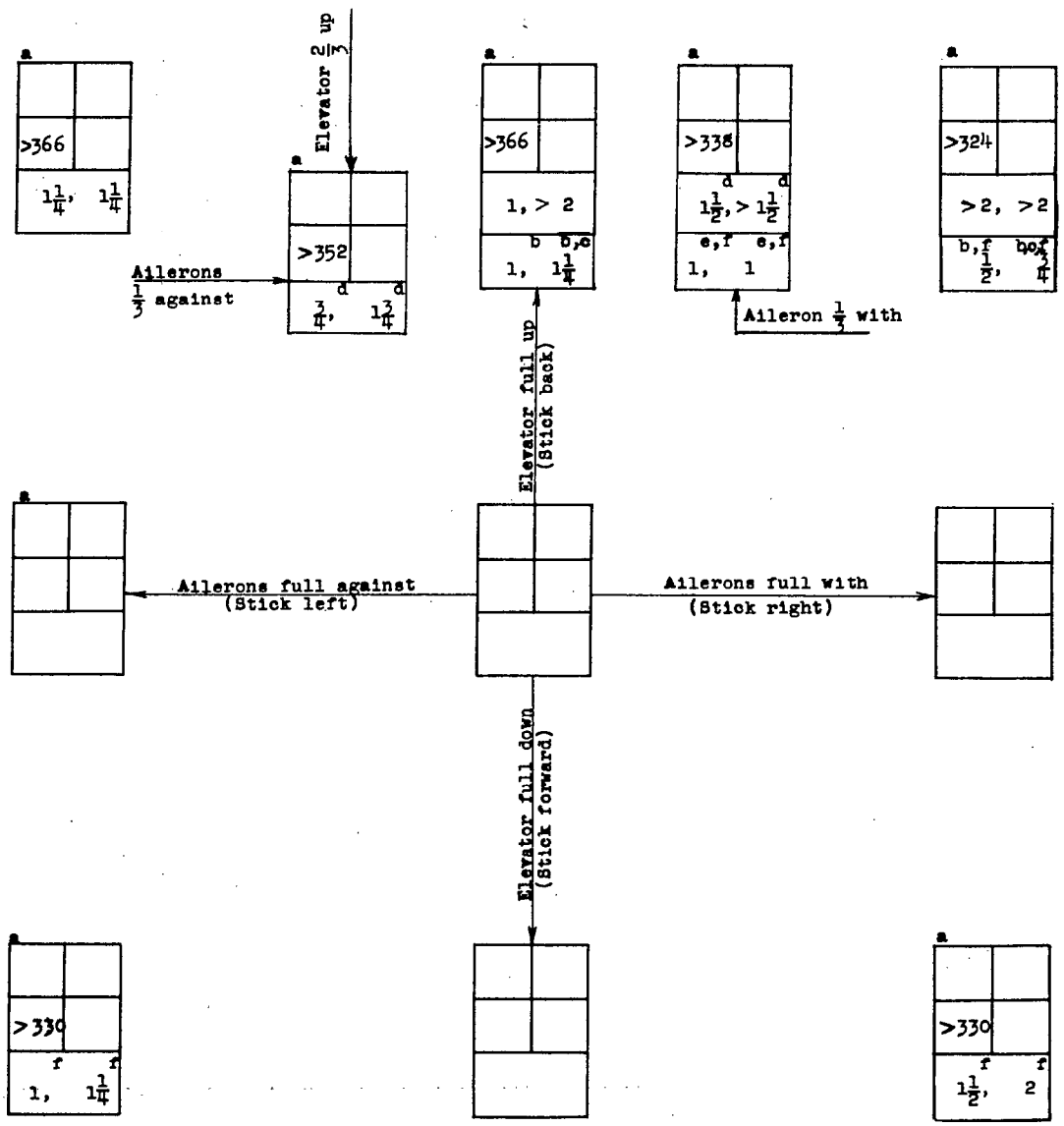


CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH THE WING-TIP TANKS FULLY LOADED

[Loading point 4 on table II and figure 5; flaps neutral; cockpit closed; recovery attempted by rapid rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]




