# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

## FREE-SPINNING-TUNNEL TESTS OF A 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

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 0.057-scale model of the Chance Vought XF7U-1 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 were determined, as were also the effects of extending the wing slats, of center-of-gravity movement, and of variation in the mass distribution. The investigation also included wing-tip spin-recovery-parachute tests, pilot-escape tests, and rudder-control-force tests.

The investigation indicated that the spin and recovery characteristics of the airplane will be satisfactory for all conditions. It was found that a single 4.24-foot (full-scale) parachute when opened alone from the outboard wing tip or two 8.77-foot (full-scale) parachutes when opened simultaneously, one from each wing tip, would effect satisfactory emergency recoveries (the drag coefficients of the parachutes, based on the surface area of the parachute, were 0.83 and 0.70 for the 4.24-and 8.77-foot parachutes, respectively). The towline length in both cases was 25 feet (full scale). Tests results showed that, if the pilot should have to leave the airplane during a spin, he should jump from the outboard side (left side in a right spin) of the cockpit. The rudder-control force necessary for recovery from a spin was found to be rather high but appeared to be within the upper limits of a pilot's capabilities.

## INTRODUCTION

In accordance with a request of the Bureau of Aeronautics, Navy Department, an investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a 0.057-scale model of the Chance Vought XF7U-1 airplane. The XF7U-1 is a tailless, fighter-type airplane with sweptback wings. The airplane has twin vertical tails with rudders for directional control whereas the longitudinal and lateral controls are combined into one pair of surfaces called "ailavators".

The erect and inverted spin and recovery characteristics of the model in the normal loading were determined. The effect on the spin and recovery characteristics of extending the wing slats was also determined. Tests were made on the model with the center of gravity moved rearward and with the mass retracted along the fuselage in order to find if these loading changes would have a detrimental effect on the spin and recovery characteristics. The optimum-diameter parachute which would effect satisfactory recovery by parachute action alone was determined by opening a parachute from the outboard wing tip (left tip in a right spin) alone, and by simultaneously opening parachutes from both outboard and inboard wing tips. The angles between the towlines and the free air stream were taken from moving-picture records and the loads caused by these parachutes were calculated. Pilot-escape tests and tests to determine the rudder-control force necessary to effect satisfactory recovery were also made.

## SYMBOLS

| | |
|---|---|
| $b$ | wing span, feet |
| $S$ | wing area, square feet |
| $\bar{c}$ | mean aerodynamic chord, feet |
| $x/\bar{c}$ | ratio of distance between center of gravity and leading edge of mean aerodynamic chord to mean aerodynamic chord |
| $z/\bar{c}$ | ratio of distance between center of gravity and root chord line to mean aerodynamic chord (positive when center of gravity is below root chord 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, slug per cubic foot

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

$\alpha$ angle between root chord line and vertical (approximately 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

$\sigma$ helix angle, angle between flight path and vertical, degrees (for this model, the average absolute value of the helix angle was approximately $3^{\circ}$)

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

A angle between free air stream (vertical) and spin-recovery parachute towline as viewed from rear of model (positive when towline is inclined from the vertical to the right of a plane parallel to plane of symmetry)

B angle between free air stream (vertical) and spin-recovery parachute towline as viewed from side of model (positive when towline is inclined rearward of vertical)

## APPARATUS AND METHODS

### Model

The 0.057-scale model of the XF7U-1 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. Photographs showing the model with the slats retracted and extended are presented in figure 2. The dimensional characteristics of the airplane are given in table I.

The twin rudders of the model were interconnected to give equal deflections in the same direction. As previously indicated, lateral and longitudinal control are combined in one pair of surfaces, ailavators. Longitudinal control is obtained by deflection of the ailavators together and lateral control is obtained by differential deflection of the ailavators. Hereinafter, in this report, ailavator deflections for longitudinal and lateral control will be referred to, for simplicity, as elevator and aileron deflections, respectively.

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 per cubic foot). A remote-control mechanism was installed in the model to actuate the controls or release the parachutes for the recovery attempts and also to release the pilot for the emergency pilot-escape tests. Sufficient moment was exerted on the controls to reverse them fully and rapidly for the recovery attempts.

An 0.057-scale pilot model was built and ballasted at Langley to represent the pilot and parachute (200 lb) at 15.000 feet for the pilot-escape tests.

## 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 models are now launched by hand instead of by spindle. With the controls set in the desired position, the model is launched with a spinning motion 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 a remote-control mechanism. After recovery, the model dives into a safety net. The model is retrieved, the controls reset, and another spin is made. The data obtained from these tests are converted to corresponding full-scale values by methods described in reference 1.

The turns for recovery are measured from the time the controls are moved, or the parachute is opened, until the time the spin rotation ceases and the model dives into the safety net. For the spins which had a rate of descent in excess of that which can be readily 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, > 294. For these tests, the recovery was attempted before the model reached its final steeper spin attitude and while the model was still descending in the tunnel. Such results are considered conservative, that is, recoveries will not be as rapid as those if the model had been in its final attitude. For recovery attempts for which the model did not recover, the recovery was recorded as ∞.

In accordance with standard spin-tunnel procedure, tests were made to determine the spin and recovery characteristics of the model for the normal spinning-control configuration (elevators full up, ailerons neutral, and rudders full with the spin) and at various other aileron-elevator-control combinations including zero and maximum deflections. Recovery was generally attempted by rapid full rudder reversal. Tests were 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 were set at one-third of their full deflection in the direction conducive to slower recoveries (against the spin for the XF7U-1 model on stick left in a right spin), and the elevators were set at two-thirds of their full-up deflection (stick 2/3 back). Recovery was attempted by rapidly reversing the rudders from full with the spin to only two-thirds against the spin. This control configuration and movement is referred to as the "criterion spin." The criterion adopted for a satisfactory recovery from this criterion spin in the spin tunnel is $2\frac{1}{4}$ turns or less. This value has been selected on the basis of spin-tunnel experience and on the basis of comparable full-scale spin-recovery data that are available.

The testing technique for determining the optimum size of, and towline length for, spin-recovery parachutes is described in detail in reference 2. The optimum-size wing-tip parachute for the XF7U-1 model was determined, as previously indicated, for two methods of parachute opening: (1) opening a parachute from the outboard wing tip alone, and (2) simultaneously opening a parachute from both the outboard and inboard wing tips. The packed parachute was placed on the wing in such a manner that it did not affect the steady spin before the parachute was opened. It is recommended that the parachute be packed within the wing structure for the full-scale installation and that a positive means of ejection be provided. Since no recovery control was applied during these tests, the recoveries were due to parachute action alone. The drag coefficients of the parachutes used were measured at the time of the test.

To determine from which side of the airplane the pilot should jump in order to effect an emergency escape, the pilot model was released from the inboard and outboard sides of the fuselage at the cockpit during both flat and steep spins.

The pedal force which would have to be exerted by the pilot to move the rudder for recovery from a spin was determined by adjusting the tension in the rubber band which pulls the rudder from with to against the spin for model-recovery tests to represent known hinge moments about the rudder hinge axis. These hinge moments were systematically reduced, recovery tests being performed after each reduction. At the point where the number of turns for recovery began to increase over that number normally obtained for the spin, the corresponding hinge moment was taken as the minimum which would move the rudder for optimum recovery. This hinge moment was converted to a 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 the true values given by the model within the following limits:

| | |
|---|---|
| $\alpha$, degrees . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | ±1 |
| $\phi$, degrees . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | ±1 |
| V, percent . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | ±5 |
| $\Omega$, percent . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | ±2 |
| Turns for recovery . . . . . . . . . . | ±1/4 from motion-picture records<br>±1/2 from visual observation |

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.

Comparisons between model and full-scale results (references 1 and 3) have indicated that spin-tunnel results were 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 with $5^{\circ}$ to $10^{\circ}$ more outward sideslip than did the corresponding airplanes. The comparison made in reference 3 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 full-scale data are available. It is felt, however, that if the model pilot is observed to clear all parts of the model by a large margin after being released from both steep and flat spins, then the tests indicate that the pilot can safely escape.

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 XF7U-1 model varied from the true scaled-down values within the following limits:

Weight, percent . . . . . . . . . . . . . . . . . . . . . . . . . . . 0 to 3 high
Center-of-gravity location, percent $\bar{c}$ . . . . . . . . . . . . . . . . . . 0

Moments of inertia
- $I_X$, percent . . . . . . . . . . . . . . 1 low to 1 high
- $I_Y$, percent . . . . . . . . . . . . . . . 0 to 5 high
- $I_Z$, percent . . . . . . . . . . . . . . 1 low to 4 high

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

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

Controls were set with an accuracy of ±1°.

## TEST CONDITIONS

Tests were performed for the model conditions listed in table II. The mass characteristics and inertia parameters for loadings possible on the XF7U-1 airplane and for the loadings tested on the model are shown on table III; the inertia parameters for these loadings are also plotted on figure 3. As discussed in reference 4, figure 3 can be used in predicting the relative effectiveness of the controls on the recovery characteristics of the model.

