# NACA

# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

## FREE-SPINNING-TUNNEL INVESTIGATION OF A 0.034-SCALE MODEL OF THE PRODUCTION VERSION OF THE CHANCE VOUGHT F7U-3 AIRPLANE

TED NO. NACA AD 3103

By Walter J. Klinar and Frederick M. Healy

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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## SUMMARY

An investigation of a 0.034-scale model of the production version of the Chance Vought F7U-3 airplane has been conducted in the Langley 20-foot free-spinning tunnel. The inverted and erect spin and recovery characteristics of the model were determined for the combat loading with the model in the clean condition and the effect of extending slats was investigated. A brief investigation of pilot ejection was also performed.

The results indicate that the inverted spin-recovery characteristics of the airplane will be satisfactory by full rudder reversal. If the rudders can only be neutralized because of high pedal forces in the inverted spins, satisfactory recovery will be obtained if the auxiliary rudders can be moved to neutral or against the spin provided the stick is held full forward. Optimum control technique for satisfactory recovery from erect spins will be full rudder reversal in conjunction with aileron movement to full with the spin (stick right in a right spin). Extension of the slats will have a slightly adverse effect on recoveries from inverted spins but will have a favorable effect on recoveries from erect spins. The results of brief tests indicate that if a pilot is ejected during a spin while a spin-recovery parachute is extended and fully inflated, he will probably clear the tail parachute.

[redacted]

## INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, a spin investigation has been made in the Langley 20-foot free-spinning tunnel of a 0.034-scale model of the production version of the Chance Vought F7U-3 airplane. The production version differs from the prototype version previously tested in the spin tunnel and reported in reference 1 primarily in that the nose has been shortened, the tailcone has been extended, the deflection of the ailavators (the surfaces used for lateral and longitudinal control) has been decreased, and the canopy outline has been modified.

The primary purpose of the investigation was to investigate various recovery procedures from inverted spins. The erect spin and recovery characteristics of the model were also investigated. Tests were conducted for various settings of the auxiliary rudders with the slats both retracted and extended. At the request of Chance Vought Aircraft, brief tests were conducted wherein the pilot was ejected while the model was spinning with a spin-recovery tail parachute fully opened. The model was in the combat loading condition for all tests.

## SYMBOLS

| | |
|---|---|
| $b$ | wing span, ft |
| $S$ | wing area, sq ft |
| $\bar{c}$ | mean aerodynamic chord, ft |
| $x/\bar{c}$ | ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord |
| $z/\bar{c}$ | ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line) |
| $m$ | mass of airplane, slugs |
| $I_X$, $I_Y$, $I_Z$ | moments of inertia about X, Y, and Z body axes, respectively, slug-ft$^2$ |
| $\frac{I_X - I_Y}{mb^2}$ | inertia yawing-moment parameter |

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

$\rho$ air density, slug/cu ft

$\mu$ relative density of airplane, $\frac{m}{\rho Sb}$

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

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

V full-scale true rate of descent, ft/sec

$\Omega$ full-scale angular velocity about spin axis, rps

## MODEL AND TEST CONDITIONS

The 0.034-scale model was furnished by the Bureau of Aeronautics and was prepared for testing by the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics. A drawing of the model as tested is shown in figure 1. The dimensional characteristics of the airplane are presented in table I.

Longitudinal and lateral control of the airplane and model is obtained from deflection of one set of control surfaces called ailavators. Hereinafter, ailavator deflections for longitudinal and lateral control will be referred to, for simplicity, as elevator deflection and aileron deflection, respectively.

A remote-control mechanism was installed in the model to actuate the controls for the recovery attempts. Sufficient torque was exerted on the controls to reverse them fully and rapidly. The auxiliary rudders were generally fixed at neutral or at their maximum deflections with or against the spin for the model tests, although for a few tests they were actuated by the remote-control mechanism. On the airplane the auxiliary rudders are operated automatically to provide artificial damping in yaw and yawing moment due to sideslip. They may also be operated manually for directional trimming.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho$ = 0.001496 slug/cu ft). Mass characteristics and mass parameters for the loadings possible on the airplane and for the combat loading condition tested on the model are presented in table II.

Inverted and erect spin and recovery tests were performed with the slats retracted and extended. For all tests the landing gear and speed brakes were retracted.

The normal maximum control deflections used in the tests (measured perpendicular to the hinge lines) were:

| | |
|---|---|
| Main rudders, deg . . . . . . . . . . . . . . . . . . | 28.3 right, 28.3 left |
| Auxiliary rudders, deg . . . . . . . . . . . . . . | 21.8 right, 21.8 left |
| Elevator, deg . . . . . . . . . . . . . . . . . . . . | 32.4 up, 11 down |
| Ailerons, deg . . . . . . . . . . . . . . . . . . . . | 16.5 up, 16.5 down |

A diagram of stick-against-ailavator position is shown in figure 2.

An appendix is included which presents a general description of the model testing technique, the precision with which model test results and mass characteristics are determined, variations of model mass characteristics occuring during tests, and a general comparison between model and airplane results.

## RESULTS AND DISCUSSION

The results of the investigation are presented in charts 1 through 10. Inasmuch as the results of spins to the right and left were similar, the data are arbitrarily presented in terms of spins to the pilot's right. For all tests, the model was in the clean condition unless otherwise noted and in the normal combat loading (model loading 1 in table II).

### Inverted Spins

The results of the inverted spin and recovery tests are presented in charts 1 through 4. For inverted spins, controls crossed for the established spin (right rudder pedal forward and stick to the left of the pilot 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 spin and the rudder is set to maintain the spin, the lateral controls aid the rolling motion; when the controls are together and the rudder is set to maintain the spin, the lateral controls oppose the rolling motion. The angle $\phi$ and the elevator position in the chart are given as up or down relative to the ground.

Slats retracted.- The results of the inverted spin tests with the model in the clean condition and the auxiliary rudders set to with, neutral, or against the spin are shown in charts 1, 2, and 3, respectively. These results are tabulated below:

| | |
|---|---|
| Nature of spin | Usually oscillatory in roll, pitch, and yaw |
| Aileron setting most favorable for recovery | Full with the spin (stick left in an inverted spin to pilot's right) |
| Longitudinal stick position most favorable for recoveries by rudder reversal | Full forward |
| Auxiliary rudder setting most favorable for recovery | Full against the spin |
| Combination of lateral and longitudinal controls most adverse for recovery by rudder reversal | Stick full back and ailerons full against (stick right in an inverted spin to pilot's right) |
| Recovery by full rudder reversal | Satisfactory, even when auxiliary rudders are maintained full with the spin. Stick should be maintained full forward |
| Recovery by rudder neutralization | Unsatisfactory when auxiliary rudders are maintained full with spin. Satisfactory when auxiliary rudders are neutral or against the spin; stick should be maintained full forward |
| Recovery by movement of auxiliary rudders from full with to full against the spin | Unsatisfactory |
| Recovery by movement of ailerons to full with the spin | With auxiliary rudders set full with the spin - unsatisfactory |
| | With auxiliary rudders set at neutral - marginal; provided the stick is pulled to and maintained full back. Otherwise, unsatisfactory |
| | With auxiliary rudders set full against the spin - satisfactory provided the stick is pulled to neutral or full back |
| | When the model recovers by use of ailerons with the spin, a spiral or aileron roll results |

The test data indicate that the best manipulation of the controls for recovery from the inverted spin, regardless of the position of the auxiliary rudder, should be as follows: full reversal of the rudder with the stick maintained laterally at neutral and longitudinally full forward. As the airplane begins to recover the stick should be pulled back to regain normal flight. If the rudder can only be neutralized for recovery because of high rudder pedal forces, the auxiliary rudders should in some manner be positioned at neutral or against the spin and the recovery procedure should be as previously indicated, that is: stick should be maintained full forward and laterally neutral after rudder neutralization until the airplane begins to recover, at this point the stick should be pulled back to regain normal flight. Use of ailerons alone as a recovery measure does not appear desirable because of the limited conditions for which model results indicated satisfactory recoveries and also because the spiral or roll that results after spin recovery may not be distinguishable from the spin by the pilot.