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

[b]Recovery attempted by simultaneous full reversal of the rudder and elevator

[c]Visual estimate

[d]Recovery attempted by reversal of rudder from full with to $\frac{2}{3}$ against the spin

[e]Recovery attempted by simultaneous reversal of the rudder from full with to $\frac{2}{3}$ against the spin and the elevator from full up to $\frac{2}{3}$ down

[f]Model recovered by going into an inverted spin

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

| | |
|---|---|
| $\alpha$ (deg) | $\phi$ (deg) |
| V (fps) | $\Omega$ (rps) |
| Turns for recovery | |

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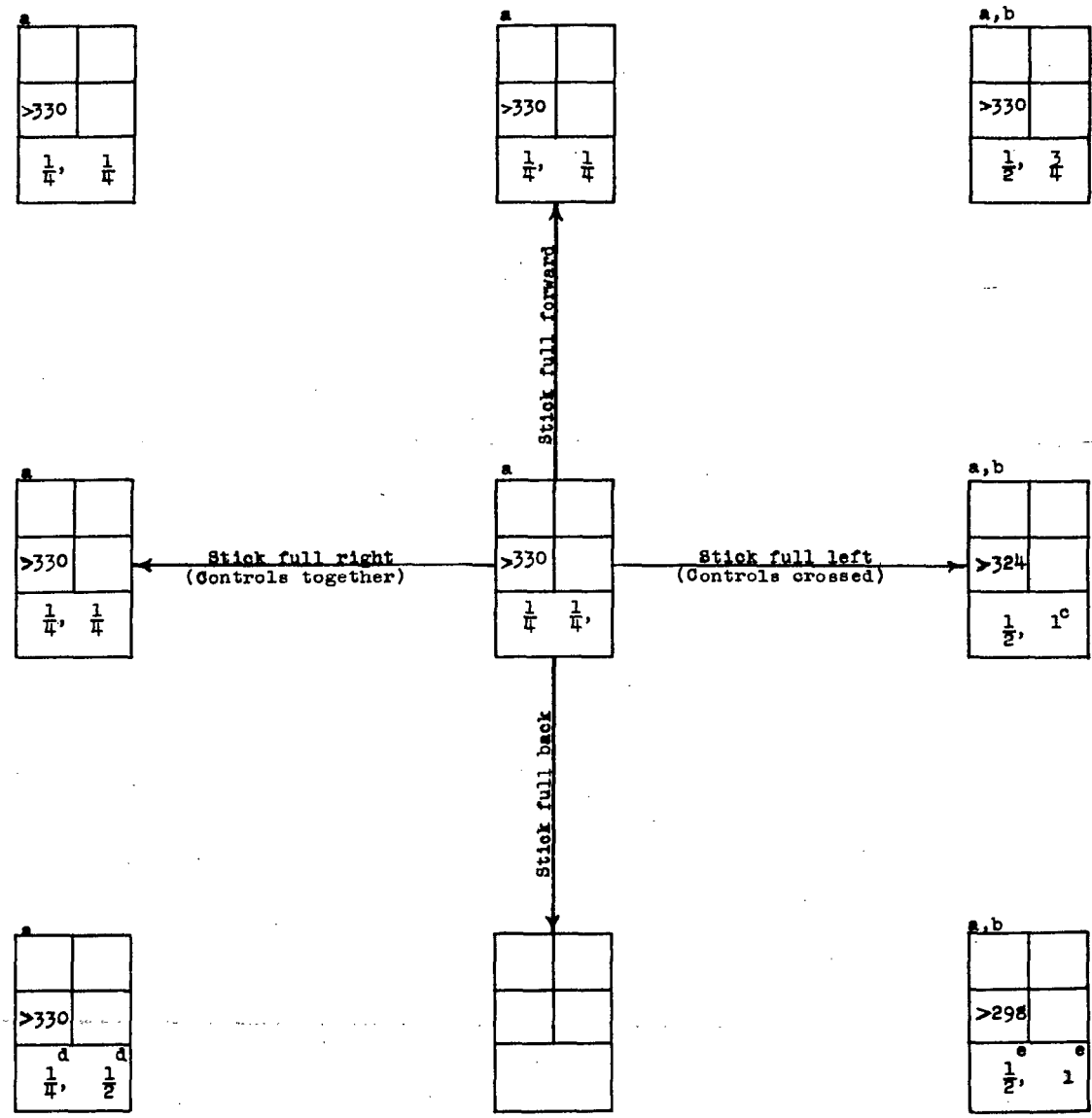
CHART 3.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE MCDONNELL F2H-3 AIRPLANE IN THE TAKE-OFF LOADING

