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RESEARCH MEMORANDUM

COMPILATION OF TEST DATA ON 111 FREE-SPINNING AIRPLANE

MODELS TESTED IN THE LANGLEY 15-FOOT AND

20-FOOT FREE-SPINNING TUNNELS

By

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

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COMPILATION OF TEST DATA ON 111 FREE-SPINNING AIRPLANE MODELS TESTED IN THE LANGLEY 15-FOOT AND 20-FOOT FREE-SPINNING TUNNELS

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SUMMARY

A compilation of free-spinning-airplane model data on the spin and recovery characteristics of 111 airplanes is presented. These data were previously published in separate memorandum reports and were obtained from free-spinning tests in the Langley 15-foot and the Langley 20-foot free-spinning tunnels. The model test data presented include the steady-spin and recovery characteristics of each model for various combinations of aileron and elevator deflections and for various loadings and dimensional configurations. Dimensional data, mass data, and a three-view drawing of the corresponding free-spinning tunnel model are also presented for each airplane. The data presented should be of value to designers and should facilitate the design of airplanes incorporating satisfactory spin-recovery characteristics.

INTRODUCTION

The spin of an airplane is a complicated three-dimensional stalled motion that at present has not been susceptible to a thorough mathematical or experimental analysis because of the lack of extensive, accurate data on the forces and moments acting on a spinning airplane. References 1 to 15 are a partial list of papers which show in some detail the mechanics of the spin and the complexity of the interactions of the inertia and aerodynamic forces causing the spinning motion. The results of free-spinning model tests have enabled practical studies of the spinning motion to be made and the determination of certain mass and dimensional parameters which predominantly affect the spin-recovery characteristics of an airplane.

In accordance with a request of the Air Materiel Command, Army Air Forces, the present paper compiles in one paper the results of free-spinning model airplane tests which have been conducted in the Langley 15-foot and 20-foot free-spinning tunnels during the years from 1935 to 1944 in order to furnish designers with data to facilitate the design of airplanes incorporating satisfactory spin-recovery characteristics.

The model test data presented have been obtained from free-spinning-tunnel model tests for the Army, Navy, Civil Aeronautics Administration, and for commercial companies, and include the steady-spin and recovery characteristics of each model for various combinations of aileron and elevator deflections, and for various mass loading conditions and dimensional configurations of the model. Included also for each model is a table of full-scale dimensional data, a table of full-scale mass data, a three-view drawing of the model as tested, and a brief résumé of the test results incorporating the more important spin and recovery characteristics of the model.

For the data presented herein, recoveries were attempted by rapidly and fully moving the control surfaces to any desired position and are independent of the forces required to move the controls.

SYMBOLS

b wing span, feet

L over-all length, feet

$\bar{c}$ mean aerodynamic chord, inches

c_a average chord, inches

c_r root chord, inches

S wing area, square feet

A aspect ratio

L.E. leading edge

S_h horizontal tail area, square feet

S_e elevator area (aft of hinge line), square feet

S_v vertical tail area, square feet

S_r	rudder area (aft of hinge line), square feet
TDPF	tail-damping power factor (fig. 5)
URVC	unshielded rudder volume coefficient (fig. 5)
TDR	tail-damping ratio (fig. 5)
W	gross weight of airplane, pounds
m	mass of airplane, slugs
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord; positive when center of gravity position is aft of L.E. of $\bar{c}$
$z/\bar{c}$	ratio of distance between center of gravity and thrust line or fuselage reference line to length of mean aerodynamic chord; positive when center of gravity is below thrust line
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, slug per cubic foot
μ	airplane relative density $(m/\rho Sb)$
α	angle between thrust line or fuselage reference line and vertical, degrees; approximately equal to absolute value of angle of attack at plane of symmetry
ϕ	angle between span axis and horizontal, degrees; positive when right or inboard wing is below horizontal in a right spin

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, degrees
β	approximate angle of sideslip at center of gravity; sideslip is positive and inward for a right spin when inner wing is down by an amount greater than the helix angle $(\phi - \sigma)$
δ_r	normal maximum deflection of rudder, degrees
δ_e	normal maximum deflection of elevator, degrees
δ_a	normal maximum deflection of ailerons, degrees
δ_f	normal maximum deflection of flaps, degrees
δ_s	normal maximum extension of slats
U	up
N	neutral
D	down
F	forward
B	back

APPARATUS AND METHODS

Models

The construction of free-spinning tunnel models is described in reference 16. Briefly, each model was constructed of balsa to be dimensionally similar to the airplane, and was ballasted for dynamic similarity to the corresponding airplane by the installation of proper weights at suitable locations. An automatic clockwork delayed action mechanism or a magnetic remote-control mechanism was installed in the model to actuate the controls for recovery. For attempted recoveries using a magnetic remote-control mechanism, a magnetic field is induced in the test section of the tunnel when the tunnel operator closes an electric circuit. The mechanism in the model reacts to the induced magnetic field and through a system of cords and pulleys the model control surfaces are rapidly moved by a rubber band to the desired positions for recovery. The delayed-action mechanism which was used in the earlier models for attempted recoveries consisted essentially of a clockwork mechanism which timed the movements of the control surfaces after a predetermined interval for the intended recovery of the model.

Wind Tunnel and Testing Technique

The tests were conducted in the Langley 15-foot and 20-foot free-spinning tunnels. Sketches of the tunnels are presented as figures 1 and 2, respectively. The operation of the 15-foot tunnel is described in reference 16; the operation of the 20-foot tunnel is similar to that of the 15-foot tunnel.

The models were launched with rotation by hand into the vertically rising air stream of the tunnel. For a few of the earlier models the launching spindle method described in reference 16 was used. The airspeed was varied by the tunnel operator until it equaled the rate of descent the model would have in still air. The model was thus maintained at approximately eye-level in the test section.

With the model spinning in the tunnel, observations were made of the general behavior of the model, and the airspeed and rate of rotation of the model were recorded. The airspeed was obtained from a calibrated tachometer, and the rate of rotation was determined by noting with a stop watch the time required for the model to make a given number of terms in the spin. The attitude of the model in the spin given approximately by α and ϕ were obtained from moving pictures taken of the spinning model. Figure 3 shows a typical model spinning freely in the Langley 20-foot spin tunnel. For spins which had a rate of descent in excess of that which can be attained in the tunnel, the rate of descent was recorded as greater than the velocity at the time the model hit the net, as >300 feet per second (full scale).

Interpretation of Recovery Data

After the established spin of the model had been observed and photographed, recoveries were attempted from the established spin condition. Figure 4 shows photographs of a recovery. The turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases.

The criterion for a satisfactory recovery from a spin for the models has been adopted as 2 turns or less. In the résumés of test results for the models presented in this paper the word marginal indicates that the recoveries were borderline cases, that is, between 2 and $2\frac{1}{2}$ turns. The recovery characteristics of a model of a military airplane are considered satisfactory if recovery from the spin at the normal-spinning control configurations (rudder full with, elevator full up, and ailerons neutral) by rapid full rudder reversal requires no more than 2 turns and if small deviations from this control do not cause recovery to exceed $2\frac{1}{4}$ turns. For many of the models in this report for which results have been compiled, determinations of the dependence of recovery upon so-called deviations involved examination of results at full aileron deflection and zero elevator setting. Recently, however, (reference 17) small deviations have been defined as setting the elevator at only two-thirds of full-up deflection, setting the ailerons one-third of full deflection in the direction conducive to slow recovery, and attempting recovery by either moving the rudder alone to two-thirds of full deflection against the spin, or by this rudder movement accompanied by movement of the elevator to one-third down.

For the spins which had a rate of descent in excess of that which could be attained in the tunnel, recovery was attempted while the model was still descending in the tunnel. Such results are considered conservative inasmuch as the model had not reached its final steep attitude. For spins which were steep with a high rate of descent and for which recoveries were not attempted, it is probable that if recoveries were attempted they would have been satisfactory (<2 turns). For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was recorded as greater than the number of turns from the time the controls moved to the time the model struck the net, as for example >3. A >3-turn recovery does not necessarily indicate an improvement over a >6-turn recovery. For the condition in which the model stopped rotating when launched in a spinning attitude, rudder remaining with the spin, the result was recorded as "No spin."

For a few of the early models for which the rate of descent of the model exceeded the tunnel airspeed an auxiliary plane surface was extended from the inboard wing tip at such an angle to the wing chord plane that the surface, commonly called a pro-spin fin, caused an additional pro-spin yawing moment to act on the model which in turn flattened the spin and decreased the rate of descent. If the model recovered satisfactorily from the spin with the pro-spin fin attached, it was assumed that recoveries of the model for the same configuration and control manipulation without the pro-spin fin attached would be satisfactory. The pro-spin fin, because of the inaccuracy involved in its usage is not at present considered a satisfactory method of obtaining data for models with high rates of descent.

PRECISION

The results of the free-spinning-tunnel tests presented are believed to be the true values given by the model within the following limits:

α, deg	±1
ϕ, deg	±1
V, percent	±5
Ω, percent	±2

Turns for recovery:

From film	$\pm\frac{1}{4}$
From visual estimate	$\pm\frac{1}{2}$

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 model and airplane results (reference 18) indicates that the spin-tunnel results are not in complete agreement with airplane spin results. In general, it is indicated that the model spins at a somewhat smaller angle of attack, a somewhat higher rate of descent, and from 5° to 10° more outward sideslip. The comparison made in reference 18 showed that 80 percent of the model recovery tests predicted satisfactorily the number of turns required for recovery from the spin for the corresponding airplanes, and that 10 percent overestimated and 10 percent underestimated the number of turns required.

Because of the impracticability of ballasting the model exactly and because of inadvertent damage to the model during tests, the measured weight and mass distribution of the models, in general, varied from the true scaled-down values of the airplanes within the following approximate limits:

Weight, percent		±1
Center-of-gravity location, percent $\bar{c}$		±2
Moments of inertia	I_X, percent	±10
	I_Y, percent	±13
	I_Z, percent	±15

The limits of accuracy of the measurements of the mass characteristics were as follows:

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

Spin-tunnel tests are performed to determine the spin and recovery characteristics of the model for the normal-spinning control configuration (elevator full-up, ailerons neutral, and rudder full with the spin) and for various other aileron-elevator deflection combinations including neutral, intermediate, and maximum deflections of the control surfaces for various model loadings and dimensional configurations. In general, the tests conducted for each model were for conditions simulating those at which the airplane was generally expected to operate (as determined from the manufacturer's mass reports) and for conditions for which it was ascertained that the airplane might have recovery characteristics different from those for the normal loading, clean condition of the airplane. Clean condition in this paper indicates landing gear retracted, canopy closed, flaps neutral, slots closed, spoilers neutral, and propeller off unless otherwise indicated. The normal-loading conditions tested are listed in the "mass-data" table for each model. The normal loading is the basic loading condition of the airplane and all changes in loading usually were made from this condition.

In order to obtain loading conditions other than normal, lead ballast was redistributed along the three body axes of the model. If it was desired to obtain a change in moments of inertia only, the weight and center of gravity of the model were held constant and mass was extended or retracted along any one axis, as shown by the following table:

Extending mass along	Change in			Algebraic change in		
	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
X-axis	--------	Increase	Increase	Decrease	--------	Increase
Y-axis	Increase	--------	Increase	Increase	Decrease	--------
Z-axis	Increase	Increase	--------	--------	Increase	Decrease

The effect of center-of-gravity movements on the spin and recovery characteristics of the model in a majority of cases were determined by making changes in the center-of-gravity position without any change in the values of the weight or moments of inertia of the model.

The normal, maximum, and intermediate control surface deflections used for the specific tests are listed in the dimensional-data table for each model and also in the chart of test results wherever considered necessary for clarity.

Dimensional changes were usually incorporated into the model by adding balsa surfaces to the fuselage, tail unit, or wing.

PRESENTATION OF DATA

The following information is presented in this report for each design:

(a) Three-view drawing of the model as tested in the clean (or normal flying) condition

(b) Table of full-scale dimensions and areas of the airplane

(c) Table of full-scale mass data used for the ballasting of the model for the various tests

(d) A résumé of the spin and recovery characteristics of the model based upon the presented test results and also upon unpublished test results of the model not included in the charts of test results presented in this paper

(e) A chart containing the results of free-spinning tests of the model for various aileron, elevator, and rudder settings and various loading conditions and dimensional configurations (on the charts the model data are listed as their full-scale equivalents, model values having been converted by the relationships given in table I)

(f) Sketches of dimensional modifications tried on the model to improve its spin and recovery characteristics, unless modification is obvious (dashed lines in the sketches indicate the dimensional modifications; the solid lines indicate the original contours of the surface)

The charts are so arranged that the chart caption indicates, in general, the configuration of the model for the tests and the method of attempted recovery from the spin, for example, "Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins." The heading for each of the tables in the chart indicates the mass loading of the model for the test results presented in the table, the flying condition of the model if different from the normal flying (clean) condition and the position and relative movements of the control surfaces during the steady-spin and recovery motions.

The footnotes given on each chart are used to denote:

(a) Important and unusual behavior of the model during its steady-spin and recovery motions

(b) Special control manipulations for attempted recovery from a spin such as, for example, "recovery attempted by simultaneous reversal of the rudder from full with to two thirds against the spin and the elevator from two thirds full up to one third down"

(c) Exceptional mass conditions, control surface deflections, or dimensional configurations

Ailerons against the spin (stick left in a right erect spin) indicate that the aerodynamic rolling moment about the body axis contributed by the ailerons is normally opposite to the rotation, and ailerons with the spin indicate that this moment is in the direction of the rotation.

For the results of model tests in which the model was spinning inverted, the following points should be noted:

(a) All inverted spin data presented are for spins to the pilot's left with left rudder pedal forward. The rotation about the spin axis as viewed by an observer situated on the spin axis above the airplane and looking towards the airplane would be clockwise.

(b) In an inverted spin to the pilot's left, the inboard wing is actually the left wing of the airplane and this wing is considered up or down depending upon whether it is above or below the horizontal with respect to the ground.

(c) In the tables, the lateral stick position is indicated relative to the pilot, and when controls are "together" (left rudder pedal forward and stick to the left), the ailerons are considered against the spin aerodynamically.

(d) The longitudinal position of the stick is also indicated in the tables, relative to the pilot, as stick forward, neutral, or back.

On the charts, changes in center-of-gravity positions are given in percent of the mean aerodynamic chord, for example, "center of gravity moved forward $0.10\bar{c}$" denotes that the center of gravity has been moved 10 percent of the length of the mean aerodynamic chord forward from its original position. Changes in moments of inertia are indicated on the chart as percent changes with respect to the moment of inertia about some axis, for example, ΔI_X and $\Delta I_Z = 0.30\ I_X$ denotes that the moment of inertia about the X-axis and the moment of inertia about the Z-axis have both been increased by 30 percent of the original value of the moment of inertia about the X-axis. For some tests, simulataneous changes were made in center-of-gravity location and moments of inertia. For tests with the model in the landing or take-off condition, the landing gear was extended and the flaps, slots, and spoilers were deflected to the positions indicated for these conditions in the dimensional-data table.

Changes in the design of the airplane in order to improve the recovery characteristics are denoted by "modification" on the test data chart. For example, modification 2, normal loading, means that a certain dimensional change has been made to the model when in the normal loading for the flying condition noted by the chart caption.

Modifications 1 and 3, normal loading, indicate that two simultaneous dimensional changes were made to the model when it was in the flying condition indicated by the chart caption and normal loading. Sketches of modifications accompany all charts unless the modification to the design of the model could be simply described.

DISCUSSION OF DATA

Spin and recovery parameters.- The results of free-spinning airplane model tests such as those presented in this paper have enabled important practical conclusions to be drawn concerning the established-spin and recovery characteristics of an airplane and the variation of these characteristics with the dimensional and mass changes of the airplane involved. The basic spin parameters presented herein, angle of attack α, angle of wing inclination ϕ, angular velocity about the spin axis Ω, the rate of descent V, and the number of turns for recovery are indicative of the spin and recovery characteristics of the airplane.

The angle of attack defines approximately the attitude of the airplane with respect to the vertical. The angle of wing inclination is a factor involved in the determination of the angle of sideslip and of the direction (and magnitude) of the inertia moments acting in a spin. The angular velocity Ω is directly responsible for the development of the centrifugal forces and moments acting on the airplane. The rate of vertical descent V is of importance in considerations involving the vertical distance available for recovery from the spin. The number of turns for recovery is used at present for indicating the recovery characteristics of an airplane. A survey of the data presented herein indicates generally that for the models tested, the angle of attack may vary from 15° to 85°, the angle of wing inclination ±30°, the rate of descent from 100 feet per second to >600 feet per second, and the number of turns for recovery from less than 1/4 to ∞. The value of Ω (revolutions/sec) varies approximately from 0.20 to 0.60. For some of the models tested the motion in the spin was very oscillatory and wandering - that is, the model would generally pitch, roll, and yaw about its body axes with changing spin radius. The wide variations in the parameters result from the effect of the different mass and dimensional characteristics and control settings for different airplane designs.

Erect Spins

In general, it has been found (references 17, 19, 20, and 21) that the spin and recovery characteristics of an airplane can be evaluated in terms of the following mass and dimensional characteristics of the airplane:

(a) The relative distribution of the mass of the airplane along the wings or fuselage indicated by the mass parameter $\frac{I_X - I_Y}{mb^2}$

(b) The position of the center of gravity, given by the parameter, x/c

(c) The relative density of the airplane, given by the parameter, $\mu = \frac{m}{\rho s b}$

(d) Tail arrangement and design as indicated by the value of the tail-damping power factor (TDPF)

These mass and dimensional factors are listed for each model and their effect on the spin-recovery characteristics of an airplane will be discussed in the following sections of this paper. It should be pointed out that factors (a) to (d) are by no means infallible indications of an airplane's spin-recovery characteristics but do indicate general trends founded on the results of free-spinning model tests.

Effect of the mass parameter $\frac{I_X - I_Y}{mb^2}$.- The inertia yawing-moment parameter $\frac{I_X - I_Y}{mb^2}$ indicates the relative distribution of the mass of the airplane along the wings and fuselage and has an important effect on the control settings and control manipulation for satisfactory recovery from the spin. As indicated in reference 19, for negative values of $\frac{I_X - I_Y}{mb^2}$ numerically greater than -50×10^{-4} (mass distributed chiefly along fuselage), aileron-with and elevator-up settings aided recoveries, and the rudder was the most powerful control for recovery. When the design approached that of multiengine airplanes or single-engine airplanes with wing tanks and wing armament, (for negative values of $\frac{I_X - I_Y}{mb^2}$ numerically smaller than -50×10^{-4} and for positive values) the aileron effect and elevator effect reversed; that is, aileron-against and elevator-down settings were conducive to the most rapid recovery and the elevator became the predominant control for recovery.

A review of the results of tests presented in this paper for which the mass was varied along the wings and along the fuselage of the model indicate that the effect of the mass parameter $\frac{I_X - I_Y}{mb^2}$

on control setting and manipulation for recovery is generally in good agreement with the conclusions stated above.

Effect of center-of-gravity location.- Reference 20 indicates that the spin and recovery characteristics of an airplane may be seriously affected by center-of-gravity location. This may be particularly true when the recovery characteristics of an airplane are marginal. The parameter $x/\bar{c}$ presented in the mass-data table for each model gives the position of the center of gravity relative to the mean aerodynamic chord. The test results and analysis of reference 20 indicate that rearward positions of the center of gravity are generally adverse, the spins become flatter and recoveries slower. Movement of the center of gravity forward, however, generally steepens the spin and improves the recovery characteristics. The spin and recovery characteristics of some airplanes, however, may be relatively insensitive to center-of-gravity movements.

For most of the models presented in this report the test results do not indicate a serious or systematic effect of center-of-gravity location on the spin and recovery characteristics as concluded in reference 20. The conclusions of reference 20 however were based on tests of lightly loaded models at low test altitudes for which case the effect of center-of-gravity location may be more pronounced than for heavier-loaded military airplanes, tested at higher equivalent test altitudes, as generally presented in this report.

Effect of airplane relative density.- Variations of the relative density parameter $\mu = \frac{m}{\rho Sb}$, given for each model in the mass-data table, may be considered either as variations in the wing loading of a given airplane with the radii of gyration kept constant and spun at a given altitude or a variation of the altitude at which the spin takes place for an airplane of fixed wing loading.

The lower values of the relative density parameter correspond to the lower wing loadings or to the lower altitudes of the spin. The results of free-spinning tests presented in reference 21 indicated that the lower values of the relative density parameter (μ varied from 6.8 to 12.0) gave steeper spins and faster recoveries whereas the higher values gave flatter spins and slower recoveries. In general, as the relative density parameter decreased, the rate of descent decreased, and the sideslip became more outward. The analysis of results of free-spinning-model tests covering a variety of airplane designs and mass loadings presented in reference 17, which included most of the data presented herein, indicates that in general the effectiveness of a given tail design in promoting satisfactory spin-recovery characteristics decreases as the value of μ increases.

Effect of tail arrangement and design.- The tail surfaces play an important aerodynamic part in determining the spin recovery characteristics of an airplane. Spin-tunnel experience indicates that if an airplane is to have safe spinning tendencies, it should be provided with adequate damping from fixed area combined with sufficient unshielded rudder area. The first of these provisions tends to prevent the development of the flat spin, while the second provides sufficient rudder area for satisfactory recovery. The tail-damping power factor (TDPF) (reference 17) listed in the dimensional table for each model gives an approximate quantitative estimation of these two provisions. Figure 5 shows the method of calculating the TDPF and it can be seen that the product of the tail-damping ratio (approximation of damping due to side area by considering the fuselage area under the horizontal tail as "effective side area") and the unshielded rudder volume coefficient is the TDPF. High values of the TDPF, indicative of satisfactory spin-recovery characteristics, can be obtained by increasing the area under the horizontal tail (area F in fig. 5), increasing the unshielded rudder area (area R_1 and R_2 in fig. 5), and increasing the length of the tail moment arm. For models fitted with antispin fillets (fins added to the fuselage adjacent to and generally in the same plane as the stabilizer), the tail-damping power factor was computed by considering the fuselage area below the fillets as effective in damping rotation. The unshielded rudder area was, however, considered unchanged by the fillet.

Tail design requirements for satisfactory spin recovery.- The minimum value of TDPF required for a given design for satisfactory recovery based upon results of free-spinning-model tests is dependent upon the value of the inertia yawing-moment parameter $\frac{I_X - I_Y}{mb^2}$ and the value of the relative density factor μ of the airplane.

An empirical requirement which considers the interrelated effect of $\frac{I_X - I_Y}{mb^2}$, μ, TDPF, and control manipulation on the recovery characteristics of an airplane has been presented in reference 17. Most of the recovery data used for determining the tail design requirements for satisfactory recovery characteristics was obtained from the test results of free-spinning models compiled in this report and included monoplane and biplane, landplane and seaplane, and single-engine and multiengine designs. The data applied only to models in the clean condition (landing gear retracted, cockpit closed, flaps neutral, and so forth). The models were tested with various tail modifications and mass changes and the results of these tests were also included in the analysis. Recovery characteristics were considered satisfactory for this tail design requirement if the model recovered in 2 turns or less from the spin when the model was in the normal-control configuration for spinning and if small deviations (criterion spin discussed previously) from this control setting did not cause recovery to exceed $2\frac{1}{4}$ turns.

The results of the investigation as given in reference 17 are summarized in figure 6 of this report. It can be observed that the relative distribution of mass along the wings and fuselage of an airplane and the relative density of the airplane as well as the design of the vertical tail and relative position of the vertical and horizontal tail (tail-damping power factor) are considered. It should be noted on figure 6 that in the region of mass distribution from values of $\frac{I_X - I_Y}{mb^2}$ from -100×10^{-4} to 20×10^{-4}, higher tail-damping-power factors are required than are necessary on either side of this region. If in designing the airplane, consideration can be given to the mass distribution and this "critical" region can be avoided, a value of the tail-damping power factor considerably lower than that indicated for relative densities of 20 or less may be acceptable.

Inverted Spins

Inverted-spin tests have been conducted for the majority of models presented in this report. An analysis reported in reference 22 indicates that:

1. Inverted spins are usually steep and therefore the rate of descent is relatively high. For the normal control configuration for spinning inverted (stick laterally neutral and longitudinally forward, rudder with rotation), recovery by reversal of the rudder alone generally was rapid (<2 turns).

2. Pulling the stick back diminished the tendency for the models to spin inverted.

3. The aileron effect was quite marked. Setting the ailerons against the spins (controls together) tended to

prevent the inverted spin and setting the ailerons with the spin (controls crossed) retarded recovery from the inverted spin.

The results and analysis of reference 22 indicate that the excellent inverted spin-recovery characteristics of conventional airplanes is apparently due to the relatively large values of the tail-damping power factor which the normal tail arrangement would have in an inverted spin inasmuch as most of the vertical tail surface is usually unshielded by the horizontal tailplane when the model is spinning inverted.

As mentioned previously, the value of the inertia yawing-moment parameter $\frac{I_X - I_Y}{mb^2}$ has a large influence upon the effect of controls and control manipulation in recovery from erect spins. Results of inverted-spin tests indicate, in general, little effect of $\frac{I_X - I_Y}{mb^2}$ on control settings and control manipulation for the range of mass distribution covered. This fact may in part be attributable to the usually high value of the tail-damping power factor of the vertical tail in the inverted position.

CONCLUDING REMARKS

1. A large quantity of airplane-model spin data have been compiled and are presented in this report. The basic mass and dimensional data presented for each airplane together with the corresponding results of free-spinning model tests should be of value to designers and should facilitate the design of airplanes incorporating satisfactory spin-recovery characteristics.

2. The results presented herein bear out the conclusions of previously published data that indications of the spin and recovery

characteristics of an airplane may be obtained by consideration of its mass distribution, center-of-gravity position, and tail arrangement.

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L-370

TABLE I

DYNAMIC RELATIONSHIPS

[For dynamic similarity the given relationships hold, where N is the scale ratio]

	General	1/20 scale
Angle of attack, α	Constant	1
Angle of wing inclination, ϕ	Constant	1
Angular velocity, Ω	$1/\sqrt{N}$	4.47
Linear velocity, V	$\sqrt{N}$	1/4.47
Turns for recovery	Constant	1
Linear dimensions	N	1/20
Area	N^2	1/400
Volume and weight	N^3	1/8000
Moments of inertia	N^5	1/3,200,000
Wing loading, W/S	N	1/20

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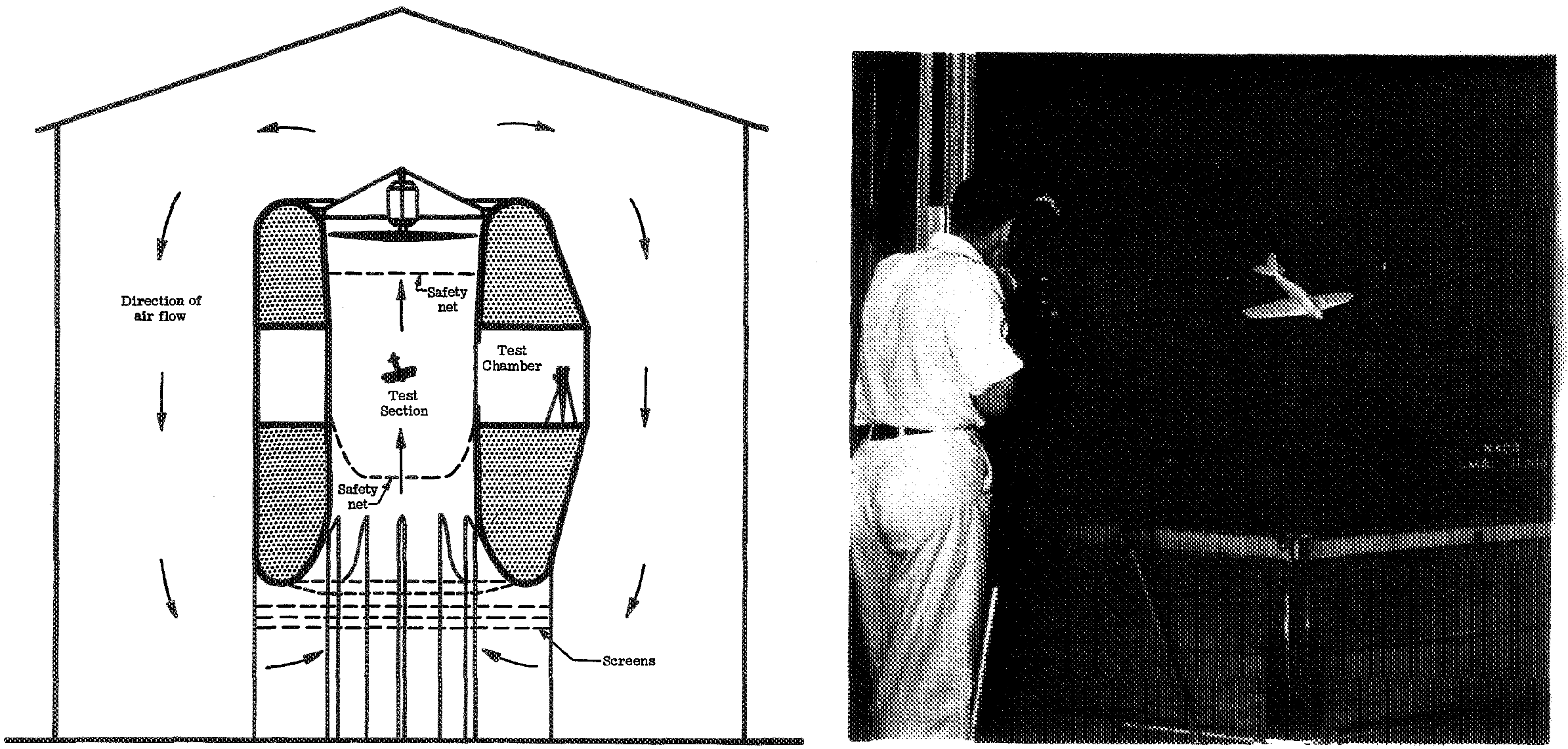
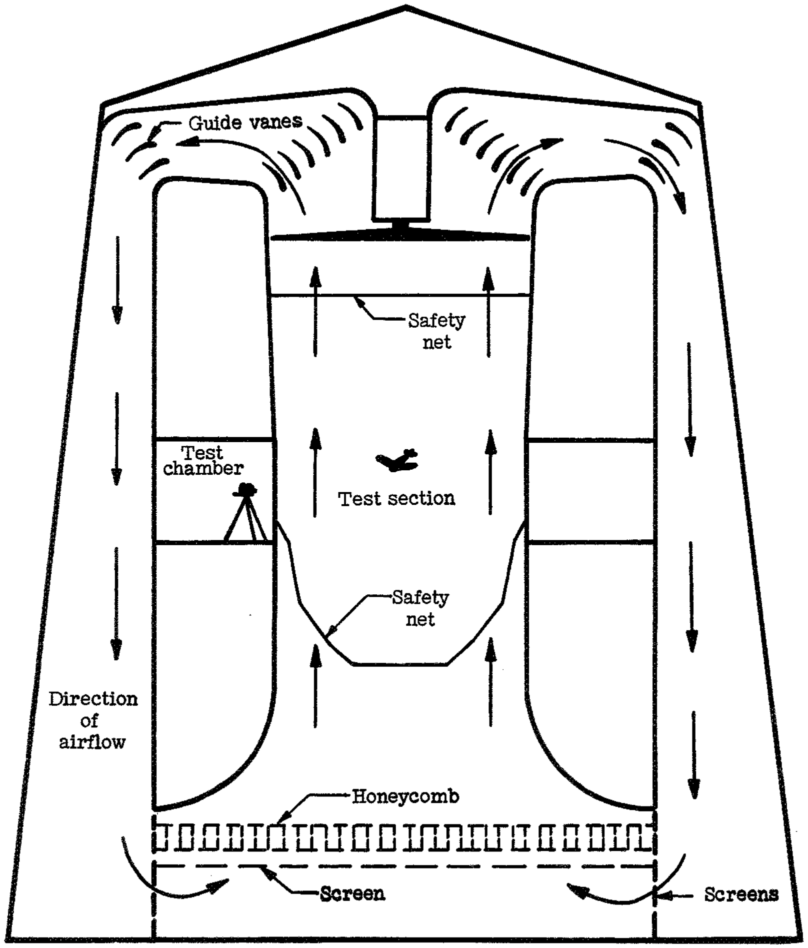


(a) Diagram of the Langley 15-foot free-spinning tunnel.

(b) Test section of the 15-foot free-spinning tunnel.

Figure 1.- Diagram of the Langley 15-foot free-spinning tunnel and photograph of test section.



(a) Diagram of the Langley 20-foot free-spinning tunnel.

(b) Test section of the 20-foot free-spinning tunnel.

Figure 2.- Diagram of the Langley 20-foot free-spinning tunnel and photograph of test section.

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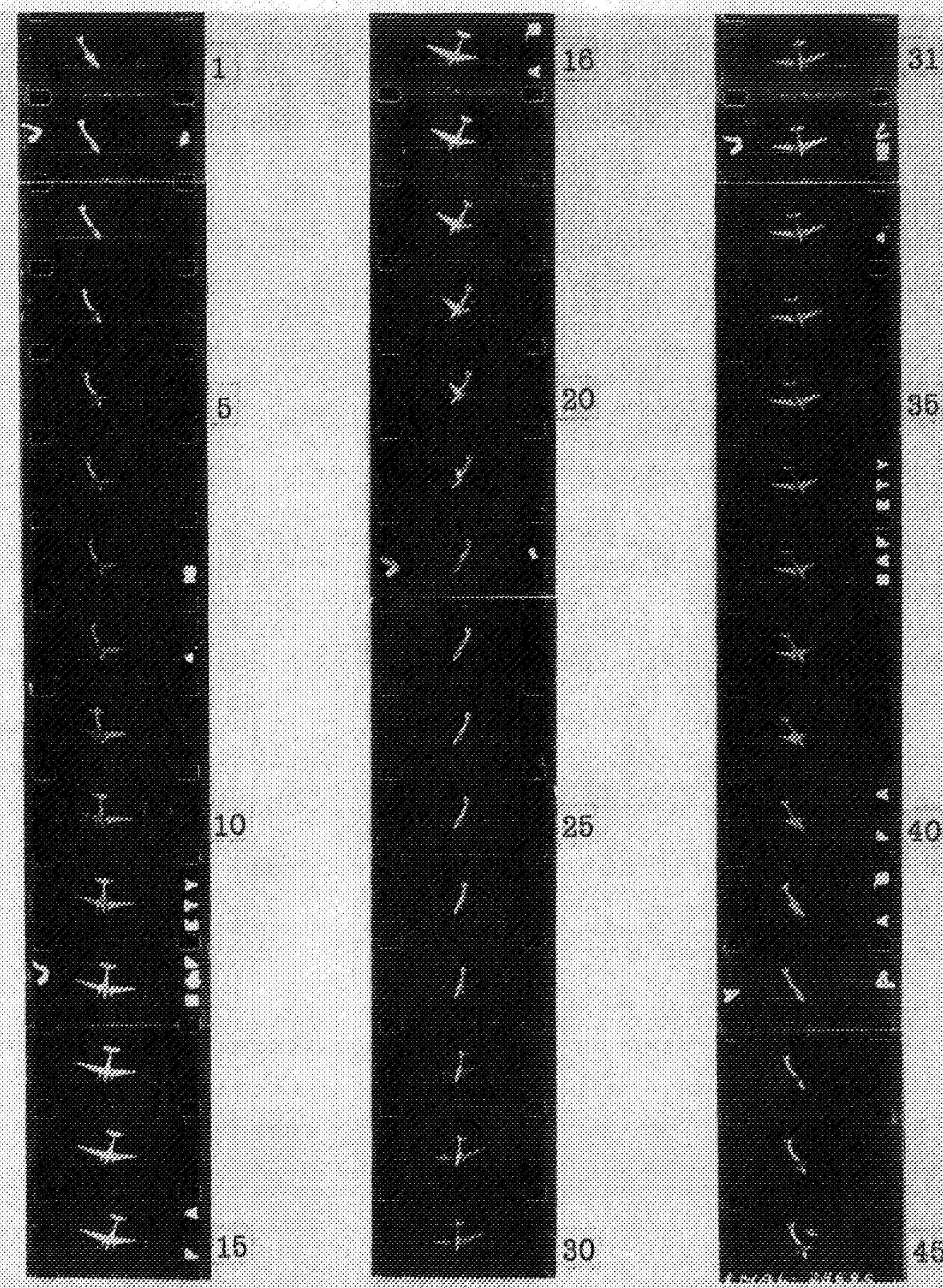


Figure 3.- Typical spin. Control settings: rudder full with the spin, elevator full up, ailerons neutral. Full-scale values: $\alpha = 35^{\circ}$, $\phi = 7^{\circ}$, $V = 172$ ft/sec (117 mph), radius of spin = 13.6 ft. $\Omega = 0.29$ rev/sec.

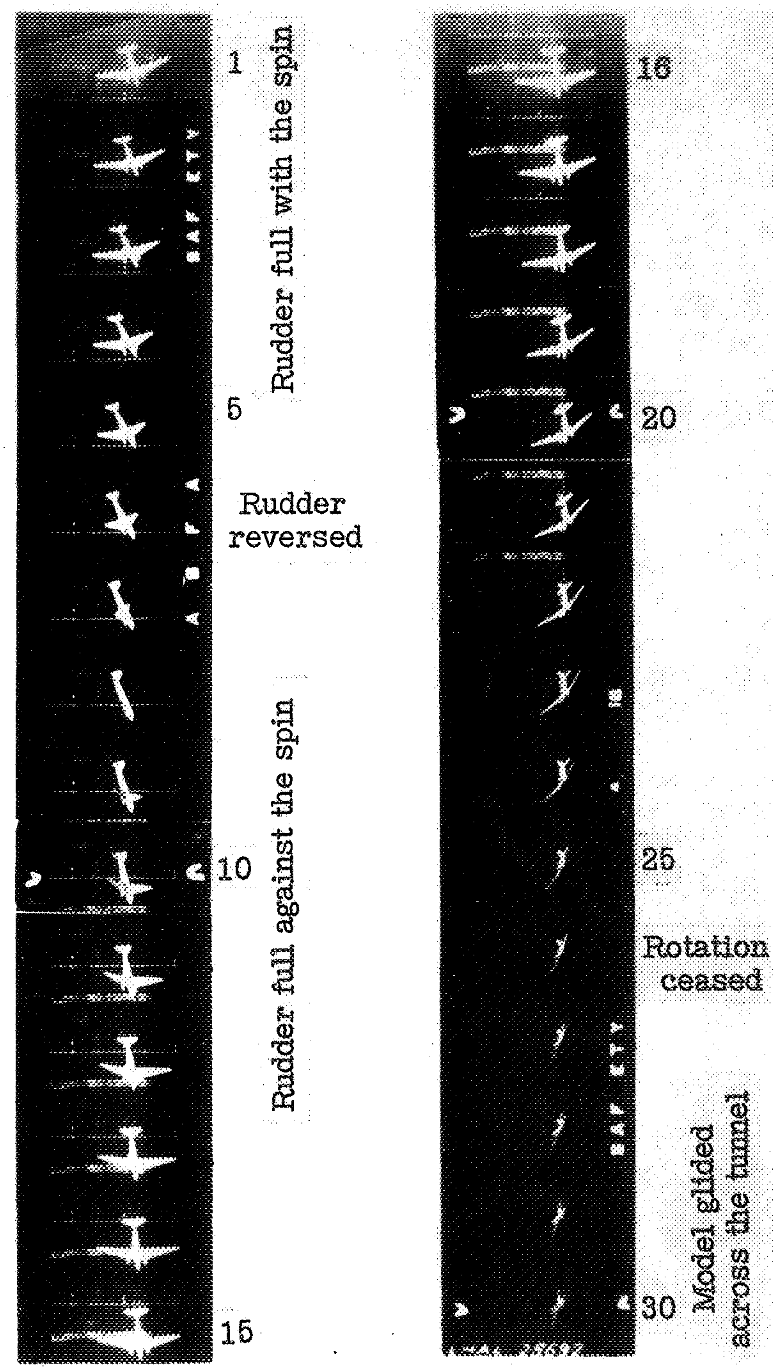
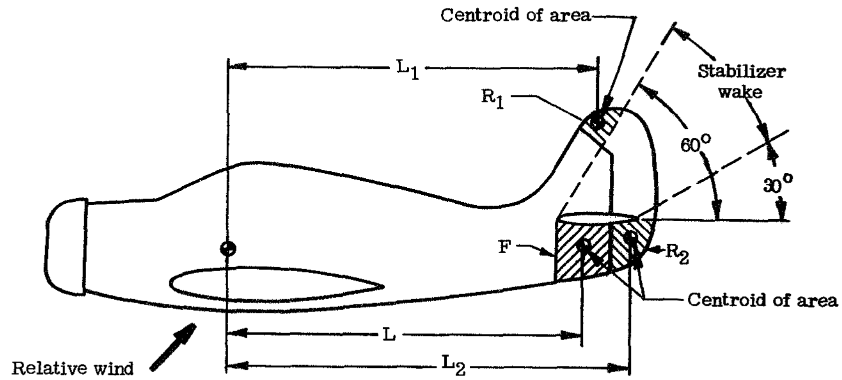
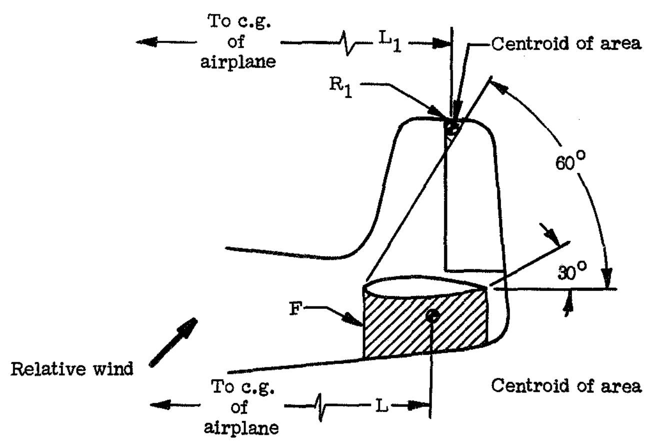


Figure 4.- Recovery from an elevator-up spin. Control settings: rudder as noted, elevator full up, ailerons neutral. Recovered in 1/2 turn (frames 6 to 26).



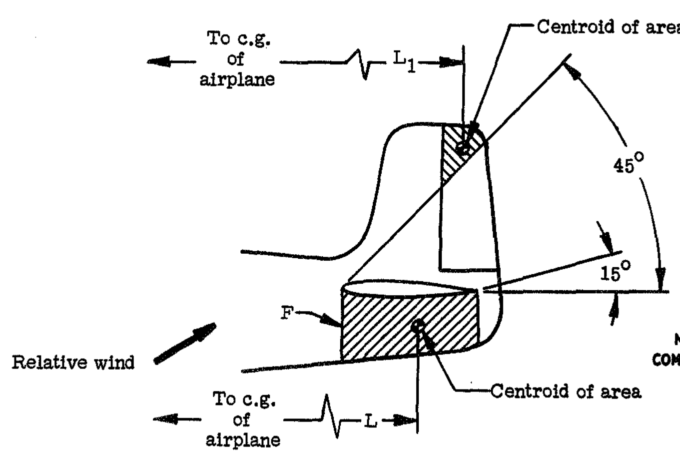
(a) Full-length rudder; α assumed to be 45°.



Tail Damping Power Factor
= Tail Damping Ratio ×
Unshielded Rudder
Volume Coefficient

$$= \frac{FL^2}{s(b/2)^2} \times \frac{R_1L_1 + R_2L_2}{s(b/2)}$$

(b) Partial-length rudder; α assumed to be 45°; TDR 0.019.



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(c) Partial-length rudder; α assumed to be 30°; TDR 0.019.

Figure 5.- Method of computing tail-damping power factor.

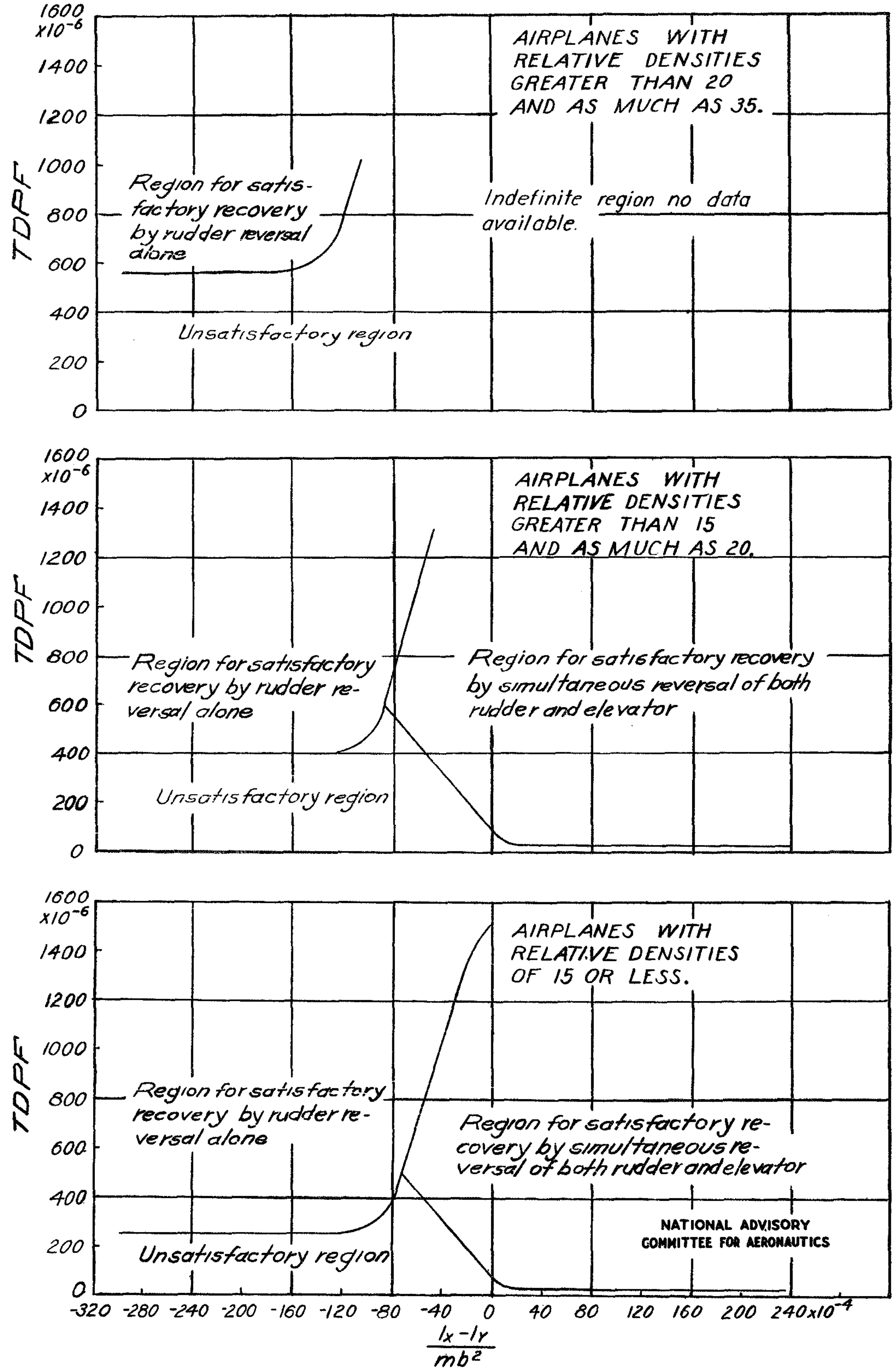


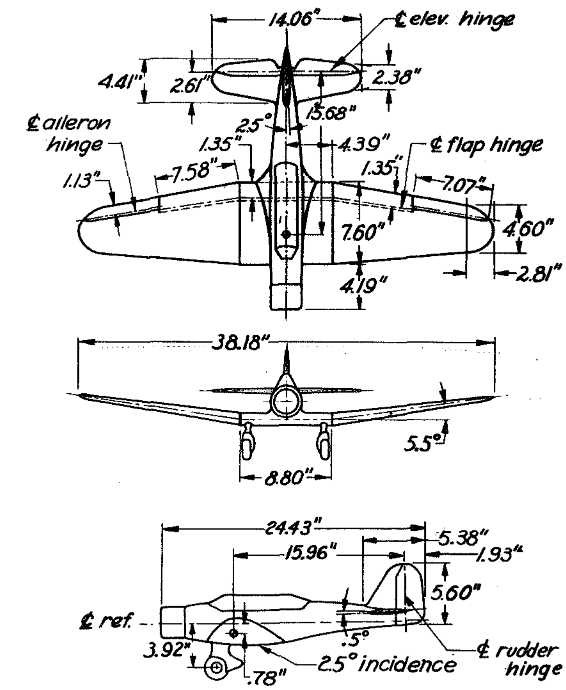
FIGURE 6 - SPIN-RECOVERY DESIGN REQUIREMENTS FOR AIRPLANES WITH RELATIVE DENSITIES BETWEEN 0 AND 35.

$\frac{1}{15}$-SCALE MODEL OF THE NORTHROP A-17 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	47.70
L, ft	32.10
$\bar{c}$, in.	96.90
S, sq ft	363.00
A	6.30
L.E. $\bar{c}$ aft L.E. c_r, in.	5.70
S_h, sq ft	64.06
S_e, sq ft (inc. bal.)	28.26
S_v, sq ft	26.80
S_r, sq ft (inc. bal.)	14.80
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 25 D
δ_a, deg	30 U, 25 D
δ_f, deg	45 D
TDPF	70×10^{-6}
Landing gear	Fixed



Model as tested.

Mass Data

Normal Loading

W, lb	7311
$x/\bar{c}$	0.304
$z/\bar{c}$	0.122
I_X, slug-ft^2	6206
I_Y, slug-ft^2	7677
I_Z, slug-ft^2	12,442
Test altitude, ft	6000
μ (at sea level)	5.51
μ' (6000 ft)	6.60

$\frac{I_X - I_Y}{mb^2}$	-29×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-92×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	121×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, the model spun very steeply. With the elevator down, two types of spin were obtained, either a very steep and wandering spin or a flat spin (data not presented).

Extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ led to spins that were flat and stable; as a result, this condition was used as the basic condition in determining comparative effects of various loadings instead of the normal loading. For this condition, recoveries from steady spins obtained were unsatisfactory except when the ailerons were set full with the spin for which settings the model had a rate of descent in excess of the maximum airspeed of the tunnel from which it is believed that recoveries would have been satisfactory.

Extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$, retracting mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = -0.20\ I_X\right)$, extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.20\ I_X\right)$, moving the center of gravity back $0.05\bar{c}$ from its normal position, or a combination consisting of retracting mass along the wings and moving the center of gravity back from its normal position generally had no appreciable effect on the unsatisfactory recovery characteristics of the model. Deflecting the flaps to 15° and to 45° with the mass increased along the wings generally led to flat spins from which recovery by rapid full rudder reversal was unsatisfactory.

When the center of gravity was moved forward $0.10\bar{c}$ from its normal position with the mass distributed along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$, satisfactory recoveries by rapid full rudder reversals from spins were obtained with the elevator up and the ailerons neutral.

The addition of a ventral fin (modification 1) slightly improved the recovery characteristics of the model; however, recoveries were still generally unsatisfactory.

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SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODEL OF THE NORTHROP A-17 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	ΔI_Y and ΔI_Z = 0.20 I_Y											ΔI_Y and ΔI_Z = 0.20 I_Y, Rudder neutral spins		
Ailerons	Against 19.5°U 15.5°D		Against 5.5°U 8°D		Neutral			With 5.5°U 8°D		With 19.5°U 15.5°D		Neutral		
Elevator	N	D	N	D	U	N	D	N	D	N (a)	D (a)	U	N	D
α, deg	75	---	74	---	56	71	64	48	---	---	---	No spin	47	55
ø, deg	4U	---	3U	---	2U	1U	2U	1U	---	---	---		3U	3U
Ω, rps	0.61	----	0.63	----	0.42	0.55	0.54	0.46	----	----	----		0.47	0.49
V, fps	99	----	97	----	123	100	103	130	---	---	---		125	115
Turns for recovery	∞	∞	∞	∞	5, [b]$6\frac{1}{2}$	6, $9\frac{1}{2}$	$9\frac{3}{4}$	$3\frac{1}{4}$	5	---	---		---	---

Effect of mass variations and c.g. movements on turns for recovery for aileron neutral spins. Elevator	U	D
ΔI_Y and ΔI_Z = 0.20 I_Y, ΔI_X and ΔI_Z = -0.20 I_X	$5\frac{1}{4}$, [b]∞	∞
ΔI_Y and ΔI_Z = 0.20 I_Y, ΔI_X and ΔI_Z = 0.20 I_X	4	$6\frac{1}{2}$
ΔI_Y and ΔI_Z = 0.20 I_Y, c.g. moved forward 0.10$\bar{c}$	[d]$\frac{1}{2}$	$8\frac{1}{2}$
ΔI_Y and ΔI_Z = 0.20 I_Y, c.g. moved back 0.05$\bar{c}$	[e]6	∞

	ΔI_Y and ΔI_Z = 0.20 I_Y, ΔI_X and ΔI_Z = -0.20 I_X, c.g. moved back 0.05$\bar{c}$											ΔI_Y and ΔI_Z = 0.20 I_Y, ΔI_X and ΔI_Z = -0.20 I_X, c.g. moved back 0.05$\bar{c}$, Rudder against spins		
Ailerons	Against 19.5°D 15.5°D		Against 5.5°U 8°D		Neutral			With 5.5°U 8°D		With 19.5°U 15.5°D		Neutral		
Elevator	N	D	N	D	U	N	D	N	D	N	D (c)	U	N	D
α, deg	---	75	---	75	68	----	69	----	51	----	----	No spin	----	53
ø, deg	----	5U	---	3U	2U	---	2U	---	1U	---	---		---	4U
Ω, rps	----	0.63	----	0.60	0.44	----	0.57	----	0.47	----	----		----	0.48
V, fps	----	97	----	96	111	----	99	----	125	----	----		----	121
Turns for recovery	----	∞	----	∞	$6\frac{1}{2}$, [b]∞	∞	∞	----	5	----	----		----	----

ΔI_Y and ΔI_Z = 0.20I_Y, Ailerons neutral. Flaps	15°D		30°D		45°D	
Elevator	N	D	N	D	N	D
α, deg	----	57	----	55	----	55
ø, deg	----	2U	----	3U	----	3U
Ω, rps	---	0.48	----	0.48	----	0.48
V, fps	----	113	----	115	----	115
Turns for recovery	$5\frac{1}{2}$	---	$5\frac{1}{4}$	----	5	----

	ΔI_Y and ΔI_Z = 0.20 I_Y, ΔI_X and ΔI_Z = -0.20 I_X, c.g. moved back 0.05$\bar{c}$ Ailerons neutral					
Flaps	15°D		30°D		45°D	
Elevator	N	D	N	D	N	D
α, deg	----	71	----	68	----	67
ø, deg	----	3U	----	3U	----	3U
Ω, rps	----	0.53	----	0.53	----	0.53
V, fps	----	100	----	102	---	102
Turns for recovery	∞	---	∞	---	9	---

	Modification 1, ΔI_Y and ΔI_Z = 0.20 I_Y						Modification 1, ΔI_Y and ΔI_Z = 0.20 I_Y, ΔI_X and ΔI_Z = -0.20 I_X, c.g. moved back 0.05$\bar{c}$					
Ailerons	Against 19.5°U 15.5°D		Against 5.5°U 8°D		Neutral		Against 19.5°U 15.5°D		Against 5.5°U 8°D		Neutral	
Elevator	N	D	N	D	N	D	N	D	N	D	N	D
α, deg	----	----	----	----	57	----	----	----	----	----	59	----
ø, deg	----	----	----	----	2U	----	----	----	----	----	2U	----
Ω, rps	----	----	----	----	0.47	----	----	----	----	----	0.46	----
V, fps	---	---	---	---	119	---	---	---	---	---	115	---
Turns for recovery	3	---	4	---	3	$3\frac{1}{2}$	$4\frac{1}{2}$	---	5	---	[e]$4\frac{1}{4}$	4

[a]Velocity too high to test.
[b]Recovery attempted by simultaneous reversal of rudder and elevator.
[c]Steep wandering spin, velocity too high to test.
[d]Before recovery was attempted the model was in a steep, fast spin.
[e]Visual estimate.

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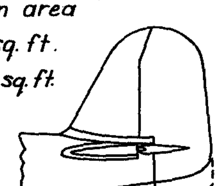
Modification I

Additional fin area
Rudder 2.30 sq. ft.
Fuselage 2.80 sq. ft.

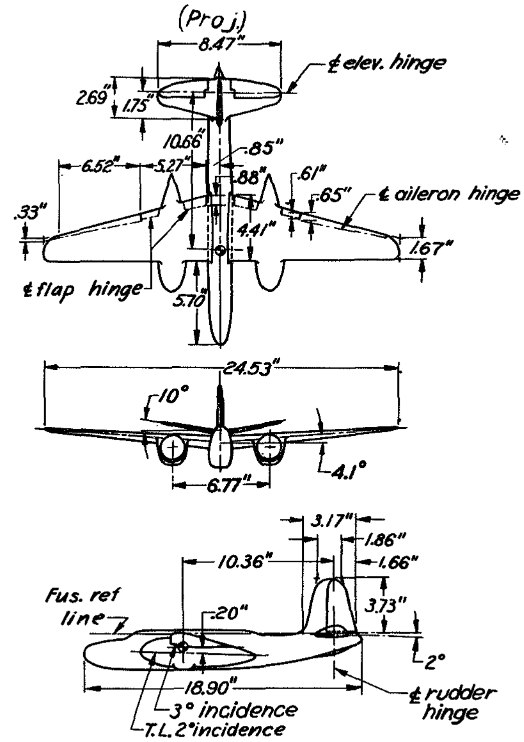


$\frac{1}{30}$-SCALE MODEL OF THE DOUGLAS A-20 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	61.33
L, ft	47.25
$\bar{c}$, in.	100.23
S, sq ft	464.80
A	8.09
L.E. $\bar{c}$ aft L.E. c_r, in.	0.06
S_h, sq ft	101.00
S_e, sq ft	39.80
S_v, sq ft	62.60
S_r, sq ft	36.10
δ_r, deg	22.5 R, 22.5 L
δ_e, deg	30 U, 20 D
δ_a, deg	12 U, 10 D
δ_f, deg	45 D
TDPF	314×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	19,050
$x/\bar{c}$	0.218
$z/\bar{c}$	-0.060
I_X, slug-ft^2	33,706
I_Y, slug-ft^2	24,557
I_Z, slug-ft^2	55,287
Test altitude, ft	20,000
μ (at sea level)	8.73
μ' (20,000 ft)	16.40

$\frac{I_X - I_Y}{mb^2}$	41×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-138×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	97×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, the recovery characteristics of the model were generally satisfactory although, when the ailerons were set full with the spin, recoveries from spins were unsatisfactory for all elevator settings.

Lowering the flaps 45° either alone or in conjunction with extending the landing gear so as to simulate the landing condition did not appreciabl alter the steady spin and recovery characteristics of the model although the adverse effect of setting the ailerons with the spin was accentuated.

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$) had little effect on the recovery characteristics of the model. Retracting mass along the wings (ΔI_X and $\Delta I_Z = -0.25\ I_X$), extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.30\ I_Y$), or a combination of these two mass variations in addition to an increase in the rudder deflection from $22\frac{1}{2}$ R, $22\frac{1}{2}$ L to 30° R 30° L improved the recovery characteristics of the model. Recoveries for all control settings tested were satisfactory by rapid full rudder reversal

Additional test results not presented indicate satisfactory recovery characteristics from inverted spins by rapid full rudder reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{30}$-SCALE MODEL OF THE DOUGLAS A-20 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading															Flaps down 45°, normal loading			Landing condition, normal loading								
Ailerons	Against						Neutral			With						With			Against			Neutral			With		
	Full			12°U 10°D						12°U 10°D			Full														
Elevator	U	N	D	U (a)	N (a)	D	U (a)	N (a)	D	U (a)	N	D (a)	U	N	D	U	N	D	U	N	D	U (ab)	N (a)	D (a)	U	N	D
α, deg	No spin	No spin	No spin	--	--	No spin	--	--	No spin	--	24	--	34	34	34	29	35	35	No spin	No spin	No spin	----	----	----	36	43	42
ø, deg				--	--		--	--		--	3D	--	9D	6D	4D	11D	7D	6D				----	----	----	13D	8D	8D
Ω, rps				--	--		--	--		--	0.60	--	0.39	0.47	0.52	0.35	0.46	0.48				----	----	----	0.37	0.49	0.48
V, fps				--	--		--	--		--	331	--	289	281	272	296	252	252				----	----	----	301	257	257
Turns for recovery				--	--		--	--		--	$2\frac{1}{2}$	--	$>3\frac{3}{4}$	$3\frac{1}{2}$	2 $2\frac{1}{2}$	>6	$>2\frac{1}{2}$ >4	$>3\frac{1}{2}$ >5				----	----	----	$>9\frac{1}{2}$	$>2\frac{1}{2}$	$>3\frac{1}{2}$ $>4\frac{1}{2}$

	Normal loading rudder travel ±30°									ΔI_X and $\Delta I_Z = 0.30 I_X$ Rudder travel ±30°						ΔI_X and $\Delta I_Z = -0.25 I_X$ Rudder travel ±30°									ΔI_Y and $\Delta I_Z = 0.30 I_Y$ Rudder travel ±30°					
Ailerons	Against			Neutral			With			Neutral			With			Against			Neutral			With			Neutral			With		
Elevator	U (a)	N	D	U (a)	N (a)	D (a)	U	N	D	U (a)	N	D	U	N	D	U (a)	N (a)	D	U (a)	N (a)	D	U (ab)	N (a)	D (a)	U (a)	N	D	U	N	D
α, deg	--	No spin	No spin	--	--	--	36	35	34	--	--	--	---	---	---	--	--	No spin	--	--	---	----	--	--	---	---	---	---	---	----
ø, deg	--			--	--	--	5D	5D	6D	--	--	--	---	---	---	--	--		--	--	---	----	--	--	---	---	---	---	---	----
Ω, rps	--			--	--	--	0.37	0.44	0.51	--	--	--	---	---	---	--	--		--	--	---	----	--	--	---	---	---	---	---	----
V, fps	--			--	--	--	284	286	280	--	--	--	---	---	---	--	--		--	--	---	----	--	--	---	---	---	---	---	----
Turns for recovery	--			--	--	--	$>2\frac{1}{2}$ >3	$>2\frac{1}{2}$	2	--	--	--	>8	>8	$4\frac{1}{2}$ 5	--	--		--	--	$1\frac{1}{4}$	----	--	--	---	1	$\frac{3}{4}$	$\frac{3}{4}$	2	2

	ΔI_X and $\Delta I_Z = -0.25 I_X$, ΔI_Y and $\Delta I_Z = +0.30 I_Y$, Rudder travel ±30°								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (a)	N (a)	D	U (ab)	N (a)	D (a)
α, deg	--	--	--	--	--	---	----	--	--
ø, deg	--	--	--	--	--	---	----	--	--
Ω, rps	--	--	--	--	--	---	----	--	--
V, fps	--	--	--	--	--	---	----	--	--
Turns for recovery	--	$\frac{1}{2}$	$\frac{3}{4}$	--	--	$\frac{3}{4}$	----	--	--

[a]Vertical velocity too high to test.
[b]Wandering spin.

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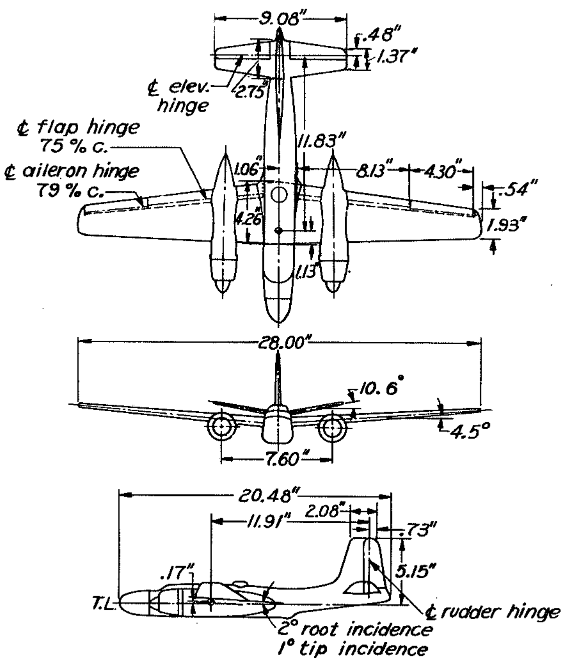
$\frac{1}{30}$-SCALE MODEL OF THE DOUGLAS XA-26 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	70.00
L, ft	51.20
$\bar{c}$, in.	97.50
S, sq ft	540.00
A	9.07
L.E. $\bar{c}$ aft L.E. c_r, in.	6.10
S_h, sq ft	116.10
S_e, sq ft	32.66
S_v, sq ft	71.30
S_r, sq ft	23.10
δ_r, deg	22.5 R, 22.5 L
δ_e, deg	30 U, 20 D
δ_a, deg	20 U, 15 D
δ_f, deg	
Landing condition	55 D
Take-off condition	38.5 D
TDPF	111×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	25,730
$x/\bar{c}$	0.284
$z/\bar{c}$	-0.053
I_X, slug-ft^2	67,827
I_Y, slug-ft^2	51,109
I_Z, slug-ft^2	115,191
Test altitude, ft	20,000
μ (at sea level)	8.9
μ (20,000 ft)	16.7

$\frac{I_X - I_Y}{mb^2}$	43×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-163×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	120×10^{-4}

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Résumé of Model Test Results

For the XA-26 model, tests were conducted only for the normal loading condition inasmuch as a comparison of the XA-26 model with the A-20 model previously tested showed the models to be generally similar in mass and dimensional characteristics, an indication the the spin and recovery characteristic of the models would be similar.

In the clean condition, normal loading, normal control configuration for spinning, the model spun steeply ($\alpha = 27^\circ$) and recoveries were satisfactory by rapid full simultaneous reversal of rudder and elevator, by simultaneous neutralization of rudder and elevator, or by rapid full elevator reversal, but were unsatisfactory by rapid full rudder reversal alone. With the elevator neutral, the spin was steep and recoveries were satisfactory by rapid full rudder reversal; with the elevator full down the model would not spin. Setting the ailerons with the spin retarded recoveries and recoveries by rapid full rudder reversal were satisfactory only for the elevator down position; setting the ailerons against the spin expedited recoveries.

The recovery characetersitics of the model when in the landing condition (landing gear extended, flaps down 55°) were generally inferior to the recovery characteristics in the clean condition; however, simultaneous reversal of rudder and elevator led to satisfactory recoveries.

There was little difference in the general spin and recovery characteristics of the model between the clean condition and the take-off condition (landing gear extended, flaps down $38\frac{1}{2}^\circ$).

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SPIN DATA OBTAINED WITH THE $\frac{1}{30}$-SCALE MODEL OF THE DOUGLAS XA-26 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins]

Normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N (b)	D	U (b)	N (b)	D (b)
α, deg	23			27	20		40	32	32
∅, deg	8U			2U	4U		4D	2D	2D
Ω, rps	0.34	No spin	No spin	0.39	0.56	No spin	0.28	0.44	0.44
V, fps	398			349	349		265	278	273
Turns for recovery	1			$>2\frac{1}{2}$ [c]$\frac{1}{2}$ [d]1 [e]1	1		$>3\frac{1}{2}$ [cf]$\frac{1}{2}$ [d]$1\frac{1}{4}$ [e]$2\frac{1}{2}$	>3	2

Rudder-neutral spins, normal loading

Ailerons	Neutral			With		
Elevator	U (g)	N	D	U (b)	N	D
α, deg	---		--	---	26	
∅, deg	---		--	---	5D	
Ω, rps	---	No spin	--	---	0.49	No spin
V, fps	---		--	---	333	
Turns for recovery	---		--	---	---	

Landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (b)	N (b)	D (b)	U (b)	N	D
α, deg	27	29		35	30	28	41	34	36
∅, deg	1U	1U		4D	4D	2D	8D	7D	5D
Ω, rps	0.35	0.43	No spin	0.30	0.42	0.42	0.29	0.39	0.44
V, fps	278	273		257	273	257	242	253	246
Turns for recovery	$1\frac{3}{4}$ $2\frac{1}{2}$	$2\frac{1}{4}$		∞ [c]1	3 $3\frac{1}{2}$	3	∞	∞	$4\frac{1}{4}$

Take-off condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N (b)	D	U (b)	N (b)	D (b)
α, deg	24			26	24		33	28	29
∅, deg	1U			2D	2D		8D	5D	3D
Ω, rps	0.42	No spin	No spin	0.37	0.47	No spin	---	0.43	0.46
V, fps	341			293	293		278	266	261
Turns for recovery	$\frac{3}{4}$ $1\frac{1}{2}$			>6	$2\frac{1}{2}$		>5	$3\frac{1}{4}$	[f]$2\frac{1}{2}$

[a]Wandering and oscillatory spin.
[b]Oscillatory spin.
[c]Recovery attempted by simultaneous reversal of rudder and elevator.
[d]Recovery attempted by simultaneous neutralization of rudder and elevator.
[e]Recovery attempted by full-elevator reversal.
[f]Model goes into inverted spin upon recovering from erect spins.
[g]Steep spin.

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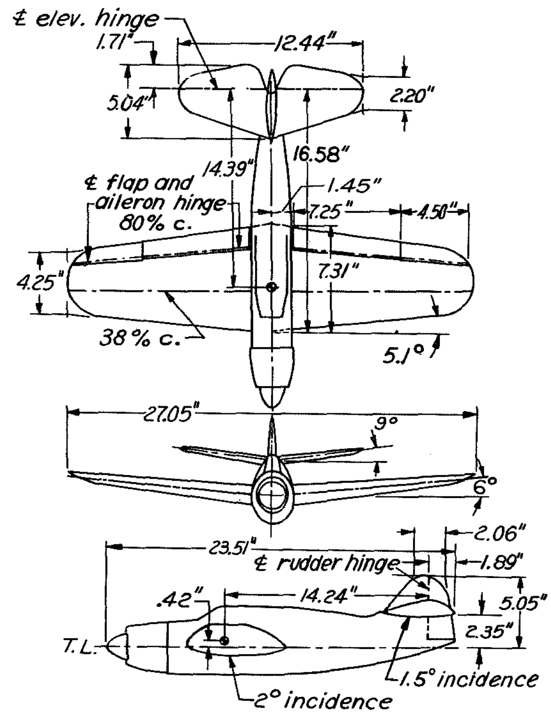
$\frac{1}{20}$-SCALE MODEL OF THE BREWSTER XA-32 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	45.08
L, ft	39.19
$\bar{c}$, in.	118.38
S, sq ft	425.00
A	4.78
L.E. $\bar{c}$ aft L.E. c_r, in.	10.58
S_h, sq ft	121.78
S_e, sq ft	39.56
S_v, sq ft	47.40
S_r, sq ft	16.80
δ_r, deg	25 R, 25L
δ_e, deg	25 U, 15 D
δ_a, deg	25 U, 20 D
Intermediate aileron deflections:	
δ_a (1/4), deg	$5\frac{3}{4}$ U, $5\frac{1}{2}$ D
δ_a (1/3), deg	$8\frac{1}{2}$ U, 8 D
δ_a (1/2), deg	12 U, 11 D
δ_f, deg	60 D
TDPF	108×10^{-6}
Landing gear	conventional



Model as tested.

Mass Data

Normal Loading

W, lb	14,790
$x/\bar{c}$	0.271
$z/\bar{c}$	-0.045
I_X, slug-ft^2	23,696
I_Y, slug-ft^2	22,500
I_Z, slug-ft^2	43,503
Test altitude, ft	17,000
μ (at sea level	10.09
μ' (17,000 feet)	17.12

$\frac{I_X - I_Y}{mb^2}$	13×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-225×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	212×10^{-4}

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Résumé of Model Test Results

The model spun steeply in the clean condition, normal loading, and normal control configuration for spinning. Recoveries were satisfactory by simultaneous reversal of rudder and elevator. With the elevator either neutral or down, satisfactory recoveries could be obtained by rapid full rudder reversal. Setting the ailerons against the spin improved the recoveries of the model, whereas setting the ailerons with the spin prolonged the recoveries of the model from spins.

Extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.27\ I_X\right)$, along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.29\ I_Y\right)$, or moving the center of gravity back $0.10\bar{c}$ from its normal position (data not presented) had no appreciable affect on the spin or recovery characteristics of the model. The recovery characteristics of the model were satisfactory when the model was ballasted to represent the airplane without wing guns and wing gun ammunition $\left(\Delta I_X \text{ and } \Delta I_Z = -0.34\ I_X \text{ and } \Delta I_Y \text{ and } \Delta I_Z = 0.10\ I_Y\right)$ except when the ailerons were with the spin.

The steady spin and recovery characteristics of the model in the torpedo, dive bombing, or landing conditions were, in general, similar to the clean condition, normal loading.

Recoveries attempted by rapid full rudder reversal from inverted spins were unsatisfactory; however, satisfactory recoveries were obtained by rapid full rudder reversal with the controls together (modification 1) when the horizontal tail was lowered 10 inches, full scale from its original position. Adding area to the top of the vertical tail (modification 2), led to inverted spin recovery characteristics similar to those obtained with modification 1.

Increasing the rudder area approximately 4 percent by a constant chordwise extension and varying the rudder travel had little effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BREWSTER XA-32 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins]

	Normal loading									
Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full		
Elevator	U (a)	N	D	U (a)	N (a)	D	17°U	U (a)	N (a)	D
α, deg	28	No spin	No spin	30	24 42	No spin	37	44	44	41
ø, deg	2D			2D	2D		0	3D	3D	2D
Ω, rps	0.43			0.44	0.67		0.44	0.35	0.49	0.53
V, fps	319			304	304		272	239	242	242
Turns for recovery	>3 [b]1 [b]$1\frac{3}{4}$ [c]1 [c]$1\frac{1}{2}$ [d]$\frac{1}{2}$			>3 [b]$3\frac{1}{2}$ [c]$3\frac{1}{4}$ [d]1	$1\frac{1}{4}$ $2\frac{1}{2}$		[b]>7 [c]5 [d]$1\frac{3}{4}$	>4 [b]>6 [c]∞ [d]$2\frac{1}{2}$ [d]3	[e]$3\frac{1}{4}$	[e]3

	Rudder-against spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (fg)	N	D	U (f)	N	D	U (h)	N	D
α, deg	----	-	-	----	-	-	----	No spin	-
ø, deg	----	-	-	----	-	-	----		-
Ω, rps	----	-	-	----	-	-	----		-
V, fps	>332	-	-	>332	-	-	----		-
Turns for recovery	---	-	-	---	-	-	----		-

	ΔI_Y and $\Delta I_Z = 0.29I_Y$									
Ailerons	Against			Neutral				With		
Elevator	U (a)	N	D (a)	U (a)	N (a)	D (ai)	D (i)	U (a)	N (a)	D (i)
α, deg	27 38	26	28	41	39	24	38	37 47	43	39
ø, deg	3U 7D	3U	4U	2D	2U 8D	0	1D	3U 7D	5U 7D	3D
Ω, rps	0.37	0.61	0.56	0.35	0.46	0.78	0.47	0.34	0.46	0.50
V, fps	278	219	272	239	245	332	242	258	258	258
Turns for recovery	$1\frac{1}{2}$ 2	$1\frac{1}{4}$	2	$>2\frac{3}{4}$	[k]$1\frac{1}{2}$ [k]2	$1\frac{1}{2}$ 2	3	$>3\frac{1}{2}$	[e]2 [e]>3	$3\frac{1}{2}$

	ΔI_X and $\Delta I_Z = -0.34I_X$; ΔI_Y and $\Delta I_Z = 0.10I_Y$									
Ailerons	Against			Neutral			With $\frac{1}{4}$	With Full		
Elevator	U (f)	N	D (a)	U (f)	N	D	U	U (a)	N (f)	D (f)
α, deg	-	30	37	---	20	22	---	32	-	--
ø, deg	-	7U	6U	---	1U	2U	---	9D	-	--
Ω, rps	-	0.52	0.54	---	0.78	0.78	---	0.40	-	--
V, fps	-	258	226	---	339	284	332	239	-	--
Turns for recovery	[l]$\frac{1}{2}$	$1\frac{1}{2}$	2 3	[l]1	$1\frac{1}{2}$	$2\frac{1}{4}$	>2	$>2\frac{1}{2}$	-	--

	ΔI_X and $\Delta I_Z = -0.34I_X$; ΔI_Y and $\Delta I_Z = 0.26I_Y$									
Ailerons	Against			Neutral			With $\frac{1}{2}$	With Full		
Elevator	U (fm)	N	D	U (f)	N (f)	D	U	U (a)	N (f)	D (f)
α, deg	----	40	40	----	-----	23	44	37 56	---	----
ø, deg	----	6U	6U	----	-----	1D	3D	1D 13D	---	----
Ω, rps	----	0.43	0.47	----	-----	0.73	0.35	0.32	---	----
V, fps	304	239	233	>339	>339	312	233	220	---	>339
Turns for recovery	[l]$\frac{1}{4}$	2	[n]3	[l]$\frac{1}{2}$	[l]$1\frac{1}{4}$ [l]$1\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$	$>2\frac{1}{2}$	[l]1 [l]$1\frac{1}{2}$	[l,e]$1\frac{1}{4}$

	Dive bombing condition, dive flaps deflected 15°U and 15°D, normal loading plus 2000 pound internal bomb.								
Ailerons	Against			Neutral			With		
Elevator	U (fm)	N	D	U (a)	N	D	U	N (a)	D (o)
α, deg	----	No spin	No spin	18 47	No spin	No spin	42	35	35
ø, deg	----			----			2D	1D	2D
Ω, rps	----			----			0.39	0.54	0.62
V, fps	>339			----			272	284	272
Turns for recovery	----			----			>3	3	$2\frac{1}{3}$ 3

[a]Oscillatory spin, where range of values is not given, average value is presented.
[b]Recovery attempted by reversal of elevator alone.
[c]Recovery attempted by freeing both rudder and elevator.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Model goes into inverted soin after recovery from erect spin.
[f]Steep spin.
[g]Model spins with increasing radius.
[h]Model will spin.
[i]Two types of spin.
[j]Steeper spin also obtained.
[k]Model goes into inverted glide after recovery.
[l]Recovery attempted before model reached final attitude.
[m]Model spins with large radius.
[n]Visual observation.
[o]Variable rate of rotation, average value given.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BREWSTER XA-32 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins]

	Dive bombing condition, dive flaps deflected 30° up and 30° down, normal loading plus 2000 pound internal bomb								
Ailerons	Against			Neutral			With		
Elevator	U (f)	N	D	U (a)	N	D	U	N	D
α, deg	----	No spin	No spin	37	39	35	41	44	41
∅, deg	----			1D	1U	1D	2D	3D	3D
Ω, rps	----			0.40	0.50	0.55	0.39	0.50	0.55
V, fps	>339			264	252	252	268	239	239
Turns for recovery	[l]$1\frac{1}{4}$			>3	2	$3\frac{1}{4}$	>4	$3\frac{1}{4}$	[k]$3\frac{1}{2}$ [k]4

	Dive bombing condition, dive flaps deflected 40° up and 40° down, normal loading plus 2000 pound internal bomb									
Ailerons	Against				Neutral			With		
Elevator	U (a)	N	D (i)	D (i)	U (a)	N	D	U	N	D
α, deg	---	37	No spin	33	38	40	34	51	41	38
∅, deg	---	5U		4U	3U	1U	1U	3D	3D	1D
Ω, rps	---	0.50		0.54	0.38	0.47	0.54	0.40	0.47	0.55
V, fps	---	261		258	258	248	251	232	242	255
Turns for recovery	[p]>2	[q]$1\frac{3}{4}$		$1\frac{1}{2}$	>$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{4}$ $2\frac{3}{4}$	>$3\frac{1}{4}$	[n]$2\frac{3}{4}$ [n]$3\frac{1}{2}$	3

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (r)	N	D	U	N	D
α, deg	No spin	No spin	No spin	40	37	37	42	37	36
∅, deg				1U	1U	2U	3D	1D	0
Ω, rps				0.34	0.44	0.48	0.35	0.45	0.48
V, fps				229	239	232	232	220	227
Turns for recovery				> 3	$2\frac{1}{2}$	[s]3	>3	>$3\frac{1}{2}$	[e]3 [e]$3\frac{1}{2}$

	Inverted spins, normal loading									Rudder area increased 4.2 percent. Normal loading. Rudder movement 23° with to 14° against the spin			Rudder movement 14° with to 23° against the spin		
Ailerons	Against			Neutral			With			Neutral			Neutral		
Elevator	U (ar)	N	D	U	N (a)	D	U	N	D (a)	U (ar)	N (a)	D	U (ar)	N (f)	D
α, deg	42	62	67	55	59 71	62 72	64	62	57 69	----	---	---	---	-----	--
∅, deg	0	1U	0	1U	6U 4D	0	0	1D	6U 4D	----	---	---	---	-----	--
Ω, rps	0.47	0.57	0.70	0.47	0.55	0.69	0.54	0.53	0.57	----	---	---	---	-----	--
V, fps	239	179	170	207	179	157	197	195	179	242 328	239 374	---	339	> 410	--
Turns for recovery	$2\frac{1}{2}$	8 ∞	9	∞	[n]>7	9	∞	∞	[n]∞	[n]>$3\frac{1}{2}$	[n]1 [n]$3\frac{1}{2}$	---	[n]>4	[l,n]$\frac{1}{2}$	--

	Modification 1, inverted spins, normal loading									Modification 2, inverted spin, normal loading					
Ailerons	Against			Neutral			With			Against		Neutral		With	
Elevator	U (ar)	N (a)	D	U	N	D (a)	U	N	D	U	N	U	N	U	N
α, deg	37	---	No spin	46	---	40	55	---	54	---	----	---	----	---	---
∅, deg	10U 1D	---		0	---	6U 5D	0	---	2D	---	----	---	----	---	---
Ω, rps	0.45	---		0.46	0.50	0.52	0.49	---	0.55	---	----	---	----	---	---
V, fps	272	272		238	229	232	220	207	210	---	----	---	----	---	---
Turns for recovery	1 $1\frac{1}{2}$	---		$2\frac{1}{2}$	---	$1\frac{3}{4}$ 3	[n]>7	---	4	---	----	$2\frac{1}{2}$	----	---	---

[a]Oscillatory spin, where range of values is not given, average value is presented.
[b]Recovery attempted by reversal of elevator alone.
[c]Recovery attempted by freeing both rudder and elevator.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Model goes into inverted spin after recovery from erect spin.
[f]Steep spin.
[g]Model spins with increasing radius.
[h]Model will spin.
[i]Two types of spin.
[j]Steeper spin also obtained.
[k]Model goes into inverted glide after recovery.
[l]Recovery attempted before model reached final attitude
[m]Model spins with large radius.
[n]Visual observation.
[o]Variable rate of rotation, average value given.
[p]Recovery attempted in steep phase of oscillation.
[q]After recovery, model enters spin in opposite direction.
[r]Wandering spin.
[s]After recovery model goes into inverted dive.

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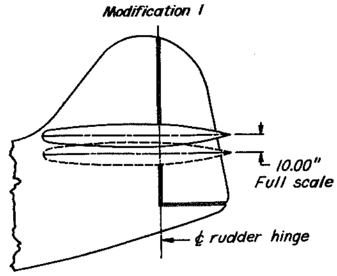
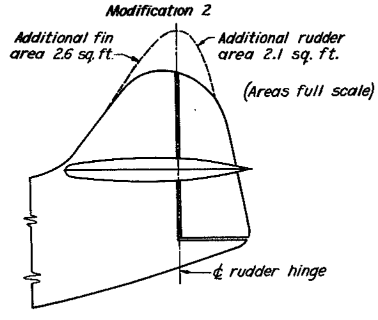
Modification 1



Modification 2



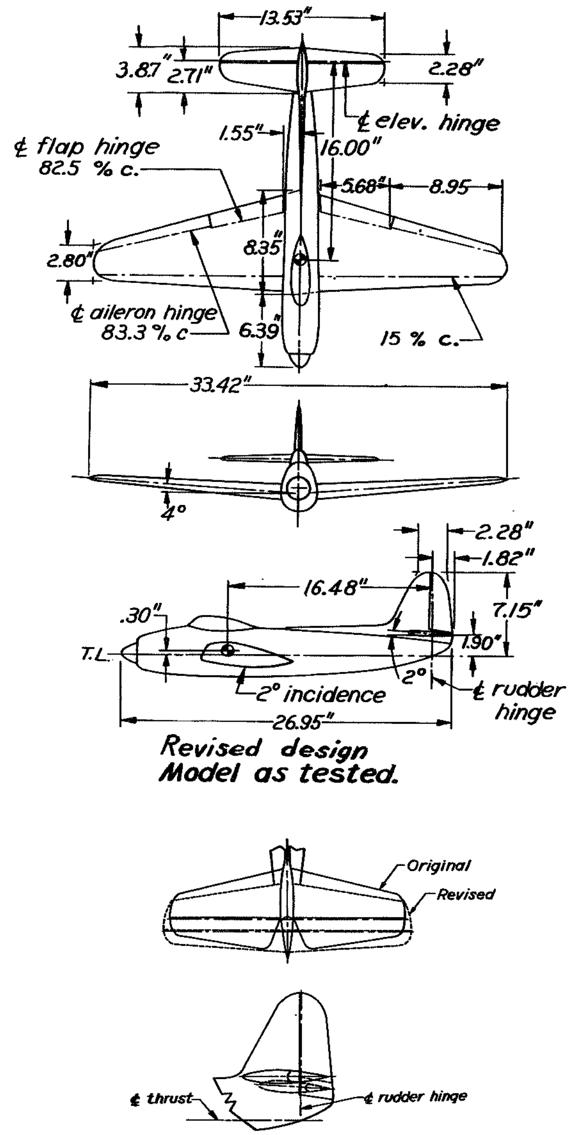
$\frac{1}{20}$-SCALE MODEL OF THE FLEETWINGS XA-39 AIRPLANE

Dimensional Data

(Full Scale)

(Values are the same for both the original and revised designs except where noted)

b, ft	55.70
L, ft	44.91
$\bar{c}$, in.	121.50
S, sq ft	513.00
A	6.04
L.E. $\bar{c}$ aft L.E. c_r, in. .	6.90
S_h, sq ft	
Original design	113.10
Revised design	110.00
S_e, sq ft	
Original design	39.55
Revised design	26.30
S_v, sq ft	
Original design	63.00
Revised design	50.42
S_r, sq ft	
Original design	25.20
Revised design	18.81
δ_r, deg	25 R, 25 L
δ_e, deg	25 U, 25 D
δ_a, deg	20 U, 20 D
δ_f, deg (take-off cond.) . .	30 D
(landing cond.) . .	50 D
TDPF	
Original design . .	428×10^{-6}
Revised design . .	145×10^{-6}
Landing gear . . .	Conventional



Mass Data

Normal Loading

(Original Design)

W, lb	16,160
$x/\bar{c}$	0.264
$z/\bar{c}$	-0.045
I_X, slug-ft^2	21,180
I_Y, slug-ft^2	26,700
I_Z, slug-ft^2	45,870
Test altitude, ft	20,000
μ (at sea level)	7.40
μ' (20,000 ft)	13.89

$\frac{I_X - I_Y}{mb^2}$	-35×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-123×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	158×10^{-4}

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(Revised Design)

W, lb	17,942
$x/\bar{c}$	0.313
$z/\bar{c}$	-0.047
I_X, slug-ft^2	22,298
I_Y, slug-ft^2	33,837
I_Z, slug-ft^2	55,253
Test altitude, ft	20,000
μ (at sea level)	8.22
μ' (20,000 ft)	15.15

$\frac{I_X - I_Y}{mb^2}$	-67×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-124×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	191×10^{-4}

Résumé of Model Test Results

In the clean condition with the original normal loading and tail design, or with the revised normal loading and tail design, the recovery characteristics of the model were satisfactory.

Extending mass along the wings (ΔI_X and ΔI_Z equal approximately 0.30 I_X) for both tail designs caused recoveries from aileron-with spins to be unsatisfactory. Retracting mass along the wings (ΔI_X and ΔI_Z = 0.083 extending mass along the fuselage (ΔI_Y and ΔI_Z = 0.19 I_Y), or moving the center of gravity 0.10$\bar{c}$ forward or 0.06$\bar{c}$ rearward from its original position had no appreciable affect on the satisfactory recovery characteristics for the model equipped with the original tail.

For the landing condition (model equipped with the revised tail), unsatisfactory recoveries were obtained only when the ailerons were against the spin with the elevator either neutral or down.

Recoveries by rapid full rudder reversal were satisfactory from all inverted spins obtained.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE FLEETWINGS XA-39 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition with the original tail design and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Original normal loading									ΔI_X and $\Delta I_Z = 0.28\ I_X$ (from original normal loading)														ΔI_X and $\Delta I_Z = -0.083\ I_X$ (from original normal loading)								
Ailerons	Against			Neutral			With			Against				Neutral				With			Against			Neutral			With		
										Full			1/3																
Elevator	U	N	D	U (a)	N	D	U (ab)	N (a)	D (a)	U	N	D	U	U (a)	50U	N	D	U (b)	N	D	U	N	D	U (a)	N	D	U (ab)	N (a)	D (a)
α, deg	No spin	No spin	No spin	----	No spin	No spin	----	----	----	No spin	No spin	No spin	No spin	----	No spin	No spin	No spin	----	40	40	No spin	No spin	No spin	----	No spin	No spin	----	----	----
ϕ, deg				----			----	----	----					----				----	5U	5U				----			----	----	----
Ω, rps				----			----	----	----					----				----	0.49	0.50				----			----	----	----
V, fps				>375			>300	>375	>375					>375				265	215	215				>375			>350	>375	>375
Turns for recovery				----			----	----	----					[c]3/4				3	3	3 1/2				[c]1/2			[c]1 1/2	[c]1 1/2	[c]3/4

	ΔI_Y and $\Delta I_Z = 0.19\ I_Y$ (from original normal loading)									c.g. moved forward $0.10\bar{c}$ (from original normal loading)													
Ailerons	Against			Neutral			With			Against				Neutral				With					
										Full			1/2					1/3		2/5	Full		
Elevator	U (a)	N	D	U (a)	N (a)	D	U (ab)	N (a)	D (a)	U	N	D	U	U (a)	17°U	N	D	N (a)	D	D (a)	U (ab)	N (a)	D (a)
α, deg	----	No spin	28	----	----	25	----	----	----	No spin	No spin	No spin	No spin	----	No spin	No spin	No spin	----	--	----	----	----	----
ϕ, deg	----		10U	----	----	4U	----	----	----					----				----	--	----	----	----	----
Ω, rps	----		----	----	----	0.73	----	----	----					----				----	--	----	----	----	----
V, fps	>375		274	>375	>375	304	>350	>375	>375					>375				>300	--	>300	>300	>370	>370
Turns for recovery	[c]1		3/4	[c]1	[c]1/2	1	[c]1	[c]3/4	[c]1 [c]1 1/2					[c]1/4 [c]3/4				----	--	----	[c]1 [c]1 1/2	[c]1 1/2	[c]2

	c.g. moved back $0.06\bar{c}$ (from original normal loading)									Revised design, revised normal loading												Revised design ΔI_X and $\Delta I_Z = 0.35\ I_X$								
Ailerons	Against			Neutral			With			Against				Neutral			With					Against			Neutral			With		
										Full			1/2				1/5	1/3	Full											
Elevator	U	N	D	U (a)	N (a)	D	U (ab)	N (a)	D (a)	U	N	D	U	U (a)	N	D	N	D	U (ab)	N (a)	D (a)	U	N	D (e)	U (a)	N	D (e)	U (b)	N (b)	D
α, deg	No spin	No spin	No spin	----	----	22	----	----	----	No spin	No spin	No spin	No spin	----	No spin	No spin	No spin	No spin	----	----	----	No spin	No spin	No spin	----	No spin	No spin	----	36	36
ϕ, deg				----	----	11U	----	----	----					----					----	----	----				----			----	7U	7D
Ω, rps				----	----	0.73	----	----	----					----					----	----	----				----			----	0.52	0.53
V, fps				>375	>375	313	>300	>370	>370					>375					>300	>375	>375				>375			>300	238	232
Turns for recovery				[c]3/4	[c]1/2	1	[c]1 1/2	[c]3/4	[c]1/2					[c]3/4 [cd]2					[c]1 [c]2 1/2 [cd]>3 1/2	[c]1 1/2 [c]2 [cd]>3 1/2	[c]2 [cd]>3 1/2				[c]1/4			[c]4	2 1/2	[f]4

	Revised design - landing condition, revised normal loading									Revised design - take-off condition, revised normal loading									Revised design - inverted spins, revised normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (b)	N (ab)	D (ab)	U	N	D (e)	U (ab)	N	D (e)	U (b)	N (b)	D (a)	U	N	D	U (b)	N (a)	D	U (ab)	N (ab)	D (ab)
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	----	----	----	No spin	No spin	No spin	----	No spin	No spin	----	----	----	No spin	No spin	No spin	----	----	No spin	----	----	----
ϕ, deg							----	----	----				----			----	----	----				----	----		----	----	----
Ω, rps							----	----	----				----			----	----	----				----	----		----	----	----
V, fps							>300	>350	>320				>350			300	320	>375				>320	>360		>320	>350	>350
Turns for recovery							[c]1 1/2 [c]2	[c]3 1/2 [c]>6	[c]3 [c]>5				[c]3/4			3	1 1/2 2	[c]1 1/2				[c]1	[c]1 1/2 [c]2		[c]2	[c]2	[c]2

[a]Steep spin, vertical velocity too high to test.
[b]Wandering and oscillatory spin.
[c]Recovery attempted before final steep attitude was attained.
[d]Recovery attempted by neutralizing the rudder.
[e]Model recovers of its own accord from spin due to initial launching, then goes into an inverted dive.
[f]Model recovers in an inverted dive.

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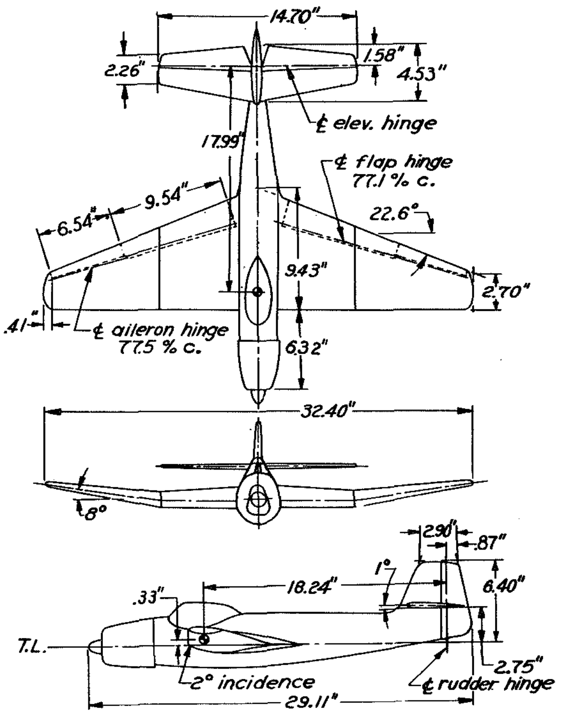
$\frac{1}{20}$-SCALE MODEL OF THE CONSOLIDATED VULTEE XA-41 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	54.00
L, ft	48.66
$\bar{c}$, in.	133.86
S, sq ft	544.00
A	5.36
L.E. $\bar{c}$ aft L.E. c_r, in.	0
S_h, sq ft	130.02
S_e, sq ft	44.80
S_v, sq ft	59.02
S_r, sq ft	23.00
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 25 D
δ_a, deg	20 U, 20 D
δ_a, deg (revised deflection)	30 U, 10 D
δ_f, deg	45 D
TDPF	1017×10^{-6}
Landing gear	Retractable



Model as tested.

Mass Data

Normal Loading

W, lb	18,800
$x/\bar{c}$	0.230
$z/\bar{c}$	0.050
I_X, slug-ft^2	21,655
I_Y, slug-ft^2	44,586
I_Z, slug-ft^2	63,263
Test altitude, ft	15,000
μ (at sea level)	8.37
μ' (15,000 ft)	13.29

$\frac{I_X - I_Y}{mb^2}$	-134×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-110×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	244×10^{-4}

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Maximum Gross Weight Loading

W, lb	24,197	$\frac{I_X - I_Y}{mb^2}$	-60×10^{-4}
$x/\bar{c}$	0.260		
$z/\bar{c}$	0.020		
I_X, slug-ft^2	33,728	$\frac{I_Y - I_Z}{mb^2}$	-137×10^{-4}
I_Y, slug-ft^2	46,848		
I_Z, slug-ft^2	76,914		
Test altitude, ft	15,000	$\frac{I_Z - I_X}{mb^2}$	197×10^{-4}
μ (at sea level)	10.73		
μ' (15,000 ft)	17.09		

Résumé of Model Test Results

For erect spins of the model, satisfactory recoveries by rapid full rudder reversal were obtained for the normal and maximum gross weight loadings, for the normal loading with the center of gravity moved rearward $0.10\bar{c}$ from its normal position, and for the landing condition (flaps down 45°, landing gear extended) and bombing condition. Recoveries from inverted spins were also satisfactory.

A change in aileron deflection from ±20° to 30° up and 10° down did not alter the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE 1/20-SCALE MODEL OF THE CONSOLIDATED VULTEE XA-41 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spin of the model in the clean condition and recoveries are attempted by rapid full rudder reversal from right erect spins]

	Normal loading											Maximum gross weight, weight loading (24,197)								
Ailerons	Against, Full			Against, 1/3	Neutral				With			Against			Neutral			With		
Elevator	U (a)	N	D	20° U (a)	U	N (b)	N (ab)	D	U (a)	N	D	U (a)	N	D	U	N	D (a)	U (a)	N	D
α, deg	---	38	44	29	---	28	19 30	23	---	---	17	---	32	30	---	33	21 32	---	---	---
∅, deg	---	6U	6U	6D	---	4D	1U 10D	1U	---	---	0	---	0	1U	---	2D	2U 5D	---	---	---
Ω, rps	---	0.43	0.43	0.87	---	0.43	0.52	0.58	---	---	0.72	---	0.46	0.56	---	---	0.80	---	---	---
V, fps	>319	226	201	311	272	221	272 291	278	272	>339	339	339	291	272	339	284	284 325	>272	>375	>375
Turns for recovery	[c]3/4 [d]1	1	2 1/2	[e]3/4	3/4 [d]1 1/2 [d]>1 1/2	1 1 1/2	1	1	1 >1 1/2	[c]1/2	1/2	1/4	1	1 1/2	1	1	1	1 1 1/2 >1 1/2	[c]1	[cf]3/4

	c.g. moved back 0.10c̄									Flaps down 45°, normal loading									Landing condition, normal loading									
Ailerons	Against			Neutral			With			Against			Neutral			With			Against				Neutral			With		
Elevator	U (a)	N (a)	D (a)	U (g)	N	D (a)	U (a)	N (a)	D	U (h)	N	D	U (h)	N	D	U (hi)	N	D	U (hj)	U (j)	N	D	U	N	D	U (i)	N	D
α, deg	---	26 32	32 40	---	---	---	---	---	---	43	50	49	37	44	No spin	---	No spin	No spin	39	No spin	44	44	No spin	No spin	No spin	---	No spin	No spin
∅, deg	---	1D 9D	9U 6D	---	---	---	---	---	---	5U	4U	4U	2D	0		---			6U		4U	4U				---		
Ω, rps	---	0.45	0.48	---	---	---	---	---	---	0.33	0.39	0.39	0.31	0.40		---			0.32		0.39	0.47				---		
V, fps	272	272	239	304	>304	339	239	>272	>339	207	194	194	201	194		213			207		194	201				272		
Turns for recovery	1/2	1	1 1/2	1/4	[c]1/2	1	1 1/4	[c]1/2 [c]1 1/4	[c]1/2	1 1/2	2 1/2	3 1/4 4	2	1 3/4		1 1/2			1/4 1		2 1/4	3				3/4		

	Bombing condition (bomb-bay doors open), normal loading									Inverted spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U (i)	N	D	U (i)	N	D	U	N	D	U (i)	N	D	U	N	D
α, deg	---	44	42	---	---	21	---	---	---	No spin	29	32	---	28	30	---	---	---
∅, deg	---	8U	6U	---	---	1U	---	---	---		0	0	---	6D	1D	---	---	---
Ω, rps	---	0.39	0.41	---	---	0.84	---	---	---		0.46	0.54	---	0.50	0.62	---	---	---
V, fps	304	220	213	271	>346	339	>272	>339	>339		272	261	272	284	284	>319	>339	>304
Turns for recovery	1/2	1 3/4	1 1/2	1/2	1/2	[k]1/4	[c]1	[c]1/2	[c]1 1/4		[l]1/2	[l]3/4	1/2	1/2	[l]1/2	[cl]1	[cl]1/2	[cl]1/2

	Dorsal fin and radio loop installed on model, normal loading														
Ailerons	Against, 30° U, 10° D			Against, 20° U, 20° D			Neutral			With, 20° U, 20° D			With, 30° U, 10° D		
Elevator	U (i)	N	D	U (g)	N	D	U (i)	N	D	U (i)	N	D	U (i)	N	D
α, deg	---	26	29	28	29	38	---	23	25	---	---	---	---	---	No spin
∅, deg	---	0	0	5D	2D	5U	---	1D	2U	---	---	---	---	---	
Ω, rps	---	0.60	0.57	0.37	0.43	0.49	---	0.60	0.68	---	---	---	---	---	
V, fps	>304	285	265	284	265	239	>325	336	298	>304	>374	>374	265	>360	
Turns for recovery	[c]1/2	3/4	1	1/4	3/4 1 1/4	1 1/4	[c]3/4	1/2 [c]3/4	1/2 1	[c]>1 1/4	[c]1	[c]1	>1 1/2	[c]1/2	

[a] Oscillatory spin; where range of values is not given, average value is presented.
[b] Two types of spin.
[c] Recovery attempted before model attained final attitude.
[d] Recovery attempted by neutralizing the rudder.
[e] Recovery attempted by reversing the rudder from 30° with to 20° against the spin.
[f] Model enters left inverted spin after recovery.
[g] Model spins in large radius with slow rotation.
[h] Model spins with slow rotation.
[i] Wandering and oscillatory spin.
[j] Two conditions possible.
[k] Visual observation.
[l] Model recovers from inverted spin, rolls over, and begins erect spin.

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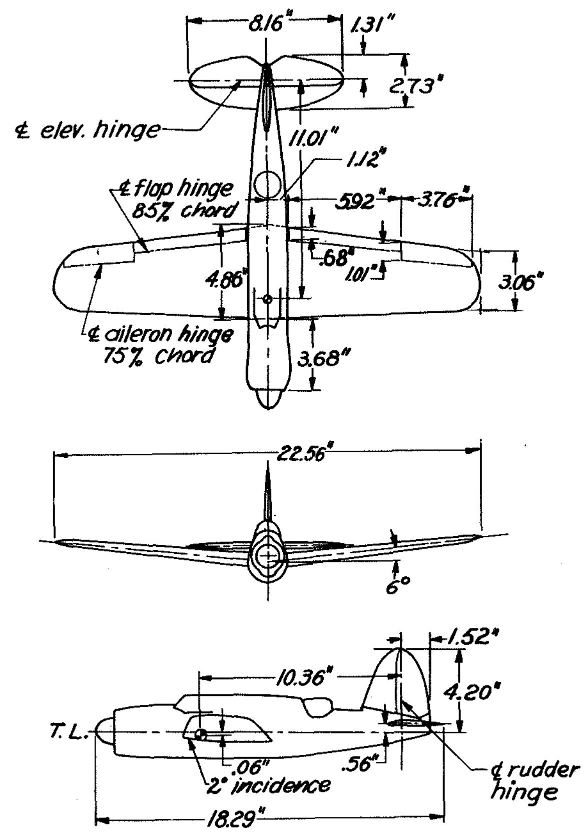
1/25-SCALE MODEL OF THE BREWSTER XSB2A-1 AIRPLANE

Dimensional Data

(Full scale)

b, ft	47.00
L, ft	38.02
$\bar{c}$, in.	101.24
S, sq ft	379.20
A	5.83
L.E. $\bar{c}$ aft L.E. c_r, in	5.05
S_h, sq ft	74.20
S_e, sq ft	33.90
S_v, sq ft	30.00
S_r, sq ft	16.40
δ_e, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	30 U, 15 D
δ_f, deg (diving cond.)	60 U, 60 D
δ_f, deg (landing cond.)	60 D
TDPF	313×10^{-6}
Landing gear	Conventional



Model as tested.

$\frac{I_X - I_Y}{mb^2}$ . . . . $-168 \times 10^{-}$

$\frac{I_Y - I_Z}{mb^2}$ . . . . $-114 \times 10^{-}$

$\frac{I_Z - I_X}{mb^2}$ . . . . $282 \times 10^{-}$

Mass Data

Normal Loading

W, lb	10,112
$x/\bar{c}$	0.257
$z/\bar{c}$	0.025
I_X, slug-ft^2	8,874
I_Y, slug-ft^2	20,544
I_Z, slug-ft^2	28,443
Test altitude, ft	10,000
μ (at sea level)	7.43
μ' (at 10,000 ft)	10.08

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Résumé of Model Test Results

For the normal loading, clean condition, normal control configuration for spinning, the spin was oscillatory and the model had a high rate of descent. Recovery by rapid full rudder reversal or by simultaneous reversal of the elevator and rudder was satisfactory $\left(\frac{3}{4}\text{ turn and }\frac{1}{2}\text{ turn, respectively}\right)$. When the elevator was set full down before reversing the rudder, the spin was flattened, the vertical velocity was decreased, and recovery became unsatisfactory $\left(3\frac{1}{4}\text{ turn}\right)$. Setting the ailerons against the spin had little effect on the recovery characteristics of the model, whereas setting the ailerons with the spin expedited recoveries.

Extending the mass along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$), extending the mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.15\ I_Y$), or moving the center of gravity forward $0.03\bar{c}$ or rearward $0.05\bar{c}$ from its normal position (data not presented) generally had little effect upon the spin and recovery characteristics of the model. The installation of two scaled-down 100-pound bombs on the wings of the model had little effect on the recovery characteristics of the model (data not presented).

For the normal fighting condition (gun turret raised), the recovery characteristics of the model were similar to the recovery characteristics for the normal-loading clean condition.

For the normal diving condition (split dive flaps 60° up and 60° down, and gun turret raised), for the normal-loading condition with the landing flaps 60° down and canopy open, or for the landing condition (landing gear extended, landing flaps down 60°), the model generally would not spin for any elevator-up settings. For the elevator-down settings, recoveries obtained by rapid full rudder reversal were satisfactory only when the ailerons were with the spin.

The model would spin inverted for stick forward and to the left. Recovery by rapid full rudder reversal was satisfactory (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{25}$-SCALE MODEL OF THE BREWSTER XSB2A-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right-erect spins]

	Normal loading												
	Against												
Ailerons	Full					$18\frac{1}{2}^{\circ}$ U, 10°D			Neutral				
Elevator	U (ab)	10°U	5°U	N	D	U (ab)	N	D	U (ac)	15°U	5°U	N	D
α, deg	-----	----	28	43	50	-----	51	51	-----	39	44	45	45
∅, deg	-----	----	9U	6U	5U	-----	3U	4U	-----	4D	0	1U	0
Ω, rps	-----	----	0.41	0.36	0.38	-----	0.36	0.38	-----	0.30	0.35	0.36	0.39
V, fps	-----	243	234	161	152	-----	155	152	-----	184	177	168	159
Turns for recovery	-----	----	$\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{4}$	-----	2	$3\frac{1}{2}$	$\frac{3}{4}$ [e]$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2 [f]4	$3\frac{1}{4}$ [f]>8

	Normal loading						Rudder neutral spins, normal loading								
	With														
Ailerons	$18\frac{1}{2}^{\circ}$ U, 10°D			Full			Against			Neutral			With		
Elevator	U (ab)	N (ac)	D	U (ad)	N (ac)	D	U	N	D	U	N	D	U	N	D
α, deg	-----	-----	22	-----	-----	23	No spin	No spin	44	No spin	No spin	45	No spin	No spin	No spin
∅, deg	-----	-----	2D	-----	-----	1D			7U			0			
Ω, rps	-----	-----	0.71	-----	-----	0.73			0.39			0.39			
V, fps	-----	-----	239	-----	-----	239			161			157			
Turns for recovery	-----	-----	$\frac{3}{4}$	-----	-----	$\frac{3}{4}$			[g]$1\frac{3}{4}$ [g]$2\frac{1}{2}$			[g]$2\frac{3}{4}$			

	Effects of mass variations on turns for recovery								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
ΔI_X and $\Delta I_Z = 0.30I_X$	[b]----	$\frac{1}{2}$	2	$1\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{1}{4}$	[c]----	$2\frac{1}{4}$	$2\frac{3}{4}$
ΔI_Y and $\Delta I_Z = 0.15I_Y$	[b]----	$1\frac{1}{4}$	$4\frac{1}{2}$	[b]1	$2\frac{3}{4}$	$3\frac{1}{2}$	[d]----	[ac]----	[a]----

	Recovery characteristics for the fighting and diving conditions, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
Fighting condition (gun turret raised)	[c]----	$1\frac{1}{2}$	2	$\frac{1}{2}$	2	$2\frac{3}{4}$	[b]---	[b]$\frac{3}{4}$	[c]$\frac{1}{2}$
Diving condition	[h]----	3	5	[h]----	[ac]----	$3\frac{1}{2}$	[h]---	[b]----	[c]$\frac{1}{2}$

	Canopy open, lower flaps down 60°, normal loading									Landing condition, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N (a)	D	U	N	D	U	N	D	U (b)	N (ac)	D	U	N (b)	D
α, deg	No spin	---	52	No spin	---	47	No spin	---	No spin	No spin	44	48	---	-----	44	No spin	---	14
∅, deg		---	5U		---	1D		---			7U	4U	---	-----	1D		---	3D
Ω, rps		---	0.36		---	0.36		---			0.34	0.36	---	-----	0.37		---	0.67
V, fps		---	138		---	145		---			157	145	---	-----	152		---	248
Turns for recovery		---	9		---	4		---			3	$4\frac{3}{4}$	---	-----	$3\frac{1}{4}$		---	$\frac{1}{2}$

[a]High vertical velocity.
[b]Wandering spin.
[c]Oscillatory spin.
[d]Wandering and oscillatory spin.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Recovery attempted by neutralizing the rudder.
[g]Recovery attempted by moving the rudder from neutral to full against the spin.
[h]No spin.

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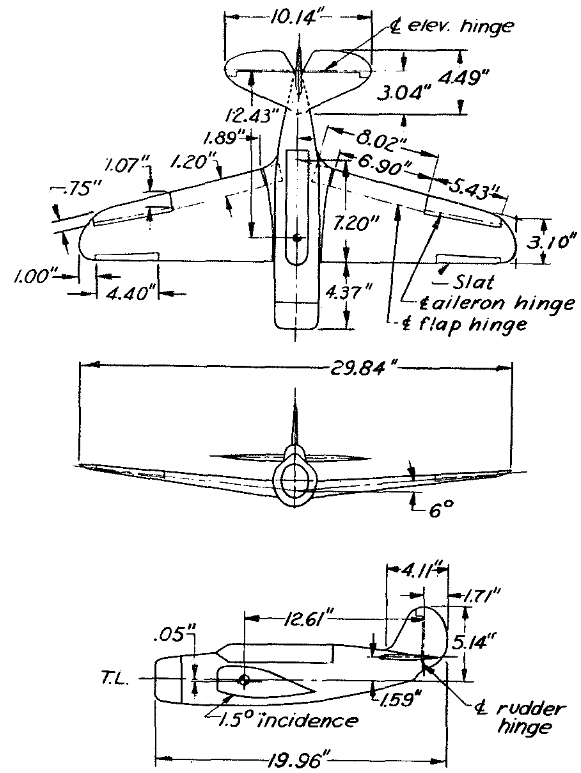
$\frac{1}{20}$-SCALE MODEL OF THE CURTISS XSB2C-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	50.00
L, ft	35.35
$\bar{c}$, in.	109.30
S, sq ft	422.00
A	5.92
L.E. $\bar{c}$ aft L.E. c_r, in.	0.70
S_h, sq ft	82.80
S_e, sq ft	30.60
S_v, sq ft	30.20
S_r, sq ft	17.00
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 20 D
δ_a, deg	35 U, 20 D
δ_a, deg (1/2 stick)	14 U, 11 D
δ_f, deg (landing cond., lower flap)	60 D
δ_f, deg (diving cond., split flaps)	60 U, 60 D
TDPF	69×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	10,189
$x/\bar{c}$	0.229
$z/\bar{c}$	0.010
I_X, slug-ft^2	8150
I_Y, slug-ft^2	13,475
I_Z, slug-ft^2	20,470
Test altitude, ft	10,000
μ (at sea level)	6.31
μ (10,000 ft)	8.55

$\frac{I_X - I_Y}{mb^2}$	-68×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-88×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	156×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, the model spun at a moderately steep angle of attack ($\alpha = 39^\circ$) and satisfactory recoveries (<2 turns) could be obtained only by simultaneous reversal of rudder and elevator. With the elevator either neutral or down, recoveries were unsatisfactory when attempted by rapid full rudder reversal $\left(4\frac{1}{2}\text{ turns and 4 turns, respectively}\right)$ Setting the ailerons partly or fully with the spin steepened the spin and satisfactory recoveries were obtained, whereas setting the ailerons partly or fully against the spin flattened the spin and, in general, unsatisfactory recoveries were obtained.

Extending mass along the wings $(\Delta I_X \text{ and } \Delta I_Z = 0.40\ I_X)$ reversed the aileron effect, whereas extending mass along the fuselage $(\Delta I_Y \text{ and } \Delta I_Z = 0.40\ I_Y)$ accentuated the adverse effect of setting ailerons against the spin.

Opening the rear cockpit (fighting condition) had little effect on the recovery characteristics of the model.

With the model in the diving condition (split flaps 60° up and 60° down, and rear cockpit open), or landing condition (landing gear extended, slots and cockpit open, and flaps down 60°), the recovery characteristics of the model were unsatisfactory. For the landing condition, raising the flaps (slots open, cockpits open, and the landing gear extended) did not improve the recovery characteristics of the model.

For inverted spins, the recovery characteristics of the model were satisfactory.

The addition of ventral fins and rudder extensions (modifications 1 to 4, inclusive) improved the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS XSB2C-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins]

	Normal loading																	
Ailerons	Against, Full			Against, 1/2			Neutral			With, 1/2			With, Full					
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U (a)	N	D			
α, deg	43	48	49	45	49	48	39	46	47	No spin	23	28	---	21	24			
ϕ, deg	3U	5U	4U	5U	6U	7U	1D	3U	3U		2D	2U	---	5D	0			
Ω, rps	0.37	0.45	0.47	0.37	0.45	0.47	0.41	0.46	0.50		0.69	0.71	---	0.73	0.74			
V, fps	178	158	148	178	158	154	182	164	160		251	211	---	266	229			
Turns for recovery	2, b 1 1/4	5 1/2	7, 13	2 1/2, b 1	5 1/2	∞	2 1/2, b 1 1/4, c >5	4 1/2, c ∞	4, c ∞		1 1/2	1 1/2	---	1	1 1/2			

	ΔI_X and $\Delta I_Z = 0.40 I_X$									ΔI_Y and $\Delta I_Z = 0.40 I_Y$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (d)	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	---	No spin	No spin	---	---	No spin	--	---	---	-	---	-	-	---	--	--	--	--
ϕ, deg	---			---	---		---	---	---	-	---	-	-	---	---	---	---	--
Ω, rps	---			---	---		---	---	---	-	---	-	-	---	---	---	---	--
V, fps	---			---	---		---	---	---	-	---	-	-	---	---	---	---	--
Turns for recovery	---			3/4	3		∞	4	4	3	∞	∞	3/4	6	7, 9	---	---	--

	Rear cockpit open, normal loading									Diving condition, normal loading									Landing condition, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	41	46	46	39	42	41	No spin	19	24	51	52	53	46	49	48	No spin	40	No spin	57	58	56	56	53	47	48	No spin	No spin
ϕ, deg	4U	4U	4U	2D	3U	4U		2D	2D	4U	4U	3U	3U	1U	3U		4D		1D	3D	2D	3D	4D	4D	10D		
Ω, rps	0.38	0.46	0.48	0.40	0.47	0.50		0.75	0.73	0.36	0.45	0.46	0.36	0.44	0.46		0.43		0.37	0.44	0.45	0.36	0.45	0.46	0.35		
V, fps	172	158	152	180	164	160		262	204	152	140	136	158	144	144		158		142	134	130	146	138	136	152		
Turns for recovery	2 1/4	5 1/2	6 3/4, 9 1/2	2 3/4	4 3/4	5 1/2		1/2	1 1/4	6 1/4	∞	∞	3 3/4	7 1/2	8 1/2		3 1/2		∞, b ∞	∞	∞	∞, b 7	8 1/2, ∞	6 3/4	∞, b 2 1/2		

	Slots open, cockpits open, landing gear extended, normal loading									Inverted spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U (d)	N	D	U (a)	N (a)	D
α, deg	54	56	56	51	53	54	No spin	No spin	No spin	No spin	No spin	No spin	--	No spin	No spin	--	--	--
ϕ, deg	2D	2D	3D	7D	6D	5D							--			--	--	--
Ω, rps	0.38	0.45	0.47	0.39	0.45	0.47							--			--	--	--
V, fps	156	140	138	160	140	140							--			--	--	--
Turns for recovery	∞	∞	∞	∞	∞	∞							--			--	--	1/2

Effect of tail modifications on turns for recovery, for ailerons against, elevator-down spins, normal loading

Condition	Clean			Landing
Modification	1	2	3	4
Turns for recovery	2 1/2	2	2 1/2	2 1/4

[a] Wandering and oscillatory spin.
[b] Recovery attempted by simultaneous reversal of rudder and elevator.
[c] Recovery attempted by rudder neutralization.
[d] Steep spin, high vertical velocity.

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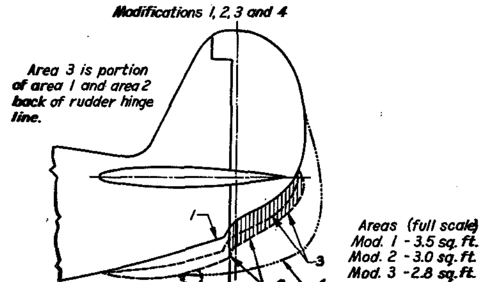
Modifications 1, 2, 3 and 4

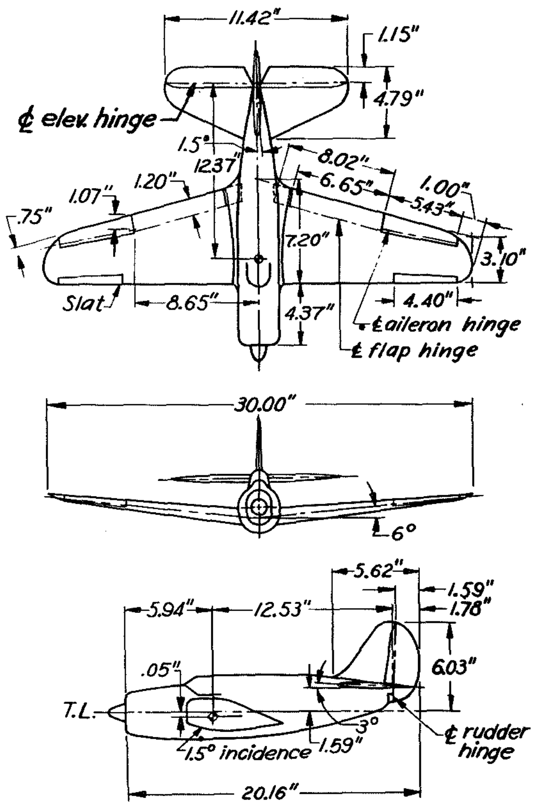


$\frac{1}{20}$-SCALE MODEL OF THE CURTISS SB2C-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	50.00
L, ft	33.61
$\bar{c}$, in.	109.30
S, sq ft	422.00
A	5.92
S_h, sq ft	107.40
S_e, sq ft	35.94
S_v, sq ft	45.70
S_r, sq ft	23.58
δ_r, deg	25 R, 25 L
δ_e, deg	35 U, 20 D
δ_a, deg	20 U, 10 D
δ_f, deg (landing cond.)	60 D
(diving cond.)	30 U, 30 D
(take-off cond.)	30 D
TDPF	140×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	12,677
$x/\bar{c}$	0.284
$z/\bar{c}$	0.009
I_X, slug-ft^2	12,410
I_Y, slug-ft^2	18,460
I_Z, slug-ft^2	29,300
Test altitude, ft	10,000
μ (at sea level)	7.85
μ' (10,000 ft)	10.43

$\frac{I_X - I_Y}{mb^2}$	-62×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-113×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	175×10^{-4}

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Résumé of Model Test Results

Preliminary tests revealed a difference between right and left spin recovery characteristics of the model. Apparently asymmetry of the model caused the differences in spin characteristics, as additional tests indicated that a fin offset of $1\frac{1}{2}^{\circ}$ was not the primary cause of the variations of recovery characteristics between right and left spins.