The maximum control deflections used in the tests were:

Rudders, degrees . . . . . . . . . . . . . . . . . . . . . . . 25 right, 25 left
Ailavators, degrees:
  As elevators . . . . . . . . . . . . . . . . . . . . . . . . 30 up, 20 down
  As ailerons . . . . . . . . . . . . . . . . . . . . . . . . 15 up, 15 down

Intermediate control deflections used were:

Rudders, two-thirds deflected, degrees . . . . . . . . . . . . . . . . . . $16\frac{2}{3}$
Ailavators, degrees:
  Deflected as elevator, stick two-thirds back . . . . . . . . . . . . . 20
  Deflected as ailerons, stick one-third right or left . . . . . . . . ±5

The differential deflections of the ailavators resulting from lateral stick displacements are added to the ailavator deflection resulting from longitudinal stick displacements.

The model tests with the center of gravity moved rearward of normal and with the mass retracted along the fuselage were included because it was felt that a possibility existed that these loadings might affect the spin and recovery characteristics of this design adversely.

## RESULTS AND DISCUSSION

The results of the model spin tests are presented in charts 1 to 5 and tables IV and V. The model steady-spin data are presented in terms of the corresponding full-scale values for right spins at a test altitude of 15,000 feet. All tests were performed with the cockpit closed, landing gear retracted, and speed brakes in neutral.

### Normal Loading

Erect spins.- The results of erect-spin tests of the model in the normal loading with the slats retracted (model loading point 1 in table III and fig. 3) are presented in chart 1. In the normal spinning-control configuration, the model spun very steeply and recovered rapidly. There was only little effect of ailerons when the elevators were full up, and although two types of spin were indicated as possible for the criterion spin, recovery was satisfactory from both. Setting the elevators down (stick forward) before reversing the rudders retarded recovery. When the elevators were neutral or down, setting the ailerons full against the spin (stick left in a right spin) led to flat spins from which recovery was not possible.

The results of erect-spin tests of the model in the normal loading with the wing slats extended are presented in chart 2. Extending the slats did not affect the elevator-neutral configurations, but generally caused slower recoveries when the elevators were up. The recovery characteristics, however, were still satisfactory.

Spin-tunnel experience, based on the results of tests of about 40 models, indicates that extending landing gear will have little or no effect on airplane spin and recovery characteristics. Analysis of the geometry of the airplane indicates that the speed brakes should have little or no shielding effect on the rudders and therefore should not affect the spin recoveries. If, however, difficulty is encountered when the speed brakes are open, they should be closed immediately.

Inverted spins.- The results of inverted-spin tests of the model in the normal loading with slats retracted 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 with rotation to the pilot's right) is presented at the right of the chart, and "stick back" is presented at the bottom. When the controls are crossed in the established spin, the ailavators as lateral controls aid the rolling motion; when the controls are together the lateral controls oppose the rolling motion. The angle of wing tilt $\phi$ on the chart is given as up or down relative to the ground.

The inverted-spin-recovery characteristics were satisfactory, recoveries being effected by rudder reversal from all control configurations tested.

### Center-of-Gravity Movement and Mass Change

The results of spin tests of the model with the center of gravity moved 7.71 percent of the mean aerodynamic chord rearward of normal (model loading point 4 in table III and fig. 3) are presented in chart 4. The spin and recovery characteristics of the model were not appreciably affected by this center-of-gravity movement. Satisfactory recovery characteristics were effected by rudder reversal.

The results of spin tests of the model with the inertia yawing-moment parameter, $\frac{I_X - I_Y}{mb^2} \times 10^{-4}$, changed from a value of -144 for the normal loading to -61 ($I_Y$ and $I_Z$ decreased 26.2 percent of $I_Y$ from the normal; model loading point 5 in table III and fig. 3) are presented in chart 5. In general, these results were similar to those for the normal loading, the recovery characteristics being satisfactory. Recoveries with the ailerons full against the spin and elevators neutral for this loading were improved over those for the normal loading, although they were still unsatisfactory. This result is consistent with previous spin-tunnel experience.

### Accelerations in the Steady Spin

In accordance with a request of Chance Vought Aircraft, brief computations of the accelerations which would be encountered by the pilot in spins of the XF7U-1 airplane were made. These calculations were based on the rate of rotation of the spin, the distance from the pilot to the center of gravity (horizontally), and the radius of the spin $\frac{g \cot \alpha}{\Omega^2}$. The acceleration of gravity was neglected. The components of the computed accelerations acting along the pilot's body were of the order of 1g and less, well within the pilot's limits of endurance (reference 5).

Spin-Recovery Parachutes

The turns for recovery obtained with different sizes of wing-tip spin-recovery parachute are presented in table IV and the measured towline angles after opening are presented in table V. The method used to define the towline angles is shown in figure 4. The results show that a 4.24-foot (full-scale) parachute attached to a 25-foot (full-scale) towline on the outboard wing tip or two 8.77-foot (full-scale) parachutes attached to 25-foot (full-scale) towlines, one attached to each tip, and opened simultaneously will be required to effect satisfactory recoveries by parachute action alone from the spin at normal spinning-control configuration or from the criterion spin. The model parachutes as tested had drag coefficients of approximately 0.83 and 0.70 (based on the canopy area when the parachute is laid out flat) for the 4.24-foot and the 8.77-foot parachutes, respectively. If a parachute with a different drag coefficient is used on the airplane, a corresponding adjustment will have to be made in the parachute size.

The calculated full-scale steady loads for the 4.24-foot and the 8.77-foot parachutes, respectively, are 759 pounds and 2725 pounds. These loads are based on the maximum velocity attained during tests with the model in the normal control configuration (294 ft/sec) and on an altitude of 15,000 feet. Based on the results of reference 6, the maximum shock loads corresponding to the previously mentioned steady loads will be 1749 and 6270 pounds, respectively.

Moving-picture-film strips showing recovery by parachute action alone are shown in figures 5 and 6. Figure 5 shows a recovery obtained by use of one parachute opened on the outboard wing tip and figure 6 shows a recovery obtained by opening simultaneously a parachute from each wing tip.

The towline angles given in table V are an indication of the directions of action of the parachute loads previously mentioned. These angles are those which exist only during the recovery, that is, from the time the parachute is opened until the rotation ceases. An indication of the motion and angles of the parachutes during and after recovery can be obtained from the film strips given in figures 5 and 6. In figure 5, the parachute is starting to open at frame 16 and the recovery is completed approximately 1 turn later at frame 57. In figure 6, the parachutes are starting to open at frame 17 and the recovery is completed approximately 1/2 turn later at frame 40. It can be seen from figure 6 that the parachutes oscillate widely after the recovery is completed, indicating that the parachutes should be released from the airplane as soon as possible after completion of the recovery. In figure 6, the parachute on the inner wing tip (right wing in a right spin) appears to be oscillating in such a manner that the towlines describe a cone with an apex angle of from $70^{\circ}$ to $80^{\circ}$.

## Pilot-Escape Tests

It was observed during tests performed to determine from which side of the spinning airplane the pilot should attempt an emergency escape that the pilot model dropped below the leading edge of the outboard wing and dropped away from the airplane when released from the outboard side in a flat spin. When the pilot model was released from the inboard side in a flat spin, he passed over the top of the cockpit and then fell toward the outboard wing either being struck by or coming dangerously close to the wing. From a steep spin, when released from either the outboard or the inboard side, the pilot moved over the cockpit then vertically upward clearing all surfaces. These results indicate that the pilot should jump from the outboard side if it should become necessary to abandon the airplane in a spin.

## Rudder-Control Force

The discussion of the results so far has been based on control effectiveness alone without regard to the forces required to reverse 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.

Tests were performed with the model in the normal-loading, clean condition, in which the force necessary to reverse the rudder in order to effect a satisfactory recovery was measured. The force was found to be approximately 350 pounds, a value barely within the capabilities of a pilot, according to the results of reference 7. Because of lack of detail in the rudder balance of the model, of inertia mass balance effects, and of scale effect, these results are 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 recommendations are made as to recovery technique for all loadings and conditions of the airplane:

For erect spins, the rudder should be reversed briskly from full with the spin to full against the spin and approximately 1/2 turn later the stick should be moved forward but maintained laterally neutral; care should be exercised to avoid moving the stick forward before the rudder is fully reversed and also to avoid excessive accelerations in the ensuing recovery dive. If an accidental spin is entered with the flaps extended, the flaps should be retracted and recovery attempted immediately.

For recovery from inverted spins, the rudder should be reversed briskly to full against the spin.

## CONCLUSIONS

Based on results of spin tests of a 0.057-scale model of the Chance Vought XF7U-1 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane spinning at an altitude of 15,000 feet are made:

1. The spin and recovery characteristics of the airplane will be satisfactory for all loading conditions. For recovery, the rudder should be reversed fully and rapidly and 1/2 turn later the stick should be moved forward of neutral but maintained laterally neutral.

2. Extending the wing slats will retard recoveries somewhat but the recovery characteristics will still be satisfactory.

3. Recoveries from inverted spins will be satisfactory and can be effected by reversing the rudder fully and rapidly.

4. A 4.24-foot parachute attached to a 25-foot towline will effect satisfactory emergency recoveries when opened alone from the outboard wing tip; if two parachutes are to be opened simultaneously, one from each wing tip, however, 8.77-foot parachutes on 25-foot towlines will be required to effect satisfactory recoveries. These sizes are based on drag coefficients of 0.83 and 0.70 for the 4.24-foot and 8.77-foot parachutes, respectively, with the coefficient based on the laid-out-flat surface area.

5. The shock loads which each towline will have to withstand, based on the maximum velocity of descent of the steady spin which could be attained in the spin tunnel for the normal spinning-control configuration, will be 1749 and 6270 pounds for the 4.24-foot and 8.77-foot parachutes, respectively.