[Loading point 1 on table II and fig. 5; flaps neutral; cockpit closed; recovery attempted by rapid rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); spins to pilot's right]




[a]Recovery attempted before model in final, steeper attitude
[b]Model wanders somewhat
[c]Visual estimate
[d]Model recovered erect and rolled right
[e]Model recovered in erect 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 | |

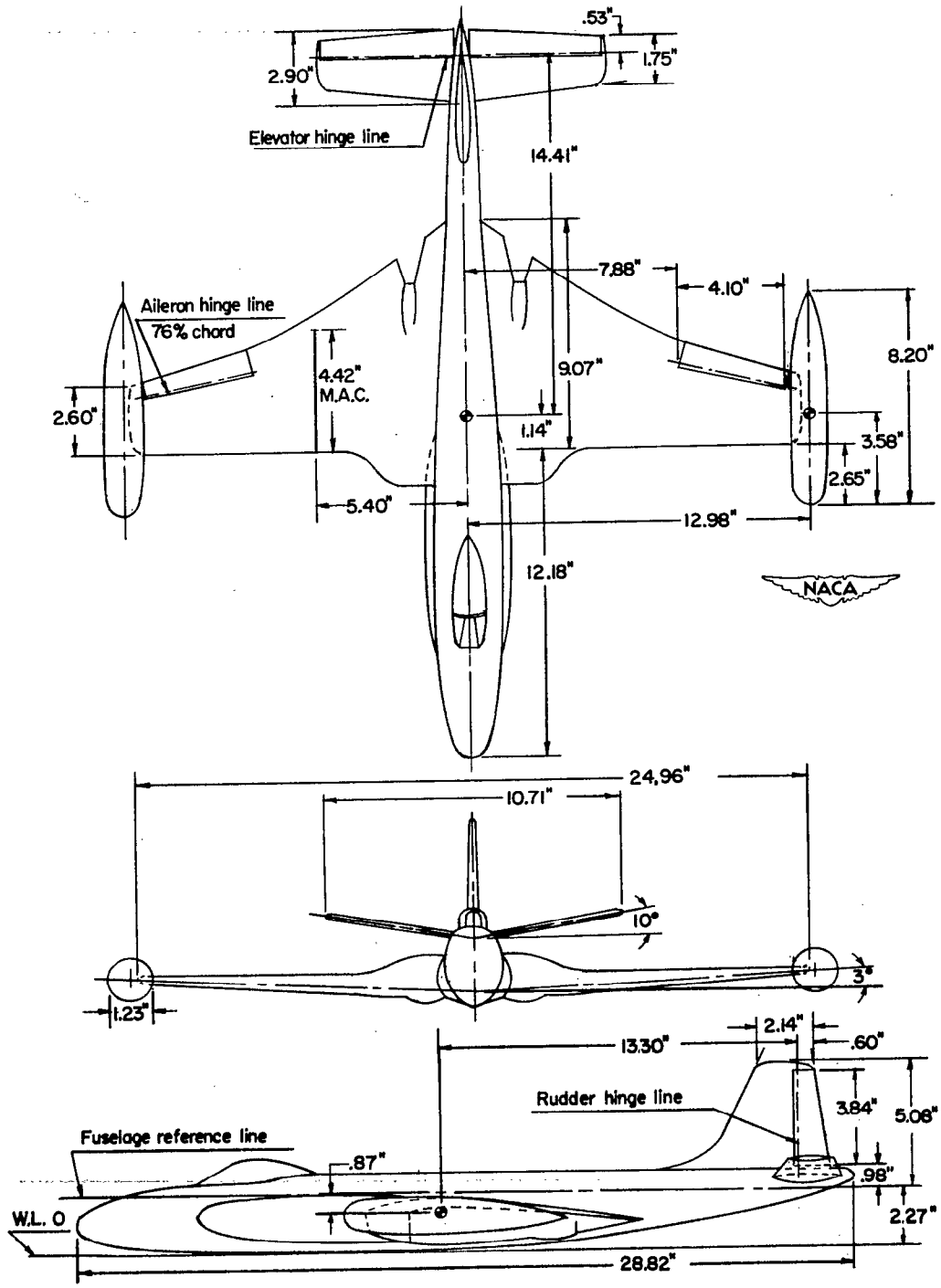



Figure 1.- Three-view drawing of the $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane as tested in the free-spinning tunnel. Center of gravity is indicated for the take-off plus full wing-tip tank loading.

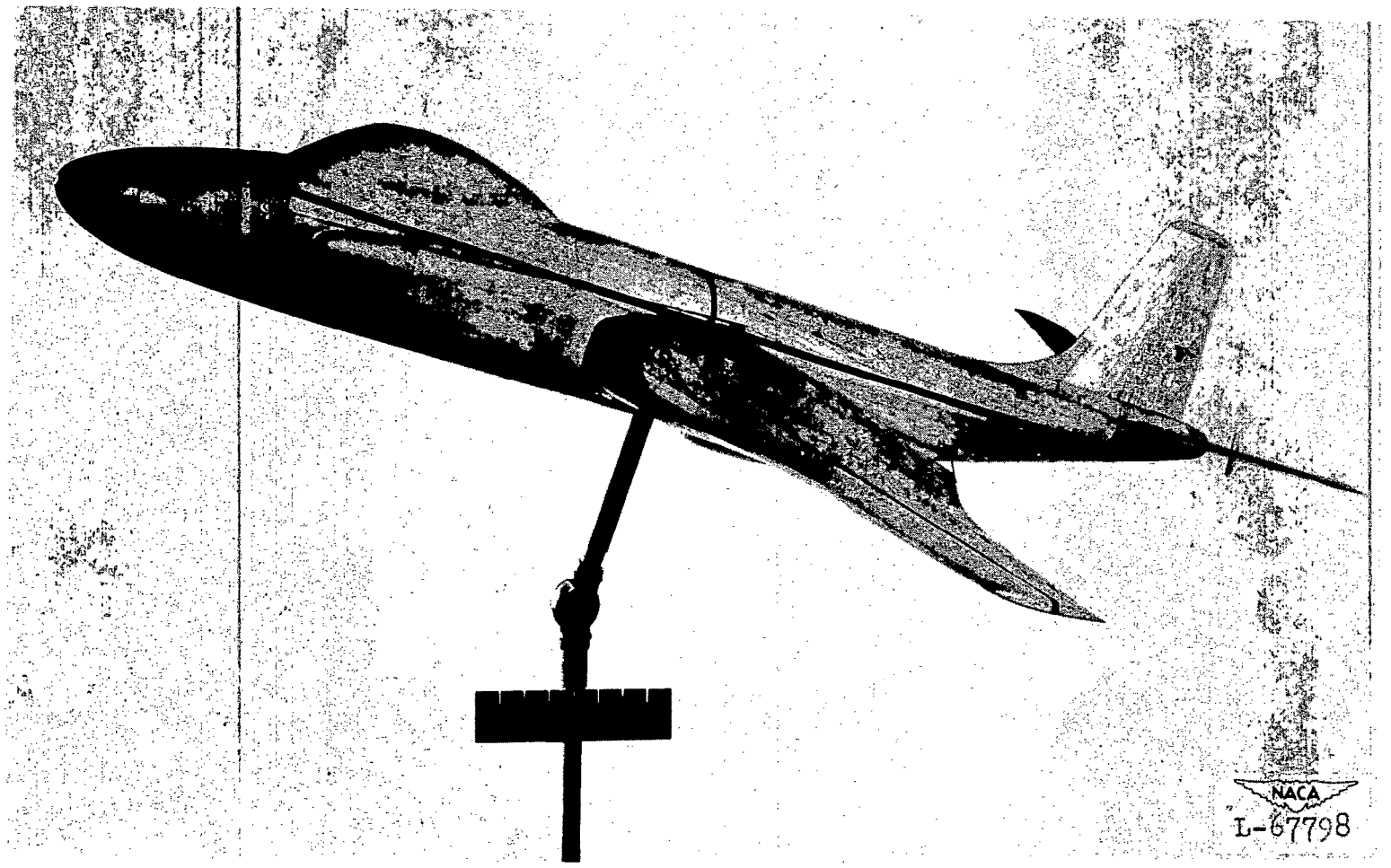



Figure 2.- Photograph of the $\frac{1}{20}$- scale model of the McDonnell F2H-3 airplane in the clean condition.

