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RESEARCH MEMORANDUM

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Bureau of Aeronautics, Navy Department

FREE-SPINNING-TUNNEL TESTS OF A $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE

TED NO. NACA 2349

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

Spin tests of a $\frac{1}{16}$-scale model of the Chance Vought XF5U-1 airplane have been performed in the Langley 20-foot free-spinning tunnel. The effect of control position and movement upon the erect and inverted spin and recovery characteristics as well as the effects of propellers, of stability flaps, and of various revisions to the design configuration have been determined for the normal fighter loading. The investigation also included spin-recovery-parachute, tumbling, and pilot-escape tests.

For the original design configuration, with or without windmilling propellers, the recovery characteristics of the model were considered unsatisfactory. Increasing the maximum upward deflection of the ailavators from 45° to 65° resulted in greatly improved recovery characteristics.

Dimensional revisions to the original airplane configuration, which satisfactorily improved the general spin and recovery characteristics of the model, consisted of: (1) a supplementary vertical tail 34 inches by 59 inches (full-scale) attached to a boom 80 inches aft of the trailing edge of the airplane in the plane of symmetry, (2) a large semispan under-surface spoiler placed along the airplane quarter-chord line and opened on the outboard side in a spin, or (3) two additional vertical tails 64 inches by 52 inches (full-scale) located at the tips of the ailavators.

A satisfactory parachute arrangement for emergency spin recovery from demonstration spins was found to be an arrangement consisting of a 13.3-foot parachute attached by a 30-foot towline to the arresting gear mast on the airplane and opened simultaneously with an 8-foot parachute on the outboard end of the wing attached by a 3-foot towline. Tests indicated that pilot escape from a spin would be extremely hazardous unless the pilot is mechanically ejected from the cockpit.

Model tumbling tests indicated that the airplane would not tumble.

INTRODUCTION

Spin tests have been performed on a $\frac{1}{16}$-scale model of the Chance Vought XF5U-1 airplane in the Langley 20-foot free-spinning tunnel as requested by the Bureau of Aeronautics, Navy Department. This airplane which is a single-place twin-tail flying-wing fighter has an almost circular plan form and is equipped with large twin propellers, one mounted at each wing tip. Longitudinal and lateral control are combined in all-movable horizontal tails known as "ailavators."

A $\frac{1}{16}$-scale model of the prototype of the subject airplane designated the Vought-Sikorsky V-173 had previously been tested in the Langley 15-foot free-spinning tunnel (reference 1). The XF5U-1 airplane is different from the V-173 airplane previously tested in weight and in design of the horizontal tails.

The current program included tests simulating only the normal fighter loading of the XF5U-1 airplane. It was felt that the effect of variations in wing loading and moments of inertia on the spin and recovery characteristics of this design could be determined from the test results presented in reference 1 for the prototype airplane.

Erect and inverted spins were performed to determine the effect of maximum and intermediate control settings on the spin and recovery characteristics of the model, landing gear retracted. Additional tests were made to evaluate the effect on spin and recovery characteristics of various dimensional revisions to the model configuration, as well as the effect of the propellers and the stability flaps, and also to determine the parachute requirements for emergency recovery from demonstration spins. Tumbling and pilot-escape tests completed the program.

SYMBOLS

b	wing span, feet
S	wing area, square feet
$\bar{c}$	mean aerodynamic chord, inches
c	root chord (chord of airfoil section at plane of symmetry), inches
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$z/\bar{c}$ ratio of distance between center of gravity and thrust line to mean aerodynamic chord (positive when center of gravity is below thrust line)

m mass of airplane, slugs

I_X, I_Y, I_Z moments of inertia about X-, Y-, and Z-body axes, respectively, slug-feet^2

$\frac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

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

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

ρ air density, slugs per cubic foot

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

A_1 vertical angle made by towline of wing-tip parachute (angle is measured positive above thrust line), degrees

A_2 vertical angle made by towline of parachute attached at arresting gear mast (angle is measured positive above thrust line), degrees

B_1 angle made in chordal plane by towline of wing-tip parachute (in right spin,angle is measured positive to right of plane parallel to plane of symmetry), degrees

B_2 angle made in chordal plane by towline of parachute attached to arresting gear mast (in right spin,angle is measured positive to right of plane of symmetry), degrees

α	angle between thrust line and vertical (approximately equal to absolute angle of attack at plane of symmetry), degrees
ϕ	angle between span axis and horizontal, degrees
V	full-scale true rate of descent, feet per second
Ω	full-scale angular velocity about spin axis, revolutions per second
σ	helix angle, angle between flight path and vertical (for this model, the average absolute value of the helix angle was approximately 1°), degrees
β	approximate angle of sideslip at center of gravity, (sideslip is inward when inner wing is down by an amount greater than the helix angle), degrees

APPARATUS AND METHODS

Model

The $\frac{1}{16}$-scale model of the Chance Vought XF5U-1 airplane was furnished by the Bureau of Aeronautics, Navy Department. It was checked for dimensional accuracy and prepared for testing at the Langley Laboratory. The model complete with propellers is represented in the three-view drawing of figure 1 and photographs of the model as tested, with and without propellers, are shown in figure 2. The respective dimensional characteristics of the XF5U-1 and the V-173 airplanes are listed in table I and graphically compared in figure 3.

The propellers were interconnected and rotated in opposite directions, rotation being upward in the center. Each propeller had four blades, and each set of two opposite blades was constructed to allow a longitudinal flapping motion of $\pm 10^\circ$ as a unit. The model propellers were allowed to windmill during the propeller-on tests. During the propeller-off tests, the propeller assemblies were replaced with a dummy hub without blades.

The model and propeller assemblies were ballasted by means of lead weights to obtain dynamic similarity to the full-scale airplane at an altitude of 15,000 feet (ρ = 0.001496 slug/cu ft). Interchangeability between the propeller assemblies and the set of dummy hubs was afforded by ballasting the dummy hubs to simulate the weight distribution of the hubs containing the propellers. A $\frac{1}{16}$-scale dummy pilot was also ballasted to represent a 6-foot man and a parachute (200 lb) at 15,000 feet for pilot-escape tests.

Mechanical movement of the controls, opening of the parachutes, and the simulation of pilot escape were accomplished by means of a remote-control mechanism installed in the model.

The leading edge of each fin was offset 2° outboard of the model center line to conform to the full-scale vertical-tail configuration.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel which is similar in operation to the Langley 15-foot free-spinning tunnel described in reference 2, except that the model-launching technique has been changed. With the controls set in the desired positions, the model is hand-launched 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 controls by means of the remote-control mechanism. Upon recovering from a spin, the model dives into the safety net from whence it is retrieved. The spin data obtained from these tests are then converted to corresponding full-scale values by the methods described in reference 2. Figure 4(a) is a photograph of the model, without propellers, freely spinning in the Langley 20-foot free-spinning tunnel.

It became apparent after a few initial attempts to spin the model freely with the propellers installed that little progress could be made because of the frequency with which the model propellers became damaged when the model landed in the safety net. To expedite the testing with propeller installed, an apparatus was devised to support the model in the tunnel. This apparatus consisted of a nylon line attached at one end to the top net in the tunnel from whence it passed through a fixed steel ring 10 inches in diameter. The other end was attached to a universal joint (fig. 5) located on the upper surface of the model above the center of gravity to allow the model freedom of motion about three axes. The steel ring restricted lateral motion of the model, preventing contact with the tunnel wall.

When the suspension apparatus was being used, the technique differed from that described previously for the free-spinning tests only in that it eliminated the hand launching. The model, suspended in the middle of the tunnel on the end of the nylon line, was gently pushed by means of a long pole to initiate its rotation. The tunnel airspeed was then increased until the spinning motion was established. Figure 4(b) shows the model, propellers installed, spinning on this apparatus.

In accordance with standard spin-tunnel methods, tests were performed to determine the spin and recovery characteristics of the model for the normal-control configuration for spinning (stick longitudinally back and laterally neutral, rudder full with the spin) and for various other neutral, intermediate, and maximum longitudinal and lateral stick positions. Recovery from these spins was generally attempted by rapid reversal of the rudders from full with to full against the spin. Tests were also performed to obtain the spin and recovery characteristics of the model for what is referred to as the "criterion spin" to evaluate the possible adverse effects of small control deviations from the normal-control configuration for spinning. For these tests, the ailavators were set at a position simulating that existing when the stick is two-thirds full back in conjunction with the lateral positions of both one-third with and one-third against the spin (stick right in right spin and stick left in right spin). For this model, lateral stick settings of both with and against were used because it was not readily apparent which direction would be adverse. Recovery from this, the criterion spin, was attempted by rapidly reversing the rudders from full with to only two-thirds against the spin.

The turns for recovery were measured from the time the controls were moved or the parachute opened to the time the spin rotation ceased. The recovery characteristics of a model are considered satisfactory if recovery from the criterion spin requires no more than $2\frac{1}{4}$ turns.

For recovery attempts in which the model struck the safety net before recovery could be effected, because of the wandering or oscillatory nature of the spin or because of an unusually high rate of descent, the number of turns from the time the controls were moved to the time the model struck the safety net were recorded. This number indicates that the model required more turns to recover from the spin than shown as, for example, >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. The symbol ∞ is used on the charts to indicate that recovery required more than 10 turns. For a condition in which the model recovered without movement of the controls after having been launched in a spinning attitude with the controls set for a spin, the result is recorded on the charts as "no spin."

The testing technique for determining the optimum size of and towline length for spin-recovery parachutes is described in reference 3.

For the present tests, the model was launched into the tunnel with the rudders set full with the spin. In general, the steady-spin control settings were maintained, recovery being attempted by the action of one tail parachute or a combination of tail- and wing-tip parachutes, but for several tests, the ailavators were moved and a tail parachute opened simultaneously. The several parachute-attachment locations tested on the model included one suggested by the contractor. The two most practical and therefore most thoroughly investigated consisted of: (1) a tail parachute attached to the arresting gear mast (that suggested by contractor, fig. 6); and (2) a combination including (1) and a parachute attached to the outboard end of the wing at the quarter-chord line. The parachutes were installed, while packed, on the upper surface of the model near their attachment locations and in such a manner as not to affect the steady spin until opened. It is recommended, however, that for full-scale parachute installations the parachutes be packed within the airplane structure with provision for positive ejection. The parachutes used for the model tests were of the flat circular type. The drag coefficient based on the laid-out flat area was approximately 0.7.

To determine the susceptibility of the model to tumbling, two methods of launching the model were employed. It was either released from a nose-up position to simulate a whip stall or was given an initial pitching rotation about a lateral axis. The resulting motion was recorded by means of a camera. If a model can not be made to tumble by either of the two launching methods described above, it is considered incapable of tumbling.

For the pilot-escape tests, the dummy pilot was released from the inboard side (right side in a right spin) and the outboard side of the model at the cockpit when the model was in typical flat and typical steep spins.

PRECISION

The model test results are believed to be accurate within the following limits:

α, degree . . . . ± 1
ϕ, degree . . . . ± 1
V, percent . . . . ± 5
Ω, percent . . . . ± 2
Turns for recovery: . . . . $\pm 1/4$ turn when obtained from film; $\pm 1/2$ turn when obtained visually

The preceding limits may have been exceeded for certain 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 spin results of airplanes and their representative scale models (references 2 and 4) indicates that spin-tunnel results are not always in complete agreement with the results of full-scale spinning. In general, the models spin at somewhat smaller angles of attack with higher rates of descent and 5° to 10° more outward sideslip than their full-scale counterparts. The comparison made in reference 4 showed that 80 percent of the model recovery tests predicted satisfactorily the number of turns required for recovery from the corresponding airplanes while 10 percent underestimated and 10 percent overestimated the number of turns required.

The results of tests made on the suspension apparatus are of questionable exactness and are not published in detail in this paper. These results are considered of only qualitative value and are so discussed herein.

Because of the impracticability of exact ballasting of the model and because of inadvertent damage to the model during the tests, the measured weight and mass distribution of the model varies from the true scaled-down values by the following amounts:

Weight, percent	0 to 3 high
Center-of-gravity location, percent $\bar{c}$	0 to 1 rearward
I_X, percent	2 to 3 high
I_Y, percent	4 low to 4 high
I_Z, percent	3 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

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

TEST CONDITIONS

As mentioned earlier, spin tests of the $\frac{1}{16}$-scale model of the XF5U-1 airplane were limited to those for a simulation of the normal fighter loading. The mass characteristics and inertia parameters for the normal loading, and for other possible loadings of the airplane, and for the normal loading as simulated on the model (converted to full-scale values) are given in table II. The inertia parameters for the possible loadings of the XF5U-1 airplane and for the loadings tested on the XF5U-1 airplane and V-173 models are plotted in figure 7.

The normal maximum control deflections for the model were obtained from information furnished by Chance Vought. As previously indicated, the rolling and pitching controls are combined in one surface called an ailavator. The normal angular deflections are given in figure 8 which indicated that for pure longitudinal stick travel from full back to full forward the corresponding maximum ailavator deflections are 45° up and 15° down. Displacing the stick laterally affects the ailavator setting differentially, thereby creating effectively an aileron setting. Maximum lateral displacement of the stick causes, in this manner, a surface incidence differential of ±10° or, in other words, with the stick in one of the two maximum lateral positions, a total incidence difference of 20° exists between the respective chord lines of the left and right ailavators. When the stick is moved forward or backward while in this lateral position the elevator setting only is affected, the total angular differential of 20° being maintained. The rudders were deflected normally ±25°.

All lateral and longitudinal control deflections will be given in this paper in the form of stick position which when referred to figure 8 may be transposed to give the actual setting of each ailavator.

Intermediate control positions tested were as follows:

Stick laterally one-half against the spin

Stick laterally one-third with the spin or one-third against the spin

Stick laterally one-fourth against the spin

Stick longitudinally two-thirds back

Rudders deflected two-thirds $\left(16\frac{2}{3}^{\circ}\right)$

A series of tests were also performed for two up-elevator settings exceeding the design maximum up-elevator deflections of 45°. These two settings were 65° and 85°. For these tests, it was assumed that full lateral stick movement caused the same differential change of ±10° that occurred with normal stick-back deflection. The two corresponding intermediate stick-back positions (stick longitudinally two-thirds back) tested for the criterion-spin control configuration used with each of the two modified maximum deflections were $43\frac{1}{3}^{\circ}$ (for 65°) and $56\frac{2}{3}^{\circ}$ (for 85°).

The stability flap deflection tested was 25°, the angle of flap deflection being measured between the thrust center line and the flap chord line.

Four propeller pitch angles measured at 0.75 radius of the blade were used and included 10°, 30°, 60°, and 90°. For these tests the propellers were allowed to windmill.

For all the tests reported herein, the landing gear was retracted, as was previously mentioned, and the cockpit was closed.

RESULTS AND DISCUSSION

Results of tests made with the model freely spinning are presented in terms of full-scale values for the airplane at an altitude of 15,000 feet in charts 1 to 4 and in tables III to V. Inasmuch as the initial tests of the model without propellers yielded similar results for both right and left erect spins, most of the tests were arbitrarily performed with the model spinning only to the right.