Slats extended.- Results of the inverted spin tests with the slats extended and auxiliary rudders at neutral are presented in chart 4. Comparison of these results with those presented in chart 2 indicates that extending the slats had little effect except for a slightly adverse effect on recoveries attempted by rudder neutralization.

## Erect Spins

Slats retracted.- Results of the erect spins with slats retracted are presented in charts 5 through 7. The test results are tabulated as follows:

| | |
|---|---|
| Nature of spin | Generally oscillatory in roll, pitch, and yaw when spins were obtained. Model would not spin with ailerons with the spin, even when auxiliary rudders were maintained full with the spin. Proneness to spin with ailerons at neutral was decreased as auxiliary rudder settings were relaxed from full with the spin settings. |
| Aileron setting most favorable for recovery | Full with the spin (stick right in an erect spin to pilot's right). |
| Longitudinal stick position most favorable for recovery | Generally little effect of longitudinal stick position on turns for recovery. Model was somewhat less inclined to spin with stick back than with stick forward. |
| Auxiliary rudder setting most favorable for recovery | Model indicated greater reluctance to spin as auxiliary rudder setting was relaxed from its full with the spin setting and deflected to against the spin. |
| Control settings most adverse for recovery | Greatest proneness to spin was obtained with ailerons full against the spin. |
| Recovery by full rudder reversal | Unsatisfactory for all auxiliary rudder settings |
| Recovery by simultaneous full reversal or neutralization of both main and auxiliary rudders from initial full-with-the-spin settings | Unsatisfactory |
| Recovery by movement of ailerons to full with the spin | Satisfactory for all auxiliary rudder settings |

The test data indicate that movement of ailerons to full with the spin is essential for recovery from erect spins. The best position of the auxiliary rudders for recovery is full against the spin, and the optimum control technique which should be utilized for recovery regardless of auxiliary rudder position is as follows: full rudder reversal in conjunction with movement of ailerons to full with the spin. During the recovery procedure the stick should be held full back to aid the pilot in recognizing recovery inasmuch as model test data indicated that a dive or a short glide followed by a roll generally existed for this stick position when the ailerons were moved to with the spin for recovery. As the airplane begins to recover the stick should be moved forward to regain normal flight. Premature forward movement of the stick may result in a rapid aileron roll which should be terminated quickly, however, by neutralization of the ailerons.

Slats extended.- Model test results with slats extended are presented in charts 8 through 10. Comparison of these data with those presented in charts 5 through 7 indicates that extending the slats had a somewhat favorable effect in that the model was less inclined to spin with slats extended than with slats retracted.

## 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 landing gear (ref. 2) indicates that extension at the landing gear should have little appreciable effect on recoveries from spins.

## Recommended Recovery Technique

Based on the results obtained with the model, the following recovery technique is recommended for the airplane in the clean condition and the combat loading.

For recovery from inverted spins, the rudders should be reversed briskly, and the stick should be neutralized laterally and pushed to its full forward position longitudinally. As the airplane begins to recover the stick should be pulled back to regain normal flight. In the event that physical limitations permit only neutralization of the rudder because of excessive rudder pedal forces, the auxiliary rudders must be moved in some manner to neutral or against the spin and the manipulation of the stick during the recovery procedure should be as indicated above.

For recovery from erect spins, the ailerons should be moved to full with the spin (stick full right on a right spin) simultaneously with rudder reversal to full against the spin. The stick should be held full back in order to aid the pilot in recognizing recovery. As the airplane begins to recover, the stick should be moved forward to regain normal flight.

## Pilot Ejection

Brief tests were conducted in the spin tunnel simulating ejection of a pilot from the cockpit during spins. The objective of these tests was to investigate whether an ejected pilot would clear the rigging and canopy of an open spin-recovery parachute if the parachute failed to make the airplane recover from a spin. The model pilot was ballasted and was ejected with sufficient force to follow a trajectory representing that of an ejected pilot. The parachute used corresponded to a full-size parachute 24 feet in diameter (laid out flat) with a combined towline and shroudline length of 70 feet and was attached to the extreme rear of the fuselage. This corresponds to the full-scale spin-recovery parachute installation. The parachute canopy was made sufficiently porous so that it did not effect recovery from erect or inverted spins and a wire hoop was placed in the canopy hem to maintain the canopy diameter at approximately 24 feet (full scale) while the model was spinning in the tunnel. The results of the brief tests indicated that a pilot ejected during a spin should clear an open tail parachute in any attitude, with the possible exception of an extremely flat and slowly rotating erect spin. For this airplane configuration, however, it is very unlikely that this combination is likely to occur. Reference 3 discusses methods by which the approximate path of a pilot jumping from a spinning airplane relative to the spinning airplane can be calculated.

## CONCLUSIONS

Based on the results of tests of a 0.034-scale model of the production version of the Chance Vought F7U-3 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane in the combat loading condition at an altitude of 15,000 feet are made:

1. In the clean condition the inverted spins will be oscillatory in roll, pitch, and yaw. The spin-recovery characteristics of the airplane from inverted spins will be satisfactory provided the following technique is used: brisk rudder reversal with the stick maintained at

neutral laterally and full forward longitudinally. As the airplane begins to recover the stick should be moved back to regain normal flight. If the rudders cannot be fully reversed because of high pedal forces and if the auxiliary rudders can be positioned at neutral or against the spin, neutralization of the main rudders and manipulation of the stick as indicated above should lead to satisfactory recoveries.

2. Erect spins may be difficult to obtain and the spins that are obtained will be oscillatory in roll, pitch, and yaw. Recovery will be satisfactory by movement of the ailerons to full with the spin (stick right in a right spin) accompanied by simultaneous full rudder reversal. The stick should be held full back until the airplane begins to recover and it should then be moved forward to regain normal flight. Recoveries by rudder reversal alone will be unsatisfactory.

3. Extending the slats will have a slightly adverse effect on recoveries from inverted spins, but will have a favorable effect on recoveries from erect spins.

4. The most favorable position of the auxiliary rudders for recovery will be full against the spin.

5. In the event that it becomes necessary for the pilot to eject during a spin while a tail parachute is attached to the airplane, the pilot will probably be thrown clear of the parachute.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 6, 1955.

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# APPENDIX

## TESTING TECHNIQUES AND PRECISION

### Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to that described in reference 4 for the Langley 15-foot free-spinning tunnel except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 4.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning-control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with moving ailerons to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model (refs. 5 and 6). 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 elevator is set at either full up or two-thirds of its full-up deflection and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which may be either against the spin (stick left in a right spin) or with the spin depending primarily on the mass characteristics of the particular model. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin, and movement of the elevator to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and stick movement to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin," with the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. Recovery characteristics of a model are generally considered satisfactory if recovery attempted from the criterion spin in any of the manners previously described is accomplished within $2\frac{1}{4}$ turns. 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 spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as greater than the velocity at the time the model hit the safety net; for example, >300 feet per second, full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude. For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin." When the turns required for recovery are in excess of 10, the result is recorded as $\infty$.

## Precision

Results determined in free-spinning-tunnel tests are believed to be true values given by models within the following limits:

| | |
|---|---|
| $\alpha$, deg | $\pm 1$ |
| $\phi$, deg | $\pm 1$ |
| V, percent | $\pm 5$ |
| $\Omega$, percent | $\pm 2$ |
| Turns for recovery obtained from motion-picture records | $\pm\frac{1}{4}$ |
| Turns for recovery obtained visually | $\pm\frac{1}{2}$ |

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

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

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

Controls are set with an accuracy of ±1°.

## Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the F7U-3 model varied from the true scaled-down values within the following limits:

| | |
|---|---|
| Weight, percent | 0 to 2 high |
| Center-of-gravity location, percent $\bar{c}$ | 0 to 1 rearward |
| Moments of inertia: | |
| $I_X$, percent | 2 high to 9 high |
| $I_Y$, percent | 1 high to 6 high |
| $I_Z$, percent | 3 high to 9 high |

## Comparison Between Model and Airplane Results

Comparison between model and full-scale results in reference 7 indicated that model tests accurately predicted full-scale recovery characteristics approximately 90 percent of the time and that 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, such as motions in the developed spin and proper recovery techniques. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 7 also indicated that generally the airplane spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding model, although the higher rate of descent was found to be generally associated with the smaller angle of attack regardless of whether it was for the model or the airplane.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE CHANCE VOUGHT

F7U-3 AIRPLANE AS SIMULATED BY THE 0.034-SCALE MODEL

| | |
|---|---|
| Overall length, ft | 43.21 |
| Wing: | |
| Span, ft | 39.72 |
| Area, sq ft | 535.3 |
| Aspect ratio | 2.94 |
| Root chord (basic wing), in. | 194.15 |
| Tip chord (basic wing), in. | 115.88 |
| $\bar{c}$, in. | 164.22 |
| Leading edge $\bar{c}$ rearward leading-edge root chord, in. | 86.51 |
| Incidence, deg | 0 |
| Dihedral, deg | 0 |
| Sweepback of quarter-chord line, deg | 35 |
| Ailavator: | |
| Span, percent b/2 | 51.2 |
| Vertical tail: | |
| Maximum height above fuselage reference line, ft | 8.70 |

[redacted]

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE CHANCE VOUGHT F7U-3 AIRPLANE AND FOR LOADING TESTED ON THE 0.034-SCALE MODEL

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

| No. | Loading | Weight (lb) | Center-of-gravity location | | Relative density $\mu$ | | Moments of inertia (slug-feet$^2$) | | | Mass parameters | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $x/\bar{c}$ | $z/\bar{c}$ | Sea level | 15,000 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 | Normal fighter, combat, gear up | 23,892 | 0.118 | -0.014 | 14.68 | 23.32 | 25,611 | 49,491 | 70,536 | $-204 \times 10^{-4}$ | $-180 \times 10^{-4}$ | $384 \times 10^{-4}$ |
| 2 | Normal fighter, takeoff, gear up | 27,060 | 0.133 | -0.014 | 16.61 | 26.41 | 28,746 | 51,001 | 75,141 | -168 | -182 | 350 |
| 3 | Normal fighter, takeoff, gear down | 27,060 | 0.120 | -0.003 | 16.61 | 26.41 | 29,408 | 51,542 | 75,020 | -167 | -177 | 344 |
| 4 | Normal fighter, landing, gear down | 21,120 | 0.127 | 0.004 | 12.97 | 20.62 | 25,968 | 46,747 | 67,030 | -201 | -196 | 397 |
| 5 | Takeoff with two 2,000-lb bombs on center section pylons and fuselage rocket pack, gear down | 32,288 | 0.121 | 0.030 | 19.84 | 31.53 | 34,614 | 53,811 | 80,340 | -121 | -168 | 289 |
| 6 | Takeoff with two sparrows on center section pylons and two sparrows on outer panel pylons, gear down | 31,657 | 0.139 | 0.008 | 19.44 | 30.90 | 43,252 | 57,399 | 94,732 | -94 | -238 | 332 |
| 7 | Clean condition, gear up | 24,770 | 0.123 | -0.012 | 15.21 | 24.17 | 26,669 | 51,468 | 72,818 | -204 | -176 | 380 |
| 8 | Clean condition plus center section pylons and empty fuselage rocket pack, gear up | 25,356 | 0.123 | -0.008 | 15.56 | 24.74 | 27,034 | 51,686 | 73,151 | -198 | -173 | 371 |
| 9 | Clean condition plus center section pylons and full fuselage rocket pack, gear up | 25,935 | 0.124 | -0.002 | 15.92 | 25.31 | 27,248 | 51,972 | 73,265 | -195 | -168 | 363 |
| | Model values | | | | | | | | | | | |
| 1 | Normal fighter, combat, gear up | 24,155 | 0.123 | 0.019 | 14.83 | 23.58 | 26,907 | 51,300 | 74,406 | $-206 \times 10^{-4}$ | $-195 \times 10^{-4}$ | $401 \times 10^{-4}$ |

[redacted]

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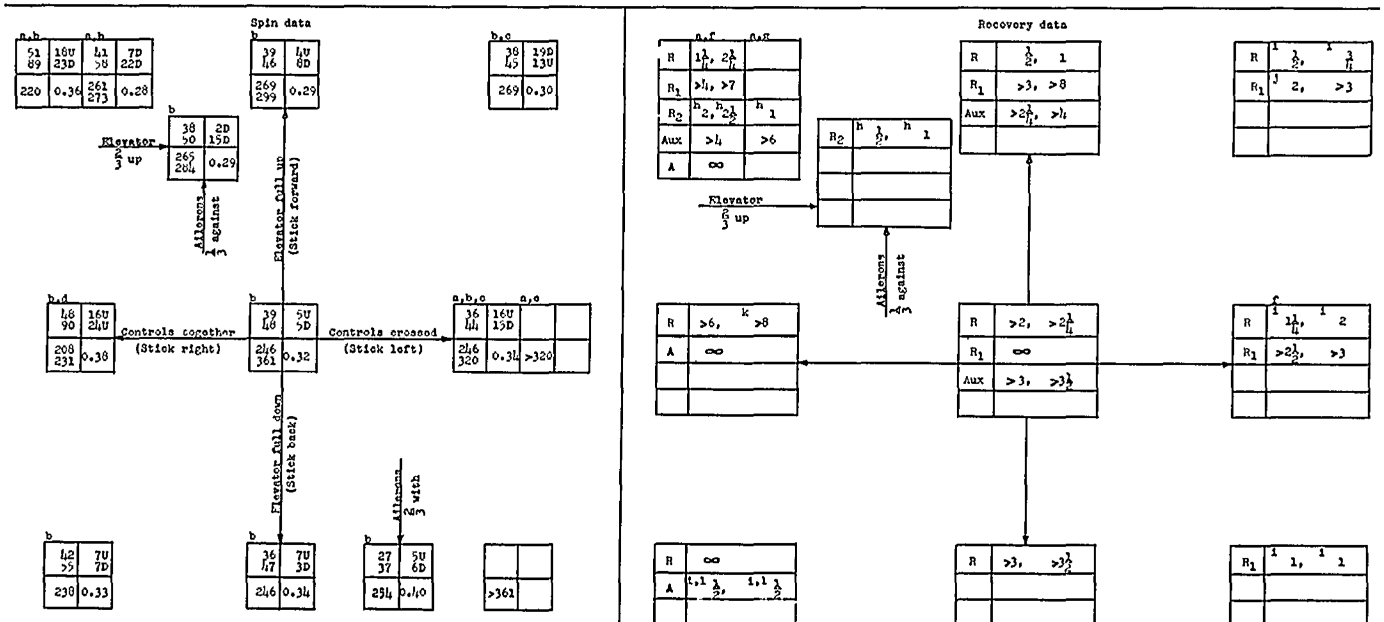
CHART 1.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS RETRACTED AND THE AUXILIARY RUDDERS WITH THE SPIN

[Model loading 1 in table II; recovery attempted by control movement as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spin); spins to pilot's right]




[a]Two conditions possible.
[b]Oscillatory spin, range of values presented.
[c]No-spin condition also obtained.
[d]Wandering spin.
[e]Very steep spin.
[f]Recovery attempted from flatter spin.
[g]Recovery attempted from steeper spin.
[h]Model entered a roll to pilot's left following recovery.
[i]Recovered in an aileron roll.
[j]After rudder neutralization model takes two more turns (as indicated) and pitches erect. Model then pitches inverted again and continues turning.
[k]Visual estimate.
[l]Recoveries appear to be critically dependent upon attaining the maximum aileron throw.

| | |
|---|---|
| α (deg) | φ (deg) |
| V (fps) | Ω (rps) |

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

| Recovery attempted by: | |
|---|---|
| R | Rudder reversal from full with to full against spin |
| $R_1$ | Rudder deflection from full with spin to neutral |
| $R_2$ | Rudder reversal from full with to 1/4 against spin |
| Aux | Auxiliary rudder reversal from full with to full against spin |
| A | Aileron movement to full with spin |