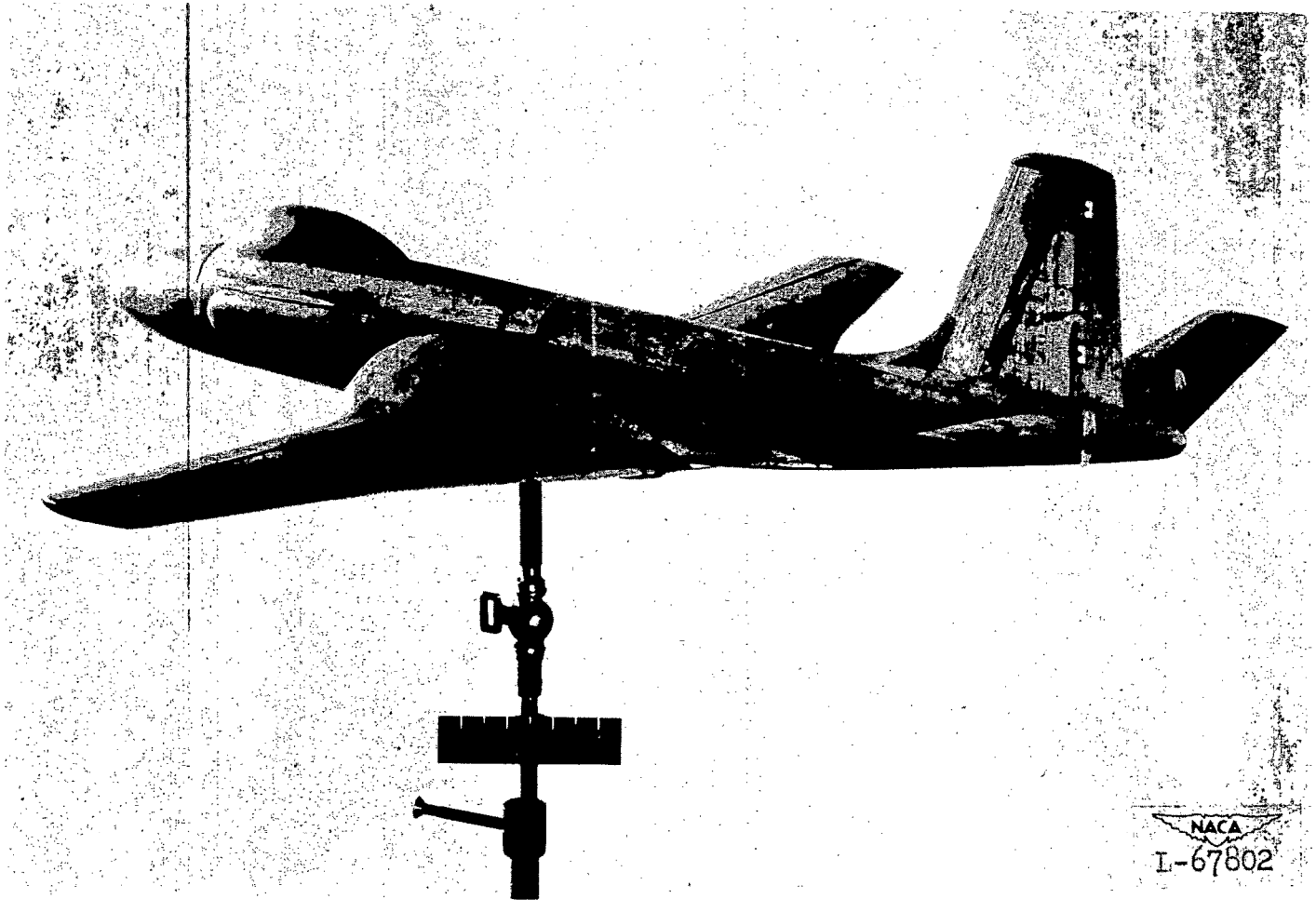



Figure 2.- Concluded.