6. If it becomes necessary for the pilot to leave the airplane while in a spin, he should jump from the outboard side of the cockpit (left side in a right spin).

7. The pedal force necessary to reverse the rudders for recovery was found to be rather high but appeared to be within the upper limits of the pilot's capabilites.

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## SUPPLEMENTARY REFERENCES


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   CVS-16292A Front View, 0.057 - Size XF7U-1 W. T. Model, Free Spinning Tunnel
   CVS-16290A Side View, 0.057 - Size XF7U-1 W. T. Model, Free Spinning Tunnel
   CVS-16291A Plan View, 0.057 - Size XF7U-1 W. T. Model, Free Spinning Tunnel

2. Dabrowski, N.: Estimated Moments of Inertia. Rep. No. 7316, Chance Vought Aircraft, Nov. 21, 1946.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE

CHANCE VOUGHT XF7U-1 AIRPLANE

| | |
|---|---|
| Over-all length, ft | 36.44 |
| **Wing:** | |
| Span, ft | 38.67 |
| Area, sq ft | 496 |
| Aspect ratio | 3.01 |
| Root chord, in. | 192 |
| Tip chord, in. | 116 |
| Mean aerodynamic chord, in | 157 |
| L.E. $\bar{c}$ rearward L.E. root chord, in. | 83.56 |
| Taper ratio | 0.60 |
| Incidence (constant), deg | 0 |
| Dihedral, deg | 0 |
| Sweepback of quarter-chord line, deg | 35 |
| Airfoil section | CVA 4 - (00) - (12) - (1.1) (1.0) |
| **Ailavator:** | |
| Span, percent b/2 | 47.2 |
| Total area, sq ft | 54.4 |
| Area rearward of hinge line, sq ft | 53.0 |
| Chord, percent c: | |
| Inboard station | 22.4 |
| Outboard station | 29.2 |
| **Vertical tail:** | |
| Height, ft | 9.24 |
| Total area, sq ft | 122.4 |
| Rudder area, sq ft | 32.0 |
| Aspect ratio | 1.31 |
| Sweepback quarter-chord line, deg | 45 |
| Airfoil section | CVA special |
| **Slats:** | |
| Span, percent b/2 | 54.4 |

[redacted]

[redacted]

TABLE II.- CONDITIONS TESTED ON THE 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[For all tests performed, the speed brakes were neutral, the cockpit was closed, and the landing gear was retracted]

| No. | Loading | Direction and type of spin | Recovery attempted by | Slats | Data presented in |
|---|---|---|---|---|---|
| 1 | Normal | Right erect | Rudder reversal | Retracted | Chart 1 |
| 2 | Normal | Right erect | Rudder reversal | Extended | Chart 2 |
| 3 | Normal | Inverted to pilot's right | Rudder reversal | Retracted | Chart 3 |
| 4 | Normal with center of gravity moved 7.71 percent of $\bar{c}$ rearward of normal | Right erect | Rudder reversal | Retracted | Chart 4 |
| 5 | Normal with $I_Y$ and $I_Z$ decreased 26.2 percent of $I_Y$ | Right erect | Rudder reversal | Retracted | Chart 5 |
| 6 | Normal | Right erect | Opening parachute on left wing tip | Retracted | Tables IV and V |
| 7 | Normal | Right erect | Simultaneously opening parachute on both left and right wing tips | Retracted | Tables IV and V |

[redacted]

[redacted]

TABLE III.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE CHANCE VOUGHT XF7U-1 AIRPLANE AND FOR LOADINGS TESTED ON THE 0.057-SCALE MODEL

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

| No. | Loading | Weight (lb) | Airplane relative density, $\mu$ | | Center-of-gravity location | | Moments of inertia (slug-ft$^2$) | | | Mass parameters | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | sea level | 15,000 feet | $x/\bar{c}$ | $z/\bar{c}$ | $I_X$ | $I_Y$ | $I_Z$ | $\frac{I_X - I_Y}{mb^2}$ | $\frac{I_Y - I_Z}{mb^2}$ | $\frac{I_Z - I_X}{mb^2}$ |
| | Airplane values | | | | | | | | | | | |
| 1 | Combat loading, 60-percent fuel full ammunition, landing gear retracted | 14,485 | 9.86 | 15.68 | 0.163 | 0.003 | 13,265 | 23,646 | 36,149 | $-154 \times 10^{-4}$ | $-186 \times 10^{-4}$ | $340 \times 10^{-4}$ |
| 2 | Take-off loading, full fuel, full ammunition, landing gear retracted | 16,812 | 11.45 | 18.20 | .164 | .008 | 19,236 | 26,935 | 45,323 | -99 | -235 | 334 |
| 3 | Landing loading, 25-percent fuel, ammunition expended, landing gear retracted | 11,949 | 8.14 | 12.93 | .180 | .006 | 11,836 | 22,737 | 33,879 | -196 | -201 | 397 |
| | Model values | | | | | | | | | | | |
| 1 | Normal | 14,517 | 9.89 | 15.72 | 0.167 | 0.004 | 13,250 | 22,943 | 35,021 | $-144 \times 10^{-4}$ | $-179 \times 10^{-4}$ | $323 \times 10^{-4}$ |
| 4 | Normal, with center of gravity moved 7.71 percent of $\bar{c}$ rearward of normal | 14,485 | 9.87 | 15.68 | .240 | .003 | 13,338 | 23,618 | 35,994 | -153 | -184 | 337 |
| 5 | Normal with $I_Y$ and $I_Z$ decreased 26.2 percent of $I_Y$ | 14,485 | 9.87 | 15.68 | .163 | .003 | 13,338 | 17,449 | 29,825 | -61 | -184 | 245 |

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TABLE IV.- WING-TIP SPIN-RECOVERY-PARACHUTE DATA OBTAINED WITH THE 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Normal loading (loading 1 in table III and fig. 3); recovery attempted by opening parachutes (as indicated); model values have been converted to corresponding full-scale values; right erect spins]

| Parachute diameter (ft) | Towline length (ft) | Parachute drag coefficient | Aileron deflection | Elevator deflection | Vertical rate of descent (ft/sec) | Turns for recovery |
|---|---|---|---|---|---|---|
| Parachute opened from left wing tip | | | | | | |
| 4.24 | 25.0 | 0.83 | 1/3 against | 2/3 up | 256 | 1, 1, 1 |
| 4.24 | 25.0 | 0.83 | Neutral | Full up | >294 | $\frac{1}{2}$, $\frac{1}{2}$ |
| Parachutes opened from both left and right wing tips simultaneously | | | | | | |
| 4.39 | 25.0 | 0.83 | 1/3 against | 2/3 up | 256 | 1, $1\frac{1}{2}$, $1\frac{3}{4}$, >2 |
| 7.31 | 25.0 | 0.70 | 1/3 against | 2/3 up | 256 | $\frac{1}{2}$, [a]$1\frac{1}{4}$, >$2\frac{1}{2}$ |
| 8.77 | 25.0 | 0.70 | 1/3 against | 2/3 up | 256 | [a]$\frac{1}{4}$, [a]$\frac{3}{4}$ |
| 8.77 | 25.0 | 0.70 | Neutral | Full up | >294 | [a]$\frac{1}{4}$, [a]$\frac{1}{2}$ |

[a]Both parachutes oscillated but did not cause model to oscillate.

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TABLE V.- SPIN-RECOVERY-PARACHUTE TOWLINE ANGLES OBTAINED

FROM FILM RECORD MADE DURING RECOVERY OF

THE 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Normal loading (loading 1 in table III and fig. 3); recovery attempted by opening parachute or parachutes alone; right erect spins]

| Elevator deflection | Aileron Deflection | Turns after parachute opened | α (deg) | ϕ (deg) (a) | A (deg) (b) | B (deg) (b) |
|---|---|---|---|---|---|---|
| 4.24-foot (full-scale) parachute on left wing tip<br>25-foot (full-scale) towline | | | | | | |
| Full up | Neutral | Before opening | 44 | 1D | -- | -- |
| | | $\frac{1}{4}$ | 32 | ---- | -- | 8 |
| | | $\frac{1}{2}$ | -- | 15D | 1 | -- |
| 2/3 up | 1/3 against | Before opening | 52 | 9U | -- | -- |
| | | $\frac{1}{4}$ | -- | 1.5U | 3 | -- |
| | | $\frac{1}{2}$ | 43 | ---- | -- | 32 |
| | | $\frac{3}{4}$ | -- | 7U | 0 | -- |
| | | 1 | 15 | ---- | -- | 20 |
| 2/3 up | 1/3 against | Before opening | 50 | 5U | -- | -- |
| | | $\frac{1}{4}$ | 49 | ---- | -- | 15 |
| | | $\frac{1}{2}$ | -- | 2D | 11 | -- |
| | | $\frac{3}{4}$ | 33 | ---- | -- | 23 |
| | | 1 | -- | 2D | 3 | -- |

[a]U and D mean inner wing up or down.
[b]Angles measured as noted on figure 4.