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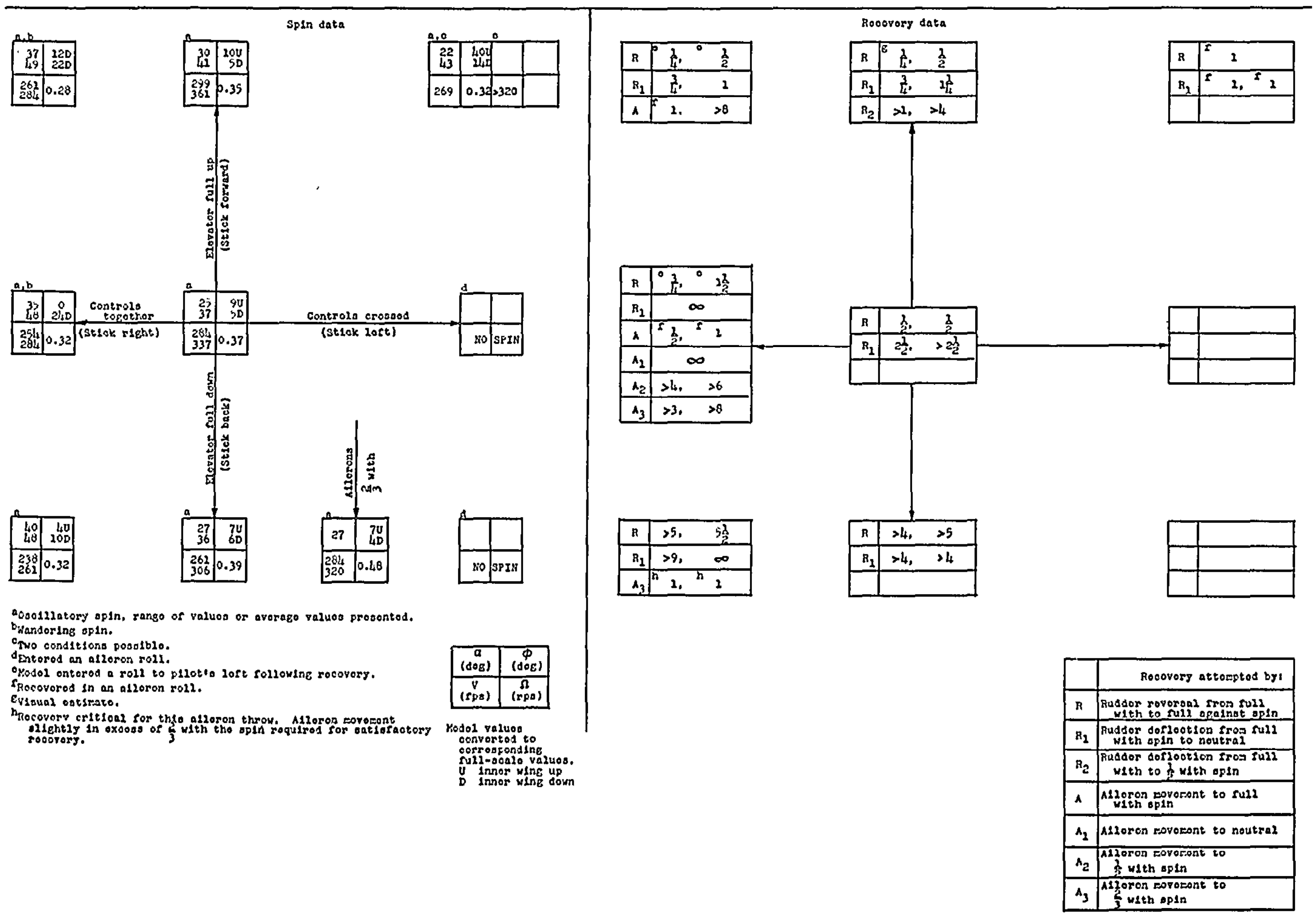
CHART 2.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS RETRACTED AND THE AUXILIARY RUDDERS NEUTRAL

[Model loading 1 in table II; recovery attempted by control movement as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]




[a]Oscillatory spin, range of values or average values presented.
[b]Wandering spin.
[c]Two conditions possible.
[d]Entered an aileron roll.
[e]Model entered a roll to pilot's left following recovery.
[f]Recovered in an aileron roll.
[g]Visual estimate.
[h]Recovery critical for this aileron throw. Aileron movement slightly in excess of 2/3 with the spin required for satisfactory recovery.

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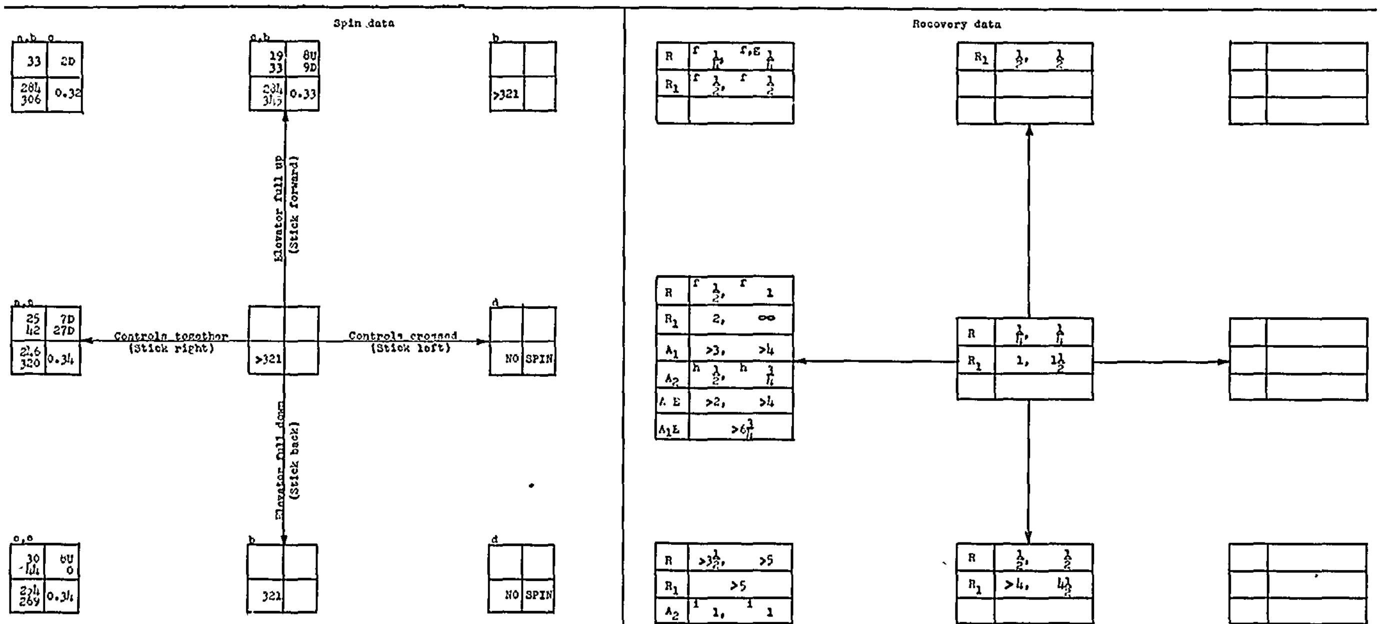
[redacted]

CHART 3.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS RETRACTED AND THE AUXILIARY RUDDERS AGAINST THE SPIN

[Model loading 1 in table II; recovery attempted by control movement as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]




[a]Whipping and wandering spin.
[b]No-spin condition also observed.
[c]Oscillatory spin, range of values presented.
[d]Entered an aileron roll.
[e]Wandering spin.
[f]Recovered in a roll to the pilot's left.
[g]Visual estimate.
[h]Recovered in a short dive followed by an aileron roll.
[i]Recovered in an aileron roll followed by an erect gliding turn.