Normal Loading, Propellers Off

The results of left and right erect spins with the model in the normal fighter loading, landing gear retracted (condition 1 on table II and fig. 7), are presented in chart 1. With the controls set for the normal-control configuration for spinning (stick back and laterally neutral, rudder full with the spin), two conditions appeared to be possible; one condition a "no spin" and the other condition a spin with a satisfactory recovery. The tendency for the spinning condition to persist was indicated, however, as slight control deviations from the normal-control configuration (criterion-spin settings) caused two types of spin, and recovery could not be obtained by rudder reversal from the flatter spin. Similarly, poor recoveries were obtained from spins in which flat attitudes and extreme wandering motions were characteristic when the stick was laterally against the spin and either neutral or forward longitudinally. The rudders were ineffective in spins at these last-mentioned control configurations and the model continued to spin following rudder reversal. Unsatisfactory spin-recovery characteristics were also indicated when the stick was longitudinally back and laterally with the spin. The optimum control positions appeared to be stick longitudinally full back and laterally full against the spin (condition for "no spin"), or stick longitudinally full forward and laterally with the spin. Recoveries attempted by simultaneous reversal of both rudders and movement of the stick full back and laterally full against the spin, however, were not considered satisfactory because of the time required following the control movement for the model to go from the flat spinning attitude to the steep attitude of the no-spin condition (chart 1).

As noted previously, it was found that a no-spin condition persisted when the stick was full back and laterally full against the spin, but that when the stick was laterally full with the spin, no recovery could be obtained for this stick-back position. Based on these results it appeared that the outboard ailavator (left ailavator in a right spin) had to have a minimum upward deflection of 55° to produce the no-spin condition obtained for the previously mentioned optimum control position in which the stick was full back and laterally full against the spin. In order to improve the spin-recovery characteristics of all spins with full-back stick, the maximum longitudinal control setting was increased to 65° up with a resultant minimum upward deflection of the outboard ailavator for any lateral stick position (stick full back) of 55°. The respective up-ailavator deflections then became 55° and 75° at either one of the two maximum lateral stick positions when the stick was held full back. A second revised maximum longitudinal control deflection tested gave ailavator deflections of 75° and 95° at either of the two maximum lateral stick positions. The results of these tests are given in table III. It is apparent that these larger longitudinal control deflections were decidedly beneficial, resulting in no-spin conditions for the stick-back control configuration.

With the ailavators completely removed, it was found that the model would not spin.

Effect of Propellers

Using the suspension apparatus previously described, spin tests were carried out to determine the effect of windmilling propellers on the spin and recovery characteristics of the model and to select the optimum propeller-blade pitch angle. Comparison of results obtained for the four-blade angles of 10°, 30°, 60°, and 90° showed that 30° was the optimum propeller pitch angle from a spin-recovery viewpoint. Brief free-spinning tests were then performed at several control configurations with the propellers set at a pitch of 30°. The results of these tests, which are presented in chart 2, reveal that the characteristically flat spin from which recovery is unsatisfactory still exists, the spins and recoveries, in general, being very similar to those obtained without propellers. It seems, therefore, that no appreciable improvement in the recovery characteristics can be expected from windmilling propellers in a spin of this airplane.

Inverted Spins

The results of inverted spin tests performed for three control configurations on the model, propellers removed, and with the model rotating to the pilot's right are given 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 pilot's right) is presented to the right of the chart and stick longitudinally forward at the top of the chart. When the controls are crossed in the established inverted spin, the ailavators aid the rolling motion; when the controls are together, the ailavators oppose the rolling motion. The angle of wing tilt ϕ on the chart is given as up or down relative to the ground.

Spinning in an inverted attitude, the model demonstrated a spinning motion similar to that exhibited for the erect spins for the control configurations tested. Recoveries from these inverted spins were also poor as shown in chart 3. Based on the model spin tests the inverted spin-recovery characteristics of the airplane are expected to be unsatisfactory.

Recommended Recovery Technique

It is advised that the airplane in its present design configuration be prohibited from any intentional spinning; however, in case of inadvertent spins, the following control technique for recovery is recommended:

Erect spins.- The stick must be set and held full back and laterally full against the spin before the rudder is reversed. Rudder reversal must be rapid and complete. This control configuration should then be maintained until the spinning rotation has ceased; the stick should then be neutralized laterally and pushed forward of neutral longitudinally to regain normal unstalled flight. If after 5 turns the rotation has not stopped, hold rudder full against the spin and push the stick forward and laterally with the spin. When the airplane has become unstalled, care should be exercised to prohibit any excessive rates of acceleration which may be coincident with the ensuing dive.

Inverted spins.– To effect optimum recovery from inverted spins, the stick should be moved full forward and laterally in the same sense as the steady–spin rudder (controls together) immediately upon entering the spin; the rudder should then be reversed briskly to full against the spin holding the stick at the prescribed position until recovery is obtained. As in the case of erect spins, if the airplane becomes unstalled, care should be taken to prohibit any excessive rates of acceleration possibly coincident with the ensuing dive.

Dimensional Revisions to the Design Configuration

The results of free–spinning tunnel tests made on the model with propellers removed for various dimensional revisions designed to improve the recovery characteristics of the model are presented in table IV. Drawings of the dimensional revisions tested are shown in figures 9 to 14.

Inasmuch as it was recognized that any improvement to the spin–recovery characteristics was dependent upon the elimination of the characteristically flat spin, the primary objective of these tests was to determine only the modifications necessary to prevent spins in the flat attitude. Accordingly, most of the tests were performed for just one control configuration, stick longitudinally neutral and laterally against the spin, known to consistently produce the flat–type spin.

The results of tests of those revisions which had no effect on the flat spin are given in section A, table IV. The results of tests of revisions which, although influencing the spin beneficially to some extent were not considered as satisfactory, are presented in section B. These revisions included such devices as slots on the leading edges of both ailavators, spoilers on the upper surfaces of both ailavators, and longitudinal fences on the upper and lower surfaces of the airplane wing plan form proper.

The results of tests of revisions that eliminated the flat spin and satisfactorily improved the spin and recovery characteristics are presented in section C of table IV. These revisions were: (1) a supplementary vertical tail 34 inches by 59 inches (full–scale) located 80 inches rearward of the airplane trailing edge in the plane of symmetry (supplementary tail 2, fig. 9); or (2) a large semispan undersurface spoiler placed along the quarter chord and deflected downward 90° to the chord on the outboard side in a spin (spoiler 4, fig. 11); or (3) two large vertical fins 64 inches by 52 inches (full-scale) located at the ailavator tips (vertical fin 7, fig. 10). For this last revision, it was found that arbitrarily fixing 16 inches of the rearward parts of both vertical fins 20° against the spin, to simulate antispin rudders, produced a no-spin condition, the spin rotation damping out rapidly (within 3 turns) after the launching (table IV). The no-spin condition still prevailed whether these simulated rudders were set at neutral or 10° with the spin, but the number of turns required before the spinning rotation ceased was definitely greater (reaching as much as 15 turns) than those for the condition in which the rudders were set against the spin.

Spin-Recovery Parachutes

The results of the spin-recovery parachute tests, propellers off, are given in table V sections (a) and (b) and the method used to define the towline angles is shown in figure 15. The results presented in section (a) are for one parachute attached to the arresting gear mast. The results show that, although parachutes as large as 16 and 20 feet in diameter (full-scale) were used, poor recoveries were obtained from the flat criterion spin (stick longitudinally two-thirds back and laterally either one-third with the spin or against the spin) and for the flat spin existent when the stick is longitudinally neutral and laterally against the spin.

It was requested by the contractor that specific tests be performed to determine the effect of opening a tail parachute while simultaneously moving the stick longitudinally back and laterally against the spin, a control configuration which had previously yielded a no-spin condition. The tests were made using a 16-foot (full-scale) parachute attached to the arresting gear mast by a 30-foot (full-scale) towline. The ailavators were set to represent a stick configuration of neutral longitudinally and against the spin laterally, to produce a flat spin prior to the recovery attempt. The results of these tests which appear in table V section (a) indicate that recovery could not be effected by this technique within $2\frac{1}{4}$ turns. This recovery technique therefore is not expected to give satisfactory recovery on the airplane.

The results presented in section (b) of table V indicate that a 13.3-foot (full-scale) parachute attached by a 30-foot (full-scale) towline to the arresting gear mast when opened simultaneously with an 8-foot (full-scale) parachute attached to the outboard end of the wing at the quarter-chord line by either a very short towline (3 feet in length, full-scale) or no towline at all gave satisfactory recovery from the criterion spin. Accordingly, it appears that such an arrangement will be necessary to insure satisfactory recovery from demonstration spins. It is at the same time advised as a precautionary measure, however, that the pilot move the stick longitudinally full back and laterally full against the spin when opening the parachutes.

It was observed during the tests that the parachutes frequently did not completely clear the model when opened and thus were slow in opening or failed to open completely. In view of this, it is especially important that some means of positive ejection be employed on the airplane.

The calculated full-scale steady-load and shock-load values for a 16-foot parachute with a drag coefficient of 0.7 will be 4130 pounds and 9500 pounds, respectively, based on reference 5, for a flat spin with a relatively low rate of descent (182 ft/sec). For the same parachute at one of the higher vertical velocities (274 ft/sec) recorded for a steady spin on the subject model, the full-scale calculated shock load is 19,000 pounds. Such loads may be excessive for the ordinary airplane structure and some special design may be necessary for the XF5U-1 airplane to withstand such loads.

Stability Flaps

Chart 4 presents the results of tests with the stability flaps deflected. These results indicate that the stability flaps were not effective in charging the general spin and recovery characteristics, although the vertical velocities of spins with the stick deflected laterally with the spin were increased somewhat.

Landing Condition

No tests were made with the landing gear extended inasmuch as current Navy specifications require airplanes in the landing condition to demonstrate satisfactory recovery characteristics only from 1-turn spins. Spin-tunnel experience indicates that the effect of landing gear on a spin is usually negligible. Comparison of current results with those of the model of the prototype airplane (reference 1), which had a fixed landing gear, shows little or no effect of this landing gear.

Increase in Wing Loading, Changes in Mass Distribution, and Center-of-Gravity Movement

In basic design the V-173 and XF5U-1 airplanes are identical. Three loadings were tested on the prototype model, the heaviest being lighter than the normal loading tested on the XF5U-1 model. The spin-recovery characteristics obtained for the heaviest of the three loadings tested on the prototype model (reference 1) closely resemble those obtained for the subject model. In the light of this it can be inferred that insofar as the dimensional revisions which distinguish the XF5U-1 from the prototype model failed to alter appreciably the spin and recovery characteristics previously obtained for the heaviest loading simulated on the prototype model, and the changes in weight and mass distribution tested on the prototype are sufficient to indicate the effect of these variations on the spin and recovery characteristics of the XF5U-1 airplane.

For instance, analysis based on a comparison of the results for the three loadings tested on the prototype with those obtained for the loading tested on the XF5U-1 shows that increasing the weight tends to make the spin and recovery characteristics progressively poorer for any constant mass distribution. From this analysis, it is concluded that the spin-recovery characteristics of the XF5U-1 airplane for any greater loading or any possible mass distributions will not be improved over those described for the normal loading. As indicated in reference 1, moderate changes in center-of-gravity location or mass distribution will not alter the general recovery characteristics. For all loadings, optimum recoveries will be obtained from spins by moving the stick longitudinally full back and laterally against the spin before fully and rapidly reversing the rudder.

Tumbling Tests

The results of tumbling tests in which the model was released without initial rotation from a nose-up position to simulate a whip stall condition are given in table VI, section (a). With rudders neutral and stick laterally neutral, the model would not tumble for control configurations in which the stick was longitudinally back, neutral, or forward. After executing several heavily damped pitching oscillations, the model trimmed each time in a nose-down gliding attitude.

The results presented in section (b) of table VI for the same rudder and lateral stick positions indicated that, although nose-up (positive) and nose-down (negative) forced pitching rotation was imparted to the model, no susceptibility to tumbling was observed. Whether the stick was longitudinally back, neutral, or forward, the model trimmed in a steep dive after exhibiting several heavily damped pitching oscillations.

Pilot-Escape Tests

The results of the pilot-escape tests revealed that it would be extremely hazardous to abandon the airplane in its present geometrical configuration for either the flat or steeper type spin. Whether the dummy pilot was released from the inboard or outboard side of the cockpit, it almost invariably slipped forward into the plane of the propellers before gaining sufficient height above the model to enable it to safely clear the propeller blades. Following this the dummy pilot usually tumbled to the outboard side, quitting the model entirely, in some cases, as far aft as the juncture of the ailavator and wing. Several times during the flat spins, the dummy pilot appeared to be struck by the leading edge of the ailavator on the outboard side in the spin, just before passing over or under this surface. The vertical tails provided a similar source of risk in the steeper spins when on several occasions the dummy pilot struck one or the other before moving off the trailing edge of the model. These results indicate that provision should be made for mechanically ejecting the pilot from the cockpit in such a way as to allow him sufficient height to clear the propeller blades.

Tank and Bomb Jettison

No tests were made to simulate the jettisoning of fuel tanks, torpedos, or bombs while in a spin. It is estimated that torpedos, heavy bombs, and full fuel tanks when dropped in either the flat or steep type of spin will clear the airplane structure but may pass through the propeller arc. As previously indicated, however, the addition of these items will not greatly affect the spin and recovery characteristics and jettisoning should not be necessary from a spin-recovery viewpoint.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of tests of a $\frac{1}{16}$-scale model of the Chance Vought XF5U-1 airplane, the following conclusions and recommendations are made regarding the spin and recovery characteristics for the airplane at an altitude of 15,000 feet:

1. The recovery characteristics from fully developed erect and inverted spins with the airplane in its present design configuration will be unsatisfactory.

2. The optimum propeller-pitch setting for spins in which the propellers are allowed to windmill is 30°.

3. The airplane should be prohibited from any intentional spinning. In the case of inadvertent spinning the following control technique for recovery should be followed:

(a) Erect spins.- Hold the stick full back and laterally full against the spin; then reverse the rudder rapidly and completely. This control configuration should be maintained until the spinning rotation has ceased; the stick should then be neutralized laterally and pushed forward of neutral to regain normal unstalled flight. If after 5 turns rotation has not stopped, hold rudder full against spin and push stick forward and laterally with spin.

(b) Inverted spins.- Push the stick full forward and laterally in the same sense as the steady-spin rudder (controls together) immediately upon entering spin. The rudder should then be briskly reversed to full against the spin.

4. Increasing the up-ailavator deflection from 45° to 65° will result in greatly improved spin-recovery characteristics for spins with stick full back and in any lateral position.

5. Dimensional revisions to the original design configuration which satisfactorily improved the spin and recovery characteristics of the model consisted of either: (1) a supplementary vertical tail 34 inches by 59 inches, full-scale, attached to a boom 80 inches rearward of the trailing edge of the airplane in the plane of symmetry; or (2) a large semispan undersurface spoiler placed along the airplane quarter-chord line and opened on the outboard side in a spin; or (3) two additional

vertical tails (end plates) of 64 inches by 52 inches (full-scale) located at the tips of the ailavators.