In general, for either right or left spins for all loadings and control settings tested, the recovery characteristics of the model were unsatisfactory. In an attempt to improve the recovery characteristics of the model the horizontal tail was raised 20 inches, full scale (modification 1). Satisfactory recoveries were obtained when the elevators were full up with the ailerons neutral or with the spin. For other aileron-elevator settings, recoveries were unsatisfactory. The addition of large antispin fillets (modification 2) slightly improved the recovery characteristics of the model although recoveries were still unsatisfactory for elevator up spins. Smaller antispin fillets (modification 3) had no effect. Adding a small area to the bottom of the rudder (modification 4) did not improve the recovery characteristics of the model appreciably (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS SB2C-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from erect spins]

	Normal loading, left spin												ΔI_X and ΔI_Z = 0.25 I_X left spin							
Ailerons	Against 35°U 20°D		Against 20°U 10°D			Neutral			With 20°U 10°D		With 35°U 20°D		Against 35°U 20°D			Neutral			With 35°U 20°D	
Elevator	U (a)	D	U (b)	N	D	U (a)	N	D	U (c)	D	U (c)	D (a)	U	N	D	U	N	D	U (b)	D
α, deg	48	55	53	-	56	46	-	--	---	46	-	48	No spin	----	----	46	-	-	---	----
φ, deg	8U	5U	5U	-	4U	2U	-	--	---	0	-	2D		----	----	3U	-	-	---	----
Ω, rps	0.36	0.45	0.37	-	0.46	0.36	-	--	---	0.46	-	0.47		0.43	0.46	0.38	-	-	---	0.46
V, fps	179	157	176	-	151	176	-	--	---	176	-	160		163	160	182	-	-	---	160
Turns for recovery	2	7	4	-	∞	5	-	--	---	$^{d}4\frac{1}{4}$	-	$^{d}7$		4	$6\frac{1}{2}$	$3\frac{3}{4}$	-	-	---	7

[a]Steeper spin also obtainable, recovery may be rapid.
[b]Oscillatory spin.
[c]Steep oscillatory spin.
[d]Model goes into inverted spin upon recovery.
[e]Two types of spin.
[f]Wandering and oscillatory spin.
[g]Steep spin.
[h]No-spin condition also obtainable.
[i]Wandering spin.
[j]Steeper oscillatory spin also obtainable.

	ΔI_X and ΔI_Z = -0.25 I_X, left spin													ΔI_Y and ΔI_Z = 0.20 I_Y left spin									c.g. moved forward 0.058 left spin								
Ailerons	Against 35°U 20°D				Neutral				With 35°U 20°D					Against			Neutral			With			Against 35°U 20°D			Neutral			With 35°U 20°D		
Elevator	U (be)	U (e)	N	D	U (ef)	U (ef)	N	D	U (a)	N (e)	N (e)	D (e)	D (e)	U	N	D	U (ab)	N	D	U (c)	N	D (a)	U	N	D	U	N	D	U (c)	N	D (a)
α, deg	52	63	66	61	44	63	54	53	62	19	59	21	56	59	-	-	61	-	-	---	-	46	51	-	58	52	-	-	---	-	47
φ, deg	4U	4U	3U	4U	2U	1U	2U	2U	3D	4D	3D	0	3D	4U	-	-	1U	-	-	---	-	0	6U	-	4U	2U	-	-	---	-	3D
Ω, rps	0.34	0.37	0.43	0.42	0.35	0.36	0.40	0.42	0.36	0.63	0.41	0.64	0.42	0.34	-	-	0.34	-	-	---	-	0.43	0.39	-	0.48	0.39	-	-	---	-	0.48
V, fps	179	161	147	147	194	161	166	157	251	290	151	258	227	173	-	-	179	-	-	---	-	173	173	-	147	166	-	-	---	-	163
Turns for recovery	$2\frac{1}{2}$	∞	∞	∞	$2\frac{3}{4}$	$7\frac{1}{2}$	∞	∞	8	1	9	$^{d}1$	$^{d}3$ $^{d}5\frac{1}{4}$	∞	-	-	3 $4\frac{1}{4}$	-	-	---	-	$^{d}4$	$2\frac{1}{2}$ $3\frac{1}{2}$	-	∞	$4\frac{1}{4}$ 7	-	-	---	-	$^{d}5\frac{1}{2}$

	Landing condition normal loading, left spin						Landing gear extended, slots open, normal loading, left spin									Take-off condition, normal loading, left spin									Diving condition, normal loading, left spin								
Ailerons	Neutral			With			Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U (g)	N (h)	D (a)	U	N	D	U	N	D	U (i)	N	D	U	N	D	U	N	D	U (c)	N	D
α, deg	50	---	-	-	48	43	---	-	-	---	54	-	--	---	47	--	--	--	--	--	--	--	50	49	60	--	--	59	--	-	----	-	--
φ, deg	2D	---	-	-	6D	5D	---	-	-	---	4D	-	--	---	5D	--	--	--	--	--	--	--	5D	6D	4U	--	--	2U	--	-	----	-	--
Ω, rps	0.36	---	-	-	0.43	0.46	---	-	-	---	0.46	-	--	---	0.47	--	--	--	--	--	--	--	0.42	0.45	0.39	--	--	0.37	--	-	----	-	--
V, fps	163	151	-	-	166	163	163	-	-	176	161	-	--	185	163	--	--	--	--	--	--	--	157	154	157	--	--	157	--	-	----	-	--
Turns for recovery	∞	∞	-	-	$6\frac{1}{2}$	4 ∞	∞	-	-	∞	∞	-	--	$3\frac{1}{2}$ 6	$^{d}4$	∞	∞	∞	∞	∞	--	--	5	5	∞	--	--	10	--	-	----	-	--

	Modification 1 normal loading, left spin						Modification 2, normal loading, left spin									Normal loading, right spin												
Ailerons	Against			Neutral			Against			Neutral			With			Against 35°U 20°D		Against 20°U 10°D			Neutral			With 20°U 10°D			With 35°U 20°D	
Elevator	U	N	D	U (c)	N	D	U (ba)	N	D	U (j)	N	D	U (c)	N	D	U	D	U	N	D	U	N	D	U (j)	N	D	U (j)	D (a)
α, deg	No spin	--	---	----	48	--	46	--	--	42	--	-	---	--	21	52	56	69	--	64	65	--	--	62	--	50	62	47
φ, deg		--	----	----	4D	--	8U	--	--	2D	--	-	---	--	4U	4U	4U	2U	--	3U	1U	--	--	1D	--	1D	3D	3D
Ω, rps		--	0.46	----	0.43	--	0.38	--	--	0.40	--	-	---	--	0.92	0.38	0.46	0.42	--	0.48	0.42	--	--	0.39	--	0.46	0.39	0.47
V, fps		--	170	207	179	--	162	--	--	201	174	-	---	--	258	173	150	161	--	144	161	--	--	161	--	163	160	160
Turns for recovery		--	$2\frac{1}{2}$	----	$2\frac{1}{2}$	--	$3\frac{1}{4}$	--	--	$2\frac{1}{4}$	--	-	---	--	$^{d}1$	6	∞	∞	--	∞	∞	--	--	∞	--	$^{d}9$	∞	$^{d}8$

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS SB2C-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from erect spins]

	ΔI_X and ΔI_Z = 0.25 I_X, right spin										ΔI_X and ΔI_Z = -0.25 I_X, right spin									ΔI_Y and ΔI_Z = 0.20 I_Y, right spin								
Ailerons	Against 35°U 20°D			Neutral				With 35°U 20°D			Against 35°U 20°D			Neutral			With 35°U 20°D			Against			Neutral			With		
Elevator	U (b)	N	D	U (e)	U (e)	N	D	U	N	D	U (b)	N	D	U (i)	N	D	U (c)	N (g)	D	U	N	D	U	N	D	U (c)	N	D
α, deg	---	-	----	65	----	-	-	----	-	---	51	60	59	51	56	53	----	-	22	59	-	63	62	-	-	----	--	46
ϕ, deg	---	-	----	1U	----	-	-	----	-	---	4U	3U	4U	2U	1U	2U	----	-	2D	3U	-	3U	1U	-	-	----	--	2D
Ω, rps	0.38	-	0.46	0.40	0.37	-	-	0.39	-	0.47	0.36	0.40	0.42	0.36	0.40	0.42	----	-	0.80	0.34	-	0.42	0.34	-	-	----	--	0.40
V, fps	179	-	154	160	174	-	-	157	-	157	182	157	154	182	161	157	----	-	272	163	-	147	163	-	-	----	--	176
Turns for recovery	$4\frac{1}{4}$	-	∞	∞	6 ∞	-	-	∞	-	∞	3 6	∞	∞	6 10	∞	∞	----	-	d 1	∞	-	∞	∞	-	-	----	--	d $4\frac{1}{4}$

	c.g. moved forward 0.05c̄, right spin									Landing condition, normal loading, right spin							Landing gear extended slots open, normal loading, right spin						Take-off condition, normal loading right spin								
Ailerons	Against 35°U 20°D			Neutral			With 35°U 20°D			Neutral			With				Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (j)	N (a)	D (a)	U	N	D	U (e)	U (ei)	N	D	U	N	D	U (j)	N	D	U	N	D	U	N	D	U	N	D
α, deg	50	-	55	54	-	-	57	51	48	66	-	-	60	47	-	43	56	56	-	58	51	52	71	63	62	63	60	-	51	58	57
ϕ, deg	6U	-	4U	1U	-	-	4D	3D	3D	0	-	-	1D	4D	-	6D	2D	2D	-	2D	6D	4D	0	0	0	1D	2D	-	6D	4D	4D
Ω, rps	0.39	-	0.47	0.38	-	-	0.40	0.47	0.50	0.41	-	-	0.37	0.59	-	0.44	0.36	0.44	-	0.37	0.44	0.46	0.44	0.44	0.46	0.38	0.46	-	0.36	0.43	0.45
V, fps	173	-	150	166	-	-	170	163	160	144	-	-	147	157	-	163	161	154	-	163	163	157	147	141	138	154	147	-	154	150	147
Turns for recovery	$4\frac{1}{2}$	-	∞	$4\frac{1}{4}$ $6\frac{3}{4}$	-	-	$7\frac{1}{2}$	6	$4\frac{1}{2}$	∞	-	-	9	>5	-	4 $7\frac{1}{4}$	∞	∞	-	∞	8	d $4\frac{1}{2}$ d $7\frac{1}{4}$	∞	∞	∞	∞	∞	-	∞	$8\frac{1}{4}$	7

	Diving condition, normal loading, right spin									Modification 1, normal loading, right spin										Modification 2, normal loading, right spin								
Ailerons	Against			Neutral			With			Against			Neutral			With 10°U 5°D	With Full			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (c)	N	D	U	N	D	U	N	D	U	U (i)	N	D	U	N	D	U	N	D	U (ci)	N	D
α, deg	60	-	-	55	-	-	-----	-	-	50	-	53	48	50	-	41	39	-	-	42	-	-	45	52	-	----	-	45
ϕ, deg	3U	-	-	2U	-	-	-----	-	-	6U	-	6U	4U	4U	-	0	3D	-	-	6U	-	-	1U	1U	-	----	-	3U
Ω, rps	0.37	-	-	0.36	-	-	-----	-	-	0.36	-	0.46	0.36	0.44	-	0.36	0.37	-	-	0.38	-	-	0.39	0.44	-	----	-	0.48
V, fps	157	-	-	157	-	-	-----	-	-	182	-	163	182	170	-	207	213	-	-	182	-	-	188	170	-	----	-	176
Turns for recovery	∞	-	-	$5\frac{1}{2}$	-	-	-----	-	-	k $1\frac{1}{2}$	-	$2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	-	>4	>4	-	-	3 $5\frac{1}{4}$	-	-	$3\frac{1}{2}$ $4\frac{3}{4}$	>7	-	----	-	d $4\frac{1}{2}$ d 5

[a]Steeper spin also obtainable, recovery may be rapid.
[b]Oscillatory spin.
[c]Steep oscillatory spin.
[d]Model goes into inverted spin upon recovery.
[e]Two types of spin.
[g]Steep spin.
[i]Wandering spin.
[j]Steeper oscillatory spin also obtainable.
[k]Model goes into left spin upon recovery.

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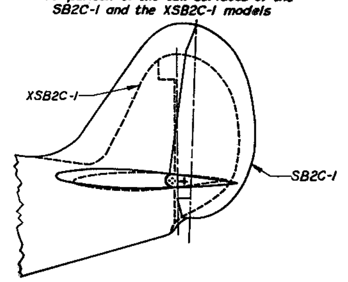
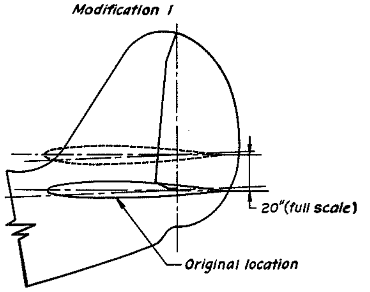
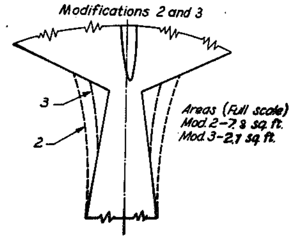
Comparison of the tail surfaces of the SB2C-1 and the XSB2C-1 models



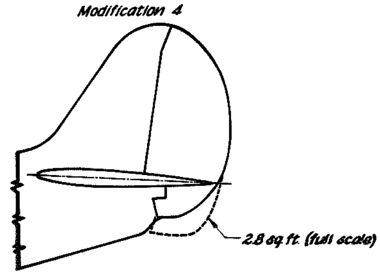
Modification 1



Modifications 2 and 3



Modification 4

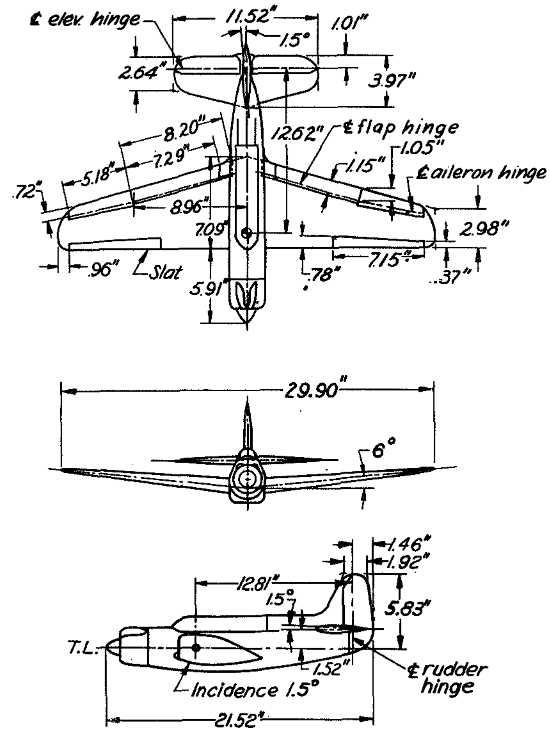


$\frac{1}{20.833}$-SCALE MODEL OF THE CURTISS XSB3C-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	51.95
L, ft	37.33
$\bar{c}$, in.	111.35
S, sq ft	451.08
A	6.00
L.E. $\bar{c}$ aft L.E. c_r, in.	0.37
S_h, sq ft	107.00
S_e, sq ft	29.00
S_v, sq ft	47.90
S_r, sq ft	21.30
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 20 D
δ_a, deg	25 U, 15 D
δ_a, deg (landing condition) drooped (Aileron deflections measured from chord plane)	15 D
δ_f, deg (landing condition)	60 D
δ_f, deg (diving condition)	30 U, 30 D
TDPF	254×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	14,058
$x/\bar{c}$	0.244
$z/\bar{c}$	0.000
I_X, slug-ft^2	16,100
I_Y, slug-ft^2	20,800
I_Z, slug-ft^2	35,200
Test altitude, ft	10,000
μ (at sea level)	7.83
μ' (10,000 ft)	10.51

$\frac{I_X - I_Y}{mb^2}$	-40×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-122×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	162×10^{-4}

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Résumé of Model Test Results

For the clean condition, normal loading, and normal control configuration for spinning, the model spin was oscillatory and recovery by rapid full rudder reversal or by simultaneous reversal of rudder and elevator was satisfactory. Recoveries obtained by neutralizing the rudder were unsatisfactory (>6 turns). With the elevator either in the neutral or full-down position (ailerons neutral), recoveries obtained by rapid full rudder reversal were unsatisfactory. Setting the ailerons with the spin for any elevator setting produced unsatisfactory recoveries from all spins, whereas setting the ailerons against the spin improved the recoveries.

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$) or along the fuselage (ΔI_Y and $\Delta I_Z = 0.25\ I_Y$) or moving of the center of gravity forward or back ($\pm 0.05\bar{c}$) from its normal position had little effect on the steady-spin or recovery characteristics of the model.

For the landing condition (landing gear extended, lower surface split-type flaps down 60°, ailerons drooped 15°, and slots open), recoveries by rapid full rudder reversal were either impossible or unsatisfactory. With the model in the landing condition but with the slots closed, satisfactory recoveries were obtained when the elevator was full up, ailerons neutral, or when the ailerons were full with the spin. Tests conducted with the model in the landing condition with the ailerons not drooped indicated an aileron effect similar to that obtained for the clean condition, normal loading.

The steady-spin and recovery characteristics of the model in the diving condition (split dive flaps up and down 30°) were, in general, similar to those of the model in the clean condition, normal loading.

The addition of area to the bottom of the fuselage and to the lower part and trailing edge of the rudder, modification 2, improved the recovery characteristics of the model in the landing condition, although recoveries obtained by rapid full rudder reversal were marginal $\left(2\frac{1}{2}\text{ turns}\right)$. Either increasing the tail length 1 foot (full scale) or increasing the tail length 1 foot in conjunction with raising the horizontal tail 1 foot (full scale) had little effect on the recovery characteristics of the model in the landing condition (data not presented).

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A series of tests (data not presented) was conducted varying the location of the slots when the model was in the landing condition. (See sketch of slot positions.) Decreasing the slot opening (positions A_3, A_2, and A_1) progressively improved the recovery characteristics of the model, whereas varying the slot positions, as shown by B_1, B_2, and B_3, had little effect on the recovery characteristics. Slot positions C_1, C_2, and C_3 improved the recovery characteristics slightly. The most favorable position of slots for spinning, either A_1 or C_2, still did not lead to satisfactory recoveries.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

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STEADY-SPIN DATA OBTAINED WITH THE $\frac{1}{20.833}$-SCALE MODEL OF THE CURTISS XSB3C-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading									Rudder neutral spins, normal loading									ΔI_X and $\Delta I_Z = 0.30 I_X$							
Ailerons	Against			Neutral			With			Against			Neutral			With			Against		Neutral				With	
Elevator	U	N (a)	D	U (b)	N	D	U (b)	N	D	U	N	D (e)	U	N	D	U	N	D	U (fg)	D	U (bh)	U (bh)	N	D	U (b)	D
α, deg	No spin	50	50	55	56	54	40	52	51	No spin	No spin	49	No spin	52	49	No spin	44	49	--	48	30	47	53	51	39	51
∅, deg		5U	4U	1D	0	1U	5D	3D	3D			4U		2U	3U		3D	3D	--	4U	0	1U	1U	2U	4D	2D
Ω, rps		0.45	0.47	0.39	0.45	0.47	0.41	0.44	0.47			0.47		0.45	0.47		0.45	0.47	--	0.48	0.53	0.40	0.46	0.47	0.42	0.47
V, fps		173	170	189	173	170	221	170	170			173		180	173		180	173	--	180	325	192	173	170	211	173
Turns for recovery		2 [c]5	$2\frac{1}{4}$ [c]>8	$1\frac{3}{4}$ $2\frac{1}{4}$ [c]6 [d]$1\frac{3}{4}$	3 [c]∞	$3\frac{1}{4}$	$2\frac{1}{4}$ [c]>4 [d]2	$3\frac{1}{4}$ $3\frac{3}{4}$	$3\frac{1}{2}$			---		---	---		---	---	--	2	1	2	3	$3\frac{1}{4}$	>5	7

	ΔI_Y and $\Delta I_Z = 0.25 I_Y$								c.g. moved forward $0.05\bar{c}$								c.g. moved back $0.05\bar{c}$						
Ailerons	Against			Neutral		With			Against			Neutral			With		Against			Neutral		With	
Elevator	U (ab)	N	D	U	D	U (i)	N	D	U (fj)	N	D	U	N	D	U (i)	D	U (fj)	N	D	U (b)	D	U (b)	D
α, deg	46	----	52	52	55	34	----	48	--	--	50	52	--	--	38	49	--	--	50	42	--	37	49
∅, deg	6U	----	4U	0	0	6D	----	3D	--	--	5U	1U	--	--	2D	1U	--	--	5U	2U	--	3D	3D
Ω, rps	0.36	0.39	0.42	0.35	0.42	0.43	0.39	0.42	--	--	0.49	0.40	--	--	0.46	0.48	--	--	0.45	0.36	--	0.40	0.45
V, fps	189	177	173	179	170	230	177	177	--	--	170	186	--	---	211	170	--	--	173	192	--	211	173
Turns for recovery	$1\frac{3}{4}$	$2\frac{3}{4}$	$4\frac{1}{2}$	$2\frac{1}{4}$	$5\frac{1}{2}$	$1\frac{3}{4}$	3	4	--	--	$2\frac{1}{2}$	$2\frac{1}{2}$	--	--	$2\frac{1}{2}$	4	--	--	2	$1\frac{3}{4}$ $2\frac{1}{4}$	--	2	4

	Landing condition, normal loading									Landing condition, slots closed, normal loading						Diving condition, normal loading								
Ailerons	Against			Neutral			With			Against		Neutral		With		Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (b)	N	D	U	D	U (gk)	D	U (gk)	D	U (be)	N	D	U	N	D	U	N	D
α, deg	65	66	66	60	61	60	46	54	54	66	60	--	55	--	No spin	51	57	55	53	57	56	45	54	53
∅, deg	0	1D	1D	3D	3D	4D	11D	8D	8D	2U	2U	--	0	--		6U	4U	4U	2U	1U	1U	4D	3D	3D
Ω, rps	0.41	0.47	0.49	0.38	0.46	0.45	0.37	0.44	0.45	0.38	0.48	--	0.46	--		0.37	0.44	0.45	0.37	0.44	0.45	0.39	0.44	0.46
V, fps	150	144	138	153	147	138	166	153	147	151	147	--	147	--		173	160	157	173	160	157	189	173	160
Turns for recovery	9	∞	∞	∞	>8	∞	$2\frac{1}{4}$ $3\frac{1}{4}$	$4\frac{1}{2}$	4	3	6	--	$4\frac{1}{2}$	--		$1\frac{1}{2}$	3	$3\frac{1}{4}$	2	$3\frac{1}{4}$	$3\frac{3}{4}$	3	$3\frac{1}{2}$	4

	Inverted spins, normal loading									Modification 1, landing condition									Modification 2, landing condition					
Ailerons	Against			Neutral			With			Against			Neutral			With			Against		Neutral		With	
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	D	U	D	U	D
α, deg	No spin	No spin	No spin	No spin	39	No spin	48	44	No spin	----	-	-	----	-	-	----	-	-	----	----	----	--	----	----
∅, deg					0		5D	4D		----	-	-	----	-	-	----	-	-	----	----	----	--	----	----
Ω, rps					0.47		0.41	0.46		0.40	-	-	0.39	-	-	0.38	-	-	0.40	0.47	0.40	--	0.37	0.45
V, fps					198		189	195		157	-	-	160			166	-	-	150	137	150	--	153	147
Turns for recovery					$\frac{3}{4}$ [c]$1\frac{1}{4}$		1 [c]>4	1 [c]$2\frac{1}{4}$		[l]$3\frac{1}{4}$	-	-	[l]$3\frac{1}{4}$	-	-	[l]3	-	-	[l]$2\frac{1}{2}$	[l]$2\frac{1}{2}$	[l]$2\frac{1}{2}$	--	[l]$2\frac{1}{2}$	[l]$2\frac{1}{2}$

[a] Steeper spin obtained occasionally.
[b] Oscillatory spin.
[c] Recovery attempted by neutralization of the rudder.
[d] Recovery attempted by simultaneous reversal of rudder and elevator.
[e] "No spin" condition obtained occasionally.
[f] Steep spin.
[g] Model recovered in approximately 3 turns when launched with rudder full against the spin.
[h] Two types of spin.
[i] Wandering and oscillatory spin.
[j] Model recovered in approximately 2 turns when launched with rudder full against the spin.
[k] Steep and oscillatory spin.
[l] Visual observation.

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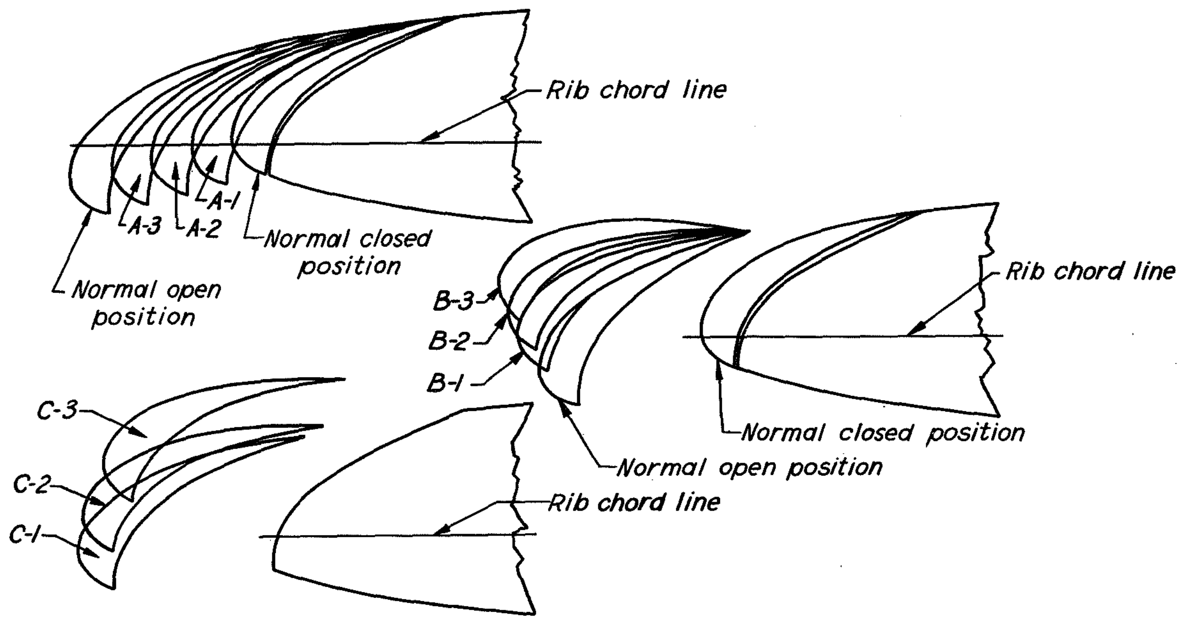
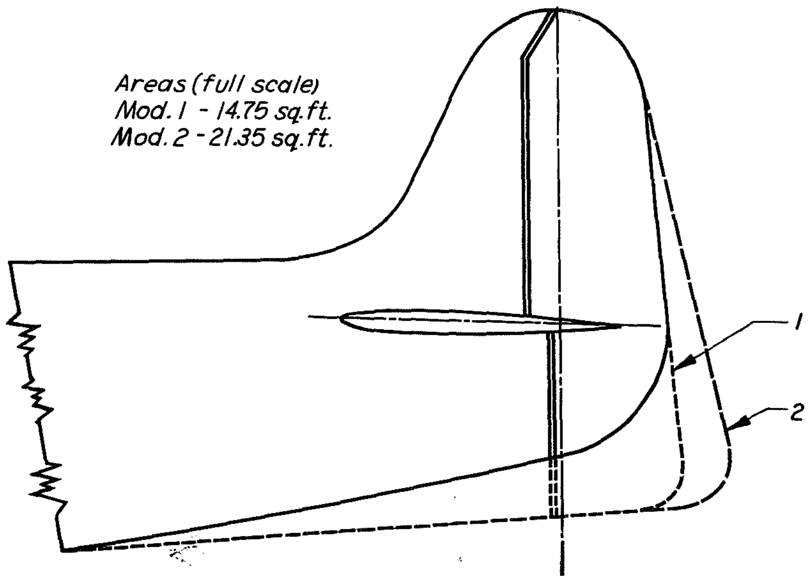
Slot Locations Tested on Model



Modifications 1 and 2



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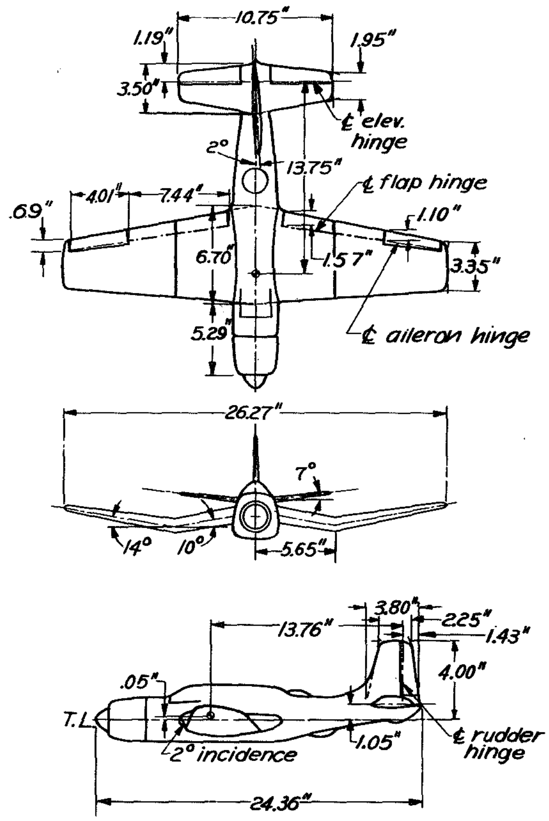
$\frac{1}{20}$-SCALE MODEL OF THE DOUGLAS XSB2D-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	45.00
L, ft	38.57
$\bar{c}$, in.	104.40
S, sq ft	375.00
A	5.40
L.E. $\bar{c}$ aft L.E. c_r, in.	0.65
S_h, sq ft	80.30
S_e, sq ft	21.25
S_v, sq ft	33.10
S_r, sq ft	11.00
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 20 D
δ_a, deg	20 U, 15 D
δ_f, deg	
Landing condition	38 D, 55 D
Diving condition, slat type dive flaps	92 U, 92 D
TDPF	32×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	14,600
x/$\bar{c}$	0.261
z/$\bar{c}$	-0.009
I_X, slug-ft^2	13,934
I_Y, slug-ft^2	25,533
I_Z, slug-ft^2	37,832
Test altitude, ft	10,000
Alternate test altitude, ft	25,000
μ (at sea level)	11.30
μ (10,000 ft)	15.31
μ (25,000 ft)	25.20

$\frac{I_X - I_Y}{mb^2}$	-126×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-134×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	260×10^{-4}

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Résumé of Model Test Results

For the clean condition, normal loading, normal control configuration for spinning, the model spun steeply, descended rapidly, and recoveries were satisfactory by rapid full rudder reversal or simultaneous neutralization or reversal of rudder and elevator. With the elevator either neutral or down, recoveries were retarded slightly but still satisfactory by rapid full rudder reversal.

Setting the ailerons with the rotation steepened the spin and satisfactory recoveries could be obtained by rapid full rudder reversal. Setting the ailerons against the rotation, flattened the spin and satisfactory recoveries could be obtained only when the elevator was full-up.

Extending or retracting mass along the wings (ΔI_X and $\Delta I_Z = 0.40\ I_X$ or $-0.20\ I_X$) or fuselage (ΔI_Y and $\Delta I_Z = \pm 0.175\ I_Y$) or moving the center of gravity forward $0.11\bar{c}$ or back $0.07\bar{c}$ from its normal position generally had little effect upon the recovery characteristics of the model.

For the torpedo loading, recoveries similar to those for the normal loading were obtained when the ailerons were neutral or with the spin. Recoveries were slow or impossible when the ailerons were set against the spin.

Recoveries from fully developed spins of the model in the landing or take-off condition were usually slow or impossible except when the ailerons were set with the spin.

The recovery characteristics of the model in the dive-bombing condition were in general similar to those for the normal flying condition.

Alternate aileron deflections of 25 U and 15 D and of 15 U and 10 D (data not presented) or the installation of dorsal fins (modifications 1 and 2) did not appreciably alter the general recovery characteristics of the model.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

Increasing the test altitude to 25,000 feet generally led to spins from which recoveries were slower than for the corresponding spins at a test altitude of 10,000 feet.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE DOUGLAS XSB2D-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude 10,000 feet]

	Normal loading										ΔI_X and ΔI_Z = $0.20I_X$									ΔI_X and ΔI_Z = $0.40I_X$								
Ailerons	Against, Full			Against, 7°U 5°D	Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D	20°U (ab)	U (bc)	N	D	U (bc)	N (d)	D (d)	U (a j)	N	D	U (bc)	N	D (a)	U (bc)	N (d)	D (d)	U (a j)	N (j)	D	U (b)	N	D	U (b c)	N (d)	D (d)
α, deg	27	43	46	26	---	23	22	---	---	---	30	49	46	-----	22	26	-----	---	---	28	39	43	26	31	38	----	---	---
∅, deg	0	4U	3U	4D	---	0	0	---	---	---	1D	0	1U	-----	3D	2D	-----	---	---	3D	3U	3U	5D	4D	2D	----	---	---
Ω, rps	0.51	0.40	0.42	0.60	---	0.64	0.67	---	---	---	0.44	0.41	0.44	-----	0.61	0.74	-----	---	---	0.45	0.46	0.43	---	0.54	0.51	----	---	---
V, fps	274	223	207	312	375	332	298	---	>339	>339	294	220	213	>304	332	291	>339	>339	>339	278	258	232	304	258	232	>325	>318	>318
Turns for recovery	1 1/4 [e]∞ [f]1 1/4 [g]2 3/4	3 1/2 [e]>9	5 1/2 [e]∞	[h]1 1/4	3/4 [e]2 3/4 [f]1/2 [g]2	1 1/4 [e]5	1 3/4 [e]∞	[i]1 1/4	[i]3/4	[i]1 3/4	1 1/2	4 1/4	5 1/4	[i]1/2	1	1 3/4	[i,k]3/4	[i]3/4	[i,l]3/4	1	1 3/4	3 1/4 4 3/4	[k]2	1 3/4 2 1/2	2 1/2	[i]1	[i]1	[h]1 1/4

	ΔI_X and ΔI_Z = $-0.20I_X$									ΔI_Y and ΔI_Z = $0.175I_Y$										ΔI_Y and ΔI_Z = $-0.175I_Y$							
Ailerons	Against			Neutral			With			Against, Full			Against, 5°D 5°D	Neutral				With		Against			Neutral			With	
Elevator	U (a)	N	D	U (c)	N	D	U (c)	N (d)	D (d)	U (a)	N (a)	D	D	U (d)	N (d)	D (m)	D (m)	U (bc)	D (d)	U (ab)	N	D	U (ab)	N (b)	D	U (bd)	D (d)
α, deg	28	48	54	---	24	24	----	---	---	26	46	50	50	----	-----	22	51	----	----	27	31	42	20	22	24	----	----
∅, deg	0	2U	3U	---	1D	1D	----	---	---	2D	3U	2U	1U	----	-----	1D	0	----	----	3D	0	3U	3D	2D	0	----	----
Ω, rps	0.50	0.37	0.40	---	1.06	0.84	----	---	---	0.56	0.35	0.38	0.37	----	-----	0.72	0.37	----	----	0.47	0.53	0.46	0.98	0.69	0.69	----	----
V, fps	264	204	192	>339	332	291	>304	>339	>339	304	220	201	197	>339	>360	325	188	>339	>339	265	265	204	352	301	291	>339	>360
Turns for recovery	1 3/4 [k]2 1/4	7 1/2	∞	[i]1/2	1	1 1/4 1 3/4	[i,k]1/2	[i,k]1/4	[i,l]3/4	3/4 1 1/4	5 3/4	∞	>5	[i]1	[i]3/4	[k]3/4	>5	[i,k]1/2	[i]1/2	1 1/2	1 3/4	2 3/4 3 1/4	3/4	1 1/4	1 1/2	[i]1 1/2	[i,l]1 1/4

	c.g. moved forward 0.11c̄								c.g. moved back 0.07c̄									Torpedoes installed (wt. of torpedoes 4272 lbs. located below fuselage approx. at the c.g.) Normal loading plus torpedoes								
Ailerons	Against			Neutral			With		Against			Neutral			With			Against, Full			Against, 10°U 7½°D	Neutral			With	
Elevator	U (a)	N	D	U (c)	N	D	U (d)	D (d)	U (a)	N	D	U (c)	N (ab)	D (a)	U (ab)	N (d)	D (d)	U	N	D	U	U (d)	N (d)	D (d)	U (d)	D (d)
α, deg	28	44	48	---	17	22	---	---	---	37	40	----	23	24	----	----	----	51	58	61	---	---	---	----	----	--
∅, deg	2D	4U	3U	---	0	1U	---	---	---	4U	3U	----	3D	1D	----	----	----	3U	2U	2U	---	---	---	----	----	--
Ω, rps	0.48	0.44	0.45	---	0.79	0.76	---	---	---	0.37	0.40	----	0.62	0.68	----	----	----	0.37	0.46	0.46	---	---	---	----	----	--
V, fps	288	223	210	>360	345	304	>339	>339	291	213	216	>278	345	298	----	>325	>339	236	213	204	251	>339	>339	>339	>339	>339
Turns for recovery	1 3/4	4 4 3/4	7 3/4	[i]3/4	3/4 1 1/4	[l]1 3/4 [l]2 1/4	[i]3/4	[i,l]1	1	3 3/4	3 3/4	[i]3/4	3/4	1 1/2	---	---	[i]1 1/4	5 1/2 7 1/2	∞	∞	3 1/4	>[i]3/4	[i]1 1/4	[i]1 3/4	[i]1/2	[i,l]1

	Landing condition, normal loading																		Flaps down 38°, normal loading					
Ailerons	Against, Full			Against, 5°U, 5°D			Neutral						With, 5°U, 5°D			With, Full			Against			Neutral	With	
Elevator	U (b)	N	D	U	N	D	U (mn)	U (m)	N (m)	N (m)	D (m)	D (m)	U (n)	N	D	U (n)	N	D	U	N	D	U (n)	U (n)	D (n)
α, deg	49	52	54	---	---	---	---	---	No spin	48	No spin	47	---	No spin	No spin	---	No spin	No spin	45	50	52	----	----	----
∅, deg	2U	1U	0	---	---	---	---	---		3D		2D	---			---			0	0	0	----	----	----
Ω, rps	0.28	0.36	0.38	---	---	---	---	---		0.37		0.39	---			---			0.33	0.38	0.39	----	----	----
V, fps	194	179	173	188	185	182	---	188		191		182	---			---			201	185	182	>339	>339	>339
Turns for recovery	∞	∞	∞	∞	∞	∞	---	∞		7 1/2		∞	3/4			1/2			----	∞	∞	[i]1/2	[i]1/4	[i]1/2

[a]Wandering spin.
[b]Whipping motion.
[c]Steep and wandering spin.
[d]Steep spin.
[e]Recovery attempted by neutralization of rudder.
[f]Recovery attempted by simultaneous reversal of rudder and elevator.
[g]Recovery attempted by simultaneous neutralization of rudder and elevator.
[h]Recovery attempted by rapid movement of rudder to 2/3 against the spin.
[i]Recovery attempted before final steep spin attitude was attained.
[j]Model oscillatory in roll.
[k]Visual observation.
[l]Model went into inverted spin upon recovery from erect spin.
[m]Two conditions possible.
[n]Wandering spin with violent whipping motion.
[o]Steeper spin also obtainable.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE DOUGLAS XSB2D-1 AIRPLANE - Continued

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude 10,000 feet]

	Dive flaps deflected ±92°, normal loading									Bomb-bay doors open, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D	U (bc)	N	D	U (bc)	N (d)	D (d)	U	N	D	U (c)	N	D	U (bc)	N (d)	D (d)
α, deg	25	37	42	----	23	27	----	----	----	----	48	49	----	22	25	----	----	----
ø, deg	0	5U	4U	----	0	0	----	----	----	----	4U	3U	----	3D	1D	----	----	----
Ω, rps	0.42	0.42	0.43	----	0.62	0.58	----	----	----	----	0.38	0.42	----	0.63	0.73	----	----	----
V, fps	291	236	220	>304	339	274	>339	>339	>339	233	204	201	339	332	284	>339	>339	>339
Turns for recovery	3/4	1 1/2	2 1/2 3 1/2	[i]1/2	3/4	1 1/4	[i]1/2	[i]1/4	[i,l]1/2	2 1/4 2 3/4	∞	∞	[i]3/4	3/4	1 1/2	[i]1/2 [i]1	[i]1/2	[i]3/4

	Dive-bombing condition, normal loading									Modification 1, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D	U (c)	N	D	U (c)	N	D (d)	U (a)	N	D	U (c)	N	D	U (bc)	N	D (d)
α, deg	24	44	48	---	27	---	---	---	---	25	38	47	----	----	24	---	---	---
ø, deg	2U	3U	2U	---	1U	---	---	---	---	2D	3U	3U	----	----	0	---	---	---
Ω, rps	0.72	0.41	0.41	---	0.61	---	---	---	---	0.45	0.42	0.40	----	----	0.69	---	---	---
V, fps	298	213	204	>304	304	---	>304	---	>339	298	232	201	>339	----	298	>325	---	>339
Turns for recovery	1/2	3 1/2 4 1/2	5	[i]1/2	1/2	---	[i]3/4	---	[i,l]1/2	3/4 1 1/4	3 3 1/2	5 6 1/2	[i]3/4	----	1 3/4	[i]1/2	---	[i,l]1 3/4

	Inverted spins, normal loading									Equivalent test altitude 25,000 feet, normal loading												
Ailerons	Against			Neutral			With			Against				Neutral			With					
										Full			5°D 5°D									
Elevator	U	N	D	U (a)	N	D	U (a)	N	D	U (o)	N	D	U (o)	U (d)	N	D	U (bc)	N (d)	15°D (d)	D (dm)	D (m)
α, deg	No spin	No spin	No spin	28	No spin	No spin	33	28	26	52	61	61	----	----	54	56	----	----	----	----	----
ø, deg				2D			4D	6D	4D	0	0	0	----	----	2D	1D	----	----	----	----	----
Ω, rps				0.45			0.38	0.44	0.54	0.35	0.41	0.46	----	----	0.41	0.42	----	----	----	----	----
V, fps				298			261	265	268	265	226	236	272	>339	239	239	>339	>339	>339	>339	288
Turns for recovery				[e,k]3/4			1 1/4 [e]2 3/4	1/2 [e]2 1/2	[k]3/4 [e,k]3	3 1/4 4 1/4	∞	∞	[k]3 1/2	[i,k]1 1/2	7 1/2	∞	[i,k]1 1/2 [i,k]2 1/4	[i]2	[i,k]1 1/2 [i,k]2	[i,k]1	>5

[a]Wandering spin.
[b]Whipping motion.
[c]Steep and wandering spin.
[d]Steep spin.
[e]Recovery attempted by neutralization of rudder.
[f]Recovery attempted by simultaneous reversal of rudder and elevator.
[g]Recovery attempted by simultaneous neutralization of rudder and elevator.
[h]Recovery attempted by rapid movement of rudder to 2/3 against the spin.
[i]Recovery attempted before final steep spin attitude was attained.
[j]Model oscillatory in roll.
[k]Visual observation.
[l]Model went into inverted spin upon recovery from erect spin.
[m]Two conditions possible.
[n]Steeper spin also obtainable.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE DOUGLAS XSB2D-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude 10,000 feet]

Take-off condition, normal loading

Ailerons	Against								
	Full			5°U, 5°D					
Elevator	U	N	D	U (dm)	U (m)	N (dm)	N (m)	D (dm)	D (m)
α, deg	43	47	50	---	--	----	---	----	---
∅, deg	2U	1U	1U	---	--	----	---	---	---
Ω, rps	0.32	0.38	0.39	---	--	----	---	---	---
V, fps	201	188	188	>318	201	>318	182	>318	188
Turns for recovery	∞	∞	∞	[i]$1\frac{1}{2}$	--	---	[k]8 [k]∞	[i]$1\frac{1}{2}$	[k]∞

Ailerons	Neutral					With					
						5°U, 5°D			Full		
Elevator	U (n)	N (dm)	N (m)	D (m)	D (m)	U (n)	N (d)	D (d)	U (n)	N (d)	D (d)
α, deg	--	---	---	---	---	--	---	---	--	---	---
∅, deg	--	---	---	---	---	--	---	---	--	---	---
Ω, rps	--	---	---	---	---	--	---	---	--	---	---
V, fps	--	>318	182	>318	179	--	>318	>318	--	>318	>318
Turns for recovery	[k]1	[i]$\frac{3}{4}$ [i]$1\frac{3}{4}$	---	[i,k]$1\frac{1}{2}$	---	[k]1	---	---	[k]1	[i,k]1	[i,k]$1\frac{1}{2}$

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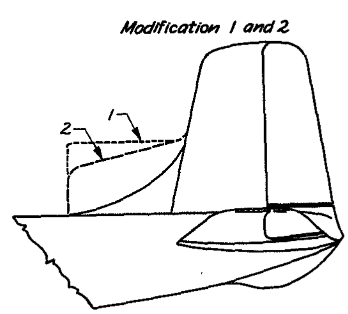
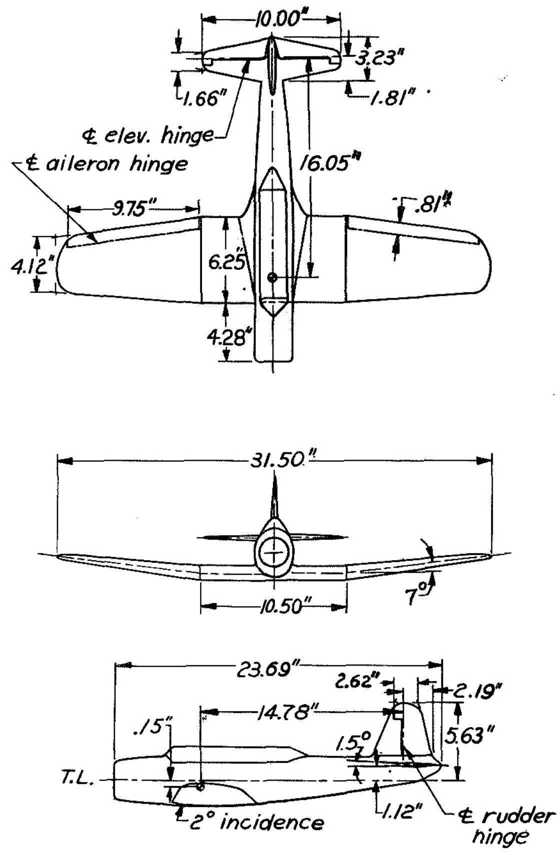
[a]Wandering spin.
[b]Whipping motion.
[c]Steep and wandering spin.
[d]Steep spin.
[e]Recovery attempted by neutralization of rudder.
[i]Recovery attempted before final steep spin attitude was attained.
[k]Visual observation.
[l]Model went into inverted spin upon recovery from erect spin.
[m]Two conditions possible.
[n]Wandering spin with violent whipping motion.
[o]Steeper spin also obtainable.



$\frac{1}{16}$-SCALE MODEL OF THE CHANCE-VOUGHT XSB2U-1



Model as tested.

Dimensional Data

(Full Scale)

b, ft	42.00
L, ft	33.08
$\bar{c}$, in.	89.50
S, sq ft	305.00
A	5.78
L.E. $\bar{c}$ aft L.E. c_r, in.	3.34
S_h, sq ft	40.20
S_e, sq ft	16.44
S_v, sq ft	21.50
S_r, sq ft	11.50
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	21 U, 6 D
δ_f, deg	60 D
TDPF	381×10^{-6}
Landing gear	Conventional

Mass Data

Normal Loading

W, lb	5575
$x/\bar{c}$	0.274
$z/\bar{c}$	0.027
I_X, slug-ft^2	3250
I_Y, slug-ft^2	7020
I_Z, slug-ft^2	9580
Test altitude, ft	9000
μ (at sea level)	5.68
μ' (9000 ft)	7.51

$\frac{I_X - I_Y}{mb^2}$	-123×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-84×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	207×10^{-4}

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Résumé of Model Test Results

The model would not spin for the normal loading, clean condition, and normal control configuration for spinning. With the elevator set full down, the model spun at a moderately flat angle of attack ($\alpha = 48^{\circ}$) and recovered by rapid full rudder reversal in $2\frac{1}{4}$ turns.

For the normal loading condition, landing gear extended, setting the ailerons with the spin indicated a favorable effect on the recovery characteristics of the model. Setting the ailerons against the spin had little effect on the recovery characteristics.

Extending the mass along the wings (ΔI_X and $\Delta I_Z = 0.18\ I_X$) or along the fuselage (ΔI_Y and $\Delta I_Z = 0.18\ I_Y$) had no appreciable effect on the recovery characteristics of the model.

With the ailerons drooped 10°, the steady spins were flat for the aileron-against spins and unsatisfactory recoveries were obtained; there was no apparent change for the aileron-neutral or aileron-with spins.

Extending the flaps had little effect upon the recovery characteristics of the model.

Moving the vertical tail back 2 feet (full scale) from its normal position indicated a detrimental effect on the spin and recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE-VOUGHT XSB2U-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading			Landing gear down, normal loading														Landing gear down, ailerons neutral, normal loading		
				Against							With									
Ailerons	Neutral			Full		9° U 4.5° D		Neutral			9° U 4.5° D		Full			Flaps		15° D	30° D	60° D
Elevator	U	N	D	U (a)	D	U (a)	D	U (a)	N	D	U (a)	D (b)	U (a)	D (b)		Elevator		D	D	D
α, deg	No spin	-	48	-	50	-	54	-	46	47	-	-	-	-		α, deg		-	-	No spin
ϕ, deg		-	0	-	2U	-	1U	-	0	0	-	-	-	-		ϕ, deg		-	-	
Ω, rps		-	0.45	-	0.42	-	0.44	-	0.45	0.44	-	-	-	-		Ω, rps		-	-	
V, fps		-	128	-	118	-	116	-	129	125	-	-	-	-		V, fps		-	-	
Turns for recovery		-	$2\frac{1}{4}$	-	$2\frac{1}{2}$	-	$3\frac{1}{2}$	-	-	2, $2\frac{1}{2}$, cd5	-	-	-	-		Turns for recovery		2	2	

Effect of weight, mass variations, and c.g. movements on turns for recovery, landing gear extended, ailerons neutral

Elevator	D
116 pound bomb added	$2\frac{1}{4}$
500 pound bomb added	$2\frac{1}{4}$
1000 pound bomb added	$2\frac{1}{4}$
ΔI_X and ΔI_Z = 0.09 I_X	$2\frac{1}{4}$
ΔI_X and ΔI_Z = 0.18 I_X	$2\frac{1}{4}$
ΔI_Y and ΔI_Z = 0.09 I_Y	$2\frac{1}{4}$
ΔI_Y and ΔI_Z = 0.18 I_Y	$2\frac{1}{4}$
c.g. moved forward 0.03$\bar{c}$	$2\frac{1}{4}$

	Ailerons drooped 10°, normal loading, landing gear extended									
	Against						With			
Ailerons	Full		3.5° U 15° D		10° D 10° D		3.5° U 15° D		Full	
Elevator	U	D	U	D	U (a)	D	U (a)	D (b)	U (a)	D (b)
α, deg	61	60	43	55	-	44	-	-	-	-
ϕ, deg	3U	3U	0	0	-	2D	-	-	-	-
Ω, rps	0.41	0.45	0.34	0.44	-	0.42	-	-	-	-
V, fps	116	111	137	114	-	126	-	-	-	-
Turns for recovery	$4\frac{3}{4}$	$4\frac{3}{4}$	2, $1\frac{1}{2}$	5	-	$2\frac{1}{2}$	-	-	-	-

	Flaps 45° down, normal loading, landing gear extended										Flaps 45° down, ailerons drooped 10°, normal loading, landing gear extended										Fin and rudder moved back 2 feet (full scale) normal loading		
	Against						With				Against						With						
Ailerons	Full		9° U 4.5° D		Neutral		9° U 4.5° D		Full		Full		3.5° U 15° D		10° D 10° D		3.5° U 15° D		Full		Neutral		
Elevator	U (a)	D	U (a)	D	U (a)	D	U (a)	D (b)	U (a)	D (b)	U	D	U (a)	D	U (a)	D	U (a)	D (b)	U (a)	D (b)	U	N	D
α, deg	57	56	-	57	-	43	-	-	-	-	62	59	-	56	-	44	-	-	-	-	-	56	56
ϕ, deg	3U	3U	-	2U	-	1D	-	-	-	-	3U	4U	-	0	-	1D	-	-	-	-	-	1D	1D
Ω, rps	0.39	0.43	-	0.43	-	0.40	-	-	-	-	0.42	0.42	-	0.43	-	0.44	-	-	-	-	-	0.44	0.46
V, fps	116	112	-	112	-	126	-	-	-	-	111	109	-	111	-	127	-	-	-	-	-	118	115
Turns for recovery	-	$3\frac{1}{4}$, 4	-	4	-	$2\frac{1}{4}$, $1\frac{3}{4}$	-	-	-	-	5, $4\frac{1}{4}$	5	-	$4\frac{1}{4}$	-	$2\frac{1}{4}$	-	-	-	-	-	-	5, 8, c$5\frac{1}{2}$

[a]Model gradually goes into spiral glide.
[b]Steep high vertical velocity spin.
[c]Recovery attempted by neutralizing the rudder.
[d]Visual observation.

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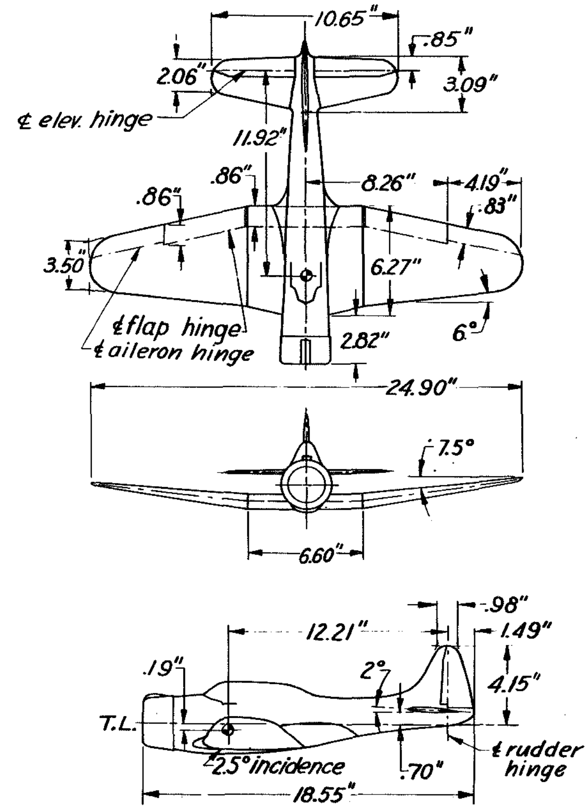
$\frac{1}{20}$-SCALE MODEL OF THE DOUGLAS SBD-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	41.51
L, ft	31.70
$\bar{c}$, in.	97.50
S, sq ft	323.80
A	5.32
L.E. $\bar{c}$ aft L.E. c_r, in. . . .	5.50
S_h, sq ft	70.76
S_e, sq ft	18.62
S_v, sq ft	22.45
S_r, sq ft	9.92
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	17 U, 10 D
δ_f, deg (landing condition, center and outer flaps) .	43 D
δ_f, deg (diving condition)	
Center and outer flaps .	42 D
Outer upper flaps . . .	37.5 U
TDPF	4×10^{-6}
Landing gear . . .	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	7,615
$x/\bar{c}$	0.267
$z/\bar{c}$	0.040
I_X, slug-ft^2	4,841
I_Y, slug-ft^2	8,692
I_Z, slug-ft^2	12,544
Test altitude, ft	10,000
μ (at sea level)	7.40
μ' (10,000 ft)	10.02

$\frac{I_X - I_Y}{mb^2}$	-94×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-95×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	189×10^{-4}

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Résumé of Model Test Results

For the normal loading clean condition, normal control configuration for spinning, the model spun with a vertical velocity exceeding 270 feet per second (full scale) and recovered in 1/2 turn when the rudder was reversed fully and rapidly. With the elevator set 5° up both a flat spin of low vertical velocity (140 feet per second) and a steep spin of high vertical velocity (234 feet per second) were obtained. From the low vertical velocity spin, recovery by rapid full rudder reversal was unsatisfactory (∞ turns), whereas the model recovered in 1/2 turn from the other type spin. With the elevator set at neutral, a flat spin was obtained from which the model did not recover by rapid full rudder reversal. With the ailerons set partly or fully against the spin, satisfactory recoveries could not be obtained for any elevator setting. Setting the ailerons full with the spin had a favorable effect and satisfactory recoveries were obtained even with the elevator full down.

With the mass extended or retracted along the wings (ΔI_X and $\Delta I_Z = \pm 0.15\ I_X$), or extended or retracted along the fuselage (ΔI_Y and $\Delta I_Z = 0.20\ I_Y$, or $= -0.10\ I_Y$), or a movement of the center of gravity forward $0.06\bar{c}$ or rearward $0.05\bar{c}$ the recovery characteristics of the model were similar to those obtained for the normal loading, clean condition.

For the landing condition (canopies open, landing gear extended and lower flaps 43° down) and the diving condition (rear canopy open, lower flaps 42° down, upper flaps $37\frac{1}{2}^\circ$ up), satisfactory recoveries were obtained only when the ailerons were full with the spin.

The model would spin inverted only when the stick was full forward and to the right. For this spin the vertical velocity of the model exceeded the maximum tunnel airspeed (data not presented).

The addition of a ventral fin (modification 1) generally improved the recovery characteristics of the model.

Raising the horizontal tail surfaces 20 inches full scale, and replacing the part length rudder with a full length rudder (modification 2) enabled satisfactory recoveries to be obtained from all elevator-up spins; whereas with the elevator either neutral or down the recoveries were marginal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE DOUGLAS SBD-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading																						
Ailerons	Against									Neutral						With							
	Full			$12\frac{1}{2}^{\circ}$ U $7\frac{1}{4}^{\circ}$ D			5°U 4°D									$12\frac{1}{2}^{\circ}$ U $7\frac{1}{4}^{\circ}$ D					Full		
Elevator	U	N	D	U	N	D	U	N	D	U (a)	25°U (b)	25°U (b)	N	D (b)	D (b)	U (a)	N (b)	N (b)	D (b)	D (b)	U (a)	N (a)	D
α, deg	66	76	74	65	74	75	---	---	---	---	---	---	65	67	28	---	48	---	47	22	---	---	19
ϕ, deg	1U	0	0	2D	1U	1D	---	---	---	---	---	---	0	2D	2U	---	1D	---	1D	4U	---	---	6U
Ω, rps	0.49	0.65	0.59	0.49	0.60	0.64	---	---	---	---	---	---	0.56	0.52	0.74	---	0.47	---	0.52	0.77	---	---	0.85
V, fps	132	110	110	136	112	110	136	---	---	>270	140	234	120	112	218	>270	148	>270	140	238	>270	>270	258
Turns for recovery	∞ [c]5 [d]8 [e]∞	∞	∞ [c]∞	∞	∞	∞	∞	---	---	[f]$\frac{1}{2}$	∞	$\frac{1}{2}$	∞	∞	$1\frac{1}{2}$ [g]2 [g]$2\frac{1}{2}$	---	9	---	8	1	---	---	$1\frac{1}{2}$ [g]$1\frac{1}{2}$

	Rudder neutral spins, normal loading									Rudder against spins, normal loading									ΔI_X and $\Delta I_Z = 0.15 I_X$										
Ailerons	Against			Neutral			With			Against			Neutral			With			Against				Neutral				With		
Elevator	U	N	D	U (a)	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U (b)	U (b)	N	D	U (b)	U (b)	N	D	U (a)	N (a)	D
α, deg	66	77	74	----	70	72	No spin	No spin	No spin	62	70	71	No spin	68	65	No spin	No spin	No spin	62	----	75	74	64	----	66	73	----	----	18
ϕ, deg	2U	1U	1U	----	0	1D				3U	0	0		1D	1D				2U	----	1U	0	3D	----	1D	1U	----	----	6U
Ω, rps	0.45	0.62	0.64	----	0.57	0.58				0.44	0.62	0.58		0.55	0.56				0.48	----	0.63	0.61	0.46	----	0.52	0.61	----	----	0.94
V, fps	132	112	112	>270	116	112				136	110	110		120	120				140	>270	112	108	140	>270	124	116	>270	>270	266
Turns for recovery	---	---	---	----	---	---				---	---	---		---	---				∞	----	∞	∞	∞	----	∞	∞	----	----	1

	ΔI_X and $\Delta I_Z = -0.15 I_X$										ΔI_Y and $\Delta I_Z = 0.20 I_Y$								
Ailerons	Against			Neutral				With			Against			Neutral			With		
Elevator	U	N	D	U (b)	U (b)	N	D	U (a)	N (a)	D	U	N	D	U (a)	N	D	U (a)	N (a)	D
α, deg	70	77	74	62	----	64	74	----	----	22	68	78	76	----	66	62	----	----	18
ϕ, deg	1U	1D	1U	1D	----	1D	0	----	----	4U	0	0	1U	----	2D	2D	----	----	3U
Ω, rps	0.48	0.61	0.63	0.43	----	0.52	0.55	----	----	0.52	0.42	0.60	0.58	----	0.47	0.47	----	----	0.78
V, fps	124	108	108	144	>270	128	114	>270	>270	250	136	114	112	>270	130	128	>270	>270	266
Turns for recovery	∞	∞	∞	∞	----	∞	∞	----	----	$\frac{1}{2}$	∞	∞	∞	----	∞	∞	----	----	$\frac{1}{2}$

	ΔI_Y and $\Delta I_Z = -0.10 I_Y$										c.g. moved forward $0.06\bar{c}$										
Ailerons	Against				Neutral			With			Against				Neutral				With		
Elevator	U (b)	U (b)	N	D	U (a)	N	D	U (a)	N (a)	D	U (b)	U (b)	N	D	U (b)	U (b)	N	D	U (a)	N (a)	D
α, deg	58	---	73	75	----	64	73	----	----	20	65	----	76	72	63	----	61	73	----	----	22
ϕ, deg	3U	---	1D	0	----	1D	0	----	----	7U	2U	----	0	1D	1D	----	0	1D	----	----	7U
Ω, rps	0.49	---	0.62	0.65	----	0.54	0.58	----	----	1.02	0.47	----	0.63	0.69	0.47	----	0.51	0.48	----	----	0.87
V, fps	132	>270	112	108	>270	124	112	>270	>270	246	136	>270	108	108	138	>270	128	112	>270	>270	246
Turns for recovery	∞	---	∞	∞	----	∞	∞	----	----	$\frac{1}{2}$	∞	----	∞	∞	∞	----	∞	∞	----	----	$\frac{1}{2}$

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[a]Steep spin.
[b]Two types of spin.
[c]Recovery attempted by simultaneous reversal of rudder and ailerons.
[d]Recovery attempted by simultaneous reversal of rudder, ailerons, and elevator.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Rudder reversed before final steep attitude was obtained.
[g]Recovery attempted by neutralizing rudder.
[h]Wandering and oscillatory spin.
[i]Flat spin.
[j]Oscillatory spin.

SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE DOUGLAS SBD-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	c.g. moved back 0.05$\bar{c}$									Landing condition, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N (a)	D	U	N	D	U	N	D	U (ah)	N (a)	D
α, deg	62	77	76	-----	65	72	-----	-----	20	72	80	77	55	65	64	-----	-----	No spin
∅, deg	3U	0	1D	-----	0	0	-----	-----	7U	1U	0	1U	1D	0	0	-----	-----	
Ω, rps	0.42	0.61	0.62	-----	0.47	0.56	-----	-----	0.96	0.47	0.70	0.68	0.41	0.48	0.52	-----	-----	
V, fps	138	112	108	>270	128	116	>270	>270	270	126	108	106	136	120	122	>270	>270	
Turns for recovery	∞	∞	∞	-----	∞	∞	-----	-----	$\frac{1}{2}$	∞	∞	∞	∞	∞	∞	-----	-----	

	Diving condition, normal loading									Modification 1, normal loading					Modification 2, normal loading							
Ailerons	Against			Neutral			With			Against			Neutral		Against			Neutral			With	
Elevator	U	N	D	U	N	D	U (ah)	N	D	U (a)	N (i)	D (i)	N (a)	D (i)	U (j)	N	D	U (j)	N	D	N (f)	D (f)
α, deg	68	78	----	54	67	60	----	No spin	No spin	----	--	--	----	--	47	60	56	---	54	50	----	----
∅, deg	1U	1U	----	0	1D	0	----			----	--	--	----	--	2U	3U	4U	---	0	1U	----	----
Ω, rps	0.46	0.67	0.65	0.39	0.33	0.50	----			----	--	--	----	--	0.30	0.47	0.49	---	0.45	0.50	----	----
V, fps	128	108	104	140	124	124	>270			>270	--	--	>270	--	160	136	136	254	144	148	>270	>270
Turns for recovery	∞	∞	∞	∞	∞	∞	----			----	∞	∞	----	∞	$1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{4}$	$\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$

[a] Steep spin.
[f] Rudder reversed before final steep attitude was obtained.
[h] Wandering and oscillatory spin.
[i] Flat spin.
[j] Oscillatory spin.

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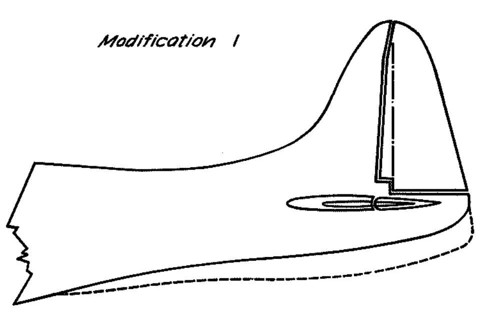
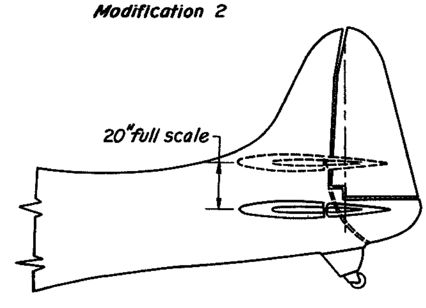
Modification 1



Modification 2

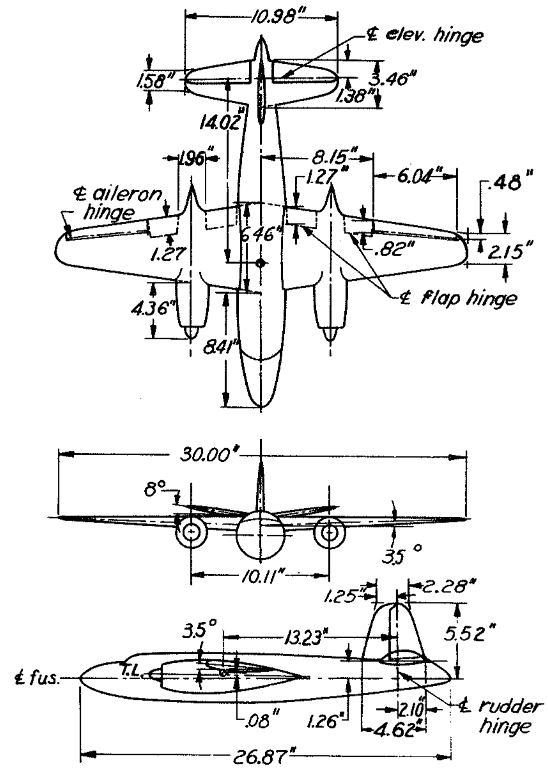


$\frac{1}{26}$-SCALE MODEL OF THE MARTIN B-26 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	65.00
L, ft	58.21
$\bar{c}$, in.	121.60
S, sq ft	612.00
A	6.90
S_h, sq ft	130.30
S_e, sq ft	54.08
S_v, sq ft	65.65
S_r, sq ft	33.18
δ_r, deg	25 R, 25 L
δ_e, deg	25 U, 15 D
δ_a, deg	25 U, 15 D
δ_f, deg	55 D
TDPF	517×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	26,594
$x/\bar{c}$	0.144
$z/\bar{c}$	-0.018
I_X, slug-ft^2	63,651
I_Y, slug-ft^2	69,798
I_Z, slug-ft^2	129,371
Test altitude, ft	10,000
μ (at sea level)	8.74
μ' (10,000 ft)	11.85

$\frac{I_X - I_Y}{mb^2}$	-17×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-170×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	187×10^{-4}

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Résumé of Model Test Results

Although complete data could not be obtained for the model at normal control configuration for spinning, normal loading, or clean condition because of high rate of descent, the results indicate satisfactory recovery characteristics if rudder and elevator were both reversed. Extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$ or fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_Y\right)$, or deflecting the flaps 55° and the landing gear did not alter the recovery characteristics of the model appreciably.

SPIN DATA OBTAINED WITH THE $\frac{1}{26}$-SCALE MODEL OF THE MARTIN B-26 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading															ΔI_X and $\Delta I_Z = 0.30\ I_X$								
Ailerons	Against						Neutral			With						Against			Neutral			With		
	Full			12.5U, 10.6D						12.5U, 10.6D			Full											
Elevator	U (a)	N	D	U (a)	N (a)	D	U (a)	N	D	U	N	D	U	N	D	U (a)	N	D	U (a)	N (e)	D	U (f)	N	D
α, deg	---	No spin	No spin	---	---	No spin	---	22	24	25	23	22	24	23	27	---	No spin	No spin	---	---	No spin	---	25	---
ø, deg	---			---	---		---	5U	7U	9D	5D	2D	4D	1D	1D	---			---	---		---	2D	---
Ω, rps	---			---	---		---	0.43	0.52	0.31	0.49	0.60	0.33	0.52	0.52	---			---	---		---	0.46	---
V, fps	---			---	---		---	315	304	312	310	294	304	301	285	---			---	---		---	294	---
Turns for recovery	---			---	---		---	$1\frac{1}{2}$	$1\frac{1}{4}$ / [b]$1\frac{1}{4}$	[c]---	$>1\frac{3}{4}$	$1\frac{1}{2}$	[c]--- / [d]$\frac{3}{4}$	2 / [b]>4	2 / [b]>4	---			---	---		---	2	---

	ΔI_Y and $\Delta I_Z = 0.30\ I_Y$									Landing condition, normal loading									Inverted spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D	U (a)	N	D	U (a)	N	D	U (af)	N	D	U (af)	N	D	U (af)	N (e)	D (e)	U	N	D	U	N	D	U	N	D
α, deg	---	No spin	27	---	24	27	---	20	25	---	22	25	---	16	18	---	---	---	No spin	---	---	38	-	32	48	---	---
ø, deg	---		11U	---	5U	4U	---	6D	0	---	10U	10U	---	9D	U	---	---	---		---	---	2D	-	1U	7D	---	---
Ω, rps	---		0.38	---	0.40	0.41	---	0.42	0.46	---	0.32	0.38	---	0.47	0.53	---	---	---		---	---	0.30	-	0.40	0.30	---	---
V, fps	---		271	---	306	273	---	304	278	---	273	260	---	310	299	---	---	---		---	---	248	-	250	206	---	---
Turns for recovery	---		$\frac{3}{4}$	---	$1\frac{1}{4}$	$1\frac{1}{4}$	---	$1\frac{1}{2}$	2	---	$\frac{1}{2}$	$\frac{3}{4}$	---	1	$\frac{3}{4}$	---	---	---		---	---	---	-	---	--	---	---

[a]Wide radius spin, vertical velocity too high to test.
[b]Recovery attempted by neutralizing the rudder.
[c]Model went into a wide spiral after rudder reversal.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Velocity too high to test.
[f]Oscillatory spin.

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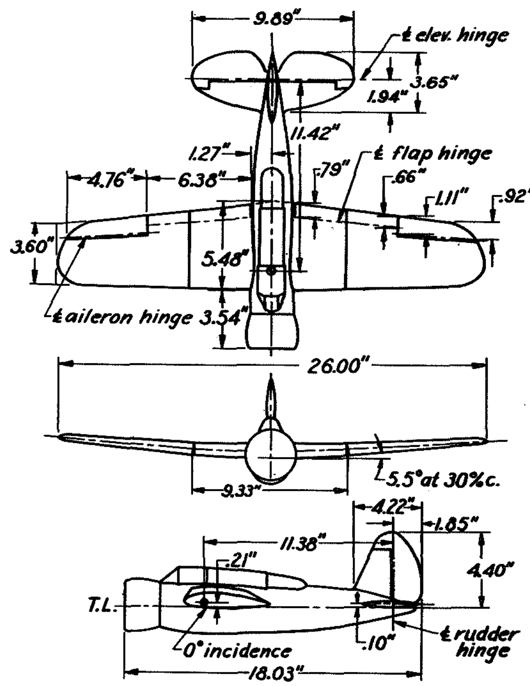
$\frac{1}{18}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY SBN-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	39.00
L, ft	27.83
$\bar{c}$, in.	83.30
S, sq ft	258.00
A	5.90
S_h, sq ft	61.12
S_e, sq ft	27.07
S_v, sq ft	25.77
S_r, sq ft	13.53
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	30 U, 15 D
δ_f, deg (landing cond.)	60 D
δ_f, deg (diving cond., split flaps)	60 U, 60 D
TDPF	73×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	5938
$x/\bar{c}$	0.272
$z/\bar{c}$	-0.045
I_X, slug-ft^2	3223
I_Y, slug-ft^2	5931
I_Z, slug-ft^2	8752
Test altitude, ft	6000
μ (at sea level)	7.67
μ' (6000 ft)	9.19

$\frac{I_X - I_Y}{mb^2}$	-97×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-100×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	197×10^{-4}

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Résumé of Model Test Results

For the normal loading and clean condition, recoveries of the model by rapid full rudder reversal were generally unsatisfactory, whereas recoveries by simultaneous full reversal of the elevator and rudder from all elevator full-up spins were satisfactory.

For the aileron-neutral spins, moderate changes in the distribution of mass along the wing or fuselage of the model or moderate movements of the center of gravity ($\pm 0.05\bar{c}$) had little effect upon the recovery characteristics of the model.

For the diving condition (split flaps 60° up and 60° down, landing gear extended) or for the landing condition (cockpit open, flaps and main landing gear extended), the recovery characteristics of the model were satisfactory only when the ailerons were set full with the spin.

Recoveries by rapid full rudder reversal from all inverted spins were satisfactory.

In order to improve the recoveries of the model by rapid full rudder reversal, vertical fin area was added successively at various points along the periphery of the vertical tail surfaces and bottom of the fuselage (test results not presented). Fin area added below the horizontal tail (modifications 1 and 2) was most effective in improving the recovery characteristics of the model. With the horizontal tail raised $11\frac{1}{4}$ inches, full scale (modification 3) from its normal position (test results not presented) satisfactory recoveries were obtained for the model in the normal loading and clean condition; for the landing condition, however, recoveries were unsatisfactory when the ailerons were set full against the spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{18}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY SBN-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading														
Ailerons	Against						Neutral			With					
	Full			9° D 17.5° U						9° D 17.5° U			Full		
Elevator	U	N	D	U	N	D	U	N	D	U (a)	N	D	U (a)	N	D
α, deg	56	59	62	61	65	62	56	58	56	---	45	44	---	43	39
ø, deg	5U	4U	3U	3U	4U	2U	1U	2U	3U	---	1D	0	---	4D	5D
Ω, rps	0.46	0.58	0.58	0.48	0.57	0.58	0.46	0.52	0.55	---	0.50	0.54	---	0.50	0.57
V, fps	129	119	112	125	114	114	131	123	117	---	146	143	---	148	148
Turns for recovery	$3\frac{1}{4}$	$7\frac{1}{2}$	∞	6	$7\frac{1}{4}$	$7\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	---	$2\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$
	----	----	----	----	----	----	[b]$5\frac{1}{2}$	[b]∞	[b]∞	---	---	$3\frac{1}{4}$	---	---	[c]$1\frac{1}{4}$
	[d]$2\frac{1}{4}$	----	----	----	----	----	[d]2	----	----	---	---	---	[d]$\frac{3}{4}$	---	----

	Rudder neutral spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	64	58	No spin	56	56	No spin	No spin	No spin
ø, deg		3U	4U		1U	1U			
Ω, rps		0.55	0.55		0.54	0.54			
V, fps		116	117		121	119			
Turns for recovery		----	----		---	---			
		----	----		----	----			
		----	----		----	----			

Effect of mass variations on turns for recovery			
Ailerons	Neutral		
Elevator	U	N	D
ΔI_X and ΔI_Z = $0.15 I_X$	$3\frac{1}{4}$	---	$3\frac{1}{4}$
ΔI_X and ΔI_Z = $-0.17 I_X$	$3\frac{1}{2}$	---	5
ΔI_Y and ΔI_Z = $0.30 I_Y$	$4\frac{1}{2}$	---	$5\frac{1}{4}$
ΔI_Y and ΔI_Z = $0.15 I_Y$	$3\frac{1}{2}$	---	$4\frac{3}{4}$

Effect of c.g. movements, extended landing gear, and tail wheel on turns for recovery			
Ailerons	Neutral		
Elevator	U	N	D
c.g. moved forward $0.05\bar{c}$	$4\frac{1}{4}$	---	$4\frac{1}{2}$
c.g. moved back $0.05\bar{c}$	$4\frac{1}{2}$	---	$5\frac{1}{2}$
Landing gear extended (normal loading)	$3\frac{1}{4}$	---	$4\frac{3}{4}$
Tail wheel installed (normal loading)	$2\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{2}$

Flaps down 60°, cockpit open normal loading						
Ailerons	Against			Neutral		
	Full		3° D 6° U			
Elevator	U	D	U	U	N	D
α, deg	-	-	---	No spin	56	57
ø, deg	-	-	---		1U	1U
Ω, rps	-	-	---		0.50	0.53
V, fps	-	-	---		116	112
Turns for recovery	-	-	$5\frac{1}{4}$		$5\frac{1}{2}$	$5\frac{3}{4}$

Diving condition, double split flaps, up and down 60°, normal loading									
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (e)	N	D	U (e)	N	D
Turns for recovery	$4\frac{1}{4}$ [b]$2\frac{1}{4}$	$6\frac{1}{2}$	∞	---	$4\frac{3}{4}$	$5\frac{1}{4}$	---	$\frac{1}{2}$	$\frac{3}{4}$

	Landing condition, normal loading										Inverted spin, normal loading								
Ailerons	Against			Neutral			With				Against			Neutral			With		
							$\frac{1}{3}$	Full											
Elevator	U	N	D	U	N	D	U	U	N (e)	D	U	N	D	U	N	D	U	N	D
α, deg	60	63	61	54	55	56	No spin	No spin	-	17	No spin	No spin	No spin	37	No spin	No spin	45	37	29
ø, deg	3U	2U	2U	1U	1U	1U			-	5U				2U			5D	4D	1U
Ω, rps	0.46	0.55	0.57	0.43	0.51	0.53			-	0.81				0.43			0.42	0.52	0.66
V, fps	125	112	108	131	119	114			-	203				174			161	164	175
Turns for recovery	∞	∞	∞	$5\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{1}{2}$			-	$\frac{3}{4}$				$\frac{1}{4}$			1	$\frac{3}{4}$	1

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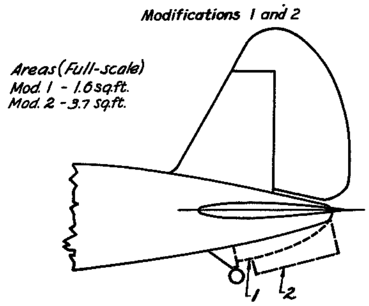
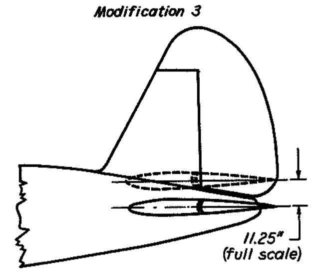
[a]Oscillatory and wandering spin.
[b]Recovery attempted by neutralizing rudder.
[c]Recovery from a steeper type of spin.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Vertical velocity too high to test.

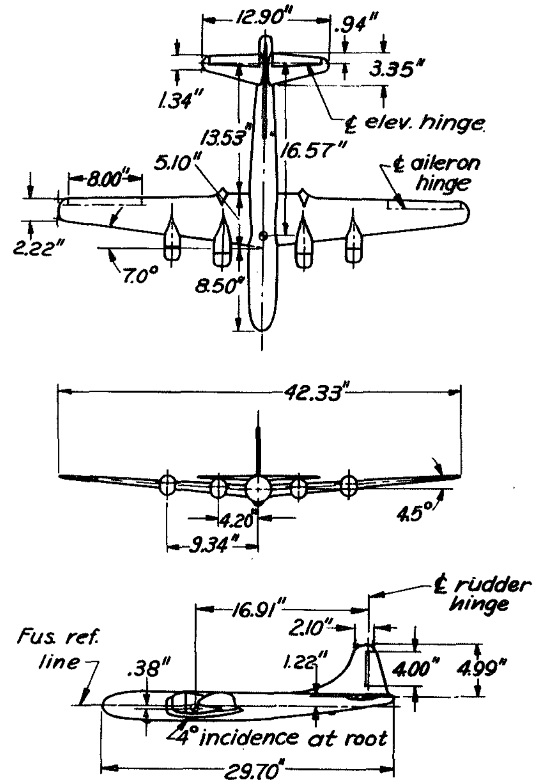
Modifications 1 and 2



Modification 3



$\frac{1}{40}$-SCALE MODEL OF THE BOEING XB-29 AIRPLANE



Model as tested.

Dimensional Data

(Full Scale)

b, ft	141.67
L, ft	98.30
$\bar{c}$, in	154.44
S, sq ft	1739.00
A	11.52
L.E. $\bar{c}$ aft L.E. cr, in	44.45
S_h, sq ft	332.00
S_e, sq ft	116.00
S_v, sq ft	238.00
S_r, sq ft	64.00
δ_r, deg	25 R, 25 L
δ_e, deg	25 U, 15 D
δ_a, deg	18 U, 18 D
TDPF	0
Landing gear	Tricycle

Mass Data

	Light loading	Alternate loading
W, lb	70,000	120,000
$x/\bar{c}$	0.250	0.250
$z/\bar{c}$	0.099	0.099
I_X, slug-ft^2	850,000	1,500,000
I_Y, slug-ft^2	730,000	800,000
I_Z, slug-ft^2	1,580,000	2,300,000
Test altitude, ft	20,000	20,000
μ (at sea level)	3.71	6.36
μ' (20,000 ft)	6.96	11.94
$\frac{I_X - I_Y}{mb^2}$	27×10^{-4}	93×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-195×10^{-4}	-201×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	168×10^{-4}	108×10^{-4}

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Résumé of Model Test Results

In general for all conditions tested, for the normal control configuration for spinning, the spins of the model were very oscillatory especially in pitch ($\alpha = 15^{\circ}$ to 75°) and recovery by neutralization or full reversal of the elevator was satisfactory. The model would also spin with the elevator up and the ailerons with the spin. These spins were similar to the spins obtained for the normal control configuration. Generally, the model would not spin for any other control settings.

The applied load factors as measured by an accelerometer were consistently lower than the load factors calculated from the formula $\frac{1}{\sin \alpha_w}$ where α_w is the acute angle between the vertical and the wing chord line (approximately equal to the absolute value of the angle of attack of the wing at the plane of symmetry). The average accelerometer reading was approximately 1.8.

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SPIN DATA OBTAINED WITH THE $\frac{1}{40}$-SCALE MODEL OF THE BOEING XB-29 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Light loading condition							Alternate loading condition					
Ailerons	Against, Full	Against, $\frac{1}{2}$	Neutral		With			Against		Neutral		With	
Elevator	U	U (a)	U (b)	N	U (b)	10° U (b)	N	U	N	U (b)	N	U (b)	N
α, deg	No spin	---	15 75	No spin	15 75	15 75	No spin	No spin	---	15 75	No spin	15 75	No spin
ϕ, deg		---	1U 5D		1U 7D	1U 5D			---	1U 5D		1U 7D	
Ω, rps		---	0.29		0.18	0.25			---	0.46		0.23	
V, fps		---	340		293	329			---	390		360	
Turns for recovery		---	[c]>1 [cd]$\frac{1}{4}$ [ce]$\frac{1}{4}$		[c]>$1\frac{1}{2}$ [ce]1 [ce]$1\frac{1}{2}$ [df]1 [df]4	[f]$1\frac{1}{2}$ [f]4			---	[cd]$1\frac{1}{4}$ [g]---		[c]>4 [df]$1\frac{1}{4}$ [df]>4 [ch]$\frac{3}{4}$	

	ΔI_X and $\Delta I_Z = -0.53 I_X$ from alternate loading condition						ΔI_Y and $\Delta I_Z = 0.40 I_Y$ from alternate loading condition						
Ailerons	Against		Neutral		With		Against		Neutral		With		
Elevator	U	N	U (b)	N	U (b)	N	U	N	U (b)	N	U	N (b)	D
α, deg	No spin	---	15 75	No spin	15 75	No spin	No spin	---	15 75	No spin	41	---	No spin
ϕ, deg		---	6U 13D		4U 13D			---	9U 1D		8D	---	
Ω, rps		---	0.33		0.23			---	0.23		0.18	---	
V, fps		---	412		321			---	412		338	---	
Turns for recovery		---	[cd]$1\frac{1}{4}$ [ce]$\frac{1}{2}$ [f]$\frac{1}{2}$ [f]$1\frac{1}{4}$		[c]>$1\frac{3}{4}$			---	[c]>$1\frac{1}{2}$ [cd]$1\frac{1}{2}$ [cd]2		>$2\frac{1}{2}$ [e]2	---	

	c.g. moved forward $0.15\bar{c}$, ΔI_Y and $\Delta I_Z = 0.34 I_Y$ from alternate loading condition						c.g. moved back $0.15\bar{c}$ from alternate loading condition						
Ailerons	Against		Neutral		With		Against		Neutral		With		
Elevator	U	N	U	N	U (b)	N	U	N	U (b)	N	U (i)	N (b)	D
α, deg	No spin	---	---	No spin	15 75	No spin	No spin	No spin	---	No spin	39	--	No spin
ϕ, deg		---	---		12U 4D				---		9D	--	
Ω, rps		---	---		0.26				---		0.13	--	
V, fps		---	>479		420				---		360	--	
Turns for recovery		---	$\frac{1}{2}$		>4 [d]>4 [e]1 [e]2				[g]---		>2 [e]1	--	

Load factors determined for various elevator settings, ΔI_X and $\Delta I_Z = -0.49 I_X$, ΔI_Y and $\Delta I_Z = 0.40 I_Y$ from alternate loading condition, aileron-neutral spins

Control setting	α (deg)	Ω (radians per second)	Applied load factor from accelerometer records
Elevator up	26	1.19	1.6
Elevator neutral	26	1.65	1.9
Elevator down	26	1.74	1.8

[a]Steep spin.
[b]Oscillatory spin; where range of values is not presented, average value is given.
[c]Number of turns required for recovery independent of phase of oscillation of spin.
[d]Recovery attempted by neutralizing the elevator.
[e]Recovery attempted by elevator reversal.
[f]Number of turns required for recovery dependent upon phase of oscillation of spin.
[g]Results indicated that the rudder was relatively ineffective, when the model was launched with the rudder full against the spin.
[h]Model goes into an inverted spin after recovery from erect spin. Recovery attempted by elevator reversal.
[i]Large radius of spin.

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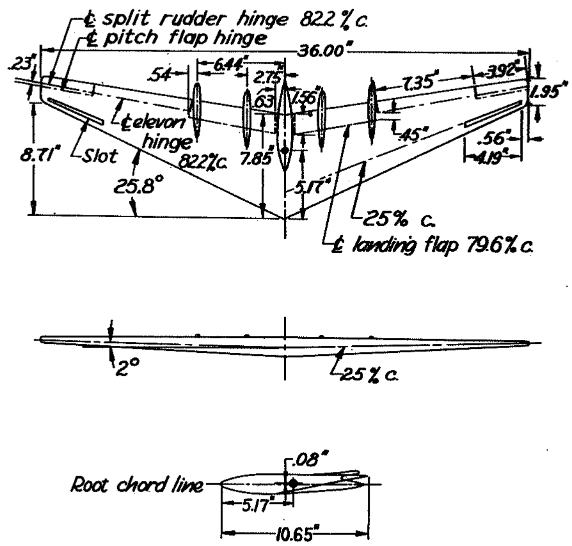
1/57-33-SCALE MODEL OF THE NORTHROP XB-35 AIRPLANE

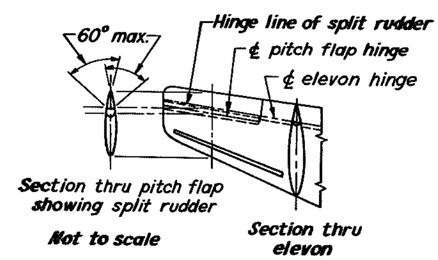
Dimensional Data

(Full-Scale)

b, ft	172.00
$\underline{L}$, ft	50.90
$\bar{c}$, in	315.00
S, sq ft	4020.00
A	7.36
L.E.$\bar{c}$ aft L.E.c_r	200.00
S elevon (aft hinge line)	273.36
S_r (total)	120.00
S_f (total)	160.00
δ_e (as elevators), deg	20 U, 10D
δ_e (as ailerons), deg	15 U, 15D
Pitch flaps, deg	30 U, 15D
δ_r deg	60 U, 60D



Model as tested.



Mass Data

(Normal Loading)

W, lb	155,000
$x/\bar{c}$	0.275
$z/\bar{c}$	-0.014
I_X, slug-ft^2	3,380,000
I_Y, slug-ft^2	433,500
I_Z, slug-ft^2	3,769,000
Test altitude, ft	20,000
μ (at sea level)	2.92
μ'(at 20,000 ft)	5.50

$\frac{I_X - I_Y}{mb^2}$	.207 × 10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-234 × 10^{-4}
$\frac{I_Z - I_X}{mb^2}$	27 × 10^{-4}

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It should be noted that a longitudinal movement of the stick (wheel neutral) deflects both elevons equally in the same direction whereas a lateral movement of the wheel deflects one elevon up and the other one down. The rudder deflections were independent of pitch flap settings. For example, pushing the right rudder pedal forward (rudder with a right spin) deflected the split rudders on the right pitch flap 70° up and 50° down from the wing chord while the rudders on the left pitch flap remained undeflected.

Résumé of Model Test Results

When the rudders were with the spin the airplane in the normal-loading clean condition would spin only when the wheel was with the spin and the stick neutral or full back. It was not possible to effect recoveries from these spins by rudder reversal inasmuch as the model spun for most combinations of stick wheel positions when the rudders were against the spin, that is, the conventional recovery technique of reversing the rudder and then moving the stick forward would probably not effect recoveries.

Extending or retracting mass along the wing had little effect on the spin characteristics.

Movement of the center of gravity forward ($0.075\bar{c}$) was somewhat beneficial. Movement of the center of gravity rearward ($0.058\bar{c}$ or $0.116\bar{c}$) reduced the number of stick wheel positions for which rudder-against spins were obtained.

For the airplane in the landing condition (landing gear extended, flaps down 60°, pitch flaps up 30°, and slots open) the spin characteristics were generally similar to those for the clean condition.

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SPIN DATA OBTAINED WITH THE $\frac{1}{57.33}$-SCALE MODEL OF THE NORTHROP XB-35 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spin of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading, rudders against spin									Normal loading, rudder neutral spins									Normal loading								
Elevons: Wheel ailerons	Left			Neutral			Right			Left			Neutral			Right			Left			Neutral			Right		
Elevons: As elevator	U (ab)	N	D	U (ab)	N (ac)	D	U (d)	N	D	U	N	D	U	N (g)	D (bd)	U	N	D (bd)	U	N	D	U	N	D	U	N (dg)	D
α, deg	---	No spin	No spin	---	---	---	36	26	25	No spin	No spin	No spin	No spin	---	----	44	32	28	No spin	No spin	No spin	No spin	No spin	No spin	44	----	No spin
ø, deg	---			---	---	---	3U	3U	5U					---	----	0	0	1D							2D	----	
Ω, rps	---			---	---	---	0.10	0.21	0.21					---	----	0.18	0.21	0.24							0.20	----	
V, fps	377			366	---	350	319	350	361					---	>350	319	350	383							298	----	
Turns for recovery	---			---	---	---	$^{e}\infty$	$^{ef}1$	$^{ef}\frac{1}{2}$					---		$^{h}\infty$ $^{e}\infty$	$^{fh}{>8}$ $^{ef}{>8}$	$^{e}2\frac{1}{2}$							$^{h}\infty$	----	

	Slots open, normal loading, rudders against spin									Slots open, normal loading									ΔI_Y and $I_Z = 0.30\ I_Y$, rudders against spin									ΔI_Y and $\Delta I_Z = 0.30\ I_Y$								
Elevons: Wheel ailerons	Left			Neutral			Right			Left			Neutral			Right			Left			Neutral			Right			Left			Neutral			Right		
Elevons: As elevator	U	N	D	U (a)	N	D	U	N (i)	D (i)	U	N	D	U	N	D	U	N (i)	D	U	N	D	U (a)	N (i)	D	U	N	D	U	N	D	U (a)	N (i)	D	U	N (i)	D (i)
α, deg	No spin	No spin	No spin	29	No spin	No spin	44	30	26	No spin	No spin	No spin	No spin	No spin	No spin	57	--	No spin	No spin	No spin	No spin	---	---	No spin	38	33	25	No spin	No spin	No spin	---	---	No spin	41	29	25
ø, deg				11D			4D	4D	5D							1U	--					---	---		5D	8D	7D				---	---		3D	1U	1U
Ω, rps				0.11			0.22	0.24	0.23							0.26	--					---	---		0.15	0.19	0.13				---	---		0.22	0.15	0.20
V, fps				377			318	329	350							377	--					---	---		320	350	350				383	---		266	372	378
Turns for recovery				----			---	---	---							∞	--					---	---		---	---	---				$f_{>4}$	---		∞	$f_{>4\frac{1}{2}}$	$r_{>8}$

	c.g. moved forward 0.075$\bar{c}$, rudders against spin									c.g. moved forward 0.075$\bar{c}$									c.g. moved back 0.058$\bar{c}$, rudders against spin									c.g. moved back 0.058$\bar{c}$								
Elevons: Wheel ailerons	Left			Neutral			Right			Left			Neutral			Right			Left			Neutral			Right			Left			Neutral			Right		
Elevons: As elevator	U (g)	N	D	U (g)	N	D	U (g)	N	D	U	N	D	U (g)	N	D	U (g)	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U (j)	N	D (j)	U	N	D
α, deg	---	No spin	No spin	---	No spin	No spin	---	No spin	No spin	No spin	No spin	No spin	---	No spin	No spin	---	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	47	36	34	No spin	No spin	No spin	53	34	25	64	49	35
ø, deg	---			---			---						---			---									6D	8D	7D				1D	1D	1U	1U	1D	2D
Ω, rps	---			---			---						---			---									0.13	0.12	0.15				0.13	0.12	0.19	0.23	0.18	0.15
V, fps	---			---			---						---			---									298	320	320				288	329	298	253	282	329
Turns for recovery	---			---			---						---			---									---	---	---				1	$2\frac{1}{2}$ 4	$7\frac{1}{2}$	∞	∞	∞

	c.g. moved back 0.116$\bar{c}$, rudders against spin									c.g. moved back 0.116$\bar{c}$									Pitch flap deflected down 15°, normal loading, rudders against spin									Pitch flap deflected down 15°, normal loading								
Elevons: Wheel ailerons	Left			Neutral			Right			Left			Neutral			Right			Left			Neutral			Right			Left			Neutral			Right		
Elevons: As elevator	U	N	D	U	N	D	U	N	D	U	N (i)	D	U	N	D	U	N	D	U	N	D	U	N	D	U (d)	N	D	U	N	D	U	N	D	U	N (d)	D
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	56	No spin	71	66	No spin	74	73	60	No spin	No spin	No spin	No spin	No spin	No spin	---	25	No spin	No spin	No spin	No spin	No spin	No spin	No spin	57	28	No spin
ø, deg											3D		2D	0		1D	1D	1D							---	4D								1U	1U	
Ω, rps											0.17		0.21	0.19		0.23	0.21	0.19							---	0.26								0.25	---	
V, fps											255		234	249		239	234	244							---	360								255	---	
Turns for recovery											f_1 r_3		2	$2\frac{1}{4}$ 3		4	3	2							---	---								∞	$f_{>8}$	

[a]Large radius oscillatory spin, average values given.
[b]Wandering spin.
[c]Steep spin and wandering spin.
[d]Oscillatory in pitch.
[e]Recovery attempted by moving rudder to full with the spin.
[f]Visual observation.
[g]Steep spin.
[h]Recovery attempted by moving rudder to full against the spin.
[i]Oscillatory spin.
[j]Occasionally oscillated out of spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{57.35}$-SCALE MODEL OF THE NORTHROP XB-35 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudders-with spin of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Landing condition, normal loading, rudders against spin								
Elevons: Wheel ailerons	Left			Neutral			Right		
Elevons: As elevator	U	N (i)	D (i)	U	N (i)	D (i)	U	N	D
α, deg	27	---	35	31	22	26	47	28	33
Ø, deg	8D	---	6D	4D	6D	4D	3D	4D	2D
Ω, rps	0.13	---	0.16	0.15	0.17	0.18	0.21	0.20	0.21
V, fps	350	383	340	320	360	308	276	320	329
Turns for recovery	----	---	----	----	----	----	----	----	----

	Landing condition, normal loading								
Elevons: Wheel ailerons	Left			Neutral			Right		
Elevons: As elevator	U	N	D	U	N	D	U (i)	N	D
α, deg							--		
Ø, deg	No spin	No spin	No spin	No spin	No spin	No spin	--	No spin	No spin
Ω, rps							--		
V, fps							--		
Turns for recovery							--		

	Landing condition, slots closed, rudders against spin, normal loading								
Elevons: Wheel ailerons	Left			Neutral			Right		
Elevons: As elevator	U	N (i)	D	U	N	D	U	N	D
α, deg	26	---	33	30	29	29	40	35	30
Ø, deg	3U	---	2U	3U	3U	2U	2U	4U	4U
Ω, rps	0.14	---	0.19	0.16	0.20	0.21	0.20	0.21	0.22
V, fps	319	---	324	303	319	319	276	298	308
Turns for recovery	----	---	----	----	----	----	----	----	----

	Landing condition, slots closed, normal loading								
Elevons: Wheel ailerons	Left			Neutral			Right		
Elevons: As elevator	U (k)	N	D	U	N	D	U	N (i)	D (a)
α, deg	----						30	----	----
Ø, deg	----	No spin	No spin	No spin	No spin	No spin	1U	----	----
Ω, rps	----						0.15	----	----
V, fps	----						340	340	----
Turns for recovery	----						∞	∞	----

[a]Large radius oscillatory spin, average values given.

[i]Oscillatory spin.

[k]Increasing radius - may not spin.

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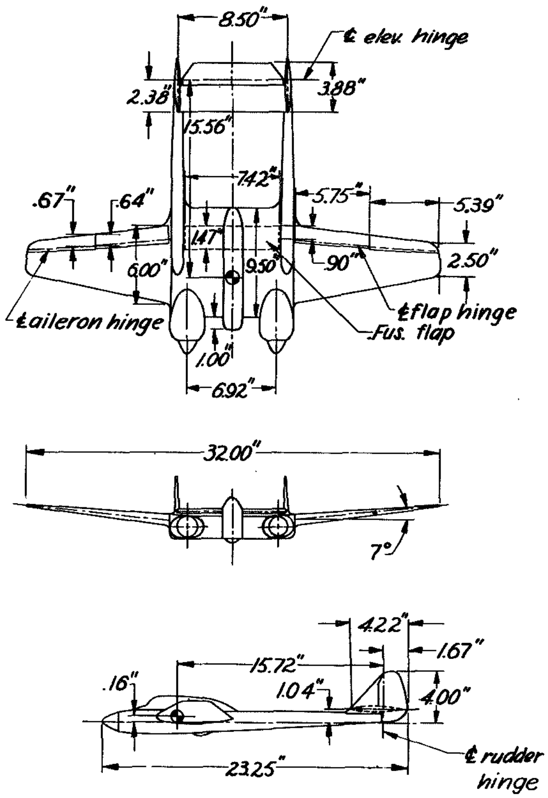
$\frac{1}{24}$-SCALE MODEL OF THE BURNELLI XB-AB-3 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	64.00
L, ft	46.50
$\bar{c}_g$ in.	151.92
S, sq ft.	700.00
A	5.85
L.E. $\bar{c}_g$ aft L.E. fus, in.	26.64
S_h, sq ft	123.00
S_e, sq ft	43.00
S_v, sq ft	72.70
S_r, sq ft	54.00
δ_r, deg	35 R, 35 L
δ_e, deg	35 U, 25 D
δ_a, deg	30 U, 20 D
δ_f, deg	60 D
TDPF.	1735×10^{-6}
Landing gear.	Conventional (with 2 tail wheels)



Model as tested.

Mass Data

Normal Loading

W, lb	24,500
$x/\bar{c}_g$	0.270
$z/\bar{c}_g$	-0.026
I_X, slug-ft^2	65,696
I_Y, slug-ft^2	39,995
I_Z, slug-ft^2	104,142
Test altitude, ft	20,000
μ (at sea level)	7.14
μ' (20,000 ft)	13.40

$\frac{I_X - I_Y}{mb^2}$	83×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-206×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	123×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, the high rate of descent (in excess of 295 feet per second), of the model did not permit recovery tests. Setting the ailerons full with the spin flattened the spin and recoveries obtained by rapid full reversal of rudders were unsatisfactory. Setting the elevator down resulted in satisfactory recovery characteristics of the model for all aileron settings.

Extending or retracting the mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$) extending the mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.30\ I_Y$) or movement of the center of gravity forward $0.05\bar{c}$ or back $0.10\bar{c}$ had no appreciable effect on the recovery characteristics of the model.

For the landing condition (landing gear extended, flaps 60° down) or for a condition with only the flaps 60° down, satisfactory recoveries were obtained from the aileron-neutral and aileron-against spins. Extending the landing gear alone had no appreciable effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{24}$-SCALE MODEL OF THE BURNELLI XB-AB-3 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading											
Ailerons	Against			Neutral			With					
Elevator	U (a)	N (a)	D	U (a)	N (a)	D	U (ab)	U (b)	N (ab)	N (b)	D (c)	D (c)
α, deg	-	-	No spin	-	-	No spin	-	48	-	45	No spin	37
ϕ, deg	-	-		-	-		-	5D	-	2D		1D
Ω, rps	-	-		-	-		-	0.39	-	0.46		0.49
V, fps	-	-		-	-		-	238	-	238		252
Turns for recovery	-	-		-	-		-	>2½	-	2¼		1½

	ΔI_X and $\Delta I_Z = 0.20 I_X$								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (a)	N	D	U	N (a)	D
α, deg	-	No spin	No spin	-	No spin	No spin	—	-	No spin
ϕ, deg	-			-			—	-	
Ω, rps	-			-			—	-	
V, fps	-			-			—	-	
Turns for recovery	-			-			>4	-	

	ΔI_X and $\Delta I_Z = 0.20 I_X$								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (a)	N (a)	D	U	N (a)	D
α, deg	-	No spin	-	-	-	No spin	49	-	-
ϕ, deg	-		-	-	-		3D	-	-
Ω, rps	-		-	-	-		0.37	-	-
V, fps	-		-	-	-		241	-	-
Turns for recovery	-		-	-	-		>2½	-	-

	ΔI_Y and $\Delta I_Z = 0.30 I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	-	-	-	-	-	-	52	42	-
ϕ, deg	-	-	-	-	-	-	3D	3D	-
Ω, rps	-	-	-	-	-	-	0.35	0.41	-
V, fps	-	-	-	-	-	-	234	258	-
Turns for recovery	-	-	-	-	-	-	>3½	1¼	-

	c.g. moved forward $0.05\bar{c}_g$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N (a)	D
α, deg	-	-	-	-	-	-	43	-	-
ϕ, deg	-	-	-	-	-	-	4D	-	-
Ω, rps	-	-	-	-	-	-	0.37	-	-
V, fps	-	-	-	-	-	-	251	-	-
Turns for recovery	-	-	-	-	-	-	>2¾	-	-

	c.g. moved back $0.10\bar{c}_g$								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D	U	N (a)	D	U	N	D (a)
α, deg	-	-	No spin	32	-	No spin	54	50	-
ϕ, deg	-	-		2U	-		3D	1D	-
Ω, rps	-	-		0.29	-		0.34	0.41	-
V, fps	-	-		295	-		234	234	-
Turns for recovery	-	-		¾	-		> 2½ [d]1¼	3	-

	Flaps down 60°, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	30	29	No spin	44	31	31	50	47	45
ϕ, deg	2D	1U		4D	1D	0	3D	3D	3D
Ω, rps	0.30	0.45		0.35	0.48	0.52	0.37	0.44	0.46
V, fps	276	276		234	252	247	227	216	212
Turns for recovery	¾	¾		2	2	1½	>2½	3¼	2¼

	Landing gear extended, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D	U (a)	N (a)	D	U	N	D
α, deg	-	-	No spin	-	-	No spin	48	38	No spin
ϕ, deg	-	-		-	-		3D	1D	
Ω, rps	-	-		-	-		0.40	0.49	
V, fps	-	-		-	-		241	261	
Turns for recovery	-	-		-	-		>2½	¾	

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (e f)	N (a)	D	U	N	D	U	N	D
α, deg	-	-	No spin	31	27	30	49	47	40
ϕ, deg	-	-		0	1U	1U	2D	1D	2D
Ω, rps	-	-		0.36	0.48	0.52	0.38	0.46	0.48
V, fps	-	-		268	268	256	227	221	221
Turns for recovery	-	-		1¼	1¾	1½	>2¾ [d]1¾	4	2¾

[a]Vertical velocity too high to test.
[b]Two conditions possible.
[c]Two types of spin.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Oscillatory spin.
[f]Large radius of spin and vertical velocity too high to test.

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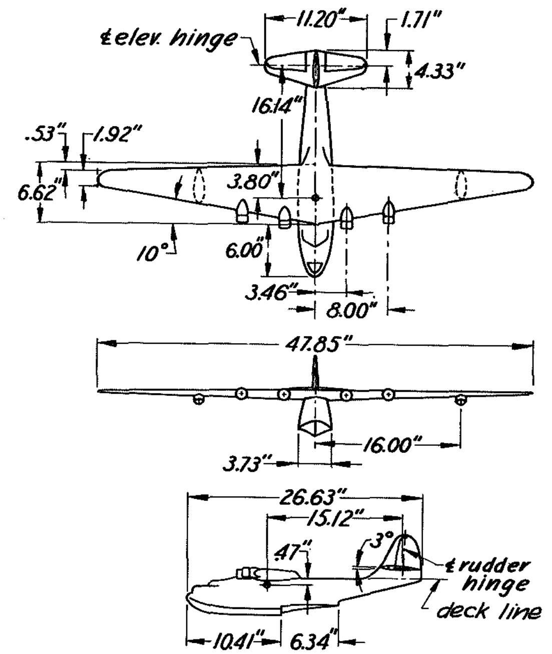
$\frac{1}{45}$-SCALE MODEL OF THE CONSOLIDATED XPB3Y-1 AIRPLANE

Dimensional Data

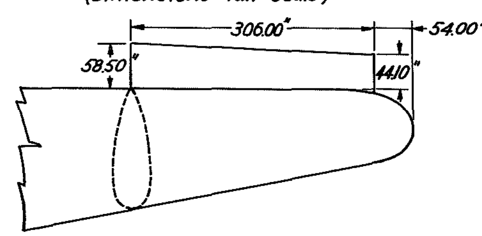
(Full Scale)

b, ft	180.00
L, ft	99.87
$\bar{c}$, in.	213.00
S, sq ft	2875.00
A	11.28
S_h, sq ft	446.00
S_e, sq ft	149.00
S_v, sq ft	157.15
S_r, sq ft	89.75
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 30 D
δ_a, deg	25 U, 15 D
TDPF	0



Model as tested.

Size and location of ailerons on model.
(Dimensions full scale)



Mass Data

Normal Loading

W, lb	105,000
$x/\bar{c}$	0.213
$z/\bar{c}$	0.158
I_X, slug-ft^2	1,195,420
I_Y, slug-ft^2	568,000
I_Z, slug-ft^2	1,740,000
Test altitude, ft	10,000
μ (at sea level)	2.65
μ' (10,000 ft)	3.59

$\frac{I_X - I_Y}{mb^2}$	59×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-111×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	52×10^{-4}

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Résumé of Model Test Results

NOTE: Because of the type of model wing construction used, the installation of conventional ailerons such as those used on the airplane was not feasible. The ailerons were simulated on the model by attaching strips of balsa of approximately correct span and area on the trailing edge of the wing.

For the normal loading, clean condition (wing floats retracted), and normal control configuration for spinning, the spin was very steep ($\alpha = 19^{\circ}$) and the rate of descent high. With the elevator up, a similar spin was obtained when the ailerons were with the spin, but the model would not spin when the ailerons were set against the spin or when the elevators were either neutral or down regardless of the aileron setting. Although no recoveries were attempted the test results indicate that full rapid reversal of both rudder and elevator would have led to satisfactory recoveries from spins obtained.

There was no appreciable effect on the spin and recovery characteristics of a large increase in the mass distribution along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.50\ I_Y\right)$ or of a rearward movement of the center of gravity $0.09\bar{c}$ from its normal position.

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SPIN DATA OBTAINED WITH THE $\frac{1}{45}$-SCALE MODEL OF THE CONSOLIDATED XPB3Y-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition]

	Normal loading							ΔI_Y and ΔI_Z = $0.50 I_Y$				ΔI_X and ΔI_Z = $0.50 I_Y$ Rudder against spin				ΔI_Y and ΔI_Z = $0.50 I_Y$ c.g. moved back $.09\bar{c}$			
Ailerons	Against		Neutral			With		Neutral		With		Neutral		With		Neutral		With	
Elevator	U	N	U	N	D	U	N	U	N	U	N	U (b)	N	U (c)	N	U	N	U	D
α, deg.	N	N	19	N	N	20	N	23	-	30	N	-	-	-	-	23	N	-	-
ϕ, deg.	o	o	12 U	o	o	1 U	o	16U	-	10D	o	-	-	-	-	6 U	o	-	-
Ω, rps	s	s	0.18	s	s	0.27	s	0.15	-	0.28	s	-	-	-	-	0.15	s	-	-
V, fps	p	p	282	p	p	255	p	273	-	226	p	-	-	-	-	273	p	-	-
Turns for recovery	i n	i n	-	i n	i n	-	i n	-	-	-	i n	-	-	-	-	-	i n	-	-
Load factor			3.07			2.88		2.58		2.03						2.53			

[a]Model went into steep tight spin.
[b]Model went into spin or spiral.
[c]Model went into steep spin or spiral.

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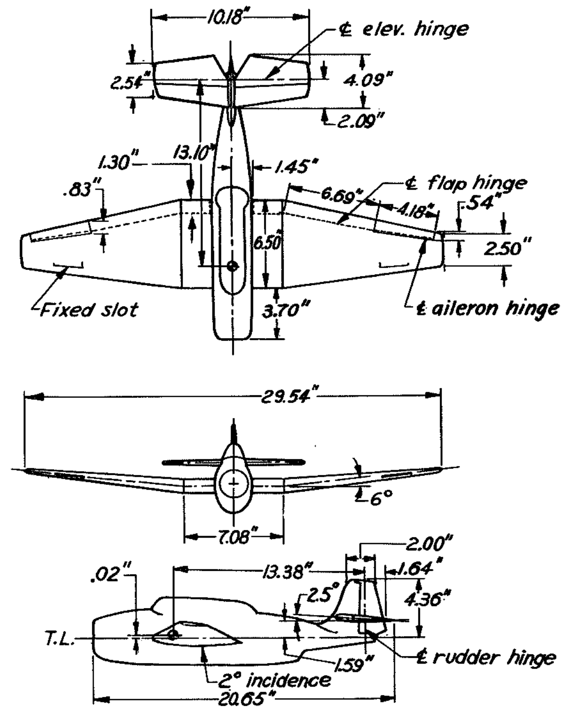
1/22-SCALE MODEL OF THE GRUMMAN XTBF-1 AIRPLANE

Dimensional Data

(Full-Scale)

b, ft	54.17
L, ft	39.90
$\bar{c}$, in	117.18
S, sq ft	490.00
A	5.99
L.E. $\bar{c}$ aft L.E. c_r	10.33
S_h, sq ft	102.65
S_e, sq ft	45.30
S_v, sq ft	38.75
S_r, sq ft	15.25
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	22 U, 18 D
δ_f, deg	45 D
TDPF	202×10^{-6}
Landing gear.	conventional



Model as tested.

Mass Data

Normal Loading

	Original	Revised
W, lb	13,224	13,975
$x/\bar{c}$	0.250	0.252
$z/\bar{c}$	-0.004	-0.004
I_X slug-ft^2	11,748	11,807
I_Y slug-ft^2	21,156	23,640
I_Z slug-ft^2	31,183	33,576
Test altitude, ft	10,000	10,000
μ (at sea level)	6.50	6.88
μ' (10,000 ft)	8.81	9.31

	Original	Revised
$\frac{I_X - I_Y}{mb^2}$ . .	-77×10^{-4}	-93×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$ . .	-83×10^{-4}	-78×10^{-4}
$\frac{I_Z - I_X}{mb^2}$ . .	160×10^{-4}	171×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, all recoveries obtained from elevator-up spins, regardless of aileron setting, were satisfactory by rapid full rudder reversal. With the elevator either neutral or down, the model spun at flatter attitudes than for elevator-up spins (45° compared to 23°) and recoveries by rapid full rudder reversal were generally unsatisfactory. In general, setting the ailerons with the spin, steepened the spins and improved the recovery characteristics of the model, whereas setting the ailerons against the spin had little effect.

Movement of the center of gravity forward $0.08\bar{c}$ or back $0.05\bar{c}$ from its normal position did not appreciably alter the recovery characteristics of the model.

Increasing the mass along the wings (ΔI_X and $\Delta I_Z = 0.40\ I_X$) enabled satisfactory recoveries to be obtained from all spins when the ailerons were set against the rotation and from the elevator-up and elevator-neutral spins when the ailerons were neutral. When the ailerons were set with the spin, recoveries were generally unsatisfactory.

Increasing the mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.40\ I_Y$) generally flattened the spins and retarded recoveries for all control settings as compared to the corresponding spins for the normal loading.

Deflecting the flaps 45° and opening the slots had an adverse effect upon the recovery characteristics of the model for all elevator-up spins; however, when the ailerons were with the spin, with the elevator either neutral or down, there was a favorable effect. Tests conducted with the slots open alone (data not presented) indicated little effect on the recovery characteristics of the model. For the landing condition (flaps and landing gear extended, slots open, pilot's canopy open, and turret fairing retracted), elevator-up spins were flatter and recoveries were generally slower than the corresponding spins for the clean condition.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

In an attempt to improve the recovery characteristics of the model for the elevator-neutral and elevator-down spins, various tail modifications were tested on the model. The results indicated that by adding area both to the top of the vertical surfaces (modification 1) and below the fuselage in the vicinity of the horizontal surfaces (modification 3) or extending the rudder downward (modification 2) greatly improved the recovery characteristics of the model. Redesign of the vertical tail surfaces (modification 4) was also beneficial. When I_Y and I_Z were increased $0.40I_Y$ above normal, however, these tail modifications would not insure satisfactory recoveries from elevator-neutral or elevator-down spins.

The model when tested in the revised design (see comparison sketch) generally exhibited steady spin and recovery characteristics similar to the spin and recovery characteristics of the model in the original design.

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SPIN DATA OBTAINED WITH THE $\frac{1}{22}$- SCALE MODEL OF THE GRUMMAN XTBF-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition original design and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading									
Ailerons	Against			Neutral			With			
Elevator	U	N	D	U	N	D	U (a)	N (b)	N (b)	D
α, deg	23	50	52	23	47	49	----	38	24	41
ϕ, deg	1U	7U	5U	7D	4U	4U	----	1D	1D	0
Ω, rps	0.38	0.45	0.46	0.49	0.46	0.47	----	0.50	0.69	0.49
V, fps	246	158	151	258	160	151	>280	181	232	170
Turns for recovery	$\frac{3}{4}$; c$1\frac{1}{4}$; d$\frac{1}{4}$; e$\frac{1}{4}$	$3\frac{3}{4}$	$7\frac{3}{4}$	$\frac{3}{4}$; c>5; d$\frac{1}{2}$; e$\frac{1}{2}$	$4\frac{1}{2}$	$8\frac{1}{2}$	c>5; d$\frac{1}{4}$; e$\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{4}$	4

	Rudder neutral spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	----	No spin	44	----	No spin	45	----	----	23
ϕ, deg	----		8U	----		5U	----	----	9U
Ω, rps	----		0.47	----		0.48	----	----	0.75
V, fps	>280		155	>280		160	>280	>280	232
Turns for recovery	----		---	----		---	----	----	----

	ΔI_X and $\Delta I_Z = 0.20I_X$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	25	46	48	23	44	46	22	26	37
ϕ, deg	0	6U	6U	4D	4U	3U	14D	2D	0
Ω, rps	0.41	0.46	0.47	0.47	0.47	0.48	0.56	0.67	0.64
V, fps	258	164	155	262	173	160	275	224	203
Turns for recovery	1	$2\frac{3}{4}$	$4\frac{1}{4}$	1	$3\frac{1}{4}$	$4\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{2}$	2

	ΔI_X and $\Delta I_Z = 0.40I_X$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	24	35	36	22	33	41	40	30	40
ϕ, deg	1U	6U	7U	3D	3U	5U	2D	1D	0
Ω, rps	0.50	0.53	0.51	0.51	0.60	0.50	0.42	0.56	0.50
V, fps	267	245	173	254	228	172	194	194	181
Turns for recovery	$\frac{3}{4}$	$\frac{3}{4}$	2	$1\frac{1}{4}$	$1\frac{1}{4}$	3	$3\frac{1}{4}$	2	3

	ΔI_Y and $\Delta I_Z = 0.20I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	-	-	50	----	-	44	-	-	21
ϕ, deg	-	-	6U	----	-	3U	-	-	0
Ω, rps	-	-	0.41	----	-	0.43	-	-	0.71
V, fps	-	-	155	275	-	164	-	-	232
Turns for recovery	-	-	∞	----	-	∞	-	-	$1\frac{3}{4}$; >5

	ΔI_Y and $\Delta I_Z = 0.40I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	52	56	57	43	50	50	-	21	20
ϕ, deg	6U	5U	4U	1D	3U	3U	-	1D	0
Ω, rps	0.32	0.39	0.39	0.37	0.38	0.39	-	0.74	0.70
V, fps	168	151	147	190	164	158	-	271	232
Turns for recovery	$2\frac{1}{2}$	∞	∞	$1\frac{3}{4}$	$5\frac{1}{4}$	∞	-	1	∞

	Slots open, flaps down 45°, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	50	50	52	48	47	47	43	18	21
ϕ, deg	3U	3U	3U	1U	1U	3U	3D	5U	5U
Ω, rps	0.36	0.44	0.45	0.37	0.45	0.46	0.37	0.72	0.70
V, fps	156	143	141	158	147	143	164	241	207
Turns for recovery	$3\frac{1}{4}$	$4\frac{1}{2}$	7	3	$4\frac{1}{2}$	6	$2\frac{1}{2}$	$\frac{3}{4}$	2

	Landing gear extended, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N	D
α, deg	47	52	55	44	48	51	---	25	42
ϕ, deg	7U	7U	6U	3U	4U	4U	---	1D	1U
Ω, rps	0.39	0.45	0.46	0.39	0.46	0.47	---	0.67	0.50
V, fps	177	149	149	190	160	153	>280	228	168
Turns for recovery	$2\frac{1}{4}$	$4\frac{1}{2}$	∞	$2\frac{1}{4}$	$6\frac{1}{4}$	∞	---	$1\frac{1}{2}$	∞

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	51	52	53	.49	49	52	46	19	39
ϕ, deg	4U	4U	4U	1U	2U	2U	2D	4U	2D
Ω, rps	0.39	0.45	0.46	0.38	0.45	0.46	0.37	0.65	0.48
V, fps	156	143	139	156	147	143	164	228	151
Turns for recovery	$3\frac{1}{2}$	5	∞	$3\frac{3}{4}$	6	8	2	1	$5\frac{3}{4}$

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	No spin	No spin	No spin	-	No spin	No spin	24	-	No spin
ϕ, deg				-			9D	-	
Ω, rps				-			0.48	-	
V, fps				>280			267	>280	
Turns for recovery				-			1	-	

Effect of tail modifications, normal loading

Ailerons		Against		Neutral
Elevator		N	D	D
	Modification			
Normal loading	1 and 3	-	3	-
	2	-	3	$3\frac{1}{2}$
	4	3	$3\frac{3}{4}$	$3\frac{3}{4}$
ΔI_Y and $\Delta I_Z = 0.40I_Y$	1 and 3	-	6	-
	2	4	∞	∞
	4	$4\frac{3}{4}$	∞	6

	Revised design, revised normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (af)	N	D	U (a)	N	D	U (a)	N	D
α, deg	---	47	48	---	44	44	---	19	22
ϕ, deg	---	6U	6U	---	4U	4U	---	1D	0
Ω, rps	---	0.44	0.44	---	0.44	0.45	---	0.75	0.72
V, fps	---	168	160	280	168	168	>280	262	228
Turns for recovery	---	5	∞	$\frac{3}{4}$	4	∞	----	1	∞

	Revised design, landing gear extended, slots closed, flaps neutral, revised normal loading						Revised design, landing condition, revised normal loading		
Ailerons	Against			Neutral			Neutral		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	-	51	52	-	46	48	49	48	---
ϕ, deg	-	7U	7U	-	4U	5U	0	1U	---
Ω, rps	-	0.44	0.45	-	0.46	0.46	0.35	0.43	---
V, fps	-	164	156	-	168	164	168	156	151
Turns for recovery	-	$7\frac{1}{2}$	∞	-	$5\frac{3}{4}$	∞	3	$6\frac{1}{4}$	∞

[a]Steep spin.
[b]Two types of spin possible.
[c]Recovery attempted by rudder neutralization.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Recovery attempted by rudder reversal and elevator neutralization.
[f]Wandering and oscillatory spin.