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

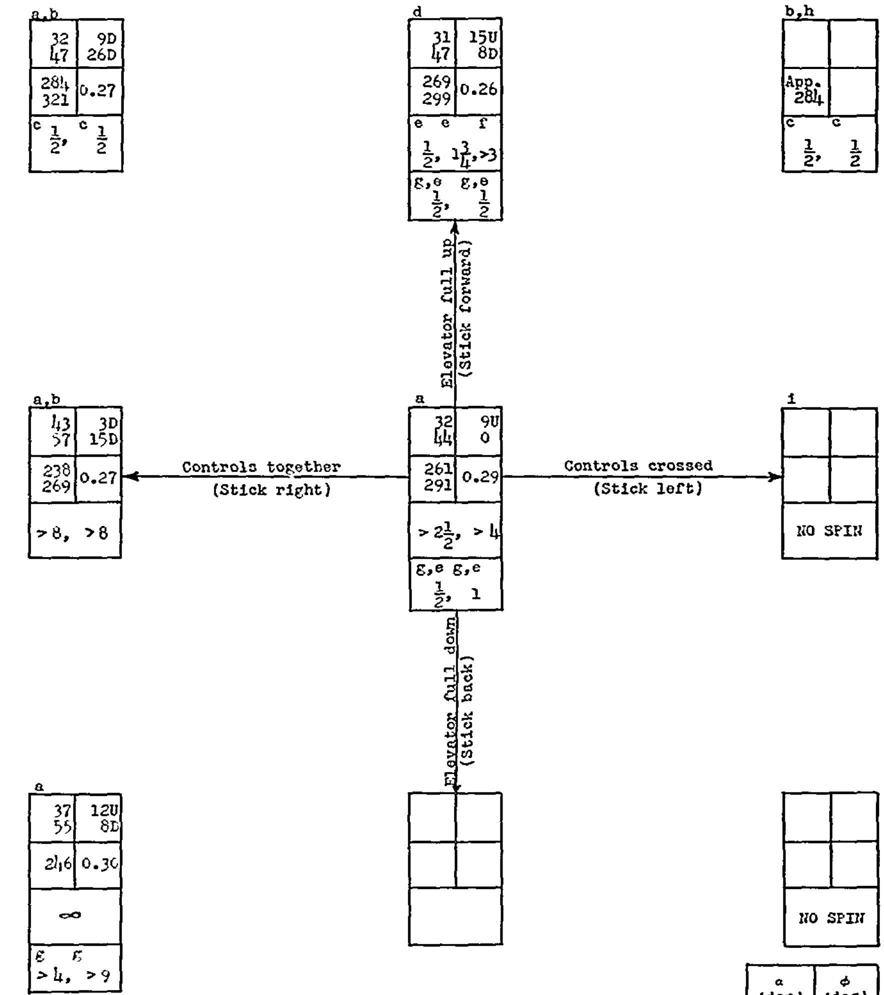
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

| Recovery attempted by: | |
|---|---|
| R | Ruddor reversal from full with to full against spin |
| $R_1$ | Rudder deflection from full with spin to neutral |
| A | Aileron movement to full with the spin |
| $A_1$ | Aileron movement to neutral |
| $A_2$ | Aileron movement to $\frac{2}{3}$ with the spin |
| E | Elevator movement to full up |

[redacted]

CHART 4.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS EXTENDED AND AUXILIARY RUDDERS NEUTRAL

[Model loading 1 in table II, recovery attempted by rudder neutralization except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]



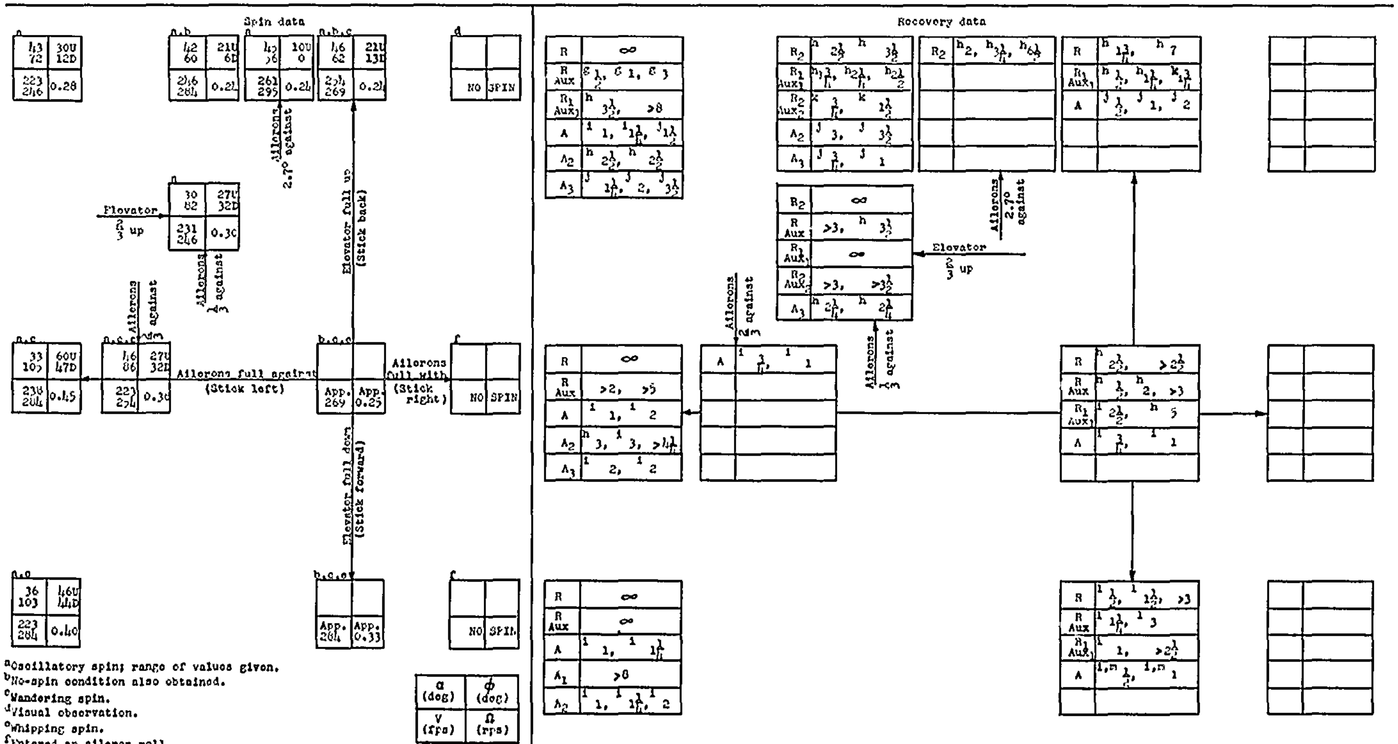

| α (deg) | φ (deg) |
|---|---|
| V (fps) | Ω (rps) |
| Turns for recovery | |

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

[a]Oscillatory spin, range of values presented.
[b]Wandering spin.
[c]Entered a roll in direction of aileron setting following recovery.
[d]Spin has both oscillatory and steady phases.
[e]Recovered in a dive.
[f]Entered a steep spin.
[g]Recovery attempted by full rudder reversal.
[h]Whipping spin.
[i]Entered a right aileron roll.

CHART 5.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS RETRACTED AND THE AUXILIARY RUDDERS WITH THE SPIN

[Model loading 1 in table II; recovery attempted by control movement as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]




[a]Oscillatory spin; range of values given.
[b]No-spin condition also obtained.
[c]Wandering spin.
[d]Visual observation.
[e]Whipping spin.
[f]Entered an aileron roll.
[g]Recovered in a dive followed by a roll.
[h]Recovered in a dive.
[i]Recovered in an aileron roll.
[j]Recovered in a short dive followed by a turn.
[k]Recovered in a dive followed by a turn in opposite direction.
[l]Recovered in an inverted dive.
[m]Visual estimate.