6. For demonstration spins satisfactory recoveries will be obtained with a 13.3-foot (full-scale) parachute attached by a 30-foot (full-scale) towline to the arresting gear mast and opened simultaneously with an 8-foot, (full-scale) parachute attached by a short towline (3 feet, full-scale) or no towline to the outboard end (left tip in a right spin) of the wing at the quarter-chord line. It is further recommended that the pilot hold the stick laterally against the spin and longitudinally back during release of the parachutes.

7. Deflecting the stability flap will have no effect on the spin and recovery characteristics.

8. The airplane will not tumble.

9. Pilot escape from the spinning airplane will be hazardous unless provision is made for mechanically ejecting the pilot from the cockpit. Care should be taken to insure that he will safely clear the propeller blades when ejected.

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4. Griffin, B.: Computation of Weight, Balance and Moments of Inertia-Model XF5U-1. Rep. No. 6522, Chance Vought Aircraft, Div. of United Aircraft Corp. (Stratford, Conn.), Oct. 5, 1944.

[redacted]

TABLE I.– DIMENSIONAL CHARACTERISTICS OF THE CHANCE VOUGHT XF5U-1 AND

VOUGHT-SIKORSKY V-173 AIRPLANES

	XF5U-1	V-173
Length over all, ft	28.13	26.64
Number of propellers	2	2
Propellers, number of blades (each)	4	2
Propeller diameter, ft	16	16.5
Normal weight, lb	16,867	4615
Normal center-of-gravity location, percent $\bar{c}$	26.2	22.5
Wing:		
Span, ft	23.33 at 25 percent chord	23.33 at 25 percent chord
Area, sq ft	427	427.52
Section (constant)	NACA 0016	NACA 0016
Mean aerodynamic chord, in.	238	238
Leading-edge M.A.C. aft of leading edge of wing, in.	10.02	10.50
Incidence, deg	0	0
Sweepback at 25 percent chord, deg	0	0
Dihedral, deg	0	0
Geometric aspect ratio (b^2/s)	1.27	1.27
Horizontal tail:		
Total area, sq ft	48.0	46.0 (including 21 sq ft of fixed stabilizer)
Root chord, in.	52.0	
Tip chord, in.	26.0	24.9 (taken perpendicular to hinge line)
Root section	NACA 0015	NACA 0015
Tip section	NACA 0009	NACA 0009
Horizontal distance from normal center of gravity to ailavator hinge line, ft	11.45	10.42 at root chord
Vertical tails:		
Total area, sq ft	28.42	28.3
Rudder area rearward of hinge line, sq ft	11.28	13.2
Horizontal distance from normal center of gravity to top of rudder hinge line, ft	12.53	15.0
Fin offset from airplane center line, deg	2 outboard (each)	0

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TABLE II.– MASS CHARACTERISTICS AND INERTIA PARAMETERS

FOR LOADINGS POSSIBLE ON THE CHANCE VOUGHT XF5U-1 AIRPLANE

AND FOR THE LOADING TESTED ON THE $\frac{1}{16}$-SCALE MODEL

[Model values are presented in terms of full-scale values, moments of inertia are about center of gravity]

No.	Loading	Weight (lb)	$x/\bar{c}$	$z/\bar{c}$	μ sea level	μ test altitude	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
						Airplane values						
1	Normal	16,867	0.262	0.004	22.10	35.15	17,783	15,905	32,700	66×10^{-4}	-591×10^{-4}	525×10^{-4}
2	Maximum increase in $\frac{I_X - I_Y}{mb^2}$	13,690	.237	.003	17.93	28.52	17,571	14,445	31,177	135	−723	588
3	Maximum decrease in $\frac{I_X - I_Y}{mb^2}$	18,982	.256	.016	24.89	39.60	18,731	17,104	33,255	51	−504	453
4	Center of gravity moved rearward	16,537	.267	.004	21.69	34.50	17,764	15,659	32,450	75	−600	525
5	Center of gravity moved forward	16,222	.231	.020	21.27	33.83	18,530	15,884	32,006	97	−589	492
6	Overload fighter	18,982	.256	.016	24.89	39.60	18,731	17,104	33,255	51	−504	453
7	Light gross weight.	14,369.9	.241	.003	19.55	31.08	17,641	14,925	31,708	112	−693	581
8	Unsymmetrical overload fighter	17,969.4	.259	.006	24.45	38.86	18,279	16,505	32,953	59	−543	484
						Model						
9	Normal	16,858	0.263	0.005	22.05	35.08	18,296	15,367	33,703	103×10^{-4}	-646×10^{-4}	543×10^{-4}

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TABLE III.- EFFECT OF REVISED MAXIMUM AND INTERMEDIATE UP-AILAVATOR DEFLECTIONS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE

Rudders maintained with spin

[redacted]

Stick position		Direction of launching rotation	Results	Remarks
Longitudinal	Lateral			
Stick longitudinally full back, ailavators 65° up; Stick longitudinally 2/3 back, ailavators $43\frac{1}{3}$° up				
Full back	Full against	Left	No spin	$2\frac{1}{2}$ turns after launching rotation stopped, model in steep glide
Full back	Full with	Left	No spin	$7\frac{3}{4}$ to 8 turns after launching rotation stopped, model in steep glide
Full back	Neutral	Left	No spin	$1\frac{3}{4}$ and $3\frac{3}{4}$ turns after launching rotation stopped, model in steep glide
$\frac{2}{3}$ back	$\frac{1}{3}$ with	Left	No spin	$\frac{1}{2}$ to $3\frac{1}{2}$ after launching rotation stopped, model in steep glide
Stick longitudinally full back, ailavators 83° up; Stick longitudinally 2/3 back, ailavators $56\frac{2}{3}$° up				
Full back	Full against	Left	No spin	3 turns after launching rotation stopped model in steep dive
Full back	Full with	Left		Large radious spin (V = 274 ft/sec, full-scale)
Full back	Neutral	Left	No spin	4 to $4\frac{1}{2}$ turns after launching, rotation stopped, model in steep dive
$\frac{2}{3}$ back	$\frac{1}{3}$ against	Left	No spin	3 to 4 turns after launching, rotation stopped, model in steep dive

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TABLE IV.– EFFECT OF DIMENSIONAL REVISIONS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE XF5U-1 MODEL

[Normal loading; cockpit closed; landing gear retracted; propellers off; stability flaps neutral; normal control deflections; recovery attempted only where indicated by rapid full rudder reversal]

[redacted]

No.	Model condition: Revision or combination of revisions	Model condition: Shown on figure	Model condition: Location on model	Model condition: Longitudinal stick position	Type of spin and recovery for lateral stick positions indicated: Full against	Type of spin and recovery for lateral stick positions indicated: 1/3 against	Type of spin and recovery for lateral stick positions indicated: 1/3 with	Type of spin and recovery for lateral stick positions indicated: Full with	Remarks
Section A – Revisions which did not satisfactorily eliminate the flat spin									
1	Ventral fin 1 added	9	Plane of symmetry	Neutral	∞				Spin obtained similar to that of unrevised model (chart 1)
	Ventral fin 1 added	9	--do--	Full back				>2, >6	
	Ventral fin 1 added	9	--do--	2/3 back		No spin	No spin		
2	Ventral fin 2 added	9	--do--	Neutral	∞				Do.
3	Vertical fin 1 added	10	Fin location 1 (fig. 14)	--do--	Flat spin				Do.
4	Vertical fins 2 added	10	--do--	--do--	--do--				Do.
5	Vertical fins 3 added	10	--do--	--do--	--do--				Do.
6	Vertical fins 4 added	10	--do--	--do--	--do--				Do.
7	Vertical fins 5 added	10	--do--	--do--	--do--				Do.
8	Vertical fins 6 added	10	--do--	--do--	--do--				Do.
9	Spoiler 1; vertical fins 2 (fin location 1)	11	Upper surface $\bar{c}/4$ line	--do--	--do--				Do.
10	Spoiler 2	11	Lower surface $\bar{c}/4$ line	do	--do--				Do.
11	Spoiler 3	11	Lower surface $\bar{c}/4$ line, outboard side	--do--	--do--				Do.
12	Longitudinal fence 1	12	Fences along ℄ thrust of each propeller	--do--	--do--				Do.
13	Longitudinal fences 1 and 2	12	--do--	do--	--do--				Do.
14	Longitudinal fences 3 and 2; vertical fin 5 (fin location 1)	12	--do--	--do--	--do--				Do.
15	Ailavator spoilers; vertical fins 5 (fin location 1)	13	Spoilers along ℄ ailavator hinge line upper surface	--do--	--do--				Do.
16	Slotted ailavators, slats 1	13	Leading edge of ailavators	--do--	--do--				Do.
17	Slotted ailavators, slats 2	13	--do--	--do--	--do--				Do.
18	Vertical fin 7; original vertical tails removed	10	Fin location 2, (fig. 14)	--do--	--do--				Do
19	--do--	10	Fin location 3, (fig. 14)	--do--	--do--				Do.
20	Dorsal fin 1; vertical fins 7 (fin location 1), original vertical tails removed	14	Dorsal fin in plane of symmetry	--do--	(a) flat spin (b) steep spin				Two types of spins obtained (a) flat spin similar to that of unrevised model (chart 1) and (b) steep spin with a rate of descent >304 ft/sec

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TABLE IV.– EFFECT OF DIMENSIONAL REVISIONS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE XF5U-1 MODEL – Concluded

[Normal loading; cockpit closed; landing gear retracted; propellers off; stability flaps neutral; normal control deflections; recovery attempted only where indicated by rapid full rudder reversal]

[redacted]

No.	Model condition: Revision or combination of revisions	Model condition: Shown on figure	Model condition: Location on model	Model condition: Longitudinal stick position	Type of spin and recovery for lateral stick positions indicated: Full against	1/3 against	1/3 with	Full with	Remarks
Section A – Revisions which did not satisfactorily eliminate the flat spin									
21	Dorsal fin 1; vertical fins 7 (fin location 3) original vertical tails removed	14	Dorsal fin in plane of symmetry	Neutral	Flat spin				Spin obtained similar to that of unrevised model (chart 1)
22	Dorsal fin 1; vertical fins 7 (fin location 4) original vertical tails removed	14	----do----	----do----	----do----				Do.
23	Dorsal fin 2; vertical fins 7 (fin location 1) original vertical tails removed	14	----do----	----do----	(a) flat spin (b) spin steepens about 5 turns				Two types of spins obtained (a) flat spin of unrevised model (chart 1) and (b) steep spin with a rate of descent > 304 ft/sec
24	Dorsal fin 2; vertical fins 7 (fin location 2); original vertical tails removed	14	--do--	----do----	Flat spin				Spins obtained similar to that of unrevised model (chart 1)
25	Dorsal fin 2; vertical fins 7 (fin location 3); original vertical tails removed	14	--do--	----do----	----do----				Do.
Section B.– Revisions which had an effect on the steady flat spin but were not considered satisfactory because of the time required before any effectiveness could be realized									
26	Supplementary tail 1	9	Plane of symmetry	Neutral	$> 2\frac{1}{2}$				Spin steepened but recovery still poor
27	Spoiler 5	11	Lower surface c̄/4 line	----do----	Steep spin				Spin steepened after approximately 8 turns
28	Spoiler 6	11	--do--	----do----	----do----				Do.
29	Spoiler 7	11	--do--	----do----	----do----				Do.
30	Spoiler 7; vertical fins 2 (fin location 1)	11	--do--	----do----	----do----				Steep spin, no recoveries attempted
Section C.– Revisions which satisfactorily eliminated the flat spin									
31	Supplementary tail 2	9	Plane of symmetry	Neutral	$1\frac{1}{2}$, $2\frac{1}{2}$				
	Supplementary tail 2	9	--do--	2/3 back		No spin			
32	Spoiler 4	11	Lower surface c̄/4 line outboard side	Neutral	No spin				Spin rotation ceased in about 20 turns
33	Vertical fins 7 (rearward 16 in. of fins simulating rudders fixed 22° against spin)	10	Vertical fins in fin location 1	----do----	----do----				Spin rotation completely damped in 3 turns
34	Vertical fins 7 (rearward 16 in. of fin simulating rudders fixed at neutral)	10	----do----	----do----	----do----				Spin rotation damped in 15 turns
35	Vertical fins 7 (rearward 16 in. of fins simulating rudders fixed 10° with spin)	10	----do----	----do----	----do----				Spin rotation damped in slightly greater than 15 turns

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TABLE V.– SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH A $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE

(a) ARRANGEMENT CONSISTING OF ONE PARACHUTE; TOWLINE ATTACHED TO THE ARRESTING GEAR MAST

[Normal Loading; landing gear retracted; stability flaps neutral; propellers off; recovery attempted by opening parachute while rudders were maintained with the spin; model values converted to corresponding full-scale values are given]

No.	Parachute diameter (ft)	Towline length (ft)		Stick position		Vertical velocity (ft/sec)	Turns for recovery	[a]Towline trailing angles measured from thrust line	
				Longitudinal	Lateral			A_2 (deg)	B_2 (deg)
1	13.3	30		2/3 back	1/3 right	205	$2\frac{1}{2}$, $3\frac{1}{4}$	48 to 61	19 to 34
2	13.3	30		Neutral	Full right		∞		
3	13.3	30		Full forward	Neutral		>3		
4	13.3	30		2/3 back	1/3 left	>304	2, 2	6 to 31	12 to 28
5	13.3	30		2/3 back	1/3 right	244	1, $3\frac{1}{2}$, $6\frac{1}{2}$	24 to 39	6 to 12
6	16	30		2/3 back	1/3 right	210	2, 2, 2	79 to 103	41 to 69
7	16	30		Neutral	Full right	188	2, ∞	111 to 119	27 to –14
8	16	23		Neutral	Full right		∞		
9	16	15		Neutral	Full right		∞		
10	16	30		Full back	Full left		>7		
11	16	15		Full back	Full left		>3		
12	16	30		2/3 back	1/3 left	206	$1\frac{3}{4}$, $2\frac{1}{2}$, 3, >$4\frac{1}{2}$	51 to 81	7 to –35

[a]Angles measured as noted on figure 15.

[redacted]

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[redacted]

TABLE V.– SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH A $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE – Continued

(a) ARRANGEMENT CONSISTING OF ONE PARACHUTE; TOWLINE ATTACHED TO THE ARRESTING GEAR MAST – Concluded

[Normal Loading; landing gear retracted; stability flaps neutral; propellers off; recovery attempted by opening parachute while rudders were maintained with the spin; model values converted to corresponding full-scale values are given]

No.	Parachute diameter (ft)	Towline length (ft)		Stick position		Vertical velocity (ft/sec)	Turns for recovery	[a]Towline trailing angles measured from thrust line	
				Longitudinal	Lateral			A_2 (deg)	B_2 (deg)
13	16	30		2/3 back	1/3 right	244	$2\frac{1}{4}$, 4	29 to 83	4 to 23
14	16	30		Neutral	Full right	193	[b]$2\frac{1}{2}$, [b]$3\frac{1}{4}$, [b]4, [b]5		
15	20	30		Neutral	Full right	193	4, ∞	93 to 104	-6 to 19
16	20	15		Neutral	Full right	193	3, 4, 4	78 to 84	-5 to 28

[a]Angles measured as noted on figure 15.
[b]Recovery attempted by releasing parachute and simultaneously moving ailavators to stick position: stick longitudinally back and laterally against spin.