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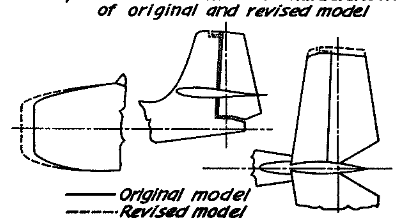
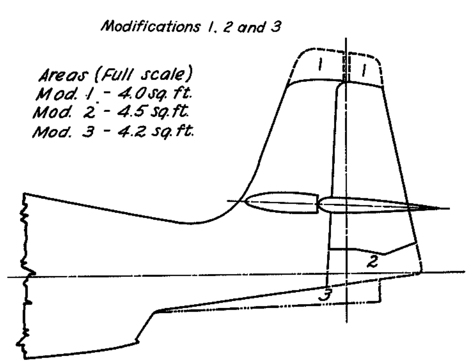
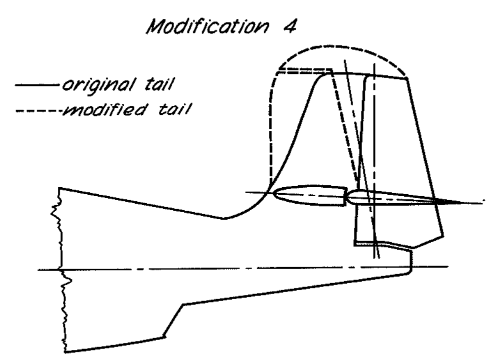
Comparison of dimensional characteristics of original and revised model







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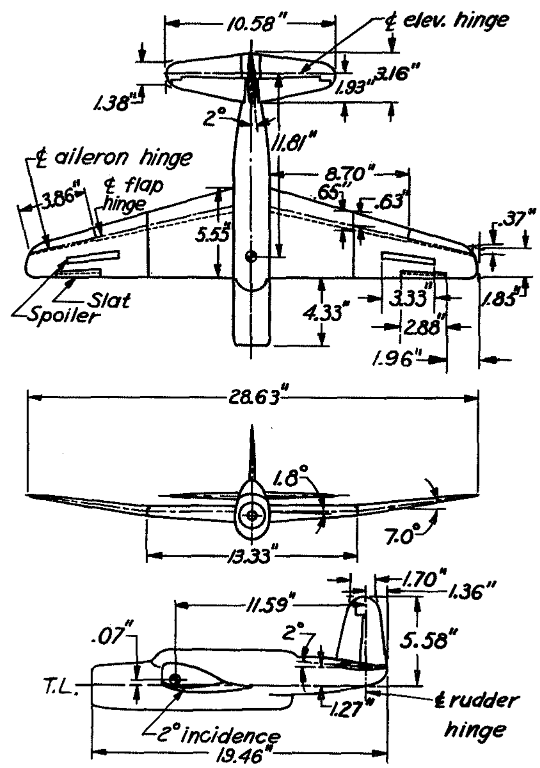
$\frac{1}{24}$-SCALE MODEL OF THE VOUGHT-SIKORSKY XTBU-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	57.17
L, ft	39.00
$\bar{c}$, in.	93.80
S, sq ft	439.50
A	7.44
L.E. $\bar{c}$ aft L.E. c_r	1.75
S_h, sq ft	96.40
S_e, sq ft	22.50
S_v, sq ft	40.50
S_r, sq ft	17.50
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 20 D
δ_a, deg	30 U, 12 D
δ_a, deg (landing condition) (Aileron deflections measured from drooped position)	25 D
δ_f, deg	50 D
δ_s, deg (spoilers)	0, 50 U
TDPF	121×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	13,216
$x/\bar{c}$	0.252
$z/\bar{c}$	-0.018
I_X, slug-ft^2	12,543
I_Y, slug-ft^2	23,969
I_Z, slug-ft^2	34,911
Test altitude, ft	10,000
μ (at sea level)	6.85
μ' (10,000 ft)	9.29

$\frac{I_X - I_Y}{mb^2}$	-85×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-80×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	165×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun very steeply ($\alpha = 22^\circ$) with a high rate of descent (288 feet per second). Satisfactory recoveries were obtained either by rapid full rudder reversal or by simultaneous neutralization of rudder and elevator. Setting the ailerons with the spin steepened the spin and hastened recovery, whereas setting the ailerons against the spin flattened the spin and produced unsatisfactory recoveries from the elevator-neutral and elevator-full-down spins.

With the mass extended along the wings (ΔI_X and $\Delta I_Z = 0.40\ I_X$), there was a reversal of aileron effect and recoveries from the aileron with spins, elevator either neutral or down, were unsatisfactory. The elevator-up spin was too oscillatory to test.

A forward or rearward movement of the center of gravity $0.05\bar{c}$ from its normal position had no appreciable effect on the recovery characteristics of the model.

For the landing condition (landing gear extended, flaps deflected 50°, ailerons drooped 25°, slots open, and spoilers in operation), recoveries by rapid full rudder reversal were satisfactory from the aileron-neutral and aileron-with spins. The model would not recover, however, from aileron-against spins. There was little effect on the recoveries of the model of either opening the slots or extending the spoilers alone (data not presented).

Recoveries by rapid full rudder reversal from inverted spins obtained were satisfactory.

SPIN DATA OBTAINED WITH THE $\frac{1}{24}$-SCALE MODEL OF THE VOUGHT-SIKORSKY XTBU-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	27	48	47	22	30	32	No spin	23	26
φ, deg	4U	4U	5U	2D	4U	2U		1D	1U
Ω, rps	0.40	0.45	0.44	0.46	0.53	0.53		0.68	0.67
V, fps	261	176	172	288	234	203		265	238
Turns for recovery	1 [a]>3 [b]3/4 [c]1/2	2 3/4 [a]5	3 [a]8 1/4	1 [a]>2 1/2 [b]1 1/4 [c]1/2	1 1/4 [a]2 1/2	1 1/2 2 1/4 [a]4		1 [a]1 3/4	1 1/2

Rudder neutral spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (d)	N	D	U (d)	N	D	U	N	D
α, deg	----	No spin	No spin	----	No spin	No spin	--	No spin	No spin
φ, deg	----			----			--		
Ω, rps	----			----			--		
V, fps	>300			>300			--		
Turns for recovery	----			----			--		

ΔI_X and ΔI_Z = 0.20 I_X

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	--	--	26	21	--	26	--	--	25
φ, deg	--	--	8U	4D	--	4U	--	--	1D
Ω, rps	--	--	0.55	0.46	--	0.57	--	--	0.68
V, fps	--	--	225	283	--	229	--	--	.238
Turns for recovery	--	--	1	----	--	1 1/2	--	--	1

ΔI_X and ΔI_Z = 0.40 I_X

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (e)	N	D
α, deg	22	No spin	No spin	21	22	23	---	40	41
φ, deg	0			3D	5U	5U	---	5D	4D
Ω, rps	0.42			0.49	0.62	0.63	---	0.43	0.46
V, fps	278			274	256	238	---	185	185
Turns for recovery	1/2			1 1/4	1	1	---	3	3 1/4

ΔI_Y and ΔI_Z = 0.30 I_Y

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	23	48	50	---	23	28	----	22	18
φ, deg	0	3U	3U	---	0	0	----	2D	1D
Ω, rps	0.37	0.38	0.37	---	0.53	0.49	----	0.69	0.69
V, fps	269	176	171	300	249	225	>300	300	274
Turns for recovery	1/2	3	4	---	1 1/4	1 3/4	----	1/4	1/2

ΔI_Y and ΔI_Z = -0.10 I_Y

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	22	28	38	23	26	39	No spin	20	23
φ, deg	2U	8U	5U	3D	4U	2U		2D	0
Ω, rps	0.44	0.53	0.47	0.50	0.57	0.52		0.74	0.66
V, fps	261	220	180	269	225	194		265	234
Turns for recovery	3/4	1	1 1/2 2	3/4	1	1 1/4 1 3/4		1 1/4	1

c.g. moved forward $0.05\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	24	35	47	20	26	36	---	19	23
φ, deg	5U	4U	4U	2D	3U	4U	---	1D	1D
Ω, rps	0.45	0.47	0.44	0.49	0.55	0.48	---	0.68	0.65
V, fps	256	174	167	269	225	194	>300	269	236
Turns for recovery	1/2	1 1/2 2 1/4	3	3/4	1 1/4	2	---	1 1 3/4	1

c.g. moved back $0.05\bar{c}$

Ailerons	Against				Neutral			With		
Elevator	U	N	D (f)	D (f)	U	N	D	U	N	D
α, deg	---	27	48	36	---	25	29	No spin	---	22
φ, deg	---	7U	6U	5U	---	2U	1U		---	1D
Ω, rps	---	0.49	0.41	0.44	---	0.52	0.51		---	0.68
V, fps	278	234	176	243	300	234	216		>300	252
Turns for recovery	---	1	2 1/4	1 1/2	---	1	1 1/4 1 3/4		---	1

Landing gear extended, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (e)	N	D
α, deg	23	28	32	22	25	27	----	20	24
φ, deg	4U	8U	7U	3D	4U	3U	----	2D	0
Ω, rps	0.43	0.50	0.52	0.47	0.58	0.56	----	0.69	0.64
V, fps	256	220	207	274	238	216	----	265	234
Turns for recovery	3/4	1 1/4	1 1/4	3/4	1 1/4	1 1/2	----	1	1 1/2

Landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	37	47	48	No spin	16	20	No spin	No spin	16
φ, deg	1D	1D	2D		8U	9U			7U
Ω, rps	0.33	0.42	0.43		0.61	0.57			0.70
V, fps	180	158	154		238	212			234
Turns for recovery	7 ∞	∞	∞		1/2	1			1

Inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	33	No spin	No spin	37	32	No spin
φ, deg				2D			4D	4D	
Ω, rps				0.35			0.35	0.46	
V, fps				247			229	238	
Turns for recovery				1/2			3/4	3/4	

[a] Recovery attempted by neutralizing rudder.
[b] Recovery attempted by simultaneous neutralization of rudder and elevator.
[c] Recovery attempted by simultaneous full rudder reversal and neutralization of the elevator.
[d] Vertical velocity too high to test.
[e] Oscillatory spin.
[f] Two types of spin.

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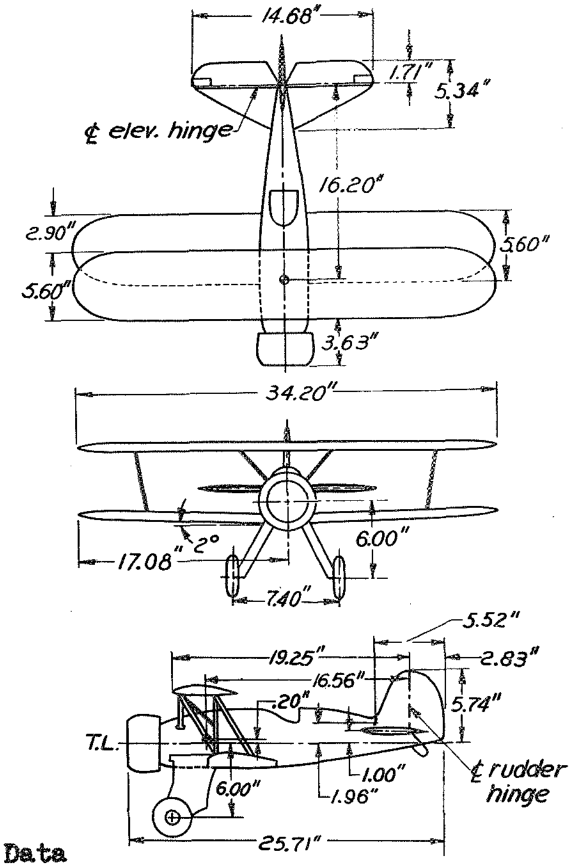
$\frac{1}{10}$-SCALE MODEL OF THE BOEING XBFB-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft (upper)	28.50
b, ft (lower)	28.46
L, ft	22.13
$\bar{c}$, in.	56.00
S, sq ft	252.00
A	3.22
S_h, sq ft	33.94
S_e, sq ft	14.70
S_v, sq ft	13.95
S_r, sq ft	9.00
δ_r, deg	32 R, 32 L
δ_e, deg	30 U, 30 D
TDPF	114×10^{-6}
Landing gear	Fixed



Model as tested.

Mass Data

Normal Loading

W, lb	3704
$x/\bar{c}$	0.253
$z/\bar{c}$	-0.035
I_X, slug-ft^2	1433
I_Y, slug-ft^2	2821
I_Z, slug-ft^2	3402
Test altitude, ft	4000
μ (at sea level)	6.73
μ' (4000 ft)	7.60

$\frac{I_X - I_Y}{mb^2}$	-149×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-62×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	211×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition, normal control configuration for spinning, the model spun in an oscillatory manner and test results indicate that recovery by rapid full rudder reversal would have been unsatisfactory. Setting the elevator either neutral or partly up had no definite effect upon the spin characteristics of the model. With the rudder set initially against the rotation, the model would continue to spin with the elevator either neutral or down.

Moderate variations in mass distribution (±20 percent) or in center-of-gravity position ($\pm 0.03\bar{c}$) had a slight favorable effect on the recovery characteristics of the model, but the recoveries from elevator-neutral spins were still generally unsatisfactory.

Attaching two 116-pound bombs, full scale, externally to the wing at approximately 44 percent of the semispan from the plane of symmetry had a favorable effect on the recovery characteristics of the model; whereas, a 474-pound bomb, full scale, attached to the bottom of the fuselage at approximately the center of gravity retarded recoveries.

In order to improve the recovery characteristics of the model, additional area was added to the top of the fin and rudder (modification 1). For the normal fighter loading and with the mass retracted along the wings (ΔI_X and $\Delta I_Z = -0.20\ I_X$) the model recovered satisfactorily except when the elevator was full down.

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SPIN DATA OBTAINED WITH THE $\frac{1}{10}$-SCALE MODEL OF THE BOEING XBFB-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading						Normal loading, rudder neutral spins									Normal loading, rudder against spins					
Ailerons	Neutral						Against			Neutral			With			Against			Neutral		
Elevator	30°U (a)	25°U	20°U (a)	15°U	10°U (a)	N (a)	U	N	D	U	N (a)	D (a)	U	N	D	U	N	D	U	N (a)	D (a)
α, deg	47	----	47	----	49	49	----	----	----	----	44	46	----	----	----	----	----	----	----	41	41
ϕ, deg	4D	----	3D	----	2D	1D	----	----	----	----	0	0	----	----	----	----	----	----	----	6U	4U
Ω, rps	0.49	----	0.52	----	0.55	0.54	----	----	----	----	0.56	0.58	----	----	----	----	----	----	----	0.57	0.57
V, fps	111	----	113	----	110	105	----	----	----	----	113	108	----	----	----	----	----	----	----	113	115
Turns for recovery	----	[c]∞	----	[b]$1\frac{1}{2}$	----	∞ 3 >3 [b]>4	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Elevator	U	25°U	N	10°D	15°D	20°D	D
ΔI_Y and $\Delta I_Z = 0.20\ I_Y$	----	----	[b]$1\frac{1}{2}$ [b]>3	----	----	----	----
ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	----	[c]$1\frac{3}{4}$	$2\frac{1}{2}$ $3\frac{1}{4}$	----	[b]$3\frac{1}{2}$	----	[b]5
ΔI_X and $\Delta I_Z = 0.20\ I_X$ ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	----	[c]$1\frac{3}{4}$	$1\frac{1}{2}$ $2\frac{3}{4}$	----	----	----	----
ΔI_X and $\Delta I_Z = -0.20\ I_X$ ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	[b]$1\frac{1}{2}$	[c]$2\frac{1}{4}$ [c]∞	2 [b]4 ∞	----	----	[c]∞	----
ΔI_Y and $\Delta I_Z = -0.20\ I_Y$ c.g. moved forward $0.03\bar{c}$	----	[c]$2\frac{1}{4}$ [c]$1\frac{3}{4}$	$2\frac{3}{4}$ $3\frac{1}{4}$	----	----	----	----

Elevator	U	25°U	N	10°D	15°D	20°D	D
ΔI_Y and $\Delta I_Z = -0.20 I_Y$ c.g. moved back $0.03\bar{c}$	----	[c]$1\frac{1}{4}$ [c]2	$2\frac{3}{4}$	----	----	----	----
ΔI_Y and $\Delta I_Z = -0.20 I_Y$ c.g. raised $0.07\bar{c}$	----	[b]2 [c]2 [c]4	[b]$1\frac{1}{2}$ [b]$3\frac{1}{2}$ [b]>8	[b]>4	----	----	----
2 - 116-pound bombs ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	----	[c]$1\frac{1}{2}$	$2\frac{1}{2}$	----	----	----	----
1 - 474-pound bomb ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	----	[c]$2\frac{3}{4}$	[b]$4\frac{1}{2}$	----	----	----	----
1 - 474-pound bomb ΔI_X and $\Delta I_Z = -0.20 I_X$ ΔI_Y and $\Delta I_Z = -0.20 I_Y$	[b]>$1\frac{1}{2}$	[bc]>5	∞	----	----	----	----

Effect of mass variations, weight changes, c.g. movements, and modifications on spin characteristics for the aileron-neutral, elevator neutral setting

		α, deg	ϕ, deg	Ω, rps	V, fps	Turns for recovery
One - 474-pound bomb	a	50	2D	0.59	113	----------
Two - 116-pound bombs	ad	48	2D	0.54	119	----------
1 - 474-pound bomb $\Delta W = -0.10W$, ΔI_X and $\Delta I_Z = -0.20 I_X$ ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	a	48	0	0.64	108	----------
Modification 1	d	47	2D	0.55	110	----------
$\Delta W = 0.08W$, ΔI_X and $\Delta I_Z = -0.20\ I_X$ ΔI_Y and $\Delta I_Z = 0.20\ I_Y$, c.g. moved back $0.03\bar{c}$	e	46	2D	0.51	115	----------
$\Delta W = -0.10W$, ΔI_X and $\Delta I_Z = -0.20\ I_X$ ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	f	46	3D	0.52	108	----------

Effect of modifications on turns for recovery for aileron-neutral spins

Elevator	U	N	D
One - 474-pound bomb ΔI_X and $\Delta I_Z = -0.20\ I_X$ 2.1 square feet fin area (full scale) added to top of fin	[bc]$1\frac{1}{4}$	----	----
One - 474-pound bomb ΔI_X and $\Delta I_Z = -0.20\ I_X$ ΔI_Y and $\Delta I_Z = -0.20\ I_Y$ 2.1 square feet fin area (full scale) added to top of fin	[bc]$1\frac{3}{4}$	----	----
Normal loading 2.1 square feet fin area (full scale) added to top of fin	[bc]1	----	[bc]2
Normal loading modification 1	[c]$1\frac{1}{4}$	$1\frac{1}{4}$ $\frac{3}{4}$ $1\frac{1}{4}$	[b]$2\frac{1}{2}$ [b]>3
ΔI_X and $\Delta I_Z = -0.20\ I_X$ modification 1	[c]$\frac{3}{4}$ [c]$1\frac{1}{4}$	[b]$1\frac{1}{4}$	[b]>4

[a]Oscillatory spin, average values presented

[b]Visual observation.

[c]Recovery attempted by simultaneous reversal of rudder and elevator from initial setting.

[d]Wandering spin.

[e]Elevator 30° down.

[f]Elevator 30° up.

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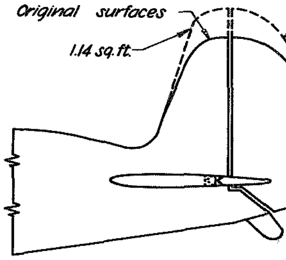

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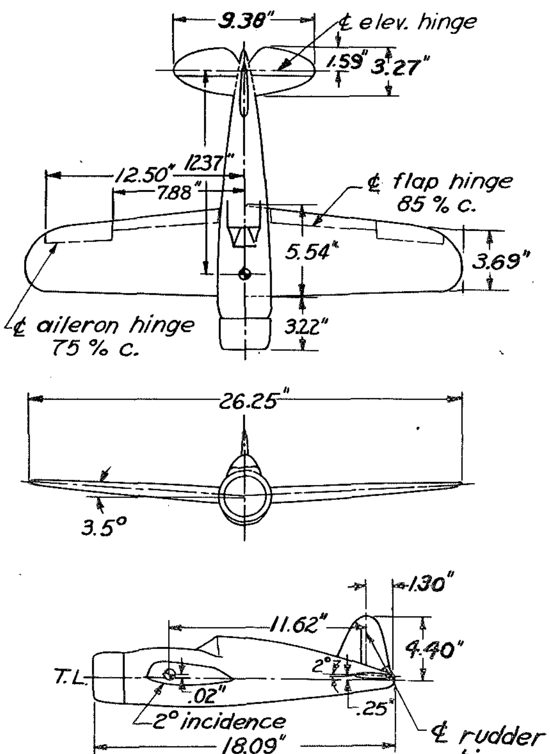
$\frac{1}{16}$-SCALE MODELS OF THE BREWSTER XF2A-1, F2A-1 AND XF2A-2 AIRPLANES

Dimensional Data

(Full Scale)

(Values are the same for all models unless otherwise noted)

b, ft	35.00
L, ft	
XF2A-1	25.45
F2A-1	26.00
XF2A-2	25.61
$\bar{c}$, in	74.88
S, sq ft	208.90
A	5.86
L.E. $\bar{c}$ aft L.E. Cr, in.	2.80
S_h, sq ft	
XF2A-1	41.50
F2A-1 and XF2A-2	41.20
S_e, sq ft	
XF2A-1	19.00
F2A-1 and XF2A-2	18.60
S_v, sq ft	17.20
S_r, sq ft	8.90
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	
XF2A-1 and XF2A-2	30 U, 15 D
F2A-1	26 U, 16 D
δ_f, deg	60 D
TDPF	
XF2A-1	$.167 \times 10^{-6}$
F2A-1 and XF2A-2	$.270 \times 10^{-6}$
Landing gear	Conventional



XF2A-1
Model as tested.

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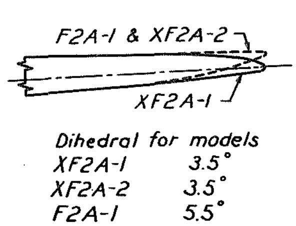
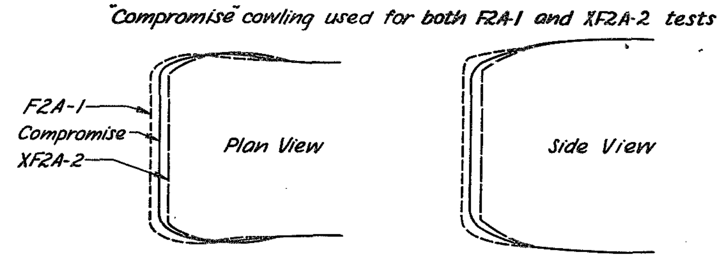


"Compromise" cowling used for both F2A-1 and XF2A-2 tests



The XF2A-1, F2A-1 and XF2A-2 models were similar in dimensional characteristics aft of the wing trailing edge. The canopies for the F2A-1 and XF2A-2 were similar to the canopy of the XF2A-1 model. Variations in the cowling design, wing tip shape, and value of wing dihedral for the models are shown in the accompanying sketches.

Mass Data

Loadings

	XF2A-1	F2A-1	XF2A-2
W, lb	4815	5066	5348
$x/\bar{c}$	0.251	0.268	0.268
$z/\bar{c}$	-0.004	0.005	0.017
I_X, slug-ft^2	2282	2095	2110
I_Y, slug-ft^2	3715	3440	3410
I_Z, slug-ft^2	5608	5130	5080
Test altitude, ft	6000	6000	6000
μ (at sea level)	8.60	9.06	9.54
μ' (6000 ft)	10.28	10.82	11.42
$\frac{I_X - I_Y}{mb^2}$	-78×10^{-4}	-69×10^{-4}	-64×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-103×10^{-4}	-87×10^{-4}	-81×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	181×10^{-4}	156×10^{-4}	145×10^{-4}

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Résumé of Model Test Results

Results obtained with the XF2A-1 model indicated that for the clean condition, normal loading, the model had satisfactory recovery characteristics. For the elevator-up spins (data not presented) the model descended in excess of 220 feet per second.

Increasing or decreasing the mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$) or moving the center of gravity forward $0.05\bar{c}$ or back $0.03\bar{c}$ from its normal position generally led to spins from which recoveries were satisfactory when the elevator was neutral with the ailerons neutral, or unsatisfactory when the elevator was down with the ailerons neutral. Increasing the mass along the fuselage generally led to spins from which recoveries were unsatisfactory for all control settings tested, while decreasing the mass along the fuselage (ΔI_Y and $\Delta I_Z = -0.10\ I_Y$) led to satisfactory recoveries for either elevator neutral or down spins. For the normal loading ΔI_X and $\Delta I_Z = -0.20\ I_X$, and for the loading ΔI_Y and $\Delta I_Z = 0.20\ I_Y$, and center of gravity moved forward $0.05\bar{c}$, a deflection of the flaps had a detrimental effect on the recovery characteristics of the model.

For the F2A-1 model the recovery characteristics were generally satisfactory for all loadings and control settings tested.

The recoveries of the XF2A-2 model were satisfactory for all conditions tested except when the mass was decreased along the wings (ΔI_X and $\Delta I_Z = -0.08\ I_X$) and/or increased along the fuselage (ΔI_Y and $\Delta I_Z = 0.30\ I_Y$) in which cases recoveries were generally unsatisfactory when the elevator was either neutral or down with the ailerons either neutral or against the spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE BREWSTER XF2A-1, F2A-1, AND XF2A-2 AIRPLANES

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins equivalent test altitude 6000 ft.]

XF2A-1, normal loading

Ailerons	Against Full	Against 9°D 14.3°U	Neutral	Neutral	With 3.5°U 2.5°D	With 7.1°U 5°D
Elevator	D	D	N	D	D	D (a)
α, deg	50	48	44	44	43	31
∅, deg	5U	7U	2U	3U	3U	3U
Ω, rps	0.57	0.58	0.54	0.57	0.59	0.78
V, fps	131	132	144	137	138	175
Turns for recovery	2	$1\frac{1}{2}$ 2	$1\frac{3}{4}$	2	2	$1\frac{1}{2}$

XF2A-1; effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Elevator	N	D
ΔI_X and $\Delta I_Z = 0.20 I_X$	2	$1\frac{1}{2}$ $2\frac{1}{4}$
ΔI_X and $\Delta I_Z = -0.20 I_X$	2	$2\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.20 I_Y$	$2\frac{1}{2}$	$2\frac{3}{4}$
ΔI_Y and $\Delta I_Z = -0.10 I_Y$	$\frac{1}{2}$	1
c.g. moved forward $0.05\bar{c}$	2	$2\frac{1}{2}$
c.g. moved back $0.03\bar{c}$	$1\frac{3}{4}$	$2\frac{1}{4}$

XF2A-1, ΔI_X and $\Delta I_Z = -0.20 I_X$, ΔI_Y and $\Delta I_Z = 0.20 I_Y$, c.g. moved forward $0.05\bar{c}$

Ailerons	Against Full	Against 14.3°U 9°D	Neutral	Neutral	Neutral	With 3.5°U 2.5°D	With 7.1°U 5°D	With 7.1°U 5°D	With 7.1°U 5°D
Elevator	D (b)	D (b)	10° U	N	D	D	U	N	D
α, deg	54	56	46	--	49	47	--	--	42
∅, deg	4U	3U	0	--	1U	1U	--	--	0
Ω, rps	0.54	0.54	0.47	--	0.52	0.54	--	--	0.55
V, fps	127	126	149	--	134	141	--	--	144
Turns for recovery	$3\frac{1}{2}$ 4	$4\frac{1}{2}$ 4	$1\frac{1}{2}$ 2	$2\frac{1}{2}$	$3\frac{1}{2}$	2 $2\frac{1}{2}$	--	--	2 $2\frac{1}{2}$

XF2A-1; effect of flap setting on turns for recovery for aileron-neutral spins

	Normal loading				ΔI_X and $\Delta I_Z = -0.20 I_X$, ΔI_Y and $\Delta I_Z = 0.20 I_Y$, c.g. moved forward $0.05\bar{c}$			
Flaps	15°D	30°D	45°D	60°D	15°D	30°D	45°D	60°D
Elevators	D	D	D	D	D	D	D	D
α, deg	48	48	48	48	50	49	49	46
∅, deg	0	1U	0	0	0	1D	1D	2D
Ω, rps	0.59	0.57	0.56	0.56	0.54	0.53	0.54	0.53
V, fps	129	126	124	123	129	127	129	129
Turns for recovery	$2\frac{3}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$

F2A-1, normal loading

Ailerons	Against Full	Against 16°U 9°D	Neutral	Neutral	Neutral	With 16°U 9°D	With Full
Elevator	D	D	U (c)	N	D	D	D
α, deg	37	40	25	27	33	27	28
∅, deg	8U	6U	3D	4U	4U	3U	1U
Ω, rps	0.66	0.65	0.58	0.75	0.73	0.84	0.84
V, fps	169	162	247	224	187	209	209
Turns for recovery	$1\frac{1}{4}$	$1\frac{1}{4}$	---	$\frac{3}{4}$	1	$\frac{3}{4}$	$\frac{3}{4}$

F2A-1; effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Elevator	D
ΔI_X and $\Delta I_Z = 0.15 I_X$	$\frac{3}{4}$
ΔI_X and $\Delta I_Z = -0.08 I_X$	1
ΔI_Y and $\Delta I_Z = 0.15 I_Y$	$1\frac{1}{4}$ 2
ΔI_Y and $\Delta I_Z = 0.30 I_Y$	2
c.g. moved back $0.03\bar{c}$	1
c.g. moved back $0.06\bar{c}$	$1\frac{1}{2}$

F2A-1, ΔI_X and $\Delta I_Z = -0.08 I_X$, ΔI_Y and $\Delta I_Z = 0.30 I_Y$, c.g. moved back $0.06\bar{c}$

Ailerons	Against 16°U 9°D	Against 16°U 9°D	Neutral	Neutral
Elevator	U	D	U	D
α, deg	--	52	--	40
∅, deg	--	4U	--	0
Ω, rps	--	0.51	--	0.52
V, fps	--	147	--	162
Turns for recovery	--	$2\frac{1}{2}$	--	2

F2A-1, inverted spins, normal loading

Ailerons	Against 9°U 16°D	Against 9°U 16°D	Neutral	Neutral	Neutral	With 9°U 16°D	With 9°U 16°D
Elevator	U (d)	D	U	N	D (d)	U	D
α, deg	No spin	--	--	No spin	No spin	38	--
∅, deg		--	--			4U	--
Ω, rps		--	--			0.53	--
V, fps		--	250			184	--
Turns for recovery		--	--			1	--

F2A-1, inverted spins, ΔI_X and $\Delta I_Z = -0.08 I_X$, ΔI_Y and $\Delta I_Z = 0.30 I_Y$, c.g. moved back $0.06\bar{c}$

Ailerons	Against	Against	Neutral	Neutral	Neutral	With	With
Elevator	U	D	U	N	D	U	D
α, deg	--	--	41	--	24	--	--
∅, deg	--	--	0	--	9D	--	--
Ω, rps	--	--	0.40	--	0.66	--	--
V, fps	--	--	184	250	213	--	--
Turns for recovery	--	--	$\frac{1}{2}$	--	$\frac{1}{4}$	--	--

F2A-1, normal loading; equivalent test altitude, 12,000 feet

Ailerons	Against 16°U 9°D	Against 16°U 9°D	Neutral	Neutral	With	With
Elevator	U	D	N (e)	D (f)	U	D
α, deg	--	48	29	43	--	--
∅, deg	--	6U	0	1U	--	--
Ω, rps	--	0.60	0.69	0.62	--	--
V, fps	--	168	236	171	--	--
Turns for recovery	--	2	$\frac{3}{4}$	2	--	--

XF2A-2, normal loading

Ailerons	Against Full	Against Full	Against Full	Against 16°U 9°D	Against 16°U 9°D	Neutral	Neutral	Neutral	With 16°U 9°D	With Full
Elevator	U	N	D	U	D	U	N	D	D	D
α, deg	--	--	51	--	52	---	28	43	26	25
∅, deg	--	--	8U	--	5U	---	4U	3U	1U	0
Ω, rps	--	--	0.60	--	0.61	---	0.73	0.64	0.84	0.90
V, fps	--	--	153	—	147	250	218	160	216	246
Turns for recovery	--	--	$1\frac{3}{4}$	--	$2\frac{1}{4}$	---	1	2 $1\frac{1}{4}$	$1\frac{1}{4}$	1

XF2A-2; effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Elevator	D
ΔI_X and $\Delta I_Z = 0.15 I_X$	$\frac{3}{4}$
ΔI_X and $\Delta I_Z = -0.08 I_X$	$2\frac{1}{4}$
ΔI_Y and $\Delta I_Z = 0.15 I_Y$	2
ΔI_Y and $\Delta I_Z = 0.30 I_Y$	$2\frac{3}{4}$
c.g. moved forward $0.03\bar{c}$	$1\frac{1}{4}$
c.g. moved back $0.03\bar{c}$	2

[a]Steep spin.
[b]Flat spin.
[c]Oscillatory spin.
[d]From the right "no spin" condition model goes into a left erect spin.
[e]Model will also spin similar to elevator down condition.
[f]Steeper spin also obtainable.
[g]Steep and oscillatory spin.
[h]Two types of spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE BREWSTER XF2A-1, F2A-1, and XF2A-2 AIRPLANES - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins equivalent test altitude 6000 feet]

	XF2A-2, ΔI_X and ΔI_Z = -0.08 I_X; ΔI_Y and ΔI_Z = 0.30 I_Y													XF2A-2, inverted spins; ΔI_X and ΔI_Y = -0.08 I_X; ΔI_Y and ΔI_Z = 0.30 I_Y						
	Against								Neutral			With		Against		Neutral			With	
	Full		16°U 9°D			10°U 6°D	5°U 3°D					16°U 9°D	Full	9°U 16°D					9°U 16°D	
Elevator	N	D	U (g)	N	D	D	N	D	N (h)	N (h)	D	D	D (c)	U	N	U	N	D	U	N
α, deg	58	55	--	--	54	--	--	--	26	37	47	--	--	--	No spin	39	-	27	--	--
ϕ, deg	8U	7U	--	--	3U	--	--	--	0	0	1U	--	--	--		0	-	8D	--	--
Ω, rps	0.52	0.55	--	--	0.55	--	--	--	0.67	0.50	0.55	--	--	--		0.42	-	0.77	--	--
V, fps	155	147	--	--	147	--	--	--	237	173	160	250	250	--		186	-	222	--	--
Turns for recovery	2	3	--	$2\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{1}{4}$	$2\frac{3}{4}$	1	$1\frac{3}{4}$	$2\frac{1}{4}$, $2\frac{3}{4}$	--	--	--		$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	--	$\frac{1}{2}$

[c]Oscillatory spin.
[g]Steep and oscillatory spin.
[h]Two types of spin.

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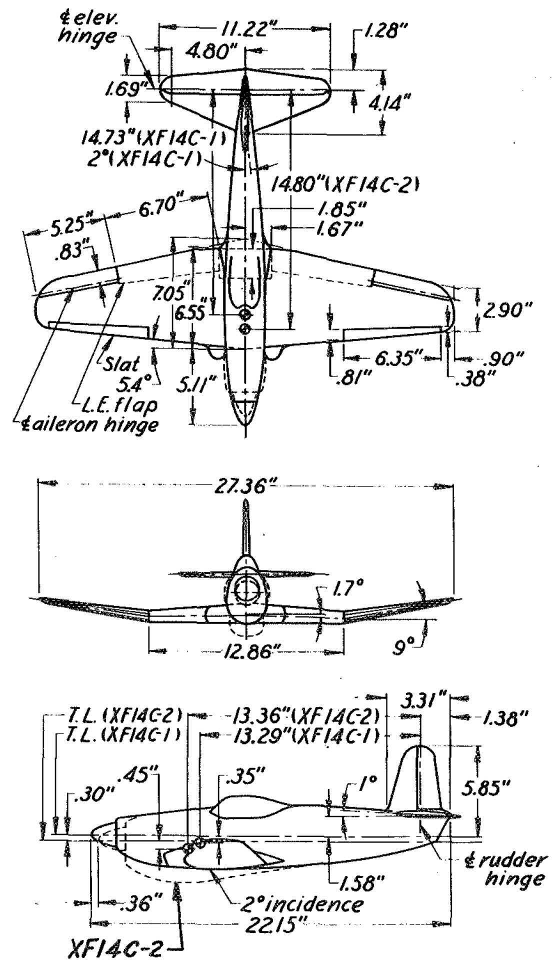
1/20-SCALE MODEL OF THE CURTISS XF14C-1 AND XF14C-2 AIRPLANES

Dimensional Data

(Full-Scale)

(The data for both airplanes are the same except where noted.)

b, ft	45.60
L, ft	
XF14C-1	38.17
XF14C-2	37.60
$\bar{c}$, in	105.47
S, sq ft	375.00
A	5.54
L.E. $\bar{c}$ aft L.E. c_r	11.09
S_h, sq ft	
XF14C-1	78.01
XF14C-2	83.25
S_e, sq ft (inc bal)	
XF14C-1	35.24
XF14C-2	35.00
S_v, sq ft	29.34
S_r, sq ft (inc bal)	16.95
δ_r, deg	
XF14C-1	30 R, 30 L
XF14C-2	27 R, 27 L
δ_e, deg	30 U, 20 D
δ_a, deg	18 U, 14 D
δ_a, (landing cond.) deg	15 D
ail. defl. meas. from drooped pos.	
δ_f, deg	50 D
TDPF	
XF14C-1	298×10^{-6}
XF14C-2	253×10^{-6}
Landing gear--conventional	



Model as tested.

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Mass Data

Normal Loading

	XF14C-1	XF14C-2
W, lb	12,750	13,633
$x/\bar{c}$	0.259	0.246
$z/\bar{c}$	0.067	0.085
I_X, slug-ft^2	11,713	11,920
I_Y, slug-ft^2	14,743	16,545
I_Z, slug-ft^2	24,338	26,164
Test altitude, ft	16,000	12,000
Alternate test altitude, ft		30,000
μ (at sea level)	9.72	10.41
μ' (at test altitude)	15.99	15.05
μ' (30,000 ft)		27.8

	XF14C-1	XF14C-2
$\frac{I_X - I_Y}{mb^2}$	-37×10^{-4}	$-52 \times 10^{-}$
$\frac{I_Y - I_Z}{mb^2}$	-116×10^{-4}	-109×10
$\frac{I_Z - I_X}{mb^2}$	153×10^{-4}	161×10

Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, the XF14C-2 model spun steeply and a satisfactory recovery was obtained by simultaneous reversal of rudder and elevator. With the elevator either neutral or down, recoveries were satisfactory by rapid full rudder reversal. Setting the ailerons partly or fully against the spin expedited recoveries of the model whereas setting ailerons with the spin retarded the recoveries.

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.35\ I_X$) led to spins from which the recoveries of the model were satisfactory when the ailerons were either neutral or against the spin regardless of elevator setting. Recoveries from all aileron with spins were unsatisfactory.

Retracting mass along the wings (ΔI_X and $\Delta I_Z = -0.12\ I_X$) or extending the mass along the fuselage led to conditions where aileron-against and elevator-down settings had an adverse effect on recoveries.

Moderate variations in the center of gravity location $\pm 0.05\bar{c}$ did not appreciably alter the recovery characteristics of the model.

For the normal-loading condition with the flaps deflected 50°, for the normal-loading condition with the slots fully opened, for the landing condition (landing gear extended, flaps down 50°, slots open and ailerons drooped 15°) or for a condition similar to the landing condition except that the ailerons were not drooped, the recovery characteristics of the model were satisfactory only for aileron with spins, regardless of elevator setting. Extending the landing gear alone did not appreciably alter the recovery characteristics of the model.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

The installation of a revised vertical tail did not appreciably alter the recovery characteristics of the model for all conditions tested.

Increasing the equivalent test altitude from 12,000 feet to 30,000 feet led to spins which were flatter and to recoveries which were slower than the corresponding spins for the equivalent test altitude of 12,000 feet.

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The spin and recovery characteristics of the XF14C-1 model were generally similar to those of the XF14C-2 model. For the XF14C-1 model, however, the aileron effect was more pronounced for the normal flying condition, aileron-against settings being favorable and aileron-with settings adverse for all elevator settings. For the landing condition, the favorable effect of aileron-with settings were less favorable for the XF14C-1 model than for the XF14C-2 model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS XF14C-1 AND XF14C-2 AIRPLANES

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins; equivalent test altitude, XF14C-1 16,000 feet, XF14C-2 12,000 feet]

	XF14C-2, normal loading, left spin									
Ailerons	Against, Full	Against, Full	Against, 4° U 3° D	Neutral	Neutral	Neutral	With, 4° U 3° D	With, Full	With, Full	With, Full
Elevator	N	D	U (a)	U (b)	N	D	U (ac)	U (ac)	N (b)	D (b)
α, deg	29	31	29	---	25	22	---	---	-	---
ϕ, deg	6U	2U	9D	---	2D	6U	---	---	-	---
Ω, rps	0.68	0.69	0.40	---	0.76	0.86	---	---	-	---
V, fps	272	232	337	311	272	271	---	---	-	342
Turns for recovery	$1\frac{1}{2}$	$\frac{3}{4}$	[d]$\frac{3}{4}$	[de]$1\frac{1}{2}$	$1\frac{1}{2}$	[f]1	[d]>3	[e]$1\frac{1}{2}$	-	---

	XF14C-2, ΔI_X and $\Delta I_Z = 0.35 I_X$ left spin								
Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With	With	With
Elevator	U (b)	N	D	U (bg)	N (b)	D	U (a)	N	D
α, deg	---	No spin	No spin	29	---	No spin	47	40	43
ϕ, deg	---			11D	---		5D	5D	2D
Ω, rps	---			0.90	---		0.43	0.58	0.62
V, fps	>319			274	>319		216	220	200
Turns for recovery	---			>1	---		>7, [e]$2\frac{1}{2}$	$3\frac{1}{2}$, 4	[f]$3\frac{1}{2}$

	XF14C-2 ΔI_X and $\Delta I_Z = -0.12 I_X$ left spin					
Ailerons	Against	Against	Neutral	Neutral	Neutral	With
Elevator	N	D	N	D (h)	D (h)	D (b)
α, deg	28	51	---	44	---	---
ϕ, deg	3U	5U	---	2U	---	---
Ω, rps	0.71	0.55	---	0.60	---	---
V, fps	245	182	339	194	305	> 353
Turns for recovery	[d]$\frac{3}{4}$	$4\frac{1}{2}$	---	$3\frac{3}{4}$, [d]4	---	---

	XF14C-2 ΔI_Y and $\Delta I_Z = 0.27 I_Y$ left spin						
Ailerons	Against, Full	Against, Full	Against, Full	Against, 4° U 3° D	Neutral	Neutral	Neutral
Elevator	U (g)	N	D	U (bc)	U (g)	N (b)	D
α, deg	---	47	49	---	--	---	---
ϕ, deg	---	5U	4U	---	--	---	---
Ω, rps	---	0.48	0.49	---	--	---	---
V, fps	339	207	194	304	--	>325	298
Turns for recovery	[d]$\frac{1}{2}$	3, $4\frac{1}{2}$	4, $3\frac{1}{2}$	[d]$\frac{3}{4}$	--	---	[d]$\frac{1}{2}$

	XF14C-2 c.g. moved forward $0.05\bar{c}$, left spin			
Ailerons	Against	Against	Neutral	Neutral
Elevator	N	D	N (b)	D
α, deg	---	36	---	26
ϕ, deg	---	4U	---	1U
Ω, rps	---	---	---	---
V, fps	251	232	---	271
Turns for recovery	1	$1\frac{3}{4}$	---	$1\frac{1}{2}$

	XF14C-2 c.g. moved back $0.05\bar{c}$, left spin				
Ailerons	Against	Against	Against	Neutral	Neutral
Elevator	U (bg)	N (b)	D	N (b)	D
α, deg	---	---	30	---	25
ϕ, deg	---	---	3U	---	3U
Ω, rps	---	---	0.70	---	0.81
V, fps	>304	>304	238	>311	287
Turns for recovery	---	---	[d]$1\frac{1}{2}$, [d]2	---	---

	XF14C-2, landing condition, normal loading, left spin								
Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With	With	With
Elevator	U	N	D	U	N	D	U	N	D
α, deg	62	57	56	56	48	47	No spin	No spin	No spin
ϕ, deg	6D	6D	5D	10D	10D	9D			
Ω, rps	0.47	0.51	0.50	0.42	0.51	0.52			
V, fps	170	163	163	176	182	176			
Turns for recovery	∞	∞	∞	∞	[d]$7\frac{1}{2}$, [d]$8\frac{1}{2}$	>8			

	XF14C-2, flaps 50° down, slots open, landing gear extended, normal loading, left spin							
Ailerons	Against	Against	Neutral	Neutral	With, 4° U 5° D	With, 9° U 7° D	With, Full	With, Full
Elevator	U	D	U	N	U	U	U	D
α, deg	53	54	---	49	---	No spin	No spin	No spin
ϕ, deg	1D	0	---	5D	---			
Ω, rps	0.52	0.51	---	0.49	---			
V, fps	179	166	191	179	188			
Turns for recovery	∞	∞	∞	∞	∞			

	XF14C-2, landing gear extended, normal loading, left spin						
Ailerons	Against, Full	Against, Full	Against, 5° U 4° D	Neutral	Neutral	Neutral	With
Elevator	N (b)	D	D	N (b)	D (h)	D (bh)	D (b)
α, deg	---	31	---	---	37	---	---
ϕ, deg	---	6U	---	---	0	---	---
Ω, rps	---	0.68	---	---	---	---	---
V, fps	>339	238	272	>339	194	298	>339
Turns for recovery	---	$1\frac{1}{2}$	[d]$1\frac{1}{2}$	---	$3\frac{1}{4}$	[d]$1\frac{1}{2}$	---

	XF14C-2, flaps down 50°, normal loading, left spin										
Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With, 5°U 4°D	With, 9° U 7° D	With, Full	With, Full	With, Full
Elevator	U	N	D	U	N	D	U	U	U	N	D
α, deg	52	52	52	49	50	50	49	No spin	No spin	No spin	No spin
ϕ, deg	3U	3U	3U	0	0	0	2D				
Ω, rps	0.40	0.50	0.54	0.38	0.51	0.54	0.39				
V, fps	188	179	179	192	182	176	194				
Turns for recovery	∞	∞	∞	∞	∞	∞	8, ∞				

	XF14C-2, slots open, normal loading, left spin								
Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With	With	With
Elevator	U	N	D	U	N	D	U (b)	N	D (b)
α, deg	---	---	---	---	---	---	-	No spin	-
ϕ, deg	---	---	---	---	---	---	-		-
Ω, rps	---	---	---	---	---	---	-		-
V, fps	278	278	278	278	298	298	-		-
Turns for recovery	∞	∞	∞	∞	∞	∞	-		-

	XF14C-2, inverted spins, normal loading								
Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With	With	With
Elevator	U	N	D	U (ab)	N	D	U	N (b)	D
α, deg	No spin	-	-	---	No spin	-	40	---	No spin
ϕ, deg		-	-	---		-	5D	---	
Ω, rps		-	-	---		-	0.45	---	
V, fps		-	-	>325		-	245	325	
Turns for recovery		-	-	---		-	$\frac{3}{4}$	---	

	XF14C-2, revised tail, normal loading												
Ailerons	Against, Full	Against, Full	Against, Full	Against, 4° U 3° D	Neutral	Neutral	Neutral	Neutral	With, 4°U 3°D	With, 5°U 4°D	With, Full	With, Full	With, Full
Elevator	U (ci)	N	D	U (ci)	U (g)	N	D (h)	D (h)	U (g)	D	U (g)	N (b)	D (b)
α, deg	---	27	31	---	---	24	29	34	---	---	---	-	-
ϕ, deg	---	4U	4U	---	---	1U	1U	0	---	---	---	-	-
Ω, rps	---	0.68	0.72	---	0.89	0.78	0.72	0.62	---	---	---	-	-
V, fps	339	248	232	339	332	304	252	200	332	200	>318	-	-
Turns for recovery	---	$1\frac{1}{4}$	[j]$1\frac{1}{2}$, [j]2	$\frac{3}{4}$	[d]$2\frac{1}{2}$, [d]$2\frac{1}{2}$	$1\frac{1}{4}$	[j]$2\frac{1}{4}$	3, $3\frac{3}{4}$	>3	3	---	-	-

[a] Oscillatory spin.
[b] Steep spin.
[c] Wandering spin.
[d] Visual observation.
[e] Recovery attempted by simultaneous rudder and elevator reversal.
[f] Recovers in inverted dive.
[g] Oscillatory and wandering spin.
[h] Two types of spin.
[i] Wide radius of spin.
[j] Upon recovery, the model goes into an inverted spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS XF14C-1 AND XF14C-2 AIRPLANES - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins; equivalent test altitude, XF14C-1 16,000 feet, XF14C-2 12,000 feet]

XF14C-2, revised tail, ΔI_X and $\Delta I_Z = 0.29 I_X$

Ailerons	Against			Neutral			With 5°U 4°D	With Full			
Elevator	U (bi)	N	D	U (a)	N	D	U	U (g)	N (hb)	N (h)	D (b)
α, deg	---	No spin	No spin	---	24	No spin	---	---	---	---	---
Ø, deg	---			---	2U		---	---	---	---	---
Ω, rps	---			---	0.78		---	---	---	---	---
V, fps	---			311	319		223	---	>374	223	>374
Turns for recovery	---			>3	[d]$\frac{3}{4}$		[d]3	---	---	[d]3 [d]$3\frac{1}{2}$	---

XF14C-2, revised tail, landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	59	54	55	48	No spin	No spin	No spin	No spin	No spin
Ø, deg	6D	5D	4D	9D					
Ω, rps	0.46	0.76	0.53	0.39					
V, fps	174	176	176	185					
Turns for recovery	∞	∞	∞	∞					

XF14C-2, revised tail, landing condition, ΔI_X and $\Delta I_Z = 0.29 I_X$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	-	59	-	---	52	-	No spin	No spin	48
Ø, deg	-	4D	-	---	7D	-			10D
Ω, rps	-	0.53	-	---	0.53	-			0.56
V, fps	-	176	-	179	179	-			179
Turns for recovery	-	∞	-	∞	∞	-			$5\frac{3}{4}$

XF14C-2, revised tail, normal loading, equivalent test altitude 30,000 ft, left spin

Ailerons	Against			Neutral			With 9°U 7°D	With 9°U 7°D	With Full		
Elevator	U	N	D	U	N	D	N	D	U (g)	N (b)	D (b)
α, deg	---	---	---	45	44	45	---	---	-	-	-
Ø, deg	---	---	---	3D	1D	1D	---	---	-	-	-
Ω, rps	---	---	---	---	---	---	---	---	-	-	-
V, fps	255	239	239	278	258	258	258	258	-	-	-
Turns for recovery	[d]$5\frac{1}{2}$	[d]∞	[d]∞	[d]4	[d]6	7	[d]6	[d]6	-	-	-

XF14C-1, original tail, normal loading, left spin

Ailerons	Against Full			Against 9°U 7°D	Against 5°U 4°D	Neutral				With 7°U 9°D			With Full		
Elevator	U (i)	N	D	U (a)	U (g)	U (g)	N	D (h)	D (h)	N	D 15°D	D (k)	U (g)	N (k)	D (k)
α, deg	26	No spin	No spin	---	31	34	28	---	46	---	---	---	-	---	---
Ø, deg	1U			---	6D	9D	4D	---	2D	---	---	---	-	---	---
Ω, rps	0.35			---	0.45	0.48	0.75	---	0.60	---	---	---	-	---	---
V, fps	339			339	332	285	274	325	201	201	204	195	-	233	201
Turns for recovery	[d]$\frac{1}{4}$			[d]$\frac{1}{2}$	[d]$2\frac{1}{2}$	>$3\frac{1}{2}$	[d]$1\frac{1}{2}$ [d]2	[d]$\frac{1}{2}$	4	[d]4	[d]5	[d]4	-	[d]2	[d]$2\frac{1}{2}$

XF14C-1, landing condition, normal loading, left spin

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	61	59	56	58	52	52	46	50	48
Ø, deg	5D	5D	5D	10D	8D	8D	12D	11D	10D
Ω, rps	0.48	0.54	0.54	0.46	0.51	0.54	0.42	0.54	0.56
V, fps	170	157	163	176	170	170	188	182	170
Turns for recovery	∞	∞	∞	∞	∞	∞	∞	∞	∞

XF14C-1, original tail, inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	-	No spin	33	No spin	No spin	41	33	31
Ø, deg		-		1U			5D	4D	4D
Ω, rps		-		0.47			0.50	0.60	0.79
V, fps		-		304			258	285	281
Turns for recovery		-		$\frac{1}{2}$			>3	$1\frac{3}{4}$	[l]$1\frac{3}{4}$

[a]Oscillatory spin.
[b]Steep spin.
[d]Visual observation.
[g]Oscillatory and wandering spin.
[h]Two types of spin.
[i]Wide radius of spin.
[k]Steeper spin also obtainable.
[l]Model recovers in erect glide.

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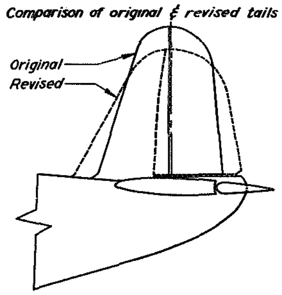
Comparison of original & revised tails

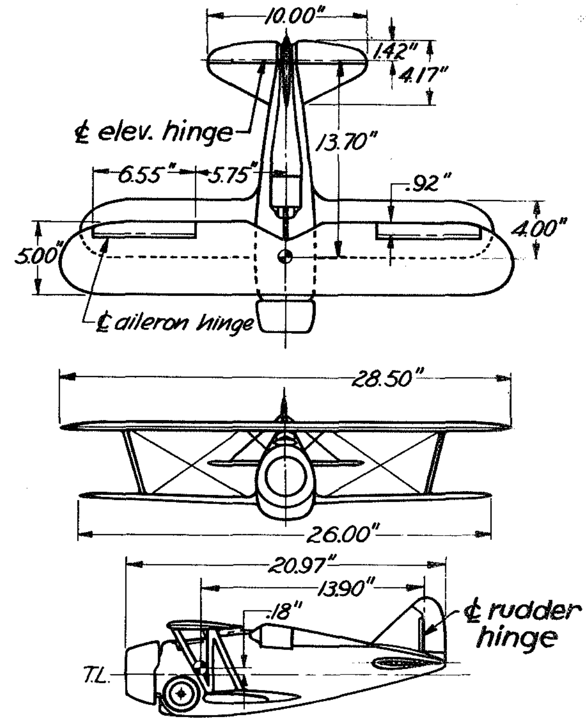


$\frac{1}{12}$-SCALE MODEL OF THE GRUMMAN F2F-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft (upper wing)	28.50
b, ft (lower wing)	26.00
L, ft	20.83
$\bar{c}$, in.	54.20
S, sq ft (total)	230.00
A (effective)	4.27
S_h, sq ft	26.40
S_e, sq ft	10.80
S_v, sq ft	12.10
S_r, sq ft	5.80
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
TDPF	0
Landing gear . . .	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	3782
$x/\bar{c}$	0.330
$z/\bar{c}$	-0.040
I_X, slug-ft^2	1003
I_Y, slug-ft^2	2198
I_Z, slug-ft^2	2631
Test altitude, ft	4000
μ (at sea level)	7.06
μ' (4000 ft)	7.97

$$\frac{I_X - I_Y}{mb^2} \;.\;.\;.\;.\;.\;.\;.\;.\; -125 \times 10^{-4}$$

$$\frac{I_Y - I_Z}{mb^2} \;.\;.\;.\;.\;.\;.\;.\;.\; -45 \times 10^{-4}$$

$$\frac{I_Z - I_X}{mb^2} \;.\;.\;.\;.\;.\;.\;.\;.\; 170 \times 10^{-4}$$

Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model spun at a moderately flat angle of attack ($\alpha = 47^{\circ}$). Recoveries by rapid full rudder reversal required $2\frac{1}{2}$ turns and by rapid full simultaneous reversal of rudder and elevator 2 to $2\frac{1}{2}$ turns. Satisfactory recoveries could not be obtained when the elevator was either neutral or down.

Slight increases or decreases in the values of the gross weight, moments of inertia, or center of gravity location did not appreciably alter the turns for recovery of the model from the rudder-with elevator-up spin.

Area added to the fin and rudder (modification 1) generally improved the recovery characteristics of the model, although recoveries were still unsatisfactory for the elevator-neutral and elevator-down settings.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE GRUMMAN F2F-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with, aileron-neutral spins of the model with the landing gear extended and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading			Modification 1		
Elevator	U	N	D	U	N	D
α, deg	47	58	59	42	58	58
∅, deg	3U	2D	3D	4U	2D	3D
Ω, rps	0.48	0.59	0.63	0.47	0.61	0.62
V, fps	124	109	106	132	109	106
Turns for recovery	2, $^a2$, $^a2\frac{1}{2}$	$>4\frac{3}{4}$	>7	1, $^a1$, $^a1\frac{1}{2}$	$3\frac{1}{4}$, $>3\frac{3}{4}$	>4

[a]Recovery attempted by simultaneous reversal of rudder and elevator.

Effect of weight changes, mass variations, c.g. movements, and retracted landing gear on turns for recovery, elevator originally up	
ΔI_X and $\Delta I_Z = 0.08\ I_X$	$^a1\frac{1}{2}$, $^a2$
ΔI_X and $\Delta I_Z = -0.08\ I_X$	$^a2\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.02\ I_Y$, c.g. moved forward $0.03\bar{c}$	$^a2$
ΔI_Y and $\Delta I_Z = 0.02\ I_Y$, c.g. moved back $0.03\bar{c}$	$^a2$, $^a2\frac{1}{2}$
$\Delta W = 0.03W$, ΔI_Y and $\Delta I_Z = 0.09\ I_Y$	$^a1\frac{3}{4}$, $^a2\frac{1}{2}$
$\Delta W = -0.03W$, ΔI_Y and $\Delta I_Z = -0.09\ I_Y$	$^a1\frac{3}{4}$
$\Delta W = 0.02W$, ΔI_X and $\Delta I_Z = -0.08\ I_X$, ΔI_Y and $\Delta I_Z = 0.09\ I_Y$, c.g. moved back $0.03\bar{c}$	$^a2\frac{1}{2}$, $^a3$
$\Delta W = 0.02W$, ΔI_X and $\Delta I_Z = -0.08\ I_X$, ΔI_Y and $\Delta I_Z = 0.09\ I_Y$, c.g. moved back $0.03\bar{c}$, landing gear retracted	$^a1\frac{3}{4}$
Normal loading, landing gear retracted	$^a1\frac{1}{2}$

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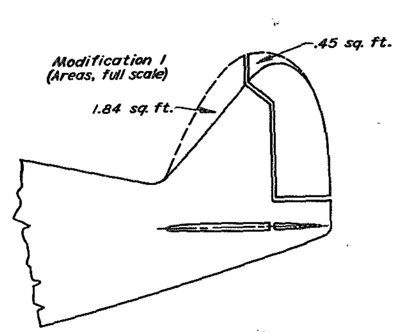
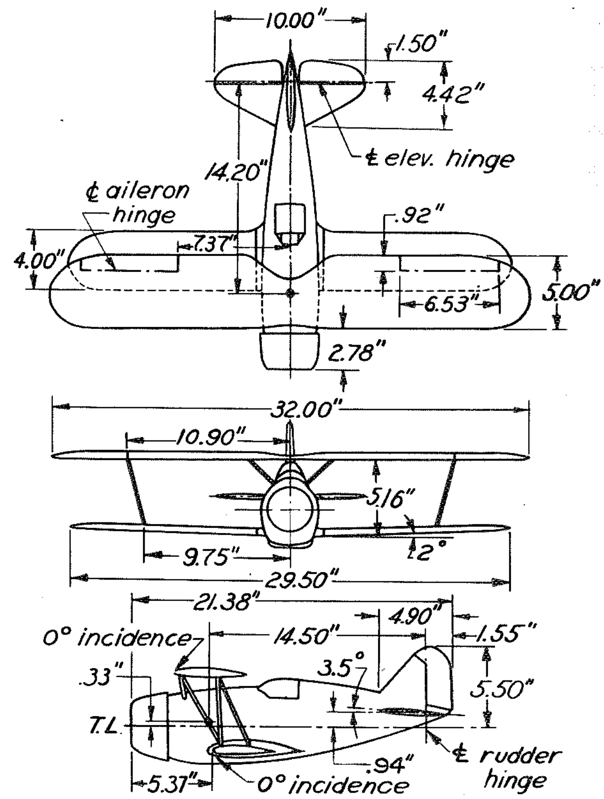


$\frac{1}{12}$-SCALE MODEL OF THE GRUMMAN XF3F-1 AIRPLANE



Dimensional Data

(Full Scale)

b (upper wing), ft	32.00
b (lower wing), ft	29.50
$\underline{L}$, ft	22.00
$\bar{c}$, in.	52.00
S, sq ft	261
A (effective)	4.75
L.E. $\bar{c}$ aft L.E. c_r in. (lower wing)	18.78
S_h, sq ft	30.64
S_e, sq ft	10.80
S_v, sq ft	12.34
S_r, sq ft	5.44
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 30 D
δ_a, deg	20 U, 20 D
TDPF	0
Landing gear	Conventional

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Mass Data

Model as tested.

	Fighter loading	Bomber loading
W, lb	4017	4250
$x/\bar{c}$	0.330	0.348
$z/\bar{c}$	-0.076	0.045
I_X, slug-ft^2	1469	2023
I_Y, slug-ft^2	2552	2615
I_Z, slug-ft^2	3380	3903
Test altitude, ft	4000	4000
μ (at sea level)	6.28	6.63
μ' (4000 ft)	7.09	7.48
$\frac{I_X - I_Y}{mb^2}$	-85×10^{-4}	-44×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-64×10^{-4}	-95×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	149×10^{-4}	139×10^{-4}

Résumé of Model Test Results

In the clean condition, normal fighter or bomber loading, normal-control configuration for spinning, the model spun at a moderately flat angle of attack ($\alpha = 46^\circ$ and $\alpha = 45^\circ$, respectively) and recovery was satisfactory only by rapid full rudder reversal. With the elevator either neutral or down, recoveries could not be obtained.

With the landing gear extended retracting mass along the wings (ΔI_X and $\Delta I_Z = -0.10\ I_X$), extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.08\ I_Y$), moving the center of gravity forward $0.03\bar{c}$ from its normal position, or various combinations of any of the foregoing changes led to spins from which satisfactory recoveries generally could not be obtained. Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.10\ I_X$) or moving the center of gravity rearward $0.03\bar{c}$ from its normal position did not appreciably effect the recovery characteristics of the model.

In an endeavor to improve the recovery characteristics of the model by simultaneous reversal of rudder and elevator, area was added below the fuselage, to the rudder, and to the leading edge of the fin (modifications 1 to 7, inclusive). In general these modifications improved the recovery characteristics of the model, particularly the simultaneous addition of modifications 6 and 7.

With area added to the trailing edge of the rudder and rear part of fuselage (modification 8), the recoveries were satisfactory from the aileron neutral, elevator-up control setting for either the normal loading or worst loading condition (ΔI_X and $\Delta I_Z = -0.10\ I_Y$ ΔI_Y and $\Delta I_Z = 0.08\ I_Y$, and center of gravity moved forward $0.03\bar{c}$ from its normal position) with the landing gear either extended or retracted.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE XF3F-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal fighter loading				Normal fighter loading, wheels down				Normal bomber loading			Normal bomber loading, wheels down		
Ailerons	Neutral				Neutral				Neutral			Neutral		
Elevator	U	N	N (a)	D	U	N	D	D (d)	U	N	D	U	N	D
α, deg	46	---	45	62	48	---	62	49	45	----	64	48	---	63
ϕ, deg	4U	---	6U	3D	6U	---	3D	6U	5U	----	3D	6U	---	3D
Ω, rps	0.43	----	0.52	0.59	0.43	----	0.57	0.53	0.42	----	0.60	0.43	----	0.60
V, fps	126	----	123	105	123	---	105	117	132	----	107	127	---	107
Turns for recovery	$1\frac{1}{2}$ $^{b}>1\frac{3}{4}$ $^{c}2\frac{1}{4}$	>6	---	>9 9	$^{b}>2\frac{1}{2}$ $^{c}\infty$	∞	∞	----	$1\frac{3}{4}$ $^{b}>1\frac{3}{4}$ $^{c}1\frac{1}{2}$	>6	>6 7	$^{b}>2$ $^{c}2$	>7	>9 ∞

Fighter, effect of mass variations and c.g. movements on turns for recovery, modification 1, wheels down

Ailerons	Neutral		
Elevator	U	N	D
Normal loading	$^{c}2$ $^{c}3$	>8	∞
ΔI_X and $\Delta I_Z = 0.10\ I_X$	$^{c}2$	---	∞
ΔI_X and $\Delta I_Z = -0.10\ I_X$	$^{c}3\frac{3}{4}$ $^{c}>4\frac{1}{2}$	∞	∞
$\Delta W = 0.01\ W$ ΔI_Y and $\Delta I_Z = 0.08\ I_Y$	$^{c}3\frac{1}{2}$ $^{c}>4$	----	----
c.g. moved forward $0.03\bar{c}$	$^{c}3$ $^{c}4$	----	----
c.g. moved back $0.03\bar{c}$	$^{c}2$	----	----
ΔI_X and $\Delta I_Z = -0.10\ I_X$ ΔI_Y and $\Delta I_Z = 0.08\ I_Y$ c.g. moved forward $0.03\bar{c}$	$^{c}\infty$	----	----

Fighter. effect of modifications on turns for recovery
ΔI_X and $\Delta I_Z = -0.10\ I_X$
ΔI_Y and $\Delta I_Z = 0.18\ I_Y$
c.g. moved forward $0.03\bar{c}$
wheels down. Aileron neutral spins.

Elevator	U	N	D
Modification .2	$^{c}\infty$	---	---
3	$^{c}>4$	---	---
4	$^{c}2\frac{3}{4}$ $^{c}4$	---	---
5	$^{c}2\frac{1}{4}$	---	---
1 and 5	$^{c}1\frac{3}{4}$ $^{c}2\frac{1}{2}$	---	---
6 and 7	$^{c}1\frac{1}{2}$ $1\frac{1}{4}$	$3\frac{1}{2}$	$4\frac{1}{4}$ $>4\frac{1}{2}$
Bomber modification 6 and 7	$^{c}1\frac{1}{4}$	----	----

Normal fighter loading, wheels down. Modification 8

Ailerons	Neutral				
Elevator	U	N	N (a)	D	D (d)
α, deg	50	---	49	62	50
ϕ, deg	5U	---	7U	2D	6U
Ω, rps	0.45	----	0.51	0.59	0.53
V, fps	121	----	118	105	118
Turns for recovery	2 $^{ce}1\frac{1}{2}$ $^{ce}2$	7 ∞	----	∞	----

Modification 8
ΔI_X and $\Delta I_Z = -0.10\ I_X$
ΔI_Y and $\Delta I_Z = 0.08\ I_Y$
c.g. moved forward $0.03\bar{c}$

Ailerons neutral

Elevator	U
Wheels up	$^{c}1\frac{1}{2}$ $^{c}2$
Bombs on	$^{c}>3$ $^{c}5$
Wheels up, bombs on, wt. of each bomb 145 lbs. located 7.5 feet from each wing tip	$^{c}1\frac{3}{4}$ $^{c}2\frac{1}{2}$

Modification 8
Effect of mass variation and c.g. movements on turns for recovery

Ailerons neutral

Elevator	U
ΔI_X and $\Delta I_Z = -0.10\ I_X$	$^{c}\infty$
$\Delta W = 0.01\ W$ ΔI_Y and $\Delta I_Z = 0.08\ I_Y$	$^{c}4\frac{3}{4}$
c.g. moved forward $0.03\bar{c}$	$^{c}2$ $^{c}3\frac{1}{2}$

[a]Rudder neutral spin.
[b]Upon recovery model tends to go into a spiral dive.
[c]Recovery attempted by simultaneous reversal of rudder and elevator.
[d]Rudder initially against the spin.
[e]Visual estimate.

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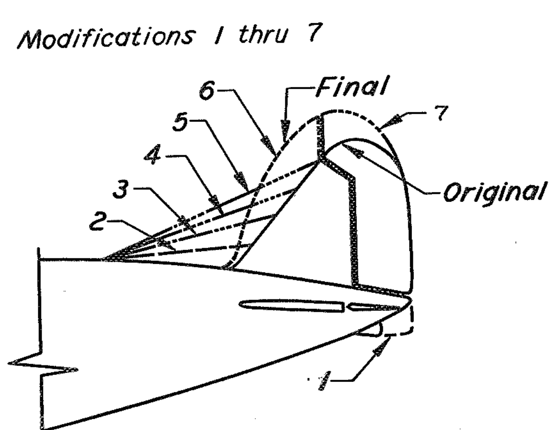
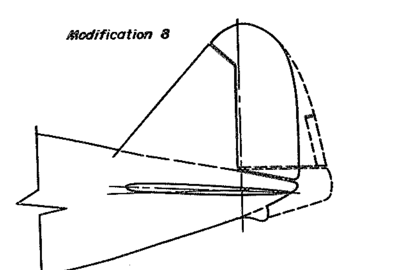


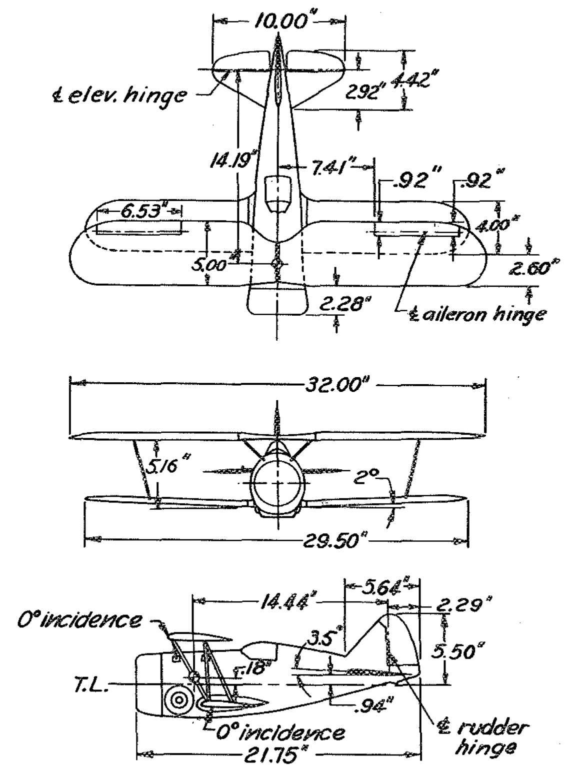


$\frac{1}{12}$-SCALE MODEL OF THE GRUMMAN F3F-2 AIRPLANE

Dimensional Data

(Full Scale)

b, ft (upper wing)	32.00
b, ft (lower wing)	29.50
L, ft	22.10
$\bar{c}$, in.	52.00
S, sq ft (total)	260.60
A (effective)	4.75
S_h, sq ft	30.64
S_e, sq ft	10.80
S_v, sq ft	12.34
S_r, sq ft	5.44
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 25 D
δ_a, deg	20 U, 20 D
TDPF	0
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	4503
$x/\bar{c}$	0.358
$z/\bar{c}$	0.035
I_X, slug-ft^2	1520
I_Y, slug-ft^2	2952
I_Z, slug-ft^2	3825
Test altitude, ft	10,000
μ (at sea level)	7.06
μ' (10,000 ft)	9.57

$$\frac{I_X - I_Y}{mb^2} \ldots \ldots -100 \times 10^{-4}$$

$$\frac{I_Y - I_Z}{mb^2} \ldots \ldots -61 \times 10^{-4}$$

$$\frac{I_Z - I_X}{mb^2} \ldots \ldots 161 \times 10^{-4}$$

Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model spun at a flat angle of attack ($\alpha = 52^{\circ}$) and recoveries by either rapid full rudder reversal or simultaneous reversal of rudder and elevator were satisfactory. Recoveries from spins for other elevator-aileron control settings for the normal-loading condition were generally unsatisfactory. There appeared to be little effect on elevator neutral or down spins (ailerons neutral) when the mass was extended or retracted along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$ or $-0.20\ I_X$), along the fuselage (ΔI_Y and $\Delta I_Z = \pm 0.20\ I_Y$), or when the center of gravity was moved forward or back $0.05\bar{c}$ from its normal position.

In an attempt to improve the recovery characteristics of the model, additional area was added to the top of the tail (modification 1). This modification proved very effective and the recovery characteristics of the model were improved. A more practical modification incorporating additional fin and rudder area, (modification 2) also led to improved recovery characteristics.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE GRUMMAN F3F-2 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading															Normal loading, rudder neutral spins								
Ailerons	Against						Neutral			With						Against			Neutral			With		
	Full			10° U, 10° D						10° U, 10° D			Full											
Elevator	U (a)	N (a)	D (b)	U (b)	N (b)	D (b)	U (b)	N	D (a)	U (b)	N (b)	D (b)	U (b)	N (b)	D (a)	U (e)	N (a)	D (b)	U (e)	N (e)	D (bf)	U (b)	N (e)	D (bf)
α, deg	49	56	60	50	58	58	52	56	57	49	55	55	47	53	57	-	46	50	-	--	30	--	--	43
ϕ, deg	7U	3U	1U	5U	2U	1D	1U	0	2D	3D	2D	3D	3D	3D	2D	-	8U	5U	-	--	2U	--	--	0
Ω, rps	0.49	0.64	0.65	0.52	0.65	0.67	0.53	0.64	0.67	0.51	0.63	0.66	0.51	0.61	0.65	-	0.62	0.65	-	--	0.82	--	--	0.65
V, fps	144	131	129	144	130	128	144	131	128	142	137	128	142	136	130	-	144	139	-	---	159	--	--	149
Turns for recovery	>2, $\frac{3}{4}$	4	4	2	5	5	[c]2, [d]$1\frac{1}{2}$	$3\frac{1}{2}$, [c]$4\frac{1}{4}$	4	>2	4	$4\frac{3}{4}$, >$4\frac{3}{4}$	>2	$3\frac{3}{4}$	>4, $6\frac{1}{2}$	-	[g]$1\frac{3}{4}$, [g]>2	[g]$3\frac{1}{4}$	-	[g]2, [g]$2\frac{1}{2}$	[g]$3\frac{1}{2}$, [g]4	--	--	[g]3, [g]$4\frac{3}{4}$

Effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Elevator	N	D
ΔI_X and $\Delta I_Z = 0.15\ I_X$	2, $2\frac{3}{4}$	[h]$4\frac{1}{2}$
ΔI_X and $\Delta I_Z = 0.30\ I_X$	[h]$2\frac{1}{2}$	[h]4
ΔI_X and $\Delta I_Z = -0.20\ I_X$	[h]$3\frac{1}{4}$, [h]4	[h]$5\frac{1}{4}$
ΔI_Y and $\Delta I_Z = 0.20\ I_Y$	$4\frac{1}{4}$	[h]5
ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	$3\frac{1}{2}$	$4\frac{1}{4}$
c.g. moved forward $0.05\bar{c}$	4	$4\frac{1}{4}$
c.g. moved back $0.05\bar{c}$	[h]3, [h]4	[h]4

	Modification 1, normal loading							Modification 2, normal loading							Modification 2, landing gear extended, normal loading.			
Ailerons	Against		Neutral			With		Against		Neutral			With		Neutral			
Elevator	N	D (b)	U (b)	N (i)	D (a)	N (b)	D (b)	N (b)	D	U (b)	N (b)	D (a)	U	N (b)	U (a)	N (b)	D (b)	D (j)
α, deg	59	60	45	58	60	50	63	60	-	46	58	57	-	42	49	60	62	47
ϕ, deg	1U	2U	3D	3D	2D	2D	5D	0	-	2U	2D	2D	-	2D	3U	2D	4D	4U
Ω, rps	0.63	0.67	0.53	0.65	0.67	0.61	0.66	0.65	-	0.52	0.63	0.65	-	0.61	0.52	0.66	0.66	0.64
V, fps	131	128	149	130	127	136	128	130	-	149	132	130	-	133	144	130	128	141
Turns for recovery	$1\frac{3}{4}$	---	[c]1	3	2, 3	$2\frac{1}{2}$, $1\frac{1}{2}$	---	$1\frac{3}{4}$	-	1	$2\frac{1}{4}$	$2\frac{3}{4}$	-	$2\frac{1}{2}$	$1\frac{1}{4}$, [d]$1\frac{1}{4}$	$2\frac{1}{2}$	4, $3\frac{1}{4}$	---

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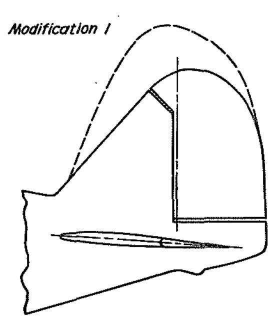
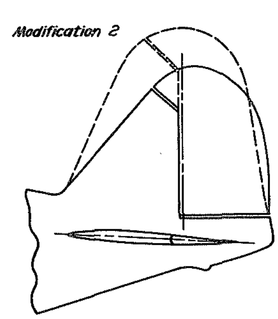
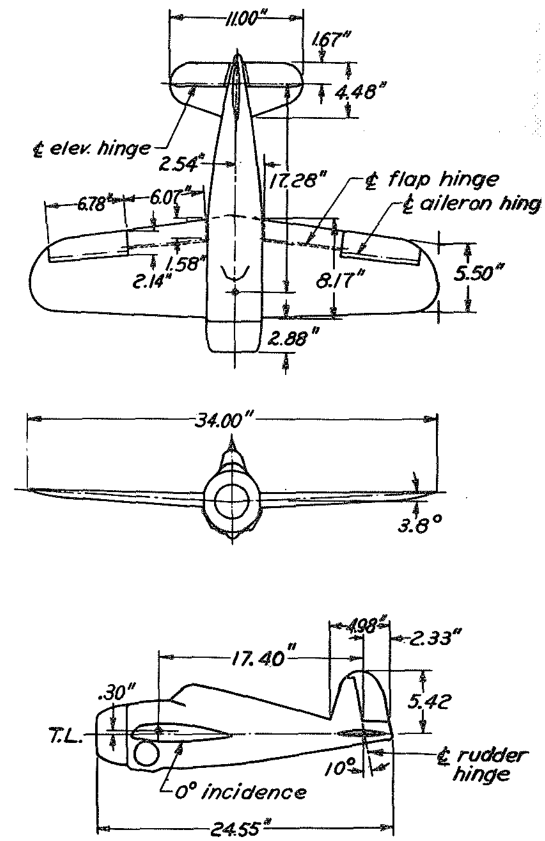
[a]Wandering and oscillatory spin.
[b]Wandering spin.
[c]Visual observation.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Velocity of model too high to test.
[f]Steep spin.
[g]Recovery attempted by movement of rudder from neutral to against the spin.
[h]Before recovery was attempted the model was in a wandering condition.
[i]Oscillatory spin.
[j]Steady spin data are for rudder neutral spins.





$\frac{1}{12}$-SCALE MODEL OF THE GRUMMAN XF4F-2 AIRPLANE



Model as tested.

Dimensional Data

(Full Scale)

b, ft	34.00
L, ft	26.43
$\bar{c}$, in.	85.39
S, sq ft	232.10
A	4.99
L.E. $\bar{c}$ aft L.E. c_r, in.	3.71
S_h, sq ft	39.40
S_e, sq ft	15.00
S_v, sq ft	16.54
S_r, sq ft	8.51
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	30 U, 20 D
δ_f, deg	60 D
TDPF	74×10^{-6}
Landing gear	Retractable

Mass Data

Normal Loading

W, lb	5386
$x/\bar{c}$	0.258
$z/\bar{c}$	0.042
I_X, slug-ft^2	1506
I_Y, slug-ft^2	3685
I_Z, slug-ft^2	4851
Test altitude, ft	4000
μ (at sea level)	8.92
μ (4000 ft)	10.08

$\frac{I_X - I_Y}{mb^2}$	-113×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-60×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	173×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model descended in a wandering motion at a rate of descent in excess of 160 feet per second, full scale. With the elevator 15° up, the model spun at a flat attitude ($\alpha = 54^\circ$) and recoveries obtained by rapid full rudder reversal or by simultaneous reversal of rudder and elevator were $2\frac{1}{2}$ and $2\frac{1}{4}$ turns, respectively. With the elevator either neutral or down for the ailerons set neutral or against the spin, recoveries by rapid full rudder reversal were unsatisfactory (>2 turns). When the ailerons were set full with the spin, the rate of descent of the model was in excess of the maximum airspeed of the tunnel, extremely steep spins being indicated from which it is believed that recoveries would have been satisfactory by rudder reversal.

Extending the mass along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$) or along the fuselage (ΔI_Y and $\Delta I_Z = 0.30\ I_Y$), moving the center of gravity forward or back $0.04\bar{c}$ from its normal position, drooping the ailerons 20°, extending the landing gear, or lowering the flaps 30° did not appreciably alter the recovery characteristics of the model. Lowering the flaps 60° produced a no-spin condition for the aileron-neutral, elevator-neutral setting, normal loading.

For the condition of mass extended along the fuselage (ΔI_Y and $\Delta I_Z = 0.30\ I_Y$), the addition of a ventral fin (modification 1) to the model did not appreciably improve the unsatisfactory recoveries from the aileron-against spins.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE GRUMMAN XF4F-2 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading									
Ailerons	Against 22°U 19°D	Against 10°U 10°D	Neutral						With 10°U 10°D	With 22°U 19°D
Elevator	N	N	U (a)	15°U	N	N (b)	D	D (b)	N (a)	N (a)
α, deg	66	62	----	54	60	No spin	58	No spin	----	----
ϕ, deg	4U	3U	----	1U	1U		1U		----	----
Ω, rps	0.62	0.61	----	0.55	0.58		0.60		----	----
V, fps	117	121	>160	134	126		122		----	----
Turns for recovery	5	4	----	$2\frac{1}{2}$ $^{c}2\frac{1}{4}$	3		$3\frac{1}{2}$		----	----

Effect of mass variations and c.g. movements on turns for recovery. Aileron-neutral spins		
Elevator	15°U	D
ΔI_X and ΔI_Z = $0.15 I_X$	$^{c}2\frac{1}{4}$	$3\frac{1}{4}$
ΔI_X and ΔI_Z = $0.30 I_Y$	$^{c}2\frac{1}{4}$	3
ΔI_Y and ΔI_Z = $0.15 I_Y$	$^{c}2\frac{3}{4}$	$^{d}4$
ΔI_Y and ΔI_Z = $0.30 I_Y$	$^{c}2\frac{3}{4}$	$^{d}4$
c.g. moved forward $0.04\bar{c}$	$^{c}2\frac{3}{4}$	$^{d}3\frac{1}{2}$
c.g. moved back $0.04\bar{c}$	$^{c}2$	$2\frac{1}{2}$

	Ailerons drooped 10°, normal loading								
Ailerons	Against 25°D 11°U			10°D 10°D			With 25°D 11°U		
Elevator	U	N	D	U	N	D	U	N (a)	D
α, deg	----	----	---	----	---	---	----	---	--
ϕ, deg	----	----	---	----	---	---	----	---	--
Ω, rps	----	----	---	----	---	---	----	---	--
V, fps	----	----	---	----	---	---	----	---	--
Turns for recovery	----	∞	---	----	$2\frac{3}{4}$	---	----	---	--

	Ailerons drooped 20°, normal loading									Flaps down 30°, normal loading			Flaps down 60°, normal loading		
Ailerons	Against R 2°D L 28°D			20°D 20°D			With 28°D 2°D			Neutral			Neutral		
Elevator	U	N	D	U	N	D	U	N (a)	D	U	N	D	U	N	D
α, deg	----	----	-	----	----	-	---	----	--	----	52	----	----	No spin	---
ϕ, deg	----	----	-	----	----	-	---	----	--	----	1D	----	----		---
Ω, rps	----	----	-	----	----	-	---	----	--	----	0.55	----	----		---
V, fps	----	----	-	----	----	-	---	----	--	----	131	----	----		---
Turns for recovery	----	$9\frac{1}{2}$	-	----	$2\frac{1}{2}$	-	---	----	--	----	$2\frac{1}{4}$	----	----		---

	ΔI_Y and ΔI_Z = $0.30 I_Y$ Landing gear extended									
Ailerons	Against 22°U, 19°D			Against 10°D 10°D	Neutral				With 10°U 10°D	With 22°U 19°D
Elevator	15°U	N	D	N	U (e)	15°U	N	D	N (a)	N (a)
α, deg	----	----	----	----	48	54	58	59	----	----
ϕ, deg	----	----	----	----	1U	1U	0	2U	----	----
Ω, rps	----	----	----	----	0.42	0.48	0.51	0.54	----	----
V, fps	----	----	----	----	159	139	130	126	----	----
Turns for recovery	∞	∞	∞	∞	$^{d}1\frac{1}{4}$	$2\frac{3}{4}$ $^{c}3$	$^{d}5$	$5\frac{1}{2}$	----	----

	ΔI_Y and ΔI_Z = $0.30 I_Y$ Landing gear extended, flaps down 30°			ΔI_Y and ΔI_Z = $0.30 I_Y$ Landing gear extended, flaps down 60°			Modification 1 ΔI_Y and ΔI_Z = $0.30 I_Y$		
Ailerons	Neutral			Neutral			Against 22°U, 19°D		
Elevator	15°U	N	D	15°U	N	D	U	N	D
α, deg	----	54	----	----	51	----	----	----	----
ϕ, deg	----	1D	----	----	1D	----	----	----	----
Ω, rps	----	0.50	----	----	0.50	----	----	----	----
V, fps	----	130	----	----	130	----	----	----	----
Turns for recovery	$^{c}3$	$2\frac{1}{2}$	----	$^{c}2\frac{3}{4}$	3	----	----	$^{d}5\frac{1}{2}$ $^{f}3\frac{3}{4}$	----

[a]Velocity too high to test.
[b]Rudder originally neutral.
[c]Recovery attempted by simultaneous reversal of rudder and elevator.
[d]Visual estimate.
[e]Wandering spin.
[f]Tail wheel installed.

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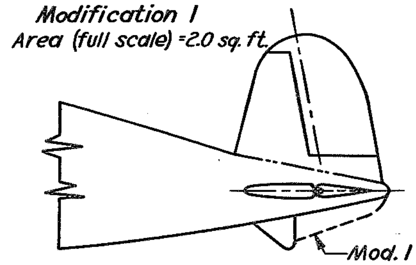
Modification I

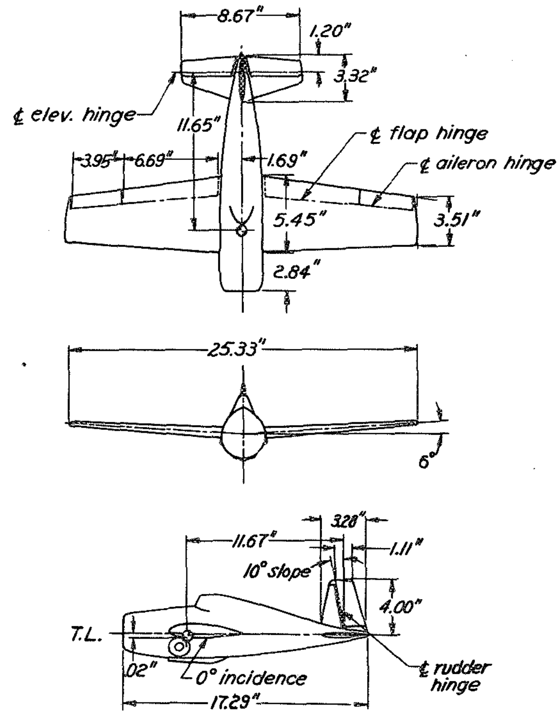


$\frac{1}{18}$-SCALE MODEL OF THE GRUMMAN XF4F-3 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	38.00
L, ft	26.92
$\bar{c}$, in.	84.14
S, sq ft	260.00
A	5.56
S_h, sq ft	46.70
S_e, sq ft	19.90
S_v, sq ft	18.38
S_r, sq ft	9.20
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	$23\frac{1}{2}$ U, 20 D
δ_f, deg	60 D
TDPF	23×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	5824
$x/\bar{c}$	0.238
$z/\bar{c}$	0.005
I_X, slug-ft^2	2310
I_Y, slug-ft^2	4996
I_Z, slug-ft^2	6809
Test altitude, ft	12,000
μ (at sea level)	7.72
μ' (12,000 ft)	11.18

$\frac{I_X - I_Y}{mb^2}$	-103×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-69×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	172×10^{-4}

Résumé of Model Test Results

For the clean condition, normal loading, and normal control configuration for spinning, the model spun at a moderately flat angle of attack ($\alpha = 49^{\circ}$) and recovery was satisfactory by rapid full rudder reversal ($1\frac{3}{4}$ turns). Setting the ailerons against the spin had an adverse effect, whereas setting ailerons with the spin had a favorable effect.

In general, for all loading and flap conditions tested, satisfactory recoveries were obtained for elevator-up spins with the ailerons neutral or with the spin; recoveries from spins with other elevator-aileron settings were generally unsatisfactory.

Raising the stabilizer 10 inches, full scale, (modification 1) or adding area to the fin and rudder (modification 2) improved the recovery characteristics of the model, although, recoveries from spins from which recoveries were previously unsatisfactory were still generally unsatisfactory. A combination of raising the horizontal tail 10 inches and adding area to the fin and rudder (modifications 1 and 2) proved effective, but recoveries were still unsatisfactory from spins with the elevator neutral or down with the ailerons set either neutral or against the spin.

Moving the fin and rudder forward 10 inches, full scale, (modification 3) in conjunction with adding area to the fin and rudder (modification 2) led to an improvement of the recovery characteristics for the normal-loading conditions and several mass variation tested; however, recoveries were still unsatisfactory for elevator-neutral and elevator-down settings with the ailerons set either neutral or against the spin.

Other modifications tested (modifications 5 to 11, inclusive) were generally not as effective as modification 2 tested in conjunction with a movement of the vertical tail 10 inches, full scale, (modification 3) forward of its original position.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

With the test altitude of the model lowered to 4000 feet, the recovery characteristics of the model improved slightly.

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SPIN DATA OBTAINED WITH THE $\frac{1}{18}$-SCALE MODEL OF THE GRUMMAN XF4F-3 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins; equivalent test altitude 12,000 feet except as indicated]

	Normal loading									Rudder neutral spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N (b)	D	U	N	D	U (b)	N	D	U (b)	N (b)	D (b)
α, deg	73	78	79	49	75	67	-	-	22	72	76	73	-	73	70	-	-	-
∅, deg	3U	2U	2U	0	1U	2U	--	--	0	3U	4U	4U	-	1U	1U	--	--	--
Ω, rps	0.60	0.68	0.75	0.44	0.68	0.60	--	--	0.85	0.59	0.69	0.66	---	0.64	0.63	---	---	---
V, fps	131	120	118	176	123	135	--	--	241	135	123	123	--	126	131	--	--	--
Turns for recovery	∞	∞	∞	$1\frac{3}{4}$ [c]$2\frac{1}{2}$	∞	∞	--	--	1	---	---	---	--	---	---	--	--	--

Effect of mass variations and flap deflections on turns for recovery									
Ailerons	Against			Neutral			With		
Elevators	U	N	D	U	N	D	U	N	D
ΔI_X and ΔI_Z = $\Delta 0.15 I_X$	----	--	--	$1\frac{1}{2}$	3	$3\frac{1}{2}$	----	----	-
ΔI_X and ΔI_Z = $0.30 I_X$	$1\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	b-	b-	b-
Flaps 30° down	2	∞	∞	No spin	3	5	b-	b-	b-
Flaps 60° down	[d]$2\frac{1}{2}$ de∞	∞	∞	[d]No spin de∞	bd- de∞	bd- de∞	No spin	No spin	b-

	Modification 1, normal loading									Inverted spins, normal loading									Inverted spins, modification 1, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U (b)	N	D	U (f)	N	D	U (f)	N (b)	D (b)	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	---	60	63	---	51	55	---	---	---	--	--	34	34	30	29	--	--	26	--	---	----	----	----	----	--	--	----
∅, deg	---	5U	5U	---	2U	2U	---	---	---	--	--	16D	0	1D	8D	--	--	2D	--	---	----	----	----	----	--	--	----
Ω, rps	---	0.52	0.56	---	0.51	0.53	---	---	---	--	--	0.60	0.48	0.60	0.66	--	--	0.77	--	---	----	----	----	----	--	--	----
V, fps	---	147	145	---	164	155	---	---	---	--	--	198	218	231	220	--	--	241	--	--	195	>225	253	225	--	--	260
Turns for recovery	---	$3\frac{1}{2}$	6	---	$3\frac{1}{2}$	6	---	---	---	--	--	----	----	$\frac{1}{4}$	----	--	--	----	--	---	h1	----	$\frac{1}{2}$	1	--	--	----

	Modification 2, normal loading									Modifications 1 and 2, normal loading									Modifications 2 and 3, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (b)	N (b)	D (b)	U (b)	N	D	U (g)	N	D	U (bg)	N (b)	D (b)	U	N	D	U	N	D	U (f)	N (b)	D (b)
α, deg	75	77	----	52	73	64	--	--	--	---	57	60	---	50	56	----	--	--	---	--	--	57	58	58	-	---	---
θ, deg	5U	4U	----	0	1U	1U	--	--	--	---	6U	6U	---	2U	2U	----	--	--	---	--	--	0	1U	1U	-	---	---
Ω, rps	0.69	0.85	----	0.45	0.60	0.58	--	--	--	---	0.52	0.54	---	0.52	0.54	----	--	--	---	--	--	0.47	0.53	0.53	--	---	---
V, fps	137	126	128	168	131	141	--	--	--	---	158	149	----	166	152	----	--	--	---	--	--	160	151	147	--	---	---
Turns for recovery	7	∞	$9\frac{1}{2}$	$1\frac{1}{4}$	$7\frac{1}{2}$	$5\frac{1}{2}$	--	--	--	---	2	$3\frac{1}{2}$	----	2	$3\frac{1}{2}$	----	--	--	$1\frac{1}{2}$	8	8	$1\frac{3}{4}$	3	$3\frac{3}{4}$	--	---	---

Effect of mass variations, c.g. movements, and landing gear on turns for recovery. Modifications 2 and 3, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
ΔI_X and ΔI_Z = $0.15 I_X$	--	--	--	$1\frac{1}{2}$	3	$3\frac{1}{2}$	--	--	--
ΔI_X and ΔI_Z = $0.30 I_X$	$1\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	f-	$\frac{1}{2}$	$\frac{1}{2}$
ΔI_Y and ΔI_Z = $0.20 I_Y$	--	--	--	$1\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{1}{2}$	--	--	--
ΔI_Y and ΔI_Z = $-0.20 I_Y$	--	--	--	$1\frac{3}{4}$	$2\frac{1}{2}$	3	--	--	--
c.g. moved forward $0.05\bar{c}$	--	--	--	$1\frac{3}{4}$	3	$3\frac{1}{2}$	--	--	--
c.g. moved back $0.05\bar{c}$	--	--	--	$1\frac{3}{4}$	3	$3\frac{1}{2}$	--	--	--
landing gear extended	--	--	--	$1\frac{3}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	--	--	--

Modifications 2 and 4, normal loading

Against	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (f)	N (b)	D (b)
α, deg	--	--	--	--	--	--	--	--	--
∅, deg	--	--	--	--	--	--	--	--	--
Ω, rps	--	--	--	--	--	--	--	--	--
V, fps	--	--	--	--	--	--	--	--	--
Turns for recovery	1	$2\frac{1}{2}$	$3\frac{1}{4}$	1	3	$3\frac{1}{2}$	--	--	--

[a]Wandering spin.
[b]Vertical velocity too high to test or attempt recovery.
[c]Recovery attempted by simultaneous reversal of rudder and elevator.
[d]Two conditions possible.
[e]Recovery attempted for the flatter of two types of spin.
[f]Model too wandering and oscillatory to test or attempt recovery.
[g]Oscillatory spin.
[h]Model recovers and goes into an erect right spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{18}$-SCALE MODEL OF THE GRUMMAN XF4F-3 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins; equivalent test altitude 12,000 feet except as indicated]

Effect of various tail modifications on turn for recovery from the aileron neutral, elevator neutral condition, normal loading

Modification	Turns for recovery
5	$3\frac{1}{2}$
6	3
7	∞
8	$5\frac{3}{4}$
9	$6\frac{1}{4}$
10	$3\frac{1}{4}$
11	>8

	Normal loading, equivalent test altitude 4000 feet				Modification 2, normal loading, equivalent test altitude 4000 feet						
Ailerons	Neutral				Neutral				With		
Elevator	U	N (1)	N (1)	D	U	N (1)	N (1)	D	--	--	--
α, deg	24	71	60	58	23	66	58	60	--	--	--
ϕ, deg	1D	2U	2U	2U	4U	2U	2U	3U	--	--	--
Ω, rps	0.55	0.66	0.58	0.59	0.57	0.62	0.57	0.61	--	--	--
V, fps	241	112	129	126	233	116	129	121	--	--	--
Turns for recovery	$1\frac{1}{4}$	5	3	$3\frac{1}{2}$	----	$3\frac{3}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	--	--	--

[1]Two types of spin possible.

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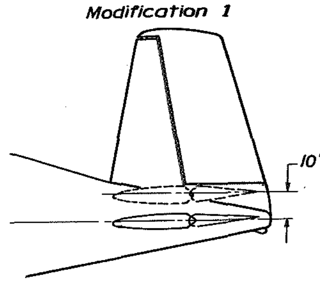
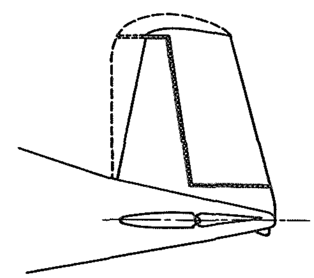
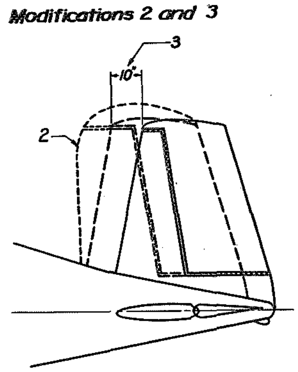
Modification 1



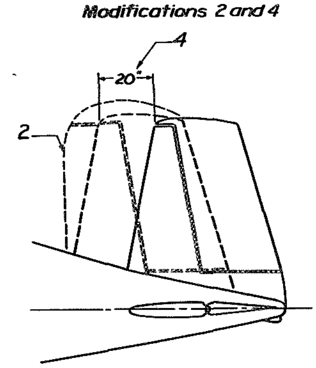
Modification 2



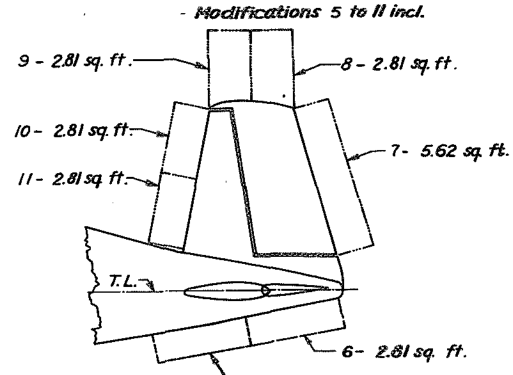
Modifications 2 and 3



Modifications 2 and 4



Modifications 5 to 11 incl.



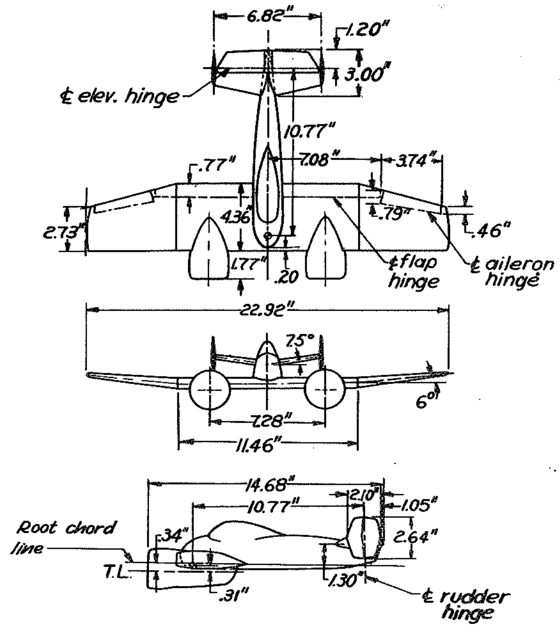
(Areas full scale)

1/22-SCALE MODEL OF THE GRUMMAN XF5F-1 AIRPLANE

Dimensional Data

(Full scale)

b, ft	42.00
L, ft	28.91
$\bar{c}$, in	88.60
S, sq ft	303.50
A	5.82
S_h, sq ft	54.20
S_e, sq ft	21.60
S_v, sq ft	30.20
S_r, sq ft	15.20
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	22 U, 15 D
δ_a, deg (1/2 stick)	9 U, 8 D
δ_f, deg	60 D
TDPF	1973×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	8,616
$x/\bar{c}$	0.234
$z/\bar{c}$	0.077
I_X, slug-ft^2	10,787
I_Y, slug-ft^2	7,174
I_Z, slug-ft^2	17,264
Test altitude, ft	10,000
μ (at sea level)	8.83
μ' (10,000 ft)	11.97

$\frac{I_X - I_Y}{mb^2}$ . . . . 76×10^{-4}

$\frac{I_Y - I_Z}{mb^2}$ . . . . -213×10^{-4}

$\frac{I_Z - I_X}{mb^2}$ . . . . 137×10^{-4}

Résumé of Model Test Results

In general, for all conditions tested with the normal control configuration for spinning the model spun steeply with a rate of descent exceeding 286 feet per second, full scale. The model generally would not spin with the elevator neutral or down or with the ailerons set against the spin. Results indicated that recoveries from all spins obtained would be satisfactory by rapid full rudder or elevator reversal.

Opening the cockpit or extending the landing gear with the cockpit open had no effect upon the spin and recovery characteristics of the model (data not presented).

SPIN DATA OBTAINED WITH THE $\frac{1}{22}$-SCALE MODEL OF THE GRUMMAN XF5F-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading															ΔI_X and ΔI_Z = 0.30 I_X								
Ailerons	Against, Full			Against, ½			Neutral			With, ½			With, Full			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N	D	U (b)	N	D	U (b)	N	D	U	N	D	U (a)	N	D	U (b)	N	D
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	---	No spin	No spin	----	No spin	No spin	---	No spin	No spin	No spin	No spin	No spin	--	No spin	No spin	--	No spin	No spin
ϕ, deg							---			----			---						--			--		
Ω, rps							---			----			---						--			--		
V, fps							---			----			200						--			--		
Turns for recovery							---			----			$1\frac{1}{4}$						--			--		

	ΔI_Y and ΔI_Z = 0.30 I_Y															c.g. moved forward 0.04c̄									c.g. moved back 0.04c̄								
Ailerons	Against, Full			Against, ½			Neutral			With, ½			With, Full			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U (b)	N (b)	D	U	N	D	U	N	D	U (a)	N	D	U (b)	N	D	U	N	D	U (a)	N	D	U (b)	N	D
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	--	No spin	No spin	---	---	No spin	50	42	No spin	No spin	No spin	No spin	--	No spin	No spin		No spin	No spin	No spin	No spin	No spin	---	No spin	No spin	--	No spin	No spin
ϕ, deg							--			---	---		5D	3D					--			---						---			--		
Ω, rps							--			---	---		0.40	0.50					--			---						---			--		
V, fps							--			---	---		198	211					--			---						---			--		
Turns for recovery							--			---	---		$1\frac{3}{4}$, [c]$\frac{3}{4}$, [d]∞	$1\frac{1}{2}$, [d]4					--			$1\frac{1}{4}$						---			$1\frac{1}{2}$		

	Flaps 60° down, cockpit open, normal loading									Landing condition, normal loading									Inverted spin, normal loading									Inverted spin ΔI_Y and ΔI_Z = 0.30 I_Y								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D	U	N	D	U (a)	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	--	No spin	No spin	46	42	No spin	No spin	No spin	No spin	--	No spin	No spin	47	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	36	31	No spin	No spin	No spin	No spin	34	No spin	No spin	44	36	32
ϕ, deg				--			6D	5D					--			6D									2D	2D					0			2D	3D	2D
Ω, rps				--			0.45	0.54					--			0.47									0.50	0.55					0.45			0.46	0.51	0.56
V, fps				--			171	173					--			162									200	213					228			188	198	211
Turns for recovery				--			2	2					--			2									2	$1\frac{3}{4}$					$\frac{3}{4}$			$2\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$

[a] Velocity too high to test.
[b] Oscillatory spin.
[c] Recovery attempted by simultaneous reversal of rudder and elevator.
[d] Recovery attempted by neutralizing rudder.

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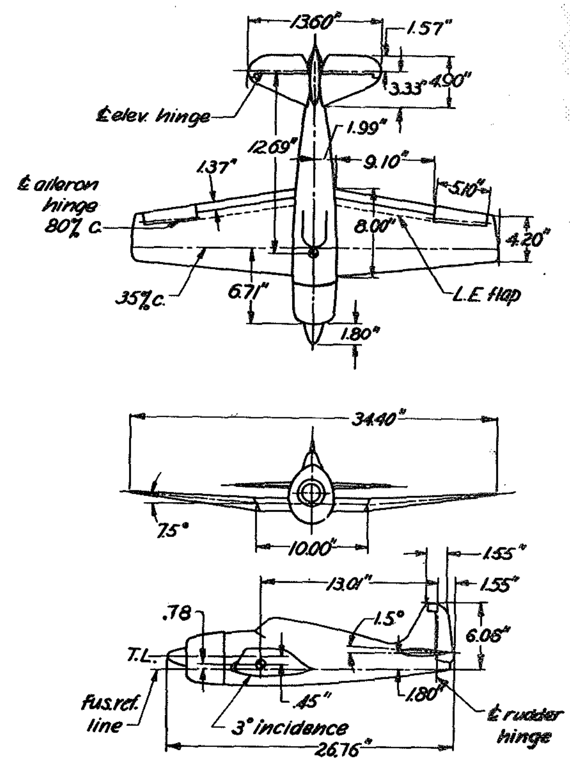
$\frac{1}{15}$-SCALE MODEL OF THE GRUMMAN XF6F-3 AND XF6F-1 AIRPLANES

Dimensional Data

(Full Scale)

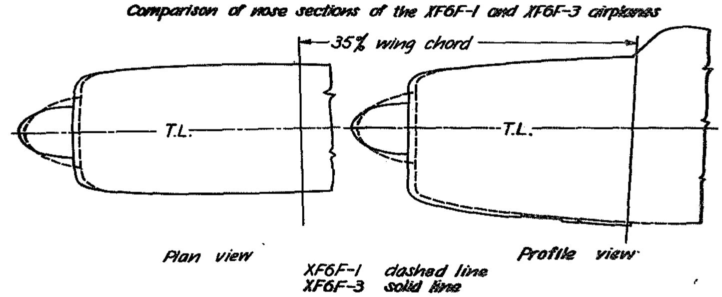
(Data are the same for both airplanes except where noted)

b, ft	42.83
L, ft	
XF6F-3 airplane	33.70
XF6F-1 airplane	33.52
$\bar{c}$, in.	97.40
S, sq ft	334.00
A	5.49
L.E. $\bar{c}$ aft L.E. c_r, in.	10.14
S_h, sq ft	76.70
S_e, sq ft	27.50
S_v, sq ft	23.40
S_r, sq ft	9.00
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	19 U, 15 D
δ_f, deg	50 D
TDPF	177×10^{-4}
Landing gear	Conventional



XF6F-3 Model

Comparison of nose sections of the XF6F-1 and XF6F-3 airplanes



The XF6F-1 and the XF6F-3 airplanes are dimensionally similar with the exception that the nose section of the XF6F-1 differed slightly from that of the XF6F-3 as shown on the comparison sketch.

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Mass Data

Normal Loading

	XF6F-3	XF6F-1
W, lb	11,087	10,558
$x/\bar{c}$	0.247	0.265
$z/\bar{c}$	0.093	0.094
I_X, slug-ft^2	8787	8860
I_Y, slug-ft^2	11,563	11,067
I_Z, slug-ft^2	19,950	19,337
Test altitude, ft	18,000	18,000
μ (at sea level)	10.10	9.64
μ' (18,000 ft)	17.69	16.91

	XF6F-3	XF6F-1
$\frac{I_X - I_Y}{mb^2}$	-44×10^{-4}	-36×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-131×10^{-4}	-137×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	175×10^{-4}	173×10^{-4}

Résumé of Model Test Results

For the XF6F-3 model in the clean condition, normal loading, normal control configuration for spinning, two types of spin were possible; recovery from the steeper of the two spins (α = approximately 25°) was satisfactory by rapid full rudder reversal, whereas recovery from the moderately flat spin (α = 44°) could only be obtained by simultaneous rapid full reversal of rudder and elevator. Unsatisfactory recoveries by rapid full rudder reversal were obtained for all other control settings except when the ailerons were against the spin and the elevator full up.

Extending or retracting the mass along the wings (ΔI_Y and $\Delta I_Z = 0.35\ I_X$, or $-0.30\ I_X$), extending or retracting the mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.25\ I_Y$, or $-0.07\ I_Y$), or a forward or rearward movement of the center of gravity $0.05\bar{c}$ from its normal position had no appreciable effect on the spin and recovery characteristics of the model.

Recoveries from spins with the model in the landing or take-off condition were slower than for the model in the clean condition. Satisfactory recoveries from inverted spins by rapid full rudder reversal were obtained only when the controls were together or neutral.

Raising the horizontal tail 12 inches, full scale (see sketch), improved the recovery characteristics of the model and recoveries were generally satisfactory from the aileron-against and aileron-neutral spins.

Installation of antispin fillets, vertical fin area below and to the rear of the fuselage, or the addition of area to the top of the fin and rudder (see sketches) did not appreciably alter the recovery characteristics of the model (data not presented).

Installation of a revised horizontal tail with decreased maximum elevator deflections of 26° up and 15° down had little effect on the recovery characteristics of the model.

Tests conducted with the XF6F-3 model ballasted and revised to conform to the XF6F-1 airplane showed similar spin and recovery characteristics as obtained with the XF6F-3 model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODEL OF THE GRUMMAN XF6F-3 AND XF6F-1 AIRPLANES

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the XF6F-3 model in the clean condition and recoveries were attempted by rapid full-reversal from right erect spins.]

Normal loading

Ailerons	Against			Neutral				With			
Elevator	U	N	D	U (a)	U (a)	N	D	$\frac{2}{3}$U	U	N	D
α, deg	---	52	50	44	25	48	48	44	46	47	45
∅, deg	---	1U	2U	2D	---	0	0	5D	1D	2D	2D
Ω, rps	---	0.54	0.55	0.44	---	0.54	0.56	0.44	0.49	0.54	0.56
V, fps	>312	198	193	210	>324	196	196	224	220	202	193
Turns for recovery	[bc]$1\frac{1}{4}$	$3\frac{3}{4}$	[cd]$5\frac{1}{2}$	[c]3 [ae]$1\frac{1}{2}$ [de]$2\frac{1}{4}$	[b]$1\frac{3}{4}$	$4\frac{1}{2}$	[d]5 [d]$5\frac{3}{4}$	$3\frac{1}{2}$ $4\frac{1}{4}$ [ef]2	[g]$3\frac{3}{4}$ [ch]$2\frac{1}{2}$ [ci]2	$3\frac{3}{4}$	[f]$4\frac{1}{2}$

ΔI_X and $\Delta I_Z = 0.35 I_X$

Ailerons	Against			Neutral			With		
Elevator	U	N (j)	D (j)	U	N	D	U (k)	N	D
α, deg	---	45	41	47	51	52	50	50	48
∅, deg	---	3U	3U	2D	0	0	3D	2D	2D
Ω, rps	---	0.54	0.56	0.44	0.54	0.56	0.44	0.54	0.55
V, fps	>312	212	212	223	196	198	215	201	196
Turns for recovery	[bc]$\frac{3}{4}$	3	[d]2	$2\frac{1}{2}$ $3\frac{1}{2}$	4	[d]$5\frac{1}{2}$	∞ [fe]$2\frac{1}{2}$	5	[f]$4\frac{1}{2}$ [f]$5\frac{1}{2}$

ΔI_X and $\Delta I_Z = -0.30 I_X$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (j)	N	D	U (kj)	N (j)	D
α, deg	24	54	52	40	48	49	42	42	---
∅, deg	2U	2U	2U	3D	0	0	7D	5D	---
Ω, rps	---	0.52	0.54	0.45	0.52	0.54	---	0.50	---
V, fps	276	190	182	224	196	190	252	224	>312
Turns for recovery	1 [de]$\frac{3}{4}$	6	∞	2 $2\frac{3}{4}$	$4\frac{1}{2}$	$6\frac{3}{4}$	2	2	[bf]$1\frac{1}{4}$

ΔI_Y and $\Delta I_Z = 0.25 I_Y$

Ailerons	Against			Neutral			With: 10°U, $7\frac{1}{2}$° D	With: Full		
Elevator	U (l)	N	D	U (j)	N	D	U (m)	U (m)	N	D (j)
α, deg	---	53	53	43	52	53	---	---	49	48
∅, deg	---	1U	1D	3D	0	0	---	---	3D	3D
Ω, rps	---	0.47	0.49	0.40	0.47	0.49	---	---	0.48	0.50
V, fps	---	193	187	229	196	190	281	---	212	198
Turns for Recovery	---	5 $6\frac{1}{4}$	[d]$9\frac{3}{4}$	$2\frac{3}{4}$	5 $5\frac{3}{4}$	[d]$6\frac{3}{4}$ [d]8	[c]$2\frac{1}{4}$	---	4	[d]5

ΔI_Y and $\Delta I_Z = -0.07 I_Y$

Ailerons	Against			Neutral			With		
Elevator	U	N (j)	D (j)	U (j)	N	D	U	N	D
α, deg	23	48	44	44	48	47	46	48	47
∅, deg	2U	2U	3U	0	0	1U	5D	2D	2D
Ω, rps	--	0.54	0.58	0.46	0.55	0.58	0.46	0.55	0.57
V, fps	293	207	202	221	198	204	224	196	202
Turns for Recovery	[c]1	3	[cd]$2\frac{3}{4}$ [d]$3\frac{1}{4}$	$2\frac{3}{4}$	$4\frac{1}{4}$	[d]$3\frac{3}{4}$	$4\frac{3}{4}$	4	[f]$4\frac{1}{4}$

c.g. moved forward $0.05\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (j)	N	D	U	N	D (j)
α, deg	25	49	48	37	50	50	45	47	45
∅, deg	1U	1U	1U	3D	1D	1D	5D	3D	3D
Ω, rps	---	0.55	0.57	---	0.56	0.57	0.47	0.56	0.58
V, fps	305	198	196	243	198	198	218	204	212
Turns for Recovery	$1\frac{1}{4}$	$3\frac{3}{4}$	5	2	4	[d]5	>4	$3\frac{3}{4}$ $4\frac{1}{2}$	[f]$3\frac{3}{4}$ [f]$4\frac{1}{2}$

c.g. moved back $0.05\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U (m)	N	D	U	N	D	U (n)	N	D
α, deg	---	50	49	47	50	49	47	48	48
∅, deg	---	2U	2U	1D	1U	0	4D	3D	2D
Ω, rps	---	0.50	0.52	0.41	0.50	0.54	0.43	0.50	0.53
V, fps	---	196	193	226	196	196	235	198	198
Turns for Recovery	---	$3\frac{3}{4}$	[d]$4\frac{3}{4}$ [d]6	$2\frac{3}{4}$ [c]$3\frac{1}{2}$	$4\frac{1}{4}$	[d]6	>6	$4\frac{1}{2}$	[f]5

Landing (or take-off) condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (l)	N	D	U (o)	N	D	U (o)	N	D
α, deg	--	46	43	--	48	47	--	43	43
∅, deg	--	0	0	--	1D	1D	--	4D	3D
Ω, rps	--	0.54	0.56	--	0.54	0.58	--	0.55	0.58
V, fps	--	182	182	--	190	184	--	190	187
Turns for Recovery	--	$6\frac{1}{2}$	$6\frac{1}{2}$	--	$4\frac{3}{4}$ $5\frac{3}{4}$	9	--	$4\frac{1}{2}$	$5\frac{1}{2}$

Inverted spins, normal loading, recovery by neutralizing the rudder

Ailerons	Against			Neutral			With		
Elevator	U (l)	N	D	U	N	D	U	N	D
α, deg	--	No spin	No spin	43	42	No spin	52	44	34
∅, deg	--			0	1D		3D	2D	3D
Ω, rps	--			0.47	----		0.43	0.55	---
V, fps	--			232	293		218	229	281
Turns for Recovery	--			>2 [p]$\frac{3}{4}$	$1\frac{1}{4}$		>3 [p]>2	[r]$2\frac{1}{2}$	$2\frac{1}{2}$

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[a]Two types of spin.
[b]Recovery attempted before final steeper altitude was attained.
[c]Visual observation.
[d]Goes into inverted flight after recovery from erect spins.
[e]Recovery by simultaneous full reversal of rudder and elevator.
[f]Goes into inverted spin after recovery from erect spin.
[g]Recovery attempted by reversing rudder from full-with to 2/3 against the spin.
[h]Recovery attempted by simultaneously reversing rudder to 2/3 against spin and neutralizing elevator.
[i]Recovery attempted by simultaneously reversing rudder to 2/3 against spin and moving elevator to full down.
[j]Steeper type of spin also possible.
[k]Oscillatory spin.
[l]Steep spin at high velocity
[m]Steep, wandering, and violently oscillatory spin.
[n]Wandering and oscillatory spin.
[o]Two types of spin possible; moderately flat spin similar to elevator-spin, and steep, wandering, and violently oscillatory, also possible.
[p]Recovery attempted by full rudder reversal.
[q]Wandering spin.
[r]Steeper type of spin similar to that with elevator neutral also possible.

SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODEL OF THE GRUMMAN XF6F-3 AND XF6F-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the XF6F-3 model in the clean condition and recoveries were attempted by rapid full-reversal from right erect spins]

	Horizontal tail raised 12 inches, normal loading										
Ailerons	Against				Neutral			With			
	Full			6°U 5°D				6°U 5°D	Full		
Elevator	U (q)	N	D	U (n)	U (nr)	N	D	U (n)	U	N	D
α, deg	26	26	30	---	33	26	28	39	46	42	25
φ, deg	3U	4U	4U	---	3D	1D	0	4D	5D	4D	3D
Ω, rps	---	0.67	0.67	---	---	0.68	0.67	---	0.42	0.65	0.69
V, fps	311	266	254	287	270	272	258	243	220	269	258
Turns for recovery	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$ 2	2	3 [de]$1\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{3}{4}$ 3	$>3\frac{3}{4}$ [e]$2\frac{1}{4}$	$2\frac{1}{4}$	[f]$2\frac{1}{2}$

	Revised horizontal tail, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (k)	N	D	U	N	D (k)
α, deg	25	48	44	---	43	46	41	48	---
φ, deg	0	2U	2U	---	1D	0	5D	3D	---
Ω, rps	---	--	0.53	---	0.52	0.54	--	---	---
V, fps	305	206	201	---	201	201	240	206	---
Turns for recovery	1	$4\frac{1}{4}$	[d]$3\frac{3}{4}$	---	4	[d]5	[c]4	$3\frac{1}{4}$	---

	XF6F-1 revised horizontal tail, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (k)	N	D	U (n)	N	D (j)
α, deg	25	49	51	---	49	50	47	44	47
φ, deg	2U	2U	1U	---	1D	1D	6D	3D	3D
Ω, rps	---	0.50	0.52	---	0.51	0.53	---	0.50	---
V, fps	305	204	198	---	212	201	240	209	204
Turns for recovery	1	4	[d]$4\frac{1}{4}$	---	$4\frac{1}{2}$	[d]$5\frac{1}{4}$	$>1\frac{1}{4}$	$3\frac{3}{4}$	$5\frac{1}{4}$

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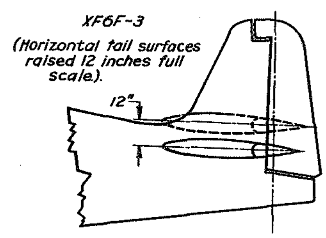
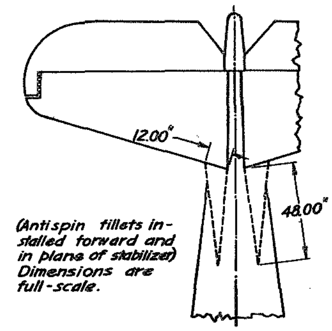
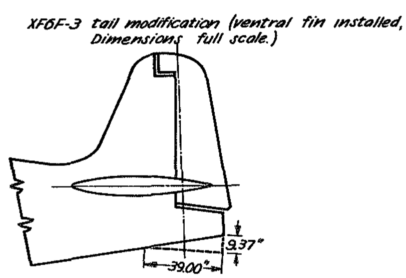
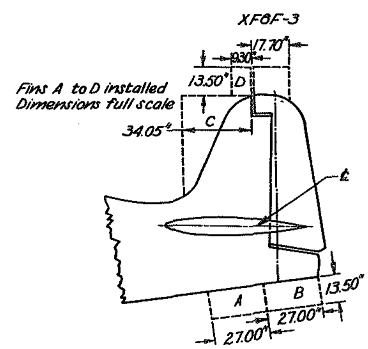
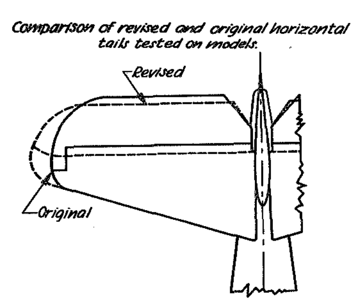
[c]Visual observation.
[d]Goes into inverted flight after recovery from erect spins.
[e]Recovery by simultaneous full reversal of rudder and elevator.
[f]Goes into inverted spin after recovery from erect spin.
[j]Steeper type of spin also possible.
[k]Oscillatory spin.
[n]Wandering and oscillatory spin.
[p]Recovery attempted by full rudder reversal.
[q]Wandering spin.
[r]Steeper type of spin similar to that with elevator neutral also possible.