[redacted]

[redacted]

TABLE V.- SPIN-RECOVERY-PARACHUTE TOWLINE ANGLES OBTAINED FROM FILM RECORD - Concluded

[Normal loading (loading 1 in table III and fig. 3); recovery attempted by opening parachute or parachutes alone; right erect spins]

| Elevator deflection | Aileron deflection | Turns after parachutes opened | α (deg) | ϕ (deg) (a) | A (deg) (b) Left towline | A (deg) (b) Right towline | B (deg) (b) Left towline | B (deg) (b) Right towline |
|---|---|---|---|---|---|---|---|---|
| 8.77-foot (full-scale) parachute on both left and right wing tips 25-foot (full-scale) towlines | | | | | | | | |
| Up | Neutral | Before opening | 40 | 1D | -- | -- | -- | --- |
| | | $\frac{1}{4}$ | -- | 18D | 21 | 9 | -- | --- |
| Up | Neutral | Before opening | 29 | 1D | -- | -- | -- | --- |
| | | $\frac{1}{4}$ | -- | 4U | 10 | 16 | -- | --- |
| Up | Neutral | Before opening | 39 | 5D | -- | -- | -- | --- |
| | | $\frac{1}{2}$ | -- | 1U | 6 | 10 | -- | --- |
| 2/3 up | 1/3 against | Before opening | 48 | 5U | -- | -- | -- | --- |
| | | At opening | -- | 3U | 15 | 1 | -- | --- |
| | | $\frac{1}{4}$ | 13 | --- | -- | -- | 8 | -28 |
| 2/3 up | 1/3 against | Before opening | 47 | 5U | -- | -- | -- | --- |
| | | $\frac{1}{4}$ | -- | 18U | 15 | 17 | -- | --- |
| | | $\frac{1}{2}$ | 24 | --- | -- | -- | 32 | -38 |
| | | $\frac{3}{4}$ | -- | 1U | -2 | 28 | -- | --- |

[a] U and D mean inner wing up or down.
[b] Angles measured as noted on figure 4.

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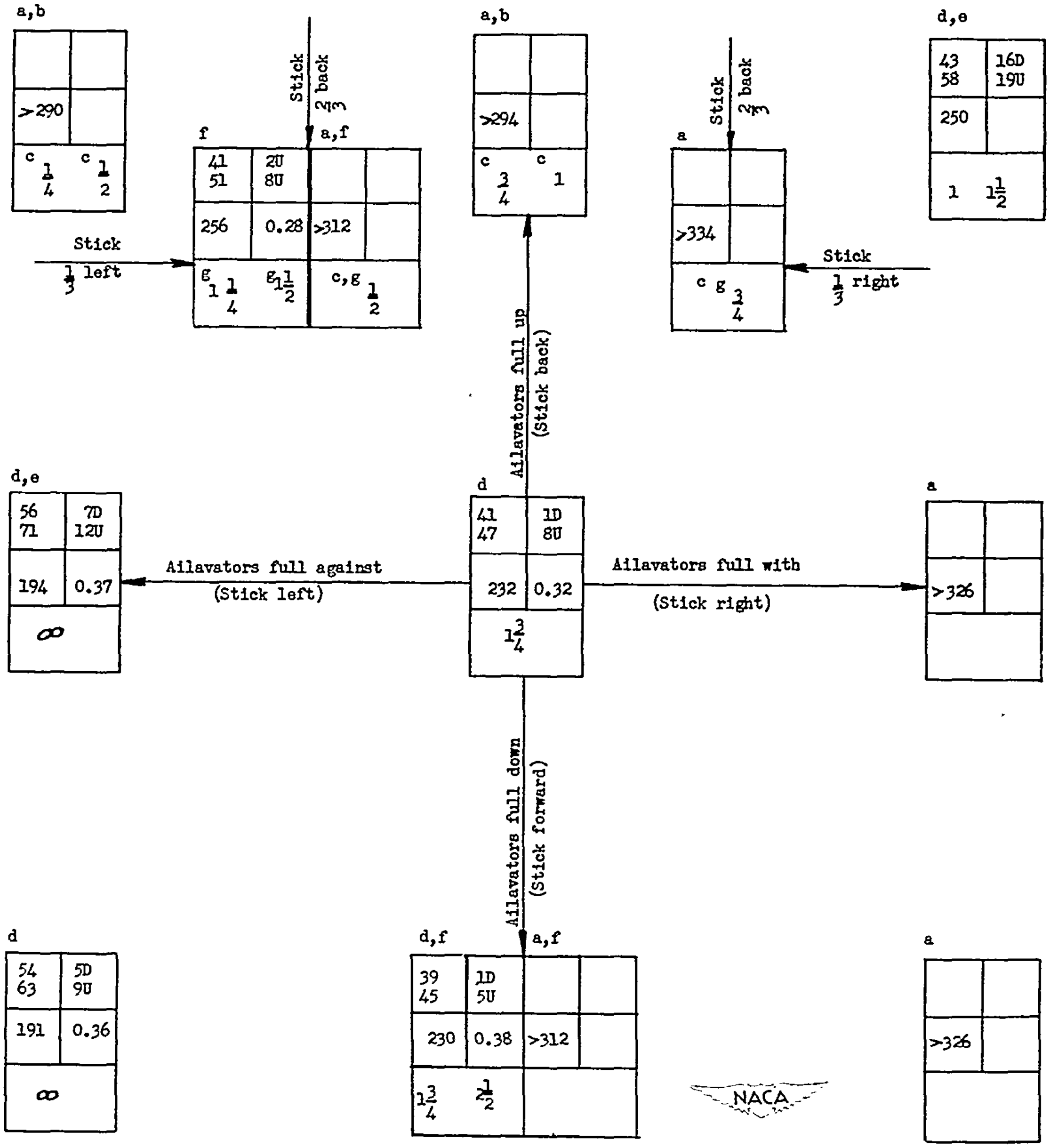
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF AN 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Normal loading (loading 1 in table III and fig. 3); recovery attempted by rapid full rudder reversal unless otherwise indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

[redacted]




[redacted]

[a] Steep spin
[b] Large-radius spin
[c] Recovery attempted before model reached final steeper attitude
[d] Wandering spin
[e] Model oscillatory in roll and pitch
[f] Two conditions possible
[g] Recovery attempted by reversing the rudder to only 2/3 against the spin

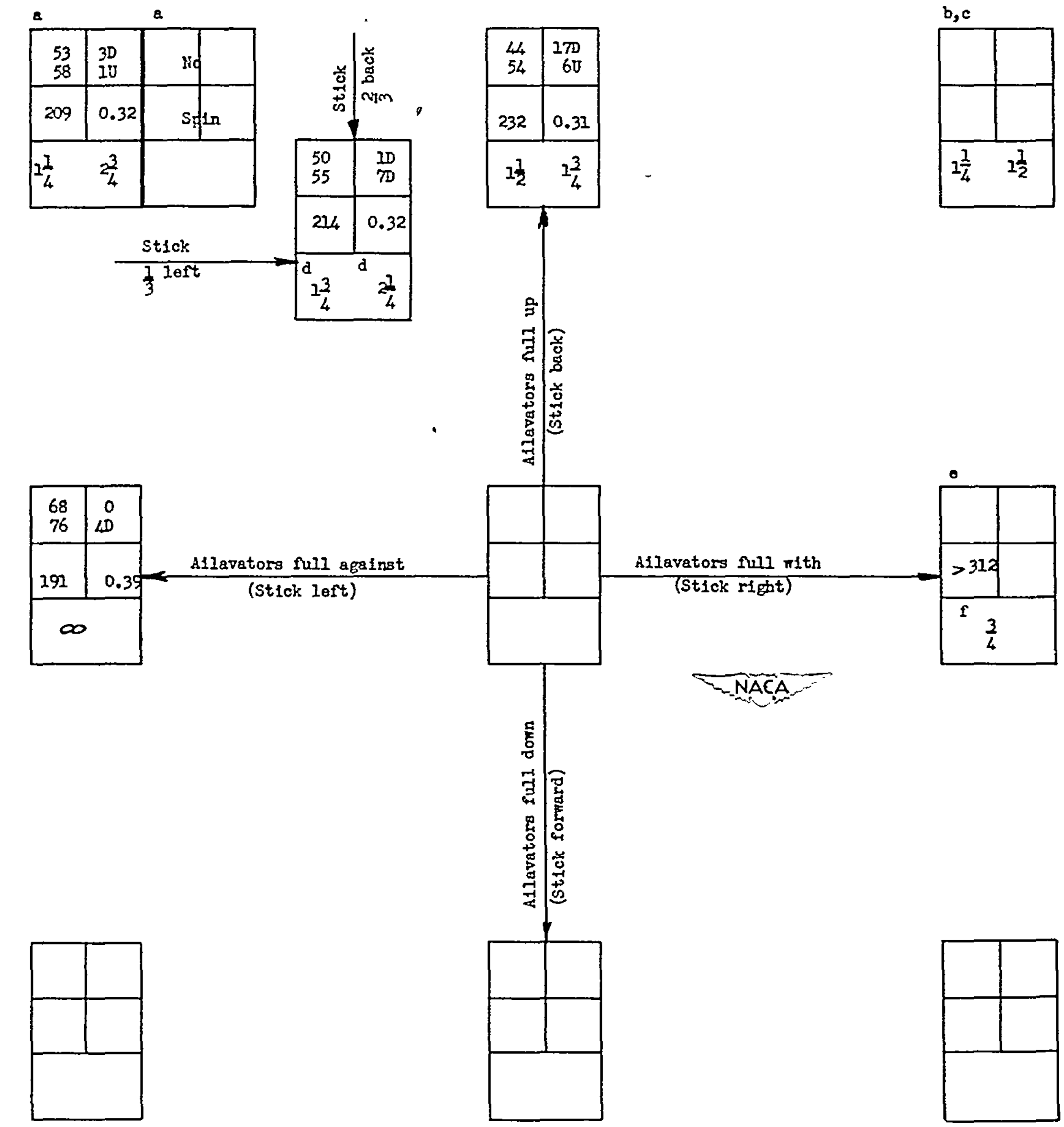
Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