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TABLE V.–SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH A $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE – Concluded

(b) ARRANGEMENT CONSISTING OF TWO PARACHUTES; TOWLINE OF ONE ATTACHED TO THE OUTBOARD END OF THE AIRPLANE QUARTER CHORD LINE, OF OTHER, TO THE ARRESTING GEAR

[Normal loading; landing gear retracted; stability flaps neutral; propellers off; recovery attempted by opening both parachutes simultaneously with the rudders maintained full with the spin; model values converted to corresponding full-scale values are given]

No.	Diameter of parachute attached to arresting gear (ft)	Towline length (ft)	Diameter of parachute attached to end of $\bar{c}/4$ line (ft)	Towline length (ft)	Stick position		Vertical velocity (ft/sec)	Turns for recovery	[a]Towline trailing angles measured from thrust line of the model			
									Outboard parachute		Aft parachute	
					Longitudinal	Lateral			A_1 (deg)	B_1 (deg)	A_2 (deg)	B_2 (deg)
1	6.9	30	13.3	0	2/3 back	1/3 right	221	$2\frac{3}{4}$, $4\frac{3}{4}$	24	------	67 to 77	22 to 48
2	11.7	30	6.9	0	2/3 back	1/3 right	221	3, $3\frac{3}{4}$, $3\frac{3}{4}$	35 to 63	-25 to 45	26 to 86	0 to 29
3	11.7	30	8.0	0	2/3 back	1/3 right	216	$2\frac{1}{2}$, 3, 3, $3\frac{1}{4}$	27 to 46	------	35 to 79	0 to 21
4	11.7	30	10.6	0	2/3 back	1/3 right	221	$>8\frac{1}{2}$	------	------	------	------
5	13.3	30	6.9	0	2/3 back	1/3 right	216	$1\frac{3}{4}$, $2\frac{1}{2}$, $2\frac{1}{2}$, $2\frac{3}{4}$	64	20	51 to 64	19 to 30
6	13.3	30	6.9	8	2/3 back	1/3 left		$1\frac{1}{2}$, $1\frac{3}{4}$	51 to 56	20	0 to 26	36 to 40
7	13.3	30	8.0	0	2/3 back	1/3 right	221	1, $1\frac{3}{4}$	31	------	47 to 50	10 to 33
8	13.3	30	8.0	3	2/3 back	1/3 right	227	$1\frac{1}{4}$, $1\frac{1}{2}$	46 to 58	2 to 34	36 to 58	2 to 28
9	13.3	30	8.0	3	2/3 back	1/3 left	216	1, $1\frac{1}{2}$, $1\frac{3}{4}$	31 to 34	8 to 20	34 to 76	12 to 24
10	13.3	30	8.0	3	2/3 back	1/3 right		$1\frac{3}{4}$	------	------	------	------
11	13.3	30	8.0	3	Neutral	Full right	193	$5\frac{1}{2}$, 8	48 to 68	20 to 52	26 to 89	0 to 8
12	13.3	30	11.2	8	2/3 back	1/3 right	227	1, $1\frac{3}{4}$, 2	63	4	38 to 68	20 to 32

[a]Angles measured as noted on figure 15.

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TABLE VI.– TUMBLING TESTS OF A $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE

[Model released in a nose-up attitude simulating a whipstall. Normal loading, landing gear retracted; propellers off] [redacted]

[a]Longitudinal stick position	Lateral stick position	Rudder setting	Tunnel airspeed at which model was launched into tunnel (full scale, fps)	Behavior of model after being launched
Without initial rotation				
Full back	Neutral	Neutral	188	Model made several heavily damped positive and negative pitching oscillations and then trimmed in steep glide
Neutral	----do----	---do---	188	Do.
Full forward	----do----	---do---	188	Do.
With forced initial rotation (a) Direction of forced initial rotation, positive (nose up)				
Full back	Neutral	Neutral	188	Model made several heavily damped positive and negative pitching oscillations and then trimmed in steep glide
Neutral	----do----	---do---	188	Model made several heavily damped negative pitching oscillations and then trimmed in steep glide
Full forward	----do----	---do---	188	Do.
(b) Direction of forced initial rotation, negative (nose down)				
Full back	Neutral	Neutral	188	Model made several heavily damped positive and negative pitching oscillations and then trimmed in a steep glide
Full forward	----do----	---do---	188	Model made several heavily damped negative pitching oscillations then trimmed in a steep glide

[a]Normal maximum longitudinal control deflections used.

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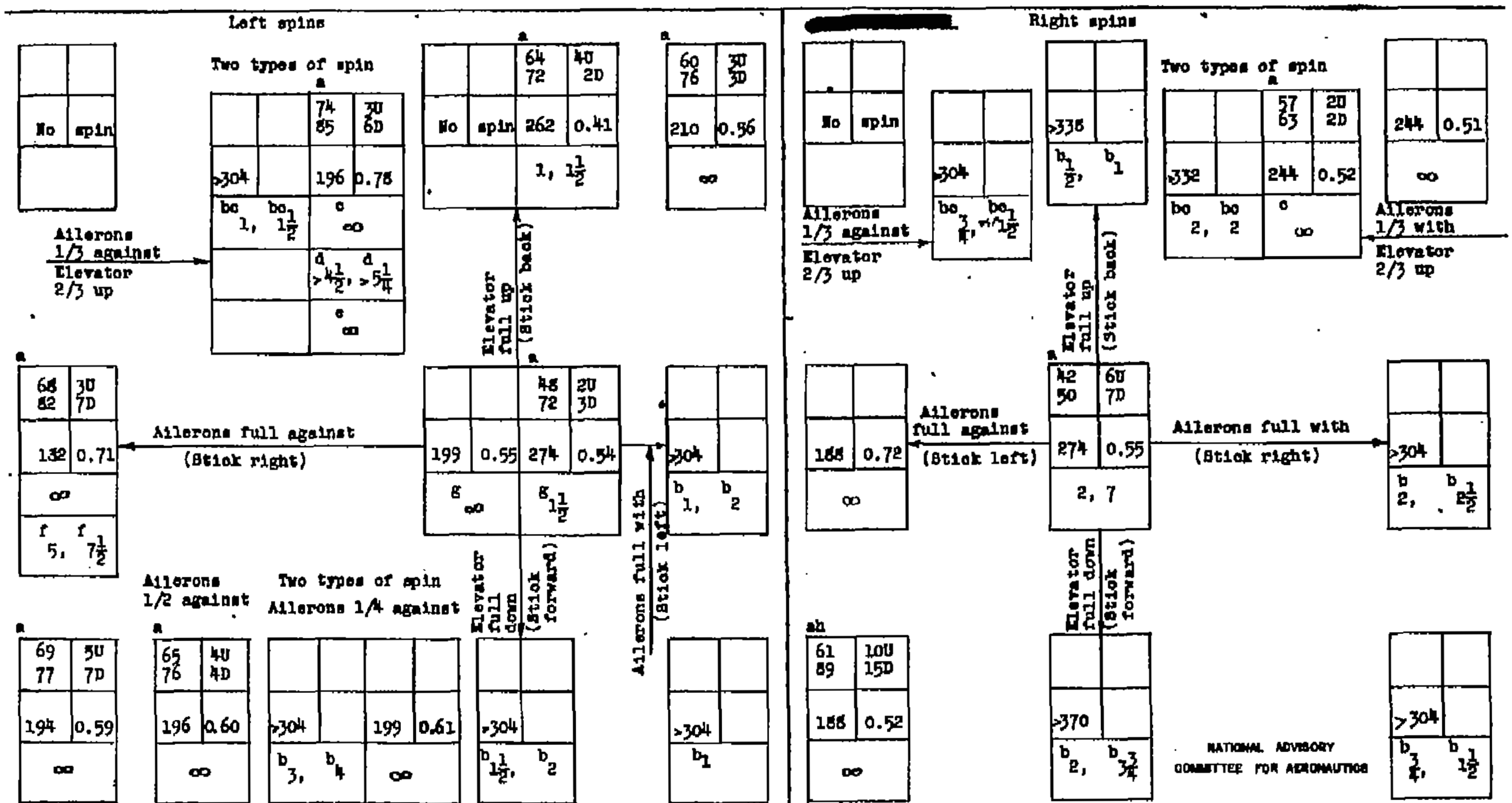
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE IN THE NORMAL FIGHTER LOADING

[Loading 1 on table II and figure 7; propellers off; stability flaps neutral; landing gear retracted; cockpit closed; normal control deflections; recovery attempted by rapid full rudder reversal except as otherwise indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); erect spins; direction of spin as indicated]

[redacted]



[a] Oscillatory spin, range of values or average value given.
[b] Recovery attempted before model reached its final steep attitude.
[c] Recovery attempted by reversal of rudders to 2/3 against the spin.
[d] Recovery attempted by simultaneous reversal of rudder to full against the spin and of stick to longitudinally full back and laterally full against the spin.
[e] Recovery attempted by simultaneous reversal of rudders to full against spin and of stick to longitudinally forward and laterally full with the spin.
[f] Recovery attempted by simultaneous reversal of rudders to full against spin and of stick to longitudinally full back.

[g] Visual estimate.
[h] Wide radius spin.

[redacted]

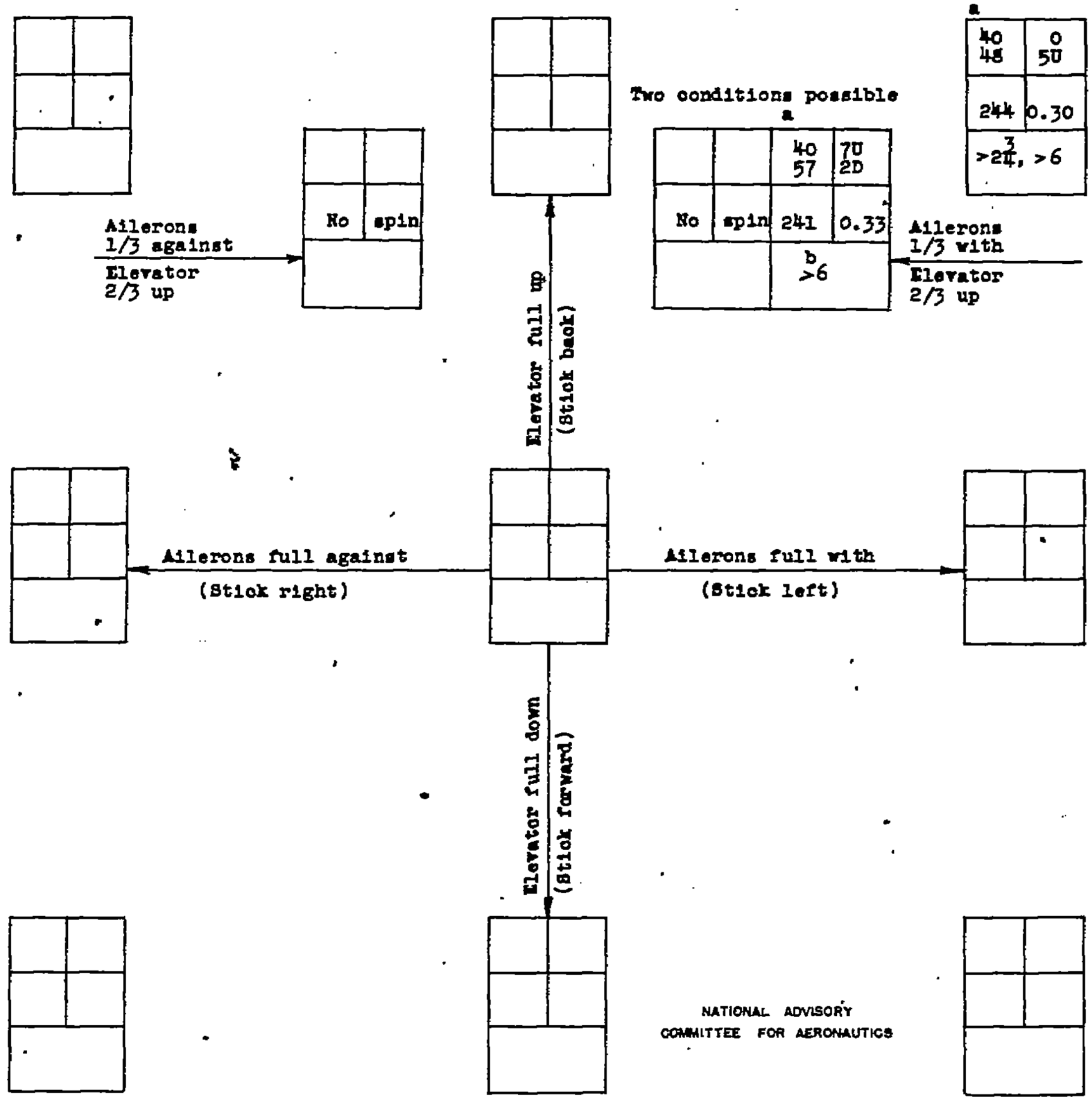
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

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

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE, PROPELLERS INSTALLED - PROPELLER PITCH = 30°

[Normal fighter loading (loading 1 on table II and figure 7); stability flaps neutral; landing gear retracted; cockpit closed; normal control deflections; recovery attempted by rapid full rudder reversal except as otherwise indicated (recovery attempted from, and steady-spin data presented for rudder-with spins); left erect spins]

[redacted]



[a]Oscillatory spin, range of values or average value given.
[b]Recovery attempted by moving rudder to 2/3 against spin.