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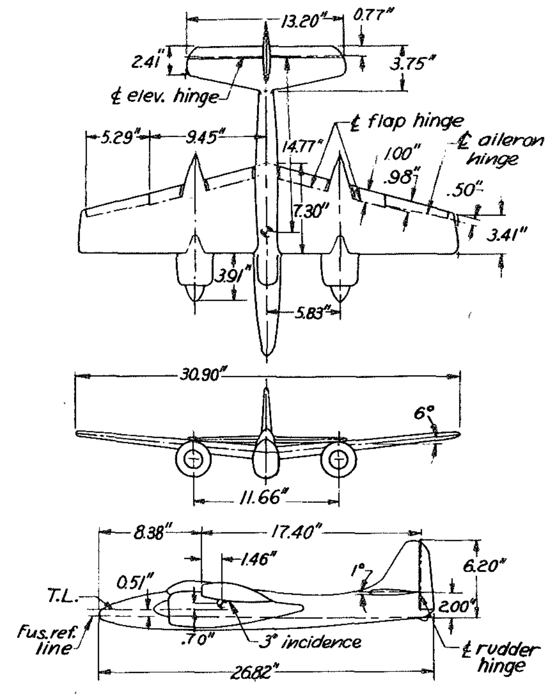
$\frac{1}{20}$-SCALE MODEL OF THE GRUMMAN XF7F-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	51.50
L, ft	44.71
$\bar{c}$, in.	111.65
S, sq ft	455.00
A	5.83
L.E. $\bar{c}$ aft L.E. c_r, in.	0
S_h, sq ft	108.80
S_e, sq ft	36.60
S_v, sq ft	53.80
S_r, sq ft	21.40
δ_r, deg	30 R, 30 L
δ_e, deg	20 U, 20 D
δ_a, deg	20 U, 18 D
δ_f, deg	40 D
TDPF	449×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

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Normal Loading

W, lb	17,777
$x/\bar{c}$	0.262
$z/\bar{c}$	0.126
I_X, slug-ft^2	40,087
I_Y, slug-ft^2	25,595
I_Z, slug-ft^2	64,151
Test altitude, ft	15,000
μ (at sea level)	9.91
μ' (15,000 ft)	16.21

$\frac{I_X - I_Y}{mb^2}$	99×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-263×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	164×10^{-4}

Résumé of Model Test Results

In the normal loading, clean condition, and normal control configuration for spinning, the spin of the model was oscillatory in pitch and rate of rotation, and recovery by rapid full rudder reversal alone was not satisfactory. The turns for recovery apparently varied with the phase of oscillation during which the rudder was reversed. Aileron-against settings expedited recoveries, whereas aileron-with settings retarded recoveries. Recovery by reversal of the elevator from full up to full down in conjunction with rudder reversal led to satisfactory recoveries for all aileron settings. The results indicate that incomplete rudder or elevator reversal would have a detrimental effect upon recovery.

Extending or retracting the mass along the wings (ΔI_X and $\Delta I_Z = \pm 0.20\ I_X$), extending or retracting the mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.20\ I_Y$ or $-0.09\ I_Y$), or a forward or rearward movement of the center of gravity $0.10\bar{c}$ from its normal position had no appreciable effects upon the recovery characteristics of the model.

Results obtained for the model in the landing or take-off condition (flaps deflected 40°, landing gear extended, and landing-gear doors open) generally were quite similar to corresponding spins for the clean condition.

Increasing the vertical tail area (modifications 1 and 2), adding an antispin sail (modifications 3 and 4), adding a dorsal fin (modification 5), or eliminating the wing duct entrances on the leading edge of the wing (data not presented) did not appreciably alter the spin and recovery characteristics of the model.

The model would not spin inverted for any control configuration (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE GRUMMAN XF7F-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

Normal loading

Ailerons	Against Full	Against Full	Against Full	Against 1/4	Against 1/4	Neutral	Neutral	Neutral	Neutral	With 1/4	With 1/3	With 1/3	With 1/2	With Full	With Full	With Full	With Full
Elevator	U (a)	N	D	U (a)	N	U (b)	N (a)	1/4 D	D	N	U (b)	2/3 U (b)	N (b)	U (b)	N (b)	D (bc)	
α, deg	----	No spin	No spin	----	No spin	----	----	No spin	No spin	----	15 35	19 45	----	14 38	22 45	27 41	No spin
φ, deg	----			----		----	----			----	5D 14U	9D 4U	----	20D 3U	9D 4U	9D 0	
Ω, rps	----			----		----	----			----	0.56	---	----	0.53	0.50	0.44	
V, fps	>304			>304		304	>311			>304	304	255	258	258	252	245	
Turns for recovery	[d]1/2			[de]1/2		1 >3 1/2	[d]1/4			[e]3/4	1 1/2 >3 1/4	1 1/2 >[e]2 1/2	[e]2 1/2 4	>8	1 1/2 3 4 1/2	2,6	

Turns for recovery obtained by different control manipulations from rudder-with spins for the normal loading condition

Ailerons	Against	Neutral	With
Elevator	U (a)	U (b)	U (b)
Simultaneous reversal of rudder and elevator	[d]1/4	3/4	2
Simultaneous reversal of rudder and neutralization of elevator	[d]1/2	1/2	>4
Simultaneous neutralization of rudder and elevator	[d]1/2 1	>1 1/2	>5
Reversal of elevator	[de]1, 1 1/2	1	2,>2 1/2
Neutralization of elevator	[de]3/4 > 3/4	>2 1/2	∞
Neutralization of rudder	[d]>1	>4	>5

ΔI_X and $\Delta I_Z = 0.20 I_X$

Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With 1/3	With Full	With Full	With Full
Elevator	U (a)	N	D	U (b)	N (a)	D	U	U (b)	N (b)	D
α, deg	----	No spin	No spin	----	----	No spin	--	21 59	32 41	No spin
φ, deg	----			----	----		--	7D 19U	6D	
Ω, rps	----			----	----		--	0.56	0.46	
V, fps	>304			257	>304		--	245	239	
Turns for recovery	[d]1/2			1 1/4	[d]3/4		[e]1 3/4	[d]>8	2 [e]4 1/2	

ΔI_X and $\Delta I_Z = -0.20 I_X$

Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With 1/3	With Full	With Full	With Full	With Full
Elevator	U (a)	N	D	U (a)	N (a)	D	U (b)	U (b)	N (b)	D (bc)	D (b)
α, deg	----	No spin	No spin	----	----	No spin	22 49	----	16 30	18 42	No spin
φ, deg	----			----	----		16D 6U	----	11D 2U	8D 1U	
Ω, rps	----			----	----		0.51	----	0.44	0.48	
V, fps	>304			>298	>298		304	245	252	271	
Turns for recovery	[d]1/2			[d]1/2 1 1/2	[d]1/4 3/4		2	>3 1/2	1 2	1/2 1 3/4	

ΔI_Y and $\Delta I_Z = 0.20 I_Y$

Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With 1/3	With Full	With Full	With Full
Elevator	U (a)	N	D	U (b)	N (b)	D	U	U (b)	N (b)	D (b)
α, deg	----	No spin	No spin	12 37	14 24	No spin	--	19 46	17 42	35 47
φ, deg	----			11D 2D	5D 4U		--	7U 14D	16D 0	11D 0
Ω, rps	----			0.44	----		--	0.34	0.42	0.46
V, fps	>304			298	294		--	258	265	272
Turns for recovery	[d]1/2			1 1/2 >1 1/2	1/2 2 1/2		1 1/4	>4	1 1/2 2	2 1/2

ΔI_Y and $\Delta I_Z = -0.09 I_Y$

Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With 1/3	With Full	With Full	With Full
Elevator	U (a)	N	D	U (a)	N (a)	D	U	U (b)	N (b)	D
α, deg	----	No spin	No spin	----	----	No spin	---	24	24 48	No spin
φ, deg	----			----	----		---	13D 3D	12D 1D	
Ω, rps	----			----	----		---	0.51	0.48	
V, fps	>304			>304	>304		---	245	252	
Turns for recovery	[d]1/4			[d]1	[d]1/2		[f]1 1/2 [e]2 1/4	>4	2 3/4	

c.g. moved forward $0.10\bar{c}$

Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With 1/3	With Full	With Full	With Full
Elevator	U (a)	N	D	U (a)	N (a)	D	U (b)	U (b)	N	D
α, deg	----	No spin	No spin	----	----	No spin	18 45	15 39	33	43
φ, deg	----			----	----		14D 4U	0	5D	2D
Ω, rps	----			----	----		0.54	0.49	0.46	0.47
V, fps	>304			>304	>304		273	273	273	235
Turns for recovery	[d]1/2			[df]1/2	[d]1 [d]1/2		>1	>4 1/2	2 1/2 7	3 1/2 ∞

c.g. moved back $0.10\bar{c}$

Ailerons	Against	Against	Against	Neutral	Neutral	Neutral	With 1/3	With Full	With Full	With Full
Elevator	U (a)	N (a)	D	U (b)	N (b)	D	U (b)	U (b)	N (b)	D (b)
α, deg	----	----	No spin	17 36	14 33	No spin	11 53	23 43	53	39 51
φ, deg	----	----		6D 10U	5D 5U		13D 6U	8D 1U	10D 0	4D
Ω, rps	----	----		----	0.36		0.34	0.35	0.37	0.38
V, fps	>304	>298		290	288		291	239	223	226
Turns for recovery	[d]1/2	[d]1/2		1 1/4	1 1/2 2 1/2		2 >2	>5	5 >7	10

[a]Steep spin.
[b]Oscillatory spin. Range of values or average values given.
[c]Two conditions possible.
[d]Recoveries attempted before final steep attitude was attained.
[e]Visual observation.
[f]Model recovers in a spiral.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE GRUMMAN XF7F-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Landing condition, normal loading

Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full		
Elevator	U	N	D	U (b)	N (b)	D	U (b)	U (b)	N	D (b)
α, deg				19 30	21 33		22 33	22 50	28 39	32 47
ø, deg	No spin	No spin	No spin	3D	3D	No spin	5D	16D 15U	4D	3D
Ω, rps				0.48	0.49		0.45	0.42	0.43	0.47
V, fps				264	255		265	226	220	220
Turns for recovery				$2\frac{1}{2}$ $4\frac{1}{2}$	$1\frac{1}{2}$ 3		>4	>7	2 5	5 >8

Flaps down 40°, normal loading

Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full		
Elevator	U (b)	N	D	U (b)	N (b)	D	U (b)	U (b)	N (b)	D
α, deg	----			19 35	23 32		22 44	20 37	39 50	43
ø, deg	----	No spin	No spin	6D	4D	No spin	10D 5U	2D 16D	8D 2U	4D
Ω, rps	----			0.45	0.48		0.44	0.41	0.40	0.45
V, fps	332			239	265		258	247	232	220
Turns for recovery	$1\frac{1}{4}$			$1\frac{1}{4}$ >3	$1\frac{3}{4}$ 4		>5	>9	>5	$3\frac{1}{2}$ >7

Modification 1, normal loading

Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full		
Elevator	U (a)	N	D	U (b)	N (b)	D	U (b)	U (b)	N (b)	D
α, deg	----			20 54	----		21 55	33 52	24 39	
ø, deg	----	No spin	No spin	11D 4U	----	No spin	11D 3U	12D 0	90 2U	No spin
Ω, rps	----			0.36	----		0.39	0.40	0.45	
V, fps	>304			272	278		248	238	238	
Turns for recovery	[d]$\frac{1}{2}$			$\frac{1}{2}$ 1	$\frac{1}{2}$ 1		[e]2	2 [e]$2\frac{1}{2}$	$1\frac{1}{2}$ [e]2	

Modification 2, normal loading

Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full		
Elevator	U (a)	N	D	U (a)	N	D	U (a)	U (b)	N (b)	D (b)
α, deg	----			----	----		----	36	29 40	24 40
ø, deg	----	No spin	No spin	----	----	No spin	----	10D 1D	5D	10D 3U
Ω, rps	----			----	----		----	0.38	0.44	0.47
V, fps	>304			>304	>304		----	243	248	232
Turns for recovery	[d]$\frac{1}{4}$			[d]$\frac{1}{2}$ $1\frac{1}{2}$	[d]$\frac{1}{2}$ 1		[de]$1\frac{1}{2}$ $1\frac{3}{4}$	[e]>$2\frac{1}{2}$	$1\frac{1}{2}$ $1\frac{3}{4}$	2 $2\frac{1}{2}$

Modification 3, normal loading

Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full		
Elevator	U (a)	N	D	U (a)	N (a)	D	U (b)	U (b)	N (b)	D
α, deg	----			----	----		----	14 31	19 56	
ø, deg	----	No spin	No spin	----	----	No spin	----	9D 2U	14D 2U	No spin
Ω, rps	----			----	----		----	0.47	0.55	
V, fps	>304			>304	>304		291	252	252	
Turns for recovery	[d]$\frac{3}{4}$			[df]$\frac{1}{2}$ [e]1	[d]$\frac{1}{2}$		>2	>3	$1\frac{1}{2}$ 2	

Modification 4, normal loading

Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full		
Elevator	U (a)	N	D	U (a)	N (a)	D	U (b)	U (b)	N	D
α, deg	----			----	----		---	----	31 40	
ø, deg	----	No spin	No spin	----	----	No spin	---	----	12D 2D	No spin
Ω, rps	----			----	----		---	----	0.44	
V, fps	>304			>304	>304		339	245	248	
Turns for recovery	[d]$\frac{1}{4}$			[d]$\frac{1}{2}$ >1	[d]$\frac{1}{2}$		[ef]>1	>3	2	

Modification 1 and 3, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (b)	N (a)	D	U (b)	N (b)	D
α, deg	---			19 55	---		21 50	24 39	
ø, deg	---	No spin	No spin	8D 2U	---	No spin	12D 12U	7D 2U	No spin
Ω, rps	---			0.47	---		0.47	0.49	
V, fps	>304			304	>304		245	250	
Turns for recovery	[d]$\frac{1}{4}$			$1\frac{1}{2}$	[d]$\frac{1}{2}$		$1\frac{1}{2}$ >$2\frac{1}{4}$	$1\frac{1}{2}$ $2\frac{1}{4}$	

[a]Steep spin.
[b]Oscillatory spin. Range of values or average values given.
[d]Recoveries attempted before final steep attitude was attained.
[e]Visual observation.
[f]Model recovers in a spiral.

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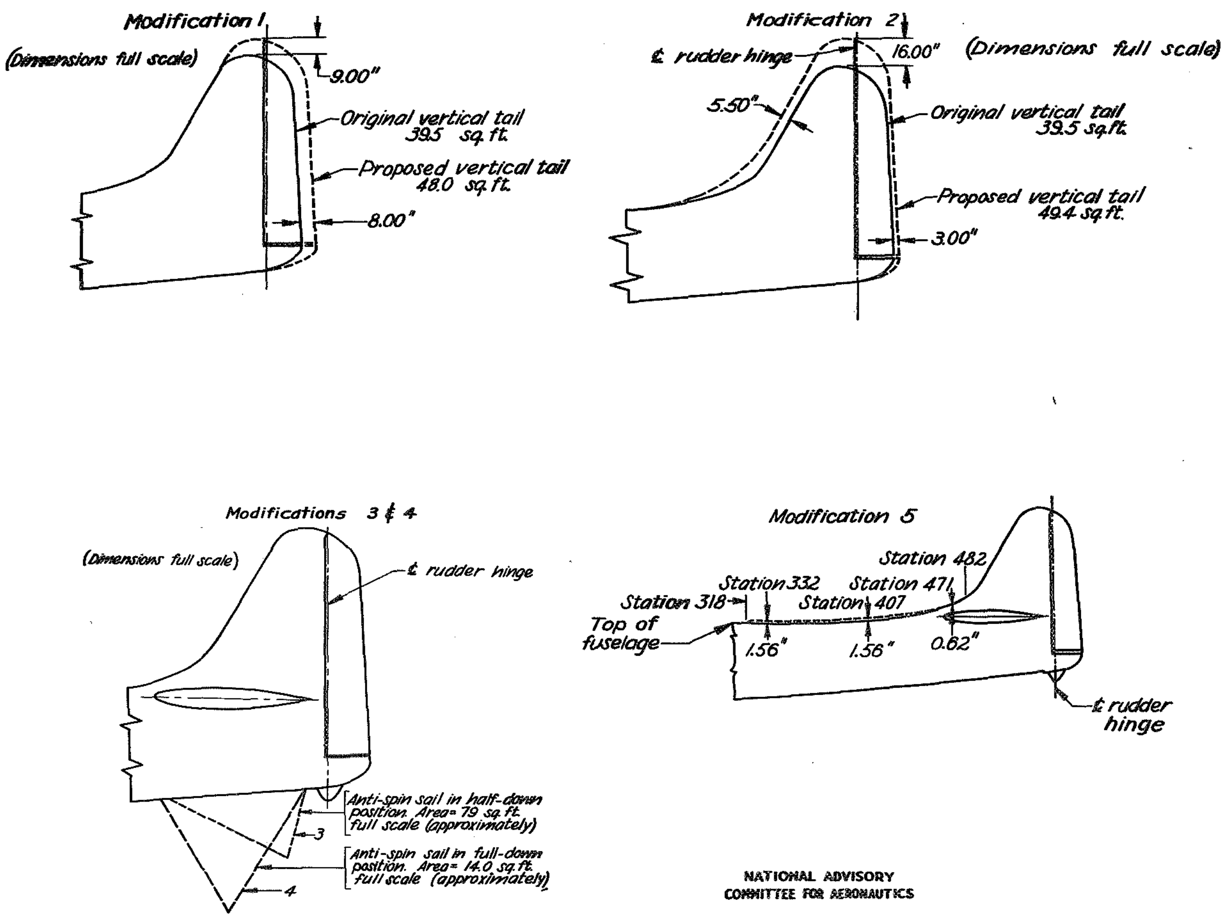
Modification 1
(Dimensions full scale)
9.00"
Original vertical tail 39.5 sq ft
Proposed vertical tail 48.0 sq ft
8.00"
Modification 2
℄ rudder hinge
16.00"
(Dimensions full scale)
5.50"
Original vertical tail 39.5 sq ft
Proposed vertical tail 49.4 sq ft
3.00"
Modifications 3 & 4
(Dimensions full scale)
℄ rudder hinge
Anti-spin sail in half-down position. Area= 79 sq ft full scale (approximately)
3
Anti-spin sail in full-down position. Area= 14.0 sq ft full scale (approximately)
4
Modification 5
Station 482
Station 332
Station 471
Station 318
Station 407
Top of fuselage
1.56"
1.56"
0.62"
℄ rudder hinge
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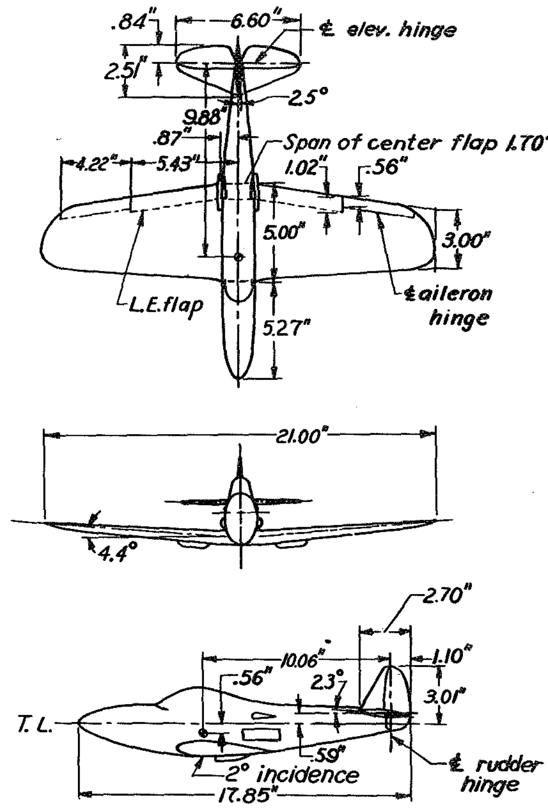
$\frac{1}{20}$-SCALE MODEL OF THE BELL XFL-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	35.00
L, ft	29.76
$\bar{c}$, in.	83.16
S, sq ft	232
A	5.28
L.E. $\bar{c}$ aft L.E. c_r, in.	4.29
S_h, sq ft	30.46
S_e, sq ft	12.02
S_v, sq ft	14.36
S_r, sq ft	8.03
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 15 D
δ_a, deg	25 U, 10 D
δ_f, deg	45 D
TDPF	175×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	6212
$x/\bar{c}$	0.290
$z/\bar{c}$	0.135
I_X, slug-ft^2	2750
I_Y, slug-ft^2	4560
I_Z, slug-ft^2	6890
Test altitude, ft	8000
μ (at sea level)	10.00
μ' (8000 ft)	12.72

$\frac{I_X - I_Y}{mb^2}$	-77×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-97×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	174×10^{-4}

Résumé of Model Test Results

The fin offset of $2\frac{1}{4}^{\circ}$, leading edge displaced to the left provided effectively more right rudder than if the model had no fin offset. The results are presented only for right spins which were slightly flatter with slower recoveries than corresponding left spins.

For the clean condition, normal loading, normal control configuration for spinning, the model spun at a moderately flat angle of attack ($\alpha = 47^{\circ}$) and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{3}{4} \text{ turns}\right)$. Moving the elevator down before the rudder was completely reversed, or merely neutralizing the rudder, gave slower recoveries.

Extending the landing gear alone had little effect upon the recovery characteristics of the model for aileron-neutral spins. For the model in the landing condition (landing gear extended, flaps down 45°) or take-off condition (landing gear extended, flaps down 20°) recoveries by rapid full rudder reversal were satisfactory for the normal-spinning control configuration.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL XFL-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal Loading														
Ailerons	Against, Full			Against, $\frac{1}{2}$			Neutral			With	With, $\frac{1}{2}$		With, Full		
Elevator	U	N	D	U	N	D	U	N	D	U	N (a)	D (a)	U (b)	N (b)	D (a)
α, deg	53	47	47	48	37	39	47	39	39	No spin	--	--	--	--	--
ϕ, deg	2U	2U	2U	1U	1U	3U	3D	1D	0		--	--	--	--	--
Ω, rps	0.35	0.44	0.46	0.34	0.44	0.48	0.34	0.44	0.46		--	--	--	--	--
V, fps	177	181	180	189	202	202	189	202	194		--	--	--	--	--
Turns for recovery	$1\frac{3}{4}$	$2\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$						
	---	---	---	---	---	---	[c]$2\frac{1}{2}$	[d]$3\frac{1}{2}$	[d]∞		--	--	--	--	--
	[c]$3\frac{1}{2}$	---	---	---	---	---	[d]$2\frac{1}{2}$	---	---						

	Normal loading, rudder neutral spins								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N (a)	D	U	N	D
α, deg	No spin	37	44	No spin	--	--	No spin	No spin	No spin
ϕ, deg		2U	0		--	--			
Ω, rps		0.46	0.46		--	--			
V, fps		202	181		--	210			
Turns for recovery		---	---		--	---			

Effect of mass variations and c.g. movements on turns for recovery			
Ailerons	Neutral		
Elevator	U	N	D
ΔI_X and ΔI_Z = $0.20\,I_X$	$1\frac{1}{2}$	--	$2\frac{1}{2}$
ΔI_X and ΔI_Z = $-0.17\,I_X$	--	$\frac{3}{4}$	$1\frac{1}{4}$
ΔI_Y and ΔI_Z = $0.20\,I_Y$	--	--	$1\frac{3}{4}$
ΔI_Y and ΔI_Z = $-0.20\,I_Y$	$1\frac{1}{2}$	$2\frac{1}{4}$	3
c.g. moved forward $0.05\bar{c}$	--	--	$2\frac{1}{4}$
c.g. moved back $0.05\bar{c}$	--	$1\frac{1}{2}$	$1\frac{1}{2}$

	Landing gear extended, normal loading				Landing condition, normal loading									Take-off condition, normal loading			Inverted spin, normal loading					
Ailerons	Neutral				Against			Neutral			With			Neutral			Against		Neutral		With	
Elevator	U (b)	N (e)	N (e)	D	U	N	D	U	N	D	U	N	D	U	N	D	U	D	U	D	U (f)	D (a)
Turns for recovery	--	$1\frac{3}{4}$	$\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$6\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{3}{4}$	4	$1\frac{1}{2}$	2	2	$1\frac{1}{2}$	$3\frac{1}{4}$	$5\frac{1}{2}$	$\frac{1}{4}$	1	$1\frac{1}{2}$	1	---	---

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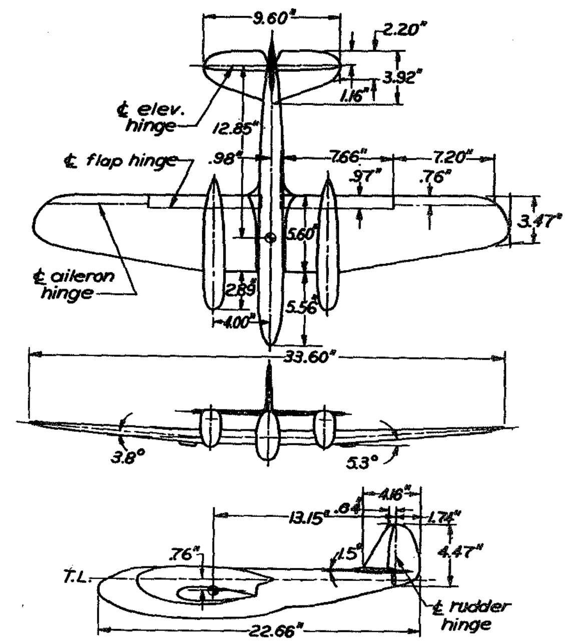
[a]Velocity too high to test.
[b]Too wandering to test.
[c]Recovery attempted by simultaneous reversal of rudder and elevator.
[d]Recovery attempted by neutralization of the rudder.
[e]Two types of spins.
[f]Wandering and oscillatory spin.

1/25-SCALE MODEL OF THE BELL YFM-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	70.00
L, ft	47.16
$\bar{c}$, in.	124.32
S, sq ft	688.00
A	7.12
L.E.$\bar{c}$ aft L.E.c_r	15.08
S_h, sq ft	115.26
S_e, sq ft	37.87
S_v, sq ft	46.83
S_r, sq ft	25.99
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 15 D
δ_a, deg	25 U, 10 D
δ_f, deg	45 D
TDPF	111×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	18,125
$x/\bar{c}$	0.318
$z/\bar{c}$	0.153
I_X, slug-ft^2	39,600
I_Y, slug-ft^2	22,800
I_Z, slug-ft^2	58,400
Test altitude, ft	14,000
μ (at sea level)	4.93
μ' (14,000 ft)	7.60

$\frac{I_X - I_Y}{mb^2}$	61×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-129×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	68×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, the model would spin only with the elevator full up. The model would continue to spin after recovery was attempted by rapid full rudder reversal, but satisfactory recoveries were obtained either by simultaneous rapid full reversal of both rudder and elevator or by a rapid full reversal of the elevator alone (data not presented). With the rudder set against the rotation the model spun in an oscillatory manner when the elevator was full up but would not spin when the elevator was 15° up (data not presented).

With the mass extended along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$, or with the center of gravity moved forward $0.05\bar{c}$ or rearward $0.10\bar{c}$ from its normal position, the spin and recovery characteristics of the model were similar to those obtained for the normal loading, clean condition.

With the mass extended along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.50\ I_Y\right)$ the model would spin for more control settings and with a more oscillatory motion than for the normal loading condition. Recoveries by rapid full rudder reversal were in general similar to those for the normal loading condition.

With the mass extended along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_Y\right)$, and the center of gravity moved rearward $0.10\bar{c}$ from its normal position, the aileron-against and aileron-neutral spins were similar to the corresponding spin for the normal loading, clean condition. With the ailerons set full with the spin, the elevator-up spin was extremely steep and the elevator neutral or down spins moderately steep with marginal recoveries.

For the landing condition (flaps 45° down and landing gear extended), the spinning characteristics of the model were similar to those obtained for the clean condition.

In order to obtain a no-spin condition when the elevator was full up and the rudder was against the spin (normal loading, clean condition), areas were added separately to the vertical and horizontal tail surfaces (see sketches). Adding area F to the vertical tail produced the desired condition, whereas the other areas had no appreciable effect (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{25}$-SCALE MODEL OF THE BELL YFM-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading											ΔI_X and $\Delta I_Z = 0.30\ I_X$									ΔI_Y and $\Delta I_Z = 0.50\ I_Y$								
	Against							With																					
Ailerons	Full			$\frac{1}{2}$	Neutral			$\frac{1}{2}$	Full			Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D	U	U	N	D	U	U	N	D	U (a)	N	D	U	N	D	U	N	D	U	N (d)	D	U	N (d)	D (d)	U	N	D
α, deg	----	No spin	No spin	28	31	No spin	No spin	32	37	No spin	No spin	---	No spin	No spin	30	No spin	No spin	39	No spin	No spin	28	----	No spin	30	----	----	40	38	38
ϕ, deg	----			6U	1D			4D	5D			---			1D			4D			0	----		2D	----	----	7D	4D	3D
Ω, rps	----			0.38	0.38			0.36	0.35			---			0.35			0.35			0.36	----		0.33	----	----	0.28	0.40	0.39
V, fps	----			273	268			255	234			---			250			220			273	----		261	----	----	239	230	216
Turns for recovery	∞ $^{b}\frac{1}{2}$			$^{c}\infty$	$^{c}\infty$ $^{b}\frac{1}{2}$			$^{c}\infty$	$^{c}\infty$ $^{b}\frac{3}{4}$			---			$^{c}\infty$			$^{c}\infty$			$^{c}\infty$	----		$^{c}\infty$	----	----	$^{c}\infty$	$2\frac{1}{2}$	2

	c.g. moved forward $0.03\bar{c}$									c.g. moved back $0.10\bar{c}$									ΔI_Y and $\Delta I_Z = 0.30\ I_Y$ c.g. moved back $0.10\bar{c}$							Landing condition, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against		Neutral		With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U (d)	N	D	U (d)	N	D	U	N (d)	D	N (de)	D	N (e)	D (e)	U (e)	N	D	U (ad)	N	D	U (ad)	N	D	U	N	D
α, deg	26	No spin	No spin	30	No spin	No spin	37	No spin	No spin	---	No spin	No spin	---	No spin	No spin	36	---	No spin	----	No spin	----	----	---	36	37	----	No spin	No spin	----	No spin	No spin	37	No spin	No spin
ϕ, deg	3U			0			4D			---			---			7D	---		----		----	----	---	5D	4D	----			----			6U		
Ω, rps	0.36			0.38			0.36			---			---			0.27	---		----		----	----	---	0.40	0.39	----			----			0.37		
V, fps	286			262			236			---			---			239	---		----		----	----	---	239	220	----			----			216		
Turns for recovery	$^{c}\infty$			$^{c}\infty$			$^{c}\infty$			---			---			$^{c}\infty$	---		----		----	----	---	2	$2\frac{1}{4}$	----			----			$^{c}\infty$		

[a] Wandering spin.
[b] Recovery attempted by simultaneous reversal of rudder and elevator.
[c] Model goes into a very oscillatory spin when rudder moves.
[d] Model too oscillatory to test.
[e] Velocity too high to test.

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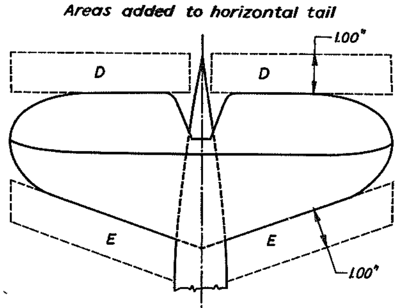
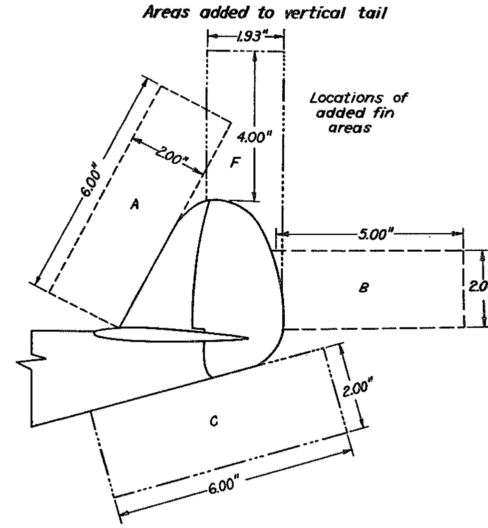
Areas added to horizontal tail



Areas added to vertical tail

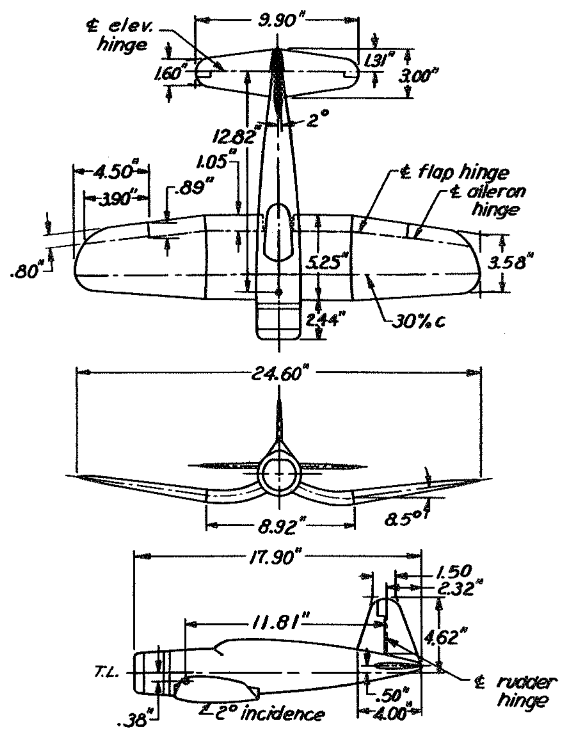


$\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF4U-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	41.00
L, ft	31.91
$\bar{c}$, in.	96.36
S, sq ft	314.00
A	5.36
L.E. $\bar{c}$ aft L.E. c_r, in. .	2.65
S_h, sq ft	61.40
S_e, sq ft	26.90
S_v, sq ft	25.70
S_r, sq ft	14.70
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 30 D
δ_a, deg	20 U, 10 D
δ_f, deg (landing condition) .	60D
δ_a, deg (landing condition) .	10D
TDPF	272×10^{-6}
Landing gear	conventional



Model as tested with original tail.

Mass Data

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	Normal	Flight loading	Alternate flight loading	Production
W, lb	8598	9166	9497	10,700
$x/\bar{c}$	0.25	0.26	0.26	0.28
$z/\bar{c}$	0.08	0.08	0.08	0.08
I_X, slug-ft^2	7400	7876	9166	9098
I_Y, slug-ft^2	8072	8615	8615	10,217
I_Z, slug-ft^2	14421	15440	16730	18,264
Test altitude, ft	8000	12000	12000	8000
μ (at sea level)	8.75	9.30	9.63	10.85
μ'(8,000 ft)	11.10	----------	----------	13.81
μ'' (12,000 ft)	----------	13.39	13.89	
$\frac{I_X - I_Y}{mb^2}$	-15×10^{-4}	-15×10^{-4}	11×10^{-4}	-20×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-140×10^{-4}	-143×10^{-4}	-164×10^{-4}	-144×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	155×10^{-4}	158×10^{-4}	153×10^{-4}	164×10^{-4}

Résumé of Model Test Results

With the model equipped with the original tail for the normal loading, clean condition and normal control configuration for spinning or slight deviations from this control position, the recovery characteristics of the model were satisfactory only by simultaneous full reversal of rudder and elevator. Setting the ailerons full against the rotation enabled satisfactory recoveries to be obtained by rudder reversal alone for all elevator settings, whereas satisfactory recoveries could not be obtained for any elevator setting when the ailerons were set full with the rotation.

In order to improve the recovery characteristics of the model obtained by rudder reversal alone, the original vertical tail surfaces were moved forward 10 inches and 20 inches full scale (modifications 1 and 2) and a ventral fin was added to the fuselage with the tail wheel extended (modification 3). Modifications 1 or 2 had no appreciable beneficial effect on the recovery characteristics of the model, whereas with modification 3 the model would not spin when the ailerons were neutral and the elevator was either neutral or down (data not presented for modification 3).

Replacement of the original vertical tail with vertical tail 1 (see sketch) had a detrimental effect on the recovery characteristics of the model by rudder reversal alone. The addition of a ventral fin with the tail wheel extended (modification 3) enabled satisfactory recoveries to be obtained by rudder reversal alone. Alternate modifications such as raising the horizontal tail 10 inches and 5 inches, respectively, from its original position (modifications 4 and 5), moving the vertical tail forward 15 inches from its original position (modification 6) or a combination of modifications 5 and 6 were not as effective in producing satisfactory recoveries as modification 3.

The arrangement of tail 2 was a practical full-scale design revision based on the results of the precious tests. It consisted of moving vertical tail 1 forward 10 inches, full scale, from its original location and raising the horizontal tail $7\frac{1}{2}$ inches, full scale, from its original location. For the normal loading, clean condition, the recoveries of the model equipped with tail 2 were satisfactory by rapid full rudder reversal only when the ailerons were set neutral or against the spin. The model appeared to be quite critical to changes in loading condition. For the production loading, for example, the recovery characteristics were unsatisfactory by rudder reversal alone although simultaneous reversal of both rudder and elevator gave satisfactory recovery characteristics of the model except when the ailerons were with the spin.

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In addition to the conditions covered in this compilation, the investigation for this model also covered tests of other loadings and of many other tail modifications in order to improve the recovery characteristics of the model when the ailerons were full with the spin. None of these additional tail modifications had any appreciable affect on the aileron-with spins. The data are not presented because of inconsistencies in the results probably associated with extensive testing of a single model over a period of several years.

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SPIN DATA OBTAINED WITH $\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF4U-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins; equivalent test altitude: Normal loading and production loading 8,000 feet, flight loading and alternate flight loading 12,000 feet]

Original tail, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	49	41	40	51	47	43	49	46	41
ϕ, deg	2U	2U	2U	1U	2U	2U	1D	0	0
Ω, rps	0.46	0.58	0.62	0.47	0.56	0.59	0.43	0.55	0.60
V, fps	173	173	169	173	165	161	173	165	167
Turns for recovery	2 [a]$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$ 2	$2\frac{1}{2}$ [a]$1\frac{1}{2}$	2 $2\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{2}$ [a]$2\frac{1}{4}$ 3	3	$2\frac{3}{4}$

Original tail, effect of modifications of vertical tail on turns for recovery, normal loading

Ailerons	Neutral		
Elevator	U	N	D
Modification 1	--	2	1
Modification 2	--		$\frac{1}{2}$

Tail 1, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
Turns for recovery	[b]--	> $2\frac{1}{2}$	$2\frac{1}{2}$	> $2\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{3}{4}$	> $2\frac{1}{4}$	> 4	$3\frac{1}{4}$

Tail 1, effect of location of horizontal and vertical tail surfaces on turns for recovery, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
Modification 3	[b]--	[b]--	No spin	[b]--	No spin	No spin	[b]--	$1\frac{1}{2}$	$1\frac{1}{4}$
Modification 4	[b]--	1	1	[b]--	$1\frac{1}{2}$	$\frac{3}{4}$	[b]--	$1\frac{3}{4}$	$1\frac{1}{2}$
Modification 5	[b]--	$2\frac{1}{2}$	2	[b]--	$2\frac{1}{2}$	3	[b]--	3	4
Modifications 5 and 6	--	$2\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$	--	$2\frac{1}{2}$	$2\frac{1}{2}$

Tail 2, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	--	No spin	No spin	--	--	--	--	--	--
ϕ, deg	--			--	--	--	--	--	--
Ω, rps	--			--	--	--	--	--	--
V, fps	--			--	--	--	--	--	--
Turns for recovery	$1\frac{1}{4}$			$1\frac{3}{4}$	$1\frac{3}{4}$	1	3	3	3

Tail 2, alternate flight loading

Ailerons	Against		Neutral		With	
Elevator	U	D	U	D	U	D
α, deg	--	--	50	52	--	--
ϕ, deg	--	--	1D	1D	--	--
Ω, rps	--	--	0.46	0.54	--	--
V, fps	202	210	189	173	181	169
Turns for recovery	> $2\frac{1}{2}$ ≫3	$1\frac{1}{2}$ 2	> $3\frac{1}{2}$ [c]4	3 $3\frac{1}{4}$	> 5	$6\frac{1}{2}$

Tail 2, flight loading

Ailerons	Against		Neutral			With	
Elevator	U (d)	D (d)	U (d)	N	D	U	D
α, deg	--	--	49	--	--	--	--
ϕ, deg	--	--	1U	--	--	---	--
Ω, rps	--	--	0.45	--	--	--	--
V, fps	214	206	194	173	173	177	169
Turns for recovery	$2\frac{1}{2}$ 3	$1\frac{1}{2}$ 2	> 3	3	3	∞	$5\frac{1}{2}$

Tail 2, production loading

Ailerons	Against			Neutral			With		
Elevator	U (d)	N	D	U	N	D	U	N	D
α, deg	--	--	--	44	53	48	--	--	--
ϕ, deg	--	--	--	2D	1U	1U	--	--	--
Ω, rps	--	--	--	0.43	0.55	0.55	--	--	--
V, fps	258	177	169	189	169	169	201	177	171
Turns for recovery	$1\frac{3}{4}$ [a]$\frac{1}{2}$ [e]$\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$ 3	> 4 [a]2 [e]2	4	4	∞ [a]4 [e]4	$5\frac{1}{2}$	5

[a]Recovery attempted by simultaneous reversal of rudder and elevator.
[b]No recovery attempted, rate of descent too high for tests.
[c]Recovery attempted by reversing rudder to 30° against the spin.
[d]Oscillatory spin.
[e]Recovery attempted by rudder reversal and neutralization of the elevator.

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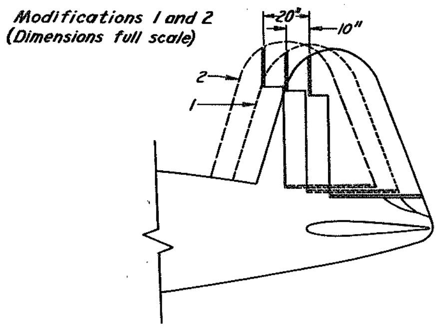

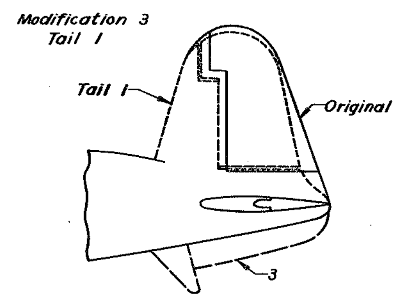

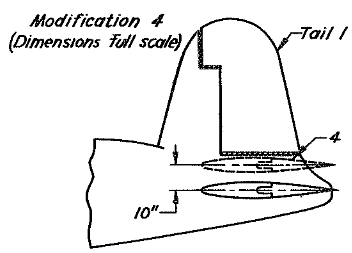

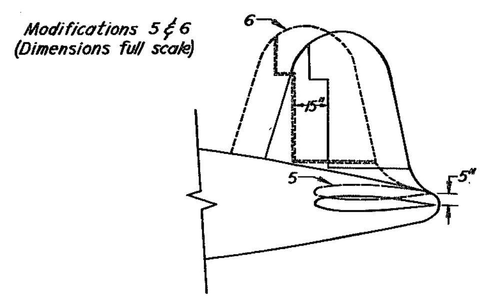

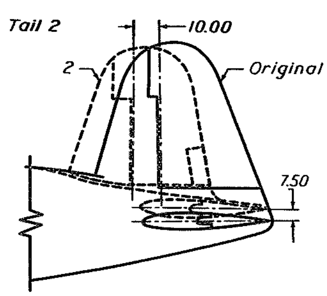

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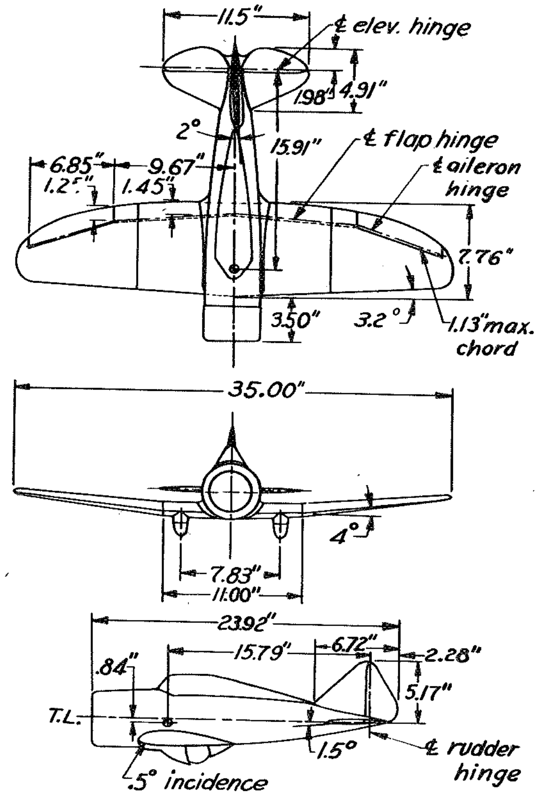
$\frac{1}{12}$-SCALE MODEL OF THE SEVERSKY AIRCRAFT CORP. NF-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	35.00
L, ft	25.17
$\bar{c}$, in	73.24
S, sq ft	198.40
A	6.17
L.E. $\bar{c}$ aft L.E. C_r, in	7.82
S_h, sq ft	35.10
S_e, sq ft	16.20
S_v, sq ft	19.10
S_r, sq ft	9.14
δ_r, deg	30 R, 30 L
δ_e, deg	31 1/2 U, 18 3/4 D
δ_a, deg	26 3/4 U, 24 D
δ_f, deg	Outboard 48 D
	Inboard 33 D
TDPF	0
Landing gear	Retractable



Model as tested.

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Mass Data

	Original Normal Loading	Revised Normal Loading	Bomber Loading
W, lb	5220	5220	5992
$x/\bar{c}$	0.280	0.280	0.292
$z/\bar{c}$	0.150	0.096	0.120
I_X, slug-ft^2	1927	2115	2480
I_Y, slug-ft^2	3890	4180	3909
I_Z, slug-ft^2	5690	5720	6234
Test altitude, ft	6000	6000	6000
μ (at sea level	9.81	9.81	11.27
μ' (6000 ft)	11.76	11.76	13.48
$\frac{I_X - I_Y}{mb^2}$	-99×10^{-4}	-104×10^{-4}	-63×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-91×10^{-4}	-78×10^{-4}	-102×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	190×10^{-4}	182×10^{-4}	165×10^{-4}

Résumé of Model Test Results

In general for all loading conditions and for all control settings tested the model spun at flat attitudes and recoveries were generally unsatisfactory. The model spun at its steepest attitude and the possibilities of recovery were greatest when the ailerons were with the spin.

In an attempt to improve the spin and recovery characteristics of the model, various modifications (1 to 29) to the tail surfaces were investigated. Modification 24, (raising the horizontal tail surfaces and installation of two ventral fins) and modification 27, (raising and moving forward the horizontal tail in addition to installing a ventral fin) generally were the most effective modifications tested.

Test results made with a corrected normal loading did not appreciably differ from the original normal loading condition tested.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE SEVERSKY NF-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Original normal loading							Original normal loading, rudder-against spins			Bomber loading			Landing gear down, tail door open, normal loading		
Ailerons	Neutral			With $\frac{1}{2}$	With $\frac{3}{4}$	With Full		Neutral			Neutral			Neutral		
Elevator	U	N	D	U	U	N (a)	D (a)	U	N	D	U	N	D	U	N	D
α, deg	82	80	-	-	-	-	-	-	81	79	-	-	80	81	-	-
ø, deg	0	0	-	-	-	-	-	-	0	0	-	-	0	1D	-	-
Ω, rps	-	-	-	-	-	-	-	-	-	-	-	-	0.82	-	-	-
V, fps	98	97	-	-	-	-	-	-	97	95	-	-	97	100	-	-
Turns for recovery	∞, $^{b}8$, $^{c}\infty$	∞	∞	∞	∞	-	$^{d}3$	-	-	-	∞, $^{c}\infty$	∞	∞	∞, $^{c}\infty$	∞	∞

Effect of modifications on turns for recovery, original normal loading

Ailerons	Neutral	$\frac{3}{4}$ With
Elevator	U	U
Modification 1	-	$^{c}6$
2	$^{e}4\frac{1}{2}$, $^{b}5$	6
3	$^{b}5$	-
4	$^{b}6\frac{1}{2}$	-
5	$^{b}{>3}$	-
6	$^{b}6\frac{1}{2}$	-

Effect of modifications on turns for recovery. Tail wheel down, tail doors open. Aileron neutral spins. Original normal loading

Elevator	50°U	U	50°D
Modification 7	-	∞, $^{c}\infty$	-
8	-	∞	-
9	5	∞, $^{c}\infty$	∞
10	$>8\frac{1}{2}$	-	-
11	5	-	-
12	6, >6	$^{c}\infty$	-
13	4, 3	$^{c}\infty$	-
14	3	>4	-
15	-	6	-

Effect of modifications on turns for recovery. Tail wheel down. Original normal loading.

Ailerons	Neutral					$\frac{3}{4}$ With
Elevator	50°U	40°D	U	N	D	U
Modification 16	$^{b}3\frac{1}{2}$	$^{b}{>4}$	$^{b}2$, $^{c}4$, $^{b}{>4}$	-	-	$^{c}2\frac{1}{2}$, $^{c}{>5}$
17	$^{b}5$	-	$^{b}6$	-	-	-
18	$^{b}3$	-	-	-	-	-
19	$^{b}3$	-	$^{b}4$	-	-	2
20	-	-	-	-	-	>3
21			$^{b}5$	-	-	-
22	-	-	$^{b}{>5}$	-	-	-
23	-	-	$^{b}4$	-	-	-
24	-	-	$^{b}1\frac{1}{2}$, 2	-	-	-
25	-	-	4, 5, $^{b}{>2\frac{1}{2}}$, $^{b}3$	-	-	-
26	-	-	$^{c}7$, >3, $^{b}2$, $^{b}{>1\frac{1}{2}}$	4	$^{b}3$, 6	-
27	-	-	$^{c}2$	2	3	-
28	-	-	7, $^{b}3$	-	∞	-
29	-	-	∞, $^{b}7$	-	$^{b}8$	-

Bomber loading, effect of modification 19 on turns for recovery, elevators up

	Tail wheel down				Landing gear down	
Ailerons	Neutral	With $\frac{3}{4}$	With Full		Neutral	With
Flaps	Down Full	Down Full	Down Full	Down Rt.10° Lt.26°	Down Full	Down Full
Turns for recovery	$^{b}{>8}$	6	>5	2, >2	$^{b}5$, $^{b}6\frac{1}{2}$	-

	Revised normal loading				Landing gear down, tail door open, revised normal loading	
Ailerons	Neutral		With		Neutral	
Elevator	U	N	N	D	U	D
α, deg	77	79	-	-	78	-
ø, deg	0	0	-	-	1D	-
Ω, rps	-	0.80	-	-	-	-
V, fps	97	97	-	-	100	-
Turns for recovery	∞, $^{b}\infty$, ∞	∞	-	$^{d}4\frac{1}{2}$, $^{d}1\frac{1}{4}$	∞, $^{c}\infty$	∞

[a] Steep spin of high vertical velocity.
[b] Recovery attempted by moving the ailerons from neutral to full-with the spin, and then followed by full rudder reversal.
[c] Recovery attempted by simultaneous reversal of rudder and elevator.
[d] Recovery attempted before final steep attitude was attained.
[e] Recovery attempted by moving the ailerons from neutral to full-with the spin and then followed by full rudder reversal and elevator reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE SEVERSKY NF-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Effect of modifications on turns for recovery, revised normal loading

Tail wheel down			Tail wheel down and tail doors open		
Ailerons	Neutral		Ailerons	Neutral	
Elevator	50°U	U	Elevator	50°U	U
Modification 17	-	$^{b}6\frac{1}{4}$	Modification 12	$>3\frac{1}{2}$	-
19	$^{b}>4$	-	14	$3\frac{1}{4}$	5
21	-	$^{b}4\frac{1}{2}$			
23	-	$^{b}4\frac{1}{2}$			

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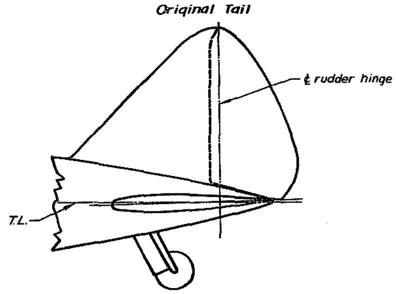
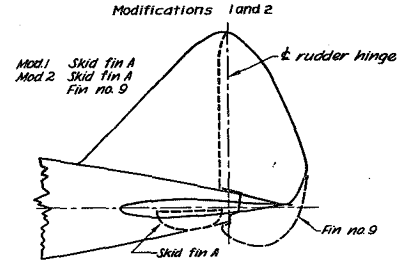
[b]Recovery attempted by moving the ailerons from neutral to full-with the spins, and then followed by full rudder reversal.
[c]Recovery attempted before final steep attitude attained.

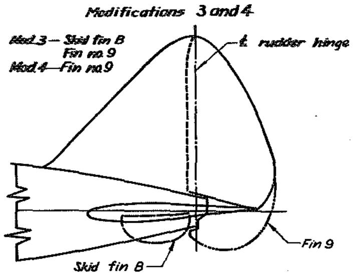
Original Tail



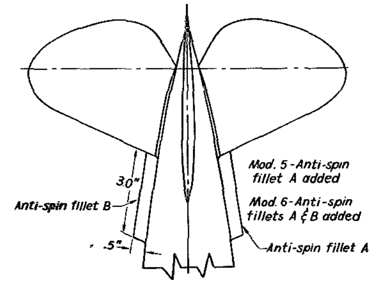
Modifications 1 and 2



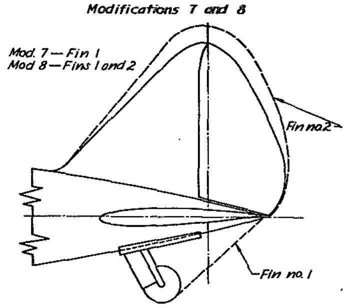
Modifications 3 and 4



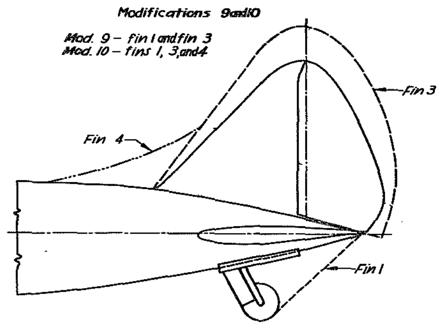
Modifications 5 and 6

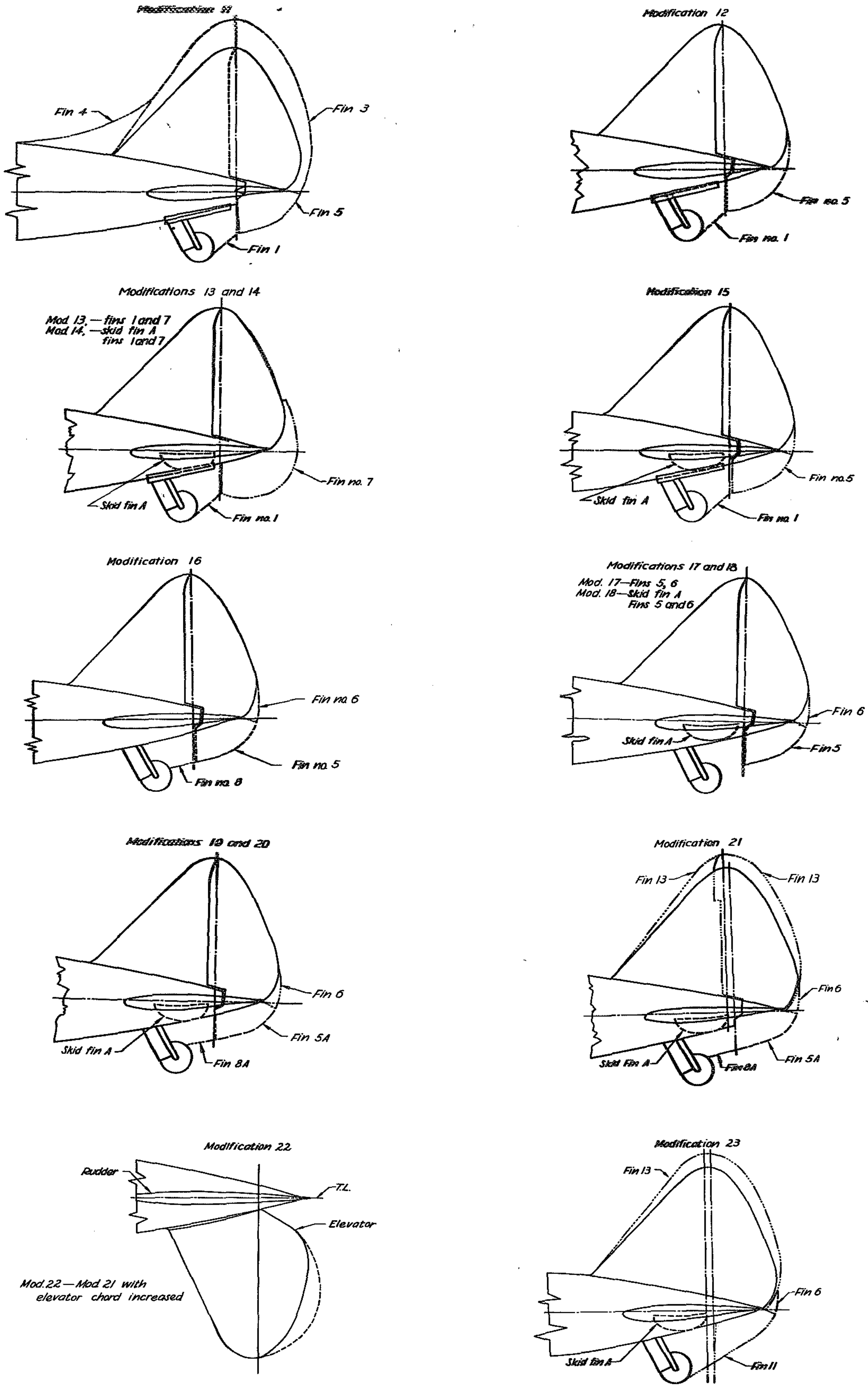


Modifications 7 and 8



Modifications 9 and 10





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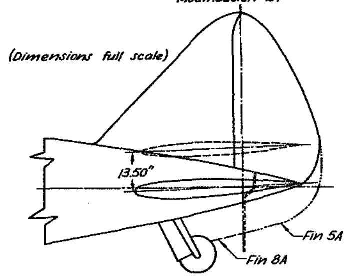
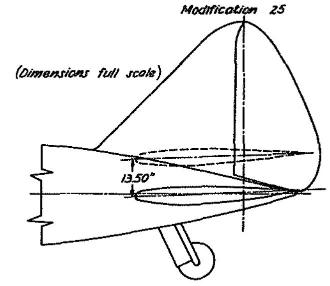
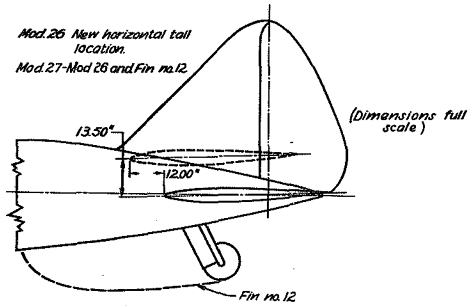
Modification 24



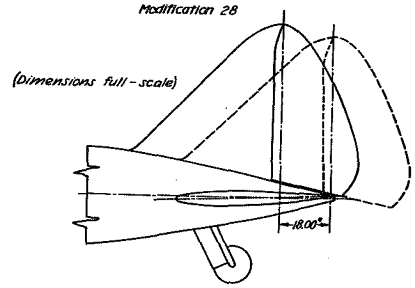
Modification 25



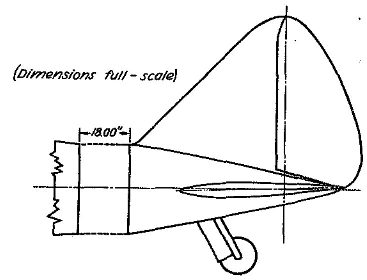
Modifications 26 and 27



Modification 28



Modification 29

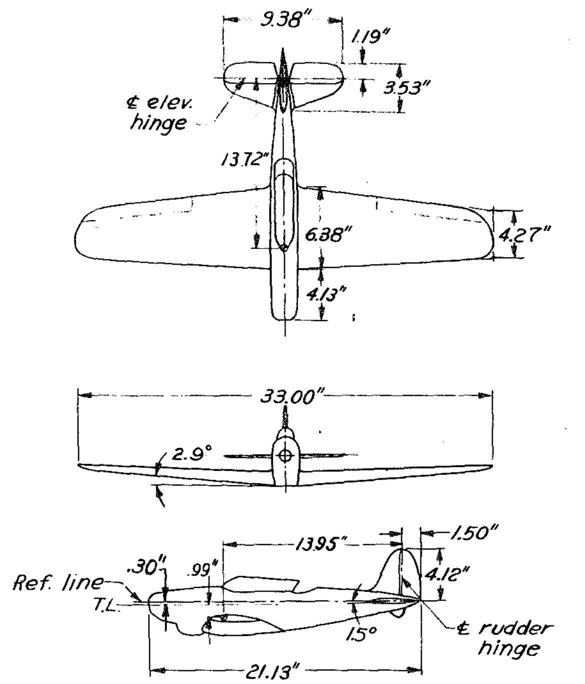


$\frac{1}{16}$-SCALE MODEL OF THE CONSOLIDATED PB-2 AND PB-2A AIRPLANES

Dimensional Data

(Full Scale)

b, sq ft	44.00
L, sq ft	28.60
$\bar{c}$, in.	106.50
S, sq ft	297.00
A	6.52
L.E. $\bar{c}$ aft L.E. c_r, in.	4.86
S_h, sq ft	40.10
S_e, sq ft	20.00
S_v, sq ft	18.70
S_r, sq ft	10.90
δ_r, deg	29 R, 29 L
δ_e, deg	35 U, 15 D
δ_a, deg	24 U, 10.4D
TDPF	$.2 \times 10^{-6}$
Landing gear	Conventional



Model as tested.

Mass Data

Stripped Loading

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W, lb	5247
$x/\bar{c}$	0.232
$z/\bar{c}$	0.149
I_X, slug-ft^2	3324
I_Y, slug-ft^2	5084
I_Z, slug-ft^2	7717
Test altitude, ft	10,000
μ (at sea level)	5.24
μ'(10,000 ft)	7.10

$\frac{I_X - I_Y}{mb^2}$	-56×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-83×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	139×10^{-4}

Résumé of Model Test Results

The PB-2 and PB-2A are dimensionally the same airplane. For the normal loaded PB-2, I_Y and I_Z were increased 0.15 I_Y from the stripped loaded PB-2; whereas, for the PB-2A, I_Y and I_Z were increased 0.30 I_Y and the center of gravity was moved forward $0.03\bar{c}$ from the stripped loaded PB-2.

For the PB-2 model in the normal loading, clean condition the recovery characteristics were generally unsatisfactory. Setting the ailerons against the rotation flattened the spin whereas setting the ailerons with the rotation produced extremely oscillatory spins. For the model in the stripped loading and clean condition the recovery characteristics of the model were generally satisfactory; recoveries from elevator-up spins, ailerons-against or ailerons-with the rotation were rapid by simultaneous reversal of rudder and elevator (data not presented).

The extension of mass along the wings (ΔI_X and ΔI_Z = 0.15 I_X and 0.30 I_X) from the normal-loading condition had a pronounced effect upon the recovery characteristics of the model. Recoveries became satisfactory when the elevator was 10° up. For the larger mass extension, recoveries were satisfactory except when the elevator was full down. Moderate movements of the center of gravity from its normal position or extending the landing gear had little effect upon the recovery characteristics of the model.

For the normal loading when the model was spun with the tail wheel installed, the recovery characteristics were satisfactory except for the elevator full-down position.

Preliminary tests with a small explorer fin located in different positions around the vertical tail and fuselage as shown on the accompanying sketch indicated that fin area located beneath the fuselage was most effective. The addition of a long ventral fin located in this region (modification 1) likewise had a favorable effect upon the spin and recovery characteristics of the PB-2 model.

With the horizontal tail surfaces moved forward and up and extending the original rudder to the bottom of the fuselage (modification 2), the recovery characteristics of the model were improved but still were unsatisfactory when the ailerons were neutral or when the elevator was full down.

For the normal loading and the clean condition, the PB-2A model would not recover from established spins by either rapid full rudder reversal or simultaneous reversal of the rudder and elevator. When the ailerons were set full with the spins, the model was too oscillatory to test.

Modification 1 had little effect on the PB-2A model.

Modification 2 had a very favorable effect on the recovery characteristics of the model, although the recoveries were still generally unsatisfactory from the aileron-neutral and aileron-against spins. When the ailerons were set full with the spin, the test results indicate that recoveries would probably have been satisfactory.

Modification 3 was quite effective (data not presented) provided a fillet was attached to the outer side of the fuselage only (left side of fuselage for a right spin). With both antispin fillets installed there was only a slight beneficial effect of the fillets on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CONSOLIDATED PB-2 AND PB-2A AIRPLANES

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	PB-2, stripped loading			PB-2, normal loading														PB-2, rudder-neutral spins, normal loading		
Ailerons	Neutral			Against							Neutral			With			Neutral		
				Full	20°U 10°D		12°U 8°D	8°U 6°D		4°U 3°D									
Elevator	10°U	N	D	10°U	10°U	N	10°U	10°U	N	10°U	10°U	N	D	U (a)	N (a)	D (a)	10°U	N	D
α, deg	-	-	-	-	56	-	58	58	-	53	47	48	49	-	-	-	50	47	48
ϕ, deg	-	-	-	-	8U	-	5U	3U	-	1U	1U	2U	3U	-	-	-	1U	3U	3U
Ω, rps	-	-	-	-	0.46	-	0.48	0.48	-	0.46	0.46	0.48	0.50	-	-	-	0.47	0.48	0.49
V, fps	-	-	-	-	131	-	126	127	-	134	139	133	129	-	-	-	133	133	129
Turns for recovery	1	2	2	$^{b}2$ $^{b}3$	$^{b}6$	7	$^{b}\infty$	$^{b}\infty$	∞	$^{b}\infty$	$9\frac{1}{2}$ $^{b}4\frac{1}{2}$	$6\frac{3}{4}$	$7\frac{1}{2}$	-	-	-	-	-	-

PB-2, effect of mass variations and c.g. movements (from the normal loading condition) on turns for recovery, aileron neutral spins			
Elevator	10°U	N	D
ΔI_X and $\Delta I_Z = 0.15 I_X$	$^{b}1\frac{1}{2}$	$4\frac{1}{4}$ 6	5
ΔI_X and $\Delta I_Z = 0.30 I_X$	1	$1\frac{3}{4}$	$2\frac{1}{2}$
c.g. moved forward $0.03\bar{c}$	8 $^{b}6\frac{1}{4}$	9	8
c.g. moved back $0.05\bar{c}$	5 $^{b}5$	6	$5\frac{1}{4}$
c.g. raised $0.05\bar{c}$, c.g. moved forward $0.08\bar{c}$	7 $^{b}6$	9	9
weight decreased 0.15w	5	$7\frac{1}{4}$	$7\frac{1}{4}$
c.g. moved back $0.10\bar{c}$	8		
c.g. lowered $0.04\bar{c}$	$^{b}3$	10	

	PB-2, landing gear extended, normal loading			PB-2, tail wheel installed, normal loading			PB-2, modification 1, normal loading					PB-2, modification 2, normal loading														
Ailerons	Neutral			Neutral			Against 8°U, 6°D		Neutral			Against						Neutral			With					
												20°U, 10°D			6°D, 8°U						8°U, 6°D			20°U, 10°D		
Elevator	10°U (c)	N	D	10°U (c)	N	D	10°U (d)	D	10°U (e)	N	D	10°U (e)	N (c)	D	10°U	N	D	10°U	N	D	10°U	N	D	10°U	N	D
α, deg	34	-	-	30	-	-	36	-	34	-	-	35	-	-	49	-	-	48	46	48	33	-	-	36	-	-
ϕ, deg	2U	-	-	1U	-	-	3U	-	6D	-	-	7U	-	-	7U	-	-	3U	3U	4U	2D	-	-	5D	-	-
Ω, rps	0.50	-	-	0.59	-	-	0.48	-	0.53	-	-	0.50	-	-	0.47	-	-	0.47	0.48	0.50	0.53	-	-	0.49	-	-
V, fps	167	-	-	170	-	-	167	-	167	-	-	162	-	-	140	-	-	135	131	131	167	-	-	158	-	-
Turns for recovery	$6\frac{3}{4}$ ∞ $^{b}5$	$6\frac{1}{4}$ 9	$5\frac{1}{4}$ 6	1 $1\frac{1}{2}$ $^{b}1\frac{1}{2}$	2 5	$5\frac{1}{4}$	$^{b}1\frac{1}{4}$	-	-	$^{f}1\frac{1}{2}$	$4\frac{1}{2}$	-	$1\frac{3}{4}$	$2\frac{1}{4}$	$^{b}2\frac{1}{4}$ $^{b}4$	$2\frac{3}{4}$ $3\frac{1}{4}$	4 $4\frac{1}{2}$	$^{b}3\frac{3}{4}$	$3\frac{1}{4}$	4	-	2	$3\frac{1}{4}$	-	$2\frac{1}{4}$	$3\frac{1}{4}$

	PB-2A, normal loading														PB-2A, rudder against spins, normal loading			PB-2A, modification 1, normal loading				
Ailerons	Against							Neutral				With			Neutral			Against 8°U, 6°D		Neutral		
	20°U, 10°D			8°D, 6°U																		
Elevator	15°U	N	D	27°U	15°U	N	D	15°U	10°U	N	D	U (a)	N (a)	D (a)	15°U	N	15°D	U	D	10°U (h)	N	D
α, deg	61	-	-	56	59	-	-	-	52	-	52	-	-	-	46	-	49	-	-	-	45	-
ϕ, deg	6U	-	-	3U	2U	-	-	-	2U	-	2U	-	-	-	1U	-	4U	-	-	-	1U	-
Ω, rps	0.46	-	-	0.41	0.47	-	-	-	0.45	-	0.46	-	-	-	0.44	-	0.47	-	-	-	0.45	-
V, fps	131	-	-	138	129	-	-	-	134	-	131	-	-	-	144	-	136	-	-	-	144	-
Turns for recovery	$^{b}\infty$	∞	∞	$^{b}\infty$	$^{b}\infty$	∞	∞ $^{g}\infty$	∞	∞ $^{b}\infty$	∞	∞	-	-	-	-	-	-	-	∞	^{b}-	7 ∞	9 ∞

[a]Model too oscillatory to test
[b]Recovery attempted by simultaneous reversal of rudder and movement of elevator from initial position to full down.
[c]Steep wandering spin.
[d]Unsteady.
[e]Oscillatory spin.
[f]Recovery attempted by simultaneous reversal of rudder with movement of elevator from neutral to 15°D.
[g]Recovery attempted after addition of modification 3.
[h]Model descended with great speed as model gradually became steeper.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CONSOLIDATED PB-2 AND PB-2A AIRPLANES - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	PB-2A, modification 2, normal loading											PB-2A, modification 4, ΔI_Y and $\Delta I_Z = 0.12 I_Y$								
Ailerons	Against				Neutral			With				Against			Neutral			With		
	20°U, 10°D		8°U, 6°D					8°U, 6°D		20°U, 10°D		8°U, 6°D								
Elevator	N	D	N	D	10°U	N	D	N (a1)	D (a1)	N (a1)	D (a1)	15°U	N	20°D	15°U	N	20°D	U	N	D
α, deg	41	-	53	-	35	48	48	-	-	-	-	-	-	-	-	-	-	-	-	-
ϕ, deg	5U	-	4U	-	1U	2U	2U	-	-	-	-	-	-	-	-	-	-	-	-	-
Ω, rps	0.47	-	0.46	-	0.47	0.46	0.47	-	-	-	-	-	-	-	-	-	-	-	-	-
V, fps	138	-	131	-	163	141	135	-	-	-	-	-	-	-	-	-	-	-	-	-
Turns for recovery	$2\frac{3}{4}$	4	$4\frac{1}{4}$	∞	[b]$3\frac{3}{4}$	3, $3\frac{1}{2}$	$5\frac{1}{2}$	-	-	-	-	[b]4	-	5	[b]$2\frac{1}{2}$	-	$3\frac{1}{2}$	-	-	-

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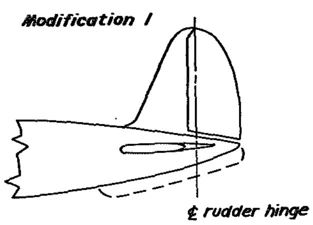
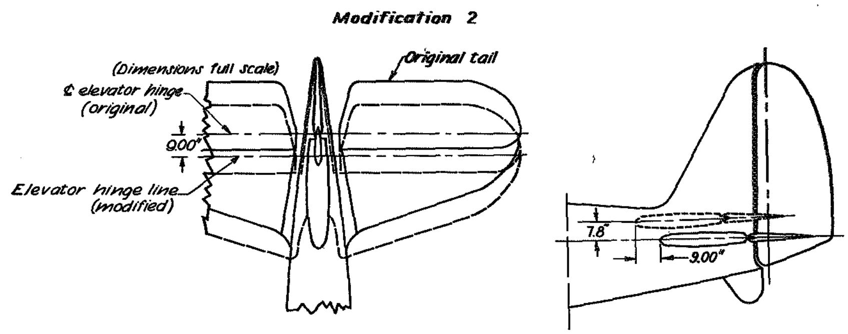
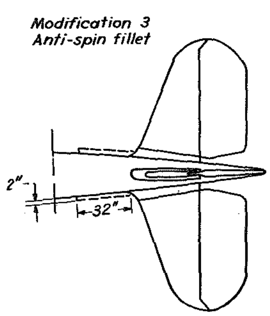
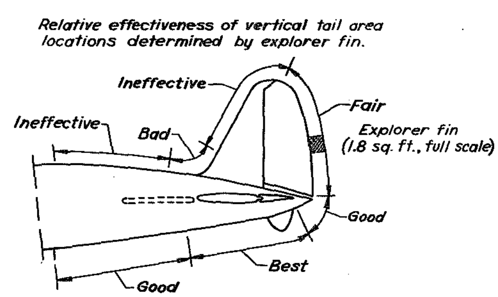
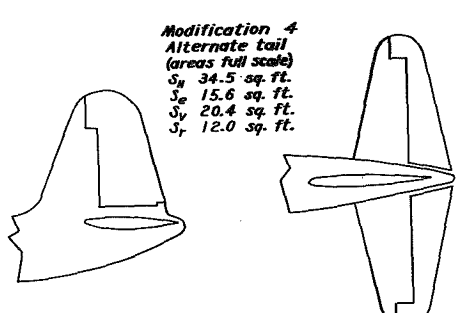
[a]Model too oscillatory to test.
[b]Recovery attempted by simultaneous reversal of rudder and movement of elevator from initial position to full down.
[1]Velocity too high to test.









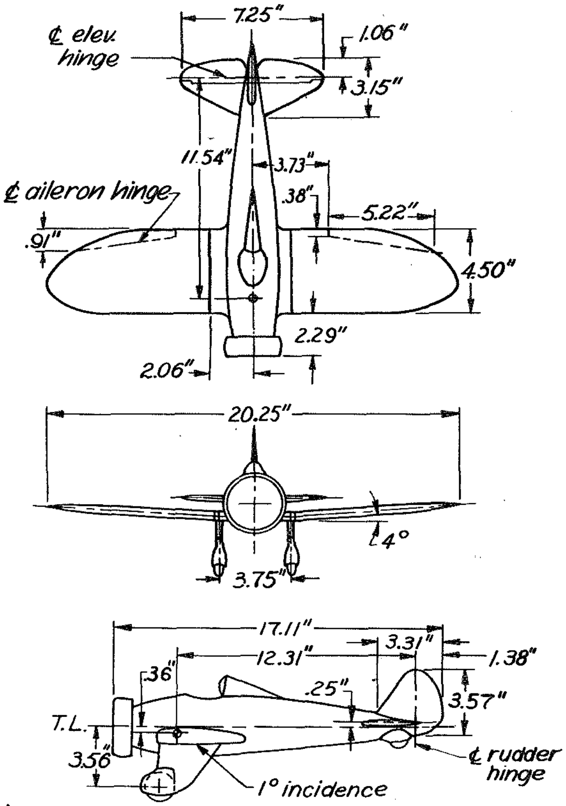


$\frac{1}{16}$-SCALE MODEL OF THE BOEING P-26A AIRPLANE

Dimensional Data

(Full Scale)

b, ft	28.00
L, ft	23.83
$\bar{c}$, in.	72.00
S, sq ft	149.50
A	5.25
L.E. $\bar{c}$ aft L.E. c_r, in.	0
S_h, sq ft	24.70
S_e, sq ft	12.40
S_v, sq ft	12.50
S_r, sq ft	6.90
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 30 D
TDPF	356×10^{-6}
Landing gear	Fixed



Model as tested.

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Mass Data

Normal Loading

W, lb	3067
$x/\bar{c}$	0.251
$z/\bar{c}$	0.080
I_X, slug-ft^2	1030
I_Y, slug-ft^2	2036
I_Z, slug-ft^2	2651
Test altitude, ft	6000
μ (at sea level)	9.40
μ' (6000 ft)	11.27

$\frac{I_X - I_Y}{mb^2}$	-135×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-82×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	217×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun in an oscillatory manner and recoveries were obtained in 1 turn by simultaneous full reversal of rudder and elevator. With the elevator set full down, recovery by rapid full rudder reversal varied from 1 to $2\frac{3}{4}$ turns, depending upon the phase of oscillation at which the rudder was reversed.

With the engine cowling removed, the model would not spin with the elevator full up. With the elevator down, the spin was steady and recovery by rapid full rudder reversal required 4 turns.

Small changes in mass distribution along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = \pm 0.09\ I_X\right)$, a moderate increase in mass distribution along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.18\ I_Y\right)$, and moderate movements of the center-of-gravity position ($\pm 0.03\bar{c}$) indicated little effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE BOEING P-26A AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with aileron neutral spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading			Cowling removed, normal loading			$\Delta W = 0.07W$; ΔI_X and $\Delta I_Z = 0.10I_X$; ΔI_Y and $\Delta I_Z = 0.17I_Y$; c.g. moved back $0.03\bar{c}$		
Elevator	U (a)	N	D (a)	U	N	D	U	N	D
α, deg	27 36	31	34	No spin	---	47	39	---	47
ϕ, deg	8D 3D	2D	0		---	3U	0	---	1U
Ω, rps	0.48 0.47	0.65	0.67		---	0.57	0.43	---	0.53
V, fps	167 149	160	140		---	128	153	---	134
Turns for recovery	[b]1	----	1 $2\frac{3}{4}$		---	4	1 [b]$1\frac{3}{4}$	1	$3\frac{1}{2}$

Effect of mass variations, change of weight, and c.g. movements on turns for recovery.			
Elevator	U	N	D
ΔI_X and $\Delta I_Z = 0.09I_X$	[b]$1\frac{1}{4}$	----	----
ΔI_X and $\Delta I_Z = -0.09I_X$	[b]$1\frac{1}{4}$	----	----
$\Delta W = 0.03W$ ΔI_Y and $\Delta I_Z = 0.09I_Y$	[b]$1\frac{1}{4}$	----	----
$\Delta W = 0.07W$ ΔI_Y and $\Delta I_Z = 0.18I_Y$	[b]1	----	----
c.g. moved forward $0.03\bar{c}$	[b]$1\frac{1}{2}$ [b]1	----	----
c.g. moved back $0.03\bar{c}$	[b]1	----	----

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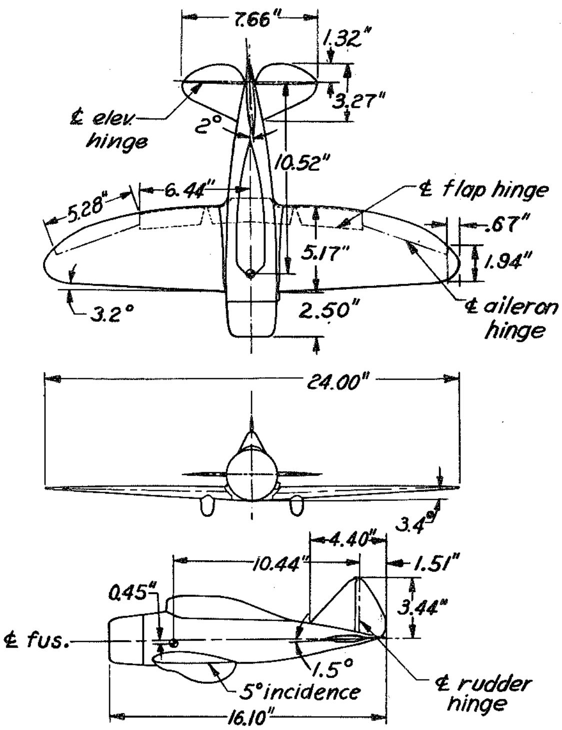
[a]Oscillatory spin.
[b]Recovery attempted by simultaneous reversal of rudder and elevator.

$\frac{1}{8}$-SCALE MODEL OF THE SEVERSKY P-35 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	36.00
L, ft	25.33
$\bar{c}$, in.	73.24
S, sq ft	220.00
A	5.90
L.E. $\bar{c}$ aft L.E. c_r, in.	7.82
S_h, sq ft	35.10
S_e, sq ft	16.20
S_v, sq ft	19.10
S_r, sq ft	9.14
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	27 U, 23 D
δ_f, deg	50 D
TDPF	0
Landing gear	Conventional



Model as tested.

Mass Data

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Normal Loading

W, lb	5563
$x/\bar{c}$	0.258
$z/\bar{c}$	0.111
I_X, slug-ft^2	2871
I_Y, slug-ft^2	4206
I_Z, slug-ft^2	6375
Test altitude, ft	8000
μ (at sea level)	9.17
μ' (8000 ft)	11.69

$$\frac{I_X - I_Y}{mb^2} \;\ldots\ldots\; -60 \times 10^{-4}$$

$$\frac{I_Y - I_Z}{mb^2} \;\ldots\ldots\; -97 \times 10^{-4}$$

$$\frac{I_Z - I_X}{mb^2} \;\ldots\ldots\; 157 \times 10^{-4}$$

Résumé of Model Test Results
(No test data available for this model)

For the normal loading, clean condition, and the normal control configuration for spinning, the model spun at an angle of attack of about 80° and had a relatively low rate of descent, approximately 100 feet per second full-scale. There was very little effect of elevator setting and the same flat spins ensued when the rudder was set neutral or full against the spin. There was no indication of recovery when the rudder was completely reversed for any elevator setting, or when both controls were reversed simultaneously. Although setting the ailerons against the spin had practically no effect on the steady spin or recovery, setting the ailerons with the spin steepened the spin slightly.

Extending the mass along the fuselage, extending or retracting the mass along the wings, moderate movements of the center of gravity foreward or aft of its original location, or extending the landing gear had no appreciable effect on the steady spin and recovery characteristics of the model.

In order to improve the recovery characteristics of the model the horizontal tail surfaces were raised vertically 2 feet - $7\frac{1}{2}$ inches full-scale as shown on the accompanying sketch. The steady spin was considerably steeper but recoveries although improved were still unsatisfactory ($3\frac{1}{4}$ turns).

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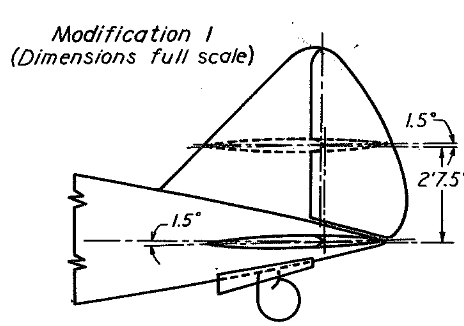
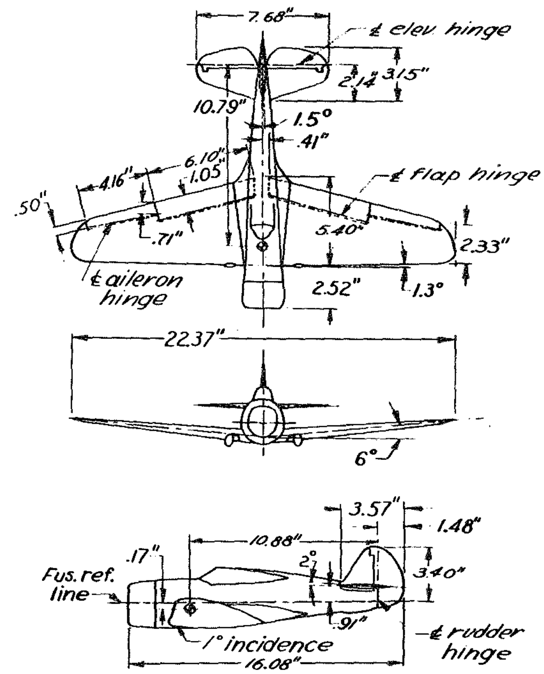


$\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-36A AIRPLANE

Dimensional Data

(Full Scale)

b, ft	37.28
L, ft	28.85
$\bar{c}$, in.	81.60
S, sq ft	236.00
A	5.90
L.E. $\bar{c}$ aft L.E. c_r, in.	2.20
S_h, sq ft	48.00
S_e, sq ft (includ. bal.)	19.20
S_v, sq ft	20.74
S_r, sq ft (includ. bal.)	13.74
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	25 U, 12 D
δ_f, deg	45 D
TDPF	473×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	5531
$x/\bar{c}$	0.267
$z/\bar{c}$	0.042
I_X, slug-ft^2	2020
I_Y, slug-ft^2	4470
I_Z, slug-ft^2	6030
Test altitude, ft	12,000
μ (at sea level)	8.20
μ' (12,000 ft)	11.85

$$\frac{I_X - I_Y}{mb^2} \ldots -102 \times 10^{-4}$$

$$\frac{I_Y - I_Z}{mb^2} \ldots -65 \times 10^{-4}$$

$$\frac{I_Z - I_X}{mb^2} \ldots 167 \times 10^{-4}$$

Résumé of Model Test Results

Satisfactory recoveries were obtained for the model in the normal loading, clean condition, and normal control configuration for spinning from both spins obtainable.

Aileron-against settings were generally adverse, whereas aileron-with settings were favorable.

Extending the mass along the wing $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$ or along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_Y\right)$ had no appreciable effect on the recovery characteristics of the model.

Deflecting the flaps 45° down or extending the landing gear had a detrimental effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-36A AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading																
Ailerons	Against						Neutral					With					
	Full			12° U, $5\frac{3}{4}$° D								12° U, $5\frac{3}{4}$° D			Full		
Elevator	U	10° U	D	U	10° U	D	U (ab)	U (b)	10° U	N	D	U (ac)	10° U	D (d)	U	10° U	D (d)
α, deg	--	53	46	--	50	48	30	45	44	45	44	--	---	24	---	---	---
∅, deg	--	6U	6U	--	3U	4U	9D	---	2U	1U	1U	--	---	0	---	---	---
Ω, rps	--	0.49	0.56	--	0.50	0.55	0.46	---	0.50	0.52	0.54	--	---	0.87	---	---	---
V, fps	--	161	163	--	154	160	244	185	162	156	157	--	>260	232	>260	>260	>260
Turns for recovery	[e]1	[f]$3\frac{1}{2}$	$4\frac{1}{2}$ $5\frac{1}{2}$	[e]$1\frac{1}{2}$	[f]$4\frac{1}{4}$ [f]$3\frac{1}{2}$	4	1 [e]$\frac{1}{2}$ [e]2 [g]2 [eg]3	2	$1\frac{1}{2}$ [f]2	2	$2\frac{3}{4}$ [g]2 [g]3	--	---	1	---	---	---

Effect of mass variations and c.g. movements on turns for recovery from aileron-neutral spins		
Elevator	10° U	D
ΔI_X and $\Delta I_Z = 0.15 I_X$	[f]2	$2\frac{1}{2}$ 2
ΔI_X and $\Delta I_Z = 0.30 I_X$	[f]2	$2\frac{1}{4}$
ΔI_Y and $\Delta I_Z = 0.15 I_Y$	[f]$2\frac{1}{4}$	$2\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.30 I_Y$	[f]2	$2\frac{1}{2}$
c.g. moved forward $0.05\bar{c}$	[f]$2\frac{1}{4}$	3
c.g. moved back $0.05\bar{c}$	[f]$1\frac{3}{4}$	$2\frac{1}{2}$

	Flaps down 20°, normal loading				Flaps down 45°, normal loading							
Ailerons	Neutral				Against		Neutral				With	
					Full	12° U, $5\frac{3}{4}$° D					12° U, $5\frac{3}{4}$° D	Full
Elevator	U	10° U	N	D	10° U	10° U	U	10° U	N	D	10° U	10° U (h)
α, deg	--	--	--	--	--	--	50	51	50	46	--	--
∅, deg	--	--	--	--	--	--	1D	1D	0	0	--	--
Ω, rps	--	--	--	--	--	--	0.42	0.49	0.50	0.53	--	--
V, fps	--	--	--	--	--	--	149	147	144	140	--	--
Turns for recovery	$1\frac{1}{2}$ [e]$1\frac{3}{4}$	2 [f]2	$2\frac{1}{2}$	$2\frac{1}{2}$	[f]$3\frac{1}{4}$	[f]$4\frac{3}{4}$	$2\frac{1}{4}$ [e]2	$2\frac{1}{2}$ [f]$3\frac{1}{4}$	$2\frac{3}{4}$ $3\frac{1}{4}$	$2\frac{1}{2}$	[f]$2\frac{1}{4}$	[f]2

	Landing gear extended, normal loading												Landing gear extended, flaps down 45°, normal loading			
Ailerons	Against				Neutral				With				Neutral			
	Full		12° U, $5\frac{3}{4}$° D						12° U, $5\frac{3}{4}$° D		Full					
Elevator	U	D	U	D	U (a)	10° U	N	D	U (a)	D	U (a)	D	U	10° U	N	D
α, deg	--	-	--	-	3[illegible]	43	44	45	---	--	---	---	--	--	--	--
∅, deg	--	-	--	-	10D	1U	2U	3U	---	--	---	---	--	--	--	--
Ω, rps	--	-	--	-	0.52	0.51	0.55	0.55	---	--	---	---	--	--	--	--
V, fps	--	-	--	-	253	167	156	150	>260	--	>260	>260	--	--	--	--
Turns for recovery	[e]$4\frac{1}{2}$ [e]7 [e]10	5	[e]3 [e]$4\frac{1}{2}$ [e]6	$4\frac{3}{4}$	[eg]4 $1\frac{1}{4}$ $\frac{3}{4}$ [e]$\frac{1}{2}$ [g]3	$2\frac{1}{4}$ $1\frac{3}{4}$ [f]$2\frac{1}{4}$ [f]$2\frac{3}{4}$	$2\frac{3}{4}$ $2\frac{1}{4}$	3 $3\frac{1}{2}$	---	1	---	---	$2\frac{1}{2}$ [e]$1\frac{1}{2}$ [e]2	$2\frac{3}{4}$ [f]$2\frac{3}{4}$ [f]$3\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{3}{4}$

[a]Wandering and oscillatory spin.
[b]Two types of spin.
[c]High rate of descent.
[d]High angular velocity.
[e]Recovery attempted by simultaneous full reversal of rudder and elevator.
[f]Recovery attempted by simultaneous rudder reversal and movement of the elevator from 10° up to 20° down.
[g]Recovery attempted by moving the rudder from 37° with to 20° against the spin.
[h]Wandering spin.

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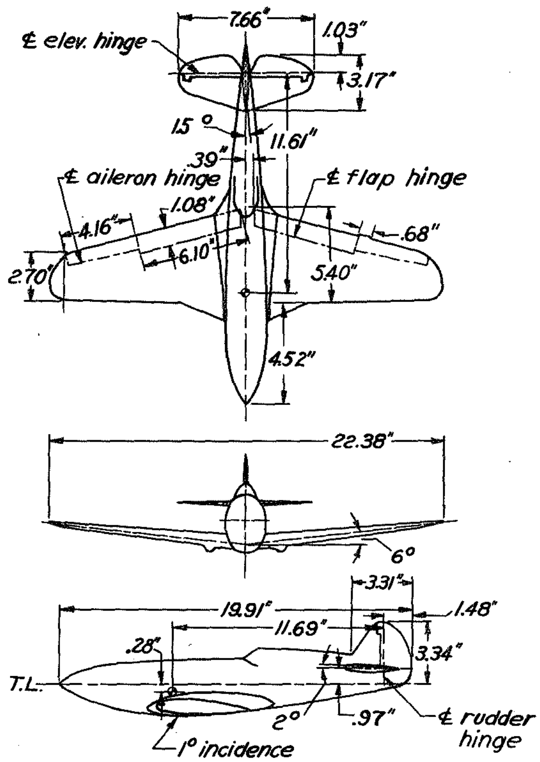
$\frac{1}{20}$-SCALE MODEL OF THE CURTISS YP-37 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	37.28
L, ft	33.18
$\bar{c}$, in.	81.60
S, sq ft	236.00
A	5.90
L.E. $\bar{c}$ aft L.E. c_r, in.	2.20
S_h, sq ft	43.20
S_e, sq ft	19.00
S_v, sq ft	20.90
S_r, sq ft	13.70
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	25 U, 12 D
δ_f, deg	45 D
TDPF	562×10^{-6}
Landing gear	Retractable



Model as tested.

Mass Data

Normal Loading

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W, lb	6700
$x/\bar{c}$	0.287
$z/\bar{c}$	0.076
I_X, slug-ft^2	2062
I_Y, slug-ft^2	7387
I_Z, slug-ft^2	8842
Test altitude, ft	12,000
μ (at sea level)	9.97
μ' (12,000 ft)	14.41

$\frac{I_X - I_Y}{mb^2}$	-184×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-50×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	234×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, recoveries attempted by either rapid full rudder reversal or by simultaneous reversal of rudder and elevator were satisfactory (1/2 turn). Setting the ailerons against the spin did not appreciably affect the recovery characteristics of the model; however, setting the ailerons with the spin had a beneficial effect in that the model would not spin with the elevator either up or neutral.

Moderate extension of mass along the wings (ΔI_X and $\Delta I_Z = 0.30$ or fuselage (ΔI_Y and $\Delta I_Z = 0.30\ I_Y$), or movements of the center of gravity forward or back $0.05\bar{c}$ from its normal position did not appreciably alter the recovery characteristics of the model.

Deflecting the flaps 45° or extending the landing gear had no appreciable effect on the recovery characteristics of the model.

The addition of a ventral fin (modification 1) led to satisfactory recoveries by rapid full rudder reversal for all control settings. Increasing the vertical fin area (modification 2) did not improve the recovery characteristics of the model. Tests conducted with modifications 1 and 2 together also led to satisfactory recoveries, although the most satisfactory recoveries were obtained with modification 1 alone.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS YP-37 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading									Normal loading, rudder-neutral spins								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N (b)	D (b)	U (c)	N (a)	D (b)	U	N	D (d)	U	N (b)	D (b)	U	N (d)	D (b)	U	N	D
α, deg	39	41	43	--	39	38	No spin	No spin	--	No spin	40	42	No spin	--	37	No spin	No spin	No spin
∅, deg	0	3U	5U	--	1D	1U			--		5U	4U		--	0			
Ω, rps	0.33	0.43	0.47	--	0.49	0.50			--		0.44	0.44		--	0.54			
V, fps	194	179	173	--	198	190			--		186	173		--	205			
Turns for recovery	$\frac{3}{4}$ [e]1 [e]$1\frac{3}{4}$	2	∞	$\frac{1}{2}$ [e]$\frac{1}{2}$	2	$3\frac{1}{2}$			--		[f]$3\frac{1}{4}$	[f]∞		--	[f]$3\frac{1}{2}$			

Effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins		
Elevator	N	D
ΔI_X and $\Delta I_Z = 0.15\ I_X$	[a]$1\frac{1}{2}$	$2\frac{3}{4}$
ΔI_X and $\Delta I_Z = 0.30\ I_X$	>$1\frac{1}{2}$ [a]2	$2\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.15\ I_Y$	[g]$1\frac{1}{2}$	[a]2
ΔI_Y and $\Delta I_Z = 0.30\ I_Y$	[g]$1\frac{1}{2}$	[g]$1\frac{3}{4}$
c.g. moved forward $0.05\bar{c}$	[g]$1\frac{3}{4}$ [h]2	[g]$3\frac{1}{2}$
c.g. moved back $0.05\bar{c}$	[g]$1\frac{1}{2}$ [g]1	[g]>$3\frac{1}{2}$ [g]4

	Flaps down 20°, normal loading						Flaps down 45°, normal loading						Landing gear extended, normal loading			Landing gear extended, flaps 45° down, normal loading			Modification 1, normal loading						Modification 2, normal loading			Modifications 1 and 2, normal loading		
Ailerons	Against			Neutral			Against			Neutral			Neutral			Neutral			Against			Neutral			Against			Against		
Elevator	U	N (g)	D (b)	U	N	D	U (b)	N (b)	D (b)	U (b)	N (b)	D (b)	U (c)	N (a)	D (b)	U	N (b)	D	U (a)	N (a)	D (a)	U (a)	N (a)	D (a)	U	N	D (a)	U	N	D (a)
α, deg	No spin	45	42	-	No spin	-	44	46	48	45	44	42	-	40	40	-	47	-	--	--	--	-	--	--	--	--	--	--	--	--
∅, deg		3U	5U	-		-	1U	1D	0	4D	2D	0	-	1U	1U	-	2D	-	--	--	--	-	--	--	--	--	--	--	--	--
Ω, rps		0.42	0.46	-		-	0.36	0.42	0.44	0.33	0.40	0.46	-	0.46	0.50	-	0.45	-	--	--	--	-	--	--	--	--	--	--	--	--
V, fps		171	167	-		-	173	169	156	183	167	167	-	186	194	-	165	-	--	--	--	-	--	--	--	--	--	--	--	--
Turns for recovery		$2\frac{1}{4}$ $6\frac{1}{4}$	3 9 ∞	-		-	1 >$\frac{3}{4}$	3	∞	1 [e]$1\frac{1}{4}$	2	$2\frac{1}{2}$	-	2	$5\frac{1}{2}$	-	$2\frac{1}{4}$	-	[h]$\frac{1}{2}$	[h]$1\frac{1}{2}$	[h]$\frac{3}{4}$	[h]$\frac{1}{2}$	$\frac{1}{2}$	[h]1	--	--	>6	--	--	[h]$1\frac{3}{4}$

[a]Wandering spin.
[b]Wandering and oscillatory spin.
[c]Wanders too greatly to test.
[d]Vertical velocity too great to test.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Recovery attempted by movement of the rudder from neutral to full against the spin.
[g]Oscillatory spin.
[h]Visual observation.

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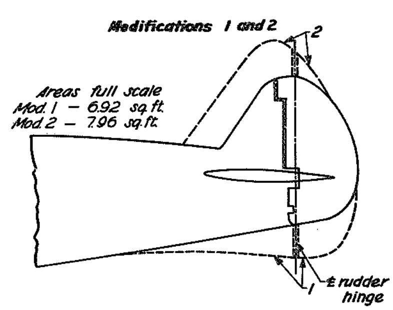
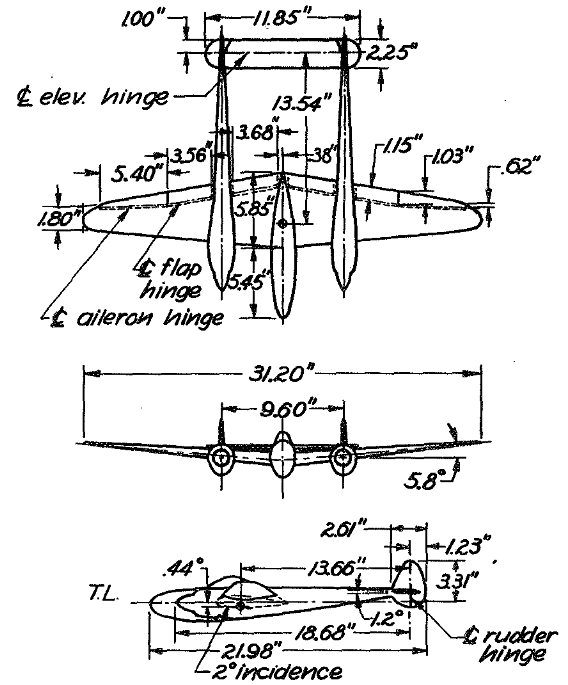


$\frac{1}{20}$-SCALE MODEL OF THE LOCKHEED XP-38 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	52.00
L, ft	36.67
$\bar{c}$, in.	84.25
S, sq ft	328.00
A	8.30
S_h, sq ft	67.20
S_e, sq ft	27.00
S_v, sq ft	40.50
S_r, sq ft	19.98
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 25 D
δ_a, deg	25 U, 25 D
δ_f, deg	35 D
TDPF	510×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	11,260
$x/\bar{c}$	0.254
$z/\bar{c}$	0.104
I_X, slug-ft^2	20,155
I_Y, slug-ft^2	13,850
I_Z, slug-ft^2	33,180
Test altitude, ft	8,000
μ (at sea level)	8.66
μ' (8000 ft)	11.03

$\frac{I_X - I_Y}{mb^2}$	67×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-205×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	138×10^{-4}

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Résumé of Model Test Results

For the normal loading and clean condition (data not presented), the model spun with a high rate of descent (>250 feet per second). In order to obtain a spin for this control configuration, a pro-spin fin was attached to the inner-wing tip (right wing tip in a right spin) of the model (see sketch below) which caused the spin to become flatter and the rate of rotation to decrease. With the pro-spin fin in place, recoveries of the model by rapid full reversal of rudders from the aileron-neutral spins were marginal (2 to $2\frac{1}{2}$ turns) which indicated that recoveries from spins without the pro-spin fin attached would probably be satisfactory.

Moderate changes in the distribution of mass along the wings for fuselage or moderate movements of the center of gravity from its normal position had no appreciable effect upon the satisfactory recovery characteristics of the model.

Fully extending the Fowler flaps had little effect on the recovery characteristics of the model.

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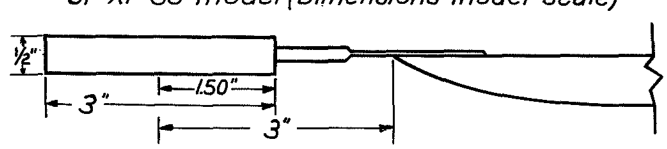
Pro-spin fin installed on wing tip of of XP-38 model (Dimensions model scale)



SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE LOCKHEED XP-38 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading, flaps down.					Normal loading pro-spin fin attached.		
Ailerons	Neutral			With		Neutral		
Elevator	U (a)	N	D	U	N	U	N	D
α, deg	-	-	-	---	---	54	46	50
ϕ, deg	-	-	-	---	---	1D	0	0
Ω, rps	-	-	-	---	---	0.39	0.50	0.50
V, fps	-	-	-	---	---	177	173	167
Turns for recovery	-	-	-	1 [b]$\frac{1}{2}$	1	[c]$2\frac{1}{2}$ [b]1	[d]$2\frac{1}{4}$ $1\frac{3}{4}$	$2\frac{1}{4}$

Effect of mass distribution and c.g. movement on turns for recovery with pro-spin fin attached.			
Ailerons	Neutral		
Elevator	U	N	D
ΔI_X and $\Delta I_Z = 0.20I_X$	[b]1	-	$2\frac{1}{4}$
ΔI_X and $\Delta I_Z = -0.20I_X$	[b]$1\frac{1}{2}$	-	2
ΔI_Y and $\Delta I_Z = 0.15I_Y$	[b]$1\frac{1}{2}$	-	2
ΔI_Y and $\Delta I_Z = 0.30I_Y$	[b]$1\frac{3}{4}$	-	$2\frac{3}{4}$
c.g. moved forward $0.05\bar{c}$	[b]$1\frac{1}{4}$	-	2
c.g. moved back $0.05\bar{c}$	[b]$1\frac{1}{4}$	-	2

ΔI_Y and $\Delta I_Z = 0.30I_Y$; ΔI_X and $\Delta I_Z = -0.20I_X$ with pro-spin fin attached.			
Ailerons	Neutral		
Elevator	U	N	D
α, deg	58	57	53
ϕ, deg	1D	1D	0
Ω, rps	0.36	0.43	0.43
V, fps	173	167	165
Turns for recovery	[c]$2\frac{1}{2}$ [b]$1\frac{1}{2}$ [b]2	$2\frac{1}{2}$	$2\frac{3}{4}$

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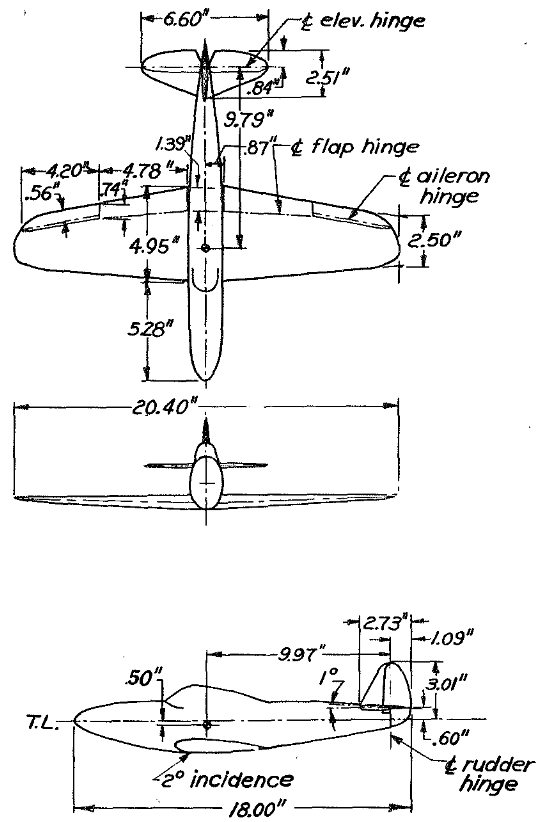
[a]Vertical velocity too high to test.
[b]Recovery attempted by simultaneous reversal of rudders and elevator.
[c]Model goes into steep spiral upon recovery.
[d]Visual observation.

$\frac{1}{20}$-SCALE MODEL OF THE BELL XP-39 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	34.00
L, ft	30.00
c_r, in	99.00
S, sq ft	213.00
A	5.42
S_h, sq ft	30.48
S_e, sq ft	12.04
S_v, sq ft	14.36
S_r, sq ft	8.03
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 15 D
δ_a, deg	25 U, 10 D
δ_a, deg (landing cond.) aileron deflections measured from drooped position	20 D
δ_f, deg	45 D
TDPF	220×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	5,834
x/c_r	0.264
z/c_r	0.100
I_X, slug-feet^2	2,074
I_Y, slug-feet^2	4,358
I_Z, slug-feet^2	6,113
Test altitude, ft	6,000
μ (at sea level)	10.6
μ'(6,000 ft)	12.7

$\frac{I_X - I_Y}{mb^2}$	-110×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-83×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	193×10^{-4}

Résumé of Model Test Results

For the clean condition, normal loading, normal control configuration for spinning, the model spun at a moderate angle of attack ($\alpha = 49^\circ$) and recoveries were satisfactory by rapid full rudder reversal or by simultaneous rapid full reversal of both rudder and elevator. With the elevator set full down (ailerons neutral), recoveries were unsatisfactory. Ailerons deflected with the rotation steepened the spin.

Extending or retracting the mass along the wings or fuselage (ΔI_X and $\Delta I_Z = -0.20\ I_X$, or ΔI_Y and $\Delta I_Z = -0.20\ I_Y$), or moving the center of gravity back $0.07c_r$ from its normal position had no appreciable effect upon the recovery characteristics of the model. A forward movement of the center of gravity $0.06c_r$ from its normal position had a slight detrimental effect upon recoveries from the aileron-neutral and aileron-against spins.

Deflecting the flaps 45° and drooping the ailerons 20° caused unsatisfactory recoveries to be obtained from the aileron neutral and against spins, whereas for the ailerons set with the rotation, no spin conditions were obtained.

Increasing the wing dihedral from 0° to 3° produced a slight beneficial effect on recoveries.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL XP-39 AIRPLANE

[Unless otherwise indicated steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins]

	Normal loading									Rudder-neutral spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N (b)	D (b)	U	N	D	U	N	D	U (a)	N	D
α, deg	49	47	47	49	41	40	---	---	----	No spin	No spin	42	No spin	No spin	No spin	----	No spin	No spin
ϕ, deg	1U	3U	3U	3D	0	1U	---	----	----			4U				----		
Ω, rps	0.37	0.48	0.52	0.37	0.49	0.51	---	----	----			0.50				----		
V, fps	172	171	167	171	181	177	---	----	----			171				----		
Turns for recovery	1 [c]1 [d]$3\frac{1}{4}$	$2\frac{1}{4}$ [d]>6	$2\frac{1}{2}$ [d]>7	$1\frac{3}{4}$ [e]$1\frac{1}{2}$ [d]$3\frac{1}{4}$	2 [d]∞	$2\frac{1}{4}$ [d]>8	---	----	----			[e]$2\frac{1}{4}$				----		

Effect of mass changes and c.g. movements on turns for recovery

Ailerons	Neutral	
Elevator	N	D
ΔI_X and $\Delta I_Z = 0.20\ I_X$	$1\frac{3}{4}$	$2\frac{1}{4}$
ΔI_X and $\Delta I_Z = -0.20\ I_X$	$1\frac{3}{4}$	$2\frac{1}{4}$
ΔI_Y and $\Delta I_Z = 0.20\ I_Y$	$1\frac{1}{2}$	2
ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	2	$2\frac{1}{4}$
c.g. moved back $0.07\bar{c}$	$1\frac{1}{2}$	$1\frac{3}{4}$

	c.g. moved forward $0.06c_r$									c.g. moved forward $0.06c_r$, rudder-neutral spins									Cockpit open, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N (b)	D (b)	U	N	D	U	N	D	U (a)	N	D	U	N	D	U	N	D	U (a)	N (b)	D (b)
α, deg	49	48	51	50	43	43	---	---	---	No spin	No spin	50	No spin	No spin	No spin	---	No spin	No spin	48	48	47	49	44	41	---	---	----
ϕ, deg	1U	3U	3U	2D	0	2U	---	---	---			3U				---			3U	3U	3U	3D	0	3D	---	---	----
Ω, rps	0.43	0.49	0.51	0.42	0.52	0.55	---	---	---			0.44				---			0.36	0.46	0.49	0.32	0.48	0.53	---	---	----
V, fps	169	165	161	173	173	172	---	---	---			161				---			174	171	169	165	179	182	---	---	----
Turns for recovery	2 $2\frac{1}{2}$	3	$4\frac{1}{4}$	2	$2\frac{1}{2}$	$3\frac{1}{4}$	---	---	---			[e]3 [e]$3\frac{1}{2}$				---			1	$2\frac{1}{2}$	$3\frac{3}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	---	---	----

Effect of cockpit covering, flaps, and landing gear on turns for recovery, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
Wheels down	----	----	----	----	2	$2\frac{3}{4}$	----	----	----
Cockpit open wheels down	1	$2\frac{1}{2}$	.	$1\frac{3}{4}$	2	$3\frac{1}{4}$	[a]----	[b]----	[b]----
Flaps down	$1\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{1}{4}$ 4	[a]----	3	$3\frac{3}{4}$	[a]----	[a]----	[f]----
Cockpit open, wheels down, flaps down	∞	∞	∞	$1\frac{1}{2}$	$3\frac{1}{2}$	5	[f]----	[f]----	[f]----

Flaps down, ailerons drooped, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	58	54	54	----	45	45	No spin	No spin	No spin
ϕ, deg	0	1U	1U	----	2D	2D			
Ω, rps	0.42	0.47	0.47	----	0.46	0.54			
V, fps	153	151	147	----	157	153			
Turns for recovery	∞	∞	∞	----	$2\frac{1}{2}$ 3	>$4\frac{1}{2}$			

	3° wing dihedral, normal loading									3° wing dihedral, flaps down 45°, ailerons drooped 20°, cockpit open, wheels down, normal loading									3° wing dihedral, c.g. moved forward $0.06c_r$								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D	U (a)	N	D	U (b)	N (b)	D (b)	U	N	D	U (a)	N	D	U	N	D	U	N	D	U	N	D	U (a)	N (a)	D (a)
α, deg	--	40	40	---	39	40	--	--	--	----	----	----	----	---	-----	-	-	-	---	---	---	---	---	---	--	--	--
ϕ, deg	--	1U	2U	---	0	1U	--	--	--	----	----	----	----	---	-----	-	-	-	---	---	---	---	---	---	--	--	--
Ω, rps	--	0.48	0.52	---	0.49	0.51	--	--	--	----	----	----	----	----	-----	-	-	-	---	---	---	---	---	---	--	--	--
V, fps	--	185	185	---	192	189	--	--	--	----	----	----	----	----	-----	-	-	-	---	---	---	---	---	---	--	--	--
Turns for recovery	--	$2\frac{1}{4}$	$2\frac{3}{4}$	---	2	2	--	--	--	∞	∞	∞	----	3	$4\frac{1}{4}$	-	-	-	2	$2\frac{1}{4}$ $2\frac{3}{4}$	$3\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$ 3	--	--	--

[a]Wandering spin.

[b]High vertical velocity.

[c]Recovery attempted by simultaneous reversal of rudder and elevator

[d]Recovery attempted by rudder neutralization.

[e]Recovery attempted by movement of rudder from neutral to full against the spin.

[f]No spin.

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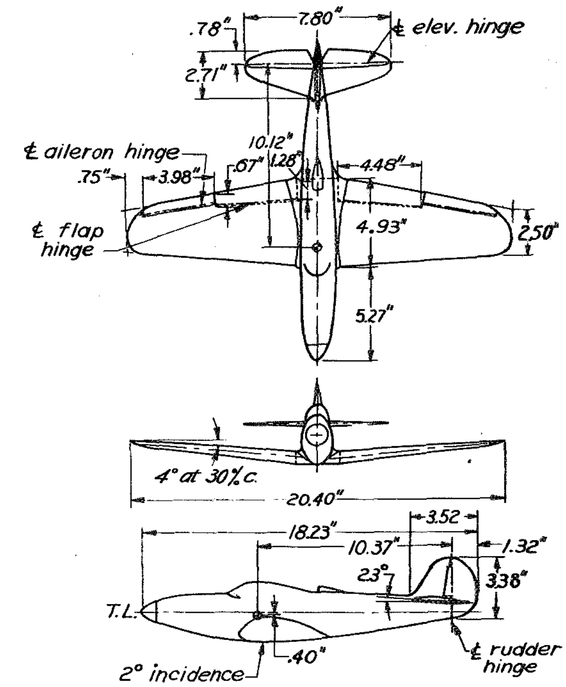
$\frac{1}{20}$-SCALE MODEL OF THE BELL P-39D, P-39D WITH ALL-MOVABLE VERTICAL TAIL AND THE P-39D-1 AIRPLANES

Dimensional Data

(Full Scale)

b, ft	34.00
L, ft	30.13
$\bar{c}$, in	8.64
S, sq ft	213.22
A	5.43
L.E. $\bar{c}$ aft L.E. C_r, in.	5.41
S_h, sq ft	41.20
S_e, sq ft (total)	17.30
S_v, sq ft	19.01
S_r, sq ft (total)	11.07
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 15 D
δ_a, deg	25 U, 10 D
δ_f, deg	45 D
TDPF	364×10^{-6}
Landing gear	Tricycle



Model as tested.

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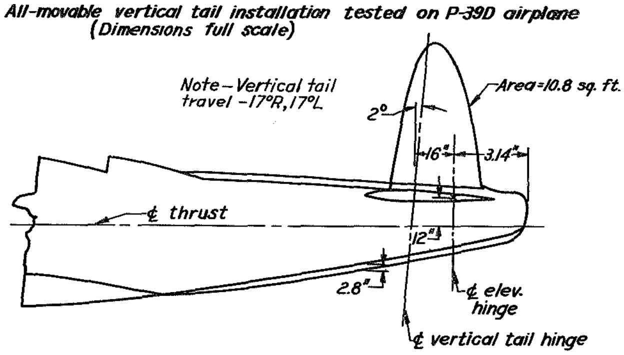
All-movable vertical tail installation tested on P-39D airplane (Dimensions full scale)



Mass Data

Normal Loading

	P-39D	P-39D-1
W, lb	7406	7734
$x/\bar{c}$	0.248	0.313
$z/\bar{c}$	0.100	0.111
I_X, slug-ft^2	5201	5069
I_Y, slug-ft^2	6077	6122
I_Z, slug-ft^2	10704	10655
Test altitude, ft	6000	6000
μ (at sea level)	13.33	13.93
μ (6000 ft)	15.96	16.66
$\frac{I_X - I_Y}{mb^2}$	-32×10^{-4}	-39×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-173×10^{-4}	-162×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	205×10^{-4}	201×10^{-4}

The P-39D model with an all-movable vertical tail had the same weight and mass distribution as the P-39D model with the conventional tail.

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Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, the P-39D model spun at a moderate angle of attack ($\alpha = 41^{\circ}$) and recoveries by rapid full rudder reversal or simultaneous reversal of rudder and elevator were satisfactory ($1\frac{3}{4}$ turns and $1\frac{1}{2}$ turns, respectively). Satisfactory recoveries by rudder reversal could be obtained when the elevator was up or when the ailerons were full against the spin. With the ailerons either neutral or with the spin and the elevator either neutral or down unsatisfactory recoveries were obtained.

Extending or retracting the mass along the wings (ΔI_X and $\Delta I_Z = \pm 0.25\ I_X$) had a detrimental effect upon the recovery characteristics of the model and recoveries from all elevator neutral or down spins were unsatisfactory. Moderate decreases in the mass distribution along the fuselage or moderate changes in the center-of-gravity location had little effect upon the recovery characteristics of the model (data not presented).

Extending the landing gear alone had little effect on the recovery characteristics of the model; however, extending the landing gear in conjunction with deflecting the landing flaps and drooping the ailerons (landing condition) led to spins from which recoveries by rapid full rudder reversal were very slow or impossible.

Recoveries from all inverted spins were satisfactory by rapid full rudder reversal.

The addition of area to the bottom of the fuselage and rear lower portion of the rudder (modifications 1 and 2) improved the recovery characteristics of the model, particularly for the landing condition. Modification 1 generally proved to be the more effective of the two modifications tested; however, recoveries were still generally unsatisfactory for the landing condition.

The substitution of an all movable vertical tail (see sketch) for the conventional tail on the P-39D model generally improved recoveries for elevator up settings. Quite often two types of spin were obtainable for elevator neutral or down spins from which recoveries by rapid full rudder reversal were satisfactory only from the steeper of the two types of spin.