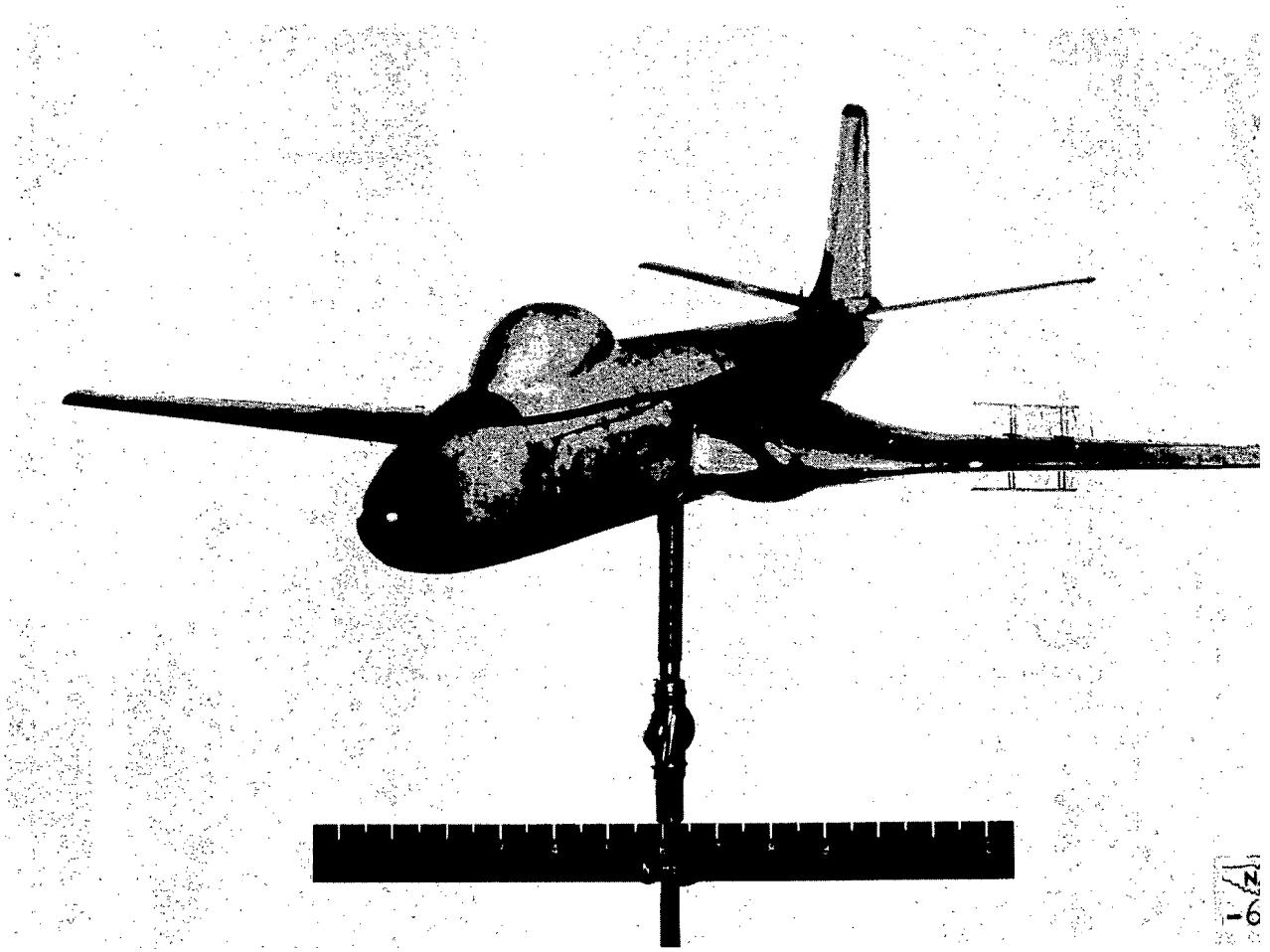


Figure 3.- Photograph of the $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane with speed brakes installed.