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

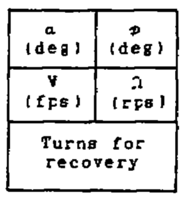


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CHART 3.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE

[Normal fighter loading (loading 1 on table II and figure 7); propellers off; stability flaps neutral; landing gear retracted; cockpit closed; normal control deflections; recovery attempted by rapid full rudder reversal (right rudder pedal forward during steady spin, left rudder pedal forward for recovery); rotation to pilot's right]

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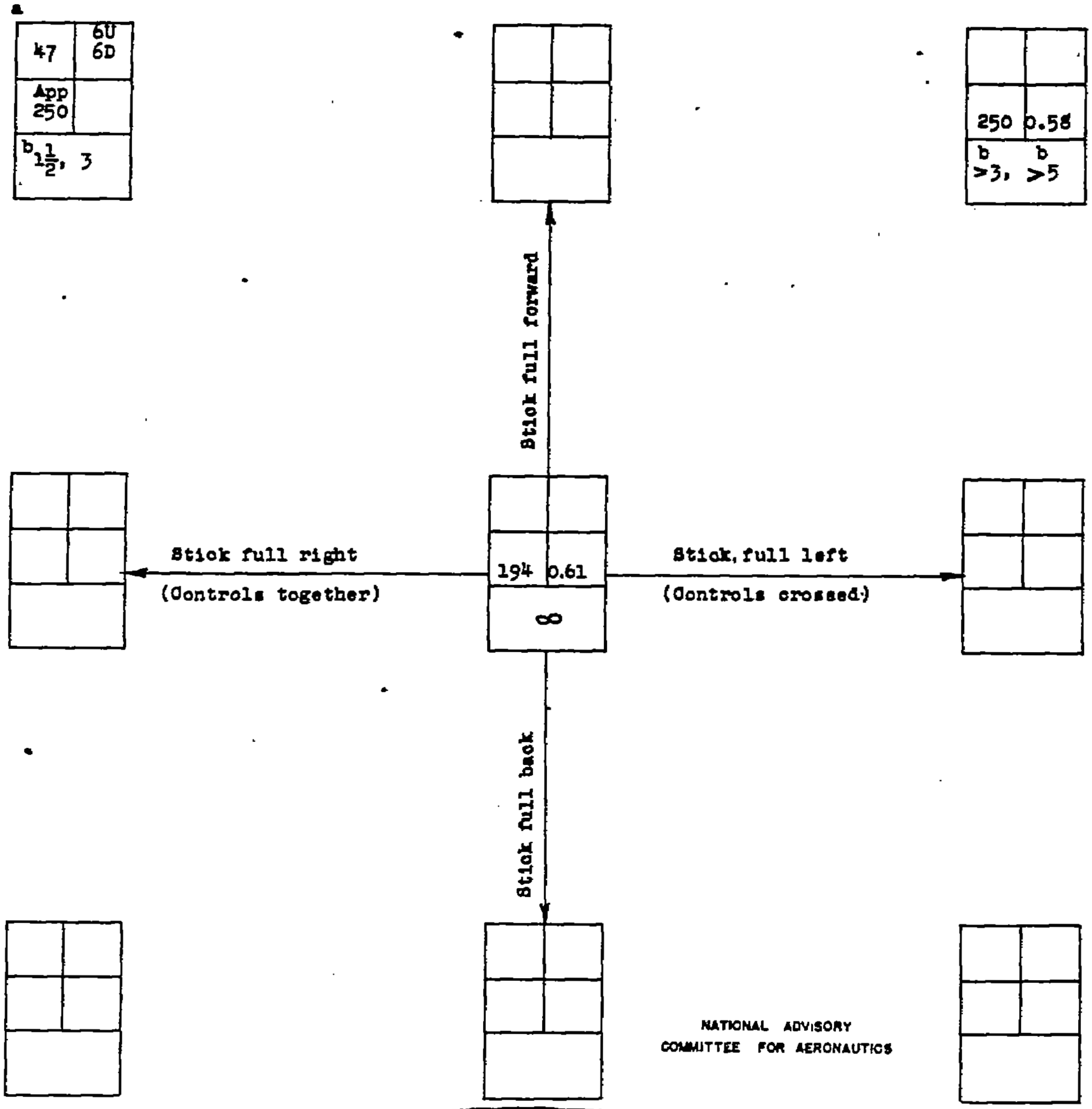


[redacted]

[a] Oscillatory spin, range of values or average value given.
[b] Visual estimate.

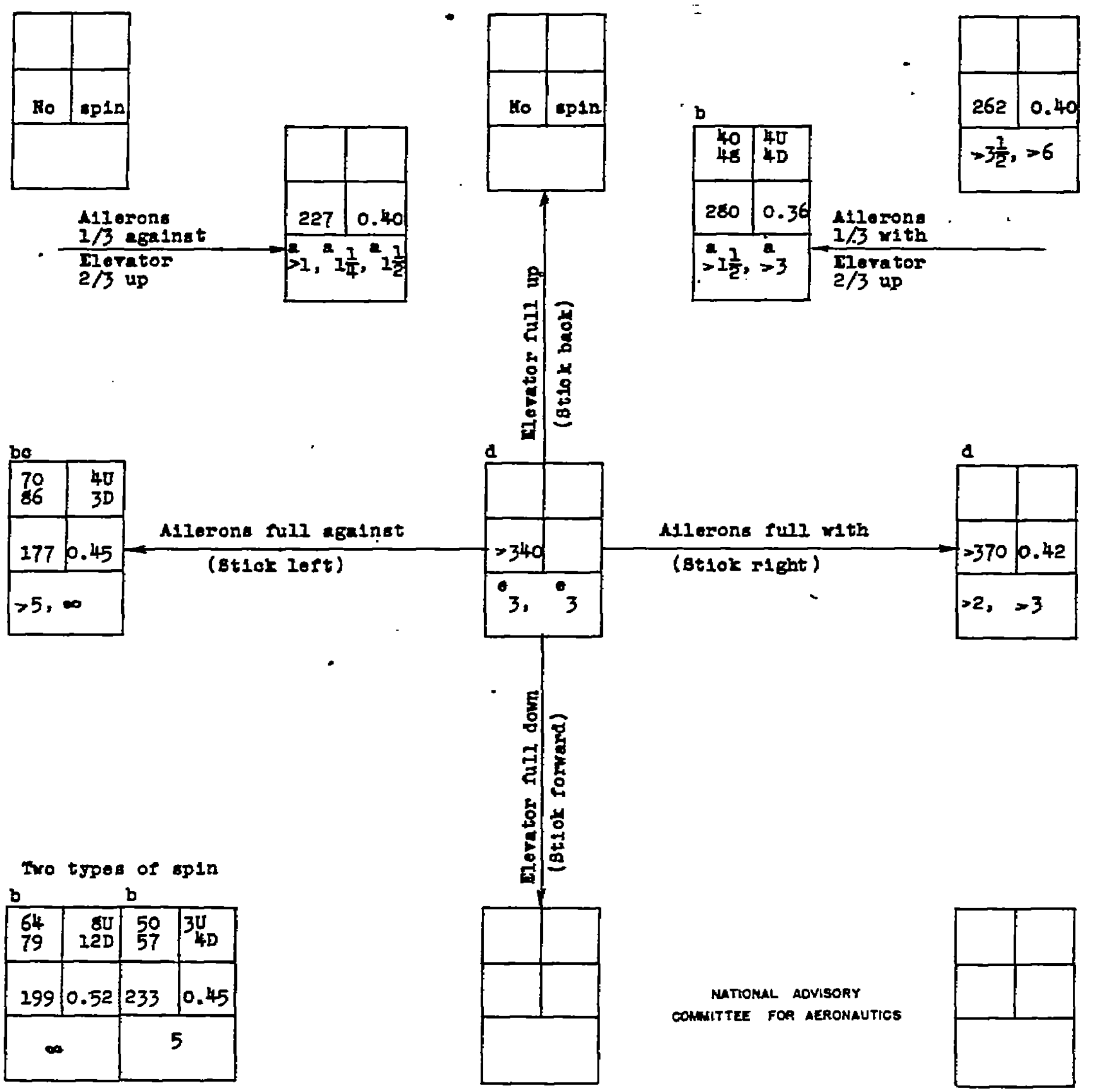
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

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

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT XF5U-1 AIRPLANE WITH STABILITY FLAPS DEFLECTED 25° DOWN

[Normal fighter loading (loading 1 on table II and figure 7); propellers off; landing gear retracted; cockpit closed; normal control deflections; recovery attempted by rapid full rudder reversal except as otherwise indicated (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]

[redacted]



[a]Recovery attempted by moving rudders to 2/3 against spin.
[b]Oscillatory spin, range of values or average value given.
[c]Very wandering spin.
[d]Very steep spin.
[e]Model recovers in steep 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	

[redacted]

[redacted]

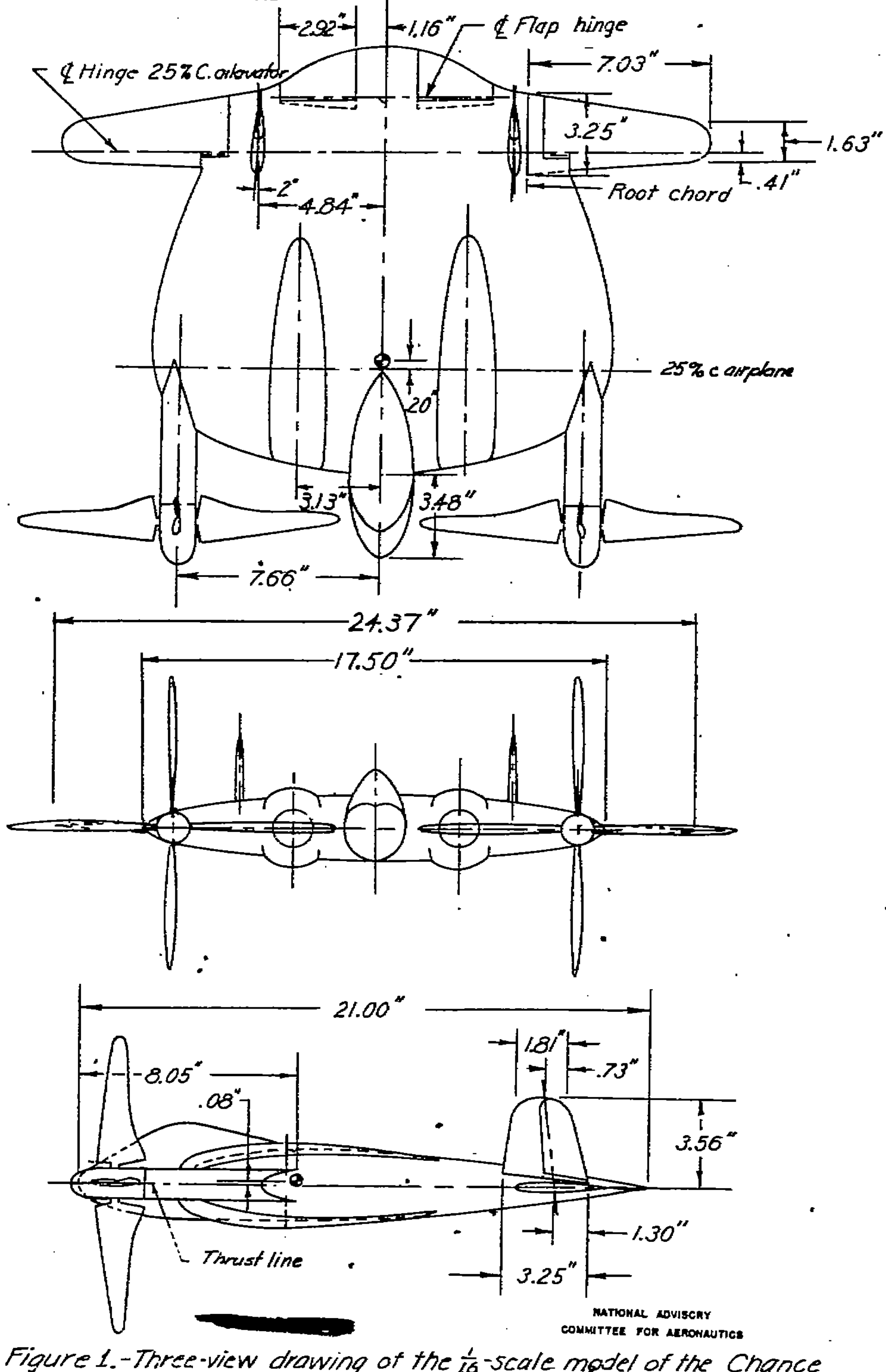


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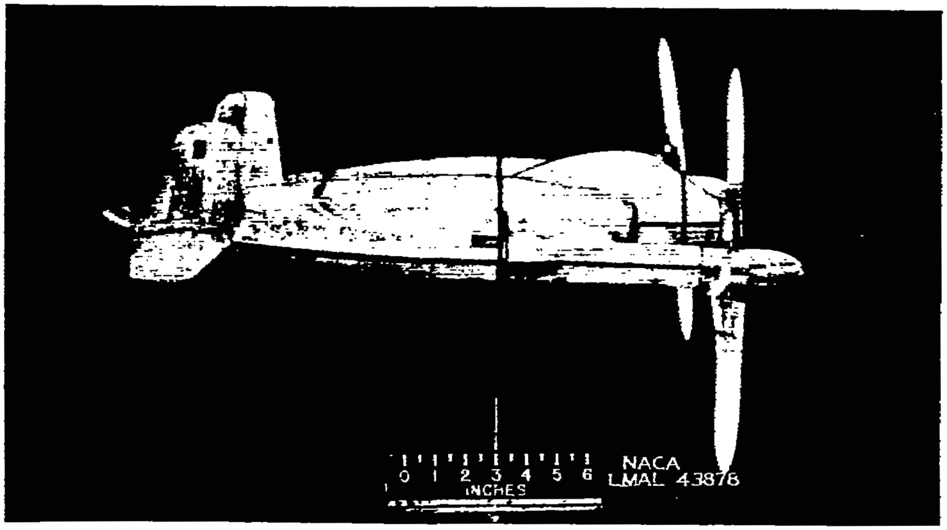
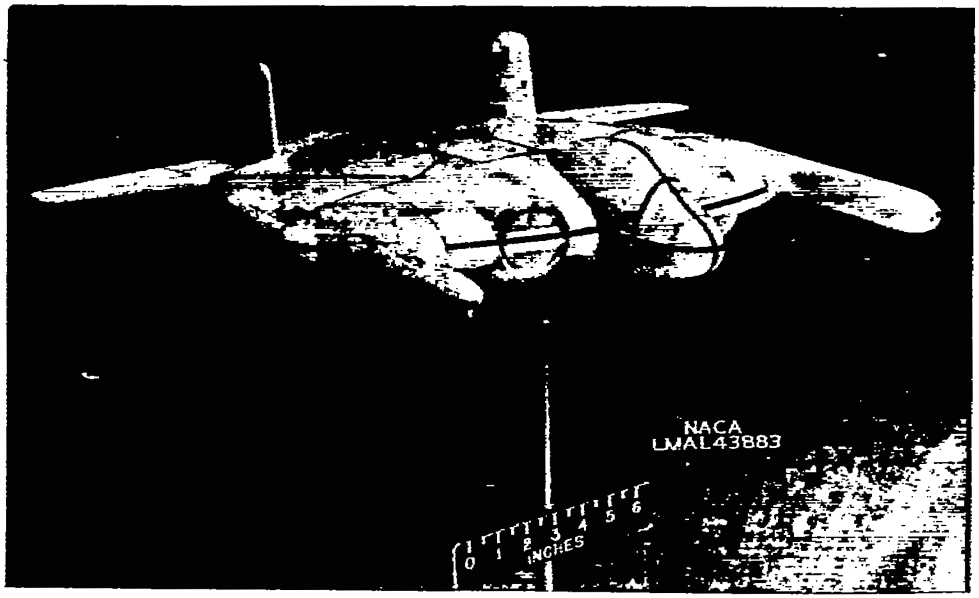
Figure 1.- Three-view drawing of the $\frac{1}{16}$-scale model of the Chance Vought XF5U-1 airplane as tested in the free-spinning tunnel. Center of gravity shown for the normal fighter loading.



(a) With propellers.



(b) Without propellers.

Figure 2.- Photograph of the $\frac{1}{16}$ - scale model of the Chance Vought XF5U-1 airplane as tested.