The recovery characteristics of the model when loaded to simulate the P-39D-1 airplane were in general, similar to the recovery characteristics obtained with the P-39D model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL P-39D AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the P-39D model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading																	
Ailerons	Against, Full			Against, 11°U 5°D			Neutral				With, 11°U 5°D			With, Full				
Elevator	U (a)	N (a)	D	U (a)	N	D	U (b)	25°U	N	D	U (b)	N	D	U (b)	N	D		
α, deg	---	---	No spin	--	52	54	41	----	53	53	---	52	53	--	60	57		
ϕ, deg	---	---		--	1U	1U	0	----	1U	0	---	0	0	--	1D	2D		
Ω, rps	---	---		--	0.53	0.55	0.42	----	0.53	0.54	---	0.52	0.54	--	0.55	0.57		
V, fps	>275	----		--	173	163	222	-----	173	171	---	169	171	--	165	161		
Turns for recovery	$^{c}\frac{3}{4}$	----		--	$3\frac{3}{4}$ $4\frac{1}{4}$	4	$1\frac{3}{4}$ $^{d}{>}3$ $^{e}1\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{2}$ $4\frac{1}{4}$ $^{d}\infty$	$4\frac{1}{2}$ $^{d}\infty$	2	$3\frac{3}{4}$	$4\frac{3}{4}$	2	$5\frac{1}{2}$	$9\frac{1}{2}$		

	Rudder neutral spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (b)	N	D
α, deg	No spin	No spin	No spin	----	52	50	----	53	53
ϕ, deg				----	0	1U	----	2D	3D
Ω, rps				---	0.61	0.63	---	0.66	0.63
V, fps				>275	171	167	---	175	167
Turns for recovery				---	----	----	---	----	---

	ΔI_X and $\Delta I_Z = 0.25\ I_X$									ΔI_X and $\Delta I_Z = -0.25\ I_X$								Landing gear extended, normal loading						
Ailerons	Against			Neutral			With			Against			Neutral		With			Against		Neutral			With	
Elevator	U (a)	N	D	U (a)	N	D	U (f)	N	D	U (a)	N	D	U	D	U (f)	N	D	U (a)	D	U (a)	N	D	U	D
V, fps	--	--	173	--	180	179	--	185	185	--	163	159	201	161	193	185	185	>275	No spin	>275	170	170	226	168
Turns for recovery	--	--	$3\frac{3}{4}$ 5	--	$3\frac{1}{4}$	$4\frac{1}{2}$ 5	--	$4\frac{1}{2}$	$4\frac{3}{4}$	--	$4\frac{1}{2}$	6	$2\frac{1}{4}$	$5\frac{1}{2}$	----	$3\frac{1}{2}$	$3\frac{1}{2}$	----		$\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{3}{4}$	$7\frac{1}{2}$

	Landing condition, normal loading									Inverted spins, normal loading								Modification 1 normal loading				
Ailerons	Against			Neutral			With			Against			Neutral			With		Neutral		With		
Elevator	U	N	D	U	N	D	U (b)	N	D	U (a)	N	D (af)	U	N	D	U	D	U	D	U	N	D
V, fps	169	161	156	173	163	156	181	166	164	>275	----	275	254	----	234	209	218	194	173	183	169	165
Turns for recovery	∞	∞	∞	∞	∞	∞	$5\frac{1}{4}$	$6\frac{3}{4}$ $9\frac{1}{4}$	9	$\frac{1}{4}$	----	----	$\frac{3}{4}$ $^{d}1\frac{1}{2}$	----	$1\frac{1}{4}$ $^{d}1\frac{1}{2}$	$1\frac{1}{2}$ $^{d}{>}4$	$1\frac{1}{2}$ $^{d}2\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{3}{4}$	3	3

	Modification 1, landing condition, normal loading									Modification 2, normal loading					Modification 2, landing condition normal loading								
Ailerons	Against			Neutral			With			Neutral		With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	D	U	N	D	U	N	D	U	N	D	U (g)	N	D
V, fps	165	158	158	171	158	158	177	165	160	201	179	195	182	176	171	159	152	173	163	156	181	169	161
Turns for recovery	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{3}{4}$	3	$3\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{1}{4}$	5 $6\frac{1}{2}$	$2\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{3}{4}$	$2\frac{1}{2}$	3	4

[a]Steep spin.
[b]Wandering and oscillatory spin.
[c]Recovery attempted before final high velocity was reached.
[d]Recovery attempted by rudder neutralization.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Wandering spin.
[g]Oscillatory spin.
[h]Two types of spin. The other is steeper; recovery effected in $\frac{1}{2}$ turn.
[i]Visual observation.
[j]Model goes into left spin after recovering from right spin.
[k]Model goes into inverted spin after recovering from erect spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL P-39D AIRPLANE WITH ALL MOVABLE VERTICAL TAIL INSTALLATION

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition, and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading														
Ailerons	Against					Neutral			With						
	Full			11°U, 5°D					11°U, 5°D				Full		
Elevator	U (a)	N	D	N	D	U (ab)	N	D	U (ab)	N (c)	N (c)	D	U (b)	N	D
α, deg	-	No spin	No spin	No spin	No spin	-	21	46	-	40	18	42	-	43	38
ϕ, deg	-					-	2D	0	-	3D	6D	2D	-	4D	5D
Ω, rps	-					-	0.69	0.54	-	0.54	-	0.54	-	0.51	0.54
V, fps	-					-	302	176	-	200	297	187	-	187	193
Turns for recovery	$\frac{1}{4}$					1 [d]$\frac{3}{4}$	1	5 9	1 $1\frac{1}{2}$	$4\frac{1}{2}$ $5\frac{1}{2}$	1	$4\frac{1}{2}$	>5 [d]$\frac{3}{4}$ [d]$1\frac{1}{2}$	∞	∞

	ΔI_X and $\Delta I_Z = -0.25 I_X$							
Ailerons	Against		Neutral				With	
Elevator	U (a)	D	U (ab)	N	D (c)	D (c)	U (b)	D
α, deg	-	No spin	-	19	39	21	-	17
ϕ, deg	-		-	2D	1D	2U	-	3D
Ω, rps	-		-	0.76	0.55	0.86	-	0.86
V, fps	-		-	324	182	290	-	304
Turns for recovery	$\frac{1}{2}$		1	$\frac{3}{4}$	4	1	$>2\frac{1}{2}$	1

	ΔI_Y and $\Delta I_Z = 0.20 I_Y$							
Ailerons	Against			Neutral			With	
Elevator	U (a)	N	D	U (ab)	N (a)	D (e)	U (f)	D (a)
α, deg	-	-	No spin	-	-	-	-	-
ϕ, deg	-	-		-	-	-	-	-
Ω, rps	-	-		-	-	-	-	-
V, fps	-	-		-	-	207	-	-
Turns for recovery	-	-		-	-	-	-	-

	Left spin, normal loading														
Ailerons	Against						Neutral			With					
	Full			11°U, 5°D						11°U, 5°D			Full		
Elevator	U (a)	N	D	U	N	D	U (ab)	N	D	U (ab)	N	D	U (b)	N (b)	D
α, deg	-	No spin	No spin	-	No spin	No spin	-	21	21	-	25	23	-	-	26
ϕ, deg	-			-			-	8D	1U	-	8D	4D	-	-	10D
Ω, rps	-			-			-	0.68	0.81	-	0.69	0.81	-	-	0.76
V, fps	-			-			-	304	304	-	285	278	-	-	~265
Turns for recovery	$\frac{3}{4}$			-			$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$ $1\frac{1}{4}$	2	2	$1\frac{1}{4}$	>2	$2\frac{1}{2}$	$1\frac{1}{2}$

	Left spin, ΔI_X and $\Delta I_Z = -0.25 I_X$								
Ailerons	Against			Neutral				With	
Elevator	U (a)	D (c)	D (c)	U (ab)	N	D (c)	D (c)	U (b)	D
α, deg	-	46	23	--	-	43	23	-	18
ϕ, deg	-	3U	2U	-	-	1U	0	-	5D
Ω, rps	-	0.55	0.92	-	-	0.53	0.69	-	0.86
V, fps	-	188	264	-	304	194	271	-	332
Turns for recovery	-	$4\frac{1}{2}$	$1\frac{1}{4}$	-	-	5	$1\frac{1}{4}$	-	$\frac{3}{4}$

	Left spin, ΔI_Y and $\Delta I_Z = 0.20 I_Y$								
Ailerons	Against			Neutral				With	
Elevator	U (a)	D (c)	D (c)	U (ab)	N	D (c)	D (c)	U (f)	D (af)
α, deg	-	49	22		22	50	24	-	-
ϕ, deg	-	3U	2U	-	4D	0	3D	-	-
Ω, rps	-	0.47	0.75	-	0.58	0.47	0.75	-	-
V, fps	-	176	298	-	304	176	278	-	-
Turns for recovery	$\frac{1}{4}$	$6\frac{1}{2}$ ∞	$\frac{1}{2}$ 1	$\frac{1}{4}$	1	4 ∞	$1\frac{1}{4}$	>2	2

[a]Steep spin.
[b]Wandering and oscillatory spin.
[c]Two types of spin.
[d]Recovery attempted by simultaneously reversing the rudder and neutralizing the elevator.
[e]Steeper spin also obtainable.
[f]Wandering spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL P-39D-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition, and recoveries were attempted by rapid full rudder reversal from right erect spins]

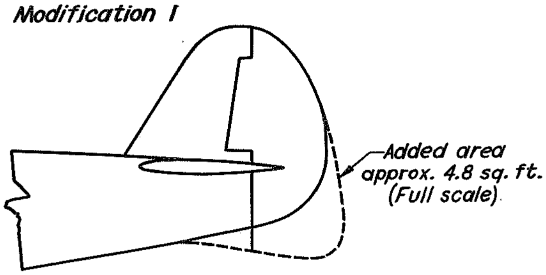
	Normal loading															ΔI_X and $\Delta I_Z = -0.25 I_X$							
Ailerons	Against					Neutral			With							Against		Neutral				With	
	Full			11°U, 5°D					11°U, 5°D				Full										
Elevator	U (a)	N	D	N	D	U (ab)	N	D	U (ab)	N (c)	N (c)	D	U (b)	N	D	U (a)	D	U (ab)	N	D (c)	D (c)	U (b)	D
α, deg	-	No spin	No spin	No spin	No spin	-	21	46	-	40	18	42	-	43	38	-	No spin	-	19	39	21	-	17
ϕ, deg	-					-	2D	0	-	3D	6D	2D	-	4D	5D	-		-	2D	1D	2U	-	3D
Ω, rps	-					-	0.69	0.54	-	0.54	-	0.54	-	0.51	0.54	-		-	0.76	0.55	0.86	-	0.86
V, fps	-					-	302	176	-	200	297	187	-	187	193	-		-	324	182	290	-	304
Turns for recovery	$\frac{1}{4}$					1 [d]$\frac{3}{4}$	1	5 9	1 $1\frac{1}{2}$	$4\frac{1}{2}$ $5\frac{1}{2}$	1	$4\frac{1}{2}$	>5 [d]$\frac{3}{4}$ [d]$1\frac{1}{2}$	∞	∞	$\frac{1}{2}$		1	$\frac{3}{4}$	4	1	>$2\frac{1}{2}$	1

	ΔI_Y and $\Delta I_Z = 0.20 I_Y$								Left spin, normal loading														
Ailerons	Against			Neutral			With		Against						Neutral			With					
									Full			11°U, 5°D						11°U, 5°D			Full		
Elevator	U (a)	N	D	U (ab)	N (a)	D (e)	U (f)	D (a)	U (a)	N	D	U	N	D	U (ab)	N	D	U (ab)	N	D	U (b)	N (b)	D
α, deg	-	-	No spin	-	-	-	-	-	-	No spin	No spin	-	No spin	No spin	-	21	21	-	25	23	-	-	26
ϕ, deg	-	-		-	-	-	-	-	-			-			-	8D	1U	-	8D	4D	-	-	10D
Ω, rps	-	-		-	-	-	-	-	-			-			-	0.68	0.81	-	0.69	0.81	-	-	0.76
V, fps	-	-		-	-	207	-	-	-			-			-	304	304	-	285	278	-	-	265
Turns for recovery	-	-		-	-	-	-	-	$\frac{3}{4}$			-			$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$ $1\frac{1}{4}$	2	2	$1\frac{1}{4}$	>2	$2\frac{1}{2}$	$1\frac{1}{2}$

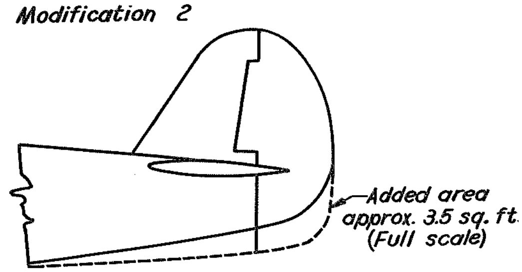
	Left spin, ΔI_X and $\Delta I_Z = -0.25 I_X$									Left spin, ΔI_Y and $\Delta I_Z = 0.20 I_Y$								
Ailerons	Against			Neutral				With		Against			Neutral				With	
Elevator	U (s)	D (c)	D (c)	U (ab)	N	D (c)	D (c)	U (b)	D	U (a)	D (c)	D (c)	U (ab)	N	D (c)	D (c)	U (f)	D (af)
α, deg	-	46	23	--	-	43	23	-	18	-	49	22	-	22	50	24	-	-
ϕ, deg	-	3U	2U	-	-	1U	0	-	5D	-	3U	2U	-	4D	0	3D	-	-
Ω, rps	-	0.55	0.92	-	-	0.53	0.69	-	0.86	-	0.47	0.75	-	0.58	0.47	0.75	-	-
V, fps	-	188	264	-	304	194	271	-	332	-	176	298	-	304	176	278	-	-
Turns for recovery	-	$4\frac{1}{2}$	$1\frac{1}{4}$	-	-	5	$1\frac{1}{4}$	-	$\frac{3}{4}$	$\frac{1}{4}$	$6\frac{1}{2}$ ∞	$\frac{1}{2}$ 1	$\frac{1}{4}$	1	4 ∞	$1\frac{1}{4}$	>2	2

[a] Steep spin.
[b] Wandering and oscillatory spin.
[c] Two types of spin.
[d] Recovery attempted by simultaneously reversing the rudder and neutralizing the elevator.
[e] Steeper spin also obtainable.
[f] Wandering spin.

Modification 1



Modification 2



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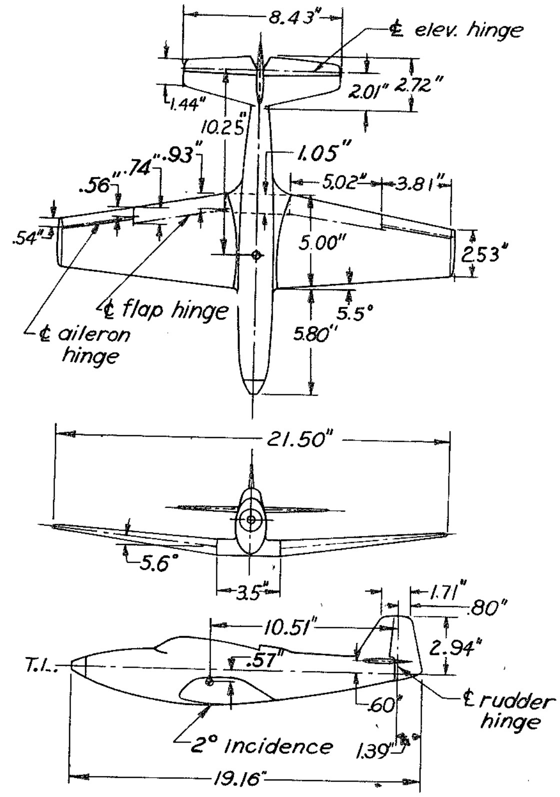
$\frac{1}{20}$-SCALE MODEL OF THE BELL XP-39E AIRPLANE

b, ft	35.83
L, ft	31.95
$\bar{c}$, in	82.43
S, sq ft	235.60
A	5.46
L.E. $\bar{c}$ aft L E. c_r, in.	6.15
S_h, sq ft	47.56
S_e, sq ft (incl. bal.)	16.16
S_v, sq ft	19.10
S_r, sq ft (incl. bal.)	11.07
δ_r, deg	25 R, 25 L
δ_e, deg	25 U, 15 D
δ_a, deg	25 U, 10 D
δ_f, deg	45 D
TDPF	361×10^{-6}
Landing gear	Tricycle



Model as tested.

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Mass Data

Normal Loading

W, lb	8984	$\frac{I_X - I_Y}{mb^2}$	-28×10^{-4}
$x/\bar{c}$	0.254		
$z/\bar{c}$	0.138		
I_X, slug-ft^2	6361	$\frac{I_Y - I_Z}{mb^2}$	-155×10^{-4}
I_Y, slug-ft^2	7357		
I_Z, slug-ft^2	12,901		
Test altitude, ft	6000	$\frac{I_Z - I_X}{mb^2}$	183×10^{-4}
μ (at sea level)	13.90		
μ'(6,000 ft)	16.63		

Flight Loading

W, lb	8053	$\frac{I_X - I_Y}{mb^2}$	-98×10^{-4}
$x/\bar{c}$	0.248		
$z/\bar{c}$	0.138		
I_X, slug-ft^2	4289	$\frac{I_Y - I_Z}{mb^2}$	-96×10^{-4}
I_Y, slug-ft^2	7446		
I_Z, slug-ft^2	10,534		
Test altitude, ft	6000	$\frac{I_Z - I_X}{mb^2}$	194×10^{-4}
μ (at sea level)	12.46		
μ'(6,000 ft)	14.90		

Résumé of Model Test Results

For the clean condition, normal loading, normal control configuration for spinning, two types of spin were possible; one spin was steep ($\alpha = 22^{\circ}$) and recovery by rapid full rudder reversal was satisfactory (3/4 turn), the other spin was flat ($\alpha = 56^{\circ}$) and recovery was unsatisfactory $\left(3\frac{1}{4}\text{ turns}\right)$. For all control settings in the normal loading, two types of spins were obtainable similar in nature to the spins obtained for the normal control configuration. Ailerons set with the spin had an adverse effect upon the recovery characteristics of the model, whereas the ailerons set against the spin improved the recovery characteristics of the model. Recoveries from spins obtained with the model in the landing condition were generally unsatisfactory.

The addition of vertical area to the fuselage below the horizontal surfaces and to the rudder (modification 1) led to an improvement in the recovery characteristics of the model and recoveries were generally satisfactory.

A number of supplementary tests were conducted with the model equipped with a modified tail (see sketch) and recoveries from spins obtained were generally unsatisfactory.

Numerous dimensional modifications (modifications 2 through 32) were tested in an attempt to improve the recovery characteristics of the model equipped with the modified tail. The basic tail modifications whi produced satisfactory recoveries were

(1) Additional fin and rudder area below rear portion of fuselage and lower portion of rudder (modification 3)

(2) Additional vertical fin area below fuselage (modification 28)

(3) Antispin fillets (modification 29)

In general, for the model equipped with the modified tail, recoveries from spins for the landing condition (flaps deflected 45°, landing gear extended) were slower than recoveries from the correspondin spins of the model in the clean condition.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL XP-39E AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading																	
Ailerons	Against						Neutral						With					
Elevator	U (a)	U (a)	N (b)	N (b)	D (b)	D (b)	U (a)	U (a)	N (a)	N (a)	D (a)	D (a)	U (ac)	U (a'c)	N (a)	N (a)	D (a)	D (a)
α, deg	56	22	---	No spin	---	No spin	56	22	49	24	46	25	57	24	53	---	53	---
Ø, deg	1U	1U	---		---		0	2D	0	1U	0	1U	2D	4D	2D	---	2D	---
Ω, rps	0.46	0.53	----		----		0.45	0.50	0.50	0.73	0.53	0.76	0.48	0.52	0.51	----	0.54	----
V, fps	188	338	271		271		188	304	188	288	188	288	182	294	182	271	170	271
Turns for recovery	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$		$\frac{3}{4}$		$3\frac{1}{4}$	$\frac{3}{4}$	$4\frac{1}{4}$	1 2	$3\frac{3}{4}$	$1\frac{1}{2}$	$7\frac{1}{4}$	1	$5\frac{1}{2}$	$1\frac{1}{2}$	$4\frac{1}{4}$ 5	[d]$1\frac{1}{2}$

	Landing condition, normal-loading											Modification 1, normal loading								
Ailerons	Against			Neutral				With				Against			Neutral			With		
Elevator	U (c)	N	D	U	N (a)	N (a)	D	U (c)	N	D (a)	D (a)	U	N	D	U	N	D	U	N	D
α, deg	47	48	50	52	---	13	54	51	52	55	13	--	--	--	--	---	--	---	---	--
Ø, deg	2U	1U	2U	0	----	2D	0	2D	2D	2D	1U	--	--	--	---	----	----	---	----	--
Ω, rps	0.43	0.49	0.50	0.42	0.48	----	0.52	0.42	0.49	0.50	1.11	--	--	--	---	----	---	----	----	--
V, fps	176	179	173	182	176	338	170	188	173	179	338	--	--	--	---	182	----	206	182	--
Turns for recovery	$2\frac{1}{4}$ $2\frac{3}{4}$	4 5	6	4	$5\frac{1}{2}$	---	$7\frac{1}{4}$	$4\frac{1}{2}$	$8\frac{1}{2}$	∞	[d]$\frac{3}{4}$	--	--	--	---	2	---	$2\frac{1}{4}$	2	--

Supplementary tests with model, normal loading

Remarks	Ailerons	Elevator (deg)	Rudder (deg)	V (fps)	Turns for recovery	Remarks	Ailerons	Elevator (deg)	Rudder (deg)	V (fps)	Turns for recovery
	Against	30U	25	176	7		Neutral	35U	25	182	∞
							Neutral	30U	35	160	[e]9
	Against	25U	25	176	∞	(f)	Neutral	30U	30	176	∞
	Right 5°D Left 5°U	25U	25	176	∞	(f)	Neutral	30U	30	185	$5\frac{1}{2}$
	Right 3°D Left 3°U	25U	25	176	∞	(f)	Neutral	30U	30	232	---------
(a)	Neutral	35U	30	185	$6\frac{1}{2}$		Neutral	25U	25	176	∞
(a)	Neutral	35U	30	304	$1\frac{1}{4}$		Neutral	30U	25	166	[g]$7\frac{1}{4}$

Modifications tested on model after crack-up, normal loading unless otherwise indicated

Modification	Remarks	Ailerons	Elevator (deg)	Rudder (deg)	V (fps)	Turns for recovery	Modification	Remarks	Ailerons	Elevator (deg)	Rudder (deg)	V (fps)	Turns for recovery
1		Neutral	25U	25	176	*$3\frac{3}{4}$	7		Neutral	25U	25	176	10
1		With	15D	25	176	8, ∞	8		Neutral	25U	25	197	3, $4\frac{1}{4}$
2		Neutral	30U	30	188	$2\frac{3}{4}$	9		Neutral	25U	25	182	6
2		With	15D	30	188	$5\frac{1}{2}$	10	(hi)	Against	25U	25	188	4
3		Neutral	30U	30	207	1	10		Neutral	25U	25	170	$6\frac{1}{2}$
3		Neutral	30U	25	191	$1\frac{1}{2}$	10		With	15D	25	166	∞
3		Neutral	25U	25	191	2	10 + 11		With	15D	25	166	∞
3		With	15D	30	188	$2\frac{3}{4}$	10 + 12	(j)	With	15D	25	304	--------
4		Neutral	30U	30	194	$2\frac{1}{2}$	10 + 13		Neutral	25U	25	179	∞
4		Neutral	25D	25	176	$3\frac{1}{2}$	10 + 13		With	15D	25	194	∞
4		With	15D	30	182	$3\frac{3}{4}$	10 + 14	(a)	Neutral	25U	25	197	$4\frac{1}{4}$
5		Neutral	30U	25	182	5	10 + 14	(a)	Neutral	25U	25	304	1
5		Neutral	25U	25	182	5							
6		Neutral	25U	25	176	$7\frac{1}{2}$	10 + 15	(jk)	Against	30U	30	374	--------

[a]Two types of spin.
[b]Two conditions possible.
[c]Wandering and oscillatory spin.
[d]Model goes into an inverted spin upon recovery.
[e]Recovery attempted by rudder reversal from 35° with to 25° against the spin.
[f]Three types of spin.
[g]Recovery attempted by rudder reversal from 25° with to 35° against the spin.
[h]Landing condition.
[i]Flight loading.
[j]Steep spin.
[k]Wandering spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL XP-39E AIRPLANE - Continued

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Modifications tested on model after crack-up, normal loading unless otherwise indicated

Modification	Remarks	Ailerons	Elevator (deg.)	Rudder (deg.)	V, (fps)	Turns for recovery
10+15		Against	30 U	30	176	$2\frac{1}{2}$
10+15		Neutral	30 U	30	176	>3
10+15		--do---	25 U	25	176	5
10+15		RT 10° D LT 10° D	30 U	30	176	$5\frac{1}{2}$
10+15		With	15 D	30	176	7
10+16		Neutral	25 U	25	304	$\frac{3}{4}$
10+16		--do---	15 D	25	182	8
10+16		With	15 D	25	188	$5\frac{1}{2}$, 7
10+16+17		Neutral	15 D	25	170	$6\frac{1}{2}$
10+18		--do---	15 D	25	170	∞
10+18		With	15 D	25	176	∞
10+16+18		Neutral	25 U	25	304	$\frac{3}{4}$
10+16+18		--do---	15 D	25	191	$5\frac{1}{4}$
10+16+18	(j)	With	15 D	25	239	-
2+10+16+18		-do-	15 D	25	239	$1\frac{1}{2}$
4+10+16+18		Neutral	15 D	25	194	$2\frac{1}{4}$
4+10+16+18	(j)	With	15 D	25	232	$1\frac{1}{4}$
19		Neutral	25 U	25	210	2 , 3
19		--do---	15 D	25	194	$3\frac{3}{4}$
20		--do---	25 U	25	194	>4
22		--do---	35 U	30	239	$1\frac{1}{4}$
22		--do---	25 U	25	210	$2\frac{3}{4}$
22+2	(i)	--do---	25 U	25	220	$1\frac{3}{4}$
22+2		--do---	15 D	25	223	2
22+2		With	15 D	25	216	$2\frac{1}{2}$
21+22		Neutral	25 U	25	223	$1\frac{1}{2}$, 2
2+10+22	(j)	Against	30 D	25	-	$\frac{1}{2}$
2+10+22	(ij)	--do---	30 D	25	-	-
2+10+22		--do---	15 U	25	No Spin	
2+10+22	(i)	--do---	15 U	25	188	$2\frac{3}{4}$
2+10+22		Neutral	30 D	25	210	$1\frac{3}{4}$
2+10+22		--do---	25 U	25	220	$1\frac{3}{4}$
2+10+22	(h)	--do---	25 U	25	194	$1\frac{3}{4}$
2+10+22		With	30 D	25	194	$3\frac{1}{2}$
2+10+22	(h)	-do-	25 U	25	194	$3\frac{1}{2}$
2+10+22		-do-	15 U	25	194	$4\frac{1}{2}$
10+21+22	(h)	-do-	15 D	25	182	$4\frac{1}{2}$
10+21+22	(jl)	Against	25 U	25		$\frac{3}{4}$

Modification	Remarks	Ailerons	Elevator (deg.)	Rudder (deg.)	V, (fps)	Turns for recovery
10 + 21 + 22	(h)	Against	15 U	25	194	$1\frac{1}{2}$, 2
10 + 21 + 22	(l)	--do---	15 U	25	182	3 , 5
10 + 21 + 22	(hj)	Neutral	25 D	25	-	-
10 + 21 + 22	(h)	With	15 D	25	191	$3\frac{3}{4}$
10 + 23	(j)	Against	30 U	30	-	-
10 + 23		--do---	15 D	25	185	$3\frac{1}{2}$
10 + 23	(h)	--do---	15 D	25	182	$4\frac{1}{4}$
10 + 23		Neutral	30 U	30	207	$1\frac{1}{4}$
10 + 23	(h)	--do---	30 U	25	191	$2\frac{1}{4}$
10 + 23		--do---	30 U	25	207	$1\frac{1}{4}$
10 + 23		--do---	25 U	25	220	2
10 + 23	(h)	--do---	25 U	25	194	$1\frac{3}{4}$, $2\frac{1}{2}$
10 + 23	(h)	--do---	0	25	185	$3\frac{1}{2}$
10 + 23		--do---	15 D	30	182	4
10 + 23		--do---	15 D	25	176	$3\frac{1}{4}$, $5\frac{1}{2}$
10 + 23	(c)	With	30 U	30	185	$2\frac{1}{4}$
10 + 23		-do-	15 D	25	220	4
10 + 23	(h)	-do-	15 D	25	188	5
24	(h)	Neutral	30 U	30	185	$3\frac{3}{4}$
24	(j)	--do---	30 D	30	339	-
24	(k)	--do---	25U	30	239	-
24		With	30 U	30	239	2
24	(h)	-do-	30 D	30	185	$4\frac{3}{4}$, $6\frac{1}{4}$, 9
24	(j)	-do-	30 D	30	291	-
2+22+24	(hj)	Neutral	30 D	30	197	-
2+22+24	(hj)	--do---	25 D	25	>304	-
2+22+24	(h)	--do---	25 U	25	194	-
25	(j)	Against	35 U	30	>304	-
25		--do---	30 U	30	176	$4\frac{3}{4}$
25	(m)	--do---	30 U	30	182	6
25	(a)	Neutral	35 U	30	188	$3\frac{1}{4}$, $4\frac{1}{2}$
25	(aj)	--do---	35 U	30	304	1
25		--do---	30	30	173	$6\frac{3}{4}$, 9
25	(n)	--do---	30 U	30	182	6
25	(m)	--do---	30 U	30	176	∞
25		--do---	0	30	163	∞
25	(m)	--do---	0	30	163	∞

[a]Two types of spin.
[c]Wandering and oscillatory spin.
[h]Landing condition.
[i]Flight loading.
[j]Steep spin.
[k]Wandering spin.
[l]Flight loading, landing condition.
[m]Landing condition, nose-wheel doors in place.
[n]Elevator cutouts increased.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL XP-39E AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Modifications tested on model after crack-up, normal loading unless otherwise indicated													
Modification	Remarks	Ailerons	Elevator (deg)	Rudder (deg)	V (fps)	Turns for recovery	Modification	Remarks	Ailerons	Elevator (deg)	Rudder (deg)	V (fps)	Turns for recovery
25	(o)	With	35 U	30	239	$3\frac{1}{2}$	25 + 29	(m)	Neutral	30 U	30	185	$2\frac{1}{2}, 3\frac{1}{2}, 4\frac{1}{2}$
25		-do-	30 U	30	166	∞	25 + 29		--do--	0	30	176	5
25	(mo)	-do-	30 U	30	176	∞	25 + 29	(m)	--do--	0	30	176	$6\frac{1}{2}$
25	(n)	-do-	30 U	30	176	∞	25 + 29		With	30 U	30	232	$2\frac{1}{2}$, 3
24 + 25		Neutral	30 U	30	239	1	25 + 29	(m)	-do-	30 U	30	185	$4\frac{1}{2}$
24 + 25	(h)	--do--	30 U	30	182	$3\frac{1}{2}$	25+28+29	(mj)	Neutral	35 U	30	---	---
22+24+25		--do--	30 D	30	239	$\frac{3}{4}$	25+28+29	(m)	Against	30 U	30	220	1
22+24+25	(h)	--do--	30 U	30	188	$2\frac{1}{2}$	25+28+29	(i)	--do--	30 U	30	223	$1\frac{3}{4}$
22+24+25	(m)	--do--	30 U	30	188	$1\frac{3}{4}$	25+28+29	(im)	--do--	30 U	30	182	4
22+24+25	(h)	With	30 U	30	185	$3\frac{1}{2}$	25+28+29	(j)	Rt. 20°D Lt. 20°U	30 U	30	>339	---
22+24+25	(m)	-do-	30 U	30	188	3	25+28+29		Neutral	30 U	30	339	$\frac{3}{4}$
22 + 25	(j)	Against	30 U	30	339	---	25+28+29	(m)	--do--	30 U	30	213	$1\frac{1}{4}, 2\frac{1}{4}, 2\frac{3}{4}$
22 + 25		Neutral	35 U	30	245	$1\frac{1}{4}$	25+28+29	(i)	--do--	30 U	30	304	$\frac{3}{4}$
22 + 25	(a)	--do--	30 U	30	201	$3\frac{1}{4}$	25+28+29	(im)	--do--	30 U	30	182	$2\frac{1}{2}$
22 + 25	(a)	--do--	30 U	30	239	$2\frac{1}{2}$	25+28+29		--do--	0	30	176	$4\frac{1}{2}$
22 + 25		--do--	0	30	188	4	25+28+29	(m)	--do--	0	30	182	5
22 + 25	(o)	With	30 U	30	216	$3\frac{1}{4}$	25+28+29	(p)	Rt. 20°U Lt. 20°D	30 U	30	>304	---
25 + 26	(j)	Against	35 U	30	339	---	25+28+29		With	30 U	30	245	$2\frac{1}{2}$
25 + 26	(j)	--do--	30 U	30	339	---	25+28+29	(m)	-do-	30 U	30	194	5
25 + 26		Neutral	35 U	30	339	1	25+28+29	(ip)	-do-	30 U	30	>304	---
25 + 26		--do--	30 U	30	304	1	25+28+29	(pq)	-do-	30 U	30	---	---
25 + 26		--do--	30 U	30	176	$4\frac{3}{4}$	25+28+29	(jr)	Neutral	30 U	30	>339	---
25 + 26		--do--	0	30	163	∞	25+28+29	(r)	--do--	0	30	194	$3\frac{3}{4}$
25 + 26	(o)	With	35 U	30	304	1	25+28+29	(r)	With	30 U	30	---	$1\frac{3}{4}$
25 + 26	(ja)	-do-	30 U	30	304	2	25+28+29	(s)	Neutral	0	30	176	$5\frac{1}{2}$
25 + 26	(a)	-do-	30 U	30	176	9	25+28+29	(s)	With	30 U	30	---	2
22+25+26	(j)	Against	30 U	30	304	---	25 + 30		Neutral	30 U	30	304	1
22+25+26		Neutral	30 U	30	325	$\frac{3}{4}$	25 + 30		--do--	0	30	163	7, $5\frac{1}{2}$
22+25+26		--do--	0	30	207	$2\frac{3}{4}$	25 + 30		With	30 U	30	231	3
22+25+26		With	30 U	30	234	$2\frac{3}{4}$	31		Neutral	30 U	30	288	1
25+26+27		Neutral	30 U	30	176	5	31		--do--	0	30	163	9
25+26+27	(a)	With	30 U	30	176	6							
25+26+27	(ap)	-do-	30 U	30	304	---	31		With	30 U	30	258	3
25 + 29	(j)	Against	30 U	30	339	---	32		Neutral	0	30	163	6
25 + 29	(m)	--do--	30 U	30	204	$1\frac{1}{4}$, $1\frac{3}{4}$							
25 + 29		Neutral	30 U	30	252	$1\frac{1}{4}$	32		With	30	30	176	∞

[a] Two types of spin.
[h] Landing condition.
[i] Flight loading.
[j] Steep spin.
[m] Landing condition, nose-wheel doors in place.
[n] Elevator cutouts increased.
[o] Oscillatory spin.
[p] Steep and oscillatory spin.
[q] Flight loading, landing condition, nose-wheel doors in place.
[r] Leading edge of anti-spin fillets lowered 5 inches full scale.
[s] Leading edge of anti-spin fillets raised 5 inches full scale.

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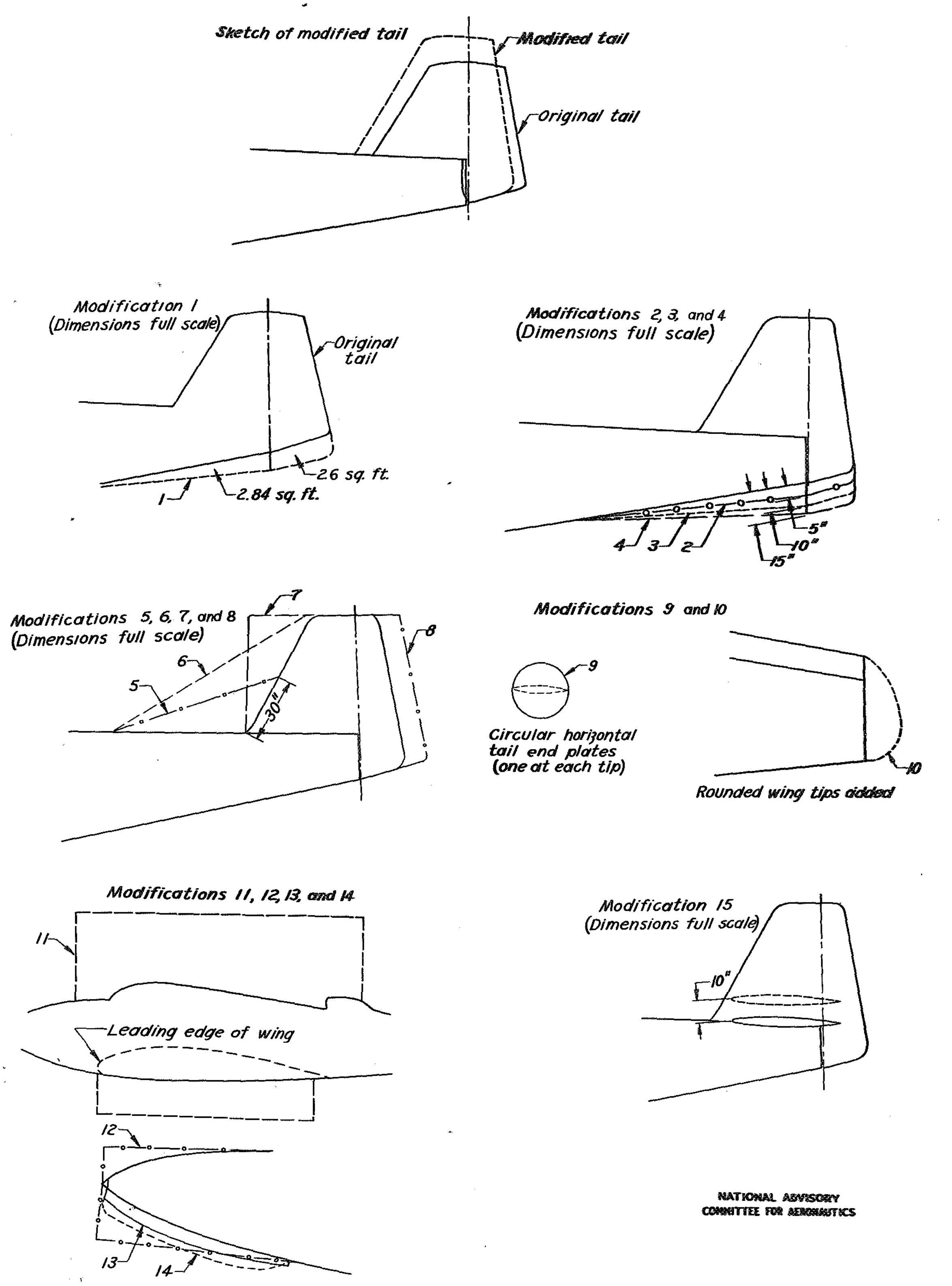

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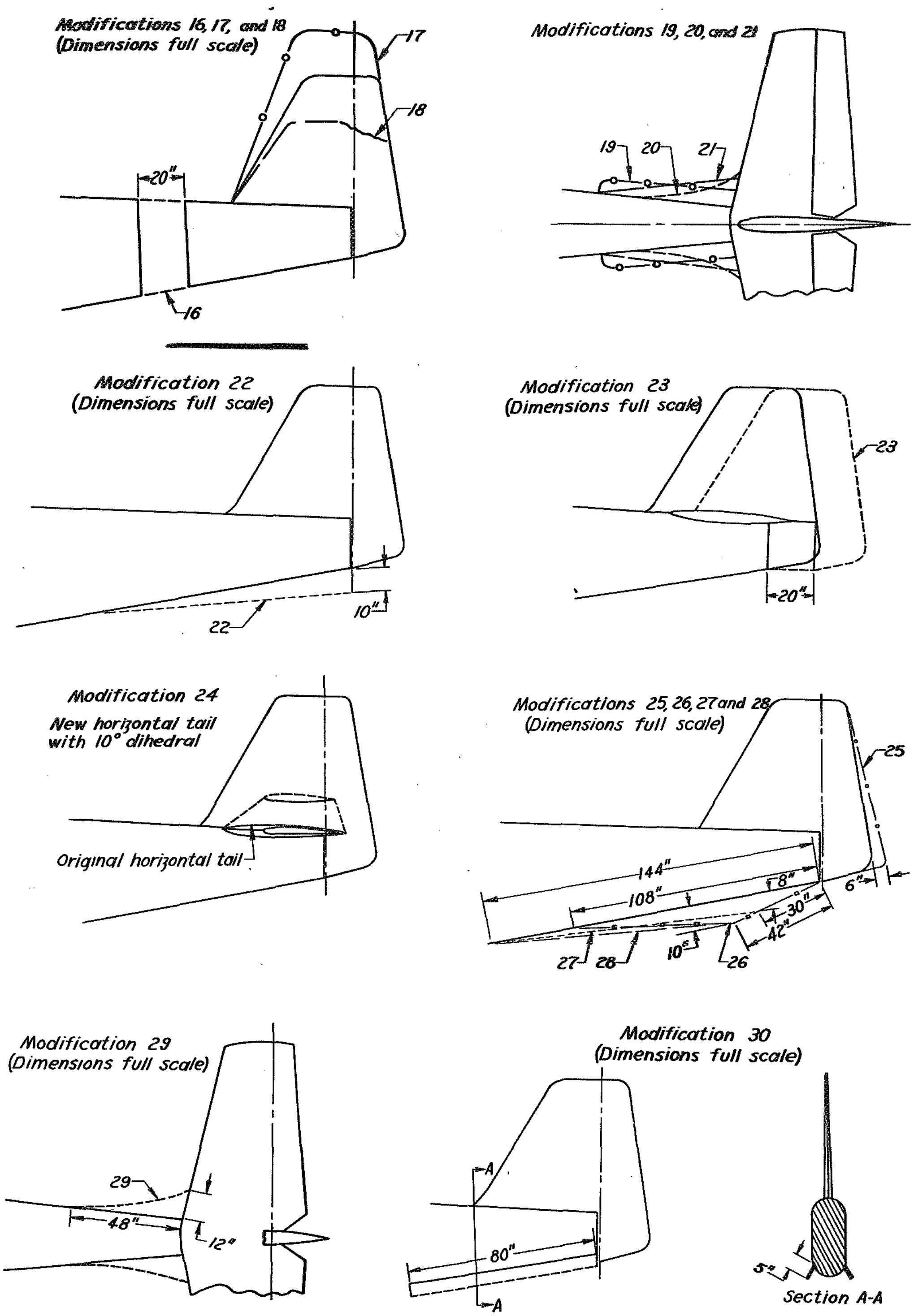
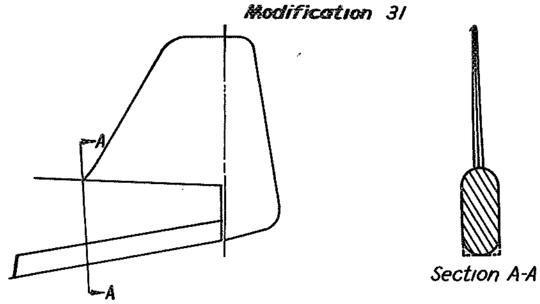
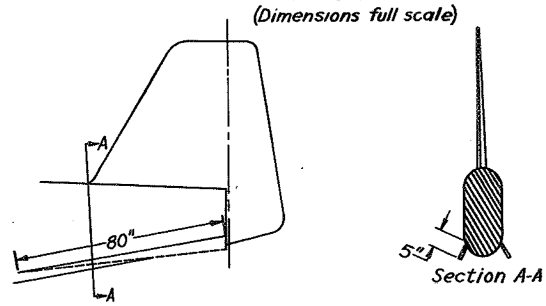

Modifications 16, 17, and 18
(Dimensions full scale)
17
18
20"
16
Modifications 19, 20, and 21
19
20
21
Modification 22
(Dimensions full scale)
10"
22
Modification 23
(Dimensions full scale)
23
20"
Modification 24
New horizontal tail with 10° dihedral
Original horizontal tail
Modifications 25, 26, 27 and 28
(Dimensions full scale)
25
144"
108"
8"
6"
30"
42"
10"
27
28
26
Modification 29
(Dimensions full scale)
29
48"
12"
Modification 30
(Dimensions full scale)
A
80"
A
5"
Section A-A

Modification 31



Modification 32
(Dimensions full scale)



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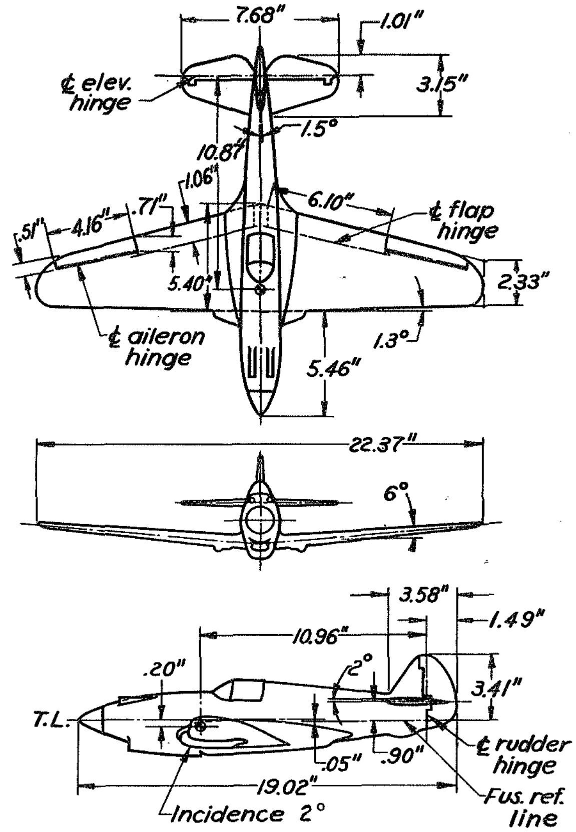
$\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-40 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	37.29
L, ft	31.70
$\bar{c}$, in.	81.60
S, sq ft	236.00
A	5.89
S_h, sq ft	48.00
S_e, sq ft	19.20
S_v, sq ft	20.74
S_r, sq ft	13.74
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	18.5 U, 10.6 D
δ_f, deg	45 D
TDPF	452×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	6825
$x/\bar{c}$	0.248
$z/\bar{c}$	0.049
I_X, slug-ft^2	2172
I_Y, slug-ft^2	6744
I_Z, slug-ft^2	8602
Test altitude, ft	12,000
μ (at sea level)	10.13
μ' (12,000 ft)	14.78

$\frac{I_X - I_Y}{mb^2}$	-155×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-63×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	218×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition the recovery characteristics of the model were satisfactory provided the aileron-with setting was less than one-third of full deflection. Setting the ailerons with the spin greater than one-third full deflection produced unsatisfactory recoveries from spins for all elevator settings.

Extending the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$, extending the mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_X\right)$, or a forward $(0.34\bar{c})$ or rearward $(0.08\bar{c})$ movement of the center of gravity from its normal position had little effect on the spin and recovery characteristics of the model (data not presented).

Extending the landing gear had an adverse effect on the recovery characteristics of the model. Lowering the flaps only $22\frac{1}{2}^{\circ}$ had little effect upon the recovery characteristics of the model. With the landing gear extended and the flaps deflected 45° down (landing condition), the recoveries were unsatisfactory when the ailerons were neutral or against the spin.

Results indicate that recovery by rapid full rudder reversal would be satisfactory from all inverted spins.

The addition of modification 1 to the bottom of the fuselage and rudder was necessary in order to obtain a 1-turn recovery by rapid full rudder reversal for the ailerons set against the spin, elevator full down, and the landing gear extended. With the addition of modification 2 to the bottom of fuselage and rudder for the same condition, the model required 5 turns for recovery (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-40 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins]

	Normal loading																					Normal loading, rudder neutral spins								
Ailerons	Against									Neutral			With						Against			Neutral			With		
	Full			8°U, 6°D			4°U, 3°D						½			Full											
Elevator	U	N	D	U	N	D	U	N	D	U (a)	N (a)	D	U (ab)	N (ab)	D (a)	U (ab)	N (ab)	D (ab)	U	N	D	U	N	D	U	N	D
α, deg	49	50	52	49	48	47	35	41	33	---	---	20	----	-----	---	----	----	---	46	49	50	No spin	No spin	No spin	No spin	No spin	No spin
φ, deg	0	1U	2U	0	0	1U	2U	1U	1U	---	---	0	----	-----	---	----	----	---	4U	2U	2U						
Ω, rps	0.40	0.46	0.48	0.40	0.46	0.47	0.38	0.48	0.53	---	---	0.89	----	-----	---	----	----	---	0.37	0.46	0.48						
V, fps	193	181	177	195	193	185	234	207	206	---	---	254	----	-----	---	----	----	---	197	181	177						
Turns for recovery	3½ [c]∞	∞	∞	2¾ [c]3 [c]5 [c]∞	∞	∞	1	2¼	4¼ 6	---	----	1½	----	-----	---	----	----	---	-----	---	-----						

	Normal loading, rudder against spins									Landing gear extended, normal loading														
Ailerons	Against			Neutral			With			Against									Neutral			With		
										Full			8°U, 6°D			4°U, 3°D								
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U (a)	N	D	U (ab)	N (ab)	D (ab)
α, deg	No spin	42	44	No spin	No spin	No spin	No spin	No spin	No spin	51	49	52	44	48	49	41	42	45	----	38	40	----	----	----
φ, deg		4U	4U							2U	2U	2U	1U	1U	2U	1D	1U	2U	----	1U	1U	----	----	----
Ω, rps		0.47	0.49							0.44	0.48	0.49	0.40	0.49	0.49	0.43	0.50	0.47	----	0.52	0.51	----	----	----
V, fps		191	185							189	181	173	206	181	181	218	195	185	----	218	193	----	----	----
Turns for recovery		---	-----							5 7	∞	∞	2 2½	∞	∞	2½	3½ 6½ 7½	∞	----	2½	4¼ 6¼ 7	----	----	----

	Flaps down 22½°, landing gear extended normal loading									Landing condition, normal loading [a]									Inverted spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D (a)	U	N (a)	D (a)	U (a)	N (a)	D (a)
α, deg	----	---	---	40	41	43	----	----	---	49	52	54	45	44	45	---	No spin	No spin	--	--	---	---	---	---	---	---	---
φ, deg	----	---	---	3D	1D	1D	----	----	---	0	2U	1U	1D	1D	1D	---			--	--	---	---	---	---	---	---	---
Ω, rps	----	---	---	0.38	0.49	0.51	----	----	---	0.40	0.48	0.49	0.38	0.47	0.48	---			--	--	---	---	---	---	---	---	---
V, fps	----	---	---	210	185	185	----	----	---	179	165	163	187	177	177	---			--	--	---	---	---	---	---	---	---
Turns for recovery	----	---	---	1½	2¾	3½	----	----	---	∞	∞	∞	2¾	4½ 5¼	4½	---			½	¼	---	¼	---	---	---	---	---

[a] Vertical velocity too high to test.
[b] Oscillatory spin.
[c] Recovery attempted by simultaneous reversal of rudder and elevator.

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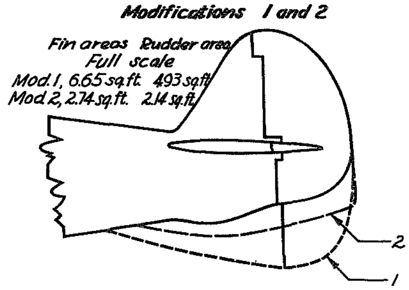
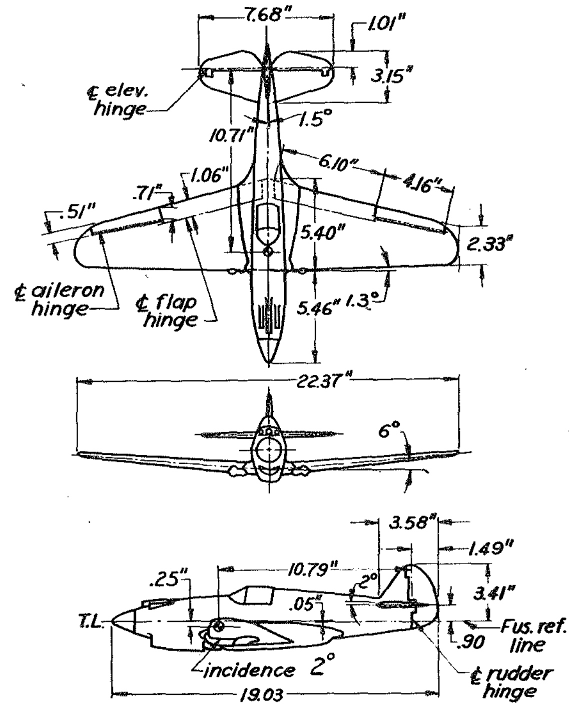
Modifications 1 and 2



$\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-40B AIRPLANE

b, ft	37.29
L, ft	31.71
$\bar{c}$, in.	81.60
S, sq ft	236.00
A	5.89
L.E. $\bar{c}$ aft L.E. c_r, in.	2.20
S_h, sq ft	48.30
S_e, sq ft (total)	17.44
S_v, sq ft	20.74
S_r, sq ft (total)	13.74
δ_r, deg (from plane of fin)	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	$18\frac{3}{4}$ U, $10\frac{3}{4}$ D
δ_a, deg (1/2 stick)	9.2 U, 7.0 D
δ_a, deg (1/4 stick)	4.0 U, 3.0 D
δ_f, deg	45 D
TDPF	388×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	7327	$\frac{I_X - I_Y}{mb^2}$	-139×10^{-4}
$x/\bar{c}$	0.288		
$z/\bar{c}$	0.061		
I_X, slug-ft^2	2532	$\frac{I_Y - I_Z}{mb^2}$	-68×10^{-4}
I_Y, slug-ft^2	6913		
I_Z, slug-ft^2	9086		
Test altitude, ft	12,000	$\frac{I_Z - I_X}{mb^2}$	207×10^{-4}
μ (at sea level)	10.87		
μ' (12,000 ft)	15.70		

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Résumé of Model Test Results

For the normal loading, clean condition, ailerons neutral or with th spin, the model spun at a steep attitude with a rate of descent in excess of the top speed of the tunnel (275 feet per second, full scale). Recoveries if attempted probably would have been satisfactory by rapid full rudder reversal. Setting the ailerons slightly against the spin (1/4 stick) definitely flattened the spin and recoveries became progressively slower as the aileron-against deflections were increased.

With the rudder neutral the model spun for all control settings except for the aileron-with, elevator-down condition. With the rudder initially full against the spin, the model would spin only when the ailerons were full against the spin and the elevator was either neutral or down.

Tests made with varied rudder settings (data not presented) indicate that rudder-with settings greater than 30° would flatten the steady spin, and reversing the rudder to less than 30° against the spin would retard recoveries. With the rudder set 35° with the spin (data not presented) flatter spins with rates of descent >275 feet per second, full scale were obtained for all aileron-neutral control configurations and reversal of the rudder to 30° against the spin gave satisfactory recoveries.

The results of brief tests (data not presented) made with variations in mass distribution (ΔI_X and $\Delta I_Z = \pm 0.37\ I_X$; ΔI_Y and $\Delta I_Z = \pm 0.20\ I_Y$ and center of gravity locations ($\pm 0.05\bar{c}$) indicated no effect on the recovery characteristics of the model.

For the landing condition (landing gear extended, flaps down 45°) the recoveries of the model were generally somewhat slower than in the clean condition. For aileron-with settings, however, no spin conditions were obtained for all elevator settings.

Extending the landing gear alone or opening the cockpit (data not presented) had very little effect upon the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-40B AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading															Rudder neutral spins, normal loading							
Ailerons	Against									Neutral			With			Against			Neutral		With	
	Full			$\frac{1}{2}$			$\frac{1}{4}$															
Elevator	U	N	D	U (a)	N (a)	D (a)	U (a b)	N (a)	D (a)	U (b)	N (b)	D (b)	U (b)	N (b)	D (b)	U (b)	N	D	U (b)	D (b)	U (b)	D
α, deg	43	48	47	40	43	41	----	42	44	----	----	----	----	----	----	----	48	52	----	----	----	No spin
ø, deg	2U	3U	2U	1D	1U	2U	----	1D	0	----	----	----	----	----	----	----	3U	2U	----	----	----	
Ω, rps	0.40	0.45	0.46	0.38	0.50	0.49	----	0.49	0.51	----	----	----	----	----	----	----	0.45	0.47	----	----	----	
V, fps	193	189	169	213	208	181	>275	222	199	>275	>275	>275	>275	>275	>275	>275	189	173	>275	>275	>275	
Turns for recovery	$1\frac{3}{4}$ c>4	∞	∞	$1\frac{1}{4}$	$2\frac{1}{4}$	∞	----	$1\frac{1}{4}$	1	----	----	----	----	----	----	----	----	----	----	----	----	

	Rudder against spin, normal loading									Landing condition, normal loading							
Ailerons	Against			Neutral			With			Against		Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	N	D	U	N	D	U	N	D
α, deg	No spin	39	46	No spin	--	No spin	No spin	--	No spin	----	---	----	----	----	No spin	No spin	No spin
ø, deg		5U	3U		--			--		----	---	----	----	----			
Ω, rps		0.48	0.49		--			--		----	---	----	----	----			
V, fps		199	185		--			--		169	---	173	173	169			
Turns for recovery		----	----		--			--		∞	---	$1\frac{1}{2}$	3	4			

[a]Slightly wandering and oscillatory spin.
[b]Steep spin.
[c]Recovery attempted by rudder neutralization.

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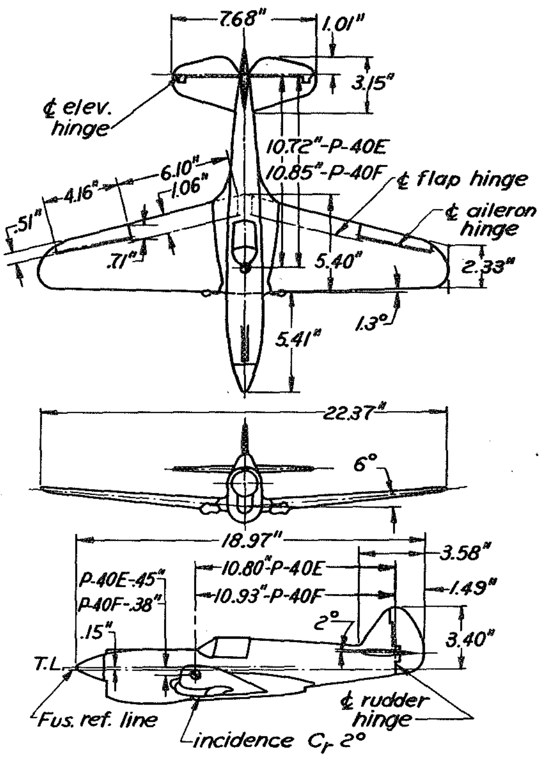
$\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-40E AND P-40F AIRPLANES

Dimensional Data

(Full Scale)

(Values are the same for both the P-40E and P-40F airplanes)

b, ft	37.29
L, ft	31.60
$\bar{c}$, in.	81.60
S, sq ft	236.00
A	5.89
L.E. $\bar{c}$ aft L.E. c_r, in.	2.20
S_h, sq ft	48.30
S_e, sq ft	13.65
S_v, sq ft	20.74
S_r, sq ft	11.76
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	$18\frac{3}{4}$ U, $10\frac{3}{4}$ D
δ_f, deg	45 D
TDPF	388×10^{-6}
Landing gear	Conventional



Model as tested.

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Mass Data

	P-40E (Normal loading)	P-40E (Est. Army flight)	P-40E (Curtiss flight)	P-40F (Normal)
W, lb	8011	8500	7769	8488
$x/\bar{c}$	0.286	0.286	0.290	0.255
$z/\bar{c}$	0.110	0.110	0.110	0.093
I_X, slug-ft^2	4903	5760	4230	5029
I_Y, slug-ft^2	7237	7827	7827	7899
I_Z, slug-ft^2	11,441	12,835	11,305	12,146
Test altitude, ft	12,000	12,000	12,000	12,000
μ (at sea level)	11.89	12.61	11.53	12.59
μ' (12,000 ft)	17.16	18.20	16.64	18.18
$\frac{I_X - I_Y}{mb^2}$	-67×10^{-4}	-56×10^{-4}	-107×10^{-4}	-78×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-121×10^{-4}	-137×10^{-4}	-104×10^{-4}	-116×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	188×10^{-4}	193×10^{-4}	211×10^{-4}	194×10^{-4}

Résumé of Model Test Results

The P-40E and P-40F airplanes differed in mass characteristics but not in external dimensions. One model with provisions for changing its mass characteristics was used to represent both airplanes. The model had no fin offset.

Although the model appeared symmetrical, a difference in the spin and recovery characteristics between right and left spins was obtained. Results are presented either for spins in both directions or for the direction of spin from which the more conservative test results were obtained.

P-40E

With the model ballasted to represent the P-40E airplane in the normal loading and clean condition, satisfactory spin and recovery characteristics were obtained for right spins. From left spins, however, slower recoveries $\left(2\frac{1}{2} \text{ to } 4\frac{1}{4} \text{ turns}\right)$ were obtained by rapid rudder reversal than from right spins when the elevator was neutral or down and the ailerons were neutral or against the spin.

For all inverted spins, in either direction, the recovery characteristics of the model were satisfactory.

P-40F

With the model ballasted to represent the P-40F airplane in the normal loading (clean condition), recoveries by rapid full rudder reversal were generally satisfactory from right spins, whereas, from left spins, the recovery characteristics were quite unsatisfactory.

Extending or retracting the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = \pm 0.20\ I_X\right)$, or extending or retracting the mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.25\ I_Y \text{ or } -0.20\ I_Y\right)$ had little effect upon recovery from the spin for the normal control configuration for spinning.

For the landing condition (landing gear extended, flaps 45° down), all recoveries from left spins were unsatisfactory; whereas, from right spins, satisfactory recoveries were obtained when the ailerons were set with the spin, or when the ailerons were neutral and the elevator was full up.

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Recoveries of the model from all inverted spins were satisfactory.

For the left erect spins for the normal loading, clean condition, the addition of a fin to the bottom of the rudder (modification 1 or 2) or to the bottom of the fuselage and rudder (modification 3) had a beneficial effect on the recovery characteristics of the model.

A new wing was installed on the model, and check spins were made with the model in the normal loading and clean condition. The results show that the left and right spins were somewhat less asymmetrical than those with the original wing but recoveries from left spins were still unsatisfactory.

Supplementary Tests P-40E

For a series of supplementary tests, the model was changed to simulate the P-40E airplane in the Curtiss flight loading condition. The changes included a fin offset of $1\frac{1}{2}^{\circ}$ to the left, open cockpit, camera, exhaust stacks, blast tubes, ventilating tubes, cowling flaps, and a dorsal fin. (See sketch of dorsal fin.) In general, there was little effect of incorporating the various details into the model or of altering the loading to simulate the Curtiss flight loading. The addition of a large dorsal fin (modification 4) had no effect on recoveries for erect spins, although a favorable effect on recoveries from inverted spins was obtained.

Installing a new fin and rudder (modification 5) had a beneficial effect on both the erect and inverted spin characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-40E AND P-40F AIRPLANES

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	P-40E Normal loading, left spin										P-40E Normal loading, right spin												
Ailerons	Against			Neutral			With 3° U, 3° D	With Full			Against Full			Against 3° U, 3° D			Neutral				With		
Elevator	U	N	D	U (a)	N	D	U (bc)	U (bc)	N (bd)	D (b)	U (g)	N	D	U	N	D	U (bc)	N (h)	N (h)	D	U (bc)	N (bd)	D (b)
α, deg	45	45	44	45	48	44	----	----	----	---	43	42	40	----	40	39	----	37	26	28	----	----	----
ø, deg	2D	3D	2D	5U	2U	2U	----	----	----	---	4U	4U	5U	----	1D	0	----	2D	10D	4D	----	----	----
Ω, rps	0.39	0.48	0.50	0.40	0.48	0.50	----	----	----	---	0.40	0.47	0.53	----	0.50	0.53	----	0.51	0.61	0.68	----	----	----
V, fps	213	207	200	197	200	200	----	----	----	---	213	207	207	----	207	207	----	216	255	252	----	----	----
Turns for recovery	$1\frac{3}{4}$; [e]$\frac{3}{4}$; [f]>7	$2\frac{3}{4}$	$4\frac{1}{4}$	2	$2\frac{1}{2}$	3	----	----	----	--	$1\frac{1}{2}$	2	$2\frac{1}{4}$	----	$1\frac{3}{4}$	$1\frac{3}{4}$	----	$1\frac{1}{2}$	$\frac{3}{4}$	1	----	----	----

	P-40E Inverted left spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (c)	N (c)	D
α, deg	No spin	No spin	No spin	28	-	-	31	31	26
ø, deg				2D	-	-	6D	5D	5D
Ω, rps				0.47	-	-	0.46	0.53	0.66
V, fps				265	-	-	255	251	251
Turns for recovery				$\frac{1}{4}$; [f]1	-	-	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$

	P-40E Inverted right spins, normal loading							
Ailerons	Against			Neutral			With	
Elevator	U	N	D	U (g)	N	D	U (c)	D
α, deg	No spin	-	-	45	-	-	40	33
ø, deg		-	-	0	-	-	0	2D
Ω, rps		--	--	0.45	-	-	0.44	0.61
V, fps		--	--	200	-	-	229	232
Turns for recovery		--	--	$\frac{3}{4}$	-	-	1	1

	P-40E Estimated Army Flight loading, inverted right spins							
Ailerons	Against			Neutral			With	
Elevator	U	N	D	U (i)	N	D	U (c)	D
α, deg	No spin	-	No spin	40	-	-	33	33
ø, deg		-		1U	-	-	4D	3D
Ω, rps		--		0.43	-	-	0.44	0.58
V, fps		--		226	-	-	251	233
Turns for recovery		--		$\frac{1}{2}$	-	-	$\frac{3}{4}$	1

	P-40E Estimated Army flight loading, and ΔI_X and ΔI_Z = 0.20 I_X, inverted right spins						
Ailerons	Against			Neutral			With
Elevator	U	N	D	U	N	D	U (a)
α, deg	No spin	-	No spin	39	-	-	37
ø, deg		-		0	-	-	1D
Ω, rps		--		0.45	-	-	0.48
V, fps		--		229	-	-	265
Turns for recovery		--		[f]2	-	-	$\frac{3}{4}$

	P-40F, normal loading, left spins								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D (j)
α, deg	43	57	54	60	58	56	58	54	43
ø, deg	1D	0	0	3U	2U	2U	5U	5U	6U
Ω, rps	0.42	0.49	0.50	0.45	0.50	0.50	0.44	0.50	0.51
V, fps	207	182	176	182	182	176	176	176	187
Turns for recovery	$1\frac{1}{2}$; $2\frac{1}{4}$	$5\frac{1}{2}$	∞	4	$5\frac{1}{2}$	6	$3\frac{3}{4}$	3	$2\frac{3}{4}$

	P-40F, normal loading, right spins					
Ailerons	Against		Neutral		With	
Elevator	U	D	U (a)	D (j)	U (b)	D (b)
α, deg	40	40	37	37	--	--
ø, deg	3U	4U	4D	2D	--	--
Ω, rps	0.42	0.54	0.44	0.59	--	--
V, fps	226	207	229	213	--	--
Turns for recovery	$1\frac{3}{4}$	$2\frac{1}{2}$	1	$1\frac{3}{4}$	--	--

	P-40F, ΔI_X and ΔI_Z = 0.20 I_X, left spins						
Ailerons	Against		Neutral			With	
Elevator	U	D	U	N	D	U	D
α, deg	58	57	58	-	-	59	55
ø, deg	0	0	2U	-	-	5U	3U
Ω, rps	0.45	0.51	0.45	-	-	0.44	0.50
V, fps	191	182	195	-	-	197	188
Turns for recovery	4	7	$4\frac{1}{2}$	-	-	$5\frac{1}{2}$	$4\frac{1}{2}$; 6

	P-40F, ΔI_X and ΔI_Z = -0.20 I_X left spins						
Ailerons	Against		Neutral			With	
Elevator	U	D	U	N	D	U (d)	D (j)
α, deg	59	58	57	-	-	51	39
ø, deg	1U	1D	4U	-	-	5U	6U
Ω, rps	0.45	0.50	0.43	-	-	----	----
V, fps	182	179	188	-	-	201	195
Turns for recovery	$4\frac{1}{2}$	∞	$3\frac{1}{2}$	-	-	----	[k,l]$2\frac{1}{2}$

	P-40F, ΔI_Y and ΔI_Z = 0.25 I_Y, left spins						
Ailerons	Against		Neutral			With	
Elevator	U	D	U	N	D	U (d)	D (dj)
α, deg	60	61	60	-	-	-	52
ø, deg	0	1U	3U	-	-	-	4U
Ω, rps	0.41	0.46	0.41	-	-	-	0.44
V, fps	188	176	185	-	-	--	185
Turns for recovery	$3\frac{3}{4}$	∞	4	-	-	--	$3\frac{1}{2}$

	P-40F, ΔI_Y and ΔI_Z = -0.20 I_Y, left spins						
Ailerons	Against		Neutral			With	
Elevator	U	D	U	N	D	U	D
α, deg	61	54	61	-	-	59	56
ø, deg	0	1D	2U	-	-	4U	2U
Ω, rps	0.49	0.56	0.50	-	-	0.49	0.56
V, fps	185	185	185	-	-	194	182
Turns for recovery	$3\frac{1}{4}$	$3\frac{3}{4}$	>4	-	-	>4	$5\frac{1}{2}$

	P-40F, landing condition, normal loading, left spins								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	59	59	57	---	----	55	56	53	52
ø, deg	0	0	0	---	----	1U	5U	4U	3U
Ω, rps	0.45	0.50	0.50	0.45	0.50	0.50	0.46	0.51	0.51
V, fps	176	175	173	176	176	173	176	176	176
Turns for recovery	$8\frac{1}{2}$	∞	∞	[l]$4\frac{1}{4}$	[l]$6\frac{3}{4}$	∞	$5\frac{1}{4}$	$5\frac{3}{4}$	[k]6

	P-40F landing condition normal loading, right spins						
Ailerons	Against		Neutral			With	
Elevator	U	D	U (d)	N	D	U (bc)	D
α, deg	42	46	45	-	-	----	No spin
ø, deg	3U	2U	1D	-	-	----	
Ω, rps	0.39	0.50	0.40	-	-	----	
V, fps	194	182	197	-	-	----	
Turns for recovery	$2\frac{1}{2}$	$7\frac{3}{4}$	$1\frac{3}{4}$; $2\frac{3}{4}$	-	-	----	

[a]Steeper spin occasionally obtained: wandering and oscillatory spin.
[b]Steep spin, high rate of descent.
[c]Wandering and oscillatory spin.
[d]Wandering spin.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Recovery attempted by neutralizing the rudder.
[g]Oscillatory spin.
[h]Two types of spin.
[i]Steeper spin also occasionally obtained; oscillatory.
[j]Steeper spin also obtained occasionally, recovery probably rapid.
[k]Model goes into an inverted spin upon recovery from an erect spin.
[l]Visual observation.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS P-40E AND P-40F AIRPLANES - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	P-40F, right inverted spins, normal loading									P-40F, modification 1, normal loading, left spins						P-40F, modification 2, normal loading, left spins					
Ailerons	Against			Neutral			With			Against			Neutral			Against			Neutral		
Elevator	U	N	D	U (g)	N	D	U (c)	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	27	-	28	29	-	-	32	-	26	----	-	----	----	----	----	----	-	----	----	-	----
∅, deg	3U	-	8U	2D	-	-	5D	-	4D	----	-	----	----	----	----	----	-	----	----	-	----
Ω, rps	0.50	-	0.62	0.49	-	-	0.46	-	0.68	----	-	----	----	----	----	----	-	----	----	-	----
V, fps	304	-	239	272	-	-	239	-	272	182	-	176	176	176	173	182	-	176	176	-	173
Turns for recovery	$\frac{1}{4}$	-	[l]$\frac{1}{2}$	$\frac{1}{2}$	-	-	----	-	$\frac{1}{4}$	$2\frac{1}{4}$	-	5	$2\frac{1}{4}$	3	4	$1\frac{1}{2}$ $2\frac{1}{4}$	-	$3\frac{1}{2}$	$1\frac{3}{4}$	-	3

	P-40F modification 3, normal loading, left spins						P-40F, normal loading, check spins with new wing, left spins							P-40F, normal loading, check spins with new wing, right spins						
Ailerons	Against		Neutral		With		Against		Neutral			With		Against		Neutral			With	
Elevator	U	D	U	D	U	D	U	D	U	N	D	U (bd)	D (bg)	U	D	U (d)	N	D	U (bd)	D (bd)
α, deg	-----	----	---	----	---	----	59	61	60	-	-	----	----	51	53	44	-	-	----	----
∅, deg	-----	----	---	----	---	----	0	1D	4U	-	-	----	----	1U	2U	3D	-	-	----	----
Ω, rps	-----	----	---	----	---	----	0.45	0.50	0.45	-	-	----	----	0.42	0.50	0.43	-	-	----	----
V, fps	179	173	185	179	185	179	188	179	185	-	-	----	----	207	182	226	-	-	----	----
Turns for recovery	$2\frac{1}{4}$	$2\frac{3}{4}$	2	$2\frac{3}{4}$	$2\frac{1}{4}$	[k]$2\frac{3}{4}$	3	$4\frac{1}{4}$	$3\frac{1}{2}$	-	-	----	----	$2\frac{1}{2}$ $3\frac{1}{4}$	∞	$1\frac{3}{4}$	-	-	----	----

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[a]Steeper spin occasionally obtained: wandering and oscillatory spin.
[b]Steep spin, high rate of descent.
[c]Wandering and oscillatory spin.
[d]Wandering spin.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Recovery attempted by neutralizing the rudder.
[g]Oscillatory spin.
[h]Two types of spin.
[i]Steeper spin also occasionally obtained; oscillatory.
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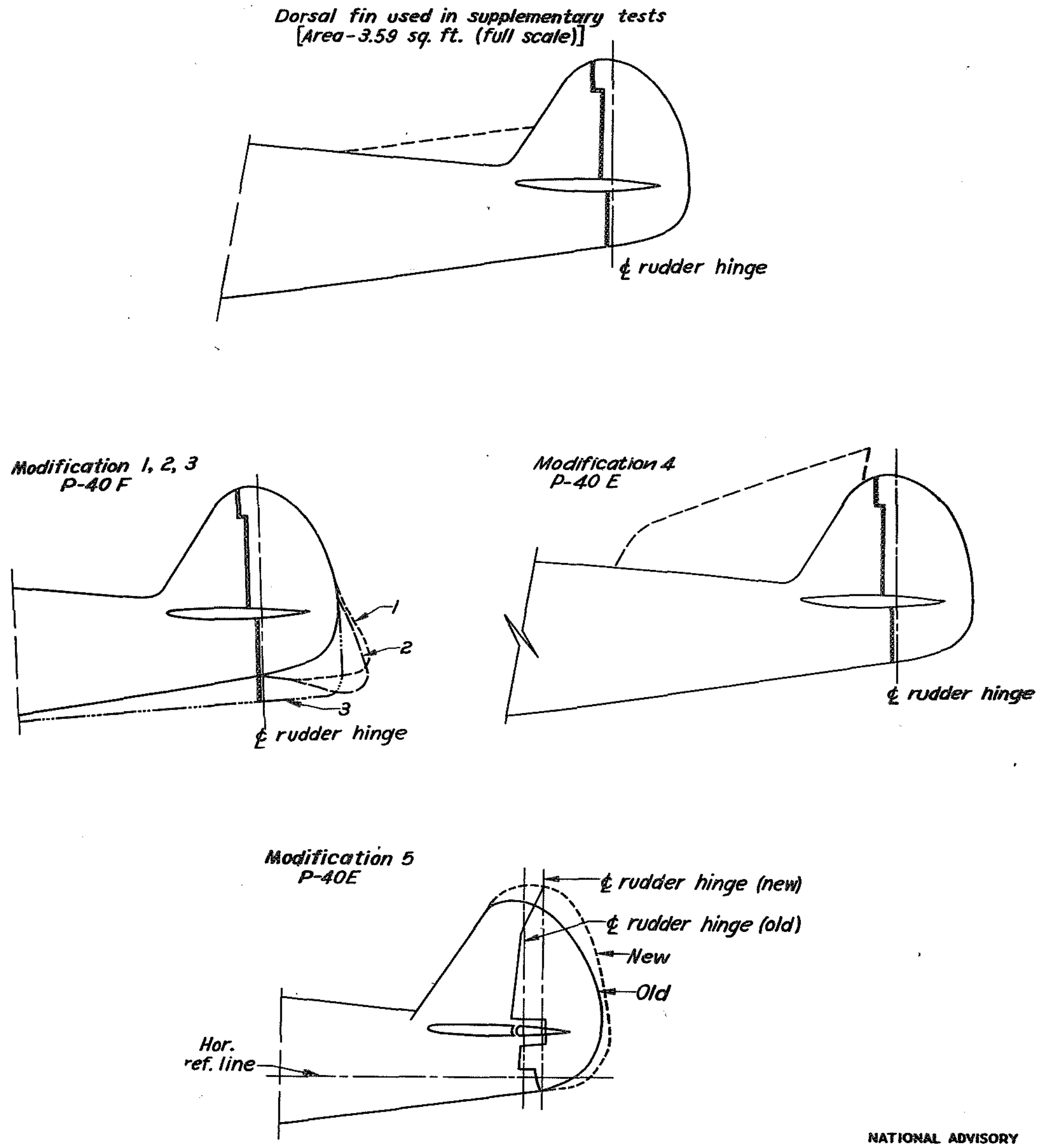
[k]Model goes into an inverted spin upon recovery from an erect spin.
[l]Visual observation.


Dorsal fin used in supplementary tests
[Area-3.59 sq. ft. (full scale)]
℄ rudder hinge
Modification 1, 2, 3
P-40 F
1
2
3
℄ rudder hinge
Modification 4
P-40 E
℄ rudder hinge
Modification 5
P-40E
℄ rudder hinge (new)
℄ rudder hinge (old)
New
Old
Hor.
ref. line

P-40E SUPPLEMENTARY TESTS FOR THE CURTISS FLIGHT NORMAL LOADING CONDITION

Test condition	Control settings				α, deg	ϕ, deg	V, fps	Turns for recovery
	Ailerons	Rudders initial	Rudders final	Elevator				
Clean condition (Dorsal fin No. 1)	Against	30W	30A	30U	47	3U	207	$1\frac{1}{2}$
	Neutral	30W	-------	30U (c)	-------	-------	>374	-------
	With	30W	-------	30U (b)	-------	-------	-------	-------
	Against	40W	20A	20D	51	3U	201	$4\frac{1}{2}$
	Neutral	30W	30A	20D	45	0	213	2
	With	40W	-------	20D (b)	-------	-------	-------	-------
[m]Pro-spin fin attached on inboard wing (Dorsal fin No. 1)	Neutral	40W	20A	0	68	0	166	∞
[m]Pro-spin fin attached on inboard wing and modification 4	Neutral	40W	20A	0	65	2U	170	∞
Modification 5	Neutral	30W	30A	30U	48	4D	197	$1\frac{1}{2}$ [p]9
	Against	30W	30A	30U	40	3U	229	$\frac{1}{2}$
	With	30W	-------	30U (b)	-------	-------	-------	-------
	With	30W	-------	20D (b)	-------	-------	-------	-------
	Against	30W	30A	20D	50	3U	185	$3\frac{3}{4}$
Inverted Spins (Dorsal fin No. 1)	Against	30W	30A	30D	25	6D	265	1
	Neutral	30W	-------	20U (g)	28	1U	291	-------
	With	30W	-------	20U (c)	-------	-------	-------	-------
	Neutral	40W	20A	0	-------	-------	220	$\frac{1}{2}$
Inverted spin, [m]pro-spin fin No. 1 attached (Dorsal fin No. 1)	Neutral	40W	20A	0	56	1U	176	∞
Inverted spin, [n]pro-spin fin No. 2 attached (Dorsal fin No. 1)	Neutral	40W	20A	0	36	3D	195	$\frac{1}{2}$
Inverted spin, [o]pro-spin fin No. 3 attached (Dorsal fin No. 1)	Neutral	40W	-------	0	-------	-------	176	-------
Inverted spin, [m]pro-spin No. 1 attached modification 4 added	Neutral	40W	20A	0	44	8U	188	$2\frac{1}{2}$
Inverted spin, propeller rotating (Dorsal fin No. 1)	Neutral	40W	20A	0	36	0	220	1
Inverted spin, propeller locked (Dorsal fin No. 1)	Neutral	40W	20A	0	45	1U	204	$\frac{1}{2}$
Inverted spin, modification 5	Against	30W	-------	20U	No spin			
	Neutral	30W	30A	20U	26	2U	304	$\frac{1}{2}$
	With	30W	30A	20U (c)	-------	-------	261	$1\frac{3}{4}$
	With	30W	30A	30D	-------	-------	288	$1\frac{1}{2}$

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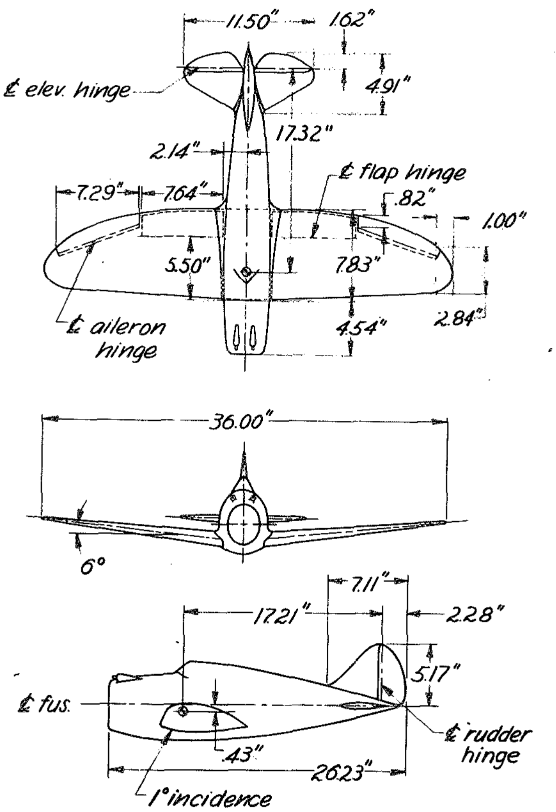
[a]Steeper spin occasionally obtained: wandering and oscillatory spin.
[b]Steep spin, high rate of descent.
[c]Wandering and oscillatory spin.
[d]Wandering spin.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Recovery attempted by neutralizing the rudder.
[g]Oscillatory spin.
[h]Two types of spin.
[i]Steeper spin also occasionally obtained; oscillatory
[j]Steeper spin also obtained occasionally; recovery probably rapid.
[k]Model goes into an inverted spin upon recovery from an erect spin.
[l]Visual observation.
[m]21 inches high × 115 inches long.
[n]21 inches high × 45 inches long.
[o]60 inches high × 100 inches long.
[p]Turns for recovery obtained by releasing the rudder.

$\frac{1}{12}$-SCALE MODEL OF THE REPUBLIC YP-43 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	36.00
L, ft	28.48
$\bar{c}$, in.	74.57
S, sq ft	223.73
A	5.80
L.E. $\bar{c}$ aft L.E. c_r, in.	8.04
S_h, sq ft	34.67
S_e, sq ft (inc. bal.)	15.52
S_v, sq ft	19.47
S_r, sq ft (inc. bal.)	9.50
δ_r, deg	30 R, 20 L
δ_e, deg	30 U, 20 D
δ_a, deg	27.5 U, 22.5 D
δ_f, deg	50 D
TDPF	0
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	6900
$x/\bar{c}$	0.250
$z/\bar{c}$	0.069
I_X, slug-ft^2	3439
I_Y, slug-ft^2	5769
I_Z, slug-ft^2	8557
Test altitude, ft	5000
μ (at sea level)	11.2
μ' (5000 ft)	13.0

$\frac{I_X - I_Y}{mb^2}$	-83×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-99×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	182×10^{-4}

Résumé of Model Test Results

For the clean condition, normal loading for all aileron-elevator settings, the model spun at a flat attitude and would not recover by rapid full rudder reversal.

Extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.20\ I_X\right)$, extending or retracting mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y, \text{ or } -0.13\ I_Y\right)$, or moving the center of gravity forward or back $0.05\bar{c}$ from its normal position had no appreciable effect on the unsatisfactory recovery characteristics of the model.

For the landing condition (landing gear extended, flaps deflected 50°), recoveries by rapid full rudder reversal were unsatisfactory from all spins.

Results of the inverted spin tests indicate that recoveries would probably be satisfactory.

Raising the horizontal tail 18.61 inches full scale from its normal location (see sketch) or adding area A to the bottom of the rudder, thus making it full length, in conjunction with the horizontal tail in the elevated position had no appreciable effect on the unsatisfactory recovery characteristics of the model (data not presented). The addition of fin area B in the region of the tail wheel in conjunction with the full-length rudder and horizontal tail in the elevated position (modification 1) enabled satisfactory recoveries to be obtained from all spins by rapid full rudder reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE REPUBLIC YP-43 AIRPLANE.

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading									ΔI_X and $\Delta I_Z = 0.20 I_X$									ΔI_X and $\Delta I_Z = -0.20 I_X$								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N (a)	D	U	N	D	U (b)	N (bc)	D (b)
α, deg	---	---	---	80	82	---	71	77	63	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	----	----	---
ø, deg	---	---	---	1D	0	---	3D	1D	3D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	----	----	---
Ω, rps	---	---	---	0.70	0.75	---	0.61	0.65	0.59	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	----	----	---
V, fps	121	118	121	121	115	118	127	124	137	124	121	124	115	---	---	128	115	128	118	115	---	115	---	---	----	----	---
Turns for recovery	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	---	---	∞	∞	∞	∞	∞	---	∞	---	---	----	d_1	---

	ΔI_Y and $\Delta I_Z = 0.20 I_Y$									ΔI_Y and $\Delta I_Z = -0.13 I_Y$									Landing gear extended, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N (c)	D (a)	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U (a)	N	D
α, deg	---	---	---	---	---	---	---	---	61	---	---	---	---	---	---	75	---	---	---	---	---	---	---	---	----	59	54
ø, deg	---	---	---	---	---	---	---	---	6D	---	---	---	---	---	---	3D	---	---	---	---	---	---	---	---	----	5D	6D
Ω, rps	---	---	---	---	---	---	---	---	0.49	---	---	---	---	---	---	0.59	---	---	---	---	---	---	---	---	----	0.53	0.53
V, fps	121	---	118	118	---	115	159	150	146	115	115	118	115	---	---	131	121	127	123	121	121	118	115	118	----	150	150
Turns for recovery	∞	---	∞	∞	---	∞	---	---	>6	∞	∞	∞	∞	---	---	∞	∞	∞	∞	∞	∞	∞	∞	∞	----	6	$6\frac{1}{2}$

	Landing condition, normal loading									Inverted spins, normal loading									Modification 1, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N	D	U (b)	N (b)	D	U (b)	N (b)	D (b)	U (a)	N	D	U	N	D	U	N	D	U (a)	N	D
α, deg	---	---	---	---	---	---	60	---	---	----	----	No spin	----	----	----	---	35	30	53	---	---	58	----	58	----	---	52
ø, deg	---	---	---	---	---	---	4D	---	---	----	----		----	----	----	---	4U	6U	5U	---	---	0	----	0	----	---	5D
Ω, rps	---	---	---	---	---	---	0.41	---	---	----	----		----	----	----	---	0.50	0.62	0.39	0.49	---	0.42	----	0.43	----	---	0.50
V, fps	118	118	118	115	112	112	150	140	131	----	----		----	----	----	175	188	188	159	153	154	153	146	143	150	150	150
Turns for recovery	∞	∞	∞	∞	∞	∞	>9	>7	>7	----	----		----	----	----	---	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$, $1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	2	$2\frac{1}{2}$	$2, 2\frac{1}{2}$

	Horizontal tail surface raised 18.6 inches, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D (a)
V, fps	153	143	143	156	143	143	156	153	146
Turns for recovery	>2	>4	>4	>4	>4	>6	>4	>4	>5

[a]Wandering spin.
[b]Velocity too high to test, steep spin.
[c]Oscillatory and wandering spin.
[d]Recovery attempted before final attitude attained.

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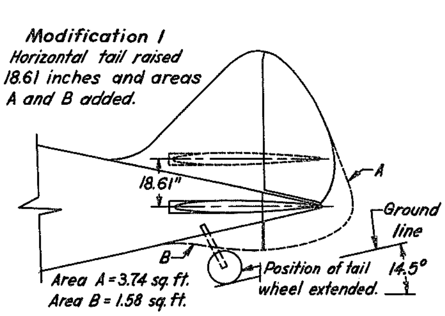
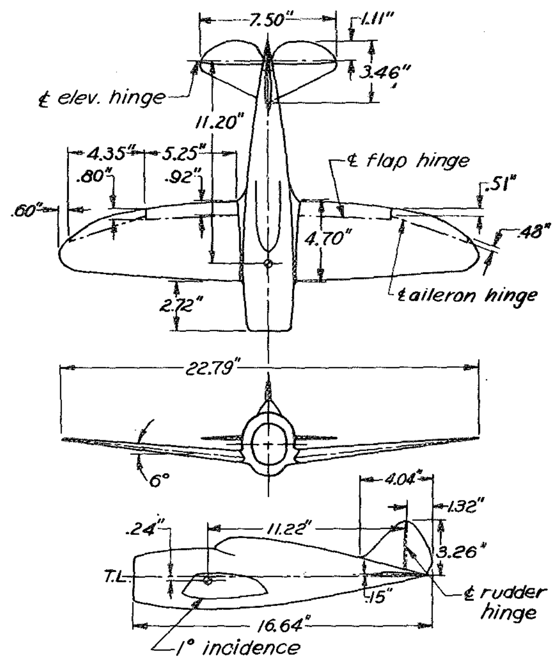


$\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC P-44 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	38.00
L, ft	27.73
$\bar{c}$, in.	74.56
S, sq ft	236.00
A	6.12
S_h, sq ft	40.44
S_e, sq ft	18.65
S_v, sq ft	19.24
S_r, sq ft	9.25
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	27.5 U, 22.5 D
δ_f, deg	40 D
TDPF	0
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	8705
$x/\bar{c}$	0.260
$z/\bar{c}$	0.104
I_X, slug-ft^2	4903
I_Y, slug-ft^2	8130
I_Z, slug-ft^2	11,819
Test altitude, ft	10,000
μ (at sea level)	12.68
μ' (10,000 ft)	17.19

$\frac{I_X - I_Y}{mb^2}$	-82×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-95×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	177×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, the model would not recover by rapid full rudder reversal for any aileron-elevator setting. From elevator-up spins the model would also not recover by simultaneous reversal of both the rudder and elevator (data not presented).

Extending or retracting the mass by 20 percent along the wings or fuselage $\left(\Delta I_X \text{ and } \Delta I_Z = 0.20\ I_X;\ \Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ or moving the center of gravity either forward or rearward $0.05\bar{c}$ from its normal position had no appreciable effect on the recovery characteristics of the model (data not presented).

For the landing condition (flaps 40° down and landing gear extended) recovery by rapid full rudder reversal could not be obtained for any control configuration (data not presented).

For the normal-loading condition the model would spin inverted only when the controls were crossed. With the rudder set against the spin the model would not spin inverted for any control configuration.

In an attempt to improve the recovery characteristics of the model, numerous modifications (modifications 1 to 16) were tested on the model. Raising the horizontal tail surfaces 35 inches, full scale (modification 16) enabled satisfactory recoveries to be obtained. When the ailerons were set with the spin, recoveries were not attempted because of the steep, wandering, and oscillatory nature of the spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC P-44 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N	D
α, deg	---	---	--	----	80	----	--	--	-----
ϕ, deg	---	---	--	----	1D	----	--	--	-----
Ω, rps	---	---	--	----	0.79	---	--	--	-----
V, fps	136	136	132	136	132	132	--	136	140
Turns for recovery	∞	∞	∞	∞	∞	∞	--	∞	∞

	Normal loading, rudder against spins								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (ab)	N	D
α, deg	---	---	----	----	----	----	---	---	---
ϕ, deg	---	---	----	----	----	----	---	---	---
Ω, rps	---	---	----	----	----	----	---	---	---
V, fps	144	140	140	144	132	140	---	162	165
Turns for recovery	---	---	----	----	----	----	---	---	---

	Inverted spin, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	43	40	31
ϕ, deg							4U	3U	5U
Ω, rps							0.48	0.50	0.62
V, fps							213	215	254
Turns for recovery							-----	---	----

Effect of changes in tail design on turns for recovery, ailerons neutral and elevator up unless otherwise indicated, normal loading

Modification	V, fps	Turns for recovery	Modification	V, fps	Turns for recovery
1	150	∞	8	161	[c]4
2	-----	(a,b)	9	156	∞
3	148	∞	10	-------	(d)
4	169	$2\frac{1}{2}$	11	-------	(ab)
4	161	∞	12	167	∞
5	167	$4\frac{1}{4}$	13	136	[c]∞
6	167	$>5\frac{1}{2}$	13	132	[c]∞
Tail cone removed aft of elevator spar	138	∞	13	136	[f]∞
7	150	∞	14	116	[c]∞
8	173	$2\frac{3}{4}$, $3\frac{3}{4}$	14	116	[g]∞

Effect of increasing the tail length 44 inches on turns for recoveries for various loading conditions and design changes

Model condition	Ailerons	Elevator	V, fps	Turns for recovery
Normal loading	Neutral	U	144	∞
------do.------	---do.---	N	138	∞
------do.------	---do.---	D	138	∞
------do.------	With	D	(d)	---------
------do.------	Against	D	142	∞
c.g. moved forward 8 percent M.A.C.	Neutral	U	140	∞
------do.-------	---do.---	D	142	∞
Normal loading, modification 6 added	---do.---	N	136	∞
------do.------	With	N	(d)	---------
------do.------	Against	N	140	∞

	Horizontal tail surfaces raised 25 inches (full scale) modification 15, normal loading							
Ailerons	Against			Neutral			With	
Elevator	U	N	D	U	N	D	U (ab)	N (ab)
α, deg	41	46	45	48	50	45	----	----
ϕ, deg	1U	3U	1U	0	0	4U	----	----
Ω, rps	0.42	0.46	0.50	0.40	0.48	0.48	----	----
V, fps	211	189	191	191	184	199	----	----
Turns for recovery	$2\frac{3}{4}$	$4\frac{1}{4}$	∞	$3\frac{3}{4}$	$4\frac{1}{4}$	>4	----	----

	Horizontal tail surfaces raised 35 inches (full scale) modification 16, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (ab)	N (ab)	D (ab)
α, deg	43	39	33	44	38	33	----	----	----
ϕ, deg	2U	2U	3U	4D	2D	4D	----	----	----
Ω, rps	0.40	0.50	0.54	0.39	0.55	0.71	----	----	----
V, fps	219	205	209	211	211	236	----	----	----
Turns for recovery	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	----	----	----

[a] Oscillatory and wandering spin.
[b] Steep spin.
[c] Elevator neutral.
[d] Velocity too high to test
[e] Ailerons with elevator neutral.
[f] Ailerons against, elevator neutral.
[g] Elevator down.
[h] For these tests normal c.g. was at $0.28\bar{c}$

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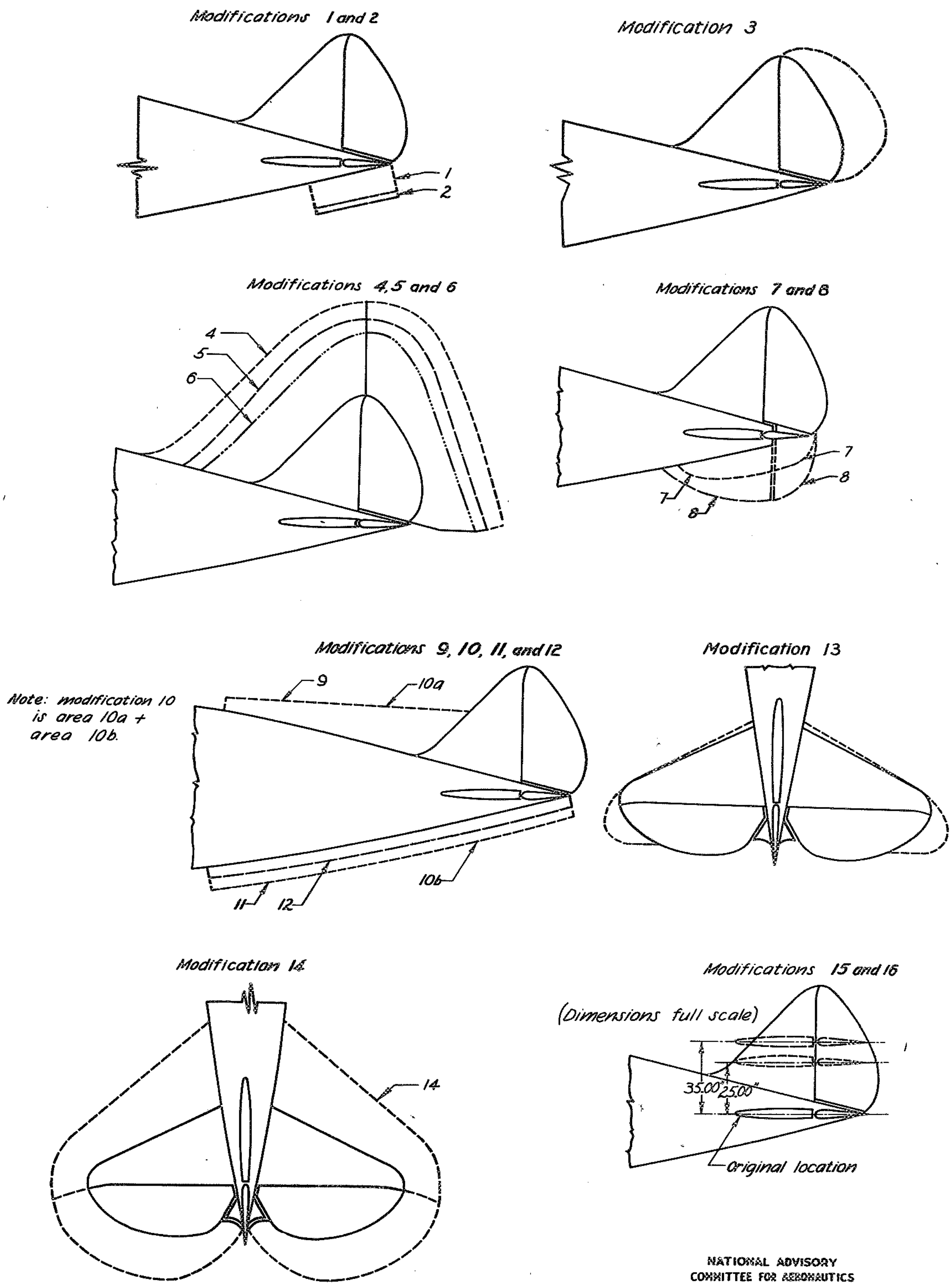
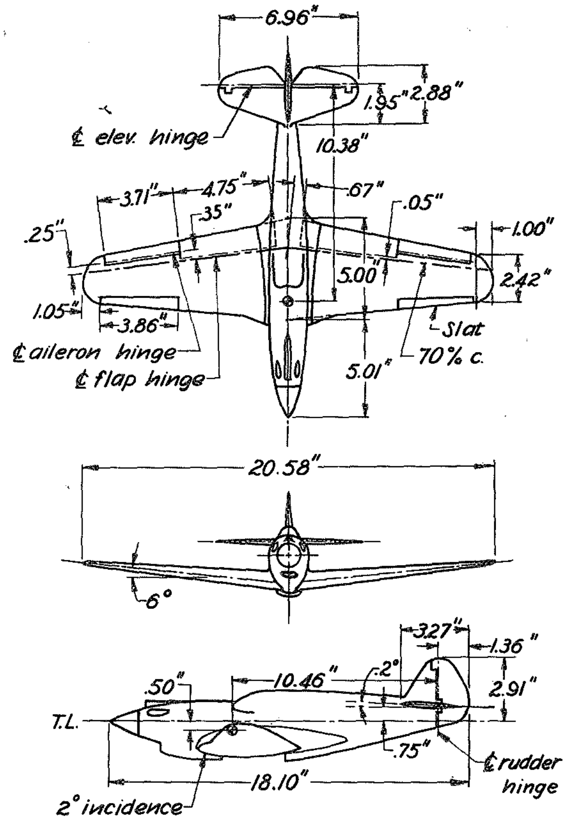

Modifications 1 and 2
1
2
Modification 3
Modifications 4,5 and 6
4
5
6
Modifications 7 and 8
7
8
7
8
Modifications 9, 10, 11, and 12
Note: modification 10 is area 10a + area 10b.
9
10a
10b
11
12
Modification 13
Modification 14
14
Modifications 15 and 16
(Dimensions full scale)
1
35.00"
25.00"
Original location

1/20-SCALE MODEL OF THE CURTISS XP-46 AIRPLANE

Dimensional Data

(Full scale)

b, ft	34.33
L, ft	30.17
$\bar{c}$, in.	78.98
S, sq ft	208.00
A	5.67
L.E. $\bar{c}$ aft L.E. C_r	7.20
S_h, sq ft	39.40
S_e, sq ft	12.90
S_v, sq ft	17.11
S_r, sq ft	9.80
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	24 U, 11.5 D
δ_a, deg (1/2 stick)	10 U, 7 D
δ_f, deg	45 D
TDPF	546×10^{-6}
Landing gear	Retractable



Model as tested.

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Mass Data

Normal Loading

W, lb	6,750
$x/\bar{c}$	0.261
$z/\bar{c}$	0.063
I_X, slug-ft^2	3,285
I_Y, slug-ft^2	5,540
I_Z, slug-ft^2	8,550
Test altitude, ft	10,000
μ (at sea level)	12.35
μ' (at 10,000 ft)	16.72

$\frac{I_X - I_Y}{mb^2}$	-91×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-122×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	213×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, normal control configuration for spinning, the model spun steeply ($\alpha = 29^\circ$) and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{2}\text{ turns}\right)$. Recoveries were unsatisfactory by rudder neutralization. When the elevator was either neutral or down, recoveries by rapid full rudder reversal were slower than when the elevator was up. Setting the ailerons against the spin had little effect on the recovery characteristics, whereas setting the ailerons with the spin led to spins which were too oscillatory or the model descended with too high a rate of descent (>272 feet per second) to test completely.

Extending or retracting mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = \pm 0.20\ I_X\right)$ or extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ had little effect upon the recovery characteristics of the model. Retracting mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = -0.20\ I_Y\right)$ generally led to spins similar to the normal loading condition, although recoveries from the aileron-with, elevator neutral or full down spins were slow $\left(2\frac{1}{4}\text{ turns and } 2\frac{3}{4}\text{ turns, respectively}\right)$.

Movement of the center of gravity forward $0.05\bar{c}$ or back $0.05\bar{c}$ from its normal position had little effect on the recovery characteristics of the model.

Opening the slots, for the model in the normal loading condition, generally expedited recoveries for the aileron-against and aileron-neutral spins. Lowering the flaps 45° generally had a detrimental effect upon the recovery characteristics of the model, particularly for elevator-down spins.

For the landing condition (slots open, landing gear and tail wheel extended, cockpit open, and flaps 45° down), the spins obtained were flatter and recoveries were somewhat slower than for the normal loading, clean condition.

The results of brief tests of the model indicated that for the normal loading condition, there was little effect of opening the cockpit, of extending the landing gear, or of offsetting the fin $1\frac{1}{2}^\circ$, on the recovery characteristics of the model.

Recoveries from inverted spins were satisfactory by rapid full rudder reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS XP-46 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading											
Ailerons	Against, Full			Against, 10°U, 7°D			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U (a)	N (b)	D (b)
a, deg	---	38	36	41	39	38	29	41	38	-	-	-
ø, deg	---	4U	4U	1U	3U	3U	0	1D	0	-	-	-
Ω, rps	0.42	0.52	0.56	0.42	0.51	0.54	0.40	0.51	0.55	-	-	-
V, fps	214	195	201	218	195	199	240	189	199	-	-	-
Turns for recovery	$1\frac{1}{4}$ c$\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{4}$	$1\frac{1}{2}$ c$1\frac{3}{4}$ d$2\frac{3}{4}$	$2\frac{1}{2}$ d$>7\frac{1}{2}$	$2\frac{1}{2}$ d∞	-	-	-

	ΔI_X and $\Delta I_Z = 0.20 I_X$									ΔI_X and $\Delta I_Z = -0.20 I_X$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (e)	N (b)	D (b)	U	N	D	U	N	D	U (e)	N (b)	D (b)
a, deg	36	36	32	31	40	36	-	-	-	37	41	38	32	38	36	-	-	-
ø, deg	3U	4U	5U	0	1U	1U	-	-	-	2U	3U	2U	1D	0	1U	-	-	-
Ω, rps	0.42	0.52	0.56	0.43	0.48	0.57	-	-	-	0.40	0.50	0.53	0.42	0.51	0.55	-	-	-
V, fps	218	201	207	230	199	205	-	-	-	205	187	191	218	197	193	-	-	-
Turns for recovery	$1\frac{1}{4}$	2	2	$1\frac{1}{2}$	2	3	-	-	-	$1\frac{1}{2}$	$2\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{4}$	4	-	-	-

	ΔI_Y and $\Delta I_Z = 0.20 I_Y$									ΔI_Y and $\Delta I_Z = -0.20 I_Y$									c.g. moved forward $0.05\bar{c}$								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U (e)	N	D	U (e)	N (e)	D (b)	U	N	D	U	N	D	U (f)	N	D	U	N	D	U (b)	N	D	U (e)	N (g)	D (b)
a, deg	40	38	37	-	40	34	-	-	-	36	34	32	32	35	34	-	33	---	31	34	35	-	31	31	-	43	-
ø, deg	4U	4U	4U	-	1D	1U	-	-	-	6U	6U	7U	1D	1U	1U	-	2D	---	1U	3U	3U	-	0	0	-	5D	-
Ω, rps	0.38	0.47	0.49	-	0.51	0.52	-	-	-	0.49	0.58	0.65	0.49	0.59	0.66	-	0.65	0.67	0.46	0.57	0.61	-	0.61	0.62	-	0.51	-
V, fps	205	193	197	-	189	201	-	-	-	218	207	207	228	205	197	-	211	207	234	218	211	-	226	214	-	189	-
Turns for recovery	$1\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	-	2 $2\frac{3}{4}$	$2\frac{1}{2}$	-	-	-	1	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	$1\frac{3}{4}$	-	$2\frac{1}{4}$	$2\frac{3}{4}$	1	$2\frac{1}{2}$	$2\frac{3}{4}$	-	$1\frac{3}{4}$	$2\frac{1}{2}$ 2	-	2	-

	c.g. moved back $0.05\bar{c}$									Slots open, normal loading									Flaps down, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U (e)	N	D	U (e)	N (e)	D (b)	U	N	D	U	N	D	U (e)	N (e)	D (b)	U	N	D	U	N	D	U (e)	N (e)	D
a, deg	32	37	34	-	32	34	-	-	-	40	43	---	49	42	34	-	-	-	42	42	43	48	46	44	-	-	43
ø, deg	4U	2U	6U	-	0	1D	-	-	-	0	2D	---	6D	4D	3D	-	-	-	3U	2U	2U	1D	1D	1U	-	-	3D
Ω, rps	0.38	0.49	0.53	-	0.53	0.56	-	-	-	---	0.48	0.52	0.38	0.50	0.62	-	-	-	0.40	0.47	0.49	0.41	0.48	0.49	-	-	0.48
V, fps	238	205	203	-	220	207	-	-	-	187	179	187	187	181	224	-	-	-	181	173	175	175	171	177	-	-	185
Turns for recovery	$\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	-	$1\frac{3}{4}$	$2\frac{1}{4}$	-	-	-	$\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$ 1	$1\frac{3}{4}$	1	-	-	-	$1\frac{1}{2}$	$3\frac{1}{4}$	$4\frac{1}{4}$	2	$2\frac{3}{4}$	4	-	-	$3\frac{1}{2}$

	Landing condition, normal loading									Inverted spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U (e)	N	D	U (e)	N (h)	D (h)	U	N	D	U (b)	N (b)	D	U	N (g)	D
a, deg	46	44	---	---	46	43	-	-	-	No spin	No spin	36	-	-	44	38	44	27
ø, deg	3D	2D	---	---	6D	6D	-	-	-			7U	-	-	1U	10D	4D	5D
Ω, rps	0.39	0.46	0.47	---	0.45	0.49	-	-	-			0.58	-	-	0.61	0.46	0.51	0.83
V, fps	181	171	173	173	169	165	-	-	-			250	-	-	236	234	205	272
Turns for recovery	$2\frac{1}{4}$	$2\frac{3}{4}$	$5\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$	3	-	-	-			$\frac{3}{4}$	-	-	$\frac{3}{4}$	$1\frac{1}{2}$	1	$\frac{3}{4}$

[a]Slightly oscillatory spin.

[b]Velocity too high to test.

[c]Recovery attempted by simultaneous rudder and elevator reversal.

[d]Recovery attempted by neutralizing rudder.

[e]Oscillatory and wandering spin.

[f]Wandering spin.

[g]Steeper spin also obtainable.

[h]Wandering, oscillatory, and steep spin.

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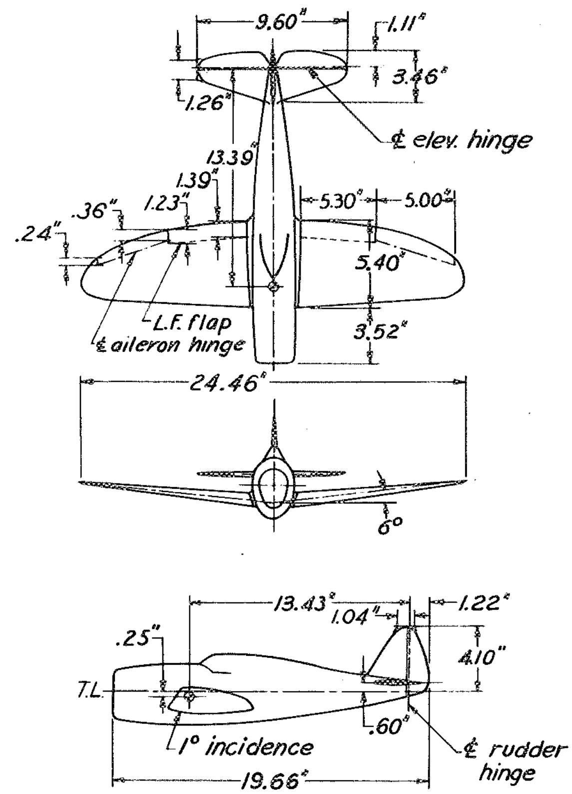
$\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC XP-47B AIRPLANE

Dimensional Data

(Full Scale)

b, ft	40.78
L, ft	35.34
$\bar{c}$, in.	87.46
S, sq ft	300.00
A	5.54
L.E. $\bar{c}$ aft L.E. c_r, in.	8.70
S_h, sq ft	55.00
S_e, sq ft	18.19
S_v, sq ft	26.50
S_r, sq ft	10.86
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	27.5 U, 22.5 D
δ_a, deg (1/2 stick)	13 U, 12 D
δ_f, deg	40 D
TDPF	160×10^{-6}
Landing gear	Conventional



Mass Data

Model as tested.

Normal Loading

W, lb	11,860
$x/\bar{c}$	0.259
$z/\bar{c}$	0.057
I_X, slug-ft^2	13,867
I_Y, slug-ft^2	13,047
I_Z, slug-ft^2	25,841
Test altitude, ft	10,000
μ (at sea level)	12.65
μ' (10,000 ft)	17.13

$\frac{I_X - I_Y}{mb^2}$	14×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-210×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	196×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun at an angle of attack of 38° with a vertical velocity of 226 feet per second, full scale, and recovery by rapid full rudder reversal or by simultaneous full reversal of rudder and elevator was satisfactory (2 and 1 turns, respectively). Recoveries from the elevator-neutral or elevator-down spins (ailerons neutral) were unsatisfactory $\left(4, > 3\frac{1}{2}\text{ turns, respectively}\right)$. For other control configurations, satisfactory recoveries by rapid full rudder reversal were obtained only when the ailerons were set full against the spin.

Retracting the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = -0.37\ I_X\right)$ caused a reversal of aileron effect. Extending or retracting mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = \pm 0.20\ I_Y\right)$ had little effect on the spin recovery characteristics.

With the flaps down 40°, normal loading, satisfactory recoveries were obtained only when the ailerons were set against the rotation. Retracting mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = -0.37\ I_X\right)$ in conjunction with deflecting the flaps 40° caused satisfactory recoveries to be obtained only when the ailerons were set with the spin.

The results indicate satisfactory recovery characteristics for the model for inverted spins.

The addition of a ventral fin to the model (modification 1) was beneficial although recoveries from aileron-with spins, normal loading, were still unsatisfactory. Raising the horizontal tail 10 inches, full scale, in conjunction with the addition of a dorsal fin (modification 3) had the same effect on the recovery characteristics of the model as did modification 1.

In an attempt to improve the recoveries from spins of the model with the flaps down 40°, normal loading, tail modifications 1 to 12 were tested on the model. Generally these modifications were not adequately effective.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC XP-47 B AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

Normal loading

Ailerons	Against			Neutral			With ½	With Full		
Elevator	U (a)	N (a)	D	U	N	D	U	U (b)	N	D
α, deg	---	--	No spin	38	44	42	---	46	50	48
ϕ, deg	---	--		2D	0	0	---	5D	3D	3D
Ω, rps	---	--		0.42	0.55	0.52	---	0.43	0.49	0.48
V, fps	---	--		226	201	201	209	213	185	181
Turns for recovery	c_	c_		2	$4\frac{1}{2}$	4	$>3\frac{1}{2}$	>4	>7	>8

ΔI_X and $\Delta I_Z = 0.20\ I_X$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (d)	N	D*
α, deg	No spin	No spin	No spin	49	---	---	53	------	52
ϕ, deg				2U	---	---	2D	------	1D
Ω, rps				0.46	---	---	0.47	------	0.55
V, fps				226	201	205	201	155	185
Turns for recovery				3	4	$>3\frac{1}{2}$	>8	>9	∞

Effect of control manipulations on turns for recovery, normal loading condition

Control manipulations	Ailerons	Neutral			With		
	Elevator	U	N	D	U	N	D
Simultaneous full reversal of rudder and elevator	V, fps	226	-----	----	213	-----	----
	Turns for recovery	1	-----	----	3	-----	----
Simultaneous full reversal of rudder and ailerons	V, fps	-----	-----	----	213	185	181
	Turns for recovery	-----	-----	----	2	$2\frac{3}{4}$	$3\frac{1}{2}$
Rudder reversal from full with to 2/3 against	V, fps	226	201	185	----	----	----
	Turns for recovery	$2\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	----	----	----
Rudder reversal from full with to 1/3 against	V, fps	226	201	185	----	----	----
	Turns for recovery	$2\frac{1}{2}$	8	6	----	----	----
Rudder reversal from full with to neutral	V, fps	226	201	185	----	----	----
	Turns for recovery	>5	∞	∞	----	----	----

ΔI_X and $\Delta I_Z = -0.20\ I_X$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D	U	N	D	U (b)	N	D
α, deg	--	----	No spin	----	----	42	50	47	47
ϕ, deg	--	----		----	----	0	7D	4D	4D
Ω, rps	--	----		----	----	0.51	---	0.50	0.55
V, fps	--	----		226	201	199	210	189	189
Turns for recovery	--	----		2	$3\frac{1}{2}$	3	---	5	5

ΔI_X and $\Delta I_Z = -0.37\ I_X$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U (b)	N (a)	D (a)
α, deg	--	---	---	--	--	--	----	--	--
ϕ, deg	--	---	---	--	--	--	----	--	--
Ω, rps	--	---	---	--	--	--	----	--	--
V, fps	--	185	181	201	193	193	----	--	--
Turns for recovery	--	3	3	1	$1\frac{3}{4}$	$2\frac{1}{2}$	----	--	--

ΔI_Y and $\Delta I_Z = 0.20\ I_Y$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D (a)	U	N	D	U	N	D
α, deg	--	--	--	50	----	50	----	52	----
ϕ, deg	--	--	--	1D	----	0	----	3D	----
Ω, rps	--	--	--	0.41	----	0.49	----	0.46	----
V, fps	--	--	--	230	193	189	222	189	185
Turns for recovery	--	--	--	$1\frac{3}{4}$	4	$4\frac{3}{4}$	>3	>8	>8

ΔI_Y and $\Delta I_Z = -0.20\ I_Y$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	--	No spin	No spin	31	20	No spin	47	51	----
ϕ, deg	--			1D	1U		4D	2D	----
Ω, rps	--			0.54	0.78		0.49	0.48	----
V, fps	--			238	270		197	181	177
Turns for recovery	--			$1\frac{1}{2}$	----		>7	∞	>9

Flaps down 40°, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U (d)	N	D
α, deg	----	No spin	No spin	----	----	----	40	----	----
ϕ, deg	----			----	----	----	4D	----	----
Ω, rps	----			----	----	----	0.37	----	----
V, fps	----			201	168	165	201	173	173
Turns for recovery				>9	∞	$8\frac{1}{2}$	>6	>9	∞

Flaps down 40°, ΔI_X and $\Delta I_Z = -0.37\ I_X$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N (a)	D (a)
α, deg	---	---	----	---	----	----	---	---	---
ϕ, deg	---	---	----	---	----	----	---	---	---
Ω, rps	---	---	----	---	----	----	---	---	---
V, fps	181	168	168	---	181	173	---	---	---
Turns for recovery	3	$4\frac{1}{2}$	6	---	$3\frac{1}{2}$	$3\frac{3}{4}$	---	---	[c]$\frac{1}{2}$

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[a]Velocity too high to test.
[b]Oscillatory and wandering spin.
[c]Rapid recoveries were obtained when rudder was reversed before final steep attitude was reached.
[d]Wandering spin.

SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC XP-47 B AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	---	--	--	----	---	---	---	---	---
ø, deg	---	--	--	----	---	---	---	---	---
Ω, rps	---	--	--	----	---	---	---	---	---
V, fps	---	--	--	----	173	168	---	189	185
Turns for recovery	---	--	--	>2	>8	>7	---	∞	>7

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N (a)	D	U	N	D (a)
α, deg	No spin	No spin	No spin	---	---	No spin	43	40	----
ø, deg				---	---		3D	4D	----
Ω, rps				---	---		0.42	0.45	----
V, fps				---	---		234	230	----
Turns for recovery				c	c		$1\frac{3}{4}$	$\frac{3}{4}$	c

	Modification 1, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U (b)	N	D
α, deg	--	No spin	No spin	---	---	---	---	---	---
ø, deg	--			---	---	---	---	---	---
Ω, rps	--			---	---	---	---	---	---
V, fps	--			226	229	229	238	193	193
Turns for recovery	--			1	1	2	3	4	4

	Modification 3, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D	U (e)	N (e)	D (ae)	U (d)	N	D
α, deg	--	--	No spin	----	--	--	---	--	--
ø, deg	--	--		----	--	--	---	--	--
Ω, rps	--	--		----	--	--	---	--	--
V, fps	--	--		234	266	--	226	205	205
Turns for recovery	c	c		$1\frac{1}{4}$	2	c $\frac{3}{4}$	>3	4	4

[f]Effect of changes in tail design on turns for recovery, flaps down 40°, normal loading.

Tail modification			1	2	3	4	5	6	7	8	9	10	11	12
Ailerons	Neutral	Elevator U	$1\frac{1}{2}$	----	2	>3	>3	>3	2	>3	3	$2\frac{1}{2}$	>6	>2
		Elevator N	$1\frac{1}{2}$	>7	4	4	3	$3\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	3	2	∞	4
		Elevator D	$2\frac{1}{4}$	>7	$3\frac{1}{4}$	$3\frac{1}{2}$	3	$4\frac{1}{2}$	4	$3\frac{1}{2}$	$2\frac{1}{2}$	2	∞	3
	With	Elevator U	>4	----	----	>3	>3	----	----	>3	>4	----	>5	>4
		Elevator N	$>3\frac{1}{2}$	>5	>5	>9	6	6	5	6	$6\frac{1}{2}$	5	∞	7
		Elevator D	>4	>5	>4	>7	7	$6\frac{1}{2}$	$4\frac{1}{2}$	6	$4\frac{1}{2}$	4	∞	6

	[g]Normal loading, stabilizer incidence increased $2\frac{1}{2}°$										
Ailerons	Against 10U 8D	Against 5U 4D		Neutral						With 5U 4D	With 10U 8D
Elevator	25U	35	25U	40U	35U	U	25U	N	D	35U	30U
V, fps	255	236	207	226	226	223	201	201	207	216	201
Turns for recovery	1	2	4	$2\frac{1}{2}$	$3\frac{1}{4}$	$2\frac{1}{4}$ $3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{1}{2}$	$>4\frac{1}{2}$	$>6\frac{1}{2}$

[a]Velocity too high to test.
[b]Oscillatory and wandering spin.
[c]Rapid recoveries were obtained when rudder was reversed before final steep attitude was reached.
[d]Wandering spin.
[e]Steep spin.
[f]Approximate velocity for all spins 185 fps.
[g]Values of turns for recovery are approximate. Use data for qualitative estimate only.