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

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF AN 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE WITH THE WING SLATS EXTENDED

[Normal loading (loading 1 in table III and fig. 3); recovery attempted by rapid full rudder reversal unless otherwise indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

[redacted]




[redacted]

[a]Two conditions possible
[b]Oscillatory spin
[c]Wandering spin
[d]Recovery attempted by reversing rudder to only $\frac{2}{3}$ against the spin
[e]Steep spin
[f]Recovery attempted before model reached final steeper attitude

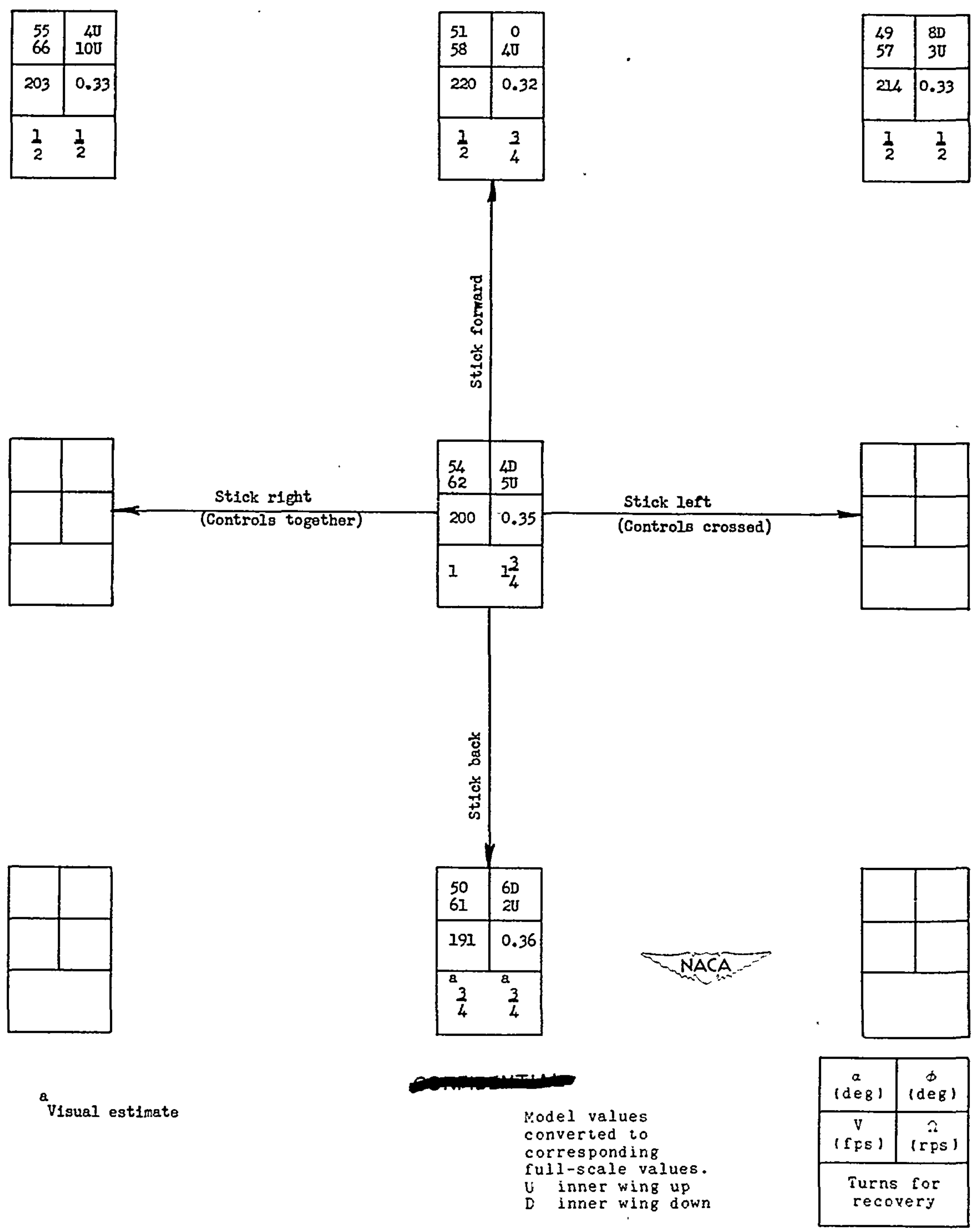
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

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

CHART 3.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF AN 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Normal loading (loading 1 in table III and fig. 3); recovery attempted by rapid full rudder reversal unless otherwise indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); rotation to pilot's right]

[redacted]




[redacted]

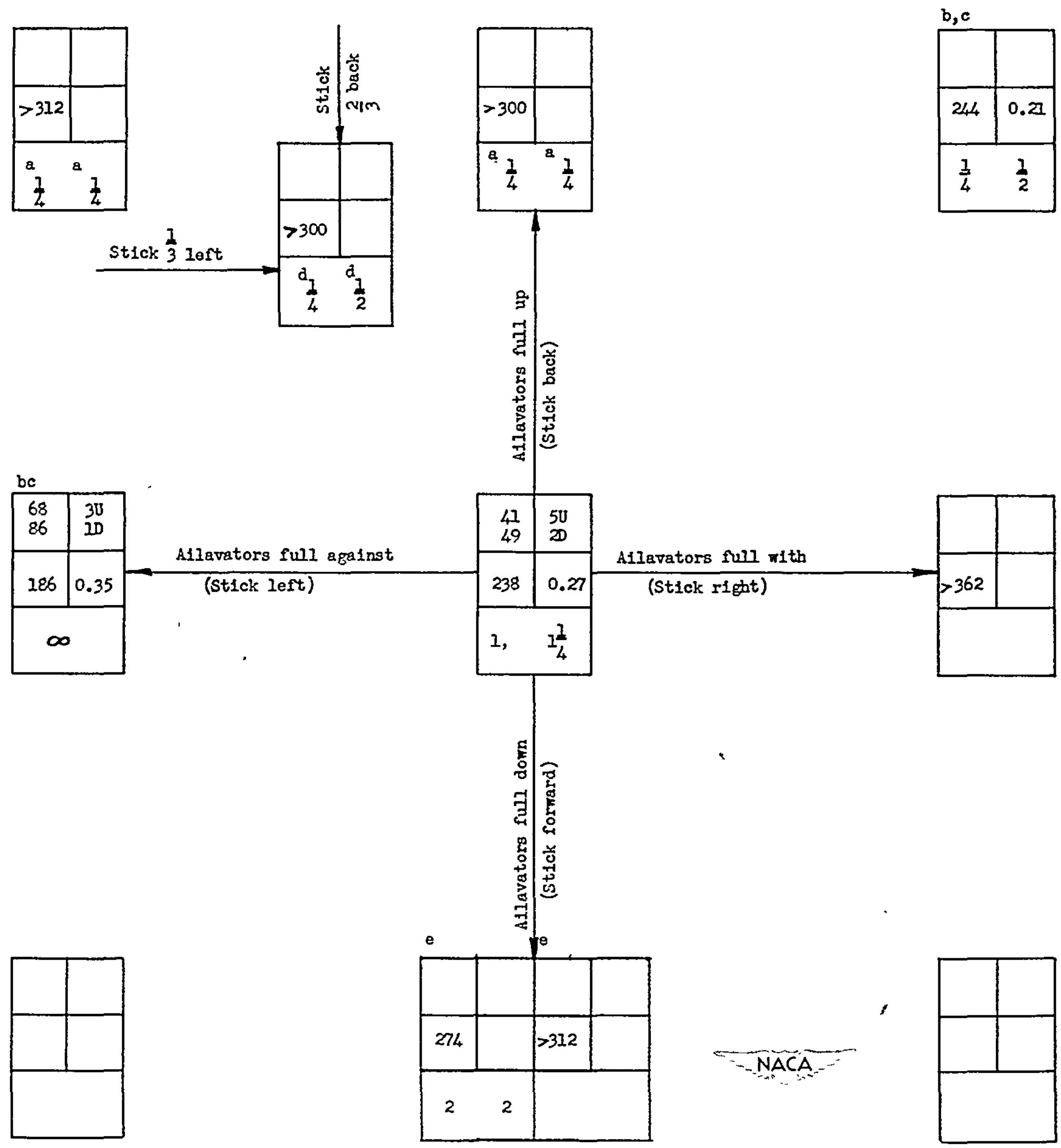
[a] Visual estimate

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

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF AN 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE WITH THE CENTER OF GRAVITY MOVED REARWARD

[Normal loading with center of gravity moved 7.71 percent of mean aerodynamic chord rearward of normal (loading 4 in table III and fig. 3); recovery attempted by rapid full rudder reversal unless otherwise indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

[redacted]




[redacted]

[a]Recovery attempted before model reached final steeper attitude
[b]Wandering spin
[c]Oscillatory spin
[d]Recovery attempted by reversing the rudder to only 2/3 against the spin
[e]Two conditions possible