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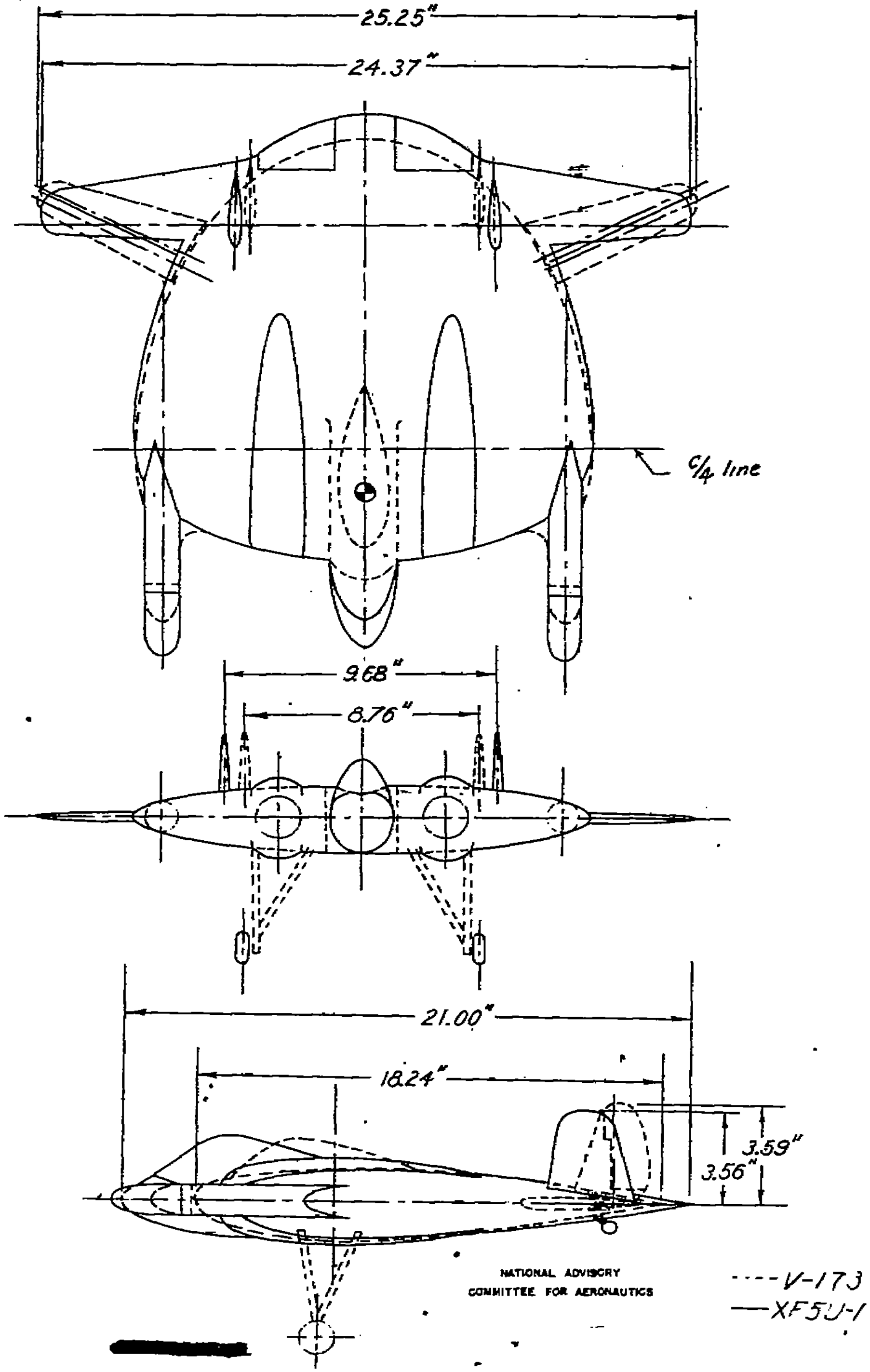

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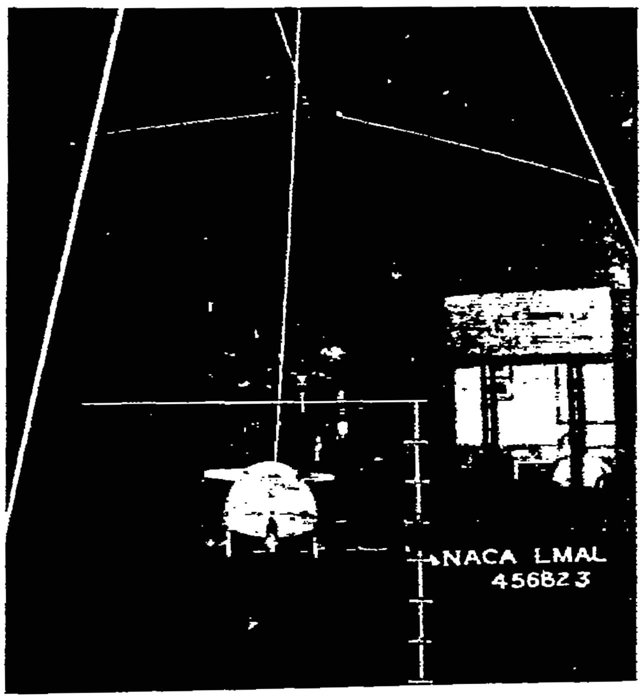
Figure 3 - Three-view comparison drawing of the $\frac{1}{6}$-scale models of the Chance Vought XF5U-1 and Vought-Sikorsky V-173 airplanes.

(a) Model spinning freely, propellers removed.



(b) Model spinning on suspension apparatus, propellers installed.

Figure 4.- The $\frac{1}{16}$-scale model of the Chance Vought XF5U-1 airplane in the normal-loading clean condition in the Langley 20-foot free-spinning tunnel.

Figure 5.- Photograph showing the installation of the universal joint used in conjunction with tests performed with XF5U-1 model spinning on the suspension apparatus.

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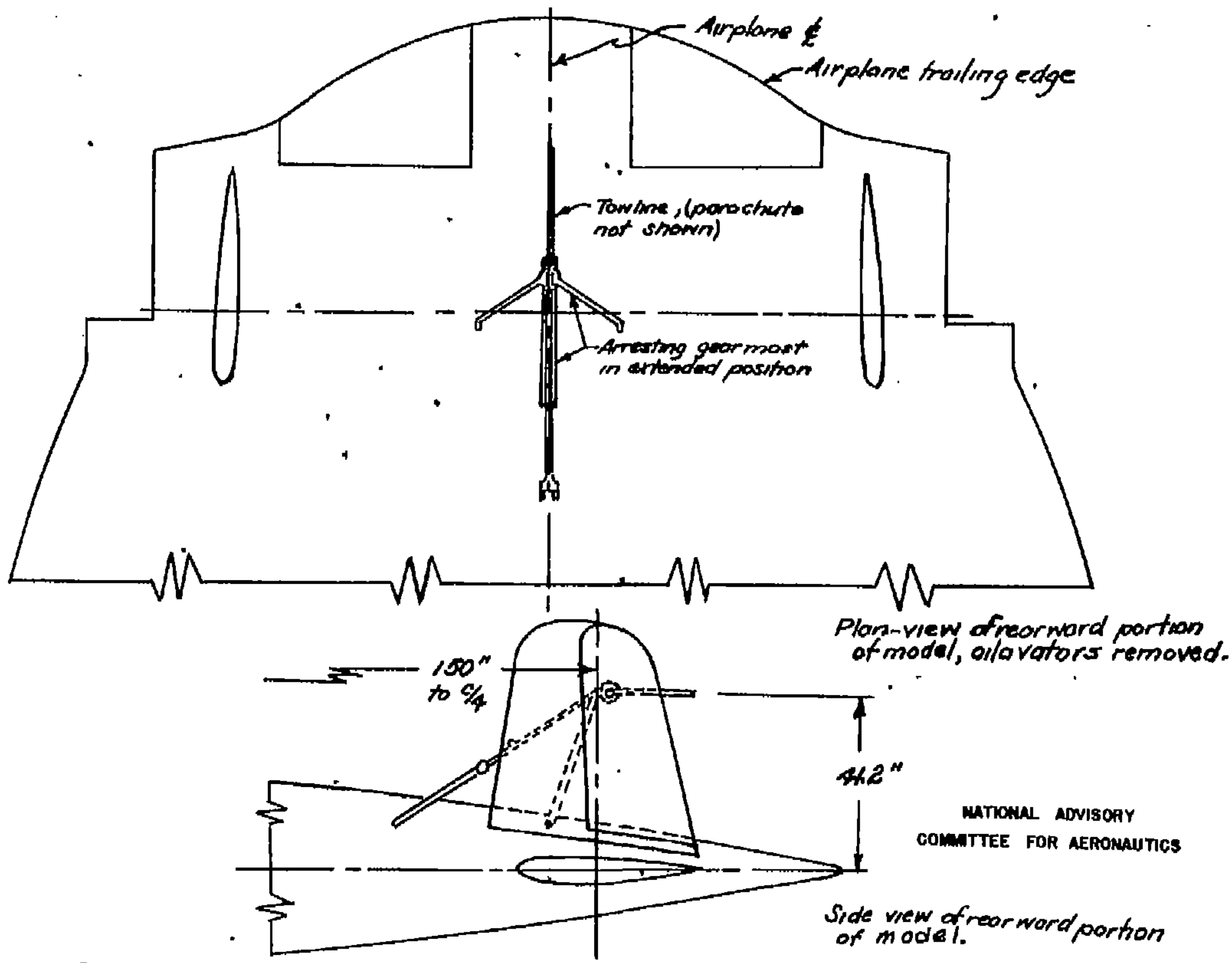

Figure 6- The location of the arresting gear mast used as a point of attachment for spin-recovery parachutes on the 1/16-scale model of the XF5U-1 airplane. Dimensions are full scale.

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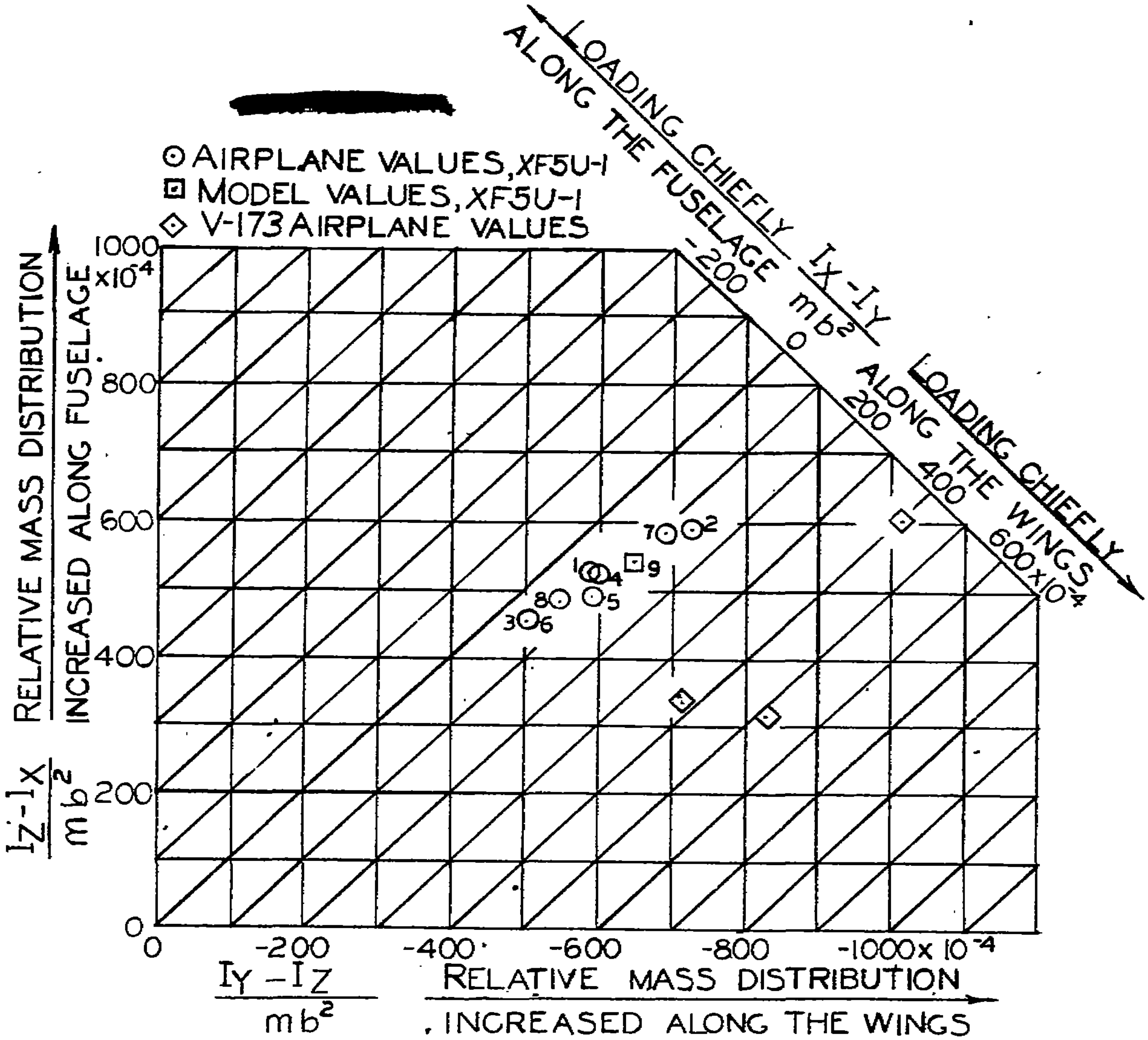

FIGURE 7.– MASS PARAMETERS FOR LOADINGS POSSIBLE ON THE XF5U-1 AIRPLANE AND FOR THE LOADING TESTED ON THE XF5U-1 MODEL AND FOR POSSIBLE V-173 AIRPLANE LOADINGS SIMULATED IN TESTS WITH THE V-173 MODEL. (XF5U-1 LOADINGS ARE LISTED IN TABLE II).