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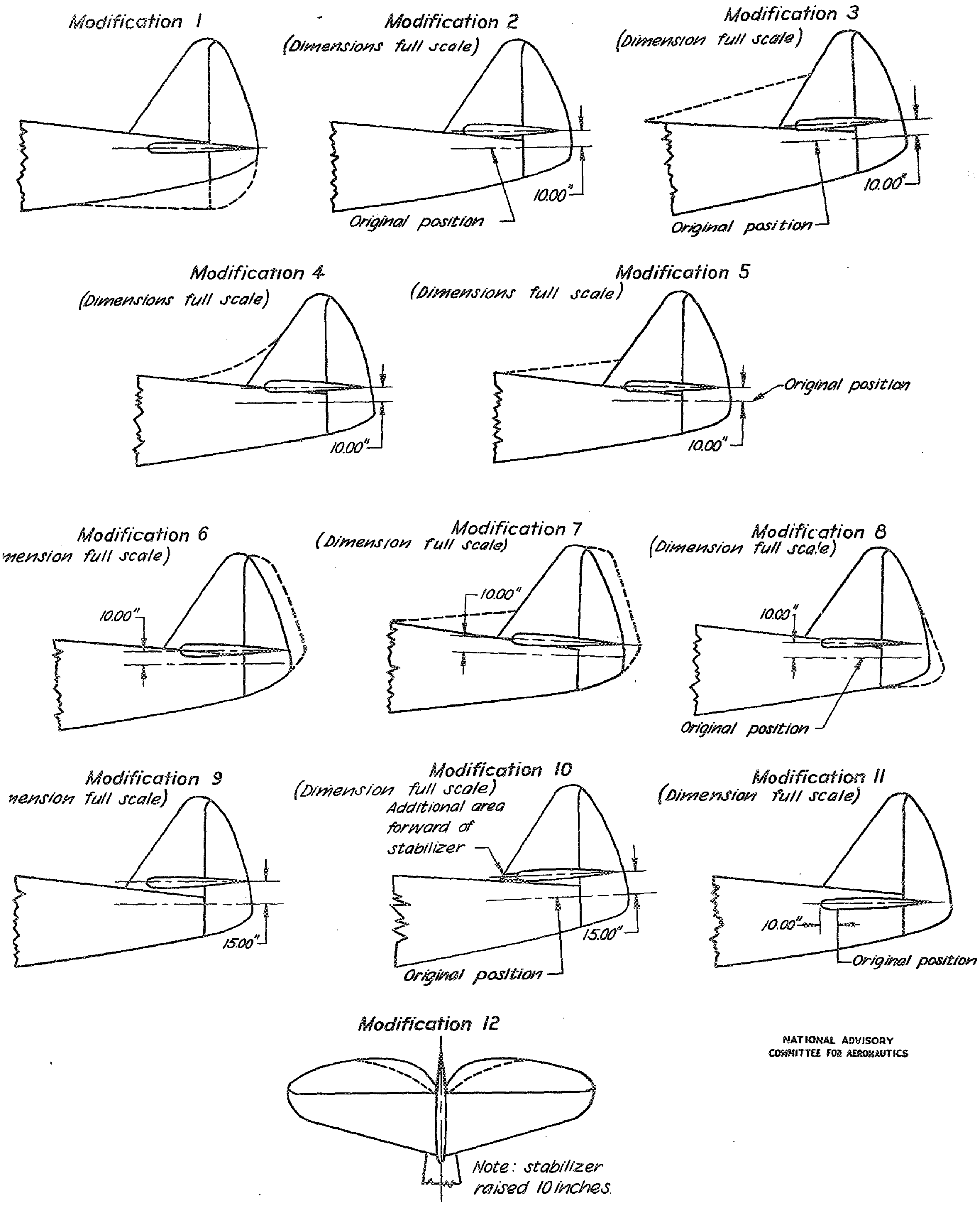
Modification 1
Modification 2
(Dimensions full scale)
10.00"
Original position
Modification 3
(Dimension full scale)
10.00"
Original position
Modification 4
(Dimensions full scale)
10.00"
Modification 5
(Dimensions full scale)
Original position
10.00"
Modification 6
mension full scale)
10.00"
Modification 7
(Dimension full scale)
10.00"
Modification 8
(Dimension full scale)
10.00"
Original position
Modification 9
mension full scale)
15.00"
Modification 10
(Dimension full scale)
Additional area
forward of
stabilizer
15.00"
Original position
Modification 11
(Dimension full scale)
10.00"
Original position
Modification 12
Note: stabilizer
raised 10 inches.
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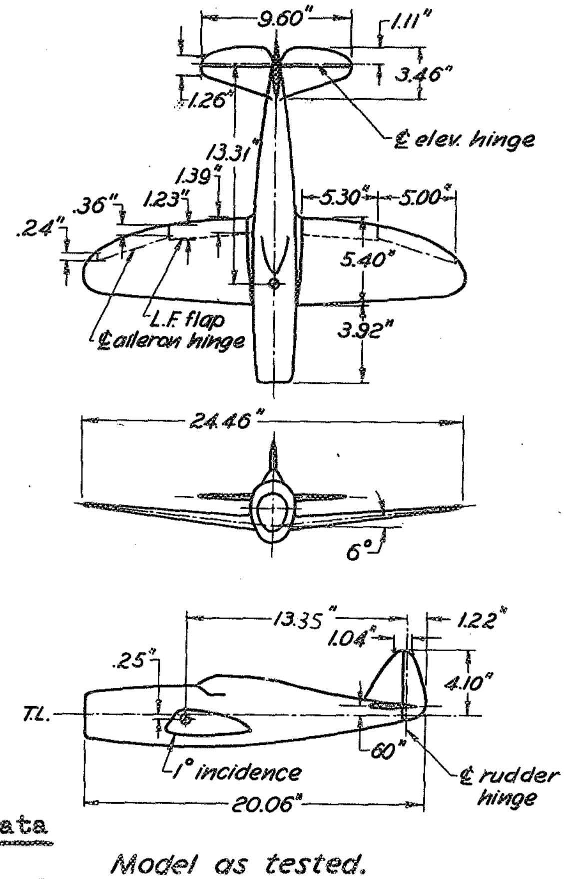
$\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC P-47D AIRPLANE



Dimensional Data

(Full Scale)

b, ft	40.78
L, ft	35.34
$\bar{c}$, in.	87.46
S, sq ft	300.00
A	5.54
L.E. $\bar{c}$ aft L.E. c_r, in.	8.70
S_h, sq ft	55.00
S_e, sq ft	18.19
S_v, sq ft	26.50
S_r, sq ft	10.86
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	27.5 U, 22.5 D
TDPF	160×10^{-6}
Landing gear	Conventional

Mass Data

Normal Loading

W, lb	12,692
$x/\bar{c}$	0.278
$z/\bar{c}$	0.060
I_X, slug-ft^2	13,870
I_Y, slug-ft^2	15,530
I_Z, slug-ft^2	28,300
Test altitude, ft	10,000
μ (at sea level)	13.55
μ' (10,000 ft)	18.35

$\frac{I_X - I_Y}{mb^2}$	-27×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-208×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	235×10^{-4}

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Résumé of Model Test Results

The results indicated that for the normal loading and clean condition, recoveries of the model by rapid full rudder reversal were satisfactory only when the ailerons were set full against the spin. For the normal control configuration for spinning, two types of spin were obtained and recovery was satisfactory only from the steeper spin by simultaneous reversal of rudder and elevator. A moderate extension of mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ had no appreciable effect on the unsatisfactory recovery characteristics of the model.

In order to improve the recovery characteristics of the model, the effects of various tail modifications were investigated (modifications 1 to 8). For the normal loading and clean condition, modification 2 (area added to bottom of fuselage and rudder) or modification 7 (antispin fillets) appeared to be the most effective modifications.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC P-47D AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading															
Ailerons	Against, Full			Against, 16° U 12° D			Neutral						With, 6° U $4\frac{1}{2}$° D	With, Full		
Elevator	U	N	D	U (a)	N	D	U (b)	U (b)	25° U	20° U	N	D	U	U (c)	N	D
α, deg	25	---	No spin	---	---	---	56	45	51	--	54	53	--	35	52	50
∅, deg	1D	---		---	---	---	1D	2D	1D	--	0	0	--	8D	5D	5D
Ω, rps	0.50	---		---	---	---	---	0.40	0.40	--	0.50	0.50	--	---	0.50	0.50
V, fps	315	339		332	200	200	197	220	204	--	195	192	--	252	197	195
Turns for recovery	$\frac{3}{4}$ [de]$\frac{1}{4}$	[df]$\frac{1}{2}$		---	[d]$3\frac{1}{2}$	[d]$3\frac{1}{2}$	3 [de]$2\frac{1}{2}$	$2\frac{1}{2}$ [de]$1\frac{1}{2}$	4	[dg]$3\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	4 [de]$2\frac{1}{2}$	>$2\frac{1}{4}$ [e]2	[d]6	7

	ΔI_Y and $\Delta I_Z = 0.20 I_Y$									
Ailerons	Against, Full			Against, 16° U 12° D	Neutral			With		
Elevator	U	N	D	U	U	20° U	N	U (h)	N (h)	D (h)
α, deg	27	53	53	28	50	56	53	--	43	46
∅, deg	1D	3U	3U	0	1D	1D	1D	--	5D	5D
Ω, rps	---	---	---	---	---	---	---	--	---	---
V, fps	290	204	195	304	230	204	201	--	232	220
Turns for recovery	$\frac{3}{4}$	$3\frac{1}{2}$	$5\frac{1}{4}$	$\frac{1}{2}$	$1\frac{3}{4}$	4	$5\frac{3}{4}$	--	$3\frac{1}{4}$ 4	3

	Modification 1, normal loading									Modification 2, normal loading									
Ailerons	Against			Neutral				With		Against			Neutral				With		
Elevator	U	N	D	U	20° U	N	D	U (h)	20° U	U	N	D	U	20° U	N	D	U (h)	N	D
α, deg	31	-	-	48	56	54	53	44	53	31	-	-	60	58	58	55	53	-	-
∅, deg	0	-	-	1D	0	0	0	6D	4D	2U	-	-	1D	1D	1D	0	2D	-	-
Ω, rps	---	-	-	---	---	---	---	---	---	---	-	-	---	---	---	---	---	-	-
V, fps	284	-	-	222	207	207	201	251	207	271	-	-	207	195	188	188	220	-	-
Turns for recovery	$\frac{1}{2}$	-	-	2	3 $2\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{4}$ 4	>2	3	$\frac{1}{2}$	-	-	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	>2	-	-

	Modification 3, normal loading			Modification 4, normal loading		
Ailerons	Neutral			Neutral		
Elevator	U	20° U	N	U	20° U	N
α, deg	55	54	52	57	60	57
∅, deg	1D	0	0	0	0	0
Ω, rps	---	---	---	---	---	---
V, fps	233	195	201	201	195	188
Turns for recovery	$1\frac{1}{4}$	$3\frac{3}{4}$	[d]$5\frac{1}{2}$	2	3	3

	Modification 5, normal loading			Modification 6, normal loading			Modification 7, normal loading			Modification 8, normal loading	
Ailerons	Neutral			Neutral			Neutral			Neutral	
Elevator	U	20° U	N	U	N	D	U	20° U	N	U	N
α, deg	42	52	52	42	52	--	41	43	42	39	50
∅, deg	0	0	0	2U	0	--	0	1D	1D	3D	0
Ω, rps	---	---	---	---	---	--	---	---	---	---	---
V, fps	226	195	188	220	204	--	236	226	216	238	207
Turns for recovery	2	3	[d]$5\frac{1}{2}$	[d]$3\frac{1}{2}$	$4\frac{1}{2}$	--	2 $2\frac{1}{2}$	2 $2\frac{1}{2}$ [i]2 [i]$2\frac{1}{2}$	3	$1\frac{3}{4}$	>4

[a]Steep spin.
[b]Two types of spin.
[c]Wandering and oscillatory spin.
[d]Visual observation.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Recovery attempted before final steep attitude was attained.
[g]Recovery attempted by simultaneous full rudder reversal and reversal of elevator from 20° up to 20° down.
[h]Wandering spin.
[i]Recovery attempted by rudder reversal to 2/3 against the spin.

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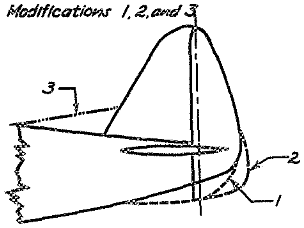
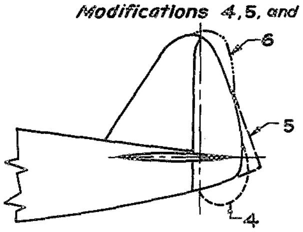
Modifications 1, 2, and 3

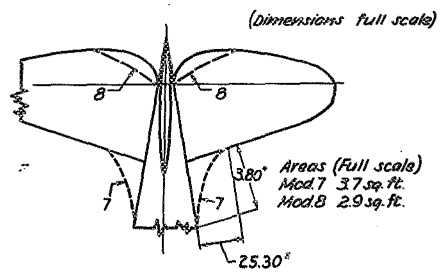


Modifications 4, 5, and 6



Modifications 7 and 8

(Dimensions full scale)

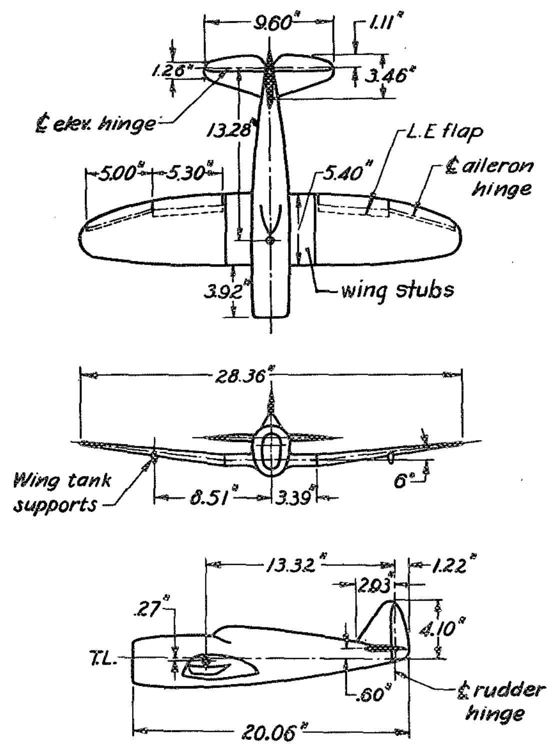


$\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC P-47D-30 AIRPLANE

Dimensional Data

(Full Scale)

	Condition I Wing-tank supports installed; no wing stubs	Condition II Wing-tank supports and wing stubs installed
b, ft	40.77	47.27
L, ft	33.44	33.44
$\bar{c}$, in.	87.46	90.16
S, sq ft	300	360
A	5.55	6.22
L.E. $\bar{c}$ aft L.E. c_r, in.	8.64	----------
S_h, sq ft	55.00	55.00
S_e, sq ft (inc. bal.)	18.19	18.19
S_v, sq ft	26.50	26.50
S_r, sq ft (inc. bal.)	10.86	10.86
δ_r, deg	28 R, 28 L	
δ_e, deg	30 U, 20 D	
δ_a, deg	16 U, 12 D	
TDPF	120×10^{-6}	53×10^{-6}
Landing gear	Conventional	



Model as tested.

Mass Data

Normal Loading

	Condition I Wing-tank supports installed; no wing stubs	Condition II Wing-tank supports and wing stubs installed
W, lb	12,981	15,942
$x/\bar{c}$	0.280	0.30
$z/\bar{c}$	0.06	0.06
I_X, slug-ft^2	9,900	21,080
I_Y, slug-ft^2	16,110	20,210
I_Z, slug-ft^2	24,700	37,970
Test altitude, ft	10,000	10,000
μ (at sea level)	13.86	12.23
μ (30,000 ft)	18.77	16.57

$\frac{1}{20}$ - SCALE MODEL OF THE REPUBLIC P-47D-30 AIRPLANE - Concluded

	Condition I	Condition II
$\frac{I_X - I_Y}{mb^2}$	-93×10^{-4}	8×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-128×10^{-4}	-161×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	221×10^{-4}	153×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, the model without the win stubs installed but with the wing tank supports attached recovered satisfactorily from all elevator-up spins by rapid full rudder reversal or by simultaneous reversal of the elevator and rudder. Recoveries from elevator-neutral spins were unsatisfactory only when the ailerons were set full against the spin. With the wing tank supports and wing stubs installed satisfactory recoveries of the model were obtained only by simultaneous reversal of the elevator and rudder when the elevator was full up.

In order to improve the recoveries obtained by rudder reversal of the model with the wing stubs and wing-tank supports installed, various tail modifications were investigated (modifications 1 to 19). The addition of a ventral and dorsal fin (modifications 2 and 5) to the model had a beneficial effect, although not an entirely satisfactory one. Moving the horizontal and vertical tail surfaces rearward 40 inch full scale from their original position had a beneficial effect on the recovery characteristics of the model although recovery by rudder reversal alone from the spin for the normal control configuration was still unsatisfactory.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC P-47D-30 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading, condition I, (only the wing tank supports installed)								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (ab)	N	D	U (ab)	N (c)	D (c)
α, deg	34	50	52	42	47	45	----	----	----
∅, deg	0	2U	3U	3D	2D	1D	----	----	----
Ω, rps	---	0.45	0.46	0.37	0.47	0.51	----	----	----
V, fps	271	210	207	264	212	219	-----	>374	>374
Turns for recovery	1 $^{d}\frac{1}{4}$	$3\frac{1}{2}$	$4\frac{1}{2}$	1 $1\frac{1}{2}$ $^{d}\frac{1}{2}$	1 $1\frac{3}{4}$	3 $4\frac{1}{2}$	$>2\frac{1}{2}$ $^{d}1\frac{1}{2}$ $^{d}2$	$\frac{3}{4}$ 1	1 $1\frac{1}{2}$

	Normal loading, condition II, (wing tank support and wing stubs installed)								
Ailerons	Against			Neutral			With		
Elevator	U (b)	N	D	U (ab)	N	D	U (ab)	N	D
α, deg	33	32	54	42	58	55	46	51	53
∅, deg	1D	0	1U	2D	1D	1D	2D	2D	2D
Ω, rps	----	0.47	0.43	0.34	0.43	0.43	0.35	0.43	0.43
V, fps	276	290	212	245	206	212	232	212	216
Turns for recovery	$1\frac{1}{2}$ $2\frac{1}{2}$ $^{d}\frac{1}{2}$	>2	>5	>4 $^{d}\frac{3}{4}$ $^{e}\infty$	>3	>5	>3 $^{d}2$ $^{e}\infty$	>5	>10

	Modification 2 and 5 normal loading, condition II					
Ailerons	Against		Neutral		With	
Elevator	U (f)	D	U	D	U (ab)	D
α, deg	---	---	---	---	---	---
∅, deg	---	---	---	---	---	---
Ω, rps	----	----	----	----	----	----
V, fps	>375	216	278	219	----	232
Turns for recovery	$\frac{1}{2}$	$2\frac{1}{2}$ 3	$1\frac{1}{2}$	$2\frac{1}{2}$ 3	>2	2

	Modification 2, normal loading, condition II						Fuselage lengthened approximately 40 inches, (full-scale) normal loading, condition II								
Ailerons	Against		Neutral		With		Against			Neutral			With		
Elevator	U (f)	D	U	D	U (ab)	D	U (f)	N	D	U	N	D	U (ab)	N	D
α, deg	----	48	37	48	----	42	----	----	----	----	----	----	----	----	----
∅, deg	----	2D	3U	0	----	2U	----	----	----	----	----	----	----	----	----
Ω, rps	----	0.42	0.45	0.43	----	0.45	----	----	----	----	----	----	----	----	----
V, fps	>370	216	278	220	----	223	>370	359	352	332	325	320	----	272	291
Turns for recovery	$\frac{3}{4}$	$2\frac{1}{2}$ 3	>2	4 $4\frac{1}{2}$	>2	$3\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	>2	$2\frac{1}{2}$	1	>2	3	$2\frac{1}{2}$

[a]Wandering spin.
[b]Oscillatory in pitch and yaw.
[c]Velocity too high to test.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Recovery attempted by elevator reversal alone.
[f]Steep spin.

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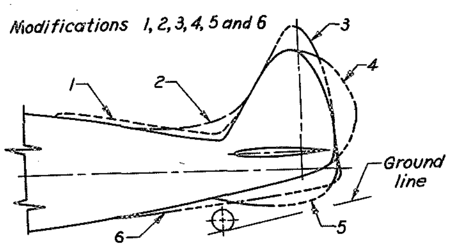
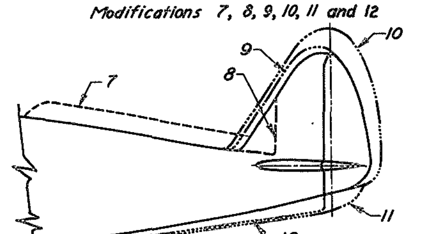
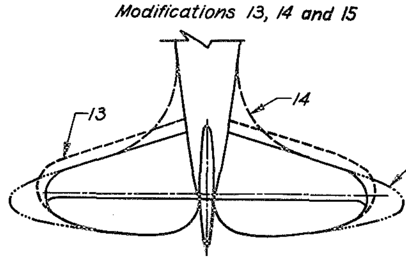
Modifications 1, 2, 3, 4, 5 and 6



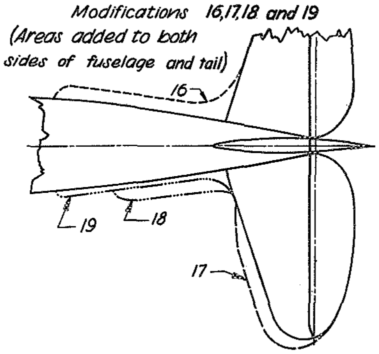
Modifications 7, 8, 9, 10, 11 and 12



Modifications 13, 14 and 15



Modifications 16, 17, 18 and 19 (Areas added to both sides of fuselage and tail)

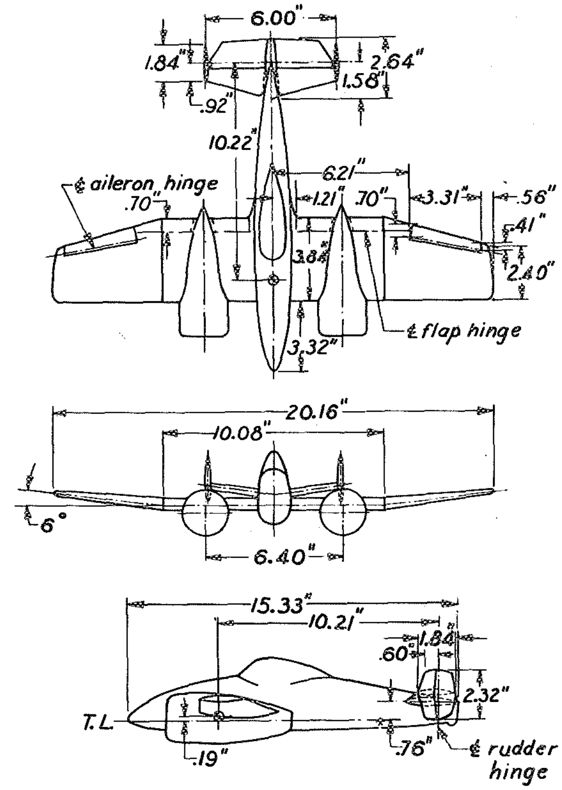


$\frac{1}{25}$-SCALE MODEL OF THE GRUMMAN XP-50 AIRPLANE

<u>Dimensional Data</u>

(Full Scale)

b, ft	42.00
L, ft	31.94
$\bar{c}$, in.	88.52
S, sq ft	303.50
A	5.83
L.E. $\bar{c}$ aft L.E. c_r, in.	0.00
S_h, sq ft	54.60
S_e, sq ft	22.00
S_v, sq ft	30.20
S_r, sq ft	15.20
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	20.5 U, 17.5 D
δ_a, deg (1/2 stick)	10 U, 9 D
δ_f, deg	45 D
TDPF	2410×10^{-6}
Landing gear	Tricycle



<u>Mass Data</u>

Model as tested.

Normal Loading

W, lb	10,440
$x/\bar{c}$	0.205
$z/\bar{c}$	-0.055
I_X, slug-ft^2	13,793
I_Y, slug-ft^2	7,582
I_Z, slug-ft^2	21,210
Test altitude, ft	13,000
μ (at sea level)	10.70
μ' (13,000 ft)	15.98

$\frac{I_X - I_Y}{mb^2}$	108×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-238×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	130×10^{-4}

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Résumé of Model Test Results

The test results indicated that recoveries by rapid full rudder reversal from all spins for all conditions tested generally were satisfactory except when the ailerons were partly or fully, with the spin and the elevator partly or fully up. Setting the elevator down and/or setting the ailerons against the spin was conducive in promoting no spin conditions.

SPIN DATA OBTAINED WITH THE $\frac{1}{25}$-SCALE MODEL OF THE GRUMMAN XP-50 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading										
Ailerons	Against			Neutral			With, $\frac{1}{2}$	With, Full			
Elevator	U	N	D	U (a)	N	D	U	U	$\frac{1}{2}$U	N	D
α, deg	No spin	--	--	--	No spin	No spin	36	44	37	No spin	No spin
∅, deg		--	--	--			1D	3D	2D		
Ω, rps		--	--	--			0.52	0.47	0.55		
V, fps		--	--	--			266	216	243		
Turns for recovery		--	--	--			>2	>$2\frac{1}{2}$ [c]$1\frac{1}{4}$ [b]$2\frac{1}{2}$ [d]$2\frac{1}{2}$	>$2\frac{1}{2}$		

	ΔI_X and ΔI_Z = $0.30 I_X$					
Ailerons	Neutral			With		
Elevator	U (a)	N	D	U	N	D
α, deg	-	-	-	45	No spin	-
∅, deg	-	-	-	2D		-
Ω, rps	-	-	-	0.48		-
V, fps	-	-	-	234		-
Turns for recovery	-	-	-	∞		-

	ΔI_Y and ΔI_Z = $0.30 I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (e)	N	D	U	N	D
α, deg	No spin	-	-	-	No spin	-	50	46	26
∅, deg		-	-	-		-	3D	2D	0
Ω, rps		-	-	-		-	0.44	0.54	0.56
V, fps		-	-	-		-	207	211	230
Turns for recovery		-	-	-		-	∞	2	1 $1\frac{1}{2}$

	c.g. moved forward $0.05\bar{c}$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	No spin	--	--	--	No spin	--	48	No spin	--
∅, deg		--	--	--		--	3D		--
Ω, rps		--	--	--		--	0.49		--
V, fps		--	--	--		--	221		--
Turns for recovery		--	--	--		--	>$3\frac{1}{2}$		--

	c.g. moved back $0.05\bar{c}$									Landing condition, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U (a)	N	D	U	N	D
α, deg	No spin	--	--	23	No spin	--	49	36	No spin	No spin	--	--	--	No spin	--	47	No spin	--
∅, deg		--	--	0		--	2D	2D			--	--	--		--	4D		--
Ω, rps		--	--	0.50		--	0.47	0.51			--	--	--		--	0.50		--
V, fps		--	--	298		--	202	234			--	--	--		--	198		--
Turns for recovery		--	--	2		--	>4	$1\frac{1}{2}$			--	--	--		--	>$2\frac{1}{2}$		--

	Flaps down 45°, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (f)	N	D	U	N	D
α, deg	--	No spin	--	--	No spin	--	46	42	No spin
∅, deg	--		--	--		--	5D	3D	
Ω, rps	--		--	--		--	0.50	0.52	
V, fps	--		--	--		--	202	202	
Turns for recovery	--		--	--		--	>$2\frac{1}{2}$	2	

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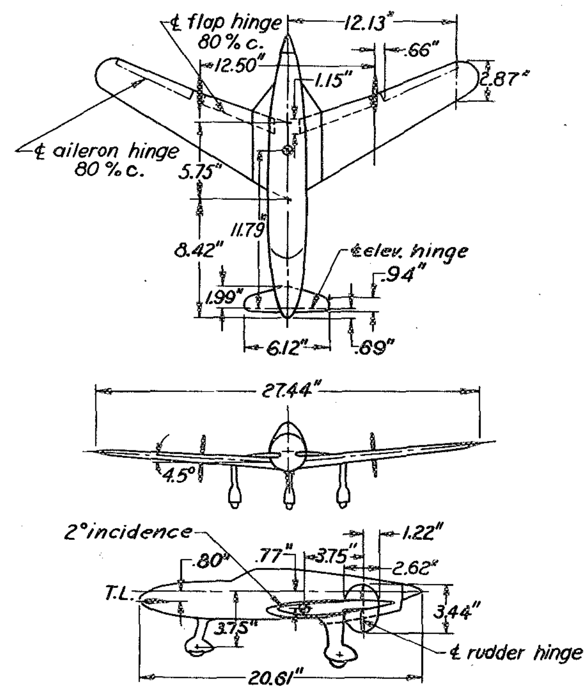
[a]Velocity too high to test.
[b]Recovery attempted by elevator reversal alone.
[c]Recovery attempted by simultaneous reversal of rudder and elevator.
[d]Recovery attempted by releasing rudder and elevator.
[e]Too wandering to test.
[f]Too oscillatory to test.

$\frac{1}{16}$-SCALE MODEL OF THE CURTISS-WRIGHT 24-B AIRPLANE

A FULL-SCALE FLYING MOCK-UP OF THE XP-55 AIRPLANE



Model as tested.

Dimensional Data

(Full Scale)

b, ft	36.58
L, ft	27.47
$\bar{c}$, in	67.71
S, sq ft	191.20
A	6.98
L.E. $\bar{c}$ aft L.E. C_r, in.	55.78
S_h, sq ft	15.56
S_v, sq ft	25.20
S_r, sq ft	11.44
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 15 D
δ_a, deg	20 U, 14.5 D
δ_f, deg	45 D
TDPF	92×10^{-6}
Landing gear	Fixed

When the flaps are down both ailerons are elevated 10° when the stick is laterally neutral. Normal deflections of 20° up and $14\frac{1}{2}$° down were then made from this position.

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Mass Data

Normal Loading

W, lb	3241
$x/\bar{c}$	0.120
$z/\bar{c}$	0.182
I_X, slug-ft^2	1409
I_Y, slug-ft^2	4062
I_Z, slug-ft^2	5041
Test altitude, ft	10,000
μ (at sea level)	6.05
μ'(10,000 ft)	8.20

$$\frac{I_X - I_Y}{mb^2} = -197 \times 10^{-4}$$

$$\frac{I_Y - I_Z}{mb^2} = -72 \times 10^{-4}$$

$$\frac{I_Z - I_X}{mb^2} = 269 \times 10^{-4}$$

Résumé of Model Test Results

For the clean condition, normal loading, the recovery characteristics of the model were unsatisfactory for all elevator settings when the ailerons were neutral. During these spins the model descended slowly with the fuselage almost horizontal, with a slow rate of rotation and an oscillation in roll of approximately $\pm 35^\circ$. Although complete reversal of the rudders stopped the rotation in less than a turn, the fuselage remained practically horizontal indicating the model was still in a stalled attitude. This occurred for all recoveries regardless of loading or control setting except where otherwise indicated in model test data.

When the ailerons were with the spin, the model did not continue to rotate after being launched into the tunnel, but the fuselage remained practically horizontal; when the ailerons were set against the spin, the model oscillated in pitch and roll, until the oscillations became so violent that the model pitched or rolled onto its back.

A moderate extension of mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.40\ I_X\right)$ or fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.40\ I_Y\right)$, a retraction of mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = -0.15\ I_Y\right)$ or changes in the center-of-gravity location forward $0.05\bar{c}$ and $0.20\bar{c}$ or back $0.10\bar{c}$ of its original position did not appreciably alter the recovery characteristics of the model. When the center of gravity was moved back $0.49\bar{c}$ from its original position, however, the model would continue to rotate after the rudders were reversed for recovery, whereas for the smaller changes of center-of-gravity location the model either remained in a stalled attitude without rotation or nosed over into a dive. Setting the flaps down 45° had little effect on the spin characteristics. A freely rotating propeller had little effect on the motion of the model in the spin.

In general, the inverted spin characteristics of the model were quite similar to those for erect spins when the ailerons were neutral. When the controls were crossed, the initial spin rotation stopped after a few turns. Setting the controls together led to spins in which the model was violently oscillatory in pitch and roll.

In an attempt to improve the recovery characteristics of the model to obtain both cessation of rotation and nosing down of the model when the rudders were reversed, various modifications in design (modifications 1 to 6) and control movements of the model were tested.

Generally the most effective modifications were a large rearward extension of the fillets between the wing and fuselage (modification 2) or drooped ailerons of approximately twice the size of the original ailerons.

SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CURTISS-WRIGHT 24-B AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading, rudders against the spin									Normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N (a)	D (a)	U (b)	N (b)	D (b)	U (c)	N (c)	D (c)	U (a)	N (a)	D (a)	U (d)	N (d)	D (d)	U (b)	N (b)	D (b)
α, deg	-	-	-	-	-	-	-	-	-	-	-	-	82	86	83	-	-	-
ø, deg	-	-	-	-	-	-	-	-	-	-	-	-	41D 30U	39D 38U	32D 29U	-	-	-
Ω, rps	-	-	-	-	-	-	-	-	-	-	-	-	0.13	0.08	0.10	-	-	-
V, fps	-	-	-	-	-	-	-	-	-	-	-	-	121	121	118	-	-	-
Turns for recovery	-	-	-	-	-	-	-	-	-	-	-	-	$^{e}\frac{1}{2}$	$^{e}\frac{1}{4}$	$^{e}\frac{3}{4}$	-	-	-

	ΔI_X and $\Delta I_Z = 0.40 I_X$									ΔI_Y and $\Delta I_Z = 0.40 I_Y$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D (a)	U (a)	N (a)	D (a)	U (b)	N	D (b)	U (a)	N	D (a)	U (d)	N (d)	D	U (b)	N	D (b)
α, deg	-	-	-	-	-	-	-	-	-	-	-	-	80	83	-	-	-	-
ø, deg	-	-	-	-	-	-	-	-	-	-	-	-	19D 24U	42D 39U	-	-	-	-
Ω, rps	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.06	-	-	-	-
V, fps	-	-	-	-	-	-	-	-	-	-	-	-	121	121	-	-	-	-
Turns for recovery	-	-	-	-	-	-	-	-	-	-	-	-	$^{e}\frac{3}{4}$	$^{e}\frac{3}{4}$	-	-	-	-

	ΔI_Y and $\Delta I_Z = -0.15 I_Y$									c.g. moved forward $0.05\bar{c}$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D (a)	U (d)	N	D (d)	U (b)	N	D (b)	U (a)	N	D (a)	U (d)	N	D (d)	U (b)	N	D (b)
α, deg	--	--	--	82	--	80	--	--	--	--	--	--	76	--	72	--	--	--
ø, deg	--	--	--	33D 20U	--	30D 26U	--	--	--	--	--	--	22D 32U	--	17D 12U	--	--	--
Ω, rps	--	--	--	0.10	--	0.12	--	--	--	--	--	--	0.08	--	---	--	--	--
V, fps	--	--	--	118	--	118	--	--	--	--	--	--	123	123	121	--	--	--
Turns for Recovery	--	--	--	$^{e}\frac{3}{4}$	--	$^{e}\frac{1}{2}$	--	--	--	--	--	--	$^{e}\frac{1}{4}$	$^{e}\frac{1}{2}$	$^{e}\frac{1}{4}$	--	--	--

	c.g. moved forward $0.20\bar{c}$									
Ailerons	Against			Neutral				With		
Elevator	U (a)	N (a)	D (a)	U	N	D (g)	D (g)	U (h)	N (h)	D (i)
α, deg	--	--	--	56	57	42	61	--	--	--
ø, deg	--	--	--	3D	2D	6U	1D	--	--	--
Ω, rps	--	--	--	0.15	0.15	0.20	--	--	--	--
V, fps	--	--	--	125	129	138	135	--	--	--
Turns for Recovery	--	--	--	$^{f}\frac{1}{2}$	$^{f}\frac{3}{4}$	>10	$^{f}\frac{3}{4}$ $^{f}1\frac{1}{2}$	--	--	--

	c.g. moved forward $0.49\bar{c}$									c.g. moved back $0.10\bar{c}$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U (a)	N	D (a)	U (a)	N	D (a)	U (b)	N	D (b)
α, deg	--	58	46	58	52	41	32	33	35	--	--	--	--	--	--	--	--	--
ø, deg	--	8U	14U	5U	6U	12U	4U	6U	9U	--	--	--	--	--	--	--	--	--
Ω, rps	0.39	0.38	0.40	0.41	0.39	0.42	0.43	0.42	0.46	--	--	--	--	--	--	--	--	--
V, fps	123	129	135	118	123	141	160	157	160	--	--	--	--	--	---	--	--	--
Turns for Recovery	∞	>5	∞	∞	∞	∞	$>2\frac{1}{2}$	$>4\frac{1}{2}$	∞	--	--	--	--	--	--	--	--	--

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (d)	N (d)	D (d)	U (d)	N (d)	D (d)	U (b)	N	D (b)
α, deg	83	80	68	82	89	78	---	--	---
ø, deg	39D 51U	42D 48U	41D 44U	21D 25U	16D 23U	20D 18U	---	--	---
Ω, rps	0.13	0.14	0.17	0.17	0.13	0.14	---	--	---
V, fps	123	121	121	121	118	121	---	--	---
Turns for Recovery	$>3\frac{1}{2}$	$^{e}1\frac{3}{4}$	>5	$^{e}1$	$^{e}1$	$^{e}\frac{3}{4}$	---	--	---

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[a]Oscillated violently in pitch and roll. Rate of rotation decreased as the violence of the oscillations increased.

[b]Initial rotation stopped. Fuselage remained approximately horizontal.

[c]Initial rotation stopped. Model then began to rotate in opposite direction and oscillated violently in pitch and roll. Rate of rotation decreased as violence of the oscillations increased.

[d]Oscillated in roll.

[e]Fuselage remained approximately horizontal after rotation stopped in number of turns indicated.

[f]Model nosed over into steep dive after rotation stopped in number of turns indicated.

[g]Two types of spin.

[h]Slid around with large radius. Nose approximately 40° below horizontal.

[i]Slid around with large radius. Nose approximately 40° below horizontal. After a few turns nosed over and went into inverted dive.

[j]Initial rotation stopped. Glided forward rapidly with nose approximately 15° below horizontal.

[k]Initial rotation stopped. Model nose over into steep dive.

[l]Glided forward rapidly with nose approximately 15° below horizontal.

SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CURTISS-WRIGHT 24-B AIRPLANE - Concluded

[Unless otherwise indicated steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Flaps down 45°, normal loading									
Ailerons	Against			Neutral				With		
Elevator	U	N	D (d)	U (dg)	U (dg)	N (d)	D (d)	U (b)	N	D (b)
α, deg	90	90	81	84	88	86	84	-	-	-
ϕ, deg	5U	6U	36D 50U	20D 25U	3D 9U	8D 11U	19D 18U	-	-	-
Ω, rps	0.69	0.04	0.22	0.18	0.36	0.15	0.19	-	-	-
V, fps	107	113	123	118	118	116	118	-	-	-
Turns for Recovery	-	---	---	---	---	---	---	-	-	-

	Effect of drooped ailerons and increased aileron area on turn for recovery, normal loading											
Ailerons	Drooped 22°			Drooped 22°, flaps down 45°			Drooped 22°, chord and area doubled			Drooped 22°, chord and area doubled, flaps down 45°		
Elevator	U (b)	N (b)	D (j)	U (d)	N (d)	D (j)	U (j)	N (j)	D (k)	U (d)	N	D (k)
α, deg	---	---	--	75	79	--	---	---	---	-79	83	---
ϕ, deg	---	---	--	16D 12U	21D 17U	--	---	---	---	41D 26U	5U	---
Ω, rps	---	---	--	0.11	0.11	--	---	---	---	0.31	0.27	---
V, fps	---	---	--	116	116	--	---	---	---	107	107	---
Turns for Recovery	---	---	--	[e]$1\frac{1}{4}$	[e]$\frac{1}{2}$	--	---	---	---	[l]$2\frac{3}{4}$	[l]2	---

	Freely rotating propeller installed, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D (a)	U	N (d)	D (d)	U (c)	N (c)	D (b)
α, deg	-	-	-	--	85	80	-	-	-
ϕ, deg	-	-	-	--	36D 31U	28D 25U	-	-	-
Ω, rps	-	-	-	--	0.07	0.10	-	-	-
V, fps	-	-	-	121	121	118	-	-	-
Turns for Recovery	-	-	-	[e]$\frac{1}{2}$	[e]$\frac{1}{2}$	[e]$\frac{1}{2}$	-	-	-

	Modification 1, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D (a)	U	N	D (j)	U	N	D (j)
α, deg	-	-	-	-	-	-	-	-	-
ϕ, deg	-	-	-	-	-	-	-	-	-
Ω, rps	-	-	-	-	-	-	-	-	-
V, fps	-	-	-	-	-	-	-	-	-
Turns for Recovery	-	-	-	-	-	-	-	-	-

	Modification 1, and 2, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D (a)	U	N	D (m)	U	N	D (m)
α, deg	-	-	-	-	-	-	-	-	-
ϕ, deg	-	-	-	-	-	-	-	-	-
Ω, rps	-	-	-	-	-	-	-	-	-
V, fps	-	-	-	-	-	-	-	-	-
Turns for Recovery	-	-	-	-	-	-	-	-	-

	Modification 3, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D (a)	U	N	D (d)	U	N	D (b)
α, deg	-	-	-	-	-	78	-	-	-
ϕ, deg	-	-	-	-	-	12D 9U	-	-	-
Ω, rps	-	-	-	-	-	-	-	-	-
V, fps	-	-	-	-	-	121	-	-	-
Turns for Recovery	-	-	-	-	-	[e]$\frac{3}{4}$	-	-	-

	Modification 4, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D (a)	U	N	D (d)	U	N	D (b)
α, deg	-	-	-	-	-	84	-	-	-
ϕ, deg	-	-	-	-	-	20D 30U	-	-	-
Ω, rps	-	-	-	-	-	-	-	-	-
V, fps	-	-	-	-	-	121	-	-	-
Turns for Recovery	-	-	-	-	-	[e]$\frac{3}{4}$	-	-	-

	Modification 5, spoilers deflected up 90°, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D (a)	U (d)	N (d)	D (b)	U (b)	N	D (b)
α, deg	-	-	-	76	80	-	-	-	-
ϕ, deg	-	-	-	34D 19U	34D 46U	-	-	-	-
Ω, rps	-	-	-	0.08	0.14	-	-	-	-
V, fps	-	-	-	127	129	-	-	-	-
Turns for Recovery	-	-	-	[e]$\frac{3}{4}$	[e]$\frac{1}{2}$	-	-	-	-

	Modification 6, fins and rudders moved to wing tips, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D (a)	U (n)	N (n)	D (n)	U (b)	N (b)	D (b)
α, deg	-	-	-	-	-	-	-	-	-
ϕ, deg	-	-	-	-	-	-	-	-	-
Ω, rps	-	-	-	-	-	-	-	-	-
V, fps	-	-	-	-	-	-	-	-	-
Turns for Recovery	-	-	-	-	-	-	-	-	-

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D (a)	U (b)	N (d)	D (d)	U (b)	N (b)	D (b)
α, deg	-	-	-	-	85	82	-	-	-
ϕ, deg	-	-	-	-	31D 34U	18D 8U	-	-	-
Ω, rps	-	-	-	-	0.07	0.07	-	-	-
V, fps	-	-	-	-	121	121	-	-	-
Turns for Recovery	-	-	-	-	[e,o]$\frac{1}{4}$	[e,o]$\frac{1}{4}$	-	-	-

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[a]Oscillated violently in pitch and roll. Rate of rotation decreased as the violence of the oscillations increased.

[b]Initial rotation stopped. Fuselage remained approximately horizontal.

[c]Initial rotation stopped. Model then began to rotate in opposite direction and oscillated violently in pitch and roll. Rate of rotation decreased as violence of the oscillations increased.

[d]Oscillated in roll.

[e]Fuselage remained approximately horizontal.

[g]Two types of spin.

[j]Initial rotation stopped. Glided forward rapidly with nose approximately 15° below horizontal.

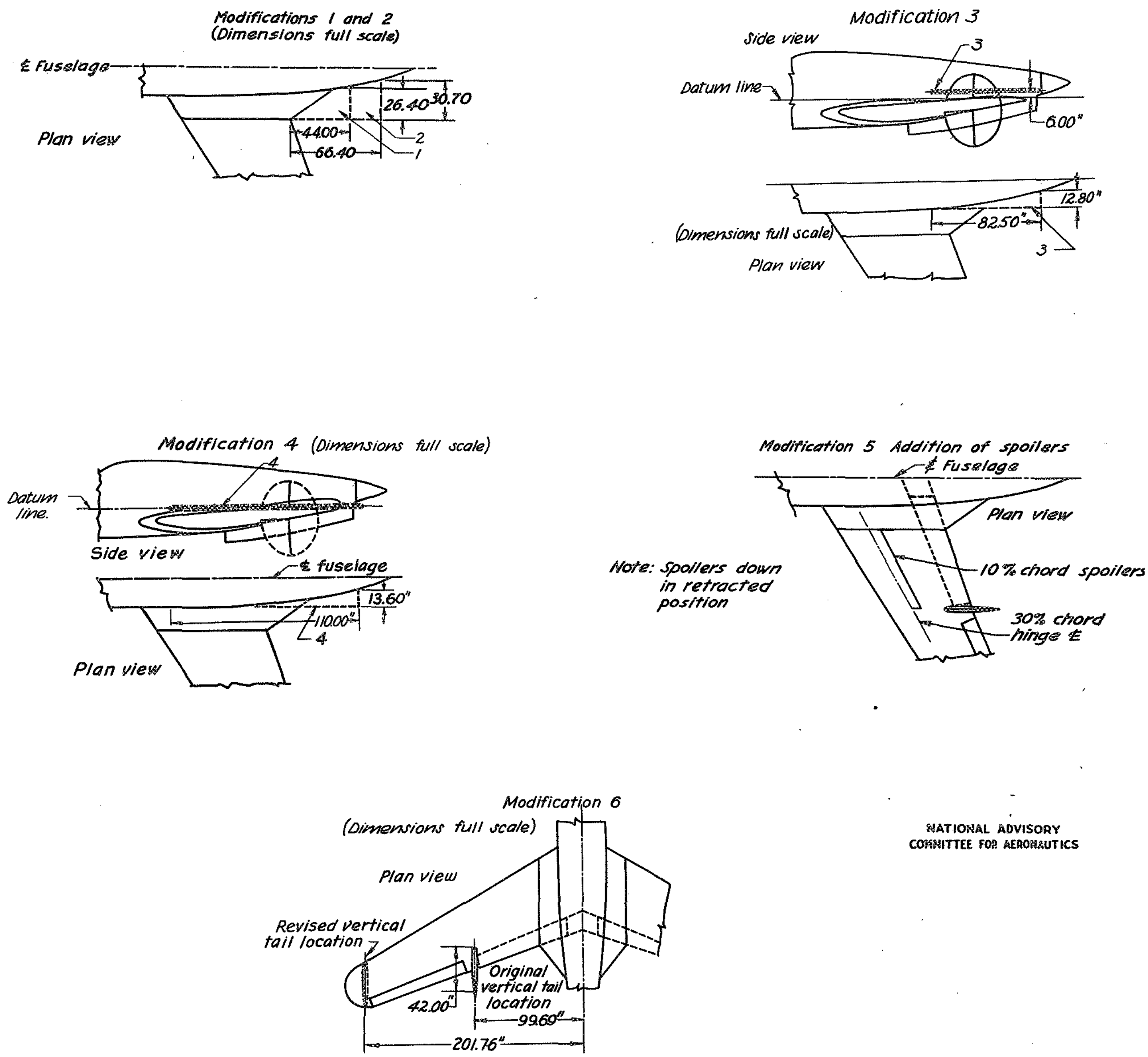
[k]Initial rotation stopped. Model nosed over into steep dive.

[l]Glided forward rapidly with nose approximately 15° below horizontal.

[m]Initial rotation stopped. Glided forward for a few feet 35° below horizontal and then nosed over into a steep dive.

[n]Initial rotation stopped. Glided with slight rotation to right. Fuselage approximately horizontal. Oscillation in roll of approximately ±25°.

[o]Visual observation.

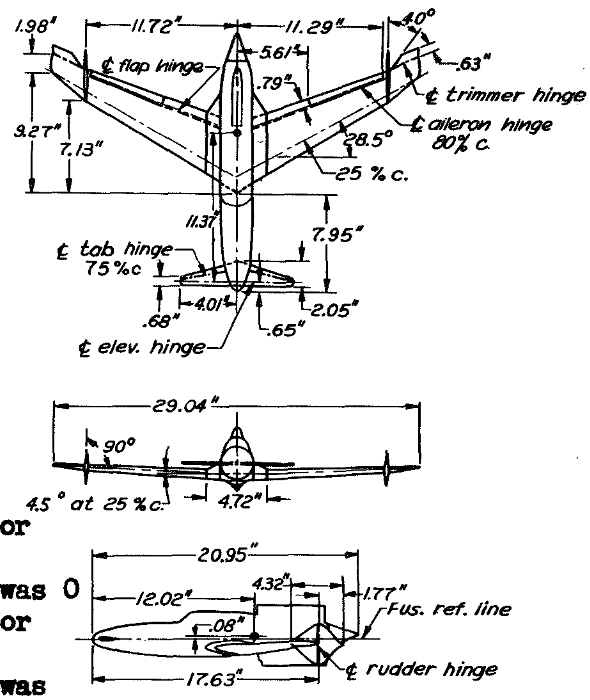

Modifications 1 and 2
(Dimensions full scale)
℄ Fuselage
Plan view
26.40
30.70
44.00
66.40
2
1
Modification 3
Side view
Datum line
3
6.00"
12.80"
82.50"
(Dimensions full scale)
Plan view
3
Modification 4 (Dimensions full scale)
Datum line.
4
Side view
℄ fuselage
13.60"
110.00"
4
Plan view
Modification 5 Addition of spoilers
℄ Fuselage
Plan view
Note: Spoilers down in retracted position
10 % chord spoilers
30% chord hinge ℄
Modification 6
(Dimensions full scale)
Plan view
Revised vertical tail location
42.00"
Original vertical tail location
99.69"
201.76"

0.059-SCALE MODEL OF THE CURTISS-WRIGHT XP-55 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	41.02
L, ft	29.58
$\bar{c}$, in	67.44
S, sq ft.	213.20
A	7.88
L.E. $\bar{c}$ aft L.E. C_r, in. .	62.88
S_h, sq ft	21.52
S_v, sq ft	27.80
S_r, sq ft	13.00
δ_r, deg (right rudder) .	40 R, 11 L
δ_r, deg (left rudder) .	11 R, 40 L
δ_e, deg	60 U, 60 D
Elevator tab deflection (deg) .	25 D when elevator was 60 U 0 when elevator was 0 25 U when elevator was 60 D 0 when elevator was free



Model as tested.

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δ_a, deg
- When flaps were neutral 28U, 9D
- When flaps were 45° down . . . . . 38 U, 1U

δ_f, deg . . . . 45 D

Wing-tip trimmers, deg 0

Extensions of wing-tip trimmers, deg
- When linked with ailerons . . . . 28 U when adjacent aileron was 28 U; 9 D when adjacent aileron was 9 D
- When linked with the elevator . . . . Both 30 D when elevator was 60 U; Both 0 when elevator was 0; Both 30 U when elevator was 60 D
- When linked with the rudders. . . . .
  - Extension of right wing-tip trimmer: 40 U when right rudder was 40 R; 11 D when right rudder was 11 L
  - Extension of left wing-tip trimmer: 11 D when left rudder was 11 R; 40 U when left rudder was 40 L

Mass Data

Normal Loading

W, lb	7717
$x/\bar{c}$	0.118
$z/\bar{c}$	-0.019
I_X, slug-ft^2	4120
I_Y, slug-ft^2	10,896
I_Z, slug-ft^2	14,712
Test altitude, ft	10,000
μ (sea level)	11.52
μ (10,000 ft)	15.61

$\frac{I_X - I_Y}{mb^2}$	-168×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-95×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	263×10^{-4}

Résumé of Model Test Results

The spins of the model for all control cinfigurations and loadings were flat and oscillatory. The spin rotation stopped shortly after rapid full reversal of the rudders for all control configurations. Spins with ailerons set against the rotation were violently oscillatory. With the elevator neutral or full-up the model remained in a flat erect attitude after the rotation stopped. With the elevator full down or free the model went into a steep dive after the rotation stopped.

Moving the center-of-gravity forward $0.08\bar{c}$, retracting mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = -0.30\ I_Y\right)$, deflecting the flaps 45° and extending the landing gear, or linking extensions of the wing-tip trimmers with the elevator increased the rapidity with which the airplane nosed down into a dive after the spin rotation stopped. Moving the center-of-gravity rearward $0.08\bar{c}$ or linking the extensions of the wing-tip trimmers with the rudders or ailerons decreased the tendency of the model to dive after the rotation stopped.

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SPIN DATA OBTAINED WITH THE 0.059-SCALE MODEL OF THE CURTISS-WRIGHT XP-55 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading, right spins												
Ailerons	Against					Neutral				With			
Elevator	U (a)	N (ab)	N (bc)	D (c)	Free	U (d)	N (d)	D (d)	Free (c)	U (d)	N	D (d)	Free (d)
α, deg	90 74	95 59	No spin	No spin	No spin	74	91 71	76 58	73 62	88 62	---	97 66	83 57
ϕ, deg	6U 8D	9U 17D				12U 18D	22U 5D	19U 12D	18U 7D	18U 19D	---	6U 18D	10U 15D
Ω, rps	0.19	0.15				0.19	0.21	0.26	0.20	0.20	0.13	0.21	0.21
V, fps	182	182				182	171	174	171	171	171	171	166
Turns for recovery	[e]3/4	[f]1/2				[e]1	[e]1	[g]1 1/4	[g]1/2	[a]1/2	[f]1/2	[g]1 [g]1 1/2	[h]1 1/2

	Normal loading, left spins													
Ailerons	Against				Neutral				With					
Elevator	U (a)	N (a)	D (c)	Free (c)	U (d)	N (d)	D (c)	Free (c)	U (d)	N (d)	D (bd)	D (bi)	Free (bd)	Free (b)
α, deg	82 54	94 55	No spin	No spin	66 54	86 69	No spin	No spin	73 62	97 64	74 61	---	79 52	No spin
ϕ, deg	10U 6D	2U			9U 12D	13U 15D			12U 12D	19U 24D	10U 7D	---	11U 21D	
Ω, rps	---	0.11			0.13	0.11			0.15	0.09	0.16	---	0.16	
V, fps	179	171			171	171			171	161	171	---	185	
Turns for recovery	[f]1/2	[a]1/2			[e]1/4	[f]1/4			[e]1/4	[e]1/4	[h]1/2 [h]1	---	[f]3/4	

	Wing-tip-trimmer used in conjunction with the ailerons, 1 to 1 deflection ratio between ailerons and the extensions, normal loading						
Ailerons	Against			With			
Elevator	U (c)	D (c)	Free (c)	U (a)	D (ab)	D (bi)	Free (a)
α, deg	No spin	No spin	No spin	94 63	78 59	----	71 56
ϕ, deg				29U 31D	11U 24D	----	2U 16D
Ω, rps				0.17	0.18	----	0.17
V, fps				171	174	----	174
Turns for recovery				[a]1/2	[e]1	----	[e]1/2

	Wing-tip-trimmer extensions used in conjunction with the rudders, 1 to 1 deflection ratio between the rudders and the extensions. Extension moves up as adjacent rudder moves outboard, normal loading											
Ailerons	Against			Neutral				With				
Elevator	U (j)	D (j)	Free (j)	U (j)	N (dk)	D	Free (j)	U (d)	N (d)	D (j)	Free (ab)	Free (bj)
α, deg	No spin	No spin	No spin	No spin	81 71	No spin	No spin	65	88 60	No spin	74 41	No spin
ϕ, deg					1U 43D			12U 11D	38U 13D		2U 14D	
Ω, rps					0.08			0.12	0.12		0.16	
V, fps					171			182	189		198	
Turns for recovery					[e]1/4			[a]3/4	[e]1/2		----	

	Wing-tip-trimmer extensions used in conjunction with the elevator. 2 to 1 deflection ratio between the elevator and the extensions. Trailing edge of extensions moves up as trailing edge of elevator moves down.					
Ailerons	Against		Neutral		With	
Elevator	U (c)	D (c)	U (c)	D (d)	U (d)	D (dl)
α, deg	No spin	No spin	No spin	60 87	92 54	92 53
ϕ, deg				3U 31U	44U 47D	23U 22D
Ω, rps				0.18	0.21	0.18
V, fps				174	189	171
Turns for recovery				[h]1 1/4	[e]1 1/4	[h]3/4

	ΔI_X and $\Delta I_Z = 0.30\ I_X$												
Ailerons	Against				Neutral					With			
Elevator	U (c)	D (b)	D (bd)	Free (m)	U (j)	N (a)	D (m)	Free (bd)	Free (b)	U (d)	D (bd)	D (bd)	Free (dk)
α, deg	No spin	No spin	74 41	No spin	No spin	92 72	No spin	68 52	No spin	71 58	70	75 47	78 58
ϕ, deg			10U 11D			58U 75D		16U 9D		2D 33D	28U 25D	10U 17D	17U 25D
Ω, rps			0.11			0.09		0.18		0.17	0.16	0.15	0.18
V, fps			182			182		182		190	182	177	185
Turns for recovery			----			[e]1/2		[h]1		[e]1/2	[f]3/4	[f]1/2	[n]2 [n]2 1/2

	ΔI_Y and $\Delta I_Z = -0.30\ I_Y$									
Ailerons	Against			Neutral				With		
Elevator	U (a)	D	Free (o)	U (d)	N (a)	D (dl)	Free (dl)	U (d)	D (dl)	Free (o)
α, deg	89 55	No spin	No spin	87 30	96 60	77 56	72 57	73 60	77 60	----
ϕ, deg	50U 25D			38U 38D	56U 67D	22U 31D	13U 7D	20D 41D	32U 20D	----
Ω, rps	0.23			0.20	0.17	0.23	0.24	0.19	0.25	----
V, fps	190			179	183	177	179	174	174	----
Turns for recovery	[a]3/4			[e]1/2	[f]1/2	[h]1	[h]1/2	[e]1/2	[h]1 1/4	----

[a]Model oscillatory in roll and pitch, range of values or average value given.

[b]Two conditions possible.

[c]Model recovered by pitching and or rolling out of the spin. Motion during recovery was extremely violent.

[d]Oscillatory spin; range of values or average value given.

[e]After recovery, model glided forward at a flap attitude for an appreciable distance.

[f]After recovery model glided forward at a flat attitude for a short distance.

[g]After recovery, model glided forward at a flat attitude for a short distance and then nosed down into a steep dive.

[h]After recovery model nosed down into a steep dive.

[i]Model too oscillatory in pitch and roll to test completely.

[j]Model yawed in a circle of extremely large radius at a high angle of attack. Rotational velocity was low.

[k]Wandering spin.

[l]Model oscillates in pitch and wanders; appears to gallop.

[m]Model recovered of its own accord in a wide spiral glide.

[n]Model recovered in a wide spiral glide.

[o]Model went into an inverted spin after a short vertical dive.

[p]High rate of descent. Model executed one violent oscillation in pitch per turn of spin.

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SPIN DATA OBTAINED WITH THE 0.059-SCALE MODEL OF THE CURTISS-WRIGHT XP-55 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	c.g. moved forward $0.077\bar{c}$														
Ailerons	Against					Neutral					With				
Elevator	U (c)	N (c)	D	Free (bd)	Free (b)	U (d)	N (d)	D (d)	Free (bd)	Free (bd)	U (d)	N (bd)	D (bq)	Free (br)	Free (bd)
α, deg	No spin	No spin	No spin	57 41	No spin	73 21	85 48	49 39	73 50	52 37	75 63	84 55	---	76 43	44
φ, deg				22U 0		21U 18D	50U 42D	8U 5D	11U 7D	1U 15D	30U 12D	19U 14D	---	0 14D	13U 6D
Ω, rps				0.18		0.13	0.20	0.19	0.22	0.21	0.20	0.22	---	0.20	0.17
V, fps				204		174	171	203	177	206	177	177	---	182	208
Turns for recovery				----		$e\frac{1}{4}$	$e\frac{1}{2}$	$h\frac{1}{2}$	$h1$	$h1$	$e\frac{3}{4}$	$h1\frac{1}{2}$	---	$h1\frac{1}{4}$	----

	c.g. moved back $0.083\bar{c}$												
Ailerons	Against				Neutral					With			
Elevator	U (a)	N (a)	D (c)	Free (c)	U (d)	N (c)	D (bd)	D (bk)	Free (j)	U (d)	N (d)	D (d)	Free (j)
α, deg	95 47	81 65	No spin	No spin	98 68	No spin	93 64	---	No spin	90 65	98 79	102 61	No spin
φ, deg	61U 48D	35U 64D			38D 48D		42U 47D	---		24U 44D	---	39U 44D	
Ω, rps	0.16	0.17			0.18		0.22	---		0.16	0.13	0.16	
V, fps	193	185			182		185	---		179	182	171	
Turns for recovery	$e\frac{1}{2}$	$e1$			$e1$		$e\frac{3}{4}$	---		$f\frac{3}{4}$	$e1$	$e\frac{1}{2}$	

	Flaps down 45° normal loading						Landing gear extended, normal loading							
Ailerons	Neutral			With			Neutral						With	
Elevator	D (d)	Free (bd)	Free (bs)	U	D (a)	Free (dl)	D (dt)	D (dt)	D (ct)	Free (dt)	Free (dt)	Free (st)	D (d)	Free (d)
α, deg	79 62	82 63	----	----	87 39	87 49	72 57	66 41	----	60 41	50 37	----	61 46	65 52
φ, deg	10U 27D	25U 18D	----	----	9U 9D	3D	15U 10D	11U 8D	----	1D	3U	----	8D	3D
Ω, rps	0.21	0.19	----	----	0.17	0.19	0.20	0.19	----	0.19	0.23	----	0.16	0.16
V, fps	179	179	----	----	179	179	185	198	----	182	201	----	195	193
Turns for recovery	$h1\frac{1}{4}$	$h\frac{3}{4}$	----	----	$h\frac{3}{4}$	$h\frac{3}{4}$	$hu\frac{3}{4}$	$hu\frac{1}{2}$	----	$hu\frac{3}{4}$	----	----	$h\frac{3}{4}$	$h\frac{1}{2}$ $h1$

	Landing condition, normal loading								
Ailerons	Against		Neutral				With		
Elevator	D (i)	Free (d)	U (bs)	U (bd)	N (d)	Free (d)	U (d)	D (d)	Free (d)
α, deg	No spin	66 22	----	65 54	91 69	62 47	69 58	78 58	64 29
φ, deg		16U 2U	----	12U 14D	27U 40D	9U 3D	20U 15D	15U 25D	13U 15D
Ω, rps		0.15	----	0.14	0.09	0.16	0.16	0.16	0.14
V, fps		198	----	176	171	188	179	176	188
Turns for recovery		$h\frac{1}{2}$	----	$e\frac{1}{2}$	$e\frac{1}{4}$	$hu\frac{1}{2}$	$f\frac{1}{4}$	$hu\frac{1}{2}$	$hu\frac{1}{4}$

	Inverted left spins, normal loading											
Ailerons	Against				Neutral				With			
Elevator	U (c)	N (a)	D (c)	Free (a)	U (d)	N (d)	D (c)	Free (d)	U	N (d)	D (c)	Free (d)
α, deg	No spin	111 74	No spin	79 46	75 58	85 66	No spin	90 57	63	86 64	No spin	75 45
φ, deg		28U 40D		4U 18D	15U 11D	16U 29D		25U 18D	6U	12U 6D		12U 10D
Ω, rps		0.18		0.16	0.17	0.10		0.19	0.15	0.13		0.21
V, fps		166		182	176	169		176	174	171		193
Turns for recovery		$e\frac{1}{2}$		$g\frac{1}{2}$	$e\frac{1}{2}$	$f\frac{1}{2}$		$h\frac{1}{2}$	$e\frac{1}{2}$	$e\frac{1}{2}$		$h1\frac{1}{2}$

	Inverted right spins, normal loading														
Ailerons	Against				Neutral						With				
Elevator	U (c)	N (c)	D (c)	Free (c)	U (d)	N (d)	D (it)	D (dt)	D (ct)	Free (d)	U (d)	N (d)	D (bd)	D (bi)	Free (d)
α, deg	No spin	No spin	No spin	No spin	85 69	101 57	----	86 55	No spin	78 47	75 59	78 67	73 51	----	81 68
φ, deg					33U 25D	50U 54D	----	25U 13D		45U 42D	23U 20D	17U 45D	13U 14D	----	17U 15D
Ω, rps					0.13	0.18	----	0.18		0.17	0.15	0.14	0.20	----	0.22
V, fps					176	182	----	174		174	171	167	176	----	176
Turns for recovery					$e\frac{3}{4}$	$f1$	----	$hv\frac{3}{4}$		$h\frac{3}{4}$	$e\frac{1}{2}$	$e\frac{1}{4}$	$h1\frac{1}{2}$	----	$h1$ $h1\frac{1}{2}$

[a]Model oscillatory in roll and pitch, range of values or average value given.

[b]Two conditions possible.

[c]Model recovered by pitching and for rolling out of the spin. Motion during recovery was extremely violent.

[d]Oscillatory spin, range of values or average value given.

[e]After recovery, model glided forward at a flat attitude for an appreciable distance.

[f]After recovery, model glided forward at a flat attitude for a short distance.

[g]After recovery, model glided forward at a flat attitude for a short distance, and then nosed down into a steep dive.

[h]After recovery model nosed down into a steep dive.

[i]Model too oscillatory in pitch and roll to test completely.

[j]Model yawed in a circle of extremely large radius at a high angle of attack. Rotational velocity was low.

[k]Wandering spin.

[l]Model oscillates in pitch and wanders; appears to gallop.

[q]Model oscillatory in pitch and roll, too wandering to test.

[r]Model oscillatory in pitch and appears to gallop; range of values or average value given.

[s]Model spins steeply and smoothly with radius of spin too large to test.

[t]Three conditions possible.

[u]Model pitched into an inverted flap attitude after short vertical dive.

[v]Visual observation.

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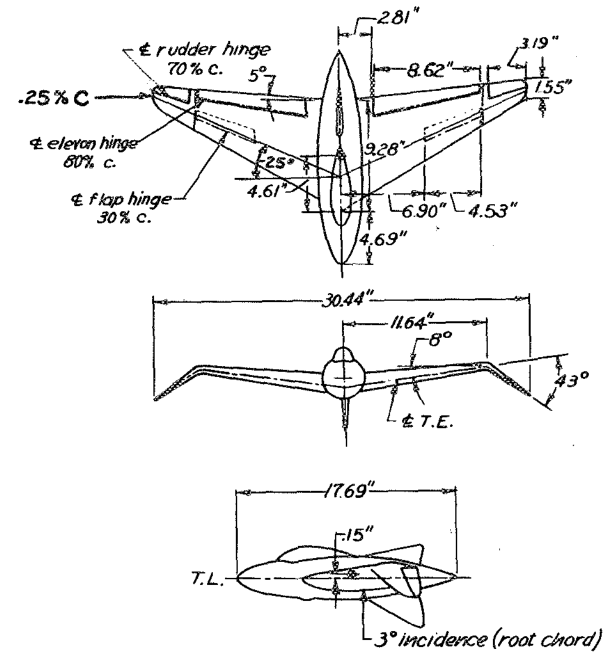
$\frac{1}{16}$-SCALE MODEL OF THE XP-56 AIRPLANE

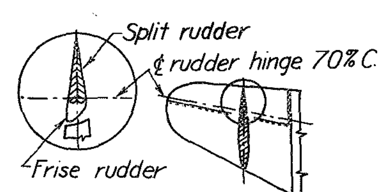


Model as tested.

Dimensional Data

(Full Scale)

b, ft	40.59
L, ft	23.58
c, in.	103.00
S, sq ft	309.32
A	5.33
L.E: $\bar{c}$ aft L.E. c_r, in.	53.80
S_h, sq ft (elevons)	36.06
S_v, sq ft	
Split	29.09
Frise	31.82
S_r, sq ft	
Frise	13.88
Split	11.15
δ_r, deg Frise balanced rudder	90 U, 20 D
δ_r, deg (split rudder)	±60
δ_e, deg (elevons as elev.)	30 U, 20 D
δ_a, deg (elevons as ails.)	30 U, 15 D
δ_f, deg (split)	60 D
Landing gear	Tricycle



Rudder detail

Deflections - Elevons

(a) A forward movement of the stick deflects both elevons 20° down.
(b) An aft movement of the stick deflects both elevons 30° up.
(c) A lateral movement of the stick to the right moves the right elevon 30° up, and the left elevon 15° down.
(d) A lateral movement of the stick to the left moves the left elevon 30° up, and the right elevon 15° down.

The "elevon" deflections due to a lateral movement of the stick are superimposed upon those due to a longitudinal movement.
Pushing right pedal will give one of the following maximum rudder movements:

a. Deflect the right Frise balanced rudder 90° up and the left 20° down.
b. Deflect the right split rudder ±60° with no effect on the left rudder.
c. Deflect the right Frise balanced rudder up 90° and open the right spoilers (on both upper and lower surfaces of the wing) and deflect the left rudder down 20°, the left spoilers remaining closed.

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Mass Data

Normal Loading

	Original	Revised
W, lb	9755	10,194
$x/\bar{c}$	0.179	0.128
$z/\bar{c}$	-0.023	-0.003
I_X, slug-ft^2	8417	9313
I_Y, slug-ft^2	12,417	6834
I_Z, slug-ft^2	20,667	15,635
Test altitude, ft	4000	4000
μ (at sea level)	10.14	10.59
μ' (4000 ft)	12.01	12.62
$\frac{I_X - I_Y}{mb^2}$	-80×10^{-4}	48×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-165×10^{-4}	-165×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	245×10^{-4}	$+117 \times 10^{-4}$

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Résumé of Model Test Results

In the clean condition, for the revised normal loading and normal control configuration for spinning, the model spun at a moderately steep angle of attack and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{4}\text{ turns}\right)$. With the elevons down (elevons as elevators) two conditions were obtained – a spin from which recoveries by rapid full reversal of the rudders was unsatisfactory $\left(2\frac{1}{2}\text{ turns}\right)$ and a no-spin condition.

Setting the elevons as ailerons with the spin caused recoveries from spins to become unsatisfactory. Setting the elevons as ailerons against the spin did not appreciably change the spin characteristics when the elevons (acting also as elevators) were either neutral or up. With the elevons (as elevators) down, recoveries were unsatisfactory (6 turns). Extending or retracting mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = +0.27\ I_X \text{ or } -0.22\ I_X\right)$, retracting mass along the wings $\left(\Delta I_Y \text{ and } \Delta I_Z = -0.18\ I_Y\right)$, or moving the center of gravity forward $0.05\bar{c}$ from its normal position did not appreciably affect the recovery characteristics of the model. Extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.35\ I_Y\right)$ or moving the center of gravity back $0.06\bar{c}$ from its normal position had an adverse effect upon recoveries.

The extension of the landing gear and flaps, individually or jointly, generally improved the recovery characteristics of the model.

Recoveries from inverted spins obtained were generally unsatisfactory by rapid full rudder reversal.

Substitution of a split rudder for the Frise balanced type rudder was detrimental to the recovery characteristics of the model. Removing the small upper fin from the model or using spoilers in conjunction with the Frise balanced rudder had little effect on the spin and recovery characteristics of the model.

With the model in the original loading condition, which differed from the revised loading condition (see mass data) in that a considerably larger proportion of the weight was distributed along the fuselage, spins were generally flatter and more oscillatory and wandering than spins for the revised loading condition; recoveries were also slower with the model ballasted to represent the original loading.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NORTHROP XP-56 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Revised normal loading condition											ΔI_X and ΔI_Z = 0.27 I_X Revised loading condition										ΔI_X and ΔI_Z = -0.22 I_X Revised loading condition										
Elevons as Ailerons	Against			Neutral					With			Against			Neutral				With			Against			Neutral					With		
Elevons as Elevators	U	N	D	U	N (a)	N (a)	D (a)	D (a)	U	N	D (b)	U (bc)	N	D	U	N (d)	N (bd)	D	U	N	D (c)	U	N	D	U (a)	U (a)	N (a)	N (a)	D (c)	U	N	D (b)
α, deg	36	No spin	82	39	---	No spin	49	No spin	76	46	--	----	No spin	79	50	67	----	No spin	76	51	--	No spin	No spin	81	---	No spin	64	No spin	--	77	38	--
∅, deg	2D		0	4D	---		2D		0	3D	--	----		0	1D	1U	----		0	5D	--			1D	---		1D		--	2D	8D	--
Ω, rps	0.40		0.92	0.40	---		0.54		0.70	0.55	--	----		0.76	0.35	0.56	----		0.64	0.40	--			0.89	0.41		0.61		--	0.72	0.51	--
V, fps	220		135	224	173		191		162	205	--	----		140	215	165	----		160	198	--			136	220		165		--	160	202	--
Turns for recovery	$\frac{3}{4}$ $1\frac{1}{4}$		6	$1\frac{1}{4}$	$1\frac{1}{4}$		$2\frac{1}{2}$		4	$2\frac{3}{4}$ 2		1		$4\frac{1}{2}$	$1\frac{1}{2}$	2			5	$1\frac{3}{4}$				6	$1\frac{1}{4}$		2		—	5	1	--

	ΔI_Y and ΔI_Z = 0.35 I_Y Revised loading condition									ΔI_Y and ΔI_Z = -0.18 I_Y Revised loading condition									c.g. moved forward 0.05$\bar{c}$ Revised loading condition								
Elevons as Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevons as Elevators	U	N	D	U	N	D	U	N	D (c)	U	N	D	U	N	D	U	N	D (c)	U	N	D	U	N	D	U	N	D (c)
α, deg	40	73	83	62	----	73	82	51	--	No spin	No spin	84	54	No spin	No spin	80	53	--	No spin	65	80	38	No spin	No spin	75	49	---
∅, deg	10D	0	0	2D	----	0	1D	8D	--			1D	0			1D	5D	--		1U	1D	1D			1D	5D	---
Ω, rps	0.54	0.72	1.00	0.57	----	0.71	0.89	0.47	--			1.04	0.44			0.79	0.57	--		0.64	0.88	0.39			0.74	0.49	---
V, fps	231	162	133	202	180	173	162	187	--			133	209			151	182	--		162	125	215			155	189	---
Turns for recovery	----	$5\frac{1}{2}$	----	$1\frac{1}{2}$	3	$>3\frac{3}{4}$	5	----	--			----	----			----	----	--		----	----	----			----	----	---

	c.g. moved back 0.06$\bar{c}$ Revised loading condition									Flaps down 60° Revised normal loading condition									Landing gear extended Revised normal loading condition									Landing condition Revised normal loading condition								
Elevons as Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevons as Elevators	U (b)	N	D	U	N	D	U	N	D (b)	U	N	D	U (c)	N	D	U	N	D	U	N	D	U	N	D	U	N	D (b)	U	N	D	U	N	D	U	N	D (b)
α, deg	--	--	83	59	74	67	80	59	--	--	--	No spin	--	No spin	No spin	75	---	--	No spin	No spin	79	No spin	No spin	No spin	78	-	--	No spin	No spin	No spin	No spin	No spin	No spin	74	41	--
∅, deg	--	--	1D	3D	1D	2D	2D	7D	--	--	--		--			0	---	--			0				1D	-	--							4D	6D	--
Ω, rps	--	--	0.84	0.34	0.64	0.56	0.72	0.45	--	--	--		--			0.72	---	--			0.77				0.72	-	--							0.62	0.48	--
V, fps	--	--	122	182	153	162	153	178	--	--	--		--			158	---	--			147				158	-	--							169	205	--
Turns for recovery	--	--	--	$2\frac{1}{2}$	3	---	--	----	--	--	--		--			----	---	--			---				---	-	--							$2\frac{1}{2}$	$1\frac{1}{2}$	--

	Inverted spins Revised normal loading conditions									Effect of split rudders right rudder 60°, left rudder 0° Revised normal loading condition										Original normal loading condition								
Elevons as Ailerons	Against			Neutral			With			Against			Neutral				With			Against			Neutral			With		
Elevons as Elevators	U	N	D	U	N (b)	D	U	N	D (b)	U	N	D	U (a)	U (a)	N	D	U	N	D	U	N	D	U (bg)	N (g)	D (g)	U	N (b)	D (b)
α, deg	No spin	No spin	76	47	42	52	70	55	---	No spin	No spin	---	No spin	69	65	71	78	67	No spin	No spin	---	81	45	---	-----	81	--	--
∅, deg			5U	2U	1U	5U	5U	4U	---			---		1U	1D	0	0	1D			---	0	6D	---	-----	1D	--	--
Ω, rps			0.72	0.36	0.42	0.49	0.59	0.47	---			---		0.55	0.64	0.71	0.78	0.58			---	0.56	0.24	---	-----	0.55	--	--
V, fps			158	227	235	173	175	193	---			136		184	162	162	158	162			173	134	200	---	-----	158	--	--
Turns for recovery			----	[e]---	[e]---	2	∞	[f]---	---			∞		[e]---	3	4	$5\frac{1}{2}$	[e]---			3 $5\frac{1}{2}$	∞	---	$>2\frac{1}{2}$	-----	$5\frac{1}{2}$ $2\frac{1}{2}$ 3	--	--

	Rudder neutral spins Original normal loading condition									Type A spoiler deflected ±60° Original normal loading condition								
Elevons as Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevons as Elevators	U	N	D	U	N	D (c)	U	N (c)	D (c)	U	N (gj)	D	U (bg)	N (bg)	D (bg)	U	N (c)	D (c)
α, deg	No spin	----	67	No spin	No spin	-----	71	---	--	No spin	----	----	----	----	----	----	--	--
∅, deg		----	1D			-----	4U	---	--		----	----	----	----	----	----	--	--
Ω, rps		----	0.47			-----	0.43	---	--		----	----	----	----	----	0.49	--	--
V, fps		218	173			-----	184	---	--		----	134	----	----	----	156	--	--
Turns for recovery		----	----			-----	----	---	--		----	----	----	----	----	----	--	--

[a]Two conditions possible.
[b]Model oscillatory in pitch.
[c]Steep spin, high rate of descent.
[d]Two types of spin.
[e]Model went into steep rapid spin after rudder reversal.
[f]Model went into spin that was oscillatory in pitch, rotation, and rate of descent after rudder reversal.
[g]Wandering spin.
[h]Recovery attempted by reversal of rudders, and movement of the stick from positions indicated to against the spin laterally and back longitudinally.
[i]Recovery attempted by lateral movement of stick alone from positions indicated to against the spin.
[j]Flat spin.

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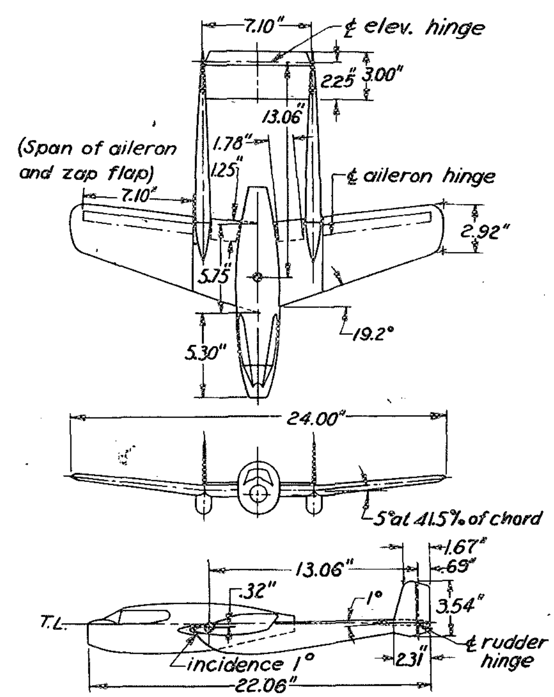
$\frac{1}{20}$-SCALE MODEL OF THE BELL XP-59 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	40.00
L, ft	36.77
$\bar{c}$, in.	90.16
S, sq ft	286.00
A	5.60
L.E. $\bar{c}$ aft L.E. c_r, in.	36.82
S_h, sq ft	59.00
S_e, sq ft (inc. bal.)	13.80
S_v, sq ft	35.00
S_r, sq ft (inc. bal.)	10.80
δ_r, deg	20 R, 20 L
δ_e, deg	25 U, 20 D
δ_a, deg (spoiler-type aileron)	35 U, 0
Outboard Zap flaps	
δ_f, percent, landing cond.	100
δ_f, percent, take-off cond.	50
Split flaps (inboard of booms)	
δ_f, deg, landing cond.	45 D
δ_f, deg, take-off cond.	22.5 D
TDPF	1575×10^{-6}
Landing gear	Tricycle



Model as tested.

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Mass Data

Normal Loading

W, lb	11,197
$x/\bar{c}$	0.275
$z/\bar{c}$	0.070
I_X, slug-ft^2	6330
I_Y, slug-ft^2	8320
I_Z, slug-ft^2	14,000
Test altitude, ft	10,000
μ (at sea level)	12.80
μ' (10,000 ft)	17.35

$\frac{I_X - I_Y}{mb^2}$	-36×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-101×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	137×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model spun very steeply ($\alpha = 16^{\circ}$) and recoveries were very satisfactory by rapid full rudder reversal, elevator reversal, or simultaneous reversal of rudder and elevator. With the elevator either neutral or down the model would not spin. Setting the ailerons either with or against the spin had little effect on the model's recovery characteristics.

Extending mass along the wings or fuselage (ΔI_X and $\Delta I_Z = 0.40\ I_X$ or ΔI_Y and $\Delta I_Z = 0.30\ I_Y$), or moving the center of gravity forward $0.08\bar{c}$ or back $0.10\bar{c}$ from its normal position had no appreciable effect upon the recovery characteristics of the model.

The steady-spin and recovery characteristics of the model in the landing condition (flaps extended 100 percent and landing gear extended) with mass extended along the wings (ΔI_X and $\Delta I_Z = 0.43\ I_X$) or in the take-off condition (flaps extended 50 percent and landing gear extended) with mass extended along the wings (ΔI_X and $\Delta I_Z = 0.32\ I_X$) were very similar to the recovery characteristics of the model in the clean condition, normal loading.

An alternate wing center section with a reflex trailing edge had little effect upon the recovery characteristics of the model.

The model would spin inverted only when the controls were crossed and the elevator was up. Results indicate that recovery would be satisfactory by rapid full rudder reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL XP-59 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N (a)	D
α, deg	17	No spin	No spin	18	No spin	No spin	16	--	No spin
ϕ, deg	5U			5U			4U	--	
Ω, rps	0.56			0.56			0.46	--	
V, fps	389			389			389	>410	
Turns for recovery	$\frac{1}{2}$			$\frac{1}{2}$			$\frac{1}{4}$	--	

Recoveries attempted by different control manipulations from elevator up spins, normal loading.		
Recovery by	Ailerons	Turns for recovery
Simultaneous reversal of rudders and elevator	Against	$\frac{1}{4}$
	Neutral	$\frac{1}{4}$
	With	$\frac{1}{4}$
Neutralization of rudders	Against	>4
	Neutral	3, 8, [b]>5
	With	$1\frac{1}{2}$, 3
Elevator reversal	Against	$\frac{3}{4}$
	Neutral	$\frac{1}{2}$
	With	$\frac{1}{2}$

	ΔI_X and $\Delta I_Z = 0.40\ I_X$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N (a)	D
α, deg	----	No spin	No spin	21	No spin	No spin	18	----	No spin
ϕ, deg	----			3U			2U	----	
Ω, rps	0.39			0.56			0.47	----	
V, fps	403			374			403	>410	
Turns for recovery	$\frac{1}{4}$			$\frac{1}{2}$			$\frac{1}{2}$	----	

	ΔI_Y and $\Delta I_Z = 0.30\ I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	---	---	24	22	20	22	17	20	24
ϕ, deg	---	---	17U	4U	4U	13U	1U	3U	13U
Ω, rps	---	---	0.72	0.53	0.78	0.78	0.64	0.69	0.79
V, fps	396	360	298	364	371	311	410	403	324
Turns for recovery	---	---	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	1

	c.g. moved forward 0.08$\bar{c}$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N (a)	D
α, deg	No spin	No spin	No spin	18	No spin	No spin	----	---	No spin
ϕ, deg				6U			----	---	
Ω, rps				0.59			----	---	
V, fps				389			>410	>410	
Turns for recovery				$\frac{1}{4}$			----	---	

	c.g. moved back 0.10$\bar{c}$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N (a)	D	U	N (a)	D (a)
α, deg	20	No spin	No spin	19	-----	No spin	20	---	---
ϕ, deg	4U			2U	-----		3U	---	---
Ω, rps	0.36			0.40	-----		0.43	---	---
V, fps	396			367	>410		389	>410	>410
Turns for recovery	$\frac{1}{4}$			$\frac{1}{4}$	-----		---	---	---

	Landing condition (ΔI_X and $\Delta I_Z = 0.43\ I_X$)								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (c)	N	D	U (c)	N (a)	D (a)
α, deg	No spin	No spin	No spin	---	No spin	No spin	--	--	---
ϕ, deg				---			--	--	---
Ω, rps				---			--	--	---
V, fps				---			--	>410	>410
Turns for recovery				---			--	--	---

	Take off condition (ΔI_X and $\Delta I_Z = 0.32\ I_X$)								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N (a)	D (a)
α, deg	No spin	No spin	No spin	20	No spin	No spin	17	---	---
ϕ, deg				2U			3U	---	---
Ω, rps				0.60			0.42	---	---
V, fps				284			319	>410	>410
Turns for recovery				1			1 $1\frac{1}{2}$	---	---

	Alternate wing center section with reflex trailing edge Normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (c)	N	D	U	N	D	U (c)	N (a)	D
α, deg	--	No spin	No spin	18	No spin	No spin	---	----	No spin
ϕ, deg	--			3U			---	----	
Ω, rps	--			0.46			---	----	
V, fps	--			396			---	>410	
Turns for recovery	---			$\frac{1}{2}$			---	----	

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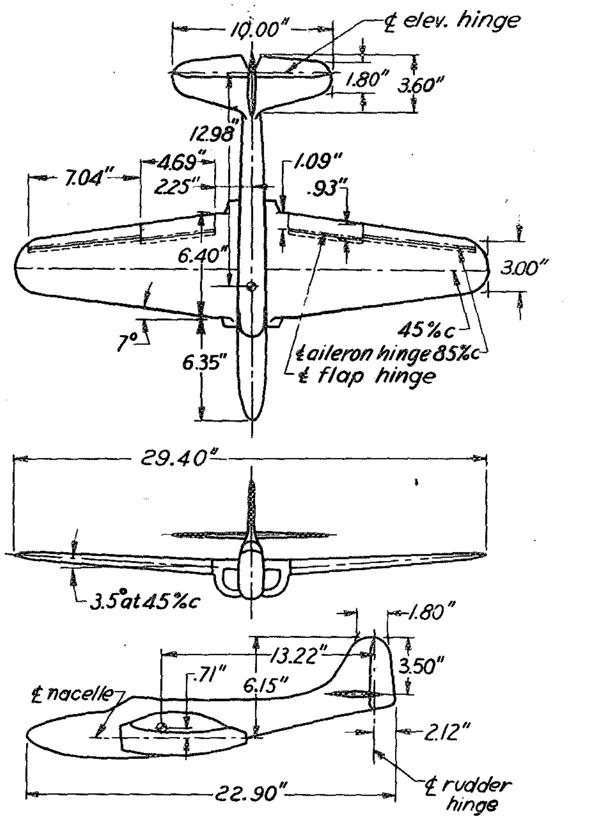
[a]Vertical velocity too high to test.
[b]Recovery attempted by releasing rudder.
[c]Large radius of spin, too oscillatory to test.

$\frac{1}{20}$-SCALE MODEL OF THE BELL YP-59A AIRPLANE

Dimensional Data

(Full Scale)

b, ft	49.00
L, ft	38.17
$\bar{c}$, in	104.70
S, sq ft	400.00
A	6.00
L.E. $\bar{c}$ aft L.E. C_r, in.	10.81
S_h, sq ft	71.22
S_e, sq ft	25.60
S_v, sq ft	32.14
S_r, sq ft	14.69
δ_r, deg	±25 R, 25 L
δ_e, deg	±25 U, 15 D
δ_a, deg	±25 U, 10 D
δ_a, deg (alternate)	±13 U, 13 D
δ_f, deg	45 D
TDPF	91.3×10^{-6}
Landing gear	Retractable



Model as tested.

Mass Data

	Normal Loading	Alternate Armament Loading
W, lb	10256	10515
$x/\bar{c}$	0.274	0.279
$z/\bar{c}$	-0.135	-0.136
I_X, slug ft^2	14143	13872
I_Y, slug ft^2	9912	11248
I_Z, slug ft^2	23181	24150
μ (at sea level)	6.83	7.02
μ' (20,000')	12.83	13.15
$\frac{I_X - I_Y}{mb^2}$	55×10^{-4}	33×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-173×10^{-4}	-164×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	118×10^{-4}	131×10^{-4}
Test altitude, ft	20,000	20,000

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Résumé of Model Test Results

For the normal loading, clean condition recoveries by rapid full rudder reversal were generally unsatisfactory except when the ailerons were set against the spin. The results indicated that simultaneous reversal of the rudder and elevator from elevator-up spins gave the most rapid recoveries.

Extending the mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$) or retracting the mass along the fuselage (ΔI_Y and $\Delta I_Z = -0.22\ I_Y$) had a beneficial effect on the recovery characteristics of the model. For these loadings, recoveries from spins by rudder reversal alone were unsatisfactory only when the ailerons were set full with the spin. Retracting the mass along the wings (ΔI_X and $\Delta I_Z = -0.30\ I_X$) or extending the mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.25\ I_Y$) had an adverse effect in that recoveries from the aileron-against spins were retarded. There was little effect on the aileron-neutral or aileron-with spins.

A $0.05\bar{c}$ forward or $0.10\bar{c}$ rearward movement of the center of gravity from its normal position had no appreciable effect on the recovery characteristics of the model.

For the landing condition (flaps down 45°, landing gear extended) the recovery characteristics of the model were similar to those obtained for the clean condition.

Recoveries by rapid full rudder reversal from all inverted spins obtained were satisfactory.

Replacing the original tail surfaces with alternate tail surfaces (modification 1) had little effect on the recovery characteristics of the model.

Modifying the tips of the wing, the horizontal tail and the vertical tail (square wing tips installed) (modifications 2 and 3) had little effect on the recovery characteristics of the model in the normal loading, clean condition, for erect or inverted spins.

All tests conducted from this point on were made with modifications 2 and 3 incorporated in the model design. The addition of a ventral fin to the fuselage and addition of area to the bottom of the rudder of the model (modification 4) improved the recovery characteristics, although recoveries from aileron-with spins were still unsatisfactory for the normal-loading condition and with the mass retracted along the wings (ΔI_X and $\Delta I_Z = -0.30\ I_X$).

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Moving the horizontal tail 19 inches up and 4 inches rearward (modification 5) had a beneficial effect on the recovery characteristics of the model for erect spins but impaired the recoveries from inverted spins.

For the armament loading condition (ΔI_X and $\Delta I_Z = -0.30\ I_X$) the model would not recover satisfactorily for any control setting. Decreasing the vertical fin chord 10 inches, full scale (modification 6) had a beneficial effect on the recovery characteristics of the model from erect spins whereas from inverted spins there was little effect.

The addition of wing tanks (see sketch) retarded recovery by rudder reversal. Test results (data not presented) indicated that the effect was due to a ballast change (increase in mass along the wings) and not due to the aerodynamic effect of the wing tanks.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL YP-59A AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Ailerons	Against Full			Against 1/3	Neutral					With 1/3				With Full		
Elevators	U (a)	N	D	D	U (b)	N (c)	N (c)	D (c)	D (c)	U (d)	$\frac{2}{3}$U (de)	D (cd)	D (c)	U	N	D
α, deg	-	No spin	No spin	No spin	-	50	No spin	53	No spin	25	53	47	No spin	53	53	54
φ, deg	-				-	2U		2U		1D	0	1U		3D	2D	0
Ω, rps	-				-	0.49		0.50		0.44	0.43	0.43		0.42	0.48	0.50
V, fps	-				-	182		185		226	197	188		191	182	179
Turns for recovery	-				-	$4\frac{3}{4}$; $5\frac{1}{2}$		[f]$4\frac{3}{4}$; [f]$3\frac{3}{4}$		[g]>3; [h]1; [h]$4\frac{1}{2}$; [h]∞; [i]$\frac{1}{2}$; [i]2; [j]2; [j]>5	[g]8; [i]$1\frac{3}{4}$; [i]$2\frac{1}{4}$	6; ∞		∞	∞	∞

ΔI_X and ΔI_Z = 0.20 I_X

Ailerons	Against			Neutral			With 1/3	With Full		
Elevators	U (a)	N	D	U (b)	N	D	$\frac{2}{3}$U (d)	U	N	D
α, deg	-	No spin	No spin	-	No spin	No spin	44	57	57	56
φ, deg	-			-			0	2D	0	1U
Ω, rps	-			-			0.43	0.42	0.48	0.51
V, fps	-			-			240	188	185	185
Turns for recovery	-			-			[i]$1\frac{3}{4}$; [i]2	∞	-	∞

ΔI_X and ΔI_Z = -0.30 I_X

Ailerons	Against			Neutral			With 1/3	With Full		
Elevator	U (a)	N	D	U	N	D	$\frac{2}{3}$U	U (k)	N	D
α, deg	-	52	56	21	54	53	22	30	48	53
φ, deg	-	5U	4U	1U	2U	2U	4D	4D	2D	1D
Ω, rps	-	0.43	0.44	0.57	0.44	0.44	0.62	-	0.44	0.44
V, fps	-	170	166	248	166	166	242	238	163	163
Turns for recovery	-	4	[l]5; [l]8	$1\frac{1}{2}$	[l]$6\frac{1}{2}$	[l]7; [l]∞	[i]$\frac{1}{2}$; [i]1	>3	∞	∞

ΔI_Y and ΔI_Z = 0.25 I_Y

Ailerons	Against			Neutral			With 1/3	With Full		
Elevator	U (a)	N (e)	D (e)	U (d)	N (e)	D (e)	$\frac{2}{3}$U (e)	U (k)	N	D
α, deg	-	57	53	25	59	51	38	42	56	53
φ, deg	-	4U	4U	2D	1U	1U	1D	3D	2D	2D
Ω, rps	-	0.42	0.43	-	0.43	0.44	0.37	-	0.42	0.45
V, fps	-	179	182	260	170	182	200	221	188	182
Turns for recovery	-	$3\frac{3}{4}$	[f]$3\frac{1}{4}$; [f]$5\frac{1}{2}$	>3	>7	[f]$4\frac{3}{4}$; [f]$7\frac{1}{4}$	[i]$1\frac{1}{4}$; [i]$1\frac{3}{4}$	∞	∞	∞

ΔI_Y and ΔI_Z = -0.22 I_Y

Ailerons	Against			Neutral			With 1/3	With Full				
Elevator	U (a)	N	D	U (b)	N	D	$\frac{2}{3}$U (b)	U	N (c)	N (c)	D (c)	D (c)
α, deg	-	No spin	No spin	-	No spin	No spin	-	54	No spin	50	50	No spin
φ, deg	-			-			-	2D		0	0	
Ω, rps	-			-			-	0.45		0.54	0.55	
V, fps	-			-			-	188		182	182	
Turns for recovery	-			-			-	∞		∞	∞	

c.g. moved forward 0.05$\bar{c}$

Ailerons	Against			Neutral					With		
Elevators	U (a)	N	D	U (b)	N (c)	N (c)	D (c)	D (c)	U	N	D
α, deg	-	No spin	No spin	-	No spin	49	49	No spin	55	56	54
φ, deg	-			-		3U	2U		2D	1D	1D
Ω, rps	-			-		0.51	0.52		0.44	0.51	0.52
V, fps	-			-		185	188		188	185	182
Turns for recovery	-			-		$3\frac{1}{2}$; $4\frac{1}{2}$	[f]2; [f]$2\frac{1}{2}$		∞	∞	∞

c.g. moved back 0.10$\bar{c}$

Ailerons	Against			Neutral				With		
Elevators	U (a)	N	D	U (b)	N	D (c)	D (c)	U (k)	N	D
α, deg	-	No spin	No spin	-	55	58	No spin	51	57	55
φ, deg	-			-	0	1U		4D	2D	2D
Ω, rps	-			-	0.43	0.45		-	0.43	0.44
V, fps	-			-	185	176		188	185	185
Turns for recovery	-			-	4	[f]5		∞	∞	∞

Landing condition, normal loading

Ailerons	Against			Neutral					With		
Elevators	U (a)	N	D	U (d)	N (c)	N (c)	D (c)	D (c)	U (d)	N	D
α, deg	-	No spin	No spin	25	46	No spin	55	No spin	45	53	53
φ, deg	-			5D	2U		1U		3D	1D	0
Ω, rps	-			0.47	0.48		0.49		0.40	0.48	0.49
V, fps	-			252	182		182		188	182	182
Turns for recovery	-			>4	5		[f]$5\frac{1}{2}$; [f]$7\frac{1}{2}$		∞	∞	∞

[a]Large spin radius, velocity too high to test, recovery by rapid full rudder reversal, probably rapid.
[b]Velocity too high and spin too oscillatory to test.
[c]Two conditions possible.
[d]Oscillatory spin.
[e]Steeper spin also obtainable.
[f]Model goes into inverted flight after recovery from right spin.
[g]Recovery attempted by reversing the rudder from full with to 2/3 against.
[h]Recovery attempted by moving the elevator to 2/3 full down, rudder remaining with the spin.
[i]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and moving the elevator to 2/3 full down; model goes into inverted spin after recovery from erect spin.
[j]Recovery attempted by simultaneous neutralization of rudder and elevator.
[k]Very oscillatory and wandering spin.
[l]Visual observation.
[m]Recovery attempted by neutralizing the rudder
[n]Oscillatory spin also obtained.
[o]Steep spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE BELL YP-59A AIRPLANE - Continued

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevators	U	N	D	U (a)	N	D	U	N	D
α, deg	No spin	No spin	No spin	-	No spin	No spin	39	39	No spin
ϕ, deg				-			5U	5U	
Ω, rps				-			0.50	0.54	
V, fps				-			229	220	
Turns for recovery				-			2; 2½; [m]∞	1; [m]>6	

	Modification 1, normal loading									
Ailerons	Against			Neutral				With		
Elevators	U (a)	N	D	U (b)	N	D (c)	D (c)	U (n)	N	D
α, deg	-	No spin	No spin	-	54	52	No spin	60	59	57
ϕ, deg	-			-	1U	2U		3D	1D	1D
Ω, rps	-			-	0.49	0.51		0.43	0.49	0.51
V, fps	-			-	182	182		188	182	179
Turns for recovery	-			-	3; 4	[f]3½; [f]6¾		∞	∞	∞

	Modification 2, normal loading									
Ailerons	Against			Neutral				With		
Elevators	U (o)	N	D	U	N (e)	D (c)	D (c)	U (d)	N	D
α, deg	-	No spin	No spin	20	41	46	No spin	20; 39	48	47
ϕ, deg	-			6D	1U	2U		2U; 11D	4D	3D
Ω, rps	-			-	0.43	0.47			0.44	0.47
V, fps	>374			339	219	210		176; 339	194	207
Turns for recovery	-			>6	>3	3½		>5	∞	∞

	Modification 2, inverted spins, normal loading								
Ailerons	Against 13°U, 13°D			Neutral			With 13°U, 13°D		
Elevators	U	N	D	U	N	D	U (K)	N	D
α, deg	No spin	No spin	No spin	30	No spin	No spin	29; 40	39	35
ϕ, deg				4U			14D; 4U	3U	3U
, rps				0.46			-	0.52	0.56
V, fps				284			258	242	252
Turns for recovery				1			3½	1½; 2	1½

	Modifications 2 and 4, normal loading														
Ailerons	Against						Neutral			With					
	25°U, 10°D			13°U, 13°D						13°U, 13°D			25°U, 10°D		
Elevators	U	N	D	U (p)	N (p)	D (p)	U	N	D	U (p)	N (p)	D (p)	U (d)	N	D
α, deg	-	No spin	No spin	-	No spin	No spin	22	-	No spin	54	55	51	34; 43	52	52
ϕ, deg	-			-			1U	-		2D	1D	0	2U; 7D	2D	0
, rps	-			-			-	-		0.42	0.47	0.50	0.39	0.48	0.49
V, fps	>360			>375			346	>360		220	200	204	272	220	216
Turns for recovery	[q]1			[q]1; [q]1½			3; [r]1¾	[q]2½		∞	3; 3½	3½	∞	>4½	[f]3½

	Modifications 2 and 4, ΔI_X and $\Delta I_Z = -0.30 I_X$																
Ailerons	Against							Neutral				With					
	25°U, 10°D			13°U, 13°D								13°U, 13°D			25°U, 10°D		
Elevators	U (d)	N	D	U (p)	N (cp)	N (cp)	D (cp)	D (cp)	U	N (e)	D (c)	D (c)	U (dp)	N (p)	D (p)	U	N	D
α, deg	-	No spin	No spin	-	51	No spin	49	No spin	17	46	45	No spin	33; 52	48	46	-	50	51
ϕ, deg	-			-	4U		5U		4D	2U	2U		0; 8D	2D	4D	-	3D	1D
, rps	-			-	0.42		0.45		0.52	0.45	0.45		-	0.43	0.45	-	0.42	0.43
V, fps	>339			>346	195		195		332	198	198		239; 339	192	188	-	195	195
Turns for recovery	-			1	2		2½		[l]4	[l]3	1½; 2½		[q]>5	6	[l]9	-	3; 4	∞

	Modifications 2 and 5, normal loading								
Ailerons	Against 13°U, 13°D			Neutral			With 13°U, 13°D		
Elevators	U	N	D	U	N	D	U	N	D (d)
α, deg	-	No spin	No spin	-	No spin	No spin	-	47	39; 56
ϕ, deg	-			-			-	1D	3U; 5D
, rps	-			-			-	0.46	0.48
V, fps	-			-			-	212	219
Turns for recovery	-			-			-	3¾	3; 4

[a]Large spin radius, velocity too high to test, recovery by rapid full rudder reversal, probably rapid.
[b]Velocity too high and spin too oscillatory to test.
[c]Two conditions possible.
[d]Oscillatory spin.
[e]Steeper spin also obtainable.
[f]Model goes into inverted flight after recovery from right spin.
[g]Recovery attempted by reversing the rudder from full with to 2/3 against.
[h]Recovery attempted by moving the elevator to 2/3 full down, rudder remaining with the spin.
[i]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and moving the elevator to 2/3 full down; model goes into inverted spin after recovery from erect spin.
[j]Recovery attempted by simultaneous neutralization of rudder and elevator.
[k]Very oscillatory and wandering spin.
[l]Visual observation.
[m]Recovery attempted by neutralizing the rudder
[n]Oscillatory spin also obtained.
[o]Steep spin.
[p]Modification 3.
[q]Recovery attempted before final steep attitude was attained.
[r]Recovery attempted by full simultaneous reversal of rudder and elevator.

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SPIN DATA OBTAINED WITH THE 1/20-SCALE MODEL OF THE YP-59A AIRPLANE (CONCLUDED)

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Modifications 2 and 5, ΔI_X and $\Delta I_Z = -0.30 I_X$

Ailerons	Against 13°U, 13°D				Neutral			With 13°U, 13°D		
Elevators	U	N	D (c)	D (c)	U	N	D	U	N	D
α, deg	18	No spin	33	No spin	25	49	45	40	44	43
ϕ, deg	2U		8U		2D	2U	4U	2D	1D	1D
Ω, rps	0.43		0.56		0.50	0.42	0.45	0.36	0.45	0.45
V, fps	311		252		264	194	197	219	201	204
Turns for recovery	1$\frac{1}{4}$		[f,l]2$\frac{1}{4}$		>3$\frac{1}{2}$	2$\frac{1}{2}$	[f]2 [f]3	>3$\frac{1}{2}$	3$\frac{1}{4}$	[f]3$\frac{3}{4}$

Modifications 2 and 5, inverted spins, normal loading

Ailerons	Against 13°U 13°D			Neutral			With 13°U, 13°D		
Elevators	U	N	D	U	N	D	U (d)	N	D (c)
α, deg	No spin	No spin	No spin	32	35	No spin	24 44	31	-
ϕ, deg				3U	2U		14U 8D	3U	-
Ω, rps				0.44	0.49		-	0.52	-
V, fps				271	257		271 319	271	226
Turns for recovery				3	2$\frac{1}{2}$ 3$\frac{1}{2}$		>4$\frac{3}{4}$	∞	[l]4$\frac{1}{2}$

Modification 2, alternate armament loading

Ailerons	Against 13°U, 13°D			Neutral			With 13°U, 13°D	
Elevators	D (c)	U	D	U	N	D	U	D
α, deg	No spin	63	56	64	54	46	61	61
ϕ, deg		0	3D	0	1U	1U	2U	2U
Ω, rps		0.44	0.47	0.42	0.45	0.47	0.40	0.44
V, fps		194	191	204	191	213	207	191
Turns for recovery		5$\frac{1}{2}$	5 7$\frac{1}{2}$	>8	5$\frac{1}{4}$	5$\frac{1}{2}$	4$\frac{1}{4}$	∞

Modifications 2 and 6, armament loading

Ailerons	Against 13°D, 13°D			Neutral			With 13°U, 13°D		
Elevator	U (s)	N	D	U	N	D	U	N	D
α, deg	21	-	No spin	-	No spin	No spin	-	-	No spin
ϕ, deg	2U	-		-			-	-	
Ω, rps	0.53	-		0.49			-	-	
V, fps	332	-		304			>374	-	
Turns for recovery	[l]2$\frac{1}{2}$	-		>3			[l,q]2$\frac{1}{2}$	-	

Modification 2, inverted spins, normal loading

Ailerons	Neutral			With 13°U, 13°D		
Elevator	U	N	D	U	N (s)	D
α, deg	36	39	No spin	34	38	36
ϕ, deg	4U	3U		5U	3U	4U
Ω, rps	0.44	0.56		0.48	0.53	0.53
V, fps	287	255		290	274	251
Turns for recovery	[l]2	1$\frac{3}{4}$		>4	3$\frac{1}{4}$	1$\frac{1}{2}$

Modifications 2 and 6, inverted spins, normal loading

Ailerons	Against 13°U, 13°D			Neutral			With 13°U, 13°D		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	33	38	No spin	36	38	33
ϕ, deg				4U	2U		3U	2U	3U
Ω, rps				0.51	0.50		-	0.42	0.56
V, fps				290	248		278	251	251
Turns for recovery				2	[l]1$\frac{3}{4}$		>3	4$\frac{1}{2}$	1$\frac{1}{2}$ 2$\frac{1}{4}$

[a]Large spin radius, velocity too high to test, recovery by rapid full rudder reversal, probably rapid.
[b]Velocity too high and spin too oscillatory to test.
[c]Two conditions possible.
[d]Oscillatory spin.
[e]Steeper spin also obtainable.
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[j]Recovery attempted by simultaneous neutralization of rudder and elevator.
[k]Very oscillatory and wandering spin.
[l]Visual observation.
[m]Recovery attempted by neutralizing the rudder.
[n]Oscillatory spin also obtained.
[c]Steep spin.
[q]Recovery attempted before final steep attitude was attained.
[s]Wandering spin.

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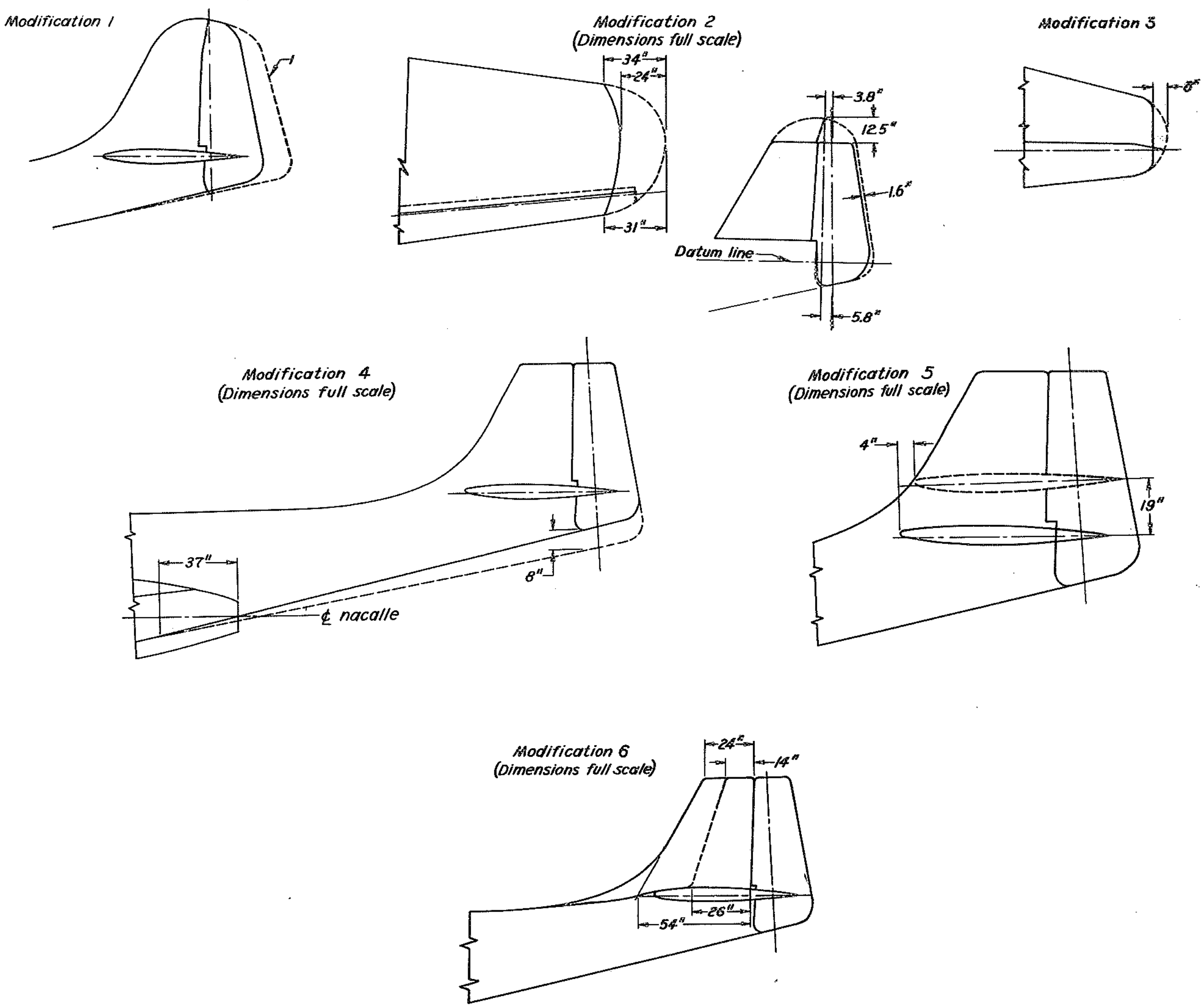

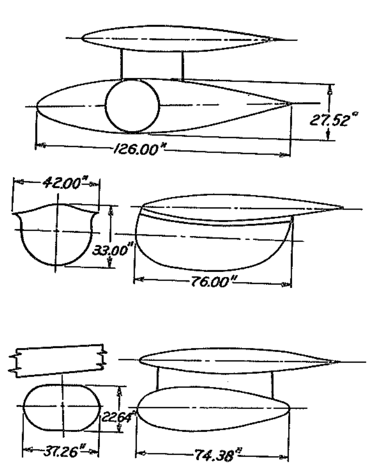

External wing tanks tested on model with modified wing and vertical tail tips. The center of gravity location of all the tanks was 12.75 feet from the plane of symmetry, 3.61 feet from the leading edge of the wing at $y = 12.75$ feet, and 0.22 feet below the center-line of the nacelle. Weight of each tank filled 1091 pounds.
(Dimensions full scale)

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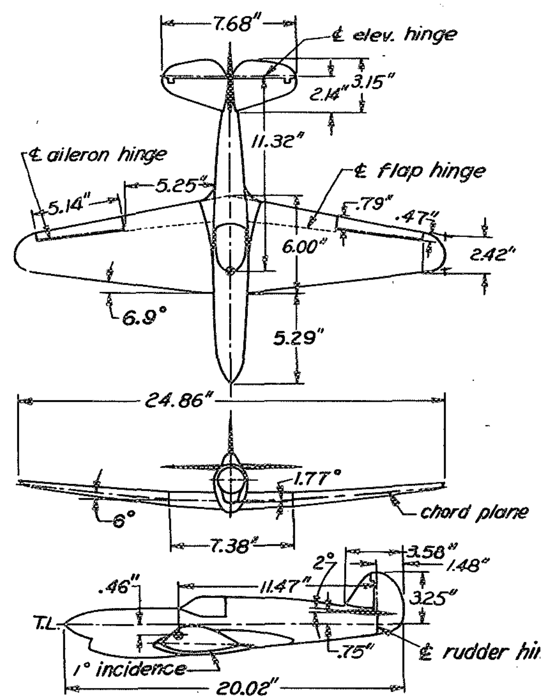
$\frac{1}{20}$-SCALE MODEL OF THE CURTISS XP-60 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	41.44
L, ft	33.37
$\bar{c}$, in.	87.00
S, sq ft	275.00
A	6.23
L.E. $\bar{c}$ aft L.E. c_r, in.	13.58
S_h, sq ft	48.30
S_e, sq ft	13.68
S_v, sq ft	20.75
S_r, sq ft	11.78
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	19 U, 11 D
δ_f, deg	45 D
TDPF	320×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	9277
$x/\bar{c}$	0.268
$z/\bar{c}$	0.105
I_X, slug-ft^2	8920
I_Y, slug-ft^2	9181
I_Z, slug-ft^2	17,224
Test altitude, ft	10,000
μ (at sea level)	10.63
μ' (10,000 ft)	14.22

$\dfrac{I_X - I_Y}{mb^2}$	-6×10^{-4}
$\dfrac{I_Y - I_Z}{mb^2}$	-163×10^{-4}
$\dfrac{I_Z - I_X}{mb^2}$	169×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model spun steeply ($\alpha = 32^{\circ}$) and recovery was satisfactory (2 turns) by rapid full rudder reversal. Setting the ailerons against the rotation steepened the spin and expedited recovery regardless of elevator setting, whereas setting the ailerons with the rotation led to spins from which recoveries were unsatisfactory by rapid full rudder reversal.

Extending or retracting mass along the wings or fuselage (ΔI_X and $\Delta I_Z = \pm 0.20\ I_X$, or ΔI_Y and $\Delta I_Z = \pm 0.20\ I_Y$), moving the center of gravity forward or back $\pm 0.05\bar{c}$ from its normal position (data not presented), extending the landing gear or deflecting the flaps 45° alone (data not presented) or in combination for the landing condition did not appreciably alter the spin and recovery characteristics of the model.

Recoveries from inverted spins obtained were generally satisfactory by rapid full rudder reversal.

Substitution of a modified tail (see sketch), revised aileron hinge line location (more rearward), and alternate maximum aileron deflections did not alter the general spin and recovery characteristics of the model.

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SPIN TESTS OF THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS XP-60 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

Normal loading

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (a)	N	D	U (a)	N	D
α, deg	20	32	32	32	37	38	44	53	47
Ø, deg	5U	7U	4U	3D	0	0	6D	4D	4D
Ω, rps	-	0.47	0.53	0.42	0.51	0.49	0.35	0.42	0.43
V, fps	274	238	234	242	225	213	201	193	193
Turns for recovery	$\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$>3\frac{1}{2}$	>6	>6

ΔI_X and ΔI_Z = 0.20 I_X

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N	D
α, deg	-	-	-	33	39	-	-	-	-
Ø, deg	-	-	-	1D	0	-	-	-	-
Ω, rps	-	-	-	0.40	0.47	-	-	-	-
V, fps	>274	258	274	242	229	230	189	193	213
Turns for recovery	b$\frac{1}{2}$	1	b$\frac{1}{2}$	2	$2\frac{1}{4}$; $2\frac{3}{4}$	$2\frac{1}{2}$	$>4\frac{1}{2}$	>7	$4\frac{1}{2}$

ΔI_X and ΔI_Z = -0.20 I_X

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N	D
α, deg	-	-	37	27	-	-	34	-	42
Ø, deg	-	-	6U	3D	-	-	8D	-	3D
Ω, rps	-	-	0.51	0.40	-	-	0.40	-	0.49
V, fps	266	234	201	254	218	213	254	221	201
Turns for recovery	1	$1\frac{1}{2}$	$3\frac{1}{2}$	$\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	>3

ΔI_Y and ΔI_Z = 0.20 I_Y

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D (a)	U (a)	N (a)	D (a)
α, deg	-	-	-	-	-	38	-	-	-
Ø, deg	-	-	-	-	-	2D	-	-	-
Ω, rps	-	-	-	-	-	0.47	-	-	-
V, fps	258	-	239	258	-	219	>274	225	209
Turns for recovery	$\frac{3}{4}$	-	$2\frac{1}{2}$	$1\frac{1}{2}$	-	3	b$>1\frac{1}{2}$	$2\frac{1}{4}$	3

ΔI_Y and ΔI_Z = -0.20 I_Y

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	-	-	-	33	-	38	-	-	-
Ø, deg	-	-	-	1D	-	2D	-	-	-
Ω, rps	-	-	-	0.50	-	0.54	-	-	-
V, fps	>274	-	>274	242	219	205	225	-	193
Turns for recovery	b$\frac{1}{2}$	-	b$\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	>4	-	>8

Landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N	D
α, deg	-	36	41	27	43	41	-	50	-
Ø, deg	-	3U	2U	7D	0	0	-	3D	-
Ω, rps	-	0.44	0.45	0.33	0.40	0.47	-	0.42	-
V, fps	>274	209	197	242	193	193	197	181	177
Turns for recovery	b$\frac{1}{2}$	$1\frac{3}{4}$	3	2	$3\frac{1}{4}$	4	>5	∞	>9

Inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (ac)	N	D
α, deg	No spin	No spin	No spin	-	-	-	-	47	-
Ø, deg				-	-	-	-	3D	-
Ω, rps				-	-	-	-	0.40	-
V, fps				>274	>274	270	234	205	209
Turns for recovery				b$\frac{1}{2}$	b$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$

Normal loading, modified tail, aileron deflections $16\frac{2}{4}°$ up and 12° down

Ailerons	Against			Neutral				With		
Elevator	U	N	D	U (a)	N	D	20°U	U (a)	N	D
α, deg	-	32	35	37	55	-	-	55	-	-
Ø, deg	-	7U	6U	3D	2D	-	-	3D	-	-
Ω, rps	-	0.51	0.56	0.41	0.46	-	-	0.43	-	-
V, fps	267	238	225	238	177	177	181	181	-	177
Turns for recovery	$\frac{1}{2}$	1	1; d5	$1\frac{1}{4}$; e$\frac{1}{4}$; d>4	$3\frac{3}{4}$	4	$3\frac{1}{2}$	4; e$3\frac{1}{2}$	-	>7

Landing condition, normal loading, modified tail

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N	D
α, deg	-	40	-	49	50	50	-	-	56
Ø, deg	-	5U	-	2D	0	1U	-	-	4D
Ω, rps	-	0.45	-	0.40	0.46	0.45	-	-	0.41
V, fps	>274	210	205	189	177	177	181	-	177
Turns for recovery	b$\frac{1}{2}$	$2\frac{1}{4}$; $1\frac{1}{2}$	$2\frac{1}{2}$; 2	$2\frac{1}{4}$	4; 3	5	>7	-	>8

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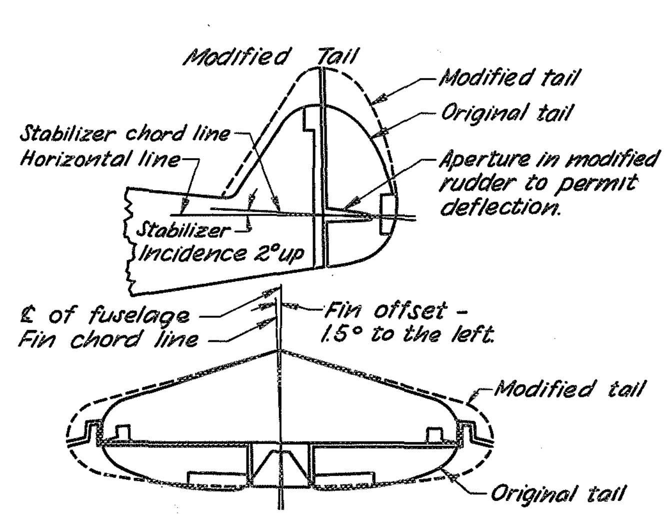
[a]Wandering spin.
[b]Recovery data obtained by reversal of rudder prior to attainment of peak velocity.
[c]Oscillatory spin.
[d]Recovery attempted by rudder neutralization.
[e]Recovery attemoted by simultaneous reversal of rudder and elevator.