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

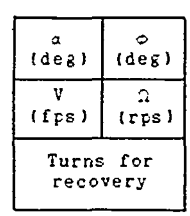
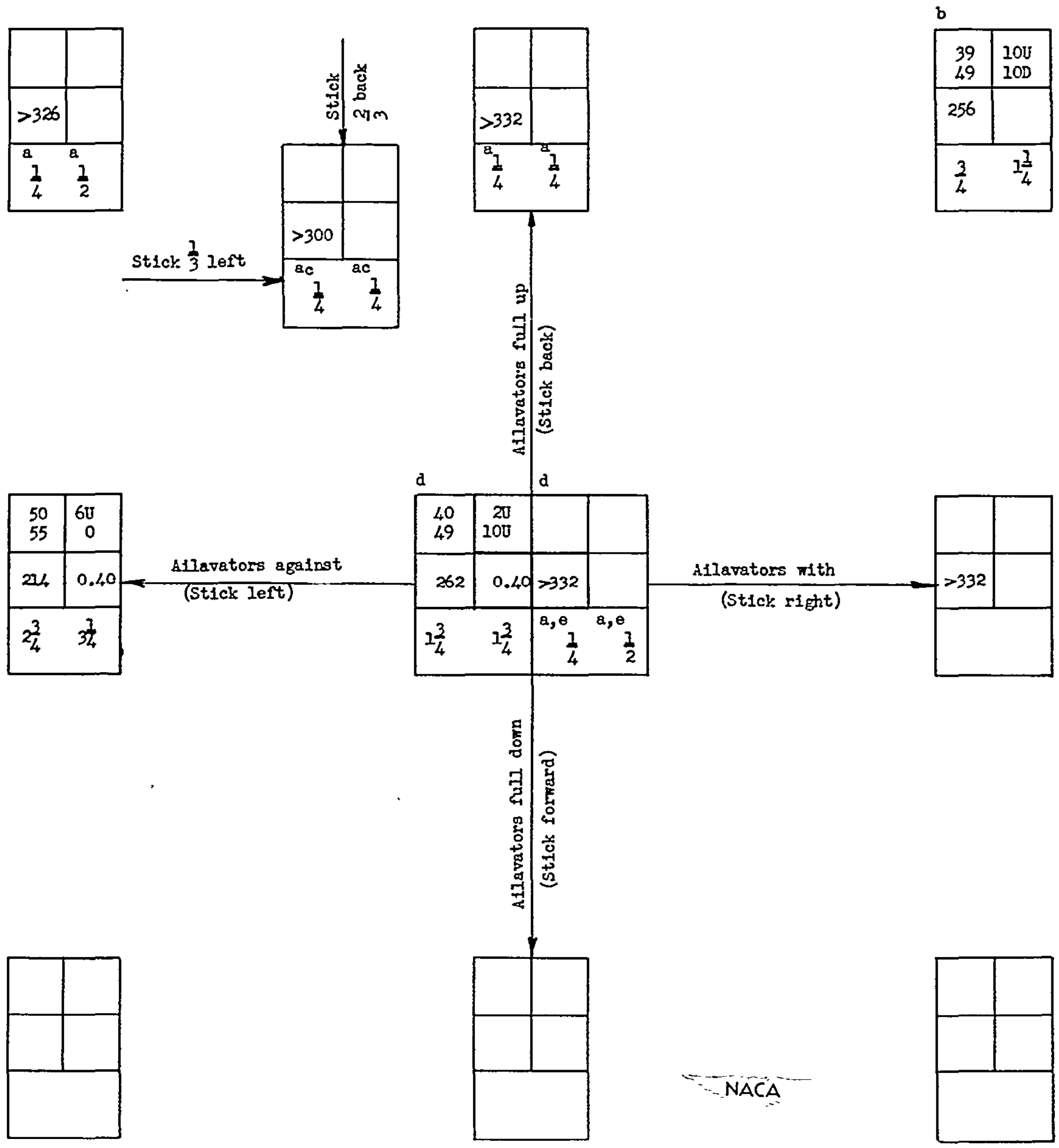


CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF AN 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE WITH MASS RETRACTED ALONG THE FUSELAGE

[Normal loading with $I_Y$ and $I_Z$ decreased 26.2 percent of $I_Y$ (loading 5 in table III and fig. 3); recovery attempted by rapid full rudder reversal unless otherwise indicated (recovery attempted from and steady-spin data presented for, rudder-full-with spins); right erect spins]

[redacted]




[redacted]

[a] Recovery attempted before model reached final steeper attitude
[b] Wandering spin
[c] Recovery attempted by reversing the rudder to only 2/3 against the spin
[d] Two conditions possible
[e] Visual estimate

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

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

[redacted]

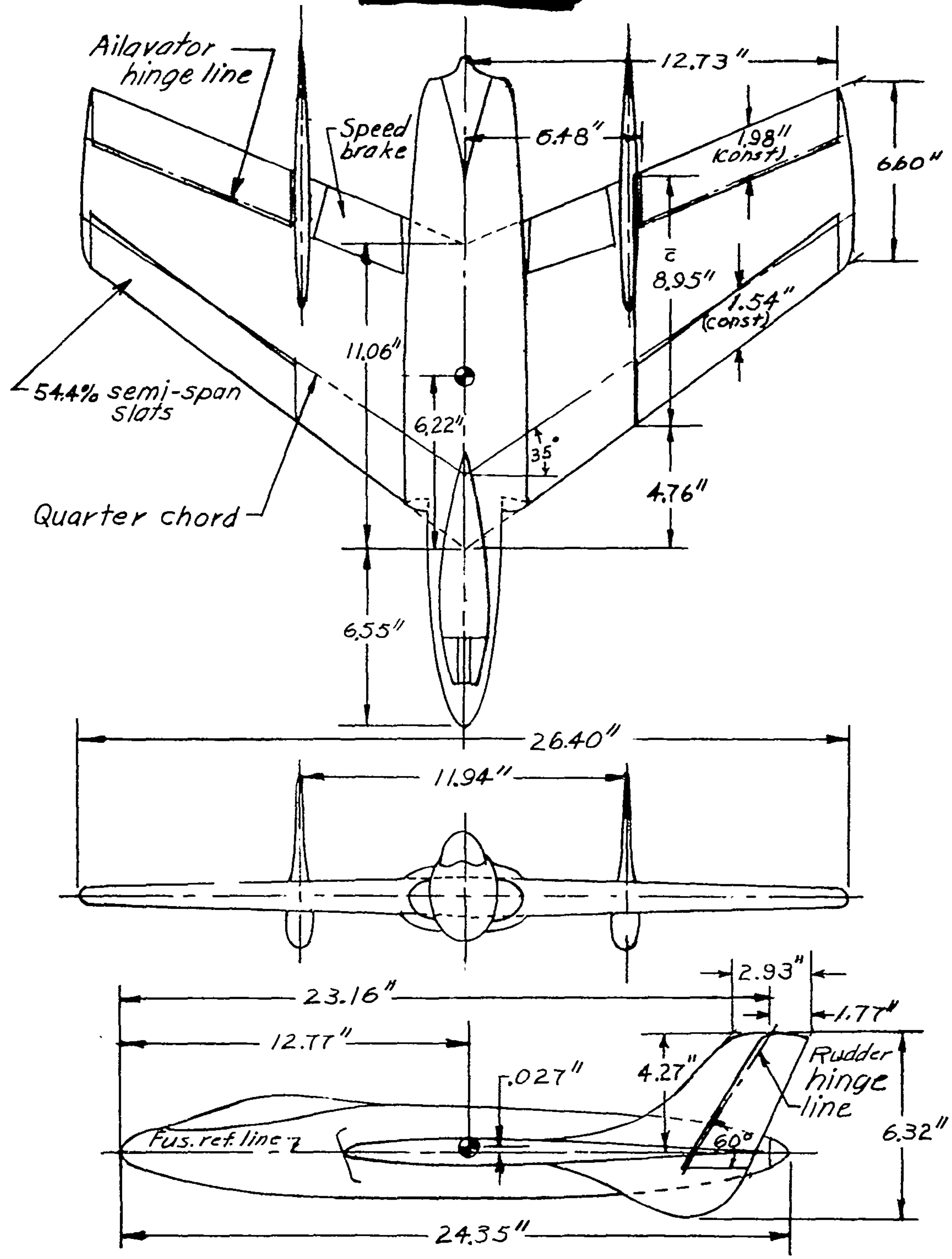



Figure 1.- Three-view drawing of the 0.057-scale model of the Chance Vought XF7U-1 airplane as tested in the free-spinning tunnel (center-of-gravity location shown is for normal loading).