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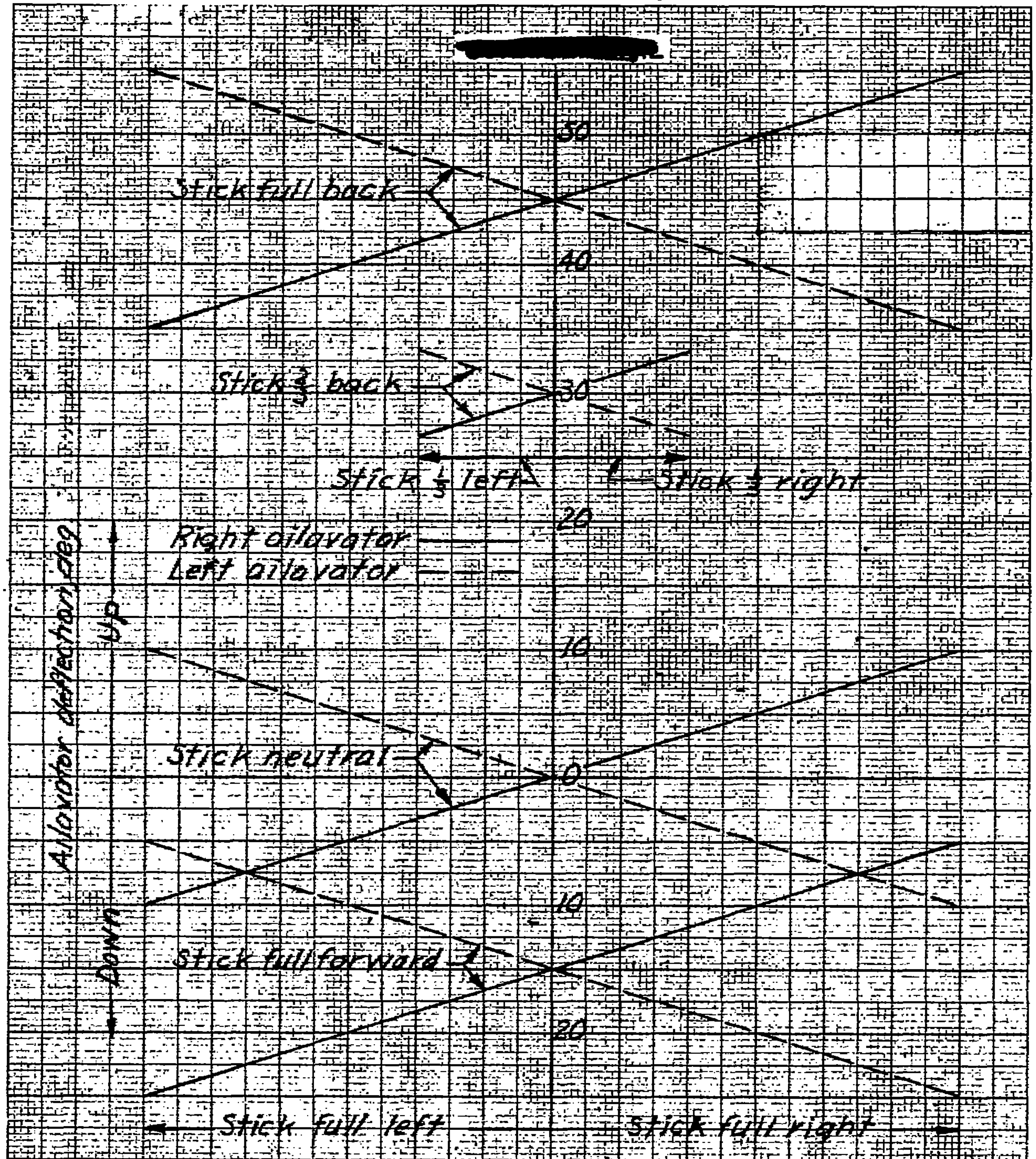

Figure 9. – Ailavator deflections used on the 1/16-scale model of the XF5U-1 airplane for various control stick positions.

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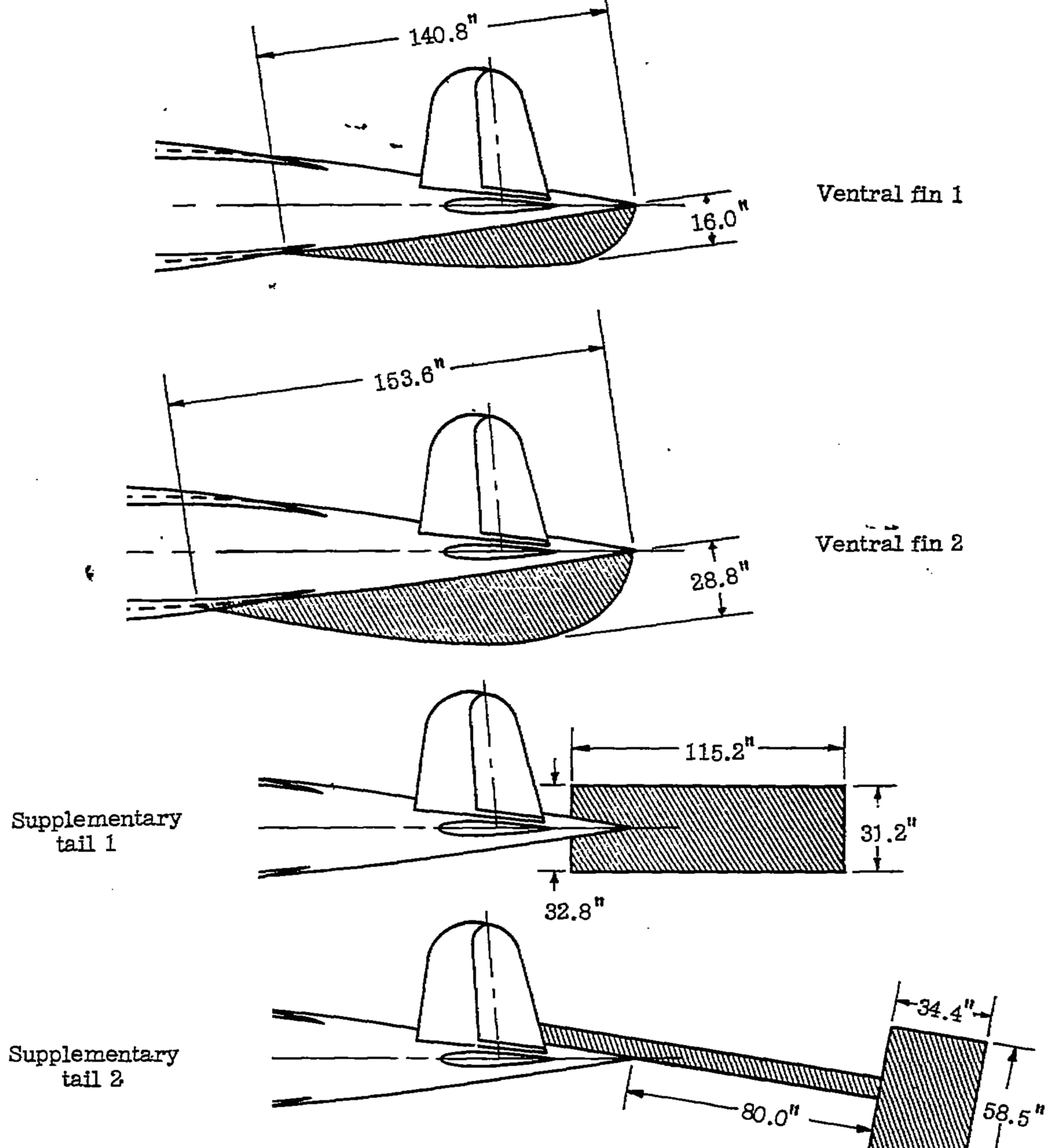

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Figure 9.- Ventral fins and supplementary tails located in the plane of symmetry as tested on the $\frac{1}{16}$-scale model of the XF5U-1 airplane. Dimensions are full scale.

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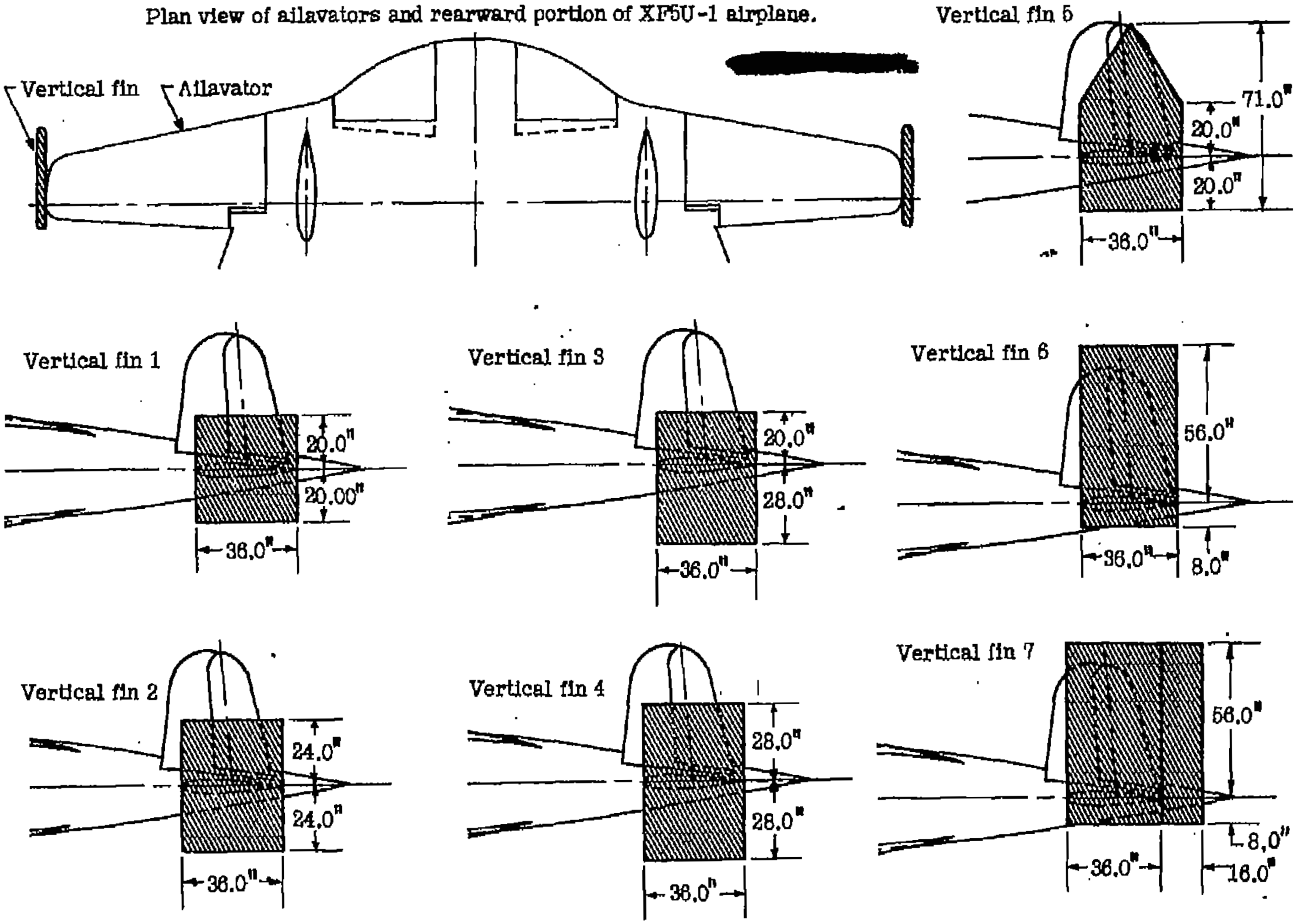

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Figure 10.- Vertical fins tested on the $\frac{1}{16}$-scale model of the XF5U-1 airplane. Dimensions are full scale.

[redacted]

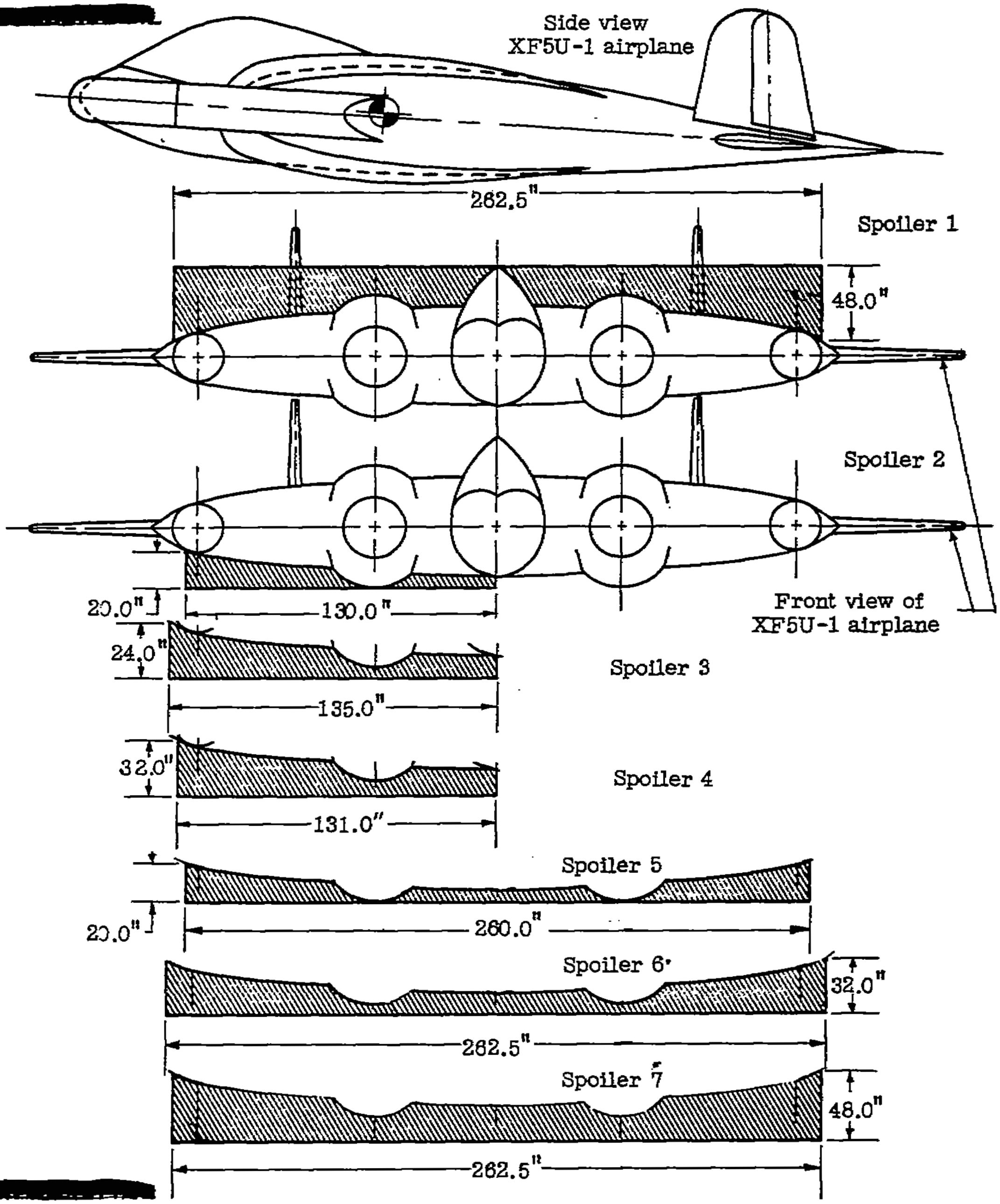

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Figure 11.- Full-span upper-surface and full-span and semispan under-surface spoilers located along airplane quarter-chord line as tested on $\frac{1}{16}$-scale model of the XF5U-1 airplane. Dimensions are full scale.