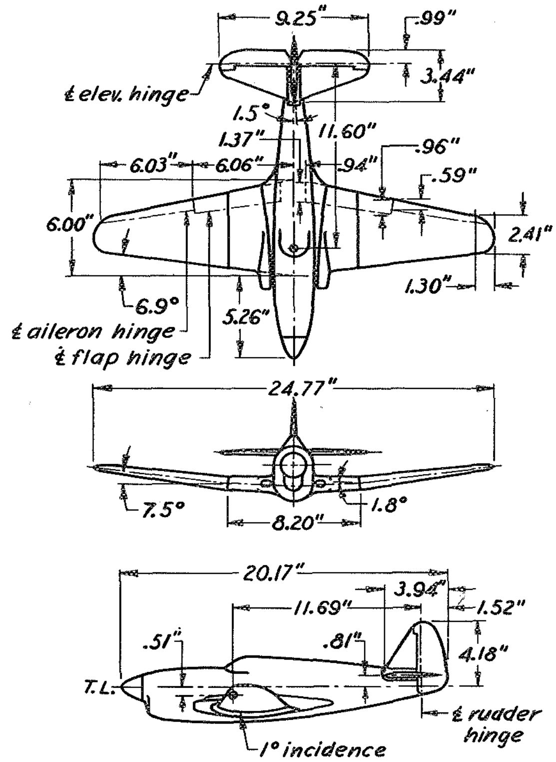


$\frac{1}{20}$-SCALE MODEL OF THE CURTISS XP-60A AIRPLANE

Dimensional Data

(Full Scale)

b, ft	41.31
L, ft	33.63
$\bar{c}$, in.	86.79
S, sq ft	275.15
A	6.21
L.E. $\bar{c}$ aft L.E. c_r, in.	12.46
S_h, sq ft	59.72
S_e, sq ft	19.33
S_v, sq ft	30.89
S_r, sq ft	17.02
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 20 D
δ_a, deg	$16\frac{1}{2}$ U, $16\frac{1}{2}$ D
δ_f, deg	45 D
TDPF	350×10^{-6}
Landing gear	Retractable



Model as tested.

Mass Data

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Normal Loading

W, lb	9451
$x/\bar{c}$	0.253
$z/\bar{c}$	0.119
I_X, slug-ft^2	7931
I_Y, slug-ft^2	10,690
I_Z, slug-ft^2	17,636
Test altitude, ft	10,000
μ (at sea level)	10.86
μ' (10,000 ft)	14.69

$\frac{I_X - I_Y}{mb^2}$	-55×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-138×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	193×10^{-4}

Resumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model spun at a moderate angle of attack ($\alpha = 44^\circ$), and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{2}\text{ turns}\right)$. Deflecting the ailerons with or against the spin did not appreciably alter the recovery characteristics of the model.

Retracting the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = -0.36\ I_X\right)$ led to a favorable effect when the ailerons were set with the spin and to an adverse effect when the ailerons were set against the spin.

Moderate changes in the center-of-gravity location ($\pm 0.05\bar{c}$) forward or back from its normal position had little effect upon the recovery characteristics of the model.

Extending the landing gear alone did not appreciably affect the recovery characteristics of the model. For the landing condition (landing gear extended and flaps down 45°) satisfactory recoveries by rapid full rudder reversal could be obtained only when the elevator was up, regardless of aileron setting.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

An all-movable horizontal tail (see sketch) was installed on the model 2.15 feet (full scale) forward and 0.32 foot (full scale) above the position of the normal tail. With this tail the steady spins were similar to those obtained using the normal tail, however, the recovery characteristics were improved. The all-movable horizontal-tail deflections were 15° up and 10° down.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS XP-60A AIRPLANE EQUIPPED WITH AN ALL-MOVABLE HORIZONTAL TAIL

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading									ΔI_X and $\Delta I_Z = 0.69 I_X$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N (a)	D (ab)	U	N (b)	D (b)	U	N (b)	D (c)	U (h)	N (i)	D	U	N	D	U (a)	N (j)	D (j)
α, deg	52	40	34	53	39	36	53	37	33	---	----	No spin	52	32	No spin	50	37	37
ϕ, deg	2U	8U	9U	2D	3U	6U	3D	1U	1U	---	----		1D	1D		3D	5D	2D
Ω, rps	0.39	0.44	0.45	0.39	0.43	0.47	0.40	0.43	0.48	---	----		0.40	0.49		0.38	0.45	1.07
V, fps	188	226	232	194	226	223	188	223	223	---	----		197	251		194	219	258
Turns for recovery	1, [de]2	[f]$1\frac{1}{2}$	[e]2	$1\frac{1}{2}$, [de]2	$1\frac{1}{2}$	[g]2	2, [dg]2	$1\frac{3}{4}$	[g]$2\frac{1}{4}$	[kl]1	[kl]1		[l]$1\frac{3}{4}$, $2\frac{1}{4}$, [dl]2, [lm]>4	$1\frac{1}{4}$, $1\frac{3}{4}$		>$2\frac{3}{4}$, [dg]2, [m]∞	[l]>$3\frac{1}{4}$	[g]$1\frac{3}{4}$, [gl]2

	ΔI_X and $\Delta I_Z = -0.32 I_X$									ΔI_X and $\Delta I_Z = -0.32 I_X$ c.g. moved forward $0.09\bar{c}$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N (a)	D (a)	U	N (b)	D (ab)	U (ab)	N (b)	D (i)	U	N (a)	D (a)	U (b)	N (b)	D (b)	U (ab)	N (i)	D (i)
α, deg	43	40	41	44	36	36	45	----	----	46	44	42	43	37	36	45	----	----
ϕ, deg	4U	7U	7U	2D	4U	6U	6D	----	----	4U	8U	9U	1D	5U	6U	7D	----	----
Ω, rps	0.36	0.41	0.42	0.35	0.43	0.46	0.35	----	----	0.42	0.45	0.47	0.42	0.49	0.48	----	----	----
V, fps	194	207	207	207	219	219	194	374	>374	192	201	197	204	220	207	201	>339	>374
Turns for recovery	1, [de]$2\frac{3}{4}$	$1\frac{1}{2}$	[el]3, [e]4	1, [dg]$2\frac{3}{4}$	[f]$1\frac{3}{4}$	[g]2, [g]3	1, [dg]2	[kl]$\frac{3}{4}$	[kl]$\frac{3}{4}$	[f]$1\frac{1}{4}$	$2\frac{1}{4}$	5, >6	[f]$1\frac{1}{2}$	2	[l]$2\frac{1}{2}$	[f]$1\frac{1}{2}$	[kl]1	[kl]1

	ΔI_X and $\Delta I_Z = -0.32 I_X$ c.g. moved back $0.10\bar{c}$									Original XP-60A horizontal tail installed on fuselage at the all-movable horizontal tail position. ΔI_X and $\Delta I_Z = -0.32 I_X$								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N (a)	D (a)	U (a)	N	D (b)	U (ab)	N (b)	D (i)	U (h)	N	D (a)	U (b)	N	D	U (b)	N (i)	D (i)
α, deg	53	39	38	46	35	35	49	----	----	----	42	40	45	39	40	45	----	----
ϕ, deg	2U	8U	10U	1U	3U	6U	4D	----	----	----	6U	7U	2D	2U	4U	4D	----	----
Ω, rps	0.33	0.35	0.37	0.29	0.37	0.39	0.31	----	----	----	0.41	0.46	0.28	0.43	0.47	----	----	----
V, fps	192	220	226	207	226	223	188	311	>339	278	207	200	219	207	200	194	>338	>338
Turns for recovery	[f]$\frac{3}{4}$	$1\frac{1}{2}$	[e]$1\frac{1}{2}$, [el]3	$\frac{3}{4}$	[f]$1\frac{1}{4}$	[gl]2	$\frac{3}{4}$	[kl]1	[kl]1	∞	$1\frac{1}{2}$	[e]3, [e]4	$\frac{3}{4}$, [d]$\frac{1}{2}$	$1\frac{1}{4}$	[g]$2\frac{1}{4}$	$1\frac{1}{4}$, [d]1	[kl]1	[kl]1

	Modification 1 ΔI_X and $\Delta I_Z = -0.32 I_X$									ΔI_X and $\Delta I_Z = -0.32 I_X$ Equivalent test altitude = 30,000 feet								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U (h)	N	D (a)	U (b)	N (b)	D	U	N (i)	D (i)	U (n)	N (ab)	D (n)	U	N (ab)	D (n)	U (bn)	N (i)	D (i)
α, deg	----	39	38	34	35	34	42	----	----	53	42	40	47	34	33	48	----	----
ϕ, deg	----	8U	8U	2D	2U	3U	7D	----	----	2U	6U	10U	2D	1U	4U	4D	----	----
Ω, rps	----	0.42	0.46	0.31	0.46	0.51	0.31	----	----	0.40	0.40	0.40	0.36	0.49	0.38	0.34	----	----
V, fps	298	216	213	251	226	226	226	>338	>338	252	298	290	272	311	311	284	>374	>374
Turns for recovery	[l]$\frac{1}{4}$, [de]$\frac{1}{2}$	$1\frac{1}{2}$	[el]3	[f]$\frac{1}{2}$, [dg]$\frac{3}{4}$	[l]$1\frac{1}{2}$	[g]2	[d]1, [dg]$1\frac{1}{4}$	[kl]1	[kl]1	[f]$1\frac{3}{4}$	2, $2\frac{1}{2}$	[l]∞	$1\frac{1}{4}$	2	[e]2, [el]3	1, $1\frac{1}{2}$	[kl]$1\frac{1}{2}$	[gk]$1\frac{1}{2}$

[a]Spin oscillatory in roll.
[b]Wandering spin.
[c]Steeper spin also obtainable.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Model goes into inverted flight after recovery.
[f]Model goes into left erect spin after recovery.
[g]Model goes into inverted spin after recovery from erect spin.
[h]Large radius spin.
[i]Velocity too high to test.
[j]Spin oscillatory in pitch.
[k]Recovery attempted before final steep attitude was attained.
[l]Visual observation.
[m]Recovery attempted by elevator reversal.
[n]Oscillatory spin in roll and pitch.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS XP-60A AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading									
Ailerons	Against			Neutral			With			
Elevator	U (a)	N (b)	D (b)	U (a)	N	D	U (a)	N (ac)	N (ac)	D (d)
α, deg	46	43	41	44	42	40	41	48	----	46
∅, deg	3U	5U	6U	2D	2U	3U	6D	5D	----	4D
Ω, rps	0.37	0.47	0.51	0.37	0.48	0.51	0.39	0.41	----	0.49
V, fps	204	207	207	216	216	210	220	200	338	197
Turns for recovery	$1\frac{1}{4}$ [ef]1 [g]3	2	[h]2 [h]$2\frac{1}{4}$	$1\frac{1}{2}$ [ef]$1\frac{1}{4}$ [g]$2\frac{3}{4}$	2	[h]$2\frac{3}{4}$	$1\frac{1}{4}$ 2 [ef]$1\frac{1}{4}$ [g]>5	$2\frac{3}{4}$	$\frac{3}{4}$	[f]2 [f]$2\frac{1}{2}$

	ΔI_X and $\Delta I_Z = -0.36 I_X$								c.g. moved forward $0.05\bar{c}$					
Ailerons	Against			Neutral			With		Against		Neutral		With	
Elevator	U (ab)	N (b)	D (b)	U (a)	N	D	U (a)	D	U (ab)	D (b)	U	D (b)	U (a)	D (d)
α, deg	46	49	45	38	42	42	---	----	45	40	43	39	----	37
∅, deg	3U	6U	6U	1D	1U	2U	---	----	3U	7U	2D	3U	----	0
Ω, rps	0.37	0.45	0.47	0.37	0.46	0.50	---	----	0.39	0.51	0.40	0.53	----	0.56
V, fps	195	191	188	226	197	195	338	>359	207	201	213	204	248	207
Turns for recovery	$1\frac{1}{2}$	$3\frac{3}{4}$	∞	1	$2\frac{1}{2}$	[f]5	$\frac{1}{4}$ $\frac{3}{4}$	[f]$\frac{3}{4}$	$1\frac{1}{2}$	[h]$2\frac{3}{4}$	$1\frac{1}{2}$	[f]$2\frac{1}{2}$	$1\frac{1}{4}$ $1\frac{3}{4}$	[f]2 [f]$2\frac{1}{4}$

	c.g. moved back $0.05\bar{c}$							Landing gear extended, normal loading					
Ailerons	Against			Neutral		With		Against		Neutral		With	
Elevator	U (b)	N	D (ab)	U (a)	D (ab)	U (a)	D (d)	U (ab)	D (b)	U (a)	D	U (a)	D (bd)
α, deg	46	----	38	41	39	----	48	36	38	40	38	35	38
∅, deg	3U	----	4U	3D	1U	----	4D	8U	6U	2D	3U	2D	0
Ω, rps	0.32	----	0.49	0.33	0.51	----	0.46	0.35	0.52	0.35	0.54	----	0.56
V, fps	201	----	201	226	210	220	194	239	213	258	207	251	213
Turns for recovery	1	----	[h]2 [h]$2\frac{1}{4}$	1	[f]2	$1\frac{1}{2}$	[f]2 [f]$2\frac{1}{4}$	$\frac{3}{4}$	[h]2	1	[f]2	$1\frac{1}{2}$	[f]2

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (ab)	N	D	U (ai)	N	D	U (ai)	N (d)	D (d)
α, deg	40	45	46	41	43	43	----	44	41
∅, deg	4U	4U	4U	2D	0	1U	----	3D	3D
Ω, rps	0.33	0.44	0.47	----	0.45	0.49	----	0.44	0.49
V, fps	201	188	188	239	197	185	304	192	192
Turns for recovery	$1\frac{1}{2}$	3	[h]$4\frac{1}{2}$	$\frac{1}{4}$	$3\frac{1}{4}$	[h]5	$\frac{1}{4}$ $\frac{3}{4}$	3	[f]3

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N (j)	D	U	N (j)	D (j)
α, deg	No spin	No spin	No spin	34	35	No spin	51	43	34
∅, deg				2D	1D		3D	4D	4D
Ω, rps				0.42	0.50		0.42	0.47	0.59
V, fps				258	238		197	197	220
Turns for recovery				$\frac{1}{4}$	[k]$\frac{1}{2}$		[l]1	[k]1	[k]1

[a]Wandering spin.
[b]Model oscillatory in roll.
[c]Two types of spin possible.
[d]Steeper type of spin also obtainable.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Model goes into inverted spin upon recovery.
[g]Recovery attempted by neutralizing the rudder.
[h]Model goes into inverted flight upon recovery.
[i]Whipping motion to spin.
[j]Oscillatory spin.
[k]Model goes into erect spin upon recovery.
[l]Model goes into wide spiral upon recovery.

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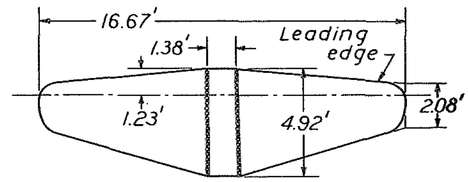
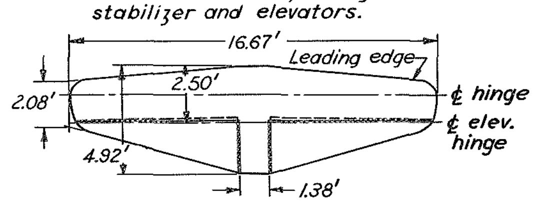
All-movable horizontal tail tested on XP-60A model



(Dimensions full scale)

Modification I
Horizontal tail of same planform as all movable tail, having fixed stabilizer and elevators.



(Dimensions full scale)

$\frac{1}{20}$-SCALE MODELS OF THE CURTISS XP-60C, P-60A-1CU AND P-60B-1CU AIRPLANES

Dimensional Data

XP-60C

(Full Scale)

b, ft	41.30
L, ft	33.92
$\bar{c}$, in.	86.79
S, sq ft	275.15
A	6.21
L.E. $\bar{c}$ aft L.E. c_r, in.	12.45
S_h, sq ft	59.80
S_e, sq ft	19.34
S_v, sq ft	30.89
S_r, sq ft	17.00
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 20 D
δ_a, deg	$16\frac{1}{2}$ U, $16\frac{1}{2}$ D
δ_f, deg	45 D
TDPF	504×10^{-6}
Landing gear	Conventional

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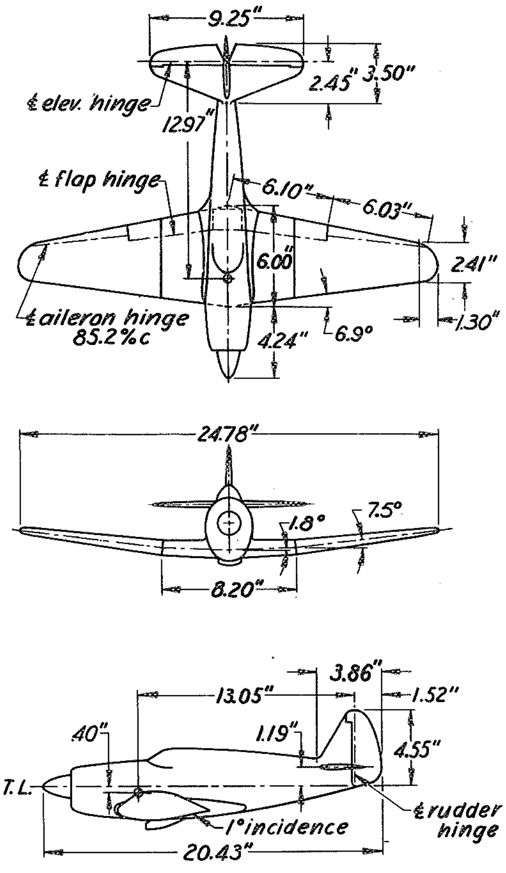
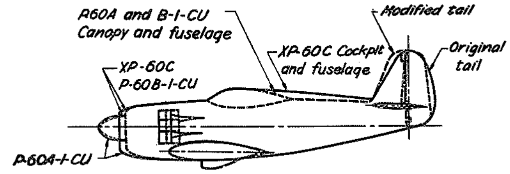


Model as tested.

Comparison of XP-60C, P-60A-1-CU, and P-60B-1-CU models.



P-60A-1CU and P-60B-1CU

(Full Scale)

b, ft	41.30	S_v, sq ft	30.89
L, ft	33.47	S_r, sq ft	17.00
$\bar{c}$, in.	86.79	δ_r, deg	25 R, 25 L
S, sq ft	275.15	δ_e, deg	30 U, 20 D
A	6.21	δ_a, deg	$16\frac{1}{2}$ U, $16\frac{1}{2}$ D
L.E. $\bar{c}$ aft L.E. c_r, in.	12.45	δ_f, deg	45 D
(Values of areas for original tail)		TDPF (orig. tail)	462×10^{-6}
S_h, sq ft	59.80	TDPF (mod. tail)	468×10^{-6}
S_e, sq ft	19.34	Landing gear	Conventional

Mass Data

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Normal Loading

	XP-60C	P-60A-1CU	P-60B-1CU
W, lb	10,370	9995	10,370
$x/\bar{c}$	0.212	0.253	0.212
$z/\bar{c}$	0.092	0.092	0.092
I_X, slug-ft^2	6969	6969	6969
I_Y, slug-ft^2	11,902	11,119	11,902
I_Z, slug-ft^2	17,330	16,547	17,330
Test altitude, ft	15,000	15,000	15,000
μ (at sea level)	11.92	11.50	11.92
μ' (15,000 ft)	18.95	18.25	18.95
$\frac{I_X - I_Y}{mb^2}$	-90×10^{-4}	-78×10^{-4}	-89×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-100×10^{-4}	-102×10^{-4}	-99×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	190×10^{-4}	180×10^{-4}	188×10^{-4}

Résumé of Model Test Results

The P-60B-1CU was tested with both the original vertical tail and a modified vertical tail. The model representing the P-60A-1CU airplane was tested only with the modified vertical-tail installation. A comparison of the XP-60C, P-60A-1CU, and the P-60B-1CU models is shown in the accompanying sketch.

In the clean condition, normal loading, and normal control configuration for spinning, the model of the XP-60C airplane spun at a moderately flat angle of attack ($\alpha = 47^{\circ}$) and recovery by rapid full rudder reversal was satisfactory (2 turns). Regardless of aileron setting, recoveries from all elevator-neutral or elevator-up spins were satisfactory by rapid full rudder reversal. The recovery characteristics of the model were unsatisfactory when tested at an equivalent test altitude of 30,000 feet; recoveries from spins by rapid full rudder reversal required about 3 turns for most control settings.

In the clean condition, normal loading, and normal control configuration for spinning, the model of the P-60B-1CU airplane spun at a moderately flat angle of attack ($\alpha = 50^{\circ}$) and recovery by rapid full rudder reversal was satisfactory. In general, recoveries from all spins for all control settings were satisfactory by rapid full rudder reversal. Substitution of a modified vertical tail (see comparison sketch) did not appreciably alter the spin and recovery characteristics of the model.

Results of spin and recovery tests of the model of the P-60A-1CU airplane with the modified vertical tail were very similar to results obtained with the P-60B-1CU model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODELS OF THE CURTISS XP-60C, P-60A-1-CU AND P-60B-1-CU AIRPLANES

[Unless otherwise indicated, steady spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude of 15,000 feet]

	XP-60C, normal loading										XP-60C, normal loading, 30,000 foot altitude								
Ailerons	Against, Full			Against, $\frac{1}{3}$	Neutral			With			Against			Neutral			With		
Elevator	U	N	D	$\frac{2}{3}$U	U	N	D	U (ab)	N	D	U (a)	N	D	U (a)	N	D	U (ab)	N (ab)	D (ab)
α, deg	44	43	41	46	47	41	39	----	23	20	50	45	41	50	47	41	----	----	----
∅, deg	4U	5U	5U	1U	2D	1U	2U	----	6D	3D	3U	3U	4U	4D	1D	1U	----	----	----
Ω, rps	0.44	0.53	0.58	0.50	0.44	0.56	0.59	----	----	----	0.41	0.52	0.54	0.41	0.52	0.57	----	----	----
V, fps	239	245	248	239	242	245	245	----	385	385	304	304	304	304	304	301	----	----	----
Turns for recovery	[c]$1\frac{1}{2}$	2	$2\frac{1}{4}$	[d]$2\frac{1}{4}$	2 [ef]$1\frac{3}{4}$ [g]$>3\frac{1}{2}$ [h]$>3\frac{1}{2}$	2	[f]$2\frac{1}{2}$	$1\frac{1}{2}$	1	[f]1	$2\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$2\frac{3}{4}$	3	[f]$2\frac{3}{4}$	----	2	[f]2

	P-60B-1-CU, normal loading										P-60B-1-CU, normal loading, modified vertical tail								
Ailerons	Against, Full			Against, $\frac{1}{3}$	Neutral			With			Against, Full			Against, $\frac{1}{3}$	Neutral			With		
Elevator	U	N	D	$\frac{2}{3}$U	U	N	D	U (i)	N (b)	D (b)	U	N	D	$\frac{2}{3}$U	U	N	D	U (i)	N (b)	D (b)
α, deg	44	42	42	47	50	43	39	---	---	----	41	43	39	46	48	41	40	--	----	----
∅, deg	4U	5U	5U	2U	2D	1U	1U	---	---	----	3U	4U	4U	2U	4D	1U	1U	--	----	----
Ω, rps	0.44	0.52	0.57	0.48	0.45	0.55	0.58	---	---	----	0.44	0.55	0.58	0.48	0.44	0.54	0.58	--	----	----
V, fps	242	236	239	245	233	246	246	---	---	385	245	238	245	242	233	242	248	--	332	353
Turns for recovery	$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{2}$	[d]$2\frac{1}{4}$	2 [e]2 [ef]$2\frac{1}{2}$ [h]$5\frac{3}{4}$	2	[f]$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$	[d]$2\frac{1}{2}$	2	$1\frac{3}{4}$	[f]$2\frac{1}{4}$	2	1	1

	P-60A-1-CU, normal loading, modified vertical tail											
Ailerons	Against, Full			Against, $\frac{1}{3}$	Neutral			With			
Elevator	U	N	D	$\frac{2}{3}$U	U	N	D	U (i)	N	D (bj)	D (bj)
α, deg	42	-	38	45	44	-	-	---	-	----	39
∅, deg	0.4U	-	6U	1U	3D	-	-	---	-	----	3D
Ω, rps	0.42	-	0.56	0.46	0.43	-	-	---	-	----	----
V, fps	229	-	236	233	223	-	-	---	-	----	234
Turns for recovery	$1\frac{1}{2}$	-	$2\frac{1}{4}$	[d]$2\frac{1}{4}$	$1\frac{3}{4}$	-	-	$1\frac{3}{4}$	-	1	[f]$1\frac{3}{4}$

[a]Wandering spin.
[b]Steep spin.
[c]Model goes into left spin upon recovery from right spin.
[d]Recovery attempted by rapid movement of rudder from full with to $\frac{2}{3}$ against the spin.
[e]Recovery attempted by simultaneous rapid full reversal of rudder and elevator.
[f]Model goes into inverted spin upon recovery from erect spin.
[g]Recovery attempted by neutralizing rudder.
[h]Recovery attempted by neutralizing rudder and the elevator simultaneously.
[i]Wandering and oscillatory spin.
[j]Two types of spin.

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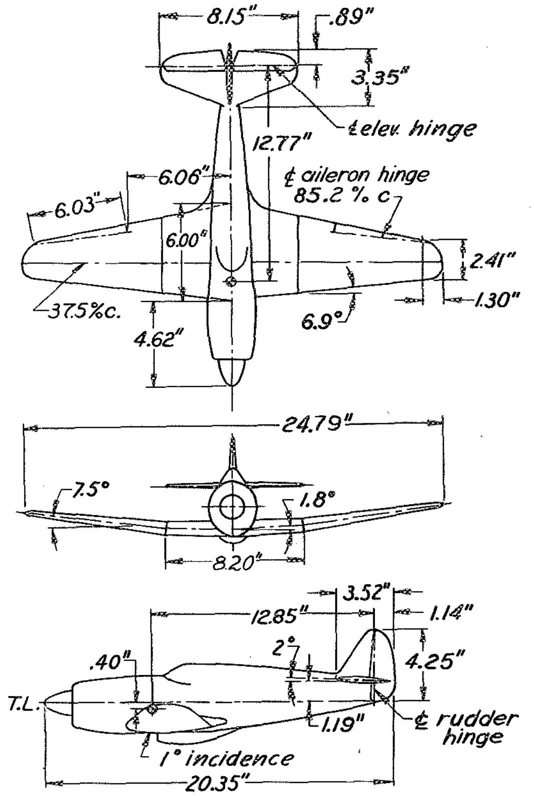
$\frac{1}{20}$-SCALE MODEL OF THE CURTISS XP-60E AIRPLANE

Dimensional Data

(Full Scale)

b, ft	41.31
L, ft	33.91
$\bar{c}$, in.	86.79
S, sq ft	275.15
A	6.20
L.E. $\bar{c}$ aft L.E. c_r, in.	12.46
S_h, sq ft	54.44
S_e, sq ft (total)	14.23
S_v, sq ft	21.45
S_r, sq ft (total)	10.39
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 20 D
δ_a, deg	$16\frac{1}{2}$ U, $16\frac{1}{2}$ D
δ_f, deg	45 D
TDPF	372×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	10,390
$x/\bar{c}$	0.257
$z/\bar{c}$	0.092
I_X, slug-ft^2	6969
I_Y, slug-ft^2	11,119
I_Z, slug-ft^2	16,547
Test altitude, ft	15,000
μ (at sea level)	11.94
μ' (15,000 ft)	19.00

$\frac{I_X - I_Y}{mb^2}$	-75×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-98×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	173×10^{-4}

Résumé of Model Test Results

Test results for both right and left spins are presented because the model as tested was slightly asymmetrical in model construction. As indicated by the data, these asymmetries did not appreciably affect the test results.

In the clean condition, normal loading, and normal control configuration for spinning, spins were steep and oscillatory with satisfactory recoveries obtained by rapid full rudder reversal (approximately 1 turn). Moving the elevator down before reversing the rudder retarded recoveries.

A moderate extension or retraction of mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = \pm 0.20\ I_X\right)$ or moving the center of gravity rearward $0.06\bar{c}$ from its normal position did not appreciably alter the spin and recovery characteristics of the model for elevator-up spins.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTIS-XP-60E AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading, left spins											
Ailerons	Against			Neutral			With $\frac{1}{3}$			With Full		
Elevator	U (a)	N	D	U (a)	N	D	U (a)	20°U (ab)	20°U (ab)	U (a)	N	D
α, deg	26	36	35	-	36	36	31	24	37	-	21	19
ϕ, deg	1U	7U	7U	-	2U	1U	2D	9D	2U	-	12D	3D
Ω, rps	0.44	0.53	0.56	-	0.56	0.55	0.47	0.53	0.45	-	0.75	0.83
V, fps	319	258	255	346	265	236	352	352	284	>340	352	388
Turns for Recovery	$\frac{1}{2}$; [c]$\frac{3}{4}$	2; $2\frac{1}{2}$	2; $2\frac{3}{4}$	1; [c]$1\frac{1}{2}$	[c]2	$2\frac{3}{4}$; >3	[d]$1\frac{1}{2}$; [d]4	[d]$>2\frac{1}{2}$	[cd]$1\frac{1}{2}$; [cd]3	$>2\frac{1}{2}$	1; [c]$1\frac{1}{2}$	$\frac{3}{4}$

	Normal loading, right spins											
Ailerons	Against			Neutral				With $\frac{1}{3}$		With Full		
Elevator	U (a)	N	D (a)	U (a)	N (be)	N (b)	D	U (a)	20°U (a)	U (a)	N	D (e)
α, deg	-	-	-	-	-	33	-	28	29	-	18	-
ϕ, deg	-	-	-	-	-	1D	-	7D	3D	-	10D	-
Ω, rps	-	0.51	0.52	-	-	0.57	-	0.57	0.50	-	0.86	-
V, fps	>385	272	252	-	-	252	396	>304	352	-	424	-
Turns for Recovery	$\frac{1}{4}$	[c]2	[c]2; [c]3	$\frac{1}{2}$; 1	-	$2\frac{1}{4}$	[c]2	[cd]$1\frac{1}{2}$; [cd]$>2\frac{1}{2}$	[d]$2\frac{1}{4}$; [d]$>2\frac{1}{4}$	>2	$\frac{3}{4}$; [c]$1\frac{1}{2}$	-

	ΔI_X and $\Delta I_Z = 0.20 I_X$ Left spins, elevator-up spins			ΔI_X and $\Delta I_Z = 0.20 I_X$ Right spins, elevator-up spins		ΔI_X and $\Delta I_Z = -0.20 I_X$ Left spins, elevator-up spins			ΔI_X and $\Delta I_Z = -0.20 I_X$ Right spins, elevator-up spins		
Ailerons	Against	Neutral (f)	With (fg)	Neutral	With (f)	Against	Neutral (f)	With (f)	Against	Neutral (f)	With (f)
α, deg	No spin	29	-	-	-	No spin	-	27	-	-	-
ϕ, deg		5D	-	-	-		-	7D	-	-	-
Ω, rps		0.41	-	-	-		-	-	-	-	-
V, fps		352	318	352	-		352	298	368	352	284
Turns for Recovery		$\frac{3}{4}$; $1\frac{1}{4}$	$>2\frac{3}{4}$	[c]$>4\frac{1}{2}$	-		$\frac{1}{2}$; [c]1	[c]$1\frac{1}{2}$; [c]$>2\frac{1}{2}$	$\frac{1}{2}$	[c]>3	[g]2; [c]$1\frac{1}{2}$

	c.g. moved back $0.06\bar{c}$, left spins, elevator-up spins			c.g. moved back $0.06\bar{c}$, right spins, elevator-up spins		
Ailerons	Against	Neutral (ef)	With (f)	Against	Neutral (ef)	With (f)
Ω, rps	-	0.83	0.80	0.76	-	-
V, fps	374	-	-	304	-	-
Turns for Recovery	$\frac{1}{2}$	$\frac{1}{2}$	[c]$>1\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	[g]3

[a]Oscillatory spin.
[b]Two types of spin.
[c]Visual observation.
[d]Recovery attempted by movement of the rudder to 17° against spin.
[e]Steep spin.
[f]Wandering and oscillatory spin.
[g]Model continued spinning when launched with rudder against spin.

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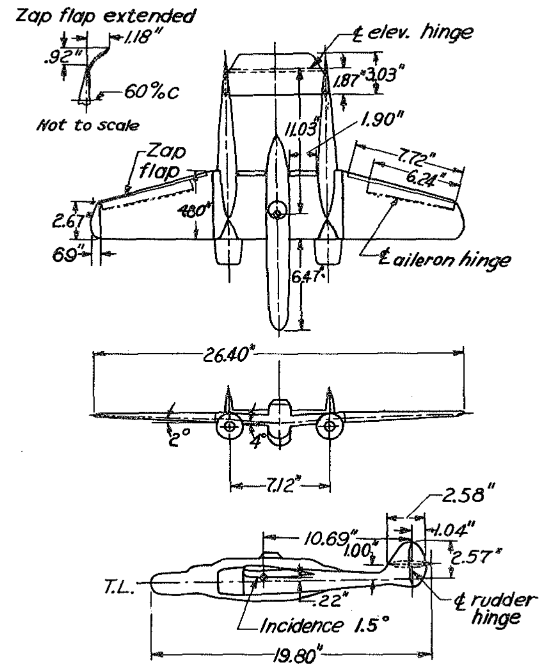
$\frac{1}{30}$-SCALE MODEL OF THE NORTHROP XP-61 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	66.00
L, ft	49.50
$\bar{c}$, in.	126.30
S, sq ft	663.30
A	6.57
L.E. $\bar{c}$ aft L.E. c_r, in.	0
S_h, sq ft	120.60
S_e, sq ft	49.50
S_v, sq ft	91.40
S_r, sq ft	39.00
δ_r, deg	35 R, 35 L
δ_e, deg	30 U, 20 D
δ_a, deg	40 U, 0 D
δ_f, percent	30 extended (for take-off); 100 extended (for landing)
TDPF	1103×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	25,750
$x/\bar{c}$	0.271
$z/\bar{c}$	-0.052
I_X, slug-ft^2	53,494
I_Y, slug-ft^2	35,082
I_Z, slug-ft^2	83,423
Test altitude, ft	20,000
μ (at sea level)	7.69
μ' (20,000 ft)	14.43

$\frac{I_X - I_Y}{mb^2}$	53×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-139×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	86×10^{-4}

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Résumé of Model Test Results

In general, the model spun moderately steep in the normal loading, clean condition, with a high rate of descent, and recoveries from all spins were satisfactory by rapid full rudder reversal or elevator reversal from elevator up spins.

Extending mass along the wings or fuselage $(\Delta I_X$ and $\Delta I_Z = 0.30\ I_X$ or ΔI_Y and $\Delta I_Z = 0.20\ I_Y)$ or moving the center of gravity forward $0.06\bar{c}$ or rearward $0.05\bar{c}$ had little effect

SPIN DATA OBTAINED WITH THE $\frac{1}{30}$-SCALE MODEL OF THE NORTHROP XP-61 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (ab)	N	D	U (c)	N	D	U (c)	N (c)	D (ab)
α, deg	---	No spin	No spin	33	No spin	No spin	37	31	---
ϕ, deg	---			1D			1D	1D	---
Ω, rps	---			0.44			0.48	0.57	---
V, fps	---			289			289	306	---
Turns for recovery	---			$\frac{3}{4}$			$1\frac{1}{4}$	$\frac{3}{4}$	---

Effect of control manipulation on turns for recovery from the elevator up position, normal loading		
Ailerons	With	Neutral
Rudder neutralization	>2	>2
Rudder released	>4	$>3\frac{1}{2}$
Elevator reversed	$\frac{3}{4}$	$\frac{3}{4}$
Elevator neutralized	$>2\frac{1}{2}$	>2
Elevator released	>2	>2
Simultaneous reversal of elevator and rudder	$\frac{1}{2}$	$\frac{3}{4}$

	ΔI_X and $\Delta I_Z = 0.30 I_X$								
Ailerons	Against			Neutral			With		
Elevator	U (ab)	N	D	U (c)	N	D	U (c)	N (ab)	D (ab)
α, deg	-----	No spin	No spin	40	No spin	No spin	--	---	---
ϕ, deg	-----			2D			--	---	---
Ω, rps	-----			0.44			--	---	---
V, fps	-----			291			--	---	---
Turns for recovery	-----			$1\frac{1}{4}$			--	---	---

	ΔI_Y and $\Delta I_Z = 0.20 I_Y$								
Aileron	Against			Neutral			With		
Elevator	U	N	D	U (c)	N	D (d)	U (c)	N (c)	D (ab)
α, deg	37	No spin	No spin	37	32	---	43	33	---
ϕ, deg	2D			4D	1D	---	2D	2D	---
Ω, rps	0.35			0.36	0.55	---	0.35	0.52	---
V, fps	274			264	291	296	271	296	---
Turns for recovery	1			$1\frac{1}{4}$	$\frac{3}{4}$	---	1	$\frac{1}{2}$	---

	ΔI_Y and $\Delta I_Z = -0.09 I_Y$								
Aileron	Against			Neutral			With		
Elevator	U	N	D	U (c)	N	D	U (c)	N (ab)	D (ab)
α, deg	--	No spin	No spin	34	No spin	No spin	32	----	----
ϕ, deg	--			2D			0	----	----
Ω, rps	--			0.40			0.47	----	----
V, fps	--			291			291	----	----
Turns for recovery	--			1			1	----	----

	c.g. moved forward $0.06\bar{c}$								
Aileron	Against			Neutral			With		
Elevator	U (ab)	N	D	U (c)	N	D	U (c)	N (ab)	D (ab)
α, deg	---	No spin	No spin	34	No spin	No spin	36	---	---
ϕ, deg	---			2D			1D	---	---
Ω, rps	---			0.51			0.46	---	---
V, fps	---			284			276	---	---
Turns for recovery	---			$1\frac{1}{4}$			$1\frac{1}{2}$	---	---

	c.g. movedback $0.05\bar{c}$								
Ailerons	Against			Neutral			With		
Elevator	U (c)	N	D	U (c)	N	D	U (c)	N (c)	D (ab)
α, deg	39	No spin	No spin	41	34	No spin	41	26	---
ϕ, deg	1D			0	1D		1D	1D	---
Ω, rps	0.35			0.35	0.46		0.34	0.51	---
V, fps	276			269	271		271	274	---
Turns for recovery	$\frac{3}{4}$			$1\frac{1}{4}$	$1\frac{1}{4}$		$\frac{3}{4}$	1	---

	Flaps fully extended, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	34	No spin	No spin	35	42	No spin	42	39	43
ϕ, deg	0			2D	4D		3D	4D	3D
Ω, rps	0.39			0.39	0.46		0.38	0.43	0.46
V, fps	209			204	199		209	199	192
Turns for recovery	$1\frac{3}{4}$			$1\frac{3}{4}$	$1\frac{3}{4}$		$2\frac{1}{4}$	2	$1\frac{1}{2}$

	Landing gear extended, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (ab)	N	D	U (c)	N	D	U (c)	N	D
α, deg	---	No spin	No spin	---	No spin	No spin	---	No spin	No spin
ϕ, deg	---			---			---		
Ω, rps	---			---			---		
V, fps	---			286			286		
Turns for recovery	---			$1\frac{3}{4}$			$1\frac{3}{4}$		

	Take-off condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (ab)	N	D	U (c)	N	D	U (c)	N	D
α, deg	---	No spin	No spin	--	No spin	No spin	--	No spin	No spin
ϕ, deg	---			--			--		
Ω, rps	---			--			--		
V, fps	---			--			--		
Turns for recovery	---			--			--		

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	44	No spin	No spin	42	44	No spin	42	45	45
ϕ, deg	3D			2D	2D		3D	2D	2D
Ω, rps	0.40			0.40	0.46		0.40	0.47	0.49
V, fps	206			204	197		206	197	189
Turns for recovery	$1\frac{1}{2}$			2	$1\frac{3}{4}$		$2\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	38	No spin	No spin	35	No spin	No spin
ϕ, deg				3D			5D		
Ω, rps				0.43			0.42		
V, fps				304			299		
Turns for recovery				$\frac{1}{2}$ $^{e}1\frac{1}{4}$			$1\frac{1}{4}$ $^{e}2\frac{1}{2}$		

[a]Steep spin.
[b]High rate of descent.
[c]Oscillatory spin.
[d]No spin condition also obtainable.
[e]Recovery attempted by neutralizing rudder.

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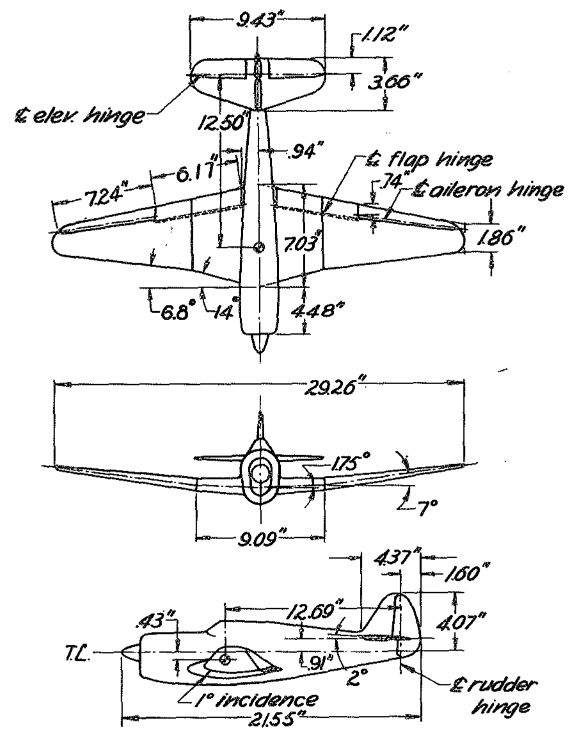
1/22-SCALE MODEL OF THE CURTISS XP-62 AIRPLANE

Dimensional Data

(Full scale)

b, ft	53.65
L, ft	39.50
$\bar{c}$, in.	104.70
S, sq ft	420.00
A	6.85
S_h, sq ft	85.95
S_e, sq ft	31.58
S_v, sq ft	36.35
S_r, sq ft	18.74
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 15 D
δ_a, deg	16 U, 16 D
δ_f, deg	45 D
TDPF	241×10^{-6}
Landing gear	Conventional



Mass Data

Model as tested.

Normal Loading

W, lb	14,545
$x/\bar{c}$,	0.250
$z/\bar{c}$,	0.095
I_X, slug-ft^2	13,241
I_Y, slug-ft^2	22,545
I_Z, slug-ft^2	33,714
Test altitude, ft	10,000
Test altitude, ft	30,000
μ (at sea level)	8.45
μ' (10,000 ft)	11.44
μ'' (30,000 ft)	22.52

$\frac{I_X - I_Y}{mb^2}$	-71×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-86×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	157×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition, normal control configuration for spinning, the model spun at a steep attitude ($\alpha = 28^{\circ}$) and recovery by rapid full rudder reversal was satisfactory. Satisfactory recoveries $\left(\frac{1}{2}\text{ turn}\right)$ were also obtained by simultaneous rapid full reversal of elevator and rudder, whereas merely neutralizing the rudder alone led to poor recoveries (>3 turns). Setting the elevator down before reversing the rudder retarded recoveries. Setting the ailerons against the spin flattened the spin, whereas setting the ailerons with the spin steepened the spin and slightly expedited recoveries.

With the mass extended along the wings to simulate an eight-gun airplane loading $\left(\Delta I_X \text{ and } \Delta I_Z = 0.41 I_X\right)$, the recovery characteristics of the model were satisfactory for all control settings except the aileron-with, elevator-up spin (3-turn recovery).

With the mass extended along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.15 I_Y\right)$, there was little change in the spin characteristics of the model for the aileron-neutral spins. Setting the ailerons against the spin flattened the spins and definitely retarded recoveries. Setting the ailerons with the spin led to very steep oscillatory spins from which recoveries were not attempted.

With the mass retracted along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = -0.15 I_Y\right)$ the recoveries were satisfactory from all spins obtained.

A forward or rearward movement of the center of gravity $\pm 0.05\bar{c}$ from its normal position had little effect on the spin or recovery characteristics of the model.

For the landing condition (landing gear extended, flaps down 45°), the model recovered satisfactorily by rapid full rudder reversal from spins only when the ailerons were set full with the spin. Extending the landing gear alone had little effect on the spin or recovery characteristics of the model.

Recoveries by rapid full rudder reversal from all inverted spins obtained were satisfactory.

For the alternate test altitude, 30,000 feet, normal loading clean condition, the model generally spun at a flatter attitude with a lower rotational velocity than for the corresponding spins at a test altitude of 10,000 feet. Results indicated that recovery by rapid full rudder reversal was satisfactory only for the elevator-up spins.

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SPIN DATA OBTAINED WITH THE $\frac{1}{22}$-SCALE MODEL OF THE CURTISS XP-62

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (ab)	N (a)	D (a)	U (c)	N	D	U (a)	N (d)	D
α, deg	34	40	51	28	35	37	26	21	25
ϕ, deg	8U	8U	6U	0	4U	4U	11D	3D	2D
Ω, rps	0.39	0.46	0.44	0.43	0.50	0.49	0.44	0.76	0.68
V, fps	257	207	191	278	230	220	337	319	278
Turns for recovery	3/4; [e]1/4; [f]>2 1/4	2; [f]∞	4 3/4; [f]∞	1; [e]1/2; [f]>3	1 3/4; [f]∞	2 1/4; [f]∞	1/2	[g]1/2	[g]1 1/4; [f]∞

	Rudder-neutral spins, normal loading					
Ailerons	Against			Neutral		
Elevator	U	N	D	U (b)	N	D
α, deg	No spin	34	48	--	No spin	No spin
ϕ, deg		9U	7U	--		
Ω, rps		---	---	--		
V, fps		231	188	--		
Turns for recovery		---	---	--		

	ΔI_X and $\Delta I_Z = 0.41 I_X$									
Ailerons	Against			Neutral			With			
Elevator	U (c)	N (a)	D	U	N	D	U (hi)	U (i)	N (a)	D
α, deg	29	32	34	30	32	34	36	---	42	32
ϕ, deg	7U	8U	8U	3D	1U	2U	8D	---	3D	5D
Ω, rps	0.41	0.53	0.56	0.41	0.54	0.54	0.39	---	0.48	0.55
V, fps	285	250	238	278	238	239	257	217	237	235
Turns for recovery	3/4	1	1 1/4	2	1 1/2	1 1/4; 1 3/4	>3	>4	2	[g]2

	ΔI_Y and $\Delta I_Z = 0.15 I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U (b)	N	D	U (c)	N	D	U (h)	N (j)	D (j)
α, deg	35	53	53	28	36	39	---	---	---
ϕ, deg	10U	5U	5U	1D	3U	5U	---	---	---
Ω, rps	0.36	0.40	0.40	0.40	0.46	0.46	---	---	---
V, fps	250	191	182	278	231	217	---	---	---
Turns for recovery	1	5	9	1	2	3 1/4	[k]4	[k]4	[gk]4

	ΔI_Y and $\Delta I_Z = -0.15 I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (h)	N (j)	D
α, deg	30	36	39	29	34	35	---	---	23
ϕ, deg	8U	11U	9U	2U	5U	6U	---	---	1U
Ω, rps	0.43	0.50	0.52	0.44	0.54	0.55	---	---	0.76
V, fps	260	220	210	271	227	217	---	---	278
Turns for recovery	1/2	3/4	1 1/2	1	1 1/2	1 1/2	---	[k]4	[g]1

	c.g. moved forward 0.05c̄								
Ailerons	Against			Neutral			With		
Elevator	U (b)	N (a)	D	U (c)	N	D	U (hj)	N (j)	D
α, deg	31	39	51	29	34	37	---	---	20
ϕ, deg	8U	9U	6U	1U	5U	5U	---	---	1D
Ω, rps	0.43	0.48	0.46	0.45	0.51	0.51	---	---	0.73
V, fps	254	217	188	274	227	217	---	---	334
Turns for recovery	3/4	2 1/4	3 1/4; 4	3/4	1 3/4	2 1/2	[k]4	[k]4	[g]1

	c.g. moved back 0.05c̄								
Ailerons	Against			Neutral			With		
Elevator	U (b)	N (a)	D	U (c)	N	D	U (hj)	N (j)	D
α, deg	31	40	47	28	34	36	---	---	16
ϕ, deg	8U	9U	6U	2D	4U	5U	---	---	1D
Ω, rps	0.35	0.43	0.42	0.41	0.48	0.48	---	---	0.82
V, fps	257	214	191	274	230	223	---	---	362
Turns for recovery	3/4	1 1/2; 2 1/4	3 1/4	1	1 3/4	2	[k]4	[k]4	[g]1/2

	Landing gear extended, normal loading						
Ailerons	Against		Neutral		With		
Elevator	U (ab)	D (a)	U (c)	N	U (a)	N (j)	D
α, deg	---	---	---	---	--	--	---
ϕ, deg	---	---	---	---	--	--	---
Ω, rps	---	---	---	---	--	--	---
V, fps	257	207	282	238	--	--	278
Turns for recovery	3/4	2	3/4	1 1/2	--	[k]4	[g]1 1/4

	Landing condition, normal loading								
Ailerons	Against: Full			Against: (l)	Neutral			With		
Elevator	U	N	D	U (bh)	U (bh)	N	D	U (bh)	N (j)	D
α, deg	45	48	48	43	---	45	45	---	---	No spin
ϕ, deg	5U	5U	6U	3U	---	1U	2U	---	---	
Ω, rps	0.35	0.43	0.43	0.33	---	0.43	0.43	---	---	
V, fps	191	178	175	194	---	185	178	---	---	
Turns for recovery	1 3/4	5 1/2	6 3/4	2	[k]4	3 3/4	4 1/4	[k]4	[k]4	

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (h)	N	D	U	N	D
α, deg	No spin	No spin	No spin	31	34	30	49	46	32
ϕ, deg				1U	2U	0	5D	5D	4D
Ω, rps				0.37	0.43	0.51	0.40	0.42	0.52
V, fps				238	238	244	191	201	230
Turns for recovery				1/2; [f]>3	1/2	1/2; [f]3/4	1 1/2; [f]>4	1 1/4	1; [f]2 1/4

	Normal loading, 30,000 feet equivalent test altitude									
Ailerons	Against			Neutral				With		
Elevator	U (b)	N	D (a)	U (i)	U (i)	N	D	U (h)	N (c)	D (c)
α, deg	33	54	55	54	32	55	54	---	53	52
ϕ, deg	5U	2U	4U	1D	1D	1D	1D	---	2D	4D
Ω, rps	0.36	0.42	0.43	0.37	0.37	0.42	0.43	---	0.42	0.43
V, fps	369	250	250	284	377	250	250	---	270	250
Turns for recovery	3/4	5	6	4	1	7 1/4	7	[k]7	5 1/4	[g]5

[a]Oscillatory spin.
[b]Large radius of spin.
[c]Wandering spin.
[d]Steeper spin also obtainable.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Recovery attempted by neutralizing rudder.
[g]Model goes into inverted spin upon recovery.
[h]Wandering and oscillatory spin.
[i]Two types of spin possible.
[j]Steep spin.
[k]Model launched with rudder against the spin.
[l]Right aileron 5° down, left aileron 5° up.

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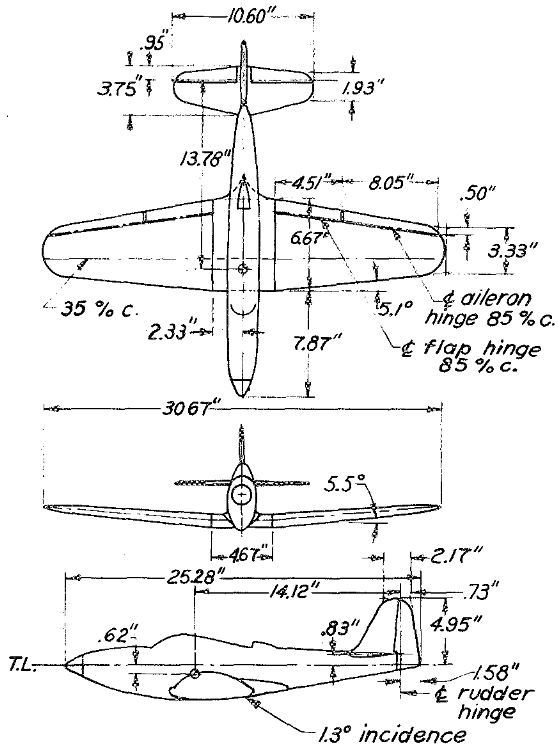
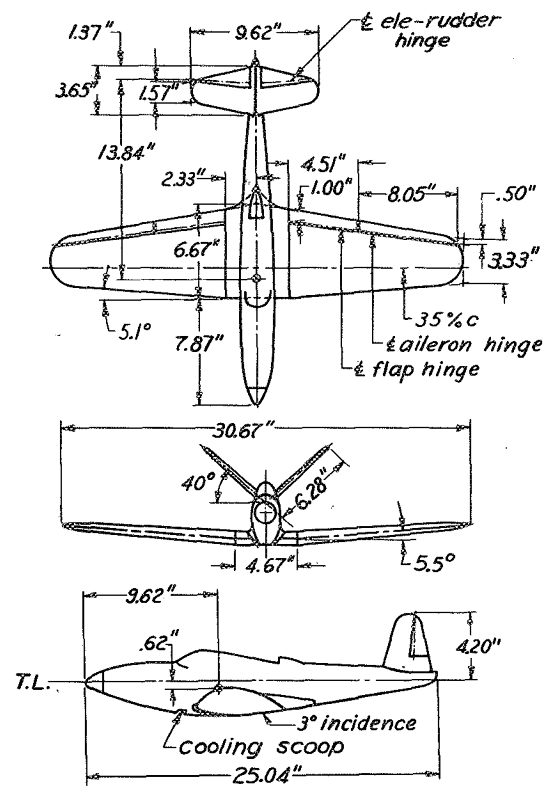
$\frac{1}{15}$-SCALE MODELS OF THE XP-63, P-63A-1-BE, AND THE

VEE-TAIL P-63A-1-BE AIRPLANE



Model as tested.



Model as tested.

Dimensional Data

(Full Scale)

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XP-63 and P-63A-1-BE

b, ft	38.33
L, ft	31.33
$\bar{c}$, in	82.54
S, sq ft	248.00
A	5.92
L.E. $\bar{c}$ aft L.E. C_r,in. . .	6.50
S_h, sq ft	44.01
S_e, sq ft (total)	14.50
S_v, sq ft	25.48
S_r, sq ft (total)	12.01
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 15 D
δ_a, deg	15 U, 15 D
δ_f, deg	45 D
TDPF	234×10^{-6}
Landing gear	Tricycle

P-63A-1-BE Vee Tail Data

Total tail area, sq ft .	49.00
Area of tail aft of hinge line, sq ft	10.80
Ele-rudder, deg . . .	40 U, 35 D

With the stick full back or full forward, full rudder deflection cannot be obtained; and, conversely, with full rudder pedal deflections, full stick movement cannot be obtained.

Mass Data

	XP-63 (Normal Loading)	P-63A-1-BE Normal	P-63A-1-BE Wing Guns Installed
W, lb	7447	7704	8 076
$x/\bar{c}$	0.237	0.245	0.244
$z/\bar{c}$	0.113	0.116	0.128
I_X, slug-ft^2	6340	6,735	7,509
I_Y, slug-ft^2	7642	7,716	7,785
I_Z, slug-ft^2	13202	13,618	14,426
Test altitude, ft	6000	6000	6,000
μ (at sea level)	10.23	10.59	11.10
μ'(6000 ft)	12.25	12.66	13.27
$I_X - I_Y/mb^2$	-38×10^{-4}	-28×10^{-4}	-8×10^{-4}
$I_Y - I_Z/mb^2$	-165×10^{-4}	-168×10^{-4}	-180×10^{-4}
$I_Z - I_X/mb^2$	203×10^{-4}	196×10^{-4}	188×10^{-4}

The mass distribution of the P-63A-1-BE model equipped with the vee-tail was similar to the P-63A-1-BE model equipped with the conventional tail.

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Résumé of Model Test Results

For the XP-63 model in the normal loading, clean condition, recoveries from spins by rapid full rudder reversal were generally unsatisfactory except when the elevator was full up and the ailerons were set either neutral or full against the spin.

Retracting mass along the wings (ΔI_X and $\Delta I_Z = -0.40\ I_X$) or moving the center of gravity rearward $0.10\bar{c}$ did not appreciably alter the recovery characteristics of the model. Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$), extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.20\ I_Y$) or moving the center of gravity forward $0.05\bar{c}$ from its normal position led to spins from which recoveries were somewhat greater than 2 turns for the normal control configuration spin obtained.

In an attempt to improve the recovery characteristics of the model for the clean condition, normal loading, various modifications were incorporated in the tail design of the model. The addition of anti-spin fillets ahead of the horizontal tail (modification 1), the addition of fin and rudder areas below the fuselage in the vicinity of the horizontal tail (modification 2), an increase in tail length, 10 or 15 inches full scale (modifications 4 or 5), or a reduction in the length of the rudder chord (modification 6), led to slight favorable effects on the recovery characteristics of the model. Increasing the tail length 17 or 20 inches, full scale, (modifications 7 or 3, respectively) greatly improved the recovery characteristics of the model and for the steady spin the model was not extremely sensitive to elevator setting.

The remainder of the results obtained for the XP-63 model were for tests of the model with the vertical tail moved rearward 17 inches, full scale, and with reduced rudder chord (modification 7).

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.22\ I_X$), extending or retracting mass along the fuselage or movements of the center of gravity forward $0.05\bar{c}$ or back $0.10\bar{c}$ from its normal position did not appreciably alter the recovery characteristics of the model. Retracting mass along the wings (ΔI_X and $\Delta I_Z = -0.36\ I_X$) produced a reversal of aileron effect. Satisfactory recoveries were obtained from all spins, except when the ailerons were against the spin and the elevator was full down.

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Extending the landing gear and flaps down 45° (landing condition) had an adverse effect upon the recovery characteristics of the model and recoveries from all spins obtained were unsatisfactory by rapid full rudder reversal.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

The P-63-1-BE model was dimensionally similar to the XP-63 model with modification 7 incorporated into its design; the model differed however in mass characteristics. Generally the spin and recovery characteristics of the model were similar to those of the XP-63 model revised with modification 7 and best recoveries were obtained with the ailerons set full against the spin.

The installation of a vee tail on the P-63A-1-BE led to spins from which recoveries were rapid when the ailerons were against the spin with best recoveries being obtained when the elerudder, acting as an elevator, was in the up position. With the elerudder acting as an elevator full-up only 1/8 rudder pedal travel was allowed. When the ailerons were set with the spin, recoveries were unsatisfactory. Moderate retraction of mass along the wings, or variations in the center-of-gravity position had little effect upon the recovery characteristics of the model (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODELS OF THE BELL XP-63 AND P-63A-1-BE AIRPLANES

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the XP-63 model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Ailerons	Against			Neutral				With $\frac{1}{3}$		With Full		
Elevator	U	N	D (a)	U (a)	27°U (b)	N	D	U (a)	23°U	U (a)	N	D
α, deg	---	59	59	40	---	59	59	---	---	---	59	57
V, fps	264	158	153	241	---	161	153	---	153	241	158	153
Turns for recovery	1	$5\frac{1}{4}$	∞	$1\frac{1}{4}$, 2, [c]$2\frac{1}{2}$, [d]1, [d]2		$6\frac{1}{2}$	∞	[e]2	[e]∞	$2\frac{1}{2}$, $>3\frac{1}{4}$, [d]1, [d]$1\frac{3}{4}$	$>7\frac{1}{4}$	∞

Effect of mass variations and c.g. movements on spin characteristics for ailerons-neutral, elevator-up spins

		α,	V,	Turns for recovery
ΔI_X and $\Delta I_Z = 0.20\ I_X$	(a)	36	236	$2\frac{1}{2}$, 3
ΔI_X and $\Delta I_Z = -0.40\ I_X$	(a)	43	197	$1\frac{1}{4}$, 2
ΔI_Y and $\Delta I_Z = 0.20\ I_Y$	(f)	38	213	$2\frac{1}{4}$
ΔI_Y and $\Delta I_Z = -0.20\ I_Y$	(a)	30	264	-------
c.g. moved forward $0.05\bar{c}$	(a)	38	224	$2\frac{1}{4}$
c.g. moved back $0.10\bar{c}$	(f)	--	207	$1\frac{1}{2}$

ΔI_X and $\Delta I_Z = 0.20 I_X$

Ailerons	Against		
Elevator	U (g)	N	D (a)
α, deg	--	59	64
ϕ, deg	--	----	----
V, fps	--	167	153
Turns for recovery	--	4	7

Modification 1, normal loading; Modification 1 and 2, normal loading

	Mod. 1					Mod. 1 and 2				
Ailerons	Neutral			$\frac{1}{3}$ With		Neutral			$\frac{1}{3}$ With	
Elevator	23°U (a)	15°U (a)	N	23°U (a)	N	15°U	N	D	15°U	N
α, deg	----	----	----	----	--	----	----	----	----	--
V, fps	207	180	164	----	--	163	158	158	163	--
Turns for recovery	$1\frac{3}{4}$, $2\frac{1}{4}$	4	$3\frac{3}{4}$	$>4\frac{1}{2}$	--	2	$2\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{1}{2}$, 3	--

Modification 3, normal loading; Modification 4, normal loading

	Mod. 3							Mod. 4						
Ailerons	Against		Neutral		With $\frac{1}{3}$	With Full		Against		Neutral				With
Elevator	N	D	N	D	N	N	D	20°U	N	23°U	20°U	15°U	N	20°U
α, deg	----	----	----	----	----	----	----	----	---	----	----	----	----	----
V, fps	207	179	202	184	236	----	264	----	---	207	215	----	174	----
Turns for recovery	$1\frac{1}{4}$	[c]3	2	[c]2, [c]$2\frac{1}{2}$	[c]$1\frac{1}{2}$	2	[c]$1\frac{1}{2}$	[g]--	---	$1\frac{1}{2}$	[c]3	[c]$2\frac{1}{2}$, [c]$3\frac{1}{2}$	4	[c]$>2\frac{3}{4}$

Modification 5, normal loading

Ailerons	Against		Neutral		With $\frac{1}{3}$		With Full			
Elevator	20°U	D	20°U	N	U	20°U	U	20°U	N	D
V, fps	----	171	----	179	----	----	----	----	----	----
Turns for recovery	[c]$\frac{1}{2}$	[c]$4\frac{1}{2}$	[c]$1\frac{3}{4}$	$3\frac{1}{4}$, 4	$2\frac{1}{4}$	[c]$>3\frac{1}{4}$	$>2\frac{1}{2}$	$>3\frac{1}{2}$, [c]>3	----	[c]$1\frac{1}{2}$

Modification 6, normal loading

Ailerons	Against Full		Against $\frac{1}{3}$		Neutral				With $\frac{1}{3}$		With Full		
Elevator	N	D	U	20°U	U	20°U	N	D	U	20°U	U (a)	N (a)	D
V, fps	174	168	258	258	207	207	174	174	----	207	----	236	196
Turns for recovery	$2\frac{1}{4}$	$3\frac{1}{4}$	[c]$1\frac{3}{4}$	[c]$1\frac{1}{4}$	$1\frac{1}{4}$	[c]$1\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	[c]$2\frac{1}{4}$	[c]$2\frac{1}{4}$	[h]--	$1\frac{1}{2}$	$2\frac{1}{2}$

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[a]Oscillatory spin.
[b]Flat spin.
[c]Recovery attempted by rudder reversal from full with to 2/3 against the spin.
[d]Recovery attempted by simultaneous reversal of elevator and rudder.
[e]Recovery attempted by neutralization of elevator and movement of rudder from full with to 2/3 against.
[f]Wandering and oscillatory spin.
[g]Very steep spin.
[h]Model seems to recover after $1\frac{1}{2}$ turn, whips and reenters spin.

SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODELS OF THE BELL XP-63 AND P-63A-1-BE AIRPLANES - Continued

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the XP-63 model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Modification 6 and 7, normal loading							Landing condition, modification 6 and 7, normal loading							Inverted spins, landing condition, modification 6 and 7					
Ailerons	Against			Neutral		$\frac{1}{3}$ With		Against		Neutral		With			Against			With		
	Full	$\frac{1}{3}$						Full	$\frac{1}{3}$			$\frac{1}{3}$	Full		Full		$\frac{1}{3}$			
Elevator	U (g)	U	20°U (g)	U	20°U	N (i)	20°U (i)	N	20°U	U	N	20°U	N	D	U	15°D	20°U (g)	N	D	D (j)
V, fps	>325	258	230	264	226	230	230	158	----	207	158	----	236	----	----	207	>294	---	No spin	No spin
Turns for recovery	----	[c]$1\frac{1}{4}$	[c]$1\frac{1}{2}$	1	[c]$1\frac{3}{4}$	[c]$1\frac{3}{4}$	[c]2	$3\frac{3}{4}$	[c]$2\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{1}{2}$	[c]2	$1\frac{1}{2}$, $2\frac{1}{2}$	----	----	[c]---	----	---		

	Normal loading, modification 7, (left spins)													Normal loading, modification 7, (right spins)						
Ailerons	Against				Neutral				With					Against		Neutral			With	
	Full			$\frac{1}{3}$					$\frac{1}{3}$		Full								$\frac{1}{3}$	Full
Elevator	20°U	N	D	20°U	U	20°U	N	D	U (a)	20°U (a)	20°U	N (a)	D (a)	U	D	20°U (i)	U (a)	N (a)	20°U (f)	D
α, deg	31	50	48	46	42	45	47	50	44	46	40	38	38	----	----	35	28	26	34	----
ϕ, deg	1U	4U	4U	0	1D	1D	0	0	3D	2D	5D	8D	5D	----	----	3D	2D	0	3D	----
Ω, rps	0.46	0.48	0.50	0.41	0.44	0.40	0.47	0.49	0.46	0.41	0.47	0.54	0.54	----	----	0.40	0.60	0.65	----	----
V, fps	281	174	167	196	196	196	179	176	136	196	190	206	206	----	----	235	246	246	235	----
Turns for recovery	$\frac{1}{2}$	2	$2\frac{1}{2}$	[c]$1\frac{3}{4}$	2	2	$3\frac{1}{2}$	$5\frac{1}{2}$	[c]2	[c]2, [c]$2\frac{1}{2}$	>$2\frac{1}{2}$	$2\frac{1}{4}$	4, [k]$2\frac{1}{2}$	----	[k,l]$\frac{3}{4}$	[c]1	----	[k]1	[c]$1\frac{1}{2}$	[k,l]$1\frac{1}{4}$

	ΔI_X and $\Delta I_Z = 0.22 I_X$ Modification 7, (right spins)				ΔI_X and $\Delta I_Z = 0.22 I_X$ Modification 7, (left spins)				ΔI_X and $\Delta I_Z = -0.36 I_X$ Modification 7, (left spins)						ΔI_Y and $\Delta I_Z = 0.20 I_Y$ Modification 7, (left spins)						ΔI_Y and $\Delta I_Z = -0.20 I_Y$ Modification 7 (left spins)				
Ailerons	Neutral		$\frac{1}{3}$ With		Neutral		$\frac{1}{3}$ With		Against		$\frac{1}{3}$ Against		With		$\frac{1}{3}$ Against			$\frac{1}{3}$ With			Against			$\frac{1}{3}$ With	
Elevator	U (a)	D	20°U (f)	N	20°U	U	20°U	U (a)	20°U	D	20°U	U	20°U (i)	D	20°U	N	D	20°U (i)	N	D	U	N	D	20°U (a)	U (a)
α, deg	32	---	35	---	45	42	49	47	46	54	44	42	--	----	44	-	-	42	-	-	--	-	--	40	37
ϕ, deg	2D	---	2D	---	1D	0	2D	2D	5U	3U	0	1U	--	----	1U	-	-	3D	-	-	--	-	--	2D	2D
Ω, rps	----	---	----	---	0.39	0.41	0.39	----	----	----	0.39	0.42	--	----	----	-	-	----	-	-	--	-	--	----	---
V, fps	241	---	235	---	196	204	190	190	174	157	196	184	--	----	196	-	-	212	-	-	--	-	--	196	201
Turns for recovery	----	----	[c]$1\frac{1}{2}$	---	[c]2	$1\frac{1}{2}$, 2	[c,k]$3\frac{1}{4}$	[c]3	$1\frac{1}{4}$	$4\frac{3}{4}$	[c]$1\frac{3}{4}$	[c]$1\frac{3}{4}$	1	[k,l]1	[c]1, [c]$1\frac{1}{2}$	-	-	[c]2	-	-	--	-	--	[c]2, [c]$2\frac{1}{2}$	[c]2

[a]Oscillatory spin.
[c]Recovery attempted by rudder reversal from full with to 2/3 against the spin.
[f]Wandering and oscillatory spin.
[g]Very steep spin.
[i]Wandering spin.
[j]Flying condition.
[k]Visual observation.
[l]Recovery attempted before final steep attitude attained.

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SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODELS OF THE BELL XP-63 AND P-63A-1-BE AIRPLANES - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the XP-63 model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	ΔI_Y and ΔI_Z = -0.20 I_Y Modification 7, (right spins)				c.g. moved forward 0.05$\bar{c}$ Modification 7, (left spins)					c.g. moved back 0.10$\bar{c}$ Modification 7, (left spins)					Landing condition, normal loading, Modification 7, (left spins)						
Ailerons	Against		$\frac{1}{3}$ With		Neutral		$\frac{1}{3}$ With			Against		$\frac{1}{3}$ With			$\frac{1}{3}$ Against			Neutral		$\frac{1}{3}$ With	
Elevator	N	D	20°U (a)	D	U (a)	D	20°U	N	D	N	D	20°U	N	D	20°U	N	D	U (a)	D	20°U	D
α, deg	----	----	34	----	36	----	44	----	----	----	----	45	----	----	46	--	--	47	---	47	----
ϕ, deg	----	----	3D	----	1D	----	1D	----	----	----	----	3D	----	----	2U	--	--	0	---	1D	----
Ω, rps	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--	--	----	---	----	----
V, fps	----	----	220	----	212	----	196	----	----	----	----	196	----	----	174	--	--	174	---	174	----
Turns for recovery	----	----	[c]$1\frac{1}{2}$	----	$1\frac{3}{4}$	----	[c]$2\frac{1}{2}$	----	----	----	----	[c]$1\frac{3}{4}$	----	----	[c]$2\frac{3}{4}$	--	--	$2\frac{1}{2}$	---	[c]$3\frac{3}{4}$	----

	P-63A-1-BE, normal loading, left spins															P-63A-1-BE, wing gun loading, left spin						
Ailerons	Against					Neutral				With						Against			Neutral		$\frac{1}{3}$ With	
	Full				$\frac{1}{3}$					$\frac{1}{3}$		Full										
Elevator	U	20°U	N	D (m)	U	U (a)	20°U	N (a)	D	U (a)	20°U (a)	U	20°U (i)	N (a)	D	U	N	D	U (a)	N	20°U (a)	N
α, deg	---	----	----	47	30	38	39	44	46	33	43	---	----	40	43	No spin	No spin	No spin	42	50	46	---
ϕ, deg	---	----	----	5U	2D	1D	1D	0	0	3D	3D	---	----	5D	3D				2D	1D	4D	---
Ω, rps	---	----	----	0.49	0.46	0.48	0.44	0.48	0.51	0.49	0.42	---	----	0.52	0.51				0.51	0.51	0.47	---
V, fps	---	>293	>293	176	249	212	207	174	174	221	190	---	196	207	176				202	168	193	---
Turns for recovery	---	[k]$\frac{1}{2}$	[k]$\frac{1}{2}$	[n]2 [n]$2\frac{1}{2}$	[c]1	$1\frac{3}{4}$	[c]$1\frac{3}{4}$ [c]2	3 $3\frac{1}{2}$	[n]$3\frac{3}{4}$	[c]2 [c]$2\frac{1}{4}$	[c]2 [c]$2\frac{3}{4}$	---	[k]$3\frac{1}{2}$	$3\frac{1}{4}$ $3\frac{3}{4}$	[n]$3\frac{1}{4}$ [n]$5\frac{1}{2}$				$2\frac{3}{4}$	$3\frac{3}{4}$	[c]$>5\frac{1}{4}$	---

	P-63A-1-BE, vee tail installed, normal loading															P-63A-1-BE, vee tail installed, inverted spins, normal loading								
Ailerons	Against					Neutral					With					Against			Neutral			With		
Elerudder as elevator	U (o)	19°U (p)	N (q)	9D (r)	D (s)	U (ot)	19°U (ip)	N (qu)	9°D (ru)	D (sv)	U (ow)	19°U (p)	N (qu)	9°D (ru)	D (sw)	U (s)	N (q)	D (o)	U (s)	N (q)	D (o)	U (s)	N (q)	D (o)
α, deg	No spin	No spin	No spin	No spin	No spin	---	41	52	50	31 42	37	45	54	61	50	No spin	61	No spin	58	59	50	49	60	52
ϕ, deg						---	1D	15D 19U	3D 7U	1D	8D	4D	20D 12U	21D 7U	6D		3U		1U	0	2U	1D	2D	2D
Ω, rps						---	0.32	0.34	0.35	----	0.25	0.30	0.34	0.36	----		0.49		0.44	0.48	0.49	0.41	0.48	0.49
V, fps						---	229	198	198	249	235	221	187	177	198		171		177	171	177	179	171	171
Turns for recovery						---	1	1, $1\frac{1}{2}$ [x]2	1	1	∞	>3	$2\frac{1}{4}$ $>3\frac{3}{4}$	3	$>3\frac{1}{2}$		1 [x]$2\frac{1}{4}$		2	$1\frac{1}{2}$ [x]∞	∞	$>3\frac{1}{2}$	$3\frac{1}{2}$ [x]∞	∞

[a]Oscillatory spin.

[c]Recovery attempted by rudder reversal from full with to 2/3 against the spin.

[i]Wandering spin.

[k]Visual observation.

[m]Steeper type of spin also obtainable.

[n]Model goes into inverted flight upon recovery.

[o]Right rudder pedal 1/8 forward position. Recovery attempted by moving left rudder pedal to 1/8 forward position.

[p]Right rudder pedal 5/8 forward. Recovery attempted by moving left rudder pedal to 5/8 forward position.

[q]Right rudder pedal full forward. Recovery attempted by moving left rudder pedal full forward.

[r]Right rudder pedal 7/8 forward. Recovery attempted by moving left rudder pedal to 7/8 forward position.

[s]Right rudder pedal 1/2 forward. Recovery attempted by moving left rudder pedal to 1/2 forward position.

[t]Steep wide radius spin.

[u]Spin oscillatory in combined yaw and roll.

[v]Spin oscillatory in pitch.

[w]Wandering spin, oscillatory in roll.

[x]Recovery attempted by neutralizing rudder pedals.

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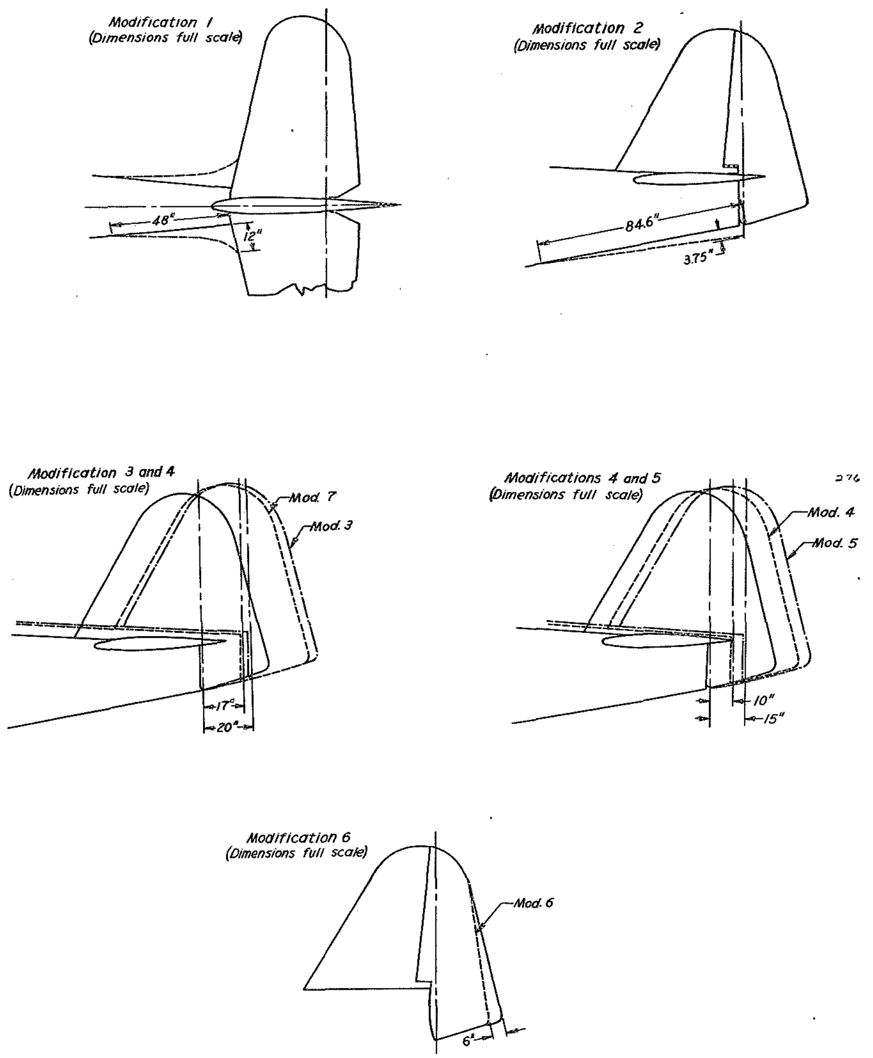

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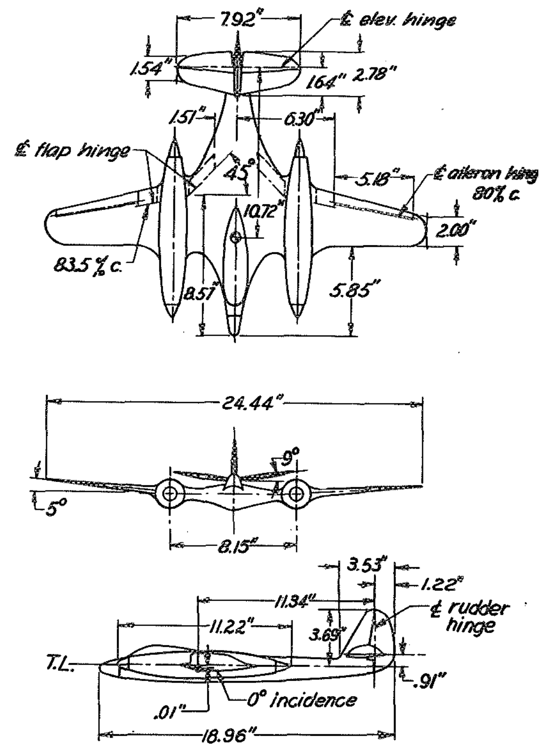
$\frac{1}{27}$-SCALE MODEL OF THE McDONNELL XP-67 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	55.00
L, ft	42.69
$\bar{c}$, in.	96.33
S, sq ft	414.00
A	7.30
L.E. $\bar{c}$ aft L.E. c_r, in.	0.00
S_h, sq ft	78.30
S_e, sq ft	36.10
S_v, sq ft	41.30
S_r, sq ft	24.60
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 15 D
δ_a, deg	30 U, 15 D
δ_a, deg $\left(\frac{1}{2}\text{ stick}\right)$	13 U, 9.5 D
δ_a, deg (revised)	15 U, 15 D
δ_a, deg (landing condition)	15 D
(Aileron deflections measured from drooped position)	
δ_f, deg	45 D
TDPF	484×10^{-6}
Landing gear	Tricycle



Model as tested.

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Mass Data

Normal Loading

W, lb	20,260
$x/\bar{c}$	0.154
$z/\bar{c}$	-0.002
I_X, slug-ft^2	41,989
I_Y, slug-ft^2	25,596
I_Z, slug-ft^2	63,625
Test altitude, ft	10,000
Alternate test altitude, ft	15,000
μ (at sea level)	11.61
μ' (10,000 ft)	15.73
μ'' (15,000 ft)	18.43

$\dfrac{I_X - I_Y}{mb^2}$	86×10^{-4}
$\dfrac{I_Y - I_Z}{mb^2}$	-200×10^{-4}
$\dfrac{I_Z - I_X}{mb^2}$	114×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun at a moderately flat angle of attack ($\alpha = 48^{\circ}$) and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{2}\text{ turns}\right)$. Setting the elevator down before reversing the rudder steepened the spin but had little effect upon recoveries. Simultaneous reversal of the rudder and elevator produced satisfactory recoveries, but merely neutralizing the rudder or reversal of the elevator alone did not give satisfactory recoveries. Setting the ailerons either partially or full with the spin had an adverse effect, whereas setting the ailerons full against the spin had a favorable effect.

Extending or retracting the mass along the wings (ΔI_X and $\Delta I_Z = 0.15\ I_X$, or ΔI_X and $\Delta I_Z = -0.10\ I_X$), extending the mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.40\ I_Y$), or a $0.05\bar{c}$ forward or a $0.10\bar{c}$ rearward movement of the center of gravity had little effect on the recovery characteristics of the model.

For the landing condition (landing gear extended, flaps 45° down, ailerons drooped 15°), the recovery characteristics of the model were similar to those obtained for the clean condition.

Satisfactory recoveries by rapid full rudder reversal were obtained from all inverted spins, except when the stick was forward and to the right.

For the normal loading clean condition increasing the spin altitude to 15,000 feet had a slight adverse effect upon the recovery characteristics of the model.

For the normal loading clean condition, modifying the horizontal tail and ailerons (with revised aileron deflections) (see sketches) had little effect on the general spin and recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{27}$-SCALE MODEL OF THE McDONNELL XP-67 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude of 10,000 feet]

Normal loading

Ailerons	Against			Neutral			With 1/2			With Full		
Elevator	U (a)	N	D	U	N	D (b)	U	N	D (b)	U	N	D
α, deg	33	No spin	No spin	48	32	32	49	44	36	53	50	47
Ø, deg	0			1D	1D	1U	3D	2D	2D	4D	3D	3D
Ω, rps	0.24			0.32	0.43	0.49	0.31	0.42	0.46	0.33	0.42	0.44
V, fps	255			212	252	240	205	215	234	198	198	198
Turns for recovery	1/2			1 1/2	1 3/4	[c]1 1/4, [c]2	2 1/4	>3 1/2	[c]3 1/4	>5 1/4	>4 1/4	[c]3 1/2

Effect of control manipulations on turns for recovery from elevator-up spins, normal loading

Recovery attempted by:	Ailerons Against	Ailerons Neutral	Ailerons With
Neutralization of rudder	3/4	>3 1/2	∞
Reversal of rudder and neutralization of elevator	1/4	1 3/4	>3
Simultaneous reversal of rudder and elevator	1/4	1 1/4	2 1/2
Reversal of elevator	1/4	>5 3/4	∞

ΔI_X and $\Delta I_Z = 0.15 I_X$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D (b)	U	N	D
α, deg	40	No spin	No spin	50	43	37	56	53	51
Ø, deg	1D			1D	0	0	3D	3D	3D
Ω, rps	0.24			0.30	0.40	0.46	0.34	0.41	0.44
V, fps	255			212	219	237	198	194	190
Turns for recovery	1/4			1 1/2	2 1/2	[c]1 3/4	>7	>5	[d]4 3/4

ΔI_X and $\Delta I_Z = -0.10 I_X$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D (b)	U	N	D
α, deg	37	No spin	No spin	49	33	32	54	51	46
Ø, deg	1D			1D	1D	1D	4D	4D	4D
Ω, rps	0.24			0.29	0.40	0.48	0.32	0.40	0.44
V, fps	255			212	263	240	202	198	198
Turns for recovery	1/4			1 1/2	1 3/4	[d]1 1/2	3 1/4, 4 1/4	>3	[c]3

ΔI_Y and $\Delta I_Z = 0.40 I_Y$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	49	29	No spin	52	44	41	58	53	48
Ø, deg	1U	2U		2D	2D	1D	4D	4D	5D
Ω, rps	0.24	0.33		0.26	0.34	0.38	0.30	0.36	0.37
V, fps	219	270		208	212	219	205	198	194
Turns for recovery	1	3/4		1 3/4	2	[d]2	>3 3/4	>3	[c]3

c.g. moved forward $0.05\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	32	No spin	No spin	46	32	32	56	52	50
Ø, deg	0			1D	1D	0	4D	3D	3D
Ω, rps	0.24			0.31	0.44	0.51	0.36	0.42	0.44
V, fps	263			219	255	244	194	194	187
Turns for recovery	1/2			1 1/2	1 1/2	[d]1 1/2	>5	>4	[c]3, [c]4

c.g. moved back $0.10\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U	N (e)	D	U	N	D	U	N	D
α, deg	48	--	No spin	52	41	31	59	52	52
Ø, deg	2U	--		2D	1D	1D	3D	3D	3D
Ω, rps	0.20	--		0.24	0.34	0.41	0.31	0.37	0.39
V, fps	219	--		205	229	248	194	198	198
Turns for recovery	1/2	--		1 1/2	1 1/2	[d]1 3/4	>3	>3 1/2	>3 3/4

Landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N (f)	D	U (f)	N	D
α, deg	49	No spin	No spin	45	27	28	26	39	31
Ø, deg	3U			3D	1D	2D	14D	6D	6D
Ω, rps	0.29			0.27	0.38	0.45	0.27	0.39	0.45
V, fps	212			219	259	255	278	226	244
Turns for recovery	1 3/4			1 1/2	1 1/2, 2 1/4	[c]1 3/4	3	>3 1/2	[c]2 1/2

Landing gear extended, flaps down 45°, normal loading

Ailerons	Neutral			With		
Elevator	U	N	D	U	N	D
α, deg	43	----	----	57	41	-
Ø, deg	3D	----	----	4D	5D	-
Ω, rps	0.27	----	----	0.34	0.41	-
V, fps	221	----	----	198	219	-
Turns for recovery	1 1/4	----	----	>3 3/4	2 3/4	-

Inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	31	No spin	No spin	41	40	37
Ø, deg				1D			5D	4D	3D
Ω, rps				0.38			0.37	0.42	0.50
V, fps				270			229	219	234
Turns for recovery				1			>2 1/2	[g]1 1/4	[h]1 1/4

Normal loading, equivalent test altitude, 15,000 ft

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D (b)	U	N	D
α, deg	33	----	No spin	49	39	37	55	49	48
Ø, deg	0	----		2D	0	0	4D	4D	4D
Ω, rps	---	----		0.31	0.45	0.49	0.35	0.45	0.47
V, fps	278	>435		234	248	263	219	219	223
Turns for recovery	1/2	----		2 1/4	3	[c]2 1/2	>5 1/2	>5	[c]5 1/2

Modified horizontal tail, modified ailerons (δ_a, 15°U, 15°D) normal loading

Ailerons	Against			Neutral			With 1/2			With Full		
Elevator	U (a)	N	D	U	N	D	U	N	D	U (i)	N	D (b)
α, deg	38	No spin	No spin	45	34	No spin	----	----	----	47	41	34
Ø, deg	0			2D	2D		----	----	----	7D	6D	4D
Ω, rps	0.28			0.29	0.44		----	----	----	0.34	0.43	0.48
V, fps	263			223	252		212	248	240	212	219	215
Turns for recovery	1/2			1 1/2	2 1/4		2 3/4	>4	2 1/2	>3	>4	[c]3

Modified horizontal tail, modified ailerons (δ_a, 15°U, 15°D), landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D (b)	U	N	D (b)	U (i)	N	D
α, deg	50	38	31	47	37	32	30	38	32
Ø, deg	0	2U	2U	2d	0	1D	9D	4D	3D
Ω, rps	0.33	0.43	0.48	0.32	0.42	0.48	0.25	0.43	0.48
V, fps	205	223	240	212	219	240	256	219	229
Turns for recovery	>3 1/4	2 3/4	[d]2 1/4	1 3/4, 2 1/4	2 3/4	[c]2	1/2	2 3/4, 3 1/4	[c]3 1/2, [c]4

[a] Large radius of spin.
[b] Oscillatory spin.
[c] Model goes into an inverted spin upon recovery.
[d] Model goes into an inverted flight upon recovery.
[e] Steep and wandering spin.
[f] Wandering and oscillatory spin.
[g] Model goes into an erect spin upon recovering.
[h] Model recovers in an erect position.
[i] Wandering spin.

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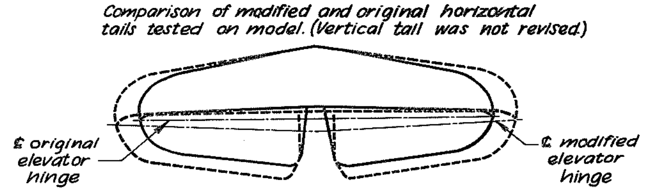

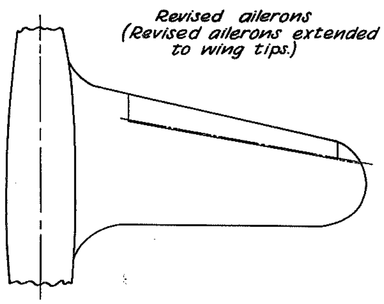

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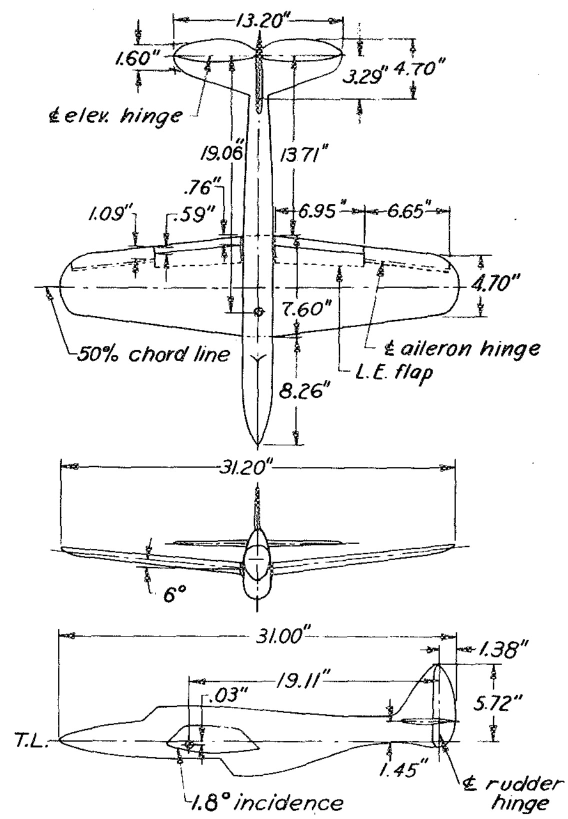
$\frac{1}{20}$-SCALE MODEL OF THE REPUBLIC XP-69 AIRPLANE



Model as tested.

Dimensional Data

(Full Scale)

b, ft	52.00
L, ft	51.67
$\bar{c}$, in.	124.00
S, sq ft	508.00
A	5.32
L.E. $\bar{c}$ aft L.E. c_r, in.	0
S_h, sq ft	102.00
S_e, sq ft	28.76
S_v, sq ft	49.50
S_r, sq ft	18.67
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	20 U, 20 D
δ_f, deg	40 D
TDPF	590×10^{-6}
Landing gear	Conventional

Mass Data

Normal Loading

W, lb	18,000
$x/\bar{c}$	0.250
$z/\bar{c}$	-0.014
I_X, slug-ft^2	26,446
I_Y, slug-ft^2	49,174
I_Z, slug-ft^2	73,746
Test altitude, ft	12,000
Alternate test altitude, ft	30,000
μ (at sea level)	8.90
μ' (12,000 ft)	12.85
μ' (30,000 ft)	23.75

$\frac{I_X - I_Y}{mb^2}$	-150×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-162×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	312×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model spun steeply ($\alpha = 28^{\circ}$) and recoveries by either reversing or neutralizing the rudder or simultaneously neutralizing or reversing the rudder and elevator were satisfactory. There was no appreciable effect of aileron or elevator settings on the satisfactory recovery characteristics of the model.

Extending or retracting mass along the wings (ΔI_X and $\Delta I_Z = \pm 0.30\ I_X$), retracting mass along the fuselage (ΔI_Y and $\Delta I_Z = -0.20\ I_Y$), or moving the center of gravity $0.10\bar{c}$ back from its normal position did not appreciably alter the recovery characteristics of the model.

For the landing condition (landing gear extended, flaps down 40°), the recovery characteristics of the model became worse inasmuch as recoveries became very slow from aileron-against spins.

Recoveries from all inverted spins were satisfactory by rapid full rudder reversal.

Increasing the test altitude from 12,000 feet to 30,000 feet led to flat spins from which recoveries were unsatisfactory by rapid full rudder reversal.

SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF REPUBLIC XP-69 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

Normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N (b)	D
α, deg	30	34	45	28	24	28	24	----	17
ϕ, deg	4U	6U	5U	6D	0	1D	16D	----	3D
Ω, rps	0.40	0.44	0.42	0.46	0.61	0.57	0.60	----	0.97
V, fps	278	246	207	294	311	265	272	>425	399
Turns for recovery	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	1	----	----	$\frac{1}{2}$

Recoveries attempted by various control manipulations, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
Neutralizing rudder	$\frac{1}{2}$	2	3	$1\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{4}$	----	----	$1\frac{1}{4}$
Releasing rudder	$1\frac{1}{4}$	2	∞	$1\frac{1}{2}$	$1\frac{1}{4}$	∞	(c)	(c)	
Simultaneous reversal of rudder and elevator	$\frac{1}{2}$	---	---	$\frac{3}{4}$	----	----	----	----	----
Simultaneous neutralization of rudder and elevator	$\frac{3}{4}$	---	---	$1\frac{1}{2}$	----	----	----	----	----
Reversal of elevator	∞	----	----	∞	----	----	----	----	----

ΔI_X and ΔI_Z = 0.30 of I_X

Ailerons	Against			Neutral			With		
Elevator	U (d)	N	D	U (e)	N	D	U (e)	N (b)	D (b)
α, deg	---	No spin	38	----	31	34	-	--	---
ϕ, deg	---		6U	---	1D	0	-	--	---
Ω, rps	--		0.44	---	0.50	0.48	--	---	---
V, fps	--		245	265	265	245	--	>375	>400
Turns for recovery	--		1	---	1	$1\frac{1}{2}$	--	---	---

ΔI_X and ΔI_Z = -0.30 of I_X

Ailerons	Against			Neutral				With		
Elevator	U (f)	N	D	U	N	D (g)	D (g)	U (b)	N (b)	D (b)
α, deg	23	46	46	17	24	37	26	--	--	--
ϕ, deg	3U	7U	7U	4D	1D	1U	0	h	--	--
Ω, rps	0.36	0.40	0.41	0.48	0.62	0.44	0.58	---	---	---
V, fps	284	201	197	339	298	213	268	>375	>375	>375
Turns for recovery	$\frac{1}{2}$	$1\frac{1}{2}$, 2	$1\frac{1}{4}$, $1\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1, $1\frac{3}{4}$	1	---	---	---

ΔI_Y and ΔI_Z = -0.20 of I_Y

Ailerons	Against			Neutral			With		
Elevator	U (i)	N	D	U	N	D	U (e)	N (b)	D
α, deg	-	No spin	38	27	29	31	--	---	16
ϕ, deg	-		5U	5D	3D	2D	--	---	2U
Ω, rps	--		0.49	0.46	0.53	0.58	-	---	1.03
V, fps	--		226	265	272	245	--	>400	360
Turns for recovery	--		1	1	1	$1\frac{1}{4}$	--	----	1

c.g. moved back 0.10$\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (e)	N (b)	D (b)
α, deg	No spin	45	44	33	33	36	--	----	----
ϕ, deg		6U	6U	8D	5D	1D	--	----	----
Ω, rps		0.35	0.38	0.32	0.41	0.43	--	----	----
V, fps		213	210	258	245	226	--	>400	>375
Turns for recovery		$1\frac{1}{4}$	$1\frac{1}{2}$, 2	1	$1\frac{1}{4}$	$1\frac{1}{2}$	--	----	----

Landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (ak)	N	D	U	N (b)	D
α, deg	42	50	49	----	40	42	No spin	---	No spin
ϕ, deg	5U	4U	3U	----	1D	1D		---	
Ω, rps	0.34	0.38	0.39	----	0.40	0.41		---	
V, fps	204	179	176	----	204	194		>350	
Turns for recovery	$2\frac{1}{4}$	$6\frac{1}{4}$	$5\frac{1}{4}$	----	2	$2\frac{3}{4}$		---	

Inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D (a)	U (a)	N (b)	D (a)
α, deg	No spin	No spin	No spin	----		---	---	----	----
ϕ, deg				----		---	---	----	----
Ω, rps				---		---	---	----	----
V, fps				319		272	304	332	>340
Turns for recovery				$\frac{1}{2}$		---	(l)	$\frac{1}{2}$, [m]$1\frac{1}{2}$, [m]$2\frac{1}{2}$	----

Normal loading - 30,000 feet equivalent test altitude

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (e)	N (b)	D (b)
α, deg	59	55	59	62	52	52	----	----	----
ϕ, deg	3U	2U	1U	2D	1D	2D	----	----	----
Ω, rps	0.33	0.37	0.38	0.35	0.36	0.38	----	----	----
V, fps	265	265	258	255	265	272	272	>336	>371
Turns for recovery	2, $2\frac{3}{4}$	$2\frac{1}{2}$	3	$3\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{1}{2}$	----	----	----

[a]Too oscillatory to test.
[b]High rate of descent.
[c]High rate of descent model will not spin with free rudder.
[d]Radius of spin increases, model probably will not continue to spin.
[e]Too wandering to test completely.
[f]Oscillatory spin.
[g]Two types of spin.
[h]Inboard wing down.
[i]Large radius of spin, model may not spin.
[k]Steep spin.
[l]Model will not spin when launched with rudder neutral or against the spin.
[m]Recovery attempted by neutralizing rudder.

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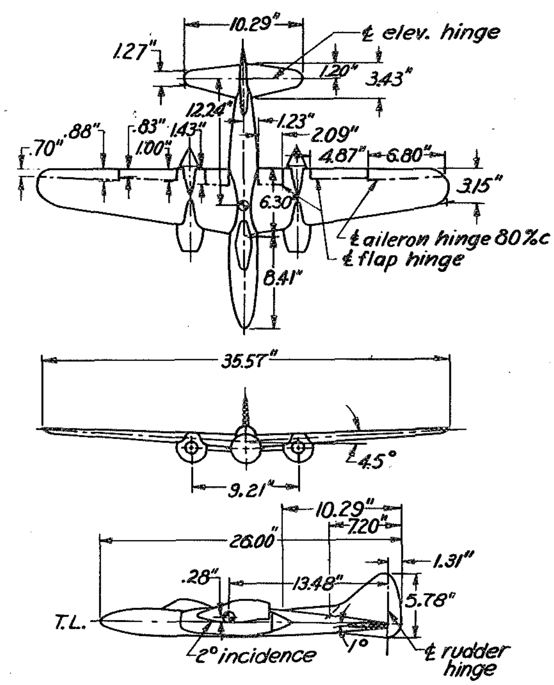
$\frac{1}{28}$-SCALE MODEL OF THE CURTISS-WRIGHT XP-71 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	83.00
L, ft	60.67
$\bar{c}$, in.	137.69
S, sq ft	903.20
A	7.64
L.E. $\bar{c}$ aft L.E. c_r, in.	38.71
S_h, sq ft	131.06
S_e, sq ft	38.88
S_v, sq ft	120.15
S_r, sq ft	31.84
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 10 D
δ_a, deg	$31\frac{1}{2}$ U, $13\frac{1}{2}$ D
δ_f, deg	60 D
TDPF	66×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	39,578
$x/\bar{c}$	0.258
$z/\bar{c}$	−0.058
I_X, slug-ft^2	155,161
I_Y, slug-ft^2	105,410
I_Z, slug-ft^2	260,571
Test altitude, ft	15,000
Alternate test altitude, ft	25,000
μ (at sea level)	6.89
μ' (15,000 ft)	10.97
μ'' (25,000 ft)	15.38

$\frac{I_X - I_Y}{mb^2}$	59×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-184×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	125×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model oscillated in pitch and roll, and the angle of attack of the spin ranged from 31° and 40°. Satisfactory recoveries were obtained only by simultaneous rapid full reversal of rudder and elevator or by rapid full reversal of rudder in conjunction with neutralizing the elevator. With the elevator either neutral or down, satisfactory recoveries by rapid full rudder reversal were obtained only from the steeper of two types of spin obtainable. Setting the ailerons with the spin had a detrimental effect on the recovery characteristics of the model, whereas setting the ailerons partly or fully against the spin enabled satisfactory recoveries to be obtained by rudder alone.

Extending or retracting mass along the wings (ΔI_X and $\Delta I_Z = 0.85\ I_X$ or $-0.30\ I_X$) or extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.20\ I_Y$), moving the center of gravity ($\pm 0.10\bar{c}$) forward or back from its normal position, lowering the flaps 60°, or extending the landing gear did not appreciably alter the recovery characteristics of the model.

Increasing the spin altitude to 25,000 feet had a detrimental effect on the recovery characteristics of the model and recoveries by rudder reversal alone were satisfactory only with the ailerons set against the spin.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

The addition of fin and rudder area below the original tail (modifications 1, 2, and 3) improved the recovery characteristics of the model; the addition of modification 2 enabled satisfactory recoveries to be obtained by rapid full rudder reversal from all elevator-up spins.

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SPIN DATA OBTAINED WITH THE $\frac{1}{28}$-SCALE MODEL OF THE CURTISS-WRIGHT XP-71 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude of 15,000 feet]

	Normal loading																						ΔI_X and $\Delta I_Z = 0.85I_X$								
Ailerons	Against							Neutral					With										Against			Neutral			With		
	Full			15°U 10°D			5°U 4°D						10°U 7.7°D		15°U 10°D				Full												
Elevator	U (ab)	N	D	N (ac)	N (ac)	D	U	U (a)	N (c)	N (ac)	D (c)	D (c)	U	20°U	N (c)	N (c)	D (c)	D (cd)	U	N	D (c)	D (c)	U (b)	N	D	U (a)	N (a)	D	U	N	D
α, deg	-	No spin	No spin	53 67	17 37	No spin	-	31 40	60	21 45	60	-	36	40	-	30	60	-	41	36	62	35	-	No spin	No spin	30 43	-	No spin	47	43	54
ϕ, deg	-	No spin	No spin	5U 9D	15U 6D	No spin	-	11U 8D	1D	10U 5D	1D	-	1D	2D	-	3D	1U	-	8D	5D	1D	4D	-	No spin	No spin	8U 15D	-	No spin	6D	3D	3D
Ω, rps	-	No spin	No spin	0.28	0.30	No spin	-	0.25	0.28	0.30	0.22	-	0.20	0.19	-	0.28	0.29	-	0.20	0.26	0.29	0.29	-	No spin	No spin	0.21	-	No spin	0.19	0.26	0.29
V, fps	-	No spin	No spin	211 208	344	No spin	305	305	215	321	208	313	298	298	282	313	211	-	268	276	215	282	-	No spin	No spin	305	238 321	No spin	275	279	238
Turns for Recovery	[e]$\frac{1}{4}$	No spin	No spin	$2\frac{1}{4}$ $1\frac{3}{4}$	$\frac{1}{2}$	No spin	$1\frac{1}{2}$	>4 [e]∞ [f]>3 [g]$\frac{1}{2}$ [h]$\frac{1}{2}$	3	$1\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{1}{2}$	[i]>3 [j]$\frac{3}{4}$	[i]>2 [j]$\frac{3}{4}$	>2	$1\frac{1}{2}$ 2	$3\frac{1}{4}$	-	>9 [e]∞ [f]∞ [g]1	∞	$7\frac{1}{2}$	2	-	No spin	No spin	∞ [g]$\frac{1}{2}$	-	No spin	∞ [gk]$\frac{1}{2}$	∞	7

	ΔI_X and $\Delta I_Z = -0.30I_X$									ΔI_Y and $\Delta I_Z = 0.20I_Y$													c.g. moved forward $0.10\bar{c}$								
Ailerons	Against			Neutral			With			Against			Neutral					With					Against			Neutral			With		
Elevator	U (ab)	N (a)	D	U	N	D	U	N	D	U	N	D	U	N (c)	N (c)	D (c)	D (c)	U	N (c)	N (c)	D (c)	D (c)	U	N	D	U (a)	N	D	U	N	D
α, deg	-	19 43	No spin	32	28	27	40	31	30	No spin	No spin	No spin	39	49	31	59	30	54	56	-	58	-	No spin	No spin	No spin	30	28	No spin	41	34	59
ϕ, deg	-	24U 3D	No spin	2U	4U	4U	8D	7D	7D	No spin	No spin	No spin	0	2U	6U	1U	5U	6D	3D	-	3D	-	No spin	No spin	No spin	10U 1U	5U	No spin	4D	2D	1D
Ω, rps	-	0.27	No spin	0.22	0.30	0.34	0.19	0.26	0.30	No spin	No spin	No spin	0.19	0.26	0.27	0.27	0.31	0.19	0.25	0.23	0.26	0.26	No spin	No spin	No spin	0.26	0.37	No spin	0.26	0.32	0.33
V, fps	321	321	No spin	313	306	321	275	306	298	No spin	No spin	No spin	290	216	322	216	322	250	216	298	223	290	No spin	No spin	No spin	322	322	No spin	282	282	216
Turns for Recovery	-	$\frac{1}{2}$	No spin	[g]$\frac{3}{4}$	1	$\frac{3}{4}$	2 [g]1	$1\frac{1}{2}$ $2\frac{1}{4}$	$1\frac{1}{4}$ $1\frac{3}{4}$	No spin	No spin	No spin	>$1\frac{1}{2}$	$2\frac{3}{4}$	1	$2\frac{3}{4}$	1	>$3\frac{1}{2}$	∞	[k]4	∞	$1\frac{1}{2}$	No spin	No spin	No spin	>2	1	No spin	∞	2	4

	c.g. moved back $0.10\bar{c}$											Landing gear extended, normal loading									Flaps down 60° normal loading								
Ailerons	Against			Neutral					With			Against			Neutral			With			Against			Neutral			With		
Elevator	U	N (l)	D	U	N (c)	N (c)	D (c)	D (c)	U (a)	N	D (l)	U (a)	N	D	U (a)	N (a)	D (l)	U	N	D	U	N	D	U (l)	N (l)	D	U	N	D
α, deg	No spin	-	No spin	51	62	35	31	60	57 67	43	36	-	No spin	No spin	36	26 38	-	41	38	35	No spin	No spin	No spin	-	-	30	43	38	36
ϕ, deg	No spin	-	No spin	6D	1D	2U	0	1U	3U 11D	9D	8D	-	No spin	No spin	14U 10D	4U 9D	-	5D	5D	6D	No spin	No spin	No spin	-	-	1D	5D	5D	4D
Ω, rps	No spin	-	No spin	0.10	0.16	0.16	-	0.24	0.14	0.18	0.18	-	No spin	No spin	0.20	0.23	-	0.19	0.24	0.27	No spin	No spin	No spin	-	-	0.26	0.18	0.23	0.25
V, fps	No spin		No spin	252	230	306	322	222	238	-	276	-	No spin	No spin	290	306	282	252	290	298	No spin	No spin	No spin	252	282	282	252	260	260
Turns for Recovery	No spin	-	No spin	$\frac{1}{4}$	$3\frac{1}{4}$ $5\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{4}$	$1\frac{1}{2}$ 3	$1\frac{1}{4}$	$1\frac{3}{4}$	-	No spin	No spin	$\frac{3}{4}$	1	-	>3	2 $2\frac{1}{2}$	$1\frac{3}{4}$ $2\frac{1}{2}$	No spin	No spin	No spin	$1\frac{1}{4}$ $1\frac{1}{2}$	$1\frac{1}{4}$ $1\frac{1}{2}$	$1\frac{1}{4}$ $1\frac{3}{4}$	>$2\frac{1}{2}$	>5	∞

[a]Oscillatory spin, range of values or average values given.
[b]Large radius of spin.
[c]Two types of spin.
[d]Steep spin.
[e]Recovery attempted by full elevator reversal.
[f]Recovery attempted by simultaneous neutralization of rudder and elevator.
[g]Recovery attempted by simultaneous full reversal of rudder and elevator.
[h]Recovery attempted by simultaneous reversal of rudder and neutralization of elevator.
[i]Recovery attempted by movement of the rudder to 20° against the spin.
[j]Recovery attempted by simultaneous movements of rudder to 20° against the spin and neutralization of elevator.
[k]Visual observation.
[l]Wandering spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{28}$-SCALE MODEL OF THE CURTISS-WRIGHT XP-71 AIRPLANE – Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude of 15,000 feet]

	Landing condition, normal loading									Inverted spins, normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N (a1)	D	U (a)	N (a)	D (a)	U	N (a)	D (a)	U	N	D	U	N	D	U	N	D (a)
α, deg	No spin	20 33	25	31	21 35	20 50	50	29 42	21 50	No spin	No spin	No spin	34	No spin	No spin	47	44	29 52
Ø, deg		4U	3U	4U 5D	7U 11D	11U 16D	5D	2D 10D	2D 18D				1D			3D	5D	0 13D
Ω, rps		0.28	0.28	0.43	0.29	0.27	0.19	0.25	0.26				0.24			0.24	0.26	0.27
V, fps		313	291	268	283	283	230	268	260				322			252	252	275
Turns for Recovery		1	$1\frac{1}{4}$	2	1 $1\frac{1}{2}$	2 $>2\frac{3}{4}$	>4	∞	$2\frac{1}{2}$ 7				$\frac{1}{2}$			1	1	1

	Normal loading, equivalent test altitude 25,000 feet									
Ailerons	Against			Neutral			With			
Elevator	U (d)	N	D	U	N	D	U	N	D (c)	D (c)
α, deg	-	66	No spin	59	59	70	48	38	61	37
Ø, deg	-	2U		1D	1U	1D	4D	4D	1D	5D
Ω, rps	-	0.33		0.24	0.30	0.36	0.21	0.28	0.31	0.30
V, fps	-	260		275	260	234	305	329	252	329
Turns for Recovery	-	2 3		>3	$2\frac{1}{2}$ 3	∞	$>2\frac{1}{2}$	>4	∞	$>2\frac{1}{2}$

Effect of tail modification on turns for recovery
Elevator up spins

Model condition		Turns for recovery		
		Ailerons		
Modification	Loading	Neutral	1/3 with	Full with
1	Normal	$\frac{1}{2}$	-	-
2	Normal	$\frac{1}{4}$	$\frac{1}{2}$, 1	2
3	Normal	$\frac{1}{2}$	2, 3	> 3
2	ΔI_X and $\Delta I_Z = 0.85 I_X$	1, $1\frac{1}{2}$	-	$>2\frac{1}{2}$
3	ΔI_X and $\Delta I_Z = 0.85 I_X$	> 3	-	-

[a] Oscillatory spin, range of values or average values given.
[c] Two types of spin.
[d] Steep spin.
[1] Wandering spin.

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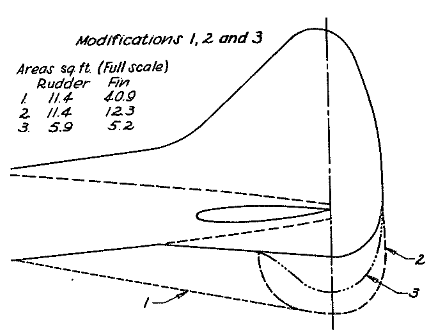
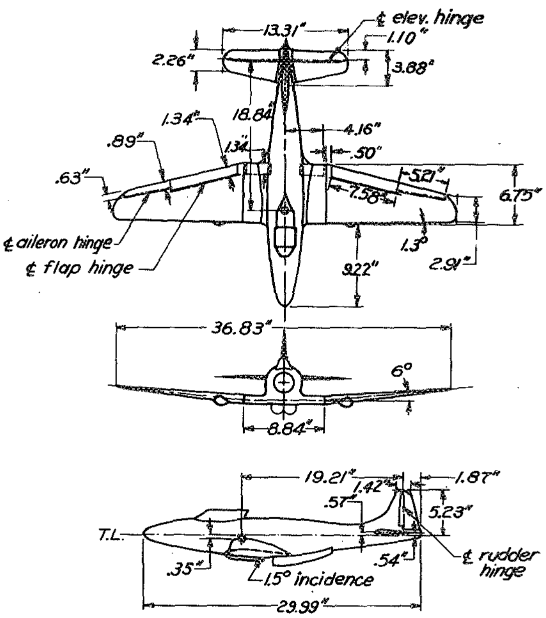


$\frac{1}{16}$-SCALE MODEL OF THE FISHER BODY DETROIT DIVISION XP-75 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	49.06
L, ft	40.00
$\bar{c}$, in.	89.78
S, sq ft	342.00
A	7.04
L.E. $\bar{c}$ aft L.E. c_r, in.	1.50
S_h, sq ft	70.76
S_e, sq ft	18.62
S_v, sq ft	22.45
S_r, sq ft	9.92
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 30 D
	25 U, 25 D
δ_a, deg	$18\frac{3}{4}$ U, $18\frac{3}{4}$ D
δ_f, deg	$42\frac{1}{2}$ D
TDPF	4.2×10^{-6}
Landing gear	Conventional



Model as tested.

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Mass Data

	Loading Normal	Loading Alternate
W, lb	11,885	14,957
$x/\bar{c}$	0.279	0.288
$z/\bar{c}$	0.062	0.105
I_X, slug-ft^2	10,124	16,610
I_Y, slug-ft^2	16,800	17,165
I_Z, slug-ft^2	25,837	32,100
Test altitude, ft	15,000	
μ (at sea level)	9.25	11.65
μ' (at 15,000 ft)	14.71	18.56

	Loading Normal	Loading Alternate
$\frac{I_X - I_Y}{mb^2}$	-75×10^{-4}	-5×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-102×10^{-4}	-133×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	177×10^{-4}	138×10^{-4}

Résumé of Model Test Results

The results indicated that for the normal loading, clean condition recoveries of the model by rapid full rudder reversal would be unsatisfactory except when the ailerons were set full with the spin. A moderate extension of mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$), or movement of the center of gravity rearward $0.10\bar{c}$ from its normal position had no appreciable effect on the recovery characteristics.

In order to improve the recovery characteristics of the model, various tail modifications were investigated (modifications 1 to 11). For the normal loading, clean condition, modification 1 (horizontal tail moved rearward 17 inches, full scale, and raised 7 inches, full scale, from its original position, in conjunction with the addition of a ventral fin, 8 inches deep) was very effective and the results indicated that satisfactory recoveries by rapid full rudder reversal would generally be obtained.

For the alternate loading condition (weight in the wing greatly increased) none of the modifications (modifications 1 to 11) led to satisfactory recovery characteristics.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE FISHER BODY DETROIT DIVISION XP-75 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading											
Ailerons	Against $18\frac{3}{4}^{\circ}$U, $10\frac{3}{4}^{\circ}$D					Neutral				With $18\frac{3}{4}^{\circ}$U, $10\frac{3}{4}^{\circ}$D		
Elevator	U (ab)	U (b)	N (ab)	N (b)	D	U (b)	U (ab)	N (a)	D	U (a)	N	D
α, deg	37 29	60 34	51	60	54	---	---	39	53	----	----	33
∅, deg	10D 3U	4U 10D	1U	0	2U	---	---	1D	0	----	----	5D
Ω, rps	0.38	0.46	0.46	0.51	0.47	---	---	0.44	0.48	----	----	0.65
V, fps	315	180	180	249	194	193	332	237	176	>309	>379	266
Turns for recovery	3 2	>5	∞	$2\frac{1}{2}$	∞	∞	>3	>4	∞	[c]$>1\frac{1}{4}$	[c]$\frac{1}{2}$ [c]1	2

	Normal loading, rudder-against spins									Landing condition, normal loading						
Ailerons	Against $18\frac{3}{4}^{\circ}$U, $10\frac{3}{4}^{\circ}$D			Neutral			With $18\frac{3}{4}^{\circ}$U, $10\frac{3}{4}^{\circ}$D			Against 25°U, 25°D		Neutral		With 25°U, 25°D		
Elevator	U (a)	N	D	U	N	D	U	N	D	N	D	D (b)	D (ab)	U (a)	N	D
α, deg	---	---	----	No spin	No spin	No spin	No spin	No spin	No spin	64	64	56	23	--	--	No spin
∅, deg	---	---	----							0	3D	2D	1D	--	--	
Ω, rps	---	---	----							0.45	0.47	0.45	0.59	--	--	
V, fps	---	335	348							168	174	168	249	--	--	
Turns for recovery	[de]>7	---	----							∞	∞	∞	$\frac{1}{2}$	--	--	

	Modification 1, normal loading								
Ailerons	Against 25°U, 25°D			Neutral			With 25°U, 25°D		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	----	----	34	----	27	28	----	----	----
∅, deg	----	----	4U	----	5D	2D	----	----	----
Ω, rps	----	----	0.47	----	0.53	0.55	----	----	----
V, fps	309	252	231	>272	278	254	354	>367	>367
Turns for recovery	[e]1	2 3	$2\frac{3}{4}$	[c]$>1\frac{1}{2}$	1	$1\frac{1}{2}$	$>1\frac{1}{2}$	[e]$\frac{3}{4}$	[c]$\frac{1}{2}$

	Modification 1 without ventral fin, normal loading									
Ailerons	Against 25°U, 25°D				Neutral			With 25°U, 25°D		
Elevator	U	N	D (b)	D (ab)	U	N	D	U (a)	N	D
α, deg	----	----	31	33	----	-	----	--	-	----
∅, deg	----	----	1U	1U	----	-	----	--	-	----
Ω, rps	----	----	0.44	0.50	----	-	----	--	-	----
V, fps	278	254	185	231	334	-	290	--	-	>358
Turns for recovery	$1\frac{1}{2}$	2	∞	$3\frac{1}{4}$	$>1\frac{1}{2}$	-	$1\frac{1}{2}$	--	-	----

	Modification 2, normal loading													
Ailerons	Against 25°U, 25°D					Neutral					With 25°U, 25°D			
Elevator	U (f)	U (f)	N	D (b)	D (b)	U (af)	U (f)	N	D (b)	D (b)	U (af)	U (f)	N (a)	D
α, deg	27 40	---	38	38	34	----	---	32	---	32	----	----	---	----
∅, deg	----	---	2U	2U	2D	----	---	3D	---	4U	----	----	---	----
Ω, rps	----	---	0.44	0.46	0.53	----	---	0.50	0.56	0.60	----	----	---	----
V, fps	290	249	234	216	237	323	249	252	243	257	249	260	>367	>367
Turns for recovery	$1\frac{1}{4}$	[g]1 [g]$\frac{1}{2}$	3	5	$1\frac{1}{2}$	>2	[g]1 [g]$1\frac{1}{2}$	4	$2\frac{1}{2}$	$2\frac{1}{2}$	>2	[g]$1\frac{1}{2}$	[c]1 [c]$\frac{1}{2}$	----

	Modification 3, normal loading					
Ailerons	Against $18\frac{3}{4}^{\circ}$U, $10\frac{3}{4}^{\circ}$D		Neutral		With $18\frac{3}{4}^{\circ}$U, $10\frac{3}{4}^{\circ}$D	
Elevator	N	D	N	D (a)	N	D
α, deg	29	45	30	32	---	26
∅, deg	0	2U	5D	3D	---	6D
Ω, rps	0.59	0.47	---	----	---	0.66
V, fps	272	199	315	243	335	269
Turns for recovery	1	∞	[c]2	$1\frac{3}{4}$	[c]$\frac{3}{4}$	[h]2

	Modification 4, normal loading									
Ailerons	Against 25°U, 25°D			Neutral				With 25°U, 25°D		
Elevator	U (a)	N	D	U (a)	N	D (b)	D (b)	U (a)	N	D
α, deg	30 39	45	52	----	30	44	30	----	----	23
∅, deg	4U 6D	1U	2U	----	2D	2D	1D	----	----	5D
Ω, rps	----	0.44	0.46	----	0.63	0.47	----	----	----	0.85
V, fps	315	203	185	>367	328	185	237	303	>367	291
Turns for recovery	$\frac{3}{4}$ $1\frac{1}{2}$	∞	∞	>[c]$2\frac{1}{2}$ [c]2 [c]1	2	∞	$3\frac{1}{2}$ 2	$>3\frac{1}{2}$ >2	[c]1	$1\frac{1}{2}$ 1

	Alternate loading c.g. moved forward 0.06$\bar{c}$								
Ailerons	Against 25°U, 25°D			Neutral			With 25°U, 25°D		
Elevator	U (a)	N	D	U	N	D	U (a)	N	D
α, deg	43 33	55	55	43	52	55	56 35	48	52
∅, deg	17D 9U	0	1D	4D	0	1D	6U 13D	3D	3D
Ω, rps	0.51	0.50	0.49	0.43	0.50	0.49	0.46	0.45	0.50
V, fps	240 205	202	208	249	214	208	265 300	208	208
Turns for recovery	[e]>7	∞	∞	∞	∞	∞	∞	∞	∞

[a] Wandering and oscillatory spin, when range of values is not given, average values are presented.
[b] Two types of spin.
[c] Recoveries attempted before model reached final attitude.
[d] Due to initial launching rotation, model did not recover in 7 turns.
[e] Visual observation.
[f] Check spins.
[g] Recovery attempted by simultaneous reversal of rudder and elevators.
[h] Model goes into an inverted spin upon recovery.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE FISHER BODY DETROIT DIVISION XP-75 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Alternate loading, modification 1									Alternate loading, modification 2									Alternate loading, modification 4										
Ailerons	Against 25°D, 25°D		Neutral				With 25°U, 25°D			Against 25°U, 25°D			Neutral			With 25°U, 25°D			Against 25°U, 25°D			Neutral					With 25°U, 25°D		
Elevator	U (a)	N	U (a)	N (ab)	N (b)	D	U	N (a)	D	U	N	D	U	N	D (a)	U (a)	N	D	U	N	D	U	N (b)	N (b)	D (b)	D (b)	U (a)	N	D (j)
α, deg	----	22	----	48 40	31	29	---	35	31	38	36	31	39	31	32	42 46	35	32	42	31	47	---	59	----	36	32	25 32	33	57
ø, deg	----	2U	----	4D	7D	3D	---	9D	10D	0	3U	2U	3D	3D	1D	6U 14D	6D	5D	3U	3U	4U	---	2D	----	0	0	7U 3D	1U	3D
Ω, rps	----	----	----	0.46	0.57	0.59	---	0.50	0.58	0.35	0.49	0.61	0.35	0.54	0.53	0.43	0.48	0.58	0.44	0.54	0.47	---	0.47	----	0.53	0.56	--	0.56	0.49
V, fps	>285	285	244 322	225 243	285	285	>303	272	266	290	278	278	266	290	315	236 309	272	285	300	290	214	367	203	319	214	266	297	285	170
Turns for recovery	[c]>2	$1\frac{1}{4}$	$>2\frac{1}{2}$	>8	3	1 $1\frac{1}{2}$	[c]>3	$2\frac{1}{4}$	$2\frac{1}{2}$	2 [g]$\frac{1}{2}$	2	2 3 4	>3 [g]1 [g]$\frac{1}{2}$	>3 3	4 3 2	>3 [1g]>3 [1g]1	>5	6 4	$1\frac{1}{4}$	$\frac{3}{4}$	$6\frac{1}{2}$	$>1\frac{1}{2}$ 4	∞	2	∞	5	$\frac{3}{4}$	$1\frac{1}{2}$ $\frac{3}{4}$	>4

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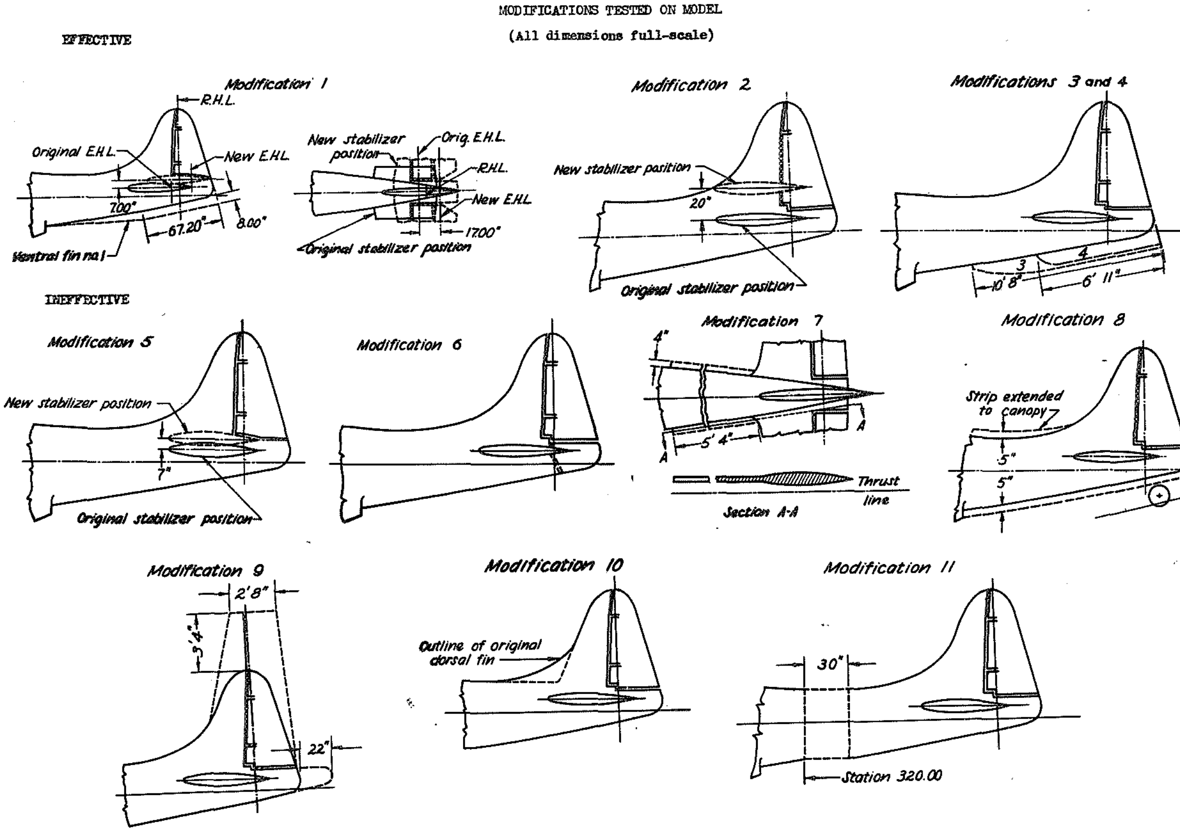
[a]Wandering and oscillatory spin, when range of values is not given, average values are presented.
[b]Two types of spin.
[c]Recoveries attempted before model reached final attitude.
[e]Visual observation.
[g]Recovery attempted by simultaneous reversal of rudder and elevators.
[i]Varied number of turns required for recovery, probably due to phase of spin oscillation in which rudder was reversed.
[j] Steeper spin also obtainable.