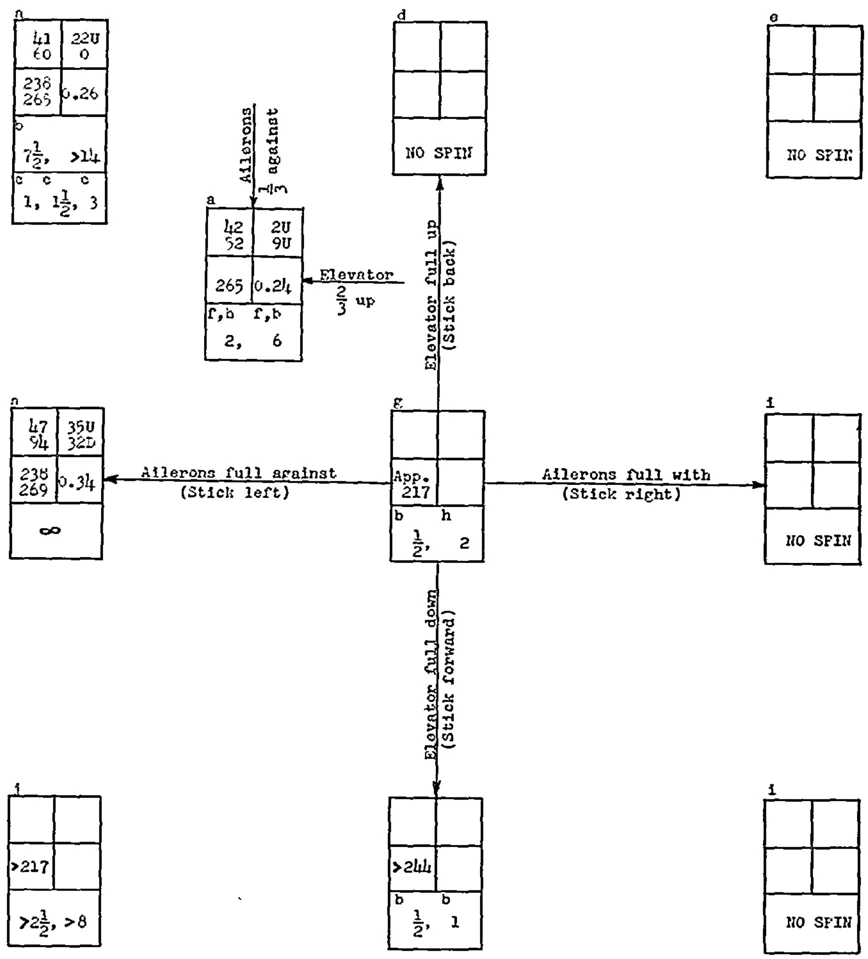
| α (deg) | φ (deg) |
|---|---|
| V (fps) | Ω (rps) |

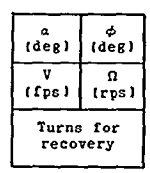
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

| Recovery attempted by: | | | |
|---|---|---|---|
| R | Rudder reversal from full with to full against the spin | $Aux_2$ | Auxiliary rudder reversal from full with to $\frac{2}{3}$ against the spin |
| $R_1$ | Rudder deflection from full with spin to neutral | A | Aileron movement to full with the spin |
| $R_2$ | Rudder reversal from full with to $\frac{2}{3}$ against the spin | $A_1$ | Aileron movement to neutral |
| Aux | Auxiliary rudder reversal from full with to full against the spin | $A_2$ | Aileron movement to $\frac{1}{3}$ with the spin |
| $Aux_1$ | Auxiliary rudder deflection from full with the spin to neutral | $A_3$ | Aileron movement to $\frac{2}{3}$ with the spin |

CHART 6.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS RETRACTED AND THE AUXILIARY RUDDERS NEUTRAL

[Model loading 1 in table II; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]



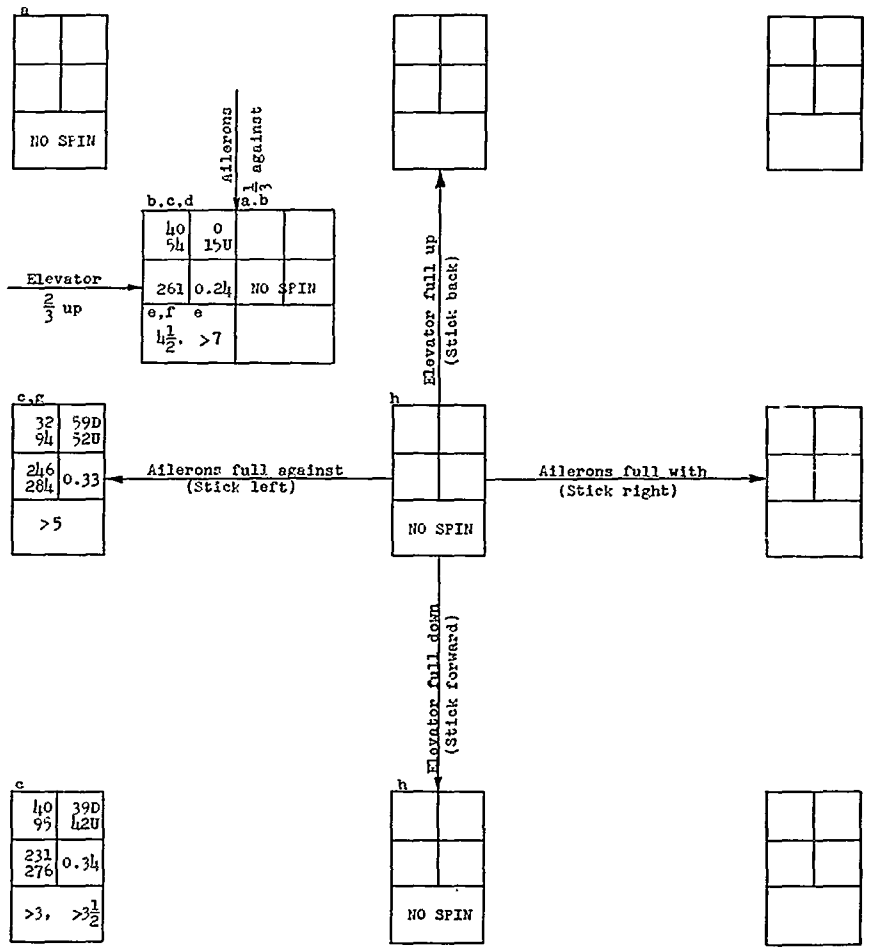




Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

[a]Oscillatory spin, range of values presented.
[b]Recovered in a dive.
[c]Recovery attempted by movement of ailerons to ⅔ with the spin.
[d]Entered a dive.
[e]Entered a dive then rolled with ailerons.
[f]Recovery attempted by rudder reversal from full with to ⅔ against the spin.
[g]Whipping and wandering spin.
[h]Recovered in a dive then went into left spin before it hit net.
[i]Entered an aileron roll.
[j]Very oscillatory and wandering spin.

CHART 7.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS RETRACTED AND THE AUXILIARY RUDDERS AGAINST THE SPIN

[Model loading 1 in table II; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]




[a]Model entered a dive.
[b]Two conditions possible.
[c]Oscillatory spin, range of values presented.
[d]Spin will not persist indefinitely.
[e]Recovery attempted by reversing the rudder from full with to $\frac{2}{3}$ against the spin.
[f]Recovered in a dive.
[g]Model sometimes rolls inverted.
[h]Model entered a vertical dive.

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

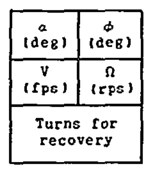
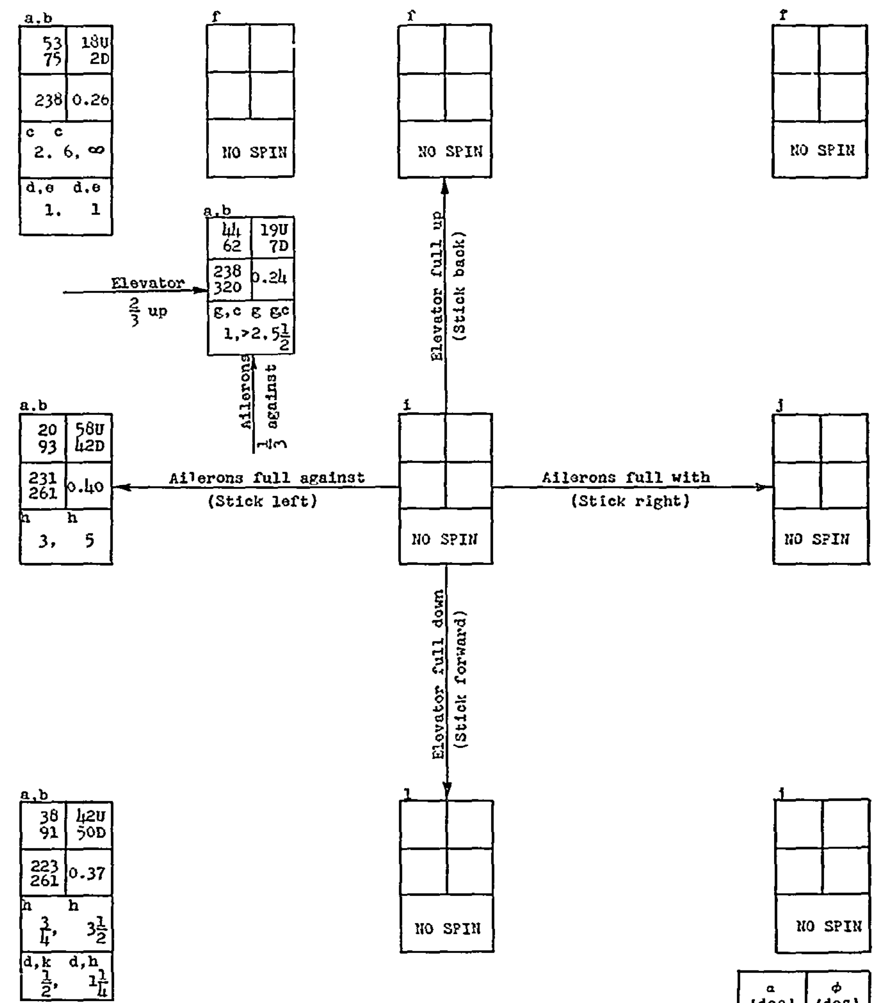