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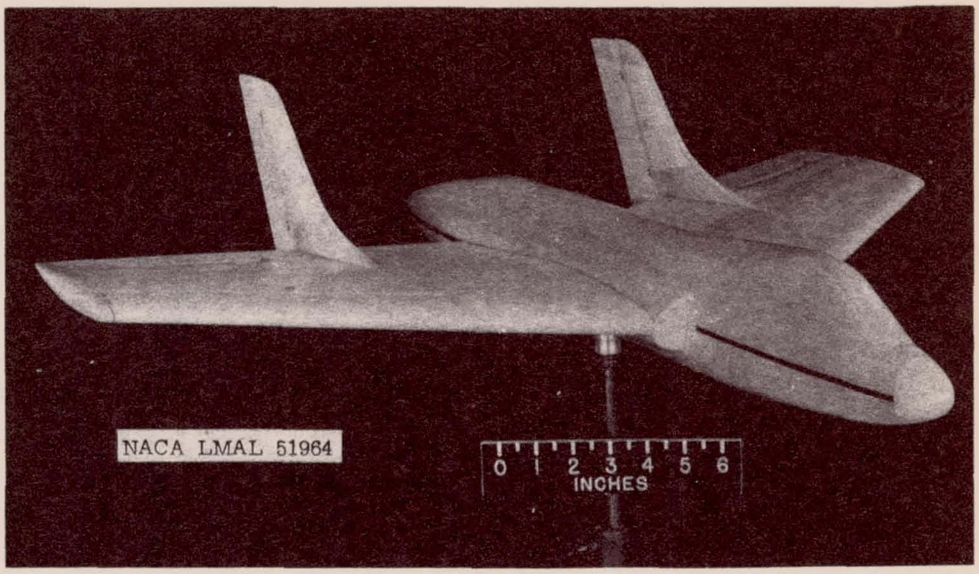


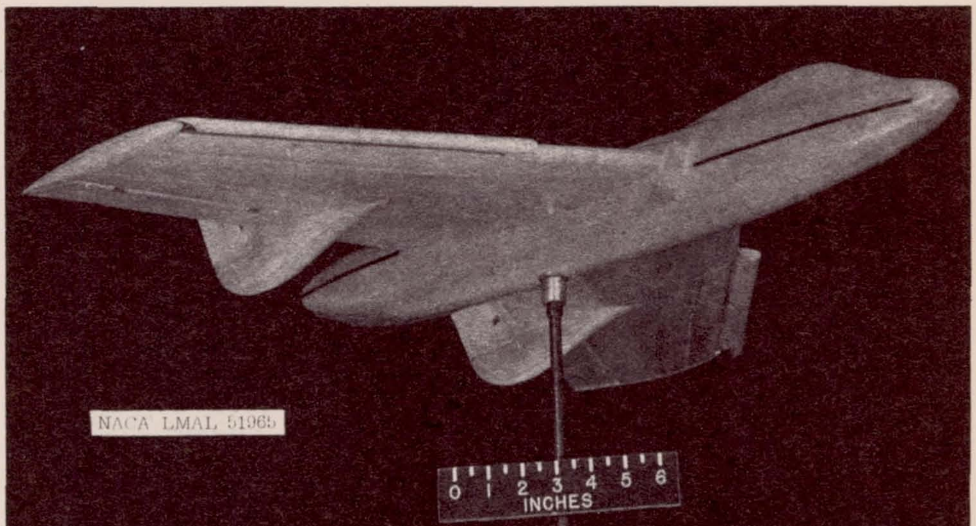


Figure 2.- Photographs of the 0.057-scale model of the Chance Vought XF7U-1 airplane showing the slats retracted and extended.

[redacted]

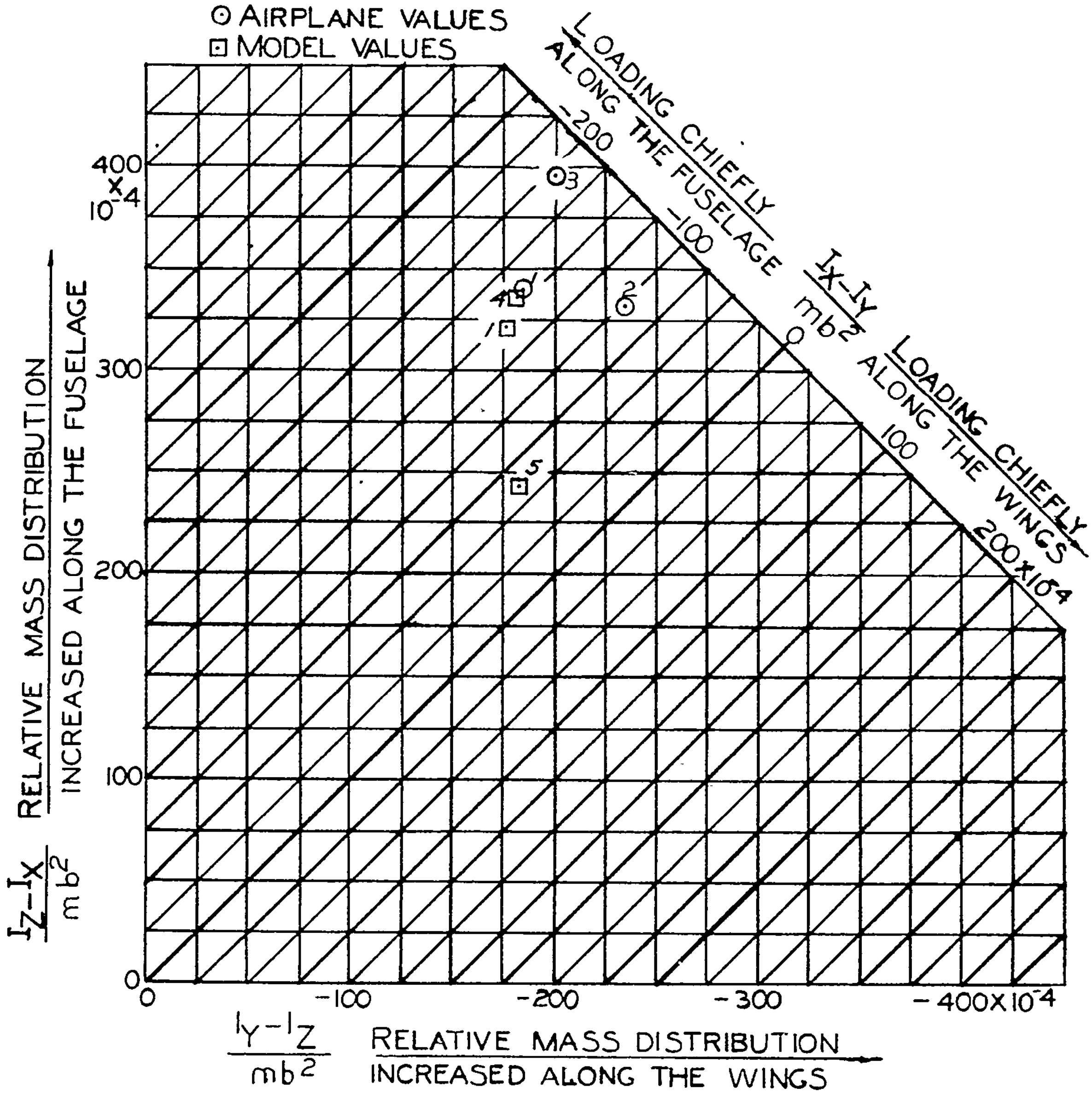


FIGURE 3.– MASS PARAMETERS FOR LOADINGS POSSIBLE ON THE CHANCE-VOUGHT XF7U-1 AIRPLANE AND FOR THE LOADINGS TESTED ON THE 0.057 SCALE MODEL (POINTS CORRESPOND TO NUMBERED LOADINGS IN TABLE III).

[redacted]

[redacted]

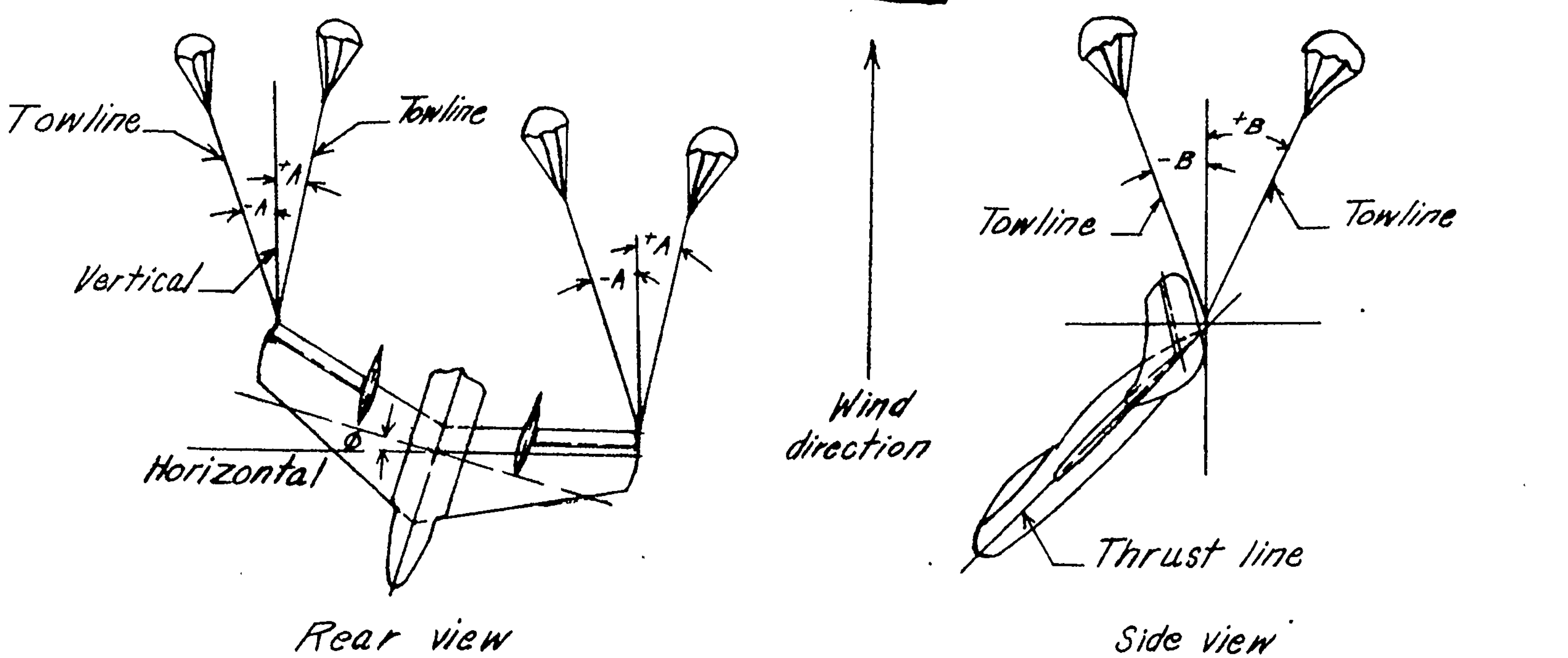


Figure 4.- Sketch of attachment points of spin-recovery parachute towlines, showing the method used in measuring the attitudes assumed by the towline during spin recoveries.