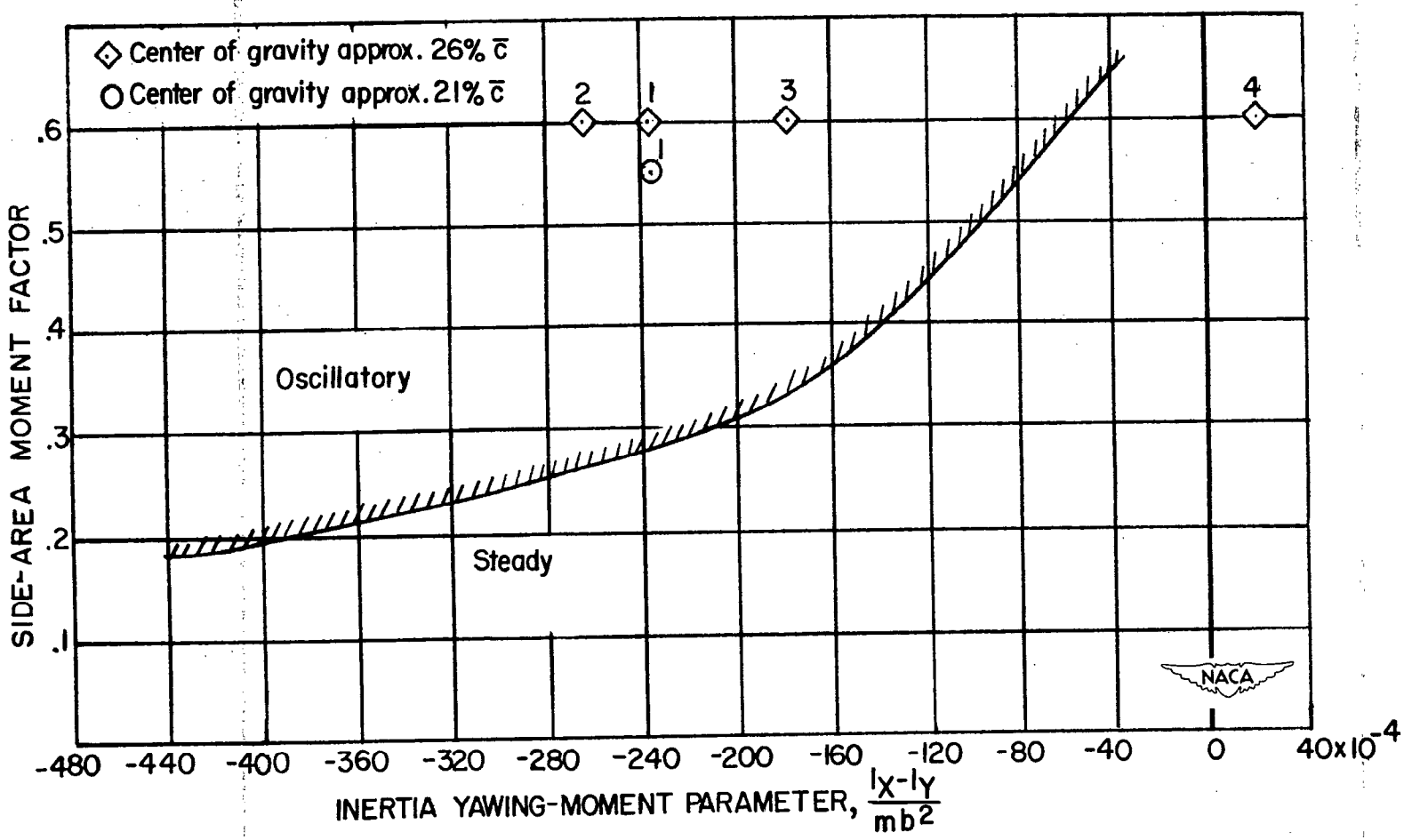



Figure 4.- Effect of side-area moment factor and inertia yawing-moment parameter on the nature of the spin of the $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane. (Points are for original airplane values listed in table II.)