CHART 8.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS EXTENDED AND THE AUXILIARY RUDDERS WITH THE SPIN

[Model loading 1 in table II; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]



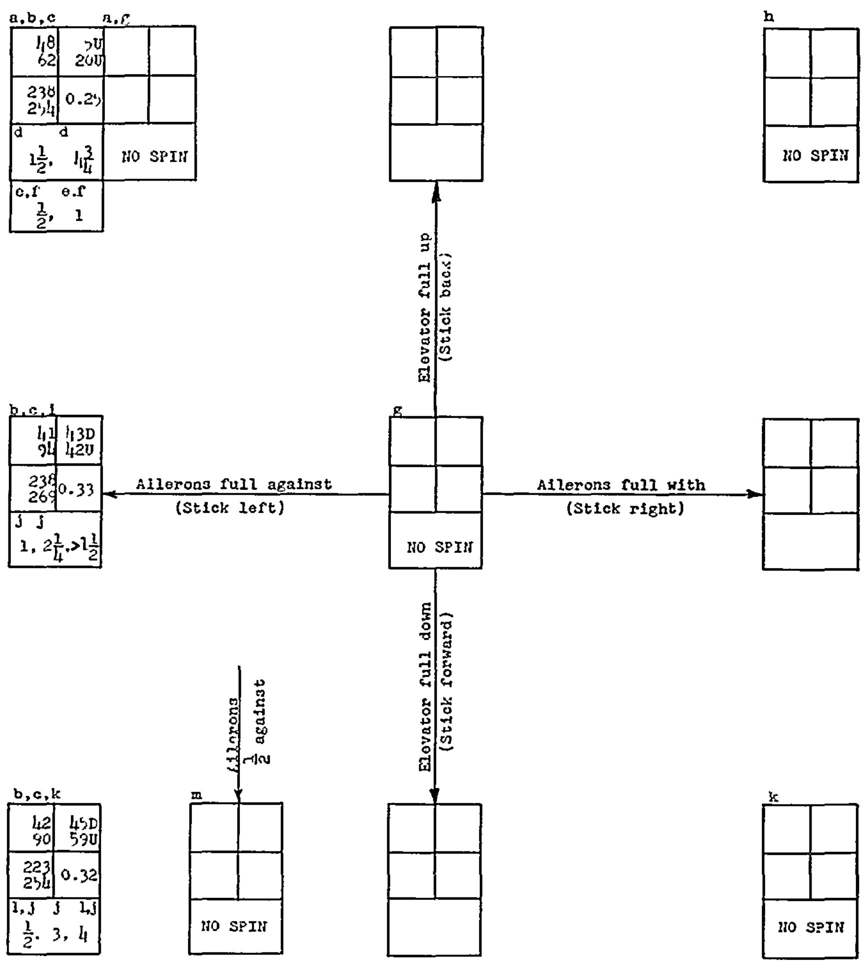

[a]Oscillatory spin, range of values presented.
[b]No-spin condition also obtained.
[c]Recovered in a dive.
[d]Recovery attempted by moving ailerons to $\frac{2}{3}$ with the spin.
[e]Recovered in a glide followed by a spiral.
[f]Entered a glide.
[g]Recovery attempted by rudder reversal from full with to $\frac{2}{3}$ against the spin.
[h]Recovered in an aileron roll.
[i]Entered a dive.
[j]Entered an aileron roll.
[k]Recovered in an inverted spin.
[l]Tends to enter a spin to the left.

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 9.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS EXTENDED AND THE AUXILIARY RUDDERS NEUTRAL

[Model loading 1 in table II; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spin to pilot's right]



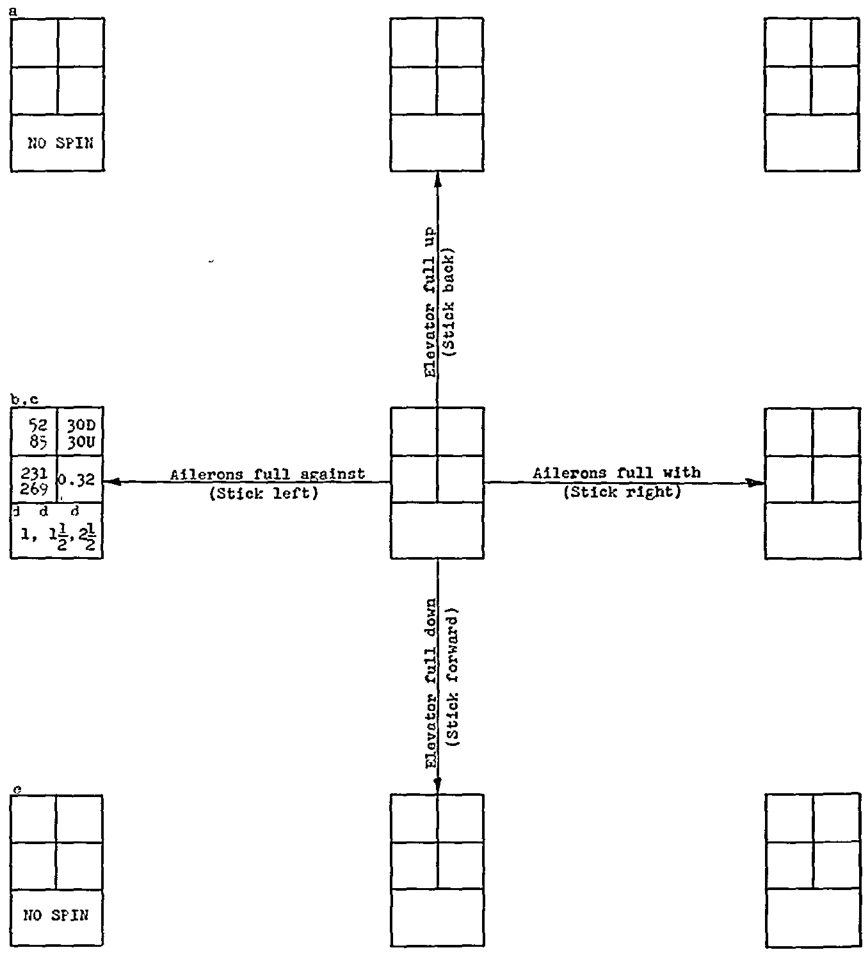

[a]Two conditions possible.
[b]Oscillatory spin, range of values given.
[c]Spin will not persist indefinitely.
[d]Recovered in a dive.
[e]Recovery attempted by reversing ailerons to $\frac{2}{3}$ with the spin.
[f]Recovered in a dive followed by a turn.
[g]Enters a dive.
[h]Enters a short dive followed by a turn or aileron roll.
[i]Model rolls inverted.
[j]Recovers in an aileron roll.
[k]Enters an aileron roll.
[l]Visual estimate.
[m]Enters an inverted 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 | |

CHART 10.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH THE SLATS EXTENDED AND THE AUXILIARY RUDDERS AGAINST THE SPIN

[Model loading 1 in table II; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]




[a]Model entered a dive.
[b]Very oscillatory, range of values given.
[c]Spin will not persist indefinitely. Model rolled inverted.
[d]Model recovered in an aileron roll.
[e]Model entered 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 | |