[redacted]

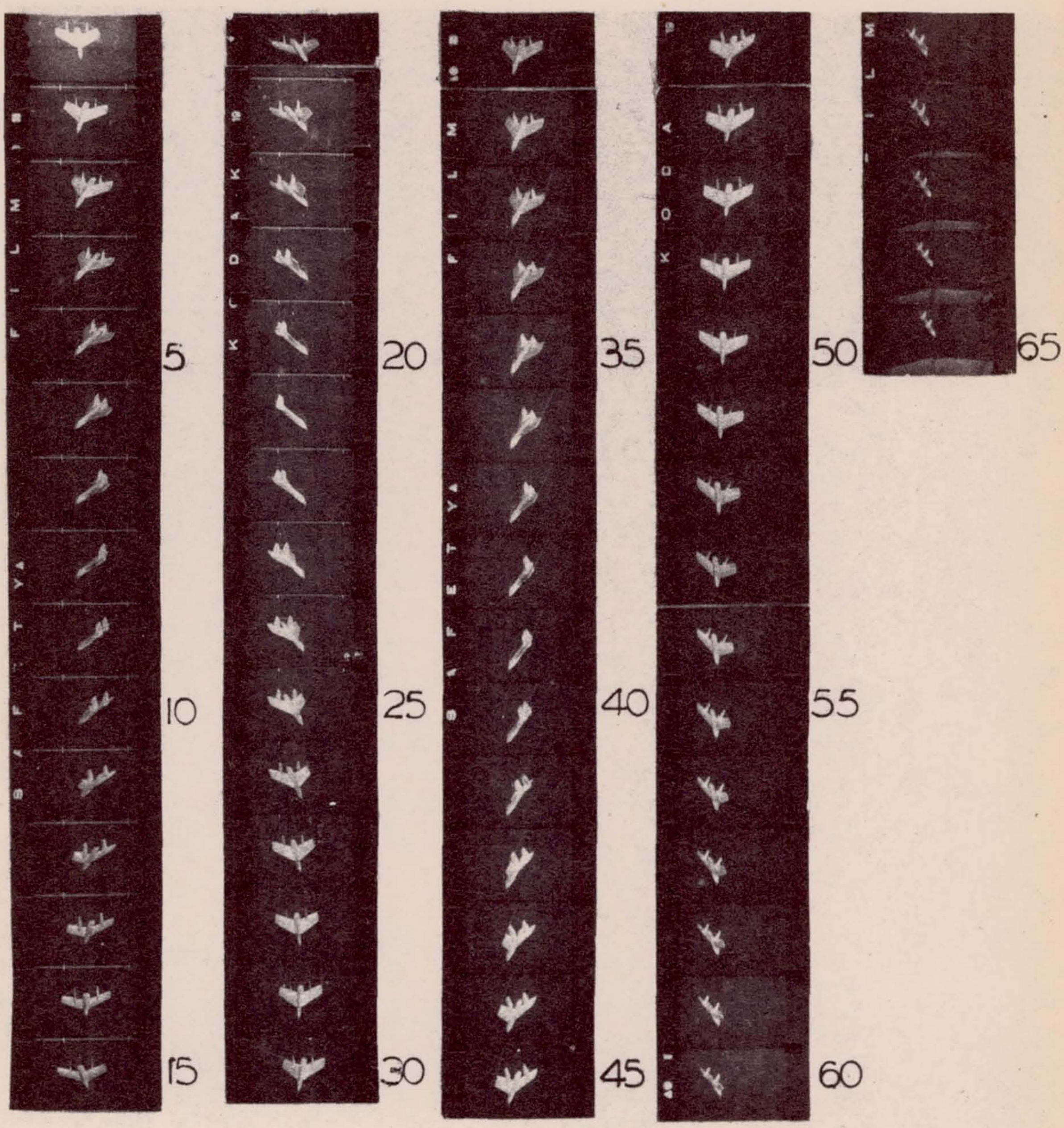


Figure 5.- Moving-picture film strips showing parachute-towline angles during a typical recovery of the XF7U-1 model by parachute action alone (4.24-foot parachute opened on a 25-foot towline from the outboard wing tip).

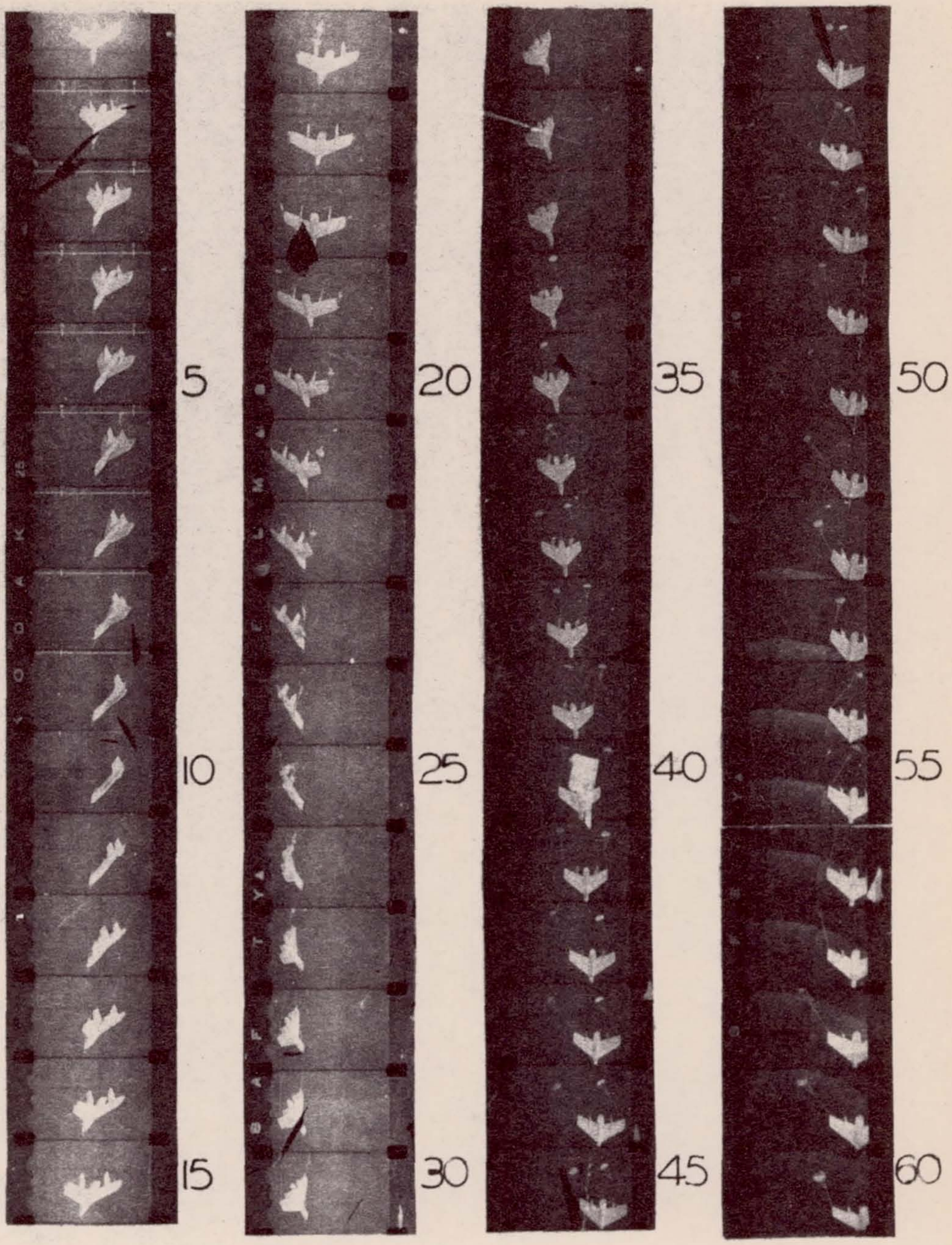


Figure 6.- Moving-picture film strips showing parachute-towline angles during a typical recovery of the XF7U-1 model by parachute action alone (8.77-foot parachutes opened simultaneously on 25-foot towlines, one from each wing tip).

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