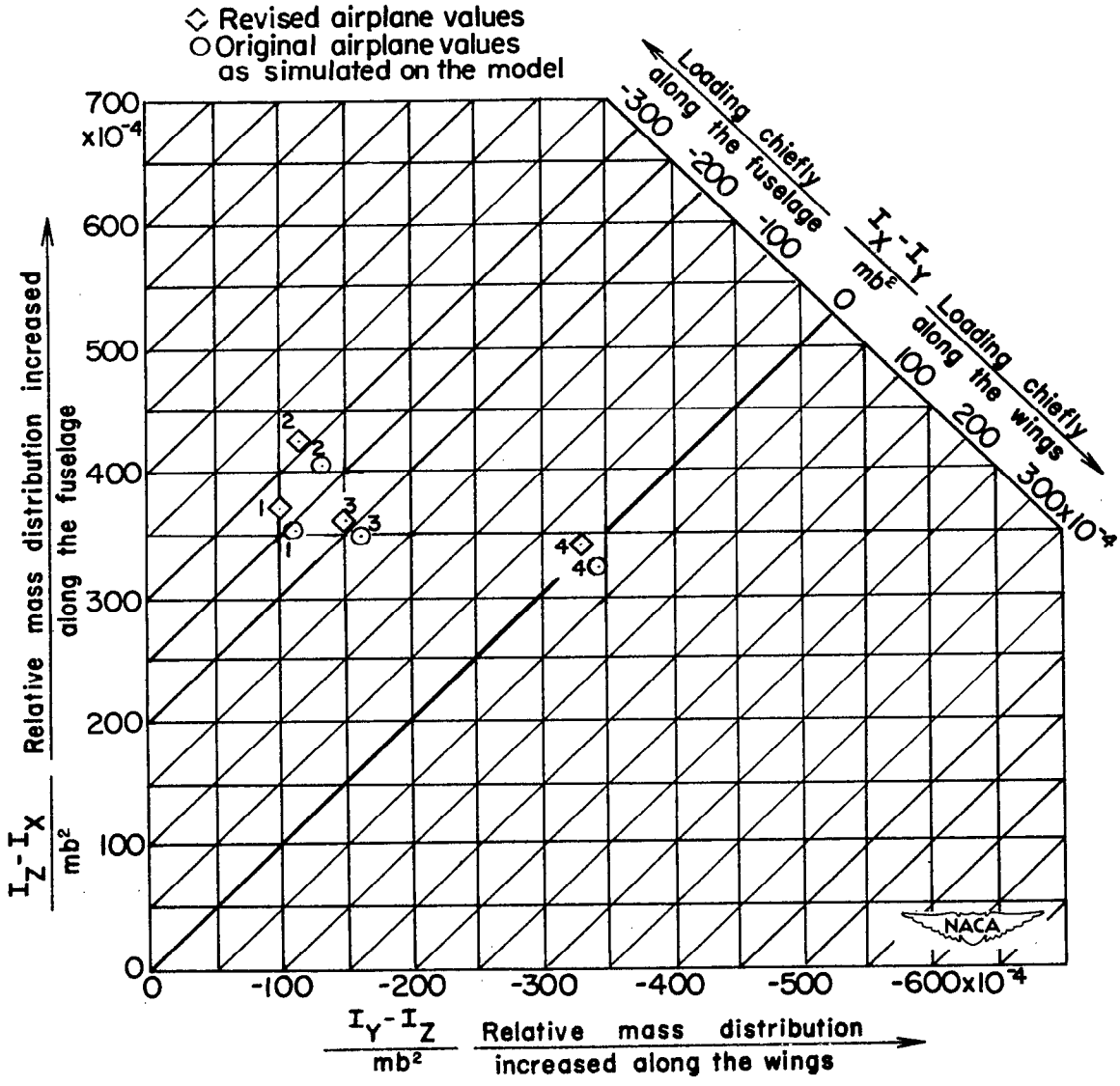



Figure 5.- Mass parameters for loadings possible on the F2H-3 airplane.

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