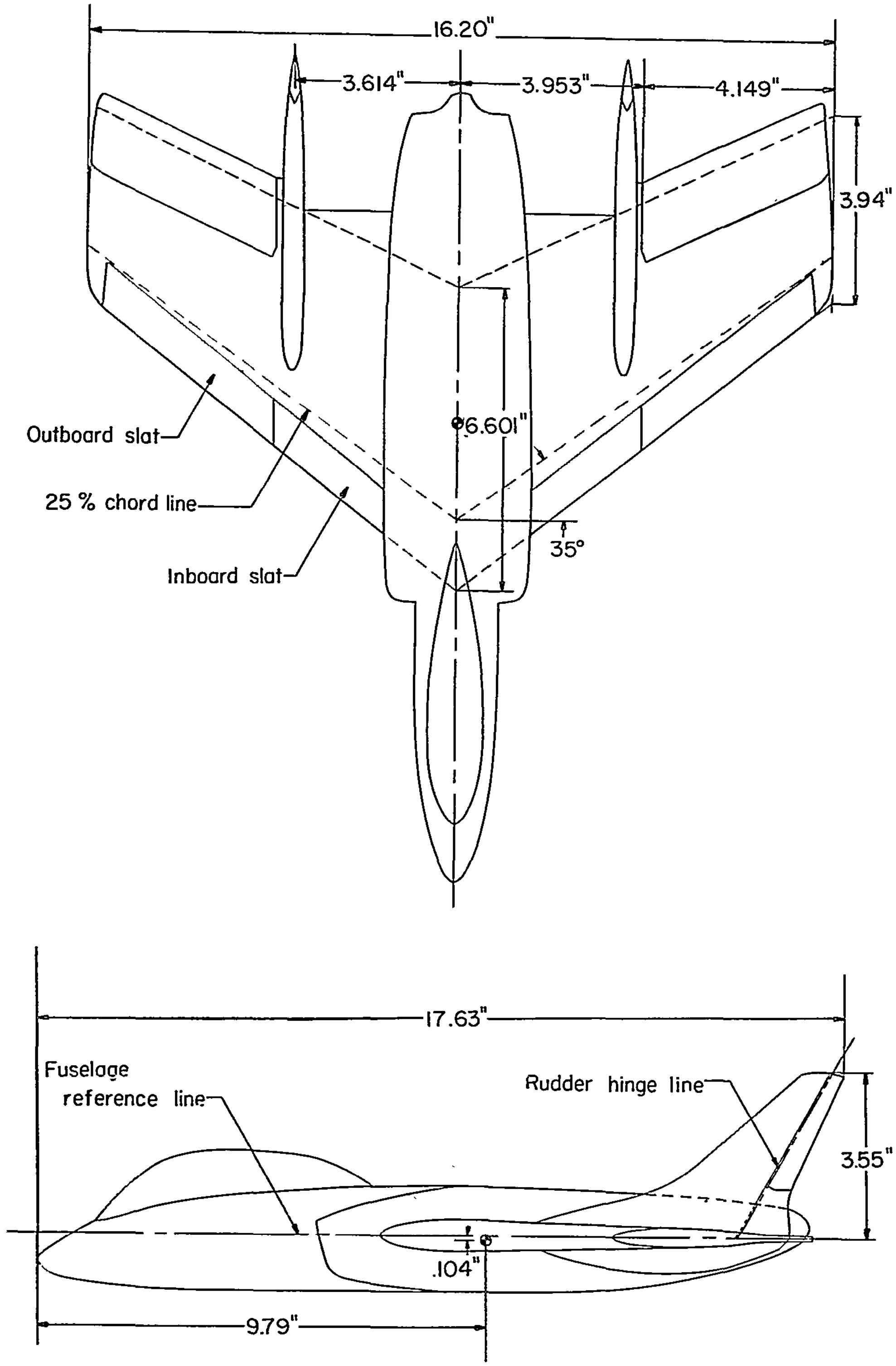



Figure 1.- Drawing of the 0.034-scale model of the Chance Vought F7U-3 airplane. Center-of-gravity position indicated is for normal fighter, combat loading.

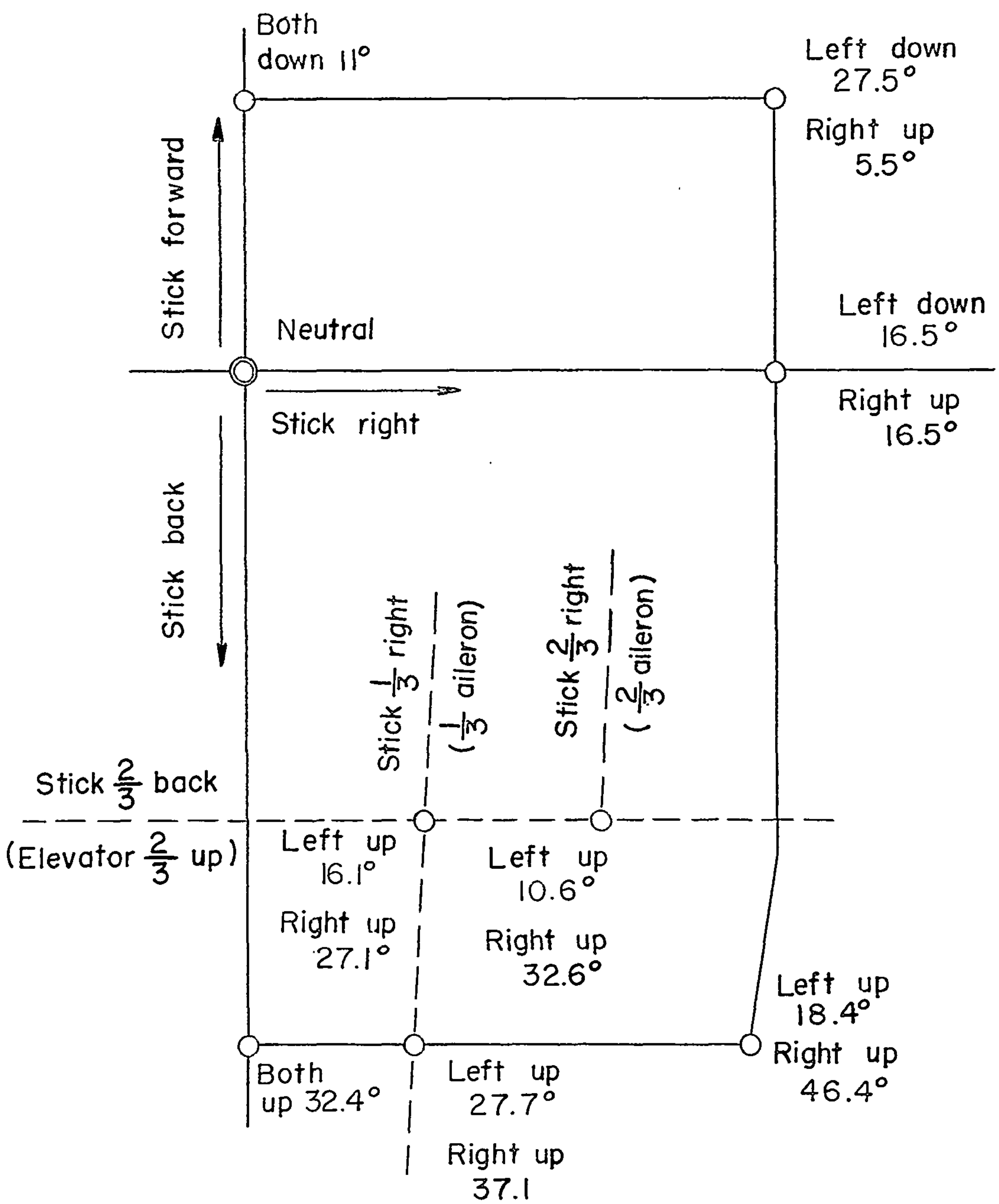



Figure 2.- Deflection of ailavator surfaces relative to control stick motion. Envelope of stick and ailavator movements shown. Ailavator position is directly proportional to control stick position; angles are measured in plane normal to hinge center line; stick travel to right is shown, left travel is symmetrical.

[redacted]