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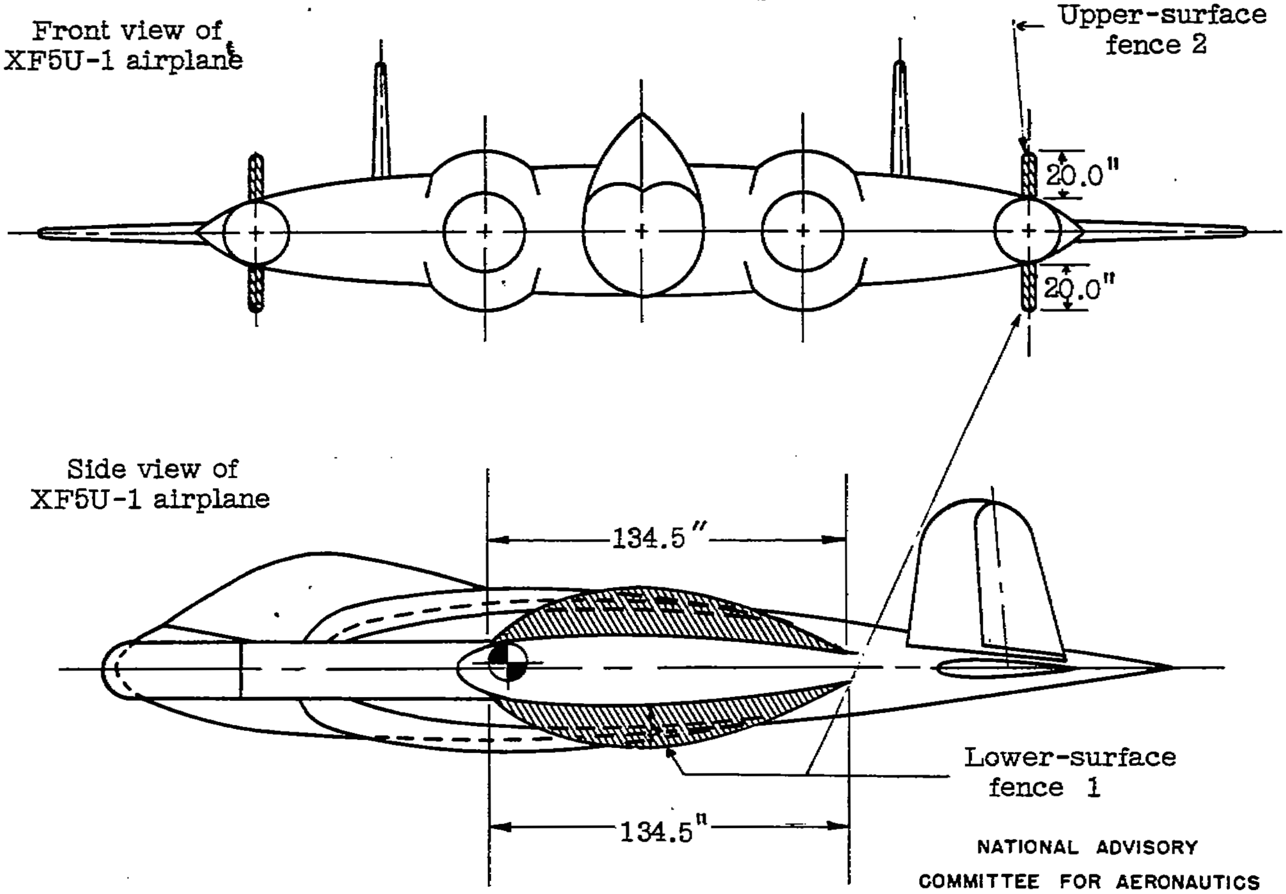

Figure 12.- Upper- and lower-surface longitudinal fences tested on the $\frac{1}{16}$-scale model of the XF5U-1 airplane. Dimensions are full scale.

[redacted]

[redacted]

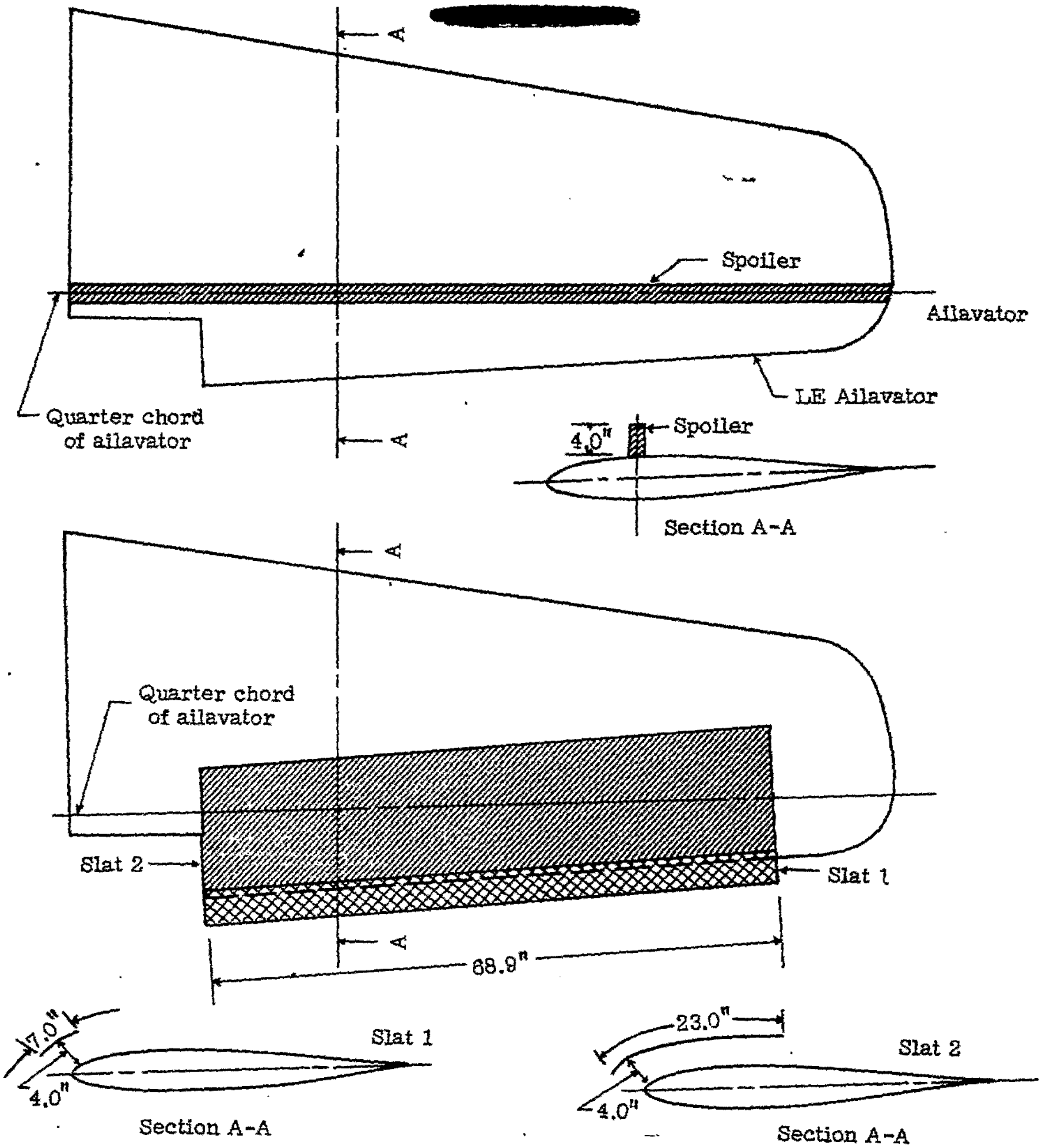

Figure 13.- Spoiler and slats tested on the ailavators of the $\frac{1}{16}$-scale model of the XF5U-1 airplane. Dimensions are full scale.

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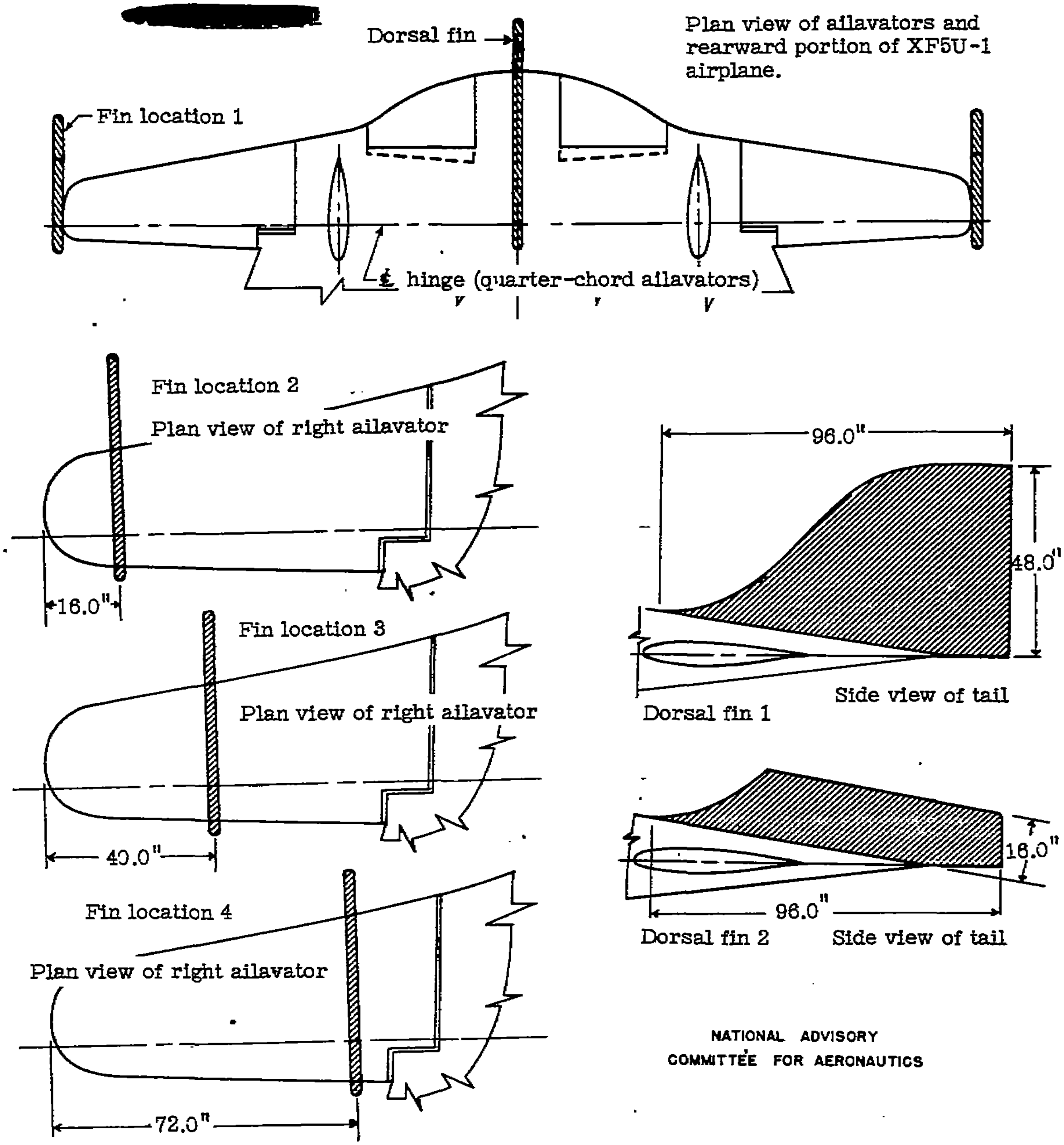

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Figure 14.- Vertical fin locations and dorsal fins tested on the $\frac{1}{16}$-scale model of the XF5U-1 airplane. Dimensions are full scale.

[redacted]

[redacted]

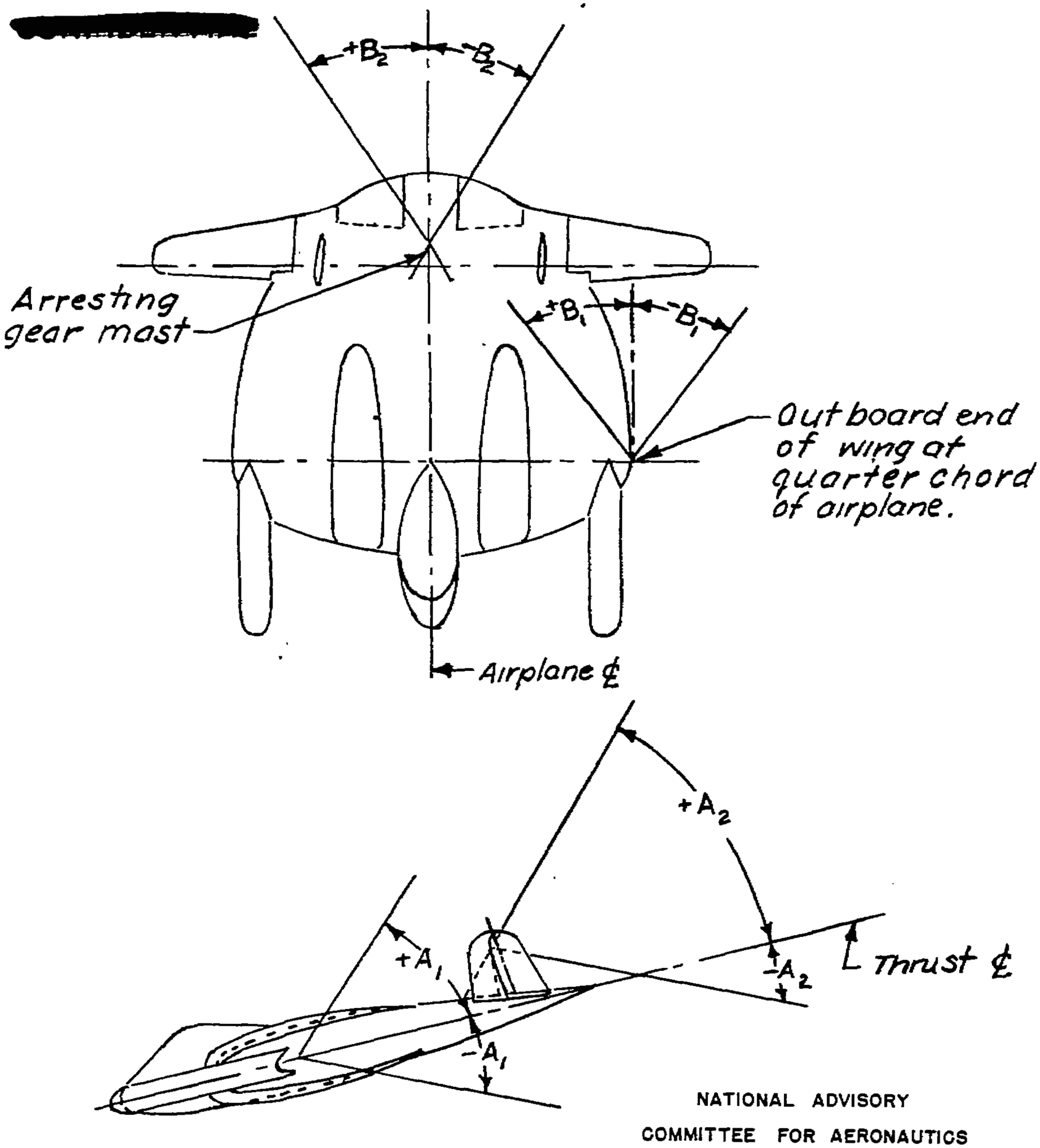

Figure 15 – Attachment points and approximate range of attitudes assumed by spin-recovery parachutes during recoveries from right spins.

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