MODIFICATIONS TESTED ON MODEL

(All dimensions full-scale)

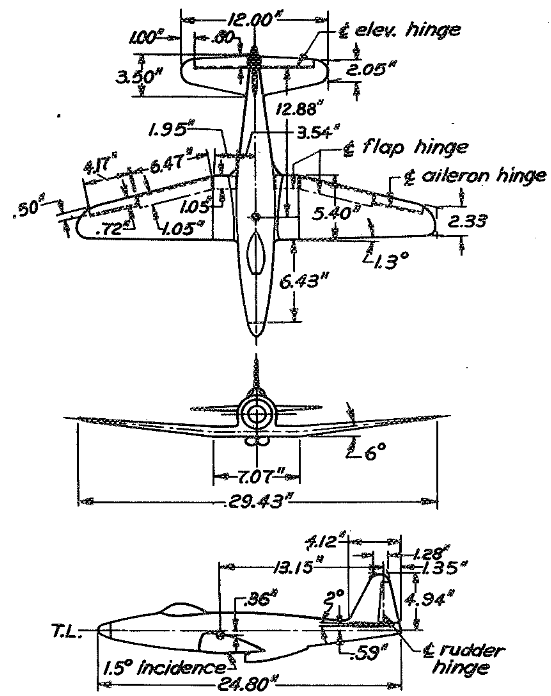


$\frac{1}{20}$-SCALE MODEL OF THE FISHER BODY DETROIT DIVISION P-75 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	49.06
L, ft	41.33
$\bar{c}$, in.	89.78
S, sq ft	342.00
A	7.05
L.E. $\bar{c}$ aft L.E. c_r, in.	1.50
S_h, sq ft	89.90
S_e, sq ft	22.06
S_v, sq ft	30.14
S_r, sq ft	10.57
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg (roung wing tips)	$18\frac{3}{4}$ U, $10\frac{1}{2}$ D
δ_a, deg (square wing tips)	$22\frac{1}{2}$ U, $22\frac{1}{2}$ D
δ_f, deg	$42\frac{1}{2}$ D
TDPF	4×10^{-6}
Landing gear	Conventional



Model as tested.

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Mass Data

Normal Loading

W, lb	13,543
$x/\bar{c}$	0.28
$z/\bar{c}$	0.08
I_X, slug-ft^2	12,400
I_Y, slug-ft^2	22,520
I_Z, slug-ft^2	33,020
Test altitude, ft	15,000
μ (at sea level)	10.55
μ' (15,000 ft)	16.80

$\frac{I_X - I_Y}{mb^2}$	-99×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-103×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	202×10^{-4}

Alternate Loading

W, lb	17,217
$x/\bar{c}$	0.29
$z/\bar{c}$	0.09
I_X, slug-ft^2	20,410
I_Y, slug-ft^2	23,420
I_Z, slug-ft^2	40,990
Test altitude, ft	15,000
μ (at sea level)	13.40
μ' (15,000 ft)	21.30

$\dfrac{I_X - I_Y}{mb^2}$	-23×10^{-4}
$\dfrac{I_Y - I_Z}{mb^2}$	-136×10^{-4}
$\dfrac{I_Z - I_X}{mb^2}$	159×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun with a vertical velocity exceeding 305 feet per second full scale. Recovery by either rapid full rudder reversal or simultaneous reversal of the rudder and elevator was satisfactory. With the elevator set either neutral or down, for any aileron setting, recovery by rapid full rudder reversal was generally unsatisfactory. Setting the ailerons against the spin with the elevator up led to an oscillatory spin from which recovery of the model was marginal depending upon the phase of oscillation at the time recovery was attempted, whereas setting the ailerons with the spin had a beneficial effect for all elevator settings on the recovery characteristics of the model.

In an attempt to improve the recovery characteristics of the model for the normal and alternate loadings, various modifications (modifications 1 to 6) were tested on the model. Modification 4 (vertical tail moved rearward 20 inches, full scale, from its normal location and tail cone lengthened to conform with the rearward location of the rudder) had a beneficial effect on the recovery characteristics of the model.

Recoveries of the model in the alternate loading clean condition with modification 4 were marginal. Replacing the partial-length rudder with a full-length rudder (modification 5) had a slight detrimental effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE FISHER BODY P-75 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading, round wing tips										
Ailerons	Against				Neutral				With		
Elevator	U (a)	N (b)	N (b)	D	U	N (ab)	N (ab)	D	U	N	D
α, deg	10 37	42	---	50	---	34 46	28	38	---	---	---
φ, deg	8U 2D	2U	---	1U	---	5U 4D	2U	2U	---	---	---
Ω, rps	0.37	0.40	0.43	0.44	---	0.48	0.52	0.44	---	---	---
V, fps	245	186	298	186	>305	215	311	221	>290	>320	>305
Turns for recovery	[c]>4 [c]1½ [cd]4 [cd]2 [cd]1	∞	10 4½	∞	[ce]2 [ce]3 [de]2½ [de]1½	8½ 4½	[c]3	6½	[e]1¼ [e]3 [de]½	[ce]1½ [ce]¾	[ce]>4 [ce]3

	Modification 1, square wing tips, normal loading									
Ailerons	Against			Neutral				With		
Elevator	U	N	D (a)	U	N	D (bf)	D (bg)	U (a)	N	D
α, deg	30	52	43 57	---	---	---	---	---	---	---
φ, deg	3U	1U	9U 6D	---	---	---	---	---	---	---
Ω, rps	0.40	0.40	---	---	---	---	---	---	---	---
V, fps	250	186	192	>304	>304	---	>274	>274	>280	>304
Turns for recovery	1 1½	∞	∞	[e]2	[e]1 [e]1½	∞	[e]1½ [e]2	[e]>2	[e]1	[e]¾

	Modification 1, square wing tips, alternate loading									
Ailerons	Against			Neutral				With		
Elevator	U	N	D	U	N	D (bf)	D (bg)	U (a)	N	D
α, deg	---	55	---	---	---	---	---	24 38	---	---
φ, deg	---	1U	---	---	---	---	---	1U 17U	---	---
Ω, rps	---	0.45	0.45	---	---	---	0.64	0.47	---	---
V, fps	>304	222	203	>289	274	226	304	320	>304	>338
Turns for recovery	[d]1½ [d]2 [de]½ [de]1	∞	∞	[e]2 [de]1	[ce]3	∞	2 1½	[c]>5 [d]1¾	[e]>3	[e]2 [e]>2

	Square wing tips, alternate loading: Modification 2			Square wing tips, alternate loading: Modification 3			Modification 4, normal loading, round wing tips								
Ailerons	Neutral			Neutral			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	---	43	-	---	---	-	-	25	25	-	-	-	-	-	-
φ, deg	---	3D	-	---	---	-	-	3U	2U	-	-	-	-	-	-
Ω, rps	---	---	-	---	---	-	-	0.54	---	-	-	-	-	-	-
V, fps	>289	262	-	>289	262	-	-	306	286	-	-	-	-	-	-
Turns for recovery	[e]>2½	[e]>7	-	[e]1½ [e]>2½	3½ 4	-	-	[c]2	1¼	-	-	-	-	-	-

	Modification 4, square wing tips, normal loading									Modification 4, square wing tips, alternate loading								
Ailerons	Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (a)	N	D	U	N	D	U	N	D	U (a)	N	D
α, deg	---	---	27	---	---	---	---	---	---	31	---	29	---	---	28	---	---	---
φ, deg	---	---	3U	---	---	---	---	---	---	1D	---	2U	---	---	2U	---	---	---
Ω, rps	---	0.69	0.57	---	---	---	---	---	---	0.51	0.54	0.61	---	---	0.65	---	---	---
V, fps	274	274	286	>274	>274	305	>274	>274	>299	290	299	305	>305	>274	305	>274	>305	>305
Turns for recovery	[e]1½ [e]2	1¼	1¼	[e]1½	[e]¾ [e]1½	1	[e]>1¼	[e]1	[e]¾	2½	2½ 3¼	2 3	[e]2	[e]1½ [e]2	2½	[e]>3	[e]2	[e]1¾

	Landing condition, modification 4, square wing tips, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D	U	N	D	U	N	D
α, deg	---	---	20	---	---	No spin	---	---	No spin
φ, deg	---	---	3U	---	---		---	---	
Ω, rps	---	---	0.51	---	---		---	---	
V, fps	>243	>274	286	>226	>274		>243	>274	
Turns for recovery	[ce]¼	[e]1	1	[ce]½	[e]1		[e]1	[e]1	

[a]Oscillatory spin, where range of values is not given, average value is given.

[b]Two types of spin.

[c]Visual observation.

[d]Recovery attempted by simultaneous reversal of rudder and elevator.

[e]Recovery attempted before model reached final steep attitude.

[f]Flat spin.

[g]Steep spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE FISHER BODY P-75 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Inverted spins, modification 4, square wing tips, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D (a)	U	N	D
α, deg	N	N	N	N	N	25 32	---	26	---
∅, deg	o	o	o	o	o	9D 7U	---	6U	---
Ω, rps	s	s	s	s	s	0.72	---	0.98	---
V, fps	p i	p i	p i	p i	p i	311	>337	367	>305
Turns for recovery	n	n	n	n	n	1 1½	[e]1½	1	[e]1

	Modification 5, square wing tips, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	---	---	---	---	---	---	---	---	---
∅, deg	---	---	---	---	---	---	---	---	---
Ω, rps	---	---	---	---	---	---	---	---	---
V, fps	215	218	239	215	>290	257	215	>274	>305
Turns for recovery	[c]1½	[c]3 [c]4	[c]4	[ce]1 [ce]1½	[e]1 [e]1½ [e]2	[c]2 [c]3	[ce]¾ [ce]1	[e]¾ [e]1½	[ce]1 [ce]1½

	Modification 5, square wing tips, alternate loading									
Ailerons	Against			Neutral				With		
Elevator	U	N	D (a)	U (a)	N	D (b)	D (ba)	U (a)	N	D
α, deg	42	---	45 70	47	---	54	29 46	---	---	28
∅, deg	3U	---	6U 9D	4U	---	2U	9U 8D	---	---	5U
Ω, rps	0.52	0.45	0.49	0.36	---	0.45	0.98	---	---	0.69
V, fps	298	250	206	226	239	200	274	>320	>305	305
Turns for recovery	[c]1 [c]2½	[c]3½	[c]9	[c]2 [c]2¼	[c]4½	6½	3	(ce) >4	ce >1½	1¾

	Modifications 5 and 6, square wing tips, alternate loading						XP-75 tail assembly installed on model, square wing tips, alternate loading								
Ailerons	Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N	D	U	N (h)	D (h)	U (a)	N	D
α, deg	-	39	-	---	-	-	38 49	-	-	---	47	50	28 40	41	43
∅, deg	-	2U	-	---	-	-	1U 7U	-	-	---	4U	4U	6U 9U	6U	6U
Ω, rps	-	---	-	---	-	-	---	-	-	---	0.45	---	---	0.40	0.42
V, fps	-	262	-	274	-	-	315	-	-	274	214	214	271	268	238
Turns for recovery	-	1½ 2	-	2	-	-	5½ 8	-	-	[e]>2¾	---	---	>2	[c]>5	>4

[a]Oscillatory spin, where range of values is not given, average value is given.
[b]Two types of spin.
[c]Visual observation.
[e]Recovery attempted before model reached final steep attitude.
[h]Rudder against steady spin.

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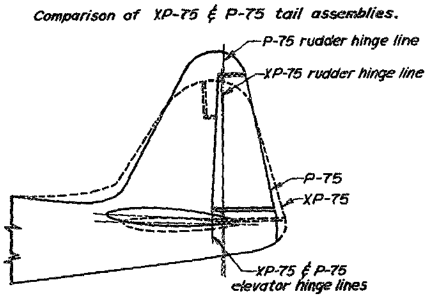
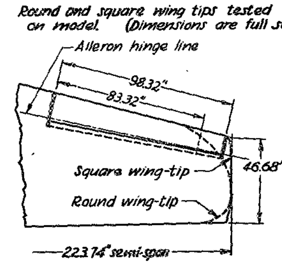
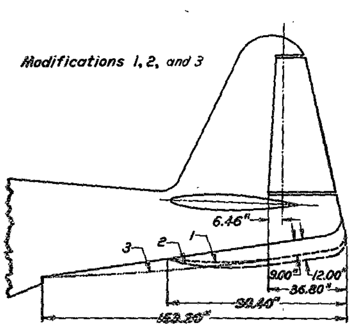
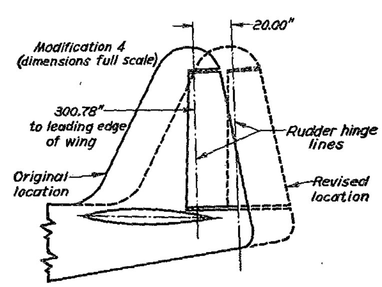
Comparison of XP-75 & P-75 tail assemblies.

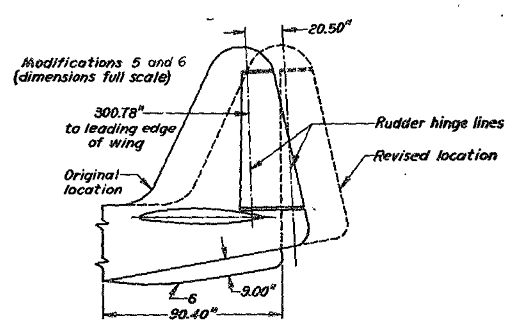


Round and square wing tips tested on model. (Dimensions are full scale)







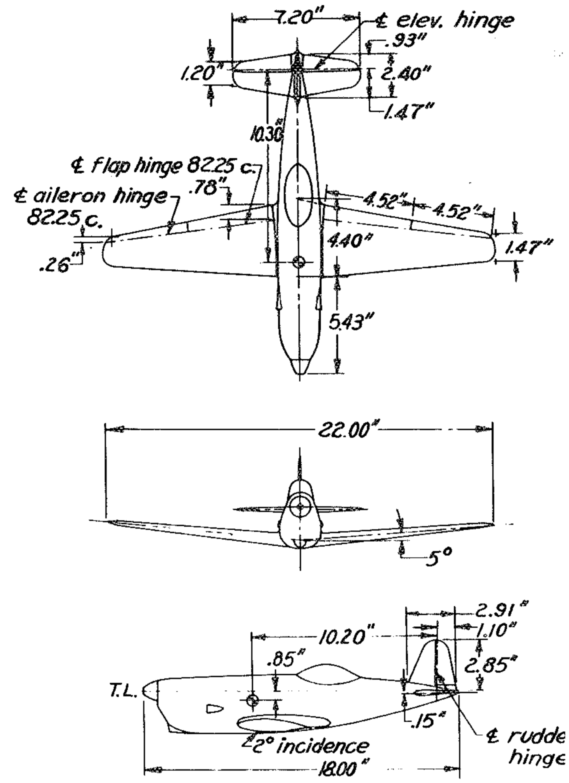


$\frac{1}{15}$ SCALE MODEL OF THE BELL XP-77 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	27.50
L, ft	22.60
$\bar{c}$, in.	47.87
S, sq ft	100.00
A	7.56
L.E. $\bar{c}$ aft L.E. c_r, in.	5.44
S_h, sq ft	20.90
S_e, sq ft	6.50
S_v, sq ft	9.63
S_r, sq ft	3.04
δ_r, deg	30 R, 30 L
δ_e, deg	25 U, 15 D
δ_a, deg	20 U, 20 D
δ_f, deg	60 D
TDPF	27×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	3387
$x/\bar{c}$	0.267
$z/\bar{c}$	0.267
I_X, slug-ft^2	652
I_Y, slug-ft^2	2224
I_Z, slug-ft^2	2650
Test altitude, ft	15,000
μ (at sea level)	16.07
μ' (15,000 ft)	25.53

$\frac{I_X - I_Y}{mb^2}$	$-198 \times 10^{-}$
$\frac{I_Y - I_Z}{mb^2}$	$-54 \times 10^{-}$
$\frac{I_Z - I_X}{mb^2}$	$252 \times 10^{-}$

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Résumé of Model Test Results

For the clean condition, normal loading, with either the original or revised tail surfaces installed on the model two types of spin were generally possible for all control settings tested; one spin was very flat from which recoveries by rapid full rudder reversal were slow or impossible, and the other spin was extremely oscillatory and recoveries by rapid full rudder reversal were satisfactory.

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$ or $1.10\ I_X$) or retracting mass along the fuselage (ΔI_X and $\Delta I_Y = -0.20\ I_Y$) did not appreciably alter the recovery characteristics of the model except for an increased tendency of the model to remain in a flat spin from which recovery was unsatisfactory. Retracting mass along the wings (ΔI_X and $\Delta I_Z = -0.20\ I_X$) or extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.20\ I_Y$), decreased the tendency of the model to maintain flat spins and only a few unsatisfactory recoveries were obtained. Moving the center of gravity forward or rearward $0.05\bar{c}$ from its normal position gave results similar to those obtained for the normal loading condition.

For the landing condition, the spin and recovery characteristics were similar to those obtained for the clean condition, normal loading.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

In an attempt to steady the spin and improve the recovery characteristics of the model, modifications 1 through 14 were tested on the model. Generally the most effective modifications to steady the spin and insure satisfactory recoveries from spins were the addition of large triangular anti-spin fillets (modification 8), an increase in the horizontal tail span by approximately 70 percent (modification 10), a movement of the vertical tail forward 24 inches full scale (modification 11), or an addition of a large area (6.0 sq ft) below the fuselage and rudder (modification 12).

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SPIN DATA OBTAINED WITH THE $\frac{1}{15}$- SCALE MODEL OF THE BELL XP-77 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition with revised tail and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading (original tail surfaces)													ΔI_X and $\Delta I_Z = 1.10 I_X$ (Original tail surfaces)									ΔI_Y and $\Delta I_Z = 0.20 I_Y$ (Original tail surfaces)					
Ailerons	Against				Neutral					With				Against			Neutral			With			Neutral			With		
Elevator	U (ab)	U (ac)	N	D	U (c)	U (cd)	N (c)	N (cd)	D (d)	U (ab)	U (a)	N (e)	D	U	N	D (f)	U (f)	N (f)	D (f)	U (f)	N	D (f)	U	N	D (fg)	U	N	D
α, deg	--	No spin	No spin	No spin	75	25 70	80	--	--	---	No spin	-	No spin	--	--	--	--	71	--	--	-	--	No spin	-	--	--	--	--
ϕ, deg	--				1D	36U 35D	0	--	--	---		-		--	--	--	--	0	--	--	-	--		-	--	--	--	--
Ω, rps	--				--	---	--	--	--	---		-		--	--	--	--	--	--	--	-	--		-	--	--	--	--
V, fps	--				163	235	153	252	252	---		-		190	184	184	190	187	193	196	-	196		-	--	--	--	--
Turns for recovery	--				∞	$\frac{3}{4}$	∞	$\frac{3}{4}$ $1\frac{1}{2}$	2	---		-		∞	∞	∞	∞	∞	∞	>5	-	∞		-	--	--	--	--

	ΔI_Y and $\Delta I_Z = -0.20 I_Y$ (Original tail surfaces)											c.g. moved forward $0.12\bar{c}$ (original tail surfaces)								Normal loading														
Ailerons	Against				Neutral				With			Against			Neutral			With		Against					Neutral					With				
Elevator	U (cb)	U (c)	N (i)	D (i)	U (j)	N (j)	D (ch)	D (cj)	U (e)	N (e)	D (k)	U	N	D	N (d)	D (ch)	D (c)	U (e)	N	U (c)	N (a)	N (a)	D (aj)	D (a)	U (c)	U (ch)	N	D (c)	D (c)	U (cj)	U (ch)	N	D (c)	D (cl)
α, deg	-	75	-	-	74	68	-	70	-	-	-	-	-	-	55 70	-	66	-	-	No spin	-	No spin	84	No spin	79	39 59	82	-	43 89	78	26 43	81	75	-
ϕ, deg	-	0	-	-	1D	1D	-	2D	-	-	-	-	-	-	30U 22D	-	1D	-	-		-		0		2D	20U 30D	2D	-	41U 40D	2D	1U 31D	2D	1D	-
Ω, rps	-	0.63	-	-	-	0.62	-	0.67	-	-	-	-	-	-	0.58	-	-	-	-		-		0.81		0.79	0.59	1.06	0.85	0.48	0.75	0.48	0.88	0.72	-
V, fps		179	-	-	163	179	-	166	-	-	-	-	168	-	168	-	174	-	-		152		152		152	207	152	158	293	163	218	152	152	235
Turns for recovery	-	∞	-	-	∞	∞	-	∞	-	-	-	-	∞	-	∞	-	∞	-	-				∞		∞	$\frac{1}{2}$	∞	∞	[m]$\frac{1}{4}$ 1	$8\frac{1}{2}$	[n]$\frac{1}{2}$	∞	[m]$8\frac{3}{4}$ [m]∞	[m]1 [m]$1\frac{1}{2}$

	ΔI_X and $\Delta I_Z = 0.20 I_X$													ΔI_X and $\Delta I_Z = -0.20 I_X$											
Ailerons	Against			Neutral						With				Against				Neutral					With		
Elevator	U (c)	U (cd)	D (d)	U (c)	U (c)	N (c)	N (cd)	D (co)	D (c)	U (c)	U (cd)	D (c)	D (co)	U (a)	U (a)	N (c)	D	U (c)	U (cd)	N (c)	N (co)	D (p)	U (e)	N (e)	D (p)
α, deg	81	36 60	29 58	77	--	79	--	--	--	77	--	76	--	No spin	81	No spin	No spin	80	--	79	--	--	--	--	--
ϕ, deg	1D	35U 37D	42U 33D	1D	--	1D	--	--	-	1D	--	2D	--		1D			1D	--	1D	--	--	--	--	--
Ω, rps	1.03	0.46	0.46	0.74	--	--	--	--	0.77	0.74	--	0.77	--		0.97			0.92	--	1.03	--	--	--	--	--
V, fps	168	218	263	163	281	158	229	--	158	168	212	155	--		152			160	>263	155	--	>263	>263	>263	>263
Turns for recovery	∞	[m]$\frac{1}{4}$ [m]$\frac{3}{4}$	[m]$1\frac{1}{2}$	∞	[m]$\frac{1}{2}$	∞	[m]$\frac{3}{4}$	--	∞	[m]$7\frac{1}{2}$	[m]$\frac{1}{4}$ [m]1	∞	--		∞			[m]7	[m]$\frac{1}{2}$	∞	--	[mq]$\frac{1}{2}$	[mn]$\frac{1}{2}$	--	[mq]$\frac{1}{2}$

	ΔI_Y and $\Delta I_Z = 0.20 I_Y$											ΔI_Y and $\Delta I_Z = -0.20 I_Y$							c.g. moved forward $0.05\bar{c}$													
Ailerons	Against			Neutral						With		Against		Neutral			With		Against					Neutral				With			
Elevator	U (c)	N	D	U (a)	U (a)	N (ar)	N (a)	D (c)	D (ch)	U (d)	D (d)	U	D	U (r)	N (f)	D (r)	U (d)	D (d)	U (c)	U (cs)	N	D (cj)	D (ch)	U (c)	U (ch)	N (f)	D	U (d)	N (cf)	N (ch)	D (f)
α, deg	No spin	-	No spin	83	No spin	82	No spin	--	-	-	-	77	75	75	75	78	-	-	82	46 65	82	81	-	78	-	83	81	15 65	80	--	79
ϕ, deg		-		0		0		--	-	-	-	0	1U	0	1D	1D	-	-	0	49U 15D	0	1D	-	1D	-	0	0	22U 40D	2D	--	2D
Ω, rps		-		0.75		0.89		--	-	-	-	0.76	0.77	0.72	0.81	0.86	-	-	1.05	0.47	0.87	0.88	-	0.72	-	0.85	0.79	0.43	0.79	--	0.83
V, fps		-		155		152		174	-	276	229	152	158	155	155	158	207	190	168	281	152	150	-	168	-	152	155	235	152	--	155
Turns for recovery		-		∞		∞		∞	-	[mn]$\frac{1}{4}$	[m]$\frac{1}{2}$	∞	∞	∞	∞	∞	[m]$\frac{1}{2}$	>3	[m]9	$\frac{1}{2}$	∞	∞	-	∞	-	∞	∞	$\frac{1}{4}$	∞	--	∞

[a]Two conditions possible.
[b]Flat spin occasionally obtained.
[c]Two types of spin.
[d]Wandering spin; oscillatory in pitch and roll.
[e]Model begins slipping after making a few turns, then turns again and repeats maneuver.
[f]Wandering spin.
[g]Steep and oscillatory spin.
[h]Steeper spin; oscillatory in pitch and roll.
[i]Model spins flat, then goes into a steeper oscillatory spin and flattens out again.
[j]Wandering and oscillatory spin.
[k]Steep and wandering spin.
[l]Wandering spin with wide radius.
[m]Visual observation.
[n]Model goes into an inverted spin upon recovery from an erect spin.
[o]Steeper spin; wandering and oscillatory in pitch and roll.
[p]Steep wandering spin, with a snap to the turning motion.
[q]Model goes into inverted flight upon recovery from erect spin.
[r]Oscillatory spin.

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SPIN DATA OBATAINED WITH THE $\frac{1}{15}$-SCALE MODEL OF THE BELL XP-77 AIRPLANE - Continued

[Unless otherwise indicated steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	c.g. moved back 0.05$\bar{c}$																	Landing condition, normal loading									
Ailerons	Against						Neutral					With						Against				Neutral				With	
Elevator	U (cj)	U (cs)	N (c)	N (ch)	D (cf)	D (ch)	U (cf)	U (cd)	N (cf)	N (ch)	D	U (c)	U (ch)	N (cf)	N (ch)	D (cf)	D (ch)	U (c)	U (cs)	D (c)	D (ch)	U (ct)	U (cs)	N (t)	D (t)	U (f)	D (f)
α, deg	83	--	80	--	79	--	83	27 47	81	--	82	78	--	80	--	79	--	81	37 68	79	--	74	--	75	77	--	--
φ, deg	1D	--	3D	--	2D	--	1D	17U 21D	1D	--	1D	2D	--	2D	--	2D	--	0	25U 28D	0	--	0	--	2D	2D	--	--
Ω, rps	0.81	--	0.69	--	0.84	--	0.77	0.33	0.92	--	0.90	0.70	--	0.88	--	0.65	--	0.96	0.41	0.76	--	0.77	--	0.75	0.96	--	--
V, fps	163	218	160	--	155	--	155	252	155	--	155	166	--	158	--	155	--	166	220	155	--	166	179	166	166	207	196
Turns for recovery	∞	[m]$\frac{1}{4}$	∞	--	[m]$6\frac{3}{4}$	--	[m]$9\frac{1}{2}$	[m]$\frac{1}{4}$	∞	--	∞	[m]6 [m]9	--	[m]$9\frac{3}{4}$	--	∞	--	∞	[m]$2\frac{1}{2}$ [m]4	∞	--	∞	$\frac{1}{2}$	∞	∞	[mn]$\frac{1}{2}$ [mn]$1\frac{1}{2}$	[m]1 >4

	Inverted spin, normal loading									Modification 1 and 2 ΔI_Y and $\Delta I_Z = -0.20 I_Y$ (Original tail surfaces)									Modification 2, ΔI_Y and $\Delta I_Z = -0.20 I_Y$											
Ailerons	Against			Neutral			With			Against			Neutral			With			Against				Neutral				With		
Elevator	U (d)	N	D (su)	U (j)	N (j)	D	U (u)	N (u)	D (sx)	U	N	D	U	N	D	U (f)	N	D (f)	U (a)	U (a)	N	D	U	15°U (c)	15°U (cy)	N	U (f)	N	D
α, deg	No spin	No spin	26 43	36	40	37	--	-	36 55	--	-	--	--	--	--	--	-	-	71	No spin	-	-	--	74	--	74	--	-	-
φ, deg			21U 1D	2D	1D	0	--	-	24U 32D	--	-	--	--	---	--	--	-	-	1D		-	-	--	1D	--	3D	--	-	-
Ω, rps			0.56	0.46	0.62	0.59	--	-	0.53	--	-	--	--	--	--	--	-	-	--		-	-	--	--	--	--	--	-	-
V, fps			258	238	234	234	206	-	201	168	-	152	>293	158	152	207	-	-	168		-	-	282	163	--	158	312	-	-
Turns for recovery			[mv]$\frac{1}{2}$ [mv]$\frac{3}{4}$	[v]$\frac{1}{4}$	[v]$\frac{1}{2}$ [vw]$\frac{1}{2}$	[v]$\frac{1}{2}$	[m]$\frac{3}{4}$	-	[v]$\frac{1}{2}$	[m]9	-	∞	[m]$\frac{1}{4}$	∞	∞	[m]$\frac{1}{2}$	-	-	∞		-	-	[m]$1\frac{1}{2}$	∞	--	∞	1	-	-

	Modification 3, ΔI_Y and $\Delta I_Z = -0.20 I_Y$												Modification 4, ΔI_Y and $\Delta I_Z = -0.20 I_Y$									Modification 5, ΔI_Y and $\Delta I_Z = -0.20 I_Y$ (Original tail surfaces)								
Ailerons	Against			Neutral						With			Against		Neutral					With		Against			Neutral			With		
Elevator	U	N	D	U	15°U (cf)	15°U (cb)	N (c)	N (cy)	D (f)	U (f)	N	D	U (c)	U (cs)	U (a)	15°U (c)	15°U (cs)	N (cf)	N (cs)	U (d)	N	U (j)	N	D	U (j)	N (j)	D (j)	U (e)	N	D
α, deg	67	-	-	--	--	--	64	-	68	--	-	-	74	--	45 64	73	--	72	38 61	--	-	--	-	-	--	--	--	--	-	-
φ, deg	1U	-	-	--	--	--	1D	-	2D	--	-	-	1U	--	29U 18D	1D	--	0	27U 23D	--	-	--	-	-	--	--	--	--	-	-
Ω, rps	--	-	-	--	--	--	--	-	--	--	-	-	--	--	---	--	--	--	---	--	-	--	-	-	--	--	--	--	-	-
V, fps	166	-	-	>293	218	--	174	-	163	>263	-	-	168	218	229	168	223	160	206	>263	-	263	-	-	206	206	263	--	-	-
Turns for recovery	[m]$6\frac{1}{2}$	-	-	[m]$\frac{1}{2}$	1 $\frac{1}{2}$	--	$4\frac{1}{2}$ [m]9	-	∞	1	-	-	∞	[m]$\frac{3}{4}$	$\frac{1}{2}$ 1	7	[m]$\frac{3}{4}$	∞	$2\frac{3}{4}$	[m]1 [m]$1\frac{1}{2}$	-	[m]$\frac{3}{4}$ [m]$1\frac{1}{2}$	-	-	[m]1 [m]$1\frac{1}{2}$	[m]2	[m]>2	--	-	-

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[a]Two conditions possible.
[b]Flat spin occasionally obtained.
[c]Two types of spin.
[d]Wandering spin; oscillatory in pitch and roll.
[e]Model begins slipping after making a few turns then turns again and repeats maneuver.
[f]Wandering spin.
[h]Steeper spin; oscillatory in pitch and roll.
[j]Wandering and oscillatory spin.
[m]Visual observation.
[n]Model goes into an inverted spin upon recovery from an erect spin.
[s]Spin oscillatory in pitch and roll.
[t]Slightly oscillatory spin, spin gets slightly steeper and wandering at times.
[u]Model appears to dive for a while and then spin inverted.
[v]Recovers in erect flight after recovery from inverted spin.
[w]Recovery attempted by neutralization of rudder; visual observation.
[x]Spins with whipping motion.
[y]Steep spin.

SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODEL OF THE BELL XP-77 AIRPLANE - Concluded

[Unless otherwise indicated steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Modification 6, ΔI_Y and $\Delta I_Z = -0.20 I_Y$									Modification 7, ΔI_Y and $\Delta I_Z = -0.20 I_Y$											Modification 8, ΔI_Y and $\Delta I_Z = -0.20 I_Y$ (Original tail surfaces with full length rudder)								
Ailerons	Against			Neutral			With			Against					Neutral			With			Against			Neutral			With		
Elevator	U (r)	N	D	U (r)	N (j)	D (y)	U (j)	N	D	U (a)	U (ab)	N (a)	N (ab)	D	U (a)	N (d)	D (d)	U (f)	N	D	U	N	D	U	N (f)	D	U (f)	N	D
α, deg	-	-	-	-	--	--	--	-	-	No spin	--	No spin	--	No spin	28 75	51 71	--	-	-	-	--	-	-	-	--	--	-	-	-
ϕ, deg	-	-	-	-	--	--	--	-	-		--		--		36U 32D	25U 21D	--	-	-	-	--	-	-	-	--	--	-	-	-
Ω, rps	-	-	-	-	--	--	--	-	-		--		--		---	---	--	-	-	-	--	-	-	-	--	--	-	-	-
V, fps	196	-	-	207	207	--	--	-	-		--		--		212	258	207	235	-	-	229	-	-	263	207	235	-	-	-
Turns for recovery	$^{m}1\frac{1}{2}$	-	-	$^{m}1\frac{1}{2}$ $^{m}2$	$^{m}1\frac{1}{2}$	$^{m}2$	$^{mn}1$	-	-		--		--		$^{m}\frac{3}{4}$	$1\frac{1}{4}$ $^{m}2$	>2	$^{mn}\frac{1}{2}$ $^{mn}1\frac{1}{2}$	-	-	$^{m}1$ $^{m}1\frac{1}{2}$	-	-	$^{m}1$	$^{m}2$	$^{m}2$ $^{m}2\frac{1}{2}$	$^{m}\frac{1}{4}$	-	-

	Modification 8, ΔI_Y and $\Delta I_Z = -0.20 I_Y$								Modification 9, ΔI_Y and $\Delta I_Z = -0.20 I_Y$					Modification 4 and 8, ΔI_Y and $\Delta I_Z = -0.20 I_Y$							Modification 10 ΔI_Y and $\Delta I_Z = -0.20 I_Y$			Modification 11 ΔI_Y and $\Delta I_Z = -0.20 I_Y$							
Ailerons	Against			Neutral			With		Against			Neutral		Against			Neutral		With		Neutral			Against			Neutral			With	
Elevator	U (s)	N	D	U (d)	N (d)	D (d)	U (x)	N	U (s)	N	D	U (d)	N (d)	U (s)	N	D	U (r)	N (f)	U (f)	N	U	N	D	U	N	D	U (r)	N	D	U (j)	N
α, deg	26 79	-	-	59 74	35 45	26 45	-	-	44 76	-	-	32 65	36 61	37 52	-	-	42	40	-	-	34	34	-	64	-	-	53	-	26	-	-
ϕ, deg	37U 20D	-	-	18U 20D	13U 10D	18U 16D	-	-	41U 28D	-	-	17U 26D	31U 30D	17U 5D	-	-	0 10D	2D	-	-	2D	2U	-	0	-	-	21U 18D	-	2D	-	-
Ω, rps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V, fps	198	-	-	235	224	212	258	-	206	-	-	212	235	196	-	-	229	241	263	-	246	224	-	174	-	-	196	>324	263	235	-
Turns for recovery	∞	-	-	$^{m}\frac{3}{4}$	$1\frac{1}{2}$ 2	$^{mq}2$ $^{q}2\frac{3}{4}$	$^{mn}\frac{1}{2}$	-	$^{m}1$ $^{m}1\frac{1}{2}$	-	-	1	1	$1\frac{3}{4}$	-	-	$^{m}1$ $^{m}1\frac{1}{2}$	$^{m}1\frac{1}{2}$	$^{m}\frac{3}{4}$	-	$\frac{3}{4}$	$1\frac{3}{4}$	-	$2\frac{1}{2}$	-	-	1 $1\frac{1}{2}$	$^{m}1$	$^{mn}1$ $^{mn}1\frac{3}{4}$	$\frac{3}{4}$ $^{m}1\frac{1}{2}$	-

	Modification 12, ΔI_Y and $\Delta I_Z = -0.20 I_Y$									Modification 13, ΔI_Y and $\Delta I_Z = -0.20 I_Y$						Modification 14, ΔI_Y and $\Delta I_Z = -0.20 I_Y$			
Ailerons	Against			Neutral			With			$\frac{1}{3}$ Against			Neutral			Neutral			
Elevator	U	N	D	U (r)	N	D	U (r)	N	D	15° U (r)	N	D	U (r)	15° U (r)	N (r)	U (s)	15° U (s)	N (s)	D
α, deg	74	-	-	69	71	73	67	-	-	-	-	-	-	-	-	62 79	-	67 80	-
ϕ, deg	1U	-	-	20U 18D	15U 14D	0	18U 17D	-	-	-	-	-	-	-	-	14U 15D	-	8U 9D	-
Ω, rps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V, fps	168	-	-	168	168	152	168	-	-	174	-	-	176	174	174	174	163	174	-
Turns for recovery	2	-	-	1 $1\frac{3}{4}$	$2\frac{1}{2}$	$^{n}2\frac{1}{2}$	$^{m}1$	-	-	$^{mz}2$ $^{mz}2\frac{3}{4}$	-	-	$^{m}2\frac{1}{4}$	$^{mz}2\frac{1}{4}$	$^{m}3\frac{1}{2}$	$^{m}2\frac{1}{2}$	$^{m}2\frac{1}{2}$ $^{m}3\frac{1}{2}$	$^{m}3$ $^{m}4$	-

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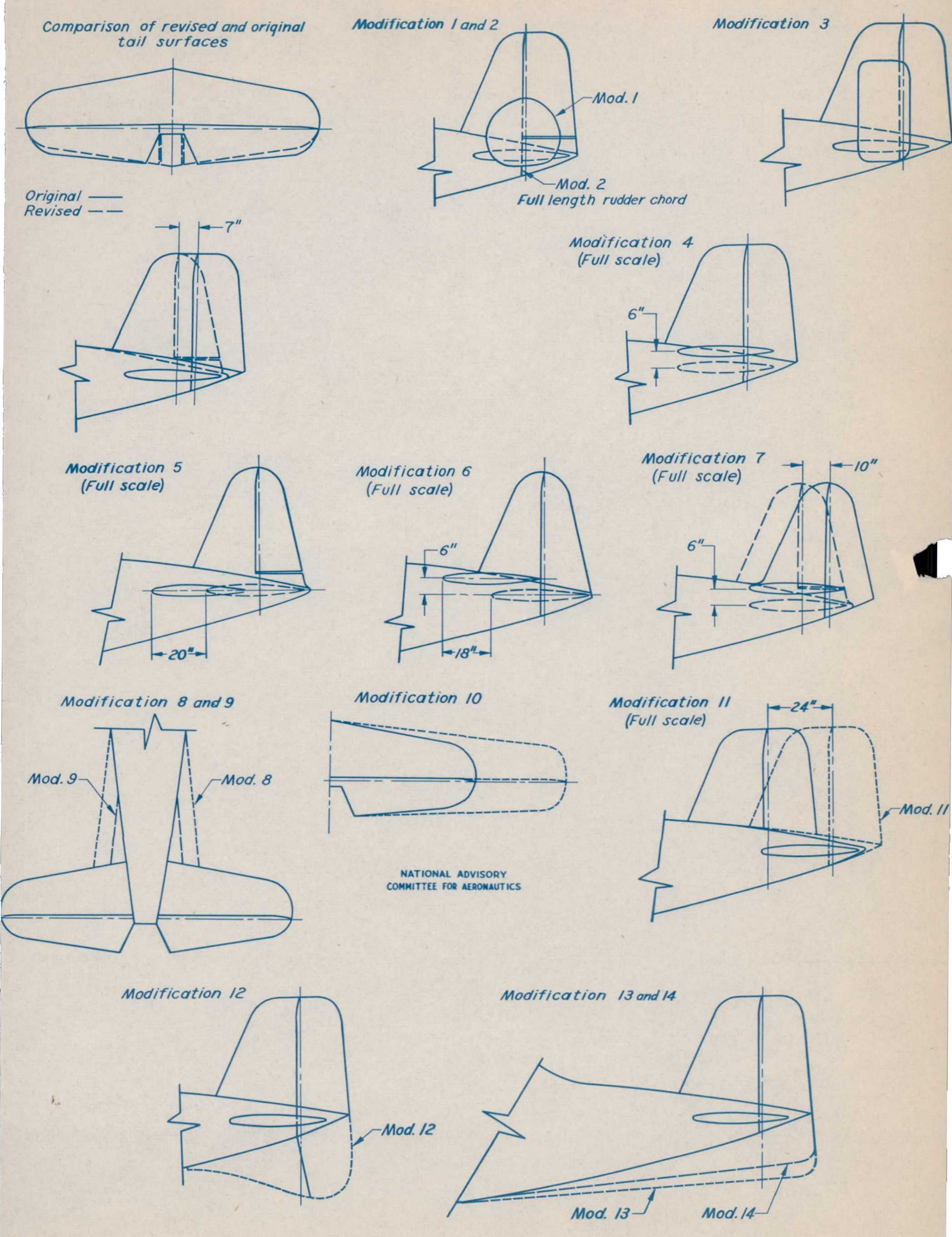
[a] Two conditions possible.
[b] Flat spin occasionally obtained.
[d] Wandering spin; oscillatory in pitch and roll
[f] Wandering spin.
[j] Wandering and oscillatory spin.
[m] Visual observation.
[n] Model goes into an inverted spin upon recovery from an erect spin.
[q] Model goes into inverted flight upon recovery from erect spin.
[r] Oscillatory spin.
[s] Spin oscillatory in pitch and roll.
[x] Spins with whipping motion.
[y] Steep spin.
[z] Recovery attempted by reversing rudder from full with to $\frac{2}{3}$ against the spin.



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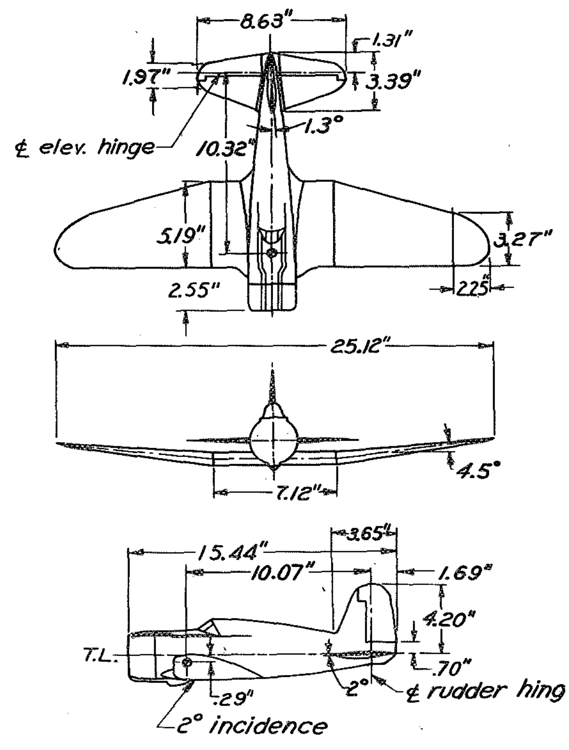
$\frac{1}{16}$-SCALE MODEL OF THE CHANCE-VOUGHT V-143 AIRPLANE

Dimensional Data

(Full Scale)

(Dimensions are the same for both tail 1 and tail 2 except where noted.)

b, ft	33.50
L, ft	
Tail 1	22.30
Tail 2	28.80
$\bar{c}$, in.	71.70
S, sq ft	187.00
A	6.00
S_h, sq ft	
Tail 1	35.76
Tail 2	25.34
S_e, sq ft	
Tail 1	13.94
Tail 2	10.24
S_v, sq ft	
Tail 1	15.20
Tail 2	12.13
S_r, sq ft	
Tail 1	9.03
Tail 2	7.53
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_f, deg	50 D
TDPF	
Tail 1	56×10^{-6}
Tail 2	693×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

	Tail 1	Tail 2
W, lb	4338	4341
$x/\bar{c}$	0.262	0.279
$z/\bar{c}$	0.066	0.066
I_X, slug-ft^2	1645	1648
I_Y, slug-ft^2	2489	2871
I_Z, slug-ft^2	3520	3893
Test altitude, ft	6000	9000
μ (at sea level)	9.05	9.06
μ' (test altitude)	10.84	11.90

	Tail 1	Tail 2
$\frac{I_X - I_Y}{mb^2}$	-56×10^{-4}	-80×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-68×10^{-4}	-68×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	124×10^{-4}	148×10^{-4}

Résumé of Model Test Results

Tail 1

For the model in the clean condition equipped with tail 1, (short) the model spun in a flat attitude ($\alpha = 75^\circ$ to 77°) and recoveries by rapid full rudder reversal were unsatisfactory.

Extending or retracting the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = \pm 0.20\ I_X\right)$, extending or retracting mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = \pm 0.20\ I_Y\right)$, or moving the center of gravity forward or back $0.03\bar{c}$ from its normal position had no appreciable effect on the unsatisfactory recovery characteristics of the model.

In an effort to improve the recovery characteristics of the model, a small fin (1.8 sq ft, full scale) was tested in different locations around the periphery of the fin and rudder. The most satisfactory location was beneath the aft portion of the fuselage; however, the recovery characteristics were still unsatisfactory (data not presented).

Tail 2

With tail 1 replaced by tail 2 (long) (see sketch) satisfactory recoveries for the normal loading condition were obtained with the elevator full up. There was an adverse effect of setting the elevator either neutral or down before reversing the rudder and recoveries were slower than when the elevator was up.

Extending or retracting the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = \pm 0.20\ I_X\right)$ or moving the center of gravity either forward or back $0.03\bar{c}$ from its normal position had little effect on the recovery characteristics of the model. Extending the mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.15\ I_Y \text{ or } 0.30\ I_Y\right)$ led to spins from which recoveries were marginal. With the mass retracted along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = -0.20\ I_X\right)$ in conjunction with the mass extended along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ and the center of gravity moved back $0.03\bar{c}$, the recoveries of the model were satisfactory for elevator-up spins. With the elevator either neutral or down, the recoveries were unsatisfactory.

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Tail 3

With the model in the normal loading condition and equipped with tail 3 (see sketch) recoveries were satisfactory when the elevator was full up. Extending the flaps 50° had an adverse effect on the recovery characteristics of the model.

The addition of an auxiliary fin $\left(2\frac{1}{2}\right.$ inches by 45 inches, full scale$\left.\right)$ to the lower rear portion of the fuselage had a beneficial effect on the recovery characteristics of the model (data not presented).

In general, there was little difference in the recovery characteristics of the model when equipped with tail 2 or tail 3.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE VOUGHT V-143 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with, aileron neutral spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Tail no. 1 normal loading

Elevator	U	U (a)	25° U	N	D
α, deg	77	67	77	76	75
ϕ, deg	0	---	1D	0	1D
Ω, rps	0.78	----	----	----	----
V, fps	104	b_	---	---	----
Turns for recovery	c∞	----	∞	∞	∞

Tail no. 1, effect of mass variations and c.g. movements on spin characteristics. Recovery attempted by simultaneous reversal of rudder and elevator from elevator up condition

	α (deg)	ϕ (deg)	Turns for recovery
ΔI_X and ΔI_Z = 0.20 I_X	78	1D	∞
ΔI_X and ΔI_Z = -0.20 I_X	74	0	∞
ΔI_Y and ΔI_Z = 0.20 I_Y	79	0	∞
ΔI_Y and ΔI_Z = -0.20 I_Y	74	0	∞
ΔI_X and ΔI_Z = -0.20 I_X; ΔI_Y and ΔI_Z = 0.20 I_Y; Tail wheel on	75	1D	d∞
c.g. moved forward 0.03c̄	76	1D	∞
c.g. moved back 0.03c̄	77	0	∞

Tail no. 2 normal loading

Elevator	U	N	D
α, deg	---	---	---
ϕ, deg	---	---	---
Ω, rps	----	----	----
V, fps	----	139	139
Turns for recovery	e1½, ce1	e3	e2

Tail no. 2, effect of mass variations and c.g. movements on spin characteristics. Recovery attempted by simultaneous reversal of rudder and elevator from elevator up spins

	α (deg)	ϕ (deg)	V (fps)	Turns for recovery
ΔI_X and ΔI_Z = 0.20 I_X	----	----	163	e1
ΔI_X and ΔI_Z = -0.20 I_X	---	---	153	e1
ΔI_Y and ΔI_Z = 0.15 I_Y	---	---	153	e2¼
ΔI_Y and ΔI_Z = 0.30 I_Y	---	---	157	e2½
c.g. moved forward 0.03c̄	47	1U	157	e1
c.g. moved back 0.03c̄	54	1D	157	e1, e1½

Tail no. 2, ΔI_X and ΔI_Z = -0.20 I_X, ΔI_Y and ΔI_Z = 0.20 I_Y, c.g. moved back 0.03c̄

Elevator	U	N	D
α, deg	53	58	59
ϕ, deg	2D	1D	0
V, fps	157	146	144
Turns for recovery	c1¾	3¾	4

Tail no. 2 modified normal loading

Elevator	U	U (f)	N	D
α, deg	49	41	52	52
ϕ, deg	0	3D	0	0
V, fps	160	163	148	---
Turns for recovery	2, c1, c1½	c1, c1½	2¾	2½, 3

	Tail no. 2 modified normal loading flaps down 50°			Tail no. 2 modified ΔI_X and ΔI_Z = -0.20 I_X, ΔI_Y and ΔI_Z = 0.20 I_Y, c.g. moved back 0.03c̄				Tail no. 2 modified flaps down 50° ΔI_X and ΔI_Z = -0.20 I_X, ΔI_Y and ΔI_Z = 0.20 I_Y, c.g. moved back 0.03c̄		
Elevator	U (g)	N	D	U	U (f)	N	D	U (g)	N	D
α, deg	----	----	49	54	49	58	54	----	47	----
ϕ, deg	----	----	0	3D	1D	3D	1U	----	3D	----
Ω, rps	----	----	----	----	----	----	----	----	----	----
V, fps	----	----	----	160	165	153	149	----	149	----
Turns for recovery	----	----	4¾	c2¼	c1½	3	3	----	∞	----

aSteady spin data for rudder against spin.
bRate of descent increased slightly after rudder reversal.
cRecovery attempted by simultaneous reversal of rudder and elevator.
dRecovery attempted by rudder reversal with elevator down.
eVisual observation.
fAuxiliary fin added beneath fuselage about 45 inches long by 2½ inches deep, full scale.
gWandering spin.

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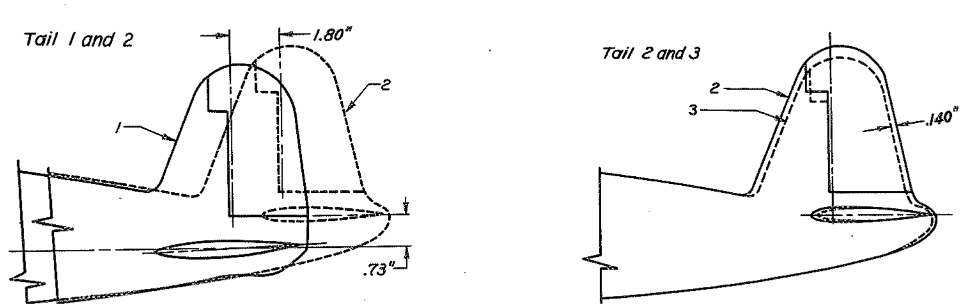
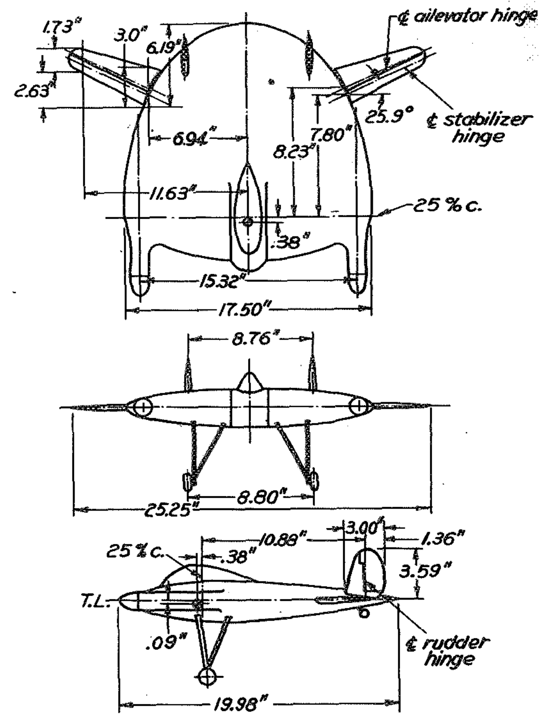


$\frac{1}{16}$-SCALE MODEL OF THE VOUGHT-SIKORSKY V-173 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	23.33
L, ft	26.64
$\bar{c}$, in.	238.00
S, sq ft	427.00
A	1.27
S_h, sq ft	46.80
S_a, sq ft (ailevators)	27.30
S_s, sq ft (stabilizer)	19.50
S_v, sq ft	28.30
S_r, sq ft	13.20
δ_r, deg	30 R, 30 L
TDPF	0
Landing condition - L.E. stab., deg	30 D
Landing gear	
Prototype and intermediate	Fixed
Fighter	Conventional



Model as tested.

Ailevator Deflections for Different Control Positions for Right Spins

(All ailevator deflections are measured from plane of stabilizer)

Ailerons	Against		Neutral		With	
	R (deg)	L (deg)	R (deg)	L (deg)	R (deg)	L (deg)
Elevator U	0	30 U	15 U	15 U	30 U	0
N	30 D	30 U	0	0	30 U	30 D
D	30 D	0	15 D	15 D	0	30 D

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Mass Data

Loading	Prototype	Intermediate	Fighter	Fighter
Landing gear	Down	Down	Up	Down
W, lb	4615	6283	11,890	11,890
$x/\bar{c}$	0.225	0.225	0.225	0.218
$z/\bar{c}$	0.006	0.006	0.017	0.030
I_X, slug-ft^2	8090	8510	17,178	17,773
I_Y, slug-ft^2	4915	4485	6900	7283
I_Z, slug-ft^2	12,780	12,056	23,571	23,415
Test altitude, ft	10,000	10,000	10,000	10,000
μ (at sea level)	6.05	8.24	15.59	15.59
μ' (10,000 ft)	8.19	11.16	21.11	21.11
$\frac{I_X - I_Y}{mb^2}$	405×10^{-4}	379×10^{-4}	511×10^{-4}	522×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-1006×10^{-4}	-713×10^{-4}	-829×10^{-4}	-803×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	601×10^{-4}	334×10^{-4}	318×10^{-4}	281×10^{-4}

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Résumé of Model Test Results

For the prototype loading condition the spins of the model for all aileron-elevator settings were very steep ($\alpha < 20^{\circ}$) and the rates of descent in excess of 245 feet per second (full scale).

Extending mass along the lateral axis (ΔI_X and $\Delta I_Z = 0.261\ I_X$) retracting mass along the lateral axis (ΔI_X and $\Delta I_Z = -0.49\ I_X$) in conjunction with an extension of mass along the longitudinal axis (ΔI_Y and $\Delta I_Z = 0.12\ I_Y$), or a forward or rearward movement of the center of gravity $0.025\bar{c}$ in conjunction with the change in mass along the lateral and longitudinal axes led to steep, high-velocity spins similar to corresponding spins for the normal prototype loading and recoveries by rapid full reversal of rudders were satisfactory. Because the spin characteristics for the prototype loading and for changes in mass distribution from the prototype loading were similar, it is believed that recoveries from spins for the normal prototype loading if attempted would have been satisfactory.

Deflecting the leading edge of the stabilizer 30° down when the ailerons were set against the spin for the prototype loading produced unsatisfactory recoveries (∞ turns), whereas for the condition of mass retracted along the lateral axis and extended along the longitudinal axis (ΔI_X and $\Delta I_Z = 0.49\ I_X$ and ΔI_Y and $\Delta I_Z = 0.12\ I_Y$), the test results indicate that generally deflection of the leading edge of the stabilizer 30° down had no appreciable effect on the satisfactory recovery characteristics of the model.

The spin and recovery characteristics of the model ballasted for the intermediate loading were similar to the spin and recovery characteristics of the model for the prototype loading except when the ailerons were full against or full with the spin with the elevator full down, for which cases recoveries were unsatisfactory. Deflecting the leading edge of the stabilizer 30° down produced satisfactory recoveries from the ailerons against or neutral spins but unsatisfactory recoveries from the aileron-with spins.

For the fighter loading (stabilizer in neutral position), the recovery characteristics of the model were unsatisfactory. Deflecting the leading edge of the stabilizer 30° down slightly improved the recovery characteristics.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE VOUGHT-SIKORSKY V-173 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition with the landing gear extended and stabilizer setting zero and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Prototype loading							Prototype loading ΔI_X and $\Delta I_Z = 0.26\ I_X$							Prototype loading ΔI_X and $\Delta I_Z = -0.49\ I_X$, ΔI_Y and $\Delta I_Z = 0.17\ I_Y$								
Ailevators as ailerons	Against		Neutral			With		Against		Neutral			With		Against			Neutral			With		
Ailevators as elevators	U (a)	D	U (a)	N (a)	D	U (a)	D (a)	U (a)	D (c)	U (a)	N (a)	D	U (ad)	D (ad)	U (f)	N	D (f)	U (f)	N (a)	D (a)	U (f)	N	D (a)
α, deg	-	-	-	-	No spin	-	-	-	-	-	-	No spin	--	-	-	-	-	-	-	-	-	-	-
Ø, deg	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Ω, rps	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
V, fps	>245	-	>245	>245		>245	>245	>245	>245	>245	>245		>245	>245	>245	-	>245	>245	>245	>245	>245	-	>245
Turns for recovery	-	-	-	[b]< $2\frac{1}{4}$		-	-	< $2\frac{1}{4}$	[e]-	-	-		-	-	< $2\frac{1}{2}$	-	< $2\frac{1}{2}$	< $2\frac{1}{2}$	< $2\frac{1}{4}$	< $2\frac{1}{4}$	< $2\frac{1}{2}$	-	< $2\frac{1}{4}$

	Prototype loading ΔI_X and $\Delta I_Z = -0.49\ I_X$, ΔI_Y and $\Delta I_Z = 0.17\ I_Y$, c.g. moved forward $0.025\bar{c}$							Prototype loading ΔI_X and $\Delta I_Z = -0.49\ I_X$, ΔI_Y and $\Delta I_Z = 0.17\ I_Y$, c.g. moved back $0.025\bar{c}$										Prototype loading Leading edge of stabilizer 30° down, normal loading					
Ailevators as ailerons	Against		Neutral			With		Against				Neutral			With			Against		Neutral		With	
Ailevators as elevators	U (f)	D	U (f)	N (a)	D (a)	U (f)	D (a)	U (f)	N	D (ag)	D (g)	U (f)	N (f)	D (a)	U (f)	N	D (a)	U	D (c)	U	N (c)	U	D
α, deg	-	28	-	-	-	-	-	-	-	-	58	-	-	-	-	-	-	No spin	-	-	-	59	59
Ø, deg	-	3U	-	-	-	-	-	-	-	-	1D	-	-	-	-	-	-		-	-	-	3D	2D
Ω, rps	-	0.61	-	-	-	-	-	-	-	-	0.53	-	-	-	-	-	-		-	-	-	0.57	0.77
V, fps	>245	162	>245	>245	>245	>245	>245	>245	-	>245	89	>245	>245	>245	>245	-	>245		-	-	-	87	87
Turns for recovery	< $2\frac{1}{2}$	3	< $2\frac{1}{2}$	< $2\frac{1}{4}$	< $2\frac{1}{4}$	< $2\frac{1}{2}$	< $2\frac{1}{4}$	< $2\frac{1}{2}$	-	-	∞	< $2\frac{1}{2}$	< $2\frac{1}{2}$	< $2\frac{1}{4}$	< $2\frac{1}{2}$	-	< $2\frac{1}{4}$		[h]5	-	[h]5	∞	∞

	Prototype loading Leading edge of stabilizer 30° down ΔI_X and $\Delta I_Z = -0.96\ I_X$, ΔI_Y and $\Delta I_Z = 0.17\ I_Y$							Intermediate loading									Intermediate loading ΔI_X and $\Delta I_Z = 0.257\ I_X$						
Ailevators as ailerons	Against		Neutral			With		Against			Neutral			With			Against		Neutral			With	
Ailevators as elevators	U	D (c)	U (c)	N (c)	D (c)	U (a)	D (c)	U (f)	N (f)	D	U (f)	N (f)	D (f)	U	N	D (f)	U	D (i)	U (a)	N (a)	D (a)	U	D
α, deg	No spin	-	-	-	-	-	-	-	-	53	-	-	-	43	38	-	No spin	-	-	-	-	43	No spin
Ø, deg		-	-	-	-	-	-	-	-	2D	-	-	-	5D	7D	-		-	-	-	-	1D	
Ω, rps		-	-	-	-	-	-	-	-	0.76	-	--	-	0.66	0.80	-		-	-	-	-	0.88	
V, fps		-	-	-	-	>245	-	>245	>245	104	>245	>245	>245	147	169	>245		>245	>245	>245	>245	147	
Turns for recovery		[h]5	[h]4	[h]4	[h]5	< $2\frac{1}{4}$	[h]5	< $2\frac{1}{2}$	< $2\frac{1}{2}$	∞	< $2\frac{1}{2}$	< $2\frac{1}{2}$	< $2\frac{1}{2}$	∞	-	< $2\frac{1}{2}$		< 2	< $2\frac{1}{4}$	< $2\frac{1}{4}$	< $2\frac{1}{4}$	8	

	Intermediate loading ΔI_Y and $\Delta I_Z = 1.22\ I_Y$							Intermediate loading, leading edge of stabilizer 30° down								Fighter loading (landing-gear retracted)									
Ailevators as ailerons	Against		Neutral			With		Against			Neutral			With		Against				Neutral			With		
Ailevators as elevators	U (f)	D	U (jk)	N (jk)	D (fj)	U (j)	D (i)	U	N	D	U (k)	N (f)	D	U	D	U (a)	N (l)	N (l)	D	U	N	D	U	N	D (a)
α, deg	-	69	-	-	-	39	-	No spin	-	No spin	-	-	-	58	54	-	No spin	-	67	43	62	59	49	45	-
Ø, deg	-	4D	-	-	-	7D	-		-		-	-	-	2D	3D	-		-	1D	0	1D	2D	1D	0	-
Ω, rps	-	0.72	-	-	-	0.57	-		-		-	-	-	0.72	0.72	-		-	0.78	0.64	0.71	0.73	0.68	0.66	-
V, fps	245	116	>245	>245	>245	184	>245		-		>245	>245	>245	125	124	>245		184	122	202	155	145	158	184	>245
Turns for recovery	< $2\frac{1}{2}$	∞	< $2\frac{1}{4}$	< $2\frac{1}{4}$	< $2\frac{1}{2}$	$2\frac{1}{4}$	> 2		-		< $2\frac{1}{4}$	< $2\frac{1}{2}$	-	∞	∞	-		3 4	∞	∞ 8	∞	∞	∞	∞	-

[a]Steep spin.
[b]Recovery was attempted before the final steep attitude was attained.
[c]Moderately steep spin with increasing radius.
[d]Model attitude did not change after rudder reversal.
[e]Slow recovery.
[f]Steep spin with increasing radius.
[g]Two types of spin.
[h]When launched in a flat attitude with the rudder against the rotation, the model ceased rotating after indicated number of turns.
[i]Steep spin with small radius.
[j]Wandering spin, rate of rotation varies.
[k]Wide radius of spin.
[l]Two conditions possible.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE VOUGHT-SIKORSKY V-173 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition with the landing gear extended and stabilizer setting zero and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Fighter loading, rudder-against spins (landing gear retracted)									Fighter loading leading edge of stabilizer 30° down,		
Allevators as ailerons	Against			Neutral			With			Against		
Allevators as elevators	U	N	D	U	N	D	U	N	D (a)	U	N	D
α, deg	No spin	No spin	-	No spin	-	-	-	-	-	No spin	No spin	-
ø, deg			-		-	-	-	-	-			-
Ω, rps			-		-	-	-	-	-			-
V, fps			127		165	149	160	195	>245			191
Turns for recovery			-		-	-	-	-	-			>6½

	Fighter loading, leading edge of stabilizer 30° down (landing gear retracted)									Fighter loading, leading edge of stabilizer 30° down, propellers attached (landing gear retracted)						
Allevators as ailerons	Against				Neutral		With			Against			Neutral		With	
Allevators as elevators	U	N	D (l)	D (l)	U	D	U	N	D	U	N	D	U	D	U	D
α, deg	No spin	No spin	No spin	-	40	-	64	-	65	No spin	No spin	-	-	-	-	-
ø, deg				-	2D	-	0	-	1D			-	-	-	-	-
Ω, rps				-	0.72	-	0.68	0.77	0.84			-	-	-	-	-
V, fps				173	216	-	160	142	136			209	216	-	191	-
Turns for recovery				[b]6	[b]6	-	∞	∞	∞			-	-	-	>2	-

[a]Steep spin.
[b]When launched in a flat attitude with the rudder against the rotation, the model ceased rotating after indicated number of turns.
[l]Two conditions possible.

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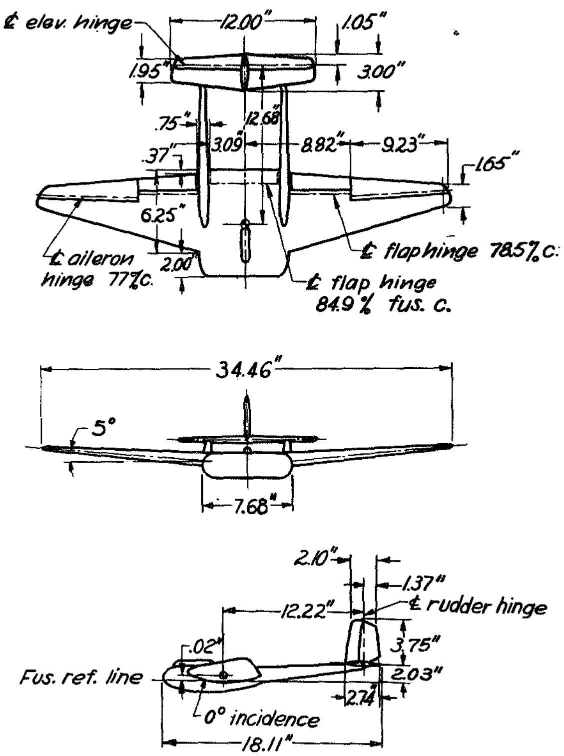
1/32 SCALE MODEL OF THE GENERAL AIRBORNE TRANSPORT COMPANY XCG-16 GLIDER

Dimensional Data

(Full Scale)

b, ft	91.83
L, ft	48.29
$\bar{c}$, in.	168.00
S, sq ft	1176.00
A	7.16
L.E. $\bar{c}$ aft L.E. c_r, in.	25.00
S_h, sq ft	204.00
S_e, sq ft	68.60
S_v, sq ft	60.30
S_r, sq ft	28.00
δ_r, deg	19 R, 19 L
δ_e, deg	33 U, 20 D
δ_a, deg (full stick)	20 U, 10 D
(1/2 stick)	10 U, 5 D
(1/3 stick)	7 U, 3 D
δ_f, deg (Wing)	45 D
δ_f, deg (Cargo section)	30 D
TDPF Normal tail	7×10^{-6}
Twin vertical tails	34×10^{-6}
Twin vertical tails with modification 1,	206×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

	Normal (Airplane)	Loading 1	Loading 2	Loading 3
		(Loadings tested with model)		
W, lb	18,040	18,040	18,950	27,250
$x/\bar{c}$	0.302	0.306	0.302	0.302
$z/\bar{c}$	-0.004	-0.032	0.013	0.106
I_X, slug-ft^2	45,000	65,100	105,900	110,200
I_Y, slug-ft^2	32,600	44,000	93,100	97,800
I_Z, slug-ft^2	74,800	105,800	137,500	137,500
Test altitude, ft		15,000	15,000	15,000
μ (at sea level)	2.18	2.18	2.29	3.30
μ' (at 15,000 ft)		3.47	3.64	5.24
$\frac{I_X - I_Y}{mb^2}$	26×10^{-4}	45×10^{-4}	26×10^{-4}	18×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-89×10^{-4}	-132×10^{-4}	-90×10^{-4}	-57×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	63×10^{-4}	87×10^{-7}	64×10^{-4}	39×10^{-4}

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Résumé of Model Test Results

Because of the structural design of the model it could not be ballasted to represent the glider at a reasonable test altitude for the normal loading condition. It was believed, however, that the spin characteristics of the glider could be estimated from results of tests for certain loadings other than the normal loading, and accordingly the model was ballasted and tested for three loading conditions at an equivalent test altitude of 15,000 feet. It is believed that the data for loading 2 is most nearly representative of the glider in its normal loading condition.

For all loading conditions tested, with the model in the clean condition equipped with either the original single vertical tail or the alternate vertical twin tails (see sketch) with or without dorsal fins, the model would spin only when the ailerons were partly or full with the rotation and the elevator was partly or full up. Recoveries from these spins were unsatisfactory by rapid full rudder reversal whereas neutralizing the elevator produced satisfactory recoveries. It should be noted that a reversal of the rudder alone caused the motions of the model to become violently oscillatory.

Deflecting the flaps 45° had little effect upon the recovery characteristics of the model except with the controls in the normal configuration for spinning, for which case an oscillatory spin was obtained and recovery from this spin was unsatisfactory. Inverted spins were attempted with the model equipped with twin vertical tails and dorsal fins (see sketch) and ballasted to represent loading 2. In general the spin recovery characteristics were similar to the spin-recovery characteristics for erect spins with the model modified with twin tails and ventral fins (modification 1) as would be expected inasmuch as the tail effectiveness for recovery is probably of the same order for both cases.

A large increase in vertical-tail area (modification 1) did not improve the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{32}$-SCALE MODEL OF GENERAL AIRBORNE TRANSPORT XCG-16 GLIDER

[Unless otherwise indicated, the model was equipped with twin vertical tails and dorsal fins, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Loading 1, single vertical tail											Loading 1, twin vertical tails									Loading 1								
Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full				Against			Neutral			With			Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	U	5° U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	15	15	18	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	16	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	22	No spin	No spin
ϕ, deg							2D	1D	1D									2D									2D		
Ω, rps							0.21	0.31	0.38									0.28									0.28		
V, fps							229	207	293									225									219		
Turns for recovery							>2 $1\frac{1}{2}$	∞ $a_1\frac{1}{4}$ $b_1\frac{1}{4}$	∞									∞ $a\frac{1}{2}$									∞ a_2 $a_1\frac{1}{4}$ $b\frac{1}{2}$		

	Loading 2												Loading 3										c.g. moved back 0.15$\bar{c}$ (loading 2)										
Ailerons	Against			Neutral			With $\frac{1}{3}$	With Full					Against			Neutral			With				Against			Neutral			With $\frac{1}{3}$	With Full			
Elevator	U	N	D	U	N	D	U	U (c)	16°U (d)	16°U (d)	N	D	U	N	D	U	N	D	U	11°U	N	D	U	N	D	U	N	D	U	U (e)	5°U	N (e)	D
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	14	12	---	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	-----	12	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	15	19	14	--	No spii
ϕ, deg							0	1D 15D	---										8D	2D									6D	5D	2D	--	
Ω, rps							0.29	0.34	---										0.35	0.36									0.20	0.23	0.31	--	
V, fps							229	221	257										247	280									218	194	218	--	
Turns for recovery							>3	∞ a_1 $a_1\frac{1}{2}$ $b\frac{1}{2}$ b_1	---										∞	∞									∞	∞ a_∞ b_3 $f\frac{1}{2}$	∞	--	

	Flaps fully deflected, (loading 2)									Inverted spin, (loading 2)											Modification 1, (loading 2)						
Ailerons	Against			Neutral			With			Against			Neutral			With $\frac{1}{3}$	With Full				Neutral			With $\frac{1}{2}$	With Full		
Elevator	U	N	D	U (c)	N	D	U (c)	N	D	U	N	D	U	N	D	U	U	10° U	N	D	U	N	D	U	U	N	D
α, deg	No spin	No spin	No spin	3 26	No spin	No spin	13 26	No spin	No spin	No spin	---	---	No spin	No spin	---	30	35	30	No spin	-	No spin	No spin	---	22	23	No spin	-
ϕ, deg				2D 17D			4D 15D				---	---			---	5U	7U	4U		-			---	6D	4D		-
Ω, rps				0.23			0.33				--	--			--	0.20	0.23	0.28		-			--	0.27	0.33		-
V, fps				201			176				--	--			--	201	171	214		-			--	224	218		-
Turns for recovery				>5			∞				--	--			--	∞	∞	∞		-			--	∞	∞		-

[a] Recovery attempted by neutralizing the elevator.
[b] Recovery attempted by releasing the elevator.
[c] Oscillatory spin. Range of values or average value given.
[d] Two conditions possible.
[e] Spin with a radius too large for testing also obtained.
[f] Recovery attempted by reversing the elevator.

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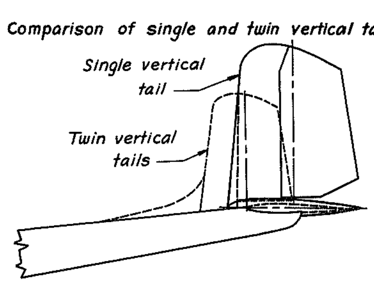
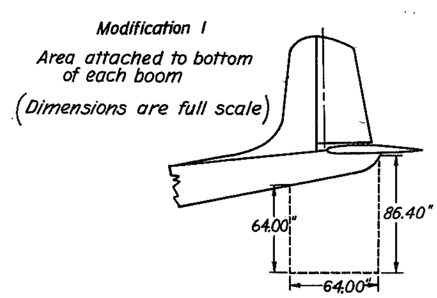


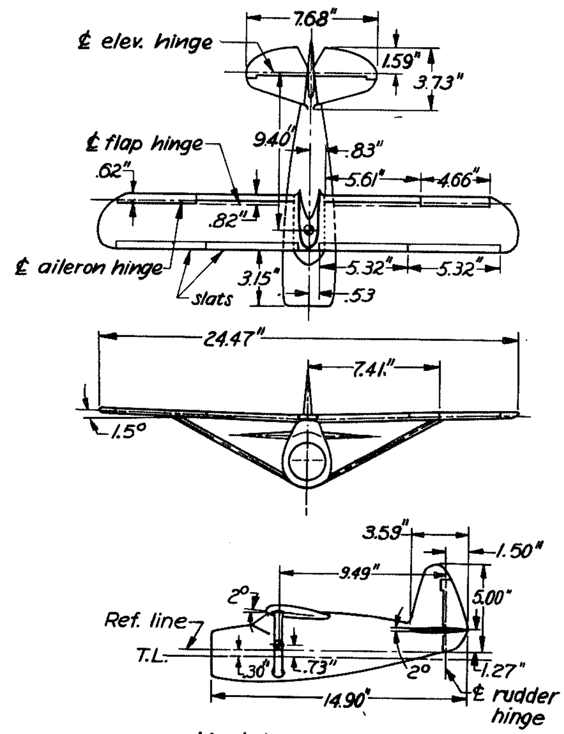


$\frac{1}{20}$-SCALE MODEL OF THE CURTISS O-52 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	40.79
L, ft	26.34
$\bar{c}$, in.	64.00
S, sq ft	210.78
A	7.89
L.E. $\bar{c}$ aft L.E. c_r	0
S_h, sq ft	55.05
S_e, sq ft	23.15
S_v, sq ft	27.60
S_r, sq ft	11.72
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 20 D
δ_a, deg	20 U, 17 D
δ_a, deg (1/2 stick)	11 U, $9\frac{1}{2}$ D
δ_a, deg (landing condition) (Aileron deflections measured from drooped position)	15 D
δ_f, deg	60 D
TDPF	224×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

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Normal Loading

W, lb	5097
$x/\bar{c}$	0.284
$z/\bar{c}$	-0.228
I_X, slug-ft^2	3705
I_Y, slug-ft^2	4970
I_Z, slug-ft^2	7580
Test altitude, ft	10,000
μ (at sea level)	7.74
μ' (10,000 ft)	10.49

$\frac{I_X - I_Y}{mb^2}$	-48×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-99×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	147×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, for all control configurations, the model spun at steep angles of attack (from 24° to 36°) and recoveries from spins were satisfactory by rapid full rudder reversal.

Extending mass along the wings or fuselage (ΔI_X and $\Delta I_Z = 0.30\ I_X$ or ΔI_Y and $\Delta I_Z = 0.34\ I_Y$) or moving the center of gravity forward or back $0.05\bar{c}$ from its normal position (data not presented) had no appreciable effect upon the satisfactory recovery characteristics of the model.

Opening the slots had a very detrimental effect on the steady spin and recovery characteristics of the model and in general all recoveries obtained with the slots open were unsatisfactory.

Lowering the flaps 60°, with or without drooping the ailerons 15°, generally did not appreciably alter the recovery characteristics of the model and rapid recoveries were still obtained for elevator up spins.

With the landing gear extended, flaps down 60°, ailerons drooped 15° and the slots open (landing condition), the recovery characteristics of the model were unsatisfactory except for aileron-with, elevator-up or elevator-neutral spins. With the ailerons not drooped, with the model in the landing condition, satisfactory recoveries were obtained when the elevator was full up for all aileron settings.

In an endeavor to improve the recovery characteristics of the model in the landing condition an alternate modified rudder (modified by the addition of approximately 1.40 square feet of area, full scale, along the lower trailing edge, (see sketch), was installed. This modified rudder gave appreciably better results than the original; however, recoveries were still generally unsatisfactory.

An inverted spin could be obtained only when the controls were crossed and the stick was forward; test results indicated (data not presented) that recovery from this spin would be satisfactory by rapid full rudder reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE CURTISS O-52 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spin]

	Normal loading														
Ailerons	Against						Neutral			With					
	Full			$\frac{1}{2}$						$\frac{1}{2}$			Full		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	24	No spin	33	26	32	35	28	34	37	32	35	36	35	35	35
ø, deg	11U		17U	10U	12U	11U	3U	6U	8U	5D	1U	3U	7D	2D	0
Ω, rps	0.31		0.54	0.41	0.53	0.54	0.45	0.53	0.54	0.40	0.53	0.55	0.36	0.54	0.55
V, fps	211		165	210	173	165	201	177	161	198	175	169	185	173	165
Turns for recovery	$\frac{1}{4}$ [b]$\frac{1}{4}$		1	1	$\frac{3}{4}$	1	$\frac{3}{4}$ [a]>3 [b]$\frac{1}{2}$	$\frac{3}{4}$ [a]$2\frac{1}{2}$	$1\frac{1}{2}$ [a]$3\frac{1}{4}$	1 2	$1\frac{3}{4}$	$1\frac{1}{4}$	3 [b]$1\frac{1}{2}$ [b]1	$1\frac{3}{4}$	$1\frac{1}{2}$ 2

Effect of mass variations on turns for recovery									
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
ΔI_X and ΔI_Z = 0.15 I_X	--	--	c	$\frac{3}{4}$	---	$1\frac{1}{2}$ 1	>4	---	--
ΔI_X and ΔI_Z = 0.30 I_X	$\frac{1}{4}$	c	c	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	>4	2	$1\frac{3}{4}$
ΔI_Y and ΔI_Z = 0.17 I_Y	$\frac{1}{2}$	--	$1\frac{1}{4}$	1	----	$1\frac{1}{2}$	2	--	$2\frac{1}{2}$
ΔI_Y and ΔI_Z = 0.34 I_Y	c	--	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{4}$	2	$1\frac{1}{4}$	--	$2\frac{1}{4}$

	Flaps 60° down, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	---	---	---	---	---	---	---	---	---
ø, deg	---	---	---	---	---	---	---	---	---
Ω, rps	---	---	---	---	---	---	---	---	---
V, fps	---	---	---	---	---	---	---	---	---
Turns for recovery	$\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{3}{4}$	2	$3\frac{1}{4}$

	Flaps 60° down, ailerons drooped 15°, normal loading							
Ailerons	Against			Neutral		With		
Elevator	U	N	D	N	D	U (d)	N	D
α, deg	---	---	---	---	---	---	----	----
ø, deg	---	---	---	---	---	---	----	----
Ω, rps	---	---	---	---	---	---	----	----
V, fps	---	---	---	---	---	---	----	----
Turns for recovery	1	$1\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{3}{4}$	2	---	$\frac{3}{4}$	$1\frac{3}{4}$

	Slots open, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	43	57	57	48	57	60	52	56	57
ø, deg	1D	3U	4U	2D	2U	2U	7D	3D	3D
Ω, rps	0.40	0.50	0.51	0.41	0.51	0.53	0.43	0.51	0.53
V, fps	160	132	128	156	128	118	144	130	124
Turns for recovery	$1\frac{1}{4}$	3	$3\frac{1}{2}$	∞	4	5	∞	∞	∞

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	69	71	69	49	63	61	46	38	55
ø, deg	4U	3U	4U	5D	1U	0	11D	12D	4D
Ω, rps	0.50	0.55	0.53	0.39	0.53	0.52	0.40	0.51	0.50
V, fps	118	108	112	140	116	114	148	126	120
Turns for recovery	∞	∞	∞	6	∞	∞	$1\frac{3}{4}$	2	5

	Landing condition, ailerons not drooped, normal loading							
Ailerons	Against			Neutral		With		
Elevator	U	N	D	U	D	U	N	D
α, deg	---	---	---	---	---	---	----	----
ø, deg	---	---	---	---	---	---	----	----
Ω, rps	---	---	---	---	---	---	----	----
V, fps	---	---	---	---	---	---	----	----
Turns for recovery	[e]$\frac{1}{8}$	$2\frac{1}{2}$	3	$2\frac{1}{2}$	---	2	∞	7

	Landing condition, normal loading, modified rudder								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	----	----	----	----	----	----	----	----	---
ø, deg	----	----	----	----	----	----	----	----	---
Ω, rps	----	----	----	----	----	----	----	----	---
V, fps	130	114	114	132	122	118	140	----	120
Turns for recovery	4	4	5	$2\frac{1}{2}$, 2 [b]$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{1}{2}$ [b]$1\frac{1}{4}$	----	3

[a]Recovery attempted by rudder neutralization.
[b]Recovery attempted by simultaneous reversal of rudder and elevator.
[c]Model would not spin.
[d]Spin too oscillatory to test.
[e]Estimated turns for recovery.

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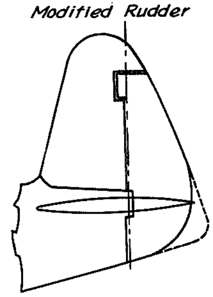
Modified Rudder

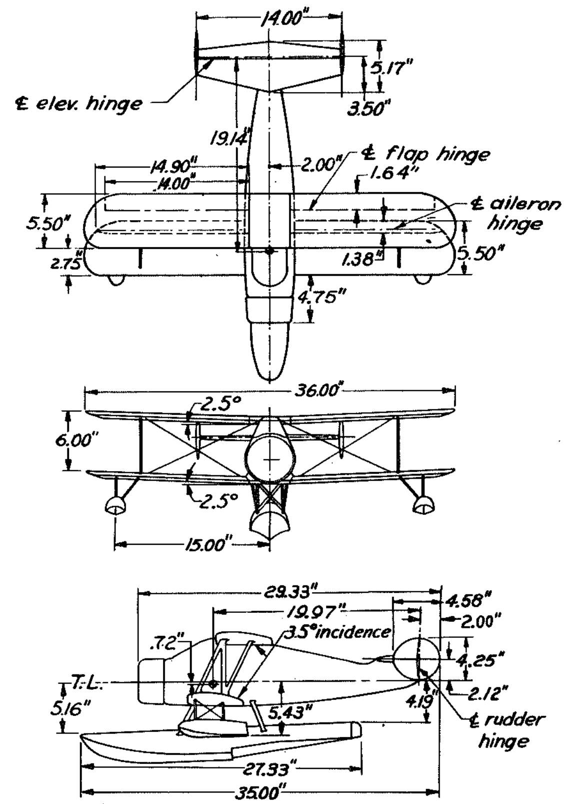


$\frac{1}{12}$-SCALE MODEL OF THE MARTIN M-159 VOS-TYPE AIRPLANE

Dimensional Data

(Full Scale)

b, ft	36.00
L, ft	35.00
$\bar{c}$, in.	66.00
S, sq ft	382.00
A (upper wing)	3.39
L.E. $\bar{c}$ aft L.E. c_r (lower wing), in.	1.32
S_h, sq ft	54.25
S_e, sq ft	17.50
S_v, sq ft	30.00
S_r, sq ft	13.40
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 25 D
δ_a, deg	30 U, 15 D
TDPF	2110×10^{-6}
Landing gear	Float



Model as tested.

Mass Data

Normal Loading

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W, lb	5116
$x/\bar{c}$	0.230
$z/\bar{c}$	0.130
I_X, slug-ft^2	3838
I_Y, slug-ft^2	6840
I_Z, slug-ft^2	8752
Test altitude, ft	10,000
μ (at sea level)	4.86
μ' (10,000 ft)	6.59

$\frac{I_X - I_Y}{mb^2}$	-146×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-93×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	239×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, the model exhibited a very pronounced tendency to wander and therefore prolonged spins could not be attained. During these tests, the wing-tip floats were broken off each time the model struck the safety netting and accordingly the wing-tip floats were removed and weights added to give the proper mass distribution value. It was determined that this change did not influence the spin characteristics of the model and the wing-tip floats were left off for the remainder of the tests.

With the mass extended along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$), the model spun in a flat attitude and was extremely oscillatory when the elevator was either partially or full up. With the elevator either neutral or down, the spin was steep and steady. With a pro-spin fin added to the model for this loading, the spin characteristics of the model were not appreciably affected. For the elevator-neutral spins, recovery by simultaneous reversal of the elevator from neutral to down and the rudder from full with to full against the spin required 3 turns. (The pro-spin fin contributed a pro-spin yawing moment of approximately 0.017.) With mass extended along the fuselage (ΔI_Y and $\Delta I_Z = 0.30\ I_Y$) and with the pro-spin fin installed (data not presented) there was but slight differences in the spin results of the model as compared with the results obtained with the mass extended along the wings and the pro-spin fin installed.

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SPIN DATA OBTAINED WITH THE $\frac{1}{12}$-SCALE MODEL OF THE MARTIN M-159 AIRPLANE

[Unless otherwise indicated, steady-spin data are for spins of the model in the clean condition]

ΔI_X and $\Delta I_Z = 0.30\,I_X$ aileron-neutral spins			ΔI_X and $\Delta I_Z = 0.30\,I_X$, aileron-neutral spins, pro-spin fin attached		
Rudder	Elevator	Description of spin	Rudder	Elevator	Description of spin
With	35° U	Flat, oscillatory spin, low velocity	With	35° U	Flat, oscillatory spin, low velocity
With	15° U	Flat, oscillatory spin, low velocity	With	15° U	Flat, oscillatory spin, low velocity
With	N	Steep spin, high velocity	With	N	Steep spin, high velocity
With	25° D	Steep spin, high velocity	With	25° D	Steep spin, high velocity
Neutral	35° U	No spin	Neutral	35° U	Flat, oscillatory spin, low velocity
Neutral	15° U	No spin	Neutral	15° U	Flat, oscillatory spin, low velocity
Neutral	N	Steep spin, high velocity	Neutral	N	Moderate attitude, moderate velocity
Neutral	25° D	Steep spin, high velocity	Neutral	25° D	Steep spin, high velocity
Against	35° U	No spin	Against	35° U	No spin
Against	15° U	No spin	Against	15° U	No spin
Against	N	No spin	Against	N	No spin
Against	25° D	No spin	Against	25° D	No spin

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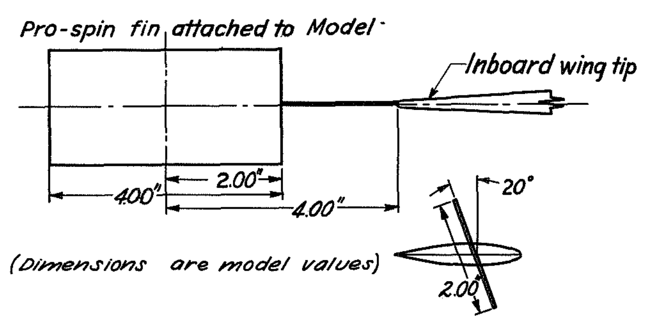
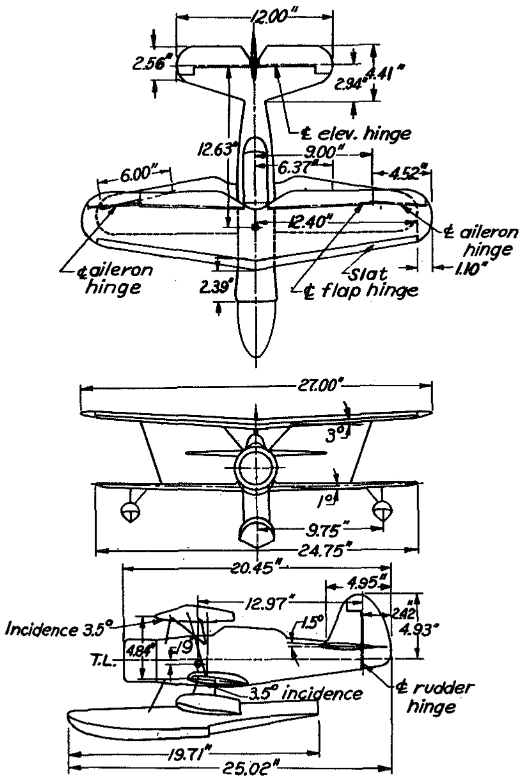
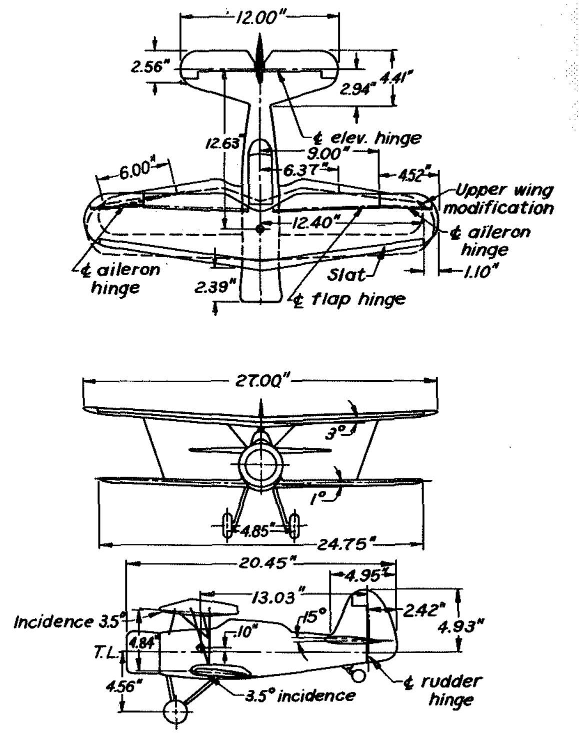


$\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XOSN-1 SEAPLANE AND LANDPLANE



Model as tested.



Model as tested.

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Dimensional Data

(Full Scale)

(Dimensions are the same for landplane and seaplane
except where noted)

b, ft	36.00
L, ft	
Seaplane	33.40
Landplane	27.90
$\bar{c}$, in	70.09
S, sq ft	378.25
A	4.06
L.E. $\bar{c}$ aft L.E. c_r, in	19.13
S_h, sq ft	69.00
S_e, sq ft	27.00
S_v, sq ft	29.70
S_r, sq ft	21.40

δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	30 U, 15 D
δ_f, deg	45 D
TDPF	
Seaplane	324×10^{-6}
Landplane	313×10^{-6}
Landing gear	
Seaplane	Float
Landplane	Fixed

Mass Data

Normal Loading

(Seaplane)

W, lb	5299	$\frac{I_X - I_Y}{mb^2}$	-99×10^{-4}
$x/\bar{c}$	0.286	$\frac{I_Y - I_Z}{mb^2}$	-64×10^{-4}
$z/\bar{c}$	0.044	$\frac{I_Z - I_X}{mb^2}$	163×10^{-4}
I_X, slug-ft^2	3610		
I_Y, slug-ft^2	5710		
I_Z, slug-ft^2	7070		
Test altitude, ft	10,000		
μ (at sea level)	5.08		
μ' (10,000 ft)	6.89		

(Landplane)

W, lb	5023	$\frac{I_X - I_Y}{mb^2}$	-119×10^{-4}
$x/\bar{c}$	0.319	$\frac{I_Y - I_Z}{mb^2}$	-68×10^{-4}
$z/\bar{c}$	-0.022	$\frac{I_Z - I_X}{mb^2}$	187×10^{-4}
I_X, slug-ft^2	2705		
I_Y, slug-ft^2	5115		
I_Z, slug-ft^2	6495		
Test altitude, ft	10,000		
μ (at sea level)	4.82		
μ' (10,000 ft)	6.53		

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Résumé of Model Test Results

The recovery characteristics of the seaplane and landplane models when in the clean condition, normal loading, were generally satisfactory by rapid full rudder reversal for all control configurations tested.

Moderate extension of mass along the wings or fuselage (see chart for quantitative values) or center-of-gravity movements forward $0.08\bar{c}$ or rearward $0.05\bar{c}$ from the normal position for either of the two models had no appreciable effect on the recovery characteristics of the models. For the "worst" loading condition, that is, mass extended along the wings (see chart for quantitative values) and the center of gravity moved forward $0.08\bar{c}$, the recovery characteristics of both models were similar to the characteristics for the normal loading condition.

For the seaplane model, deflecting the flaps or opening the slots had no appreciable effect on the recovery characteristics of the model; for the landplane model, however, deflecting the flaps had a slight beneficial effect.

Installation of a modified upper wing (original wing with no sweepback) had little effect on the turns required to effect a recovery from a spin.

In an attempt to obtain rapid recoveries for the "worst" loading conditions of the models with the elevator full down, a number of tests were conducted with a series of tail modifications (modifications 1 to 54). Results of these tests indicated that increasing the height and decreasing the chord of the rudder, or lengthening the fuselage, or lowering the horizontal tail surfaces, led to the desired results. Tail number 54 gave rapid recoveries from spins for both the seaplane and landplane models in their normal loading conditions.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XOSN-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Seaplane, normal loading

Ailerons	Against 30U 15D	Against 17.4U 9D	Neutral	Neutral	Neutral	With 17.4U 9D	With 30U 15D
Elevator	N	N	U	N	D	N	N
α, deg	50	53	46	47	49	30	25
Ø, deg	0	1U	2U	1U	0	5D	7D
Ω, rps	0.53	0.53	0.43	0.53	0.55	0.58	0.65
V, fps	118	118	129	120	118	155	156
Turns for recovery	$1\frac{1}{4}$	$1\frac{1}{2}$	$\frac{3}{4}$ [a]$1\frac{1}{4}$	$1\frac{3}{4}$ $1\frac{1}{4}$	2	1	----

Seaplane; effect of mass variations and c.g. movements on turns for recovery. Aileron-neutral spins.

Elevator	U	N
ΔI_X and $\Delta I_Z = 0.15 I_X$	[a]$1\frac{1}{2}$	$1\frac{3}{4}$
ΔI_X and $\Delta I_Z = 0.30 I_X$	[a]$1\frac{1}{2}$	$1\frac{3}{4}$
ΔI_Y and $\Delta I_Z = 0.15 I_Y$	[a]$1\frac{1}{4}$	$1\frac{1}{4}$
ΔI_Y and $\Delta I_Z = 0.30 I_Y$	[b]---	$1\frac{3}{4}$
c.g. moved forward $0.08\bar{c}$	[a]$1\frac{3}{4}$	2
c.g. moved back $0.05\bar{c}$	[ab]1	$1\frac{1}{2}$
Bomber loading	[b]$1\frac{1}{4}$	$1\frac{1}{2}$

Seaplane, ΔI_X and $\Delta I_Z = 0.30 I_X$, c.g. moved forward $0.08\bar{c}$

Ailerons	Against 30U 15D	Against 17.4U 9D	Neutral	Neutral	Neutral	With 17.4U 9D	With 30U 15D
Elevator	N	N	U	N	D	N	N
α, deg	51	52	46	46	49	32	32
Ø, deg	1D	3D	0	0	0	3D	4D
Ω, rps	0.55	0.55	0.45	0.56	0.56	0.55	0.55
V, fps	119	119	132	126	122	149	148
Turns for recovery	$1\frac{1}{2}$	$1\frac{1}{2}$	1 [a]$1\frac{1}{4}$	2	$2\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$

Seaplane, normal loading effect of flap settings for aileron neutral spins

Flaps down	15°	30°	45°
Elevator	N	N	N
α, deg	45	39	33
Ø, deg	0	2U	3U
Ω, rps	0.52	0.51	0.52
V, fps	121	126	128
Turns for recovery	$1\frac{1}{2}$	$1\frac{1}{4}$	1

Seaplane, effect of slots for aileron neutral spins, normal loading

Slots	Right open	Right open	Left open	Left open	Both open	Both open
Elevator	U	N	U	N	U	N
α, deg	---	46	---	44	---	40
Ø, deg	---	3U	---	6D	---	4D
Ω, rps	---	0.54	---	0.51	---	0.52
V, fps	---	120	---	123	---	130
Turns for recovery	---	$1\frac{1}{2}$	---	$1\frac{1}{2}$	---	1

Seaplane, effect of flaps and slots on turns for recovery for aileron neutral spins, ΔI_X and $\Delta I_Z = 0.30 I_X$ c.g. moved forward $0.08\bar{c}$

Elevator	N	Slots open N	Slots open D
Flaps 15° down	$1\frac{1}{4}$	$1\frac{1}{4}$	----
Flaps 30° down	$1\frac{1}{4}$	[c]1	[c]$1\frac{1}{2}$
Flaps 45° down	$1\frac{1}{4}$	----	----
Right slot open	$1\frac{1}{4}$	----	----
Left slot open	$1\frac{1}{2}$	----	----
Both slots open	1	----	----

Seaplane, modified upper wing, normal loading

Ailerons	Neutral	Neutral	Neutral
Elevator	U	N	D
α, deg	43	37	44
Ø, deg	1U	4U	3U
Ω, rps	0.41	0.55	0.57
V, fps	139	126	124
Turns for recovery	[a]$\frac{1}{4}$ [a]$\frac{3}{4}$ $\frac{1}{2}$	$1\frac{1}{2}$	2

Landplane, normal loading

Ailerons	Against 30U 15D	Against 17.4U 9D	Neutral	Neutral	Neutral	With 17.4U 9D	With 30U 15D
Elevator	N	N	U	N	D	N	N
α, deg	---	---	--	--	--	---	----
Ø, deg	----	---	--	--	--	----	----
Ω, rps	---	---	--	--	--	---	----
V, fps	---	---	--	--	--	----	----
Turns for recovery	$1\frac{1}{2}$	2	[a]2 1	2	3	$1\frac{3}{4}$	$\frac{3}{4}$

Landplane, effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Elevator	U	N	D
ΔI_X and $\Delta I_Z = 0.20 I_Y$		$1\frac{1}{2}$	---
ΔI_X and $\Delta I_Z = 0.40 I_X$		$1\frac{1}{2}$	--
ΔI_Y and $\Delta I_Z = 0.17 I_Y$	[a]$1\frac{1}{4}$	$1\frac{1}{4}$	--
ΔI_Y and $\Delta I_Z = 0.34 I_Y$	---	$2\frac{3}{4}$	--
c.g. moved forward $0.08\bar{c}$	---	$2\frac{1}{4}$	--
c.g. moved back $0.05\bar{c}$	---	$1\frac{3}{4}$	--
Bomber loading	[a]2	2	--
ΔI_Y and $\Delta I_Z = 0.34 I_Y$ c.g. moved forward $0.08\bar{c}$	[a]9 $1\frac{1}{4}$	$2\frac{1}{2}$	∞

Landplane, effect of flaps on turns for recovery for aileron-neutral elevator-neutral spins

Flaps down	15°	30°	45°
Normal loading	$1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
ΔI_Y and $\Delta I_Z = 0.34 I_Y$ c.g. moved forward $0.08\bar{c}$	$1\frac{1}{2}$	$1\frac{1}{2}$	--

Landplane, modified upper wings normal loading; Landplane, modified upper wings, $\Delta I_Y + \Delta I_Z = 0.34 I_Y$, c.g. moved forward $0.08\bar{c}$

Ailerons	Modified upper wings normal loading: Neutral	Neutral	Neutral	Modified upper wings, $\Delta I_Y + \Delta I_Z = 0.34 I_Y$, c.g. moved forward $0.08\bar{c}$: Neutral	Neutral	Neutral
Elevator	U	N	D	U	N	D
α, deg	43	49	48	44	47	48
Ø, deg	3U	2U	2U	1U	0	1U
Ω, rps	0.45	0.54	0.55	0.41	0.47	0.50
V, fps	130	119	115	134	127	126
Turns for recovery	[a]$1\frac{1}{4}$ $\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{1}{4}$	[a]2 [a]$3\frac{1}{2}$ $\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{1}{2}$

[a]Recovery attempted by simultaneous reversal of rudder and elevator.
[b]Before recovery was attempted model wandered.
[c]Visual observation.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XOSN-1 AIRPLANE - Continued

[Unless otherwise indicated, steady-spin data are for the rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Effect of tail modifications on turns for recovery for aileron neutral spins for an adverse loading condition, (ΔI_Y and $\Delta I_Z = 0.17 I_Y$; c.g. at $0.25\bar{c}$)

Tail number	Modification	Elevator D	Elevator N
1	Normal load, tail wheel off	3	2
1	Seaplane, normal load	2	$1\frac{3}{4}$
1	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$	∞	$2\frac{1}{2}$
1	Horizontal surface down 6 inches, tail wheel off	∞	-----
1	Horizontal surface down 16 inches	2	-----
1	Horizontal surface up 20 inches	>4	-----
1	Horizontal surface back 12 inches	∞	$2\frac{1}{2}$
1	Horizontal surface back 12 inches, fin forward 22 inches	∞	$2\frac{3}{4}$
1	Tail lengthened 12 inches	$1\frac{3}{4}$	-----
2	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	-----	$2\frac{3}{4}$
3	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	5	$2\frac{1}{4}$
4	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	-----	2
5	Normal load, tail wheel off	$1\frac{3}{4}$	-----
5	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, tail wheel off	>5	-----
6	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, tail wheel off	$2\frac{1}{2}$	-----
7	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, tail wheel off	2	-----
7	Normal load, tail wheel off	-----	1
8	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, tail wheel off	2	-----
9	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, tail wheel off	3	-----
9	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{1}{2}$	-----
9	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 2	2	-----
9	Normal load, alternate tail wheel number 2	-----	1
10	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	2	-----
11	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	∞	-----
12	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{1}{2}$	-----
13	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	∞	-----
14	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$4\frac{1}{4}$	-----
14	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1, two anti-spin fillets (32" × 2" × 2") on tail	$4\frac{1}{4}$	-----
15	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	2	-----
16	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	∞	-----
17	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	>4	$1\frac{3}{4}$
17	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1, two anti-spin fillets (32" × 2" × 2") forward horizontal surface	>4	-----
18	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{1}{4}$	-----
19	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	2	$1\frac{1}{2}$
20	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{1}{2}$	-----
21	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{1}{2}$	-----
22	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	3	-----
23	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$3\frac{1}{2}$	-----
24	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	4	-----
25	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{1}{2}$	-----
26	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{1}{4}$	-----
27	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$2\frac{3}{4}$	-----
28	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$3\frac{1}{2}$	-----
29	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$1\frac{1}{2}$	-----
30	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$1\frac{1}{2}$	-----
31	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	2	-----
32	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$1\frac{3}{4}$	-----
33	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	2	-----
34	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	$1\frac{3}{4}$	-----
35	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	>5	-----
36	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	>3	-----
37	ΔI_Y and $\Delta I_Z = 0.34 I_Y$, c.g. at $0.24\bar{c}$, alternate tail wheel number 1	2	-----
38	Horizontal surface down 6 inches	2	-----
38	Horizontal surface down 16 inches	$1\frac{3}{4}$	-----
38	Horizontal surface up 20 inches	$1\frac{1}{2}$	-----
38	Horizontal surface back 12 inches	$1\frac{1}{4}$	-----
38	Horizontal surface back 12 inches, fin forward 22 inches	$2\frac{3}{4}$	-----
38	Tail lengthened 12 inches	$1\frac{1}{4}$	-----
39	Horizontal surface down 16 inches	$1\frac{3}{4}$	-----
40	Horizontal surface down 16 inches	$1\frac{3}{4}$	-----
40	Horizontal surface back 12 inches	$3\frac{1}{2}$	$1\frac{1}{2}$
40	Tail lengthened 12 inches	$2\frac{3}{4}$	-----
41	Tail lengthened 12 inches	$1\frac{1}{4}$	-----
41	Horizontal surface down 16 inches	$2\frac{1}{2}$	-----
42	Horizontal surface down 16 inches	$2\frac{3}{4}$	-----
43	Horizontal surface down 16 inches	$2\frac{1}{2}$	-----
43	Horizontal surface up 20 inches	2	-----
44	Horizontal surface down 6 inches, and back 6 inches, one anti-spin fillet (48" × 2" × 2")	>5	2

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XOSN-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for the rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Effect of tail modifications on turns for recovery for aileron neutral spins for an adverse loading condition. (ΔI_Y and ΔI_Z = 0.17 I_Y; c.g. at 0.25$\bar{c}$).

Tail type	Modification	Elevator D	Elevator N
44	On top of fuselage ahead of vertical surface one anti-spin fillet (20" × 2" × 2")	>4	-----
44	On bottom of fuselage, forward tail wheel	>4	-----
44	Horizontal surface down 16 inches	4	-----
44	Normal load	$1\frac{1}{2}$	-----
45	Normal load	$1\frac{1}{2}$	-----
45	Normal load, horizontal surface down 6 inches, back 6 inches	$1\frac{1}{2}$	-----
45	Horizontal surface down 6 inches, back 6 inches	$2\frac{1}{2}$	-----
45	Horizontal surface down 6 inches	$2\frac{1}{4}$	-----
45	Horizontal surface down 16 inches	$2\frac{1}{4}$	-----
45	Horizontal surface down 16 inches	$2\frac{1}{4}$	-----

Tail type	Modification	Elevator D	Elevator N
45	ΔI_Y and ΔI_Z = 0.34 I_Y, c.g. at 0.24$\bar{c}$, horizontal surface down 6 inches back 6 inches	>4	-----
45	Seaplane, normal load	$1\frac{1}{2}$	-----
46	Horizontal surface down 6 inches back 6 inches	2	-----
47	Horizontal surface down 6 inches back 6 inches	$1\frac{3}{4}$	-----
48	Horizontal surface down 6 inches back 6 inches	$1\frac{1}{2}$	-----
49	Horizontal surface down 6 inches back 6 inches	2	-----
49	Horizontal surface down 16 inches	$1\frac{3}{4}$	-----
50	Horizontal surface down 6 inches back 6 inches	$1\frac{3}{4}$	-----
51	Horizontal surface down 16 inches	$1\frac{3}{4}$	-----
52	Horizontal surface down 16 inches	$1\frac{3}{4}$	-----
53	Horizontal surface down 16 inches	2	-----
54	Normal load	$1\frac{1}{2}$	-----
54	Seaplane, normal load	1	-----

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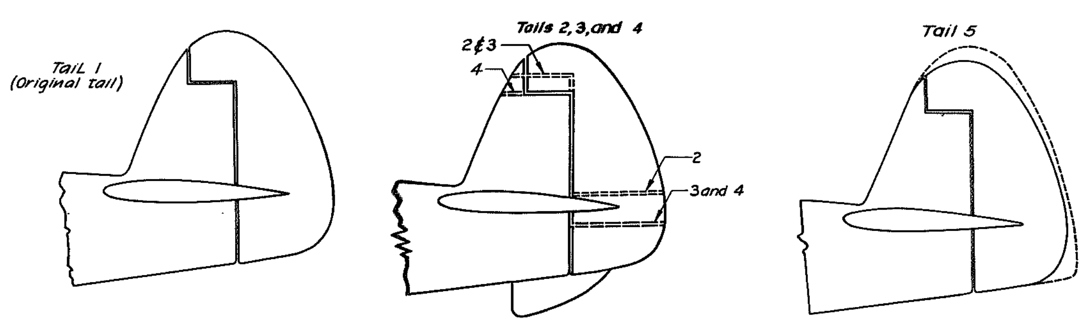

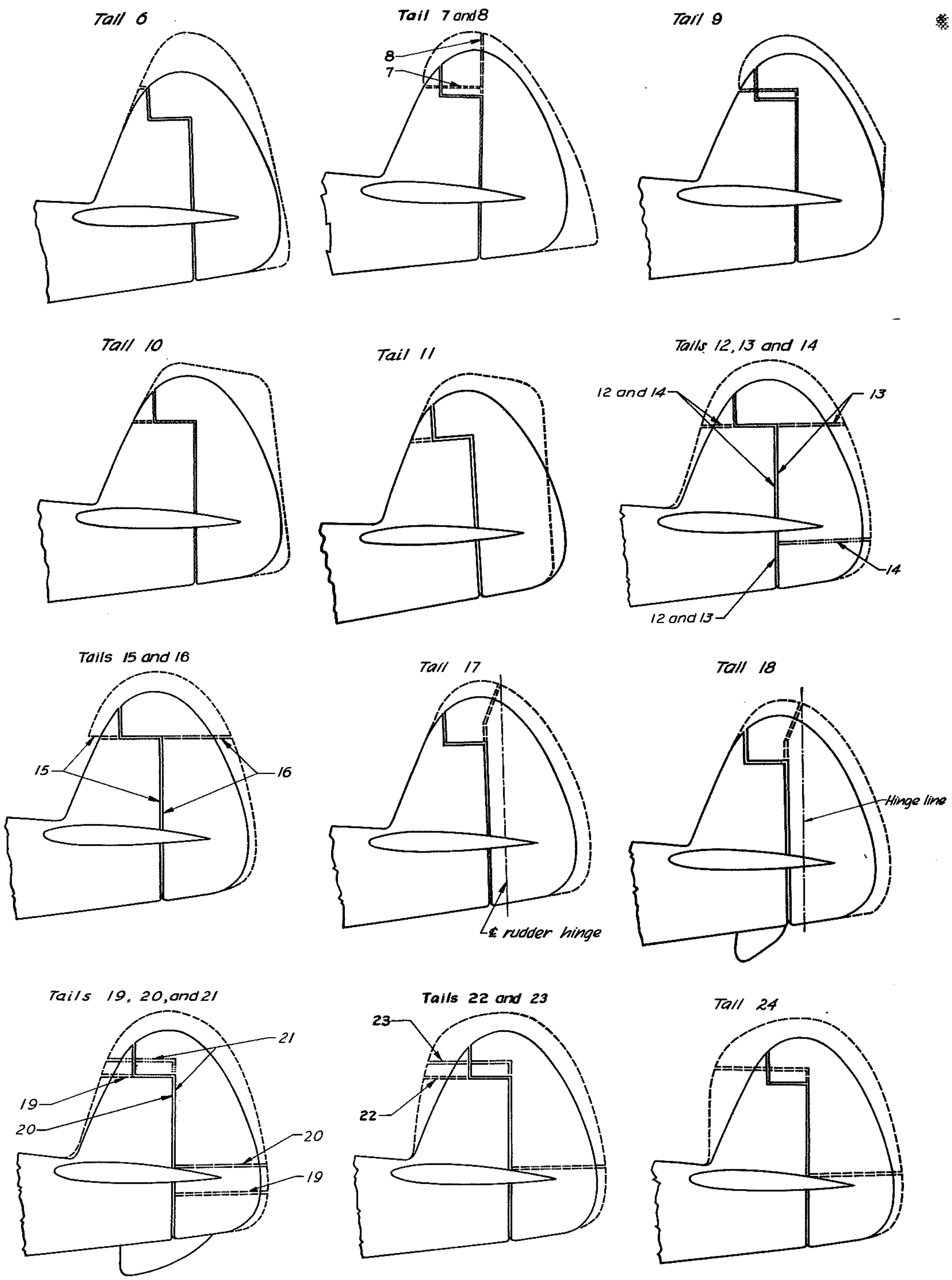

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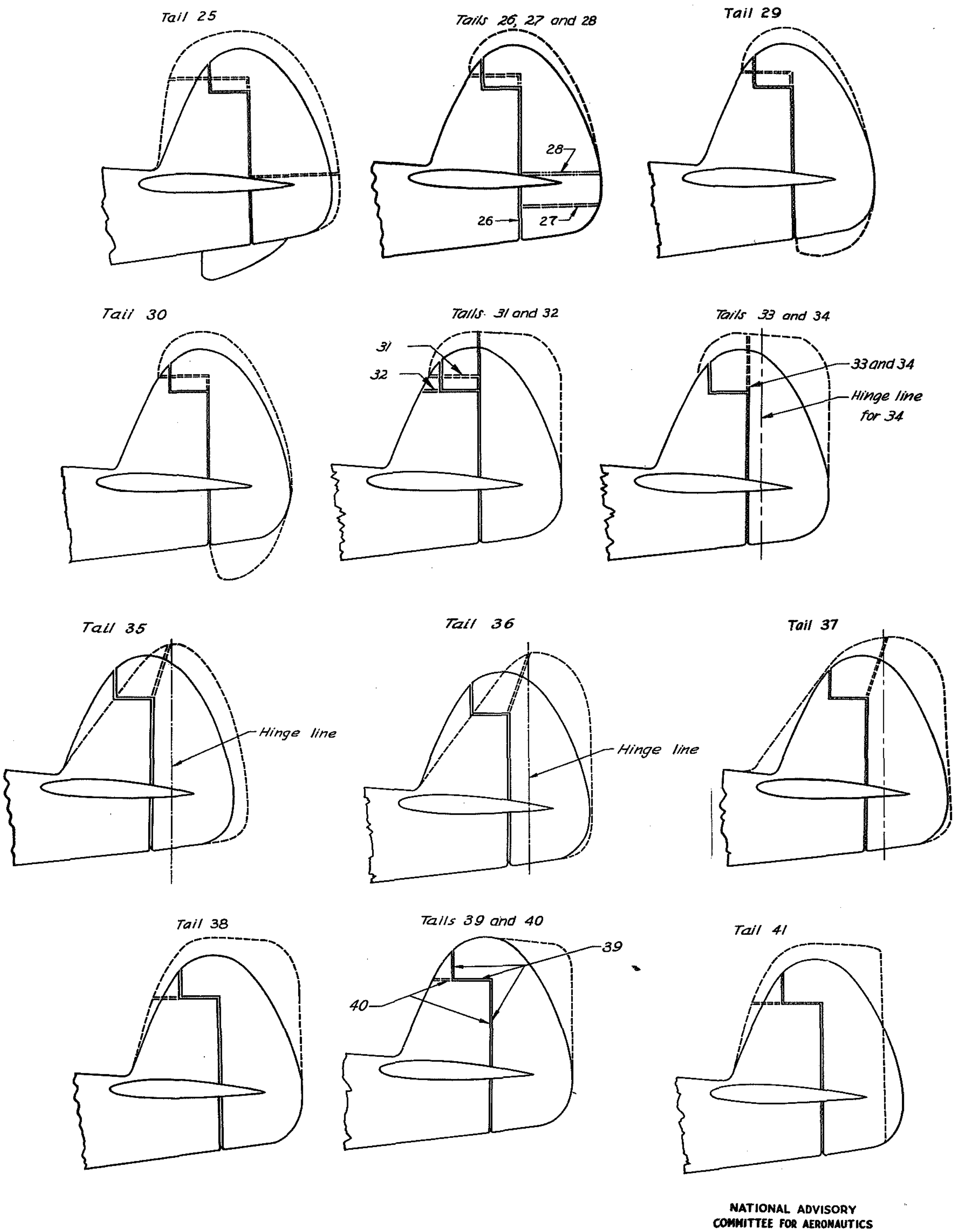
Tail 25
Tails 26, 27 and 28
28
26
27
Tail 29
Tail 30
Tails 31 and 32
31
32
Tails 33 and 34
33 and 34
Hinge line for 34
Tail 35
Hinge line
Tail 36
Hinge line
Tail 37
Tail 38
Tails 39 and 40
39
40
Tail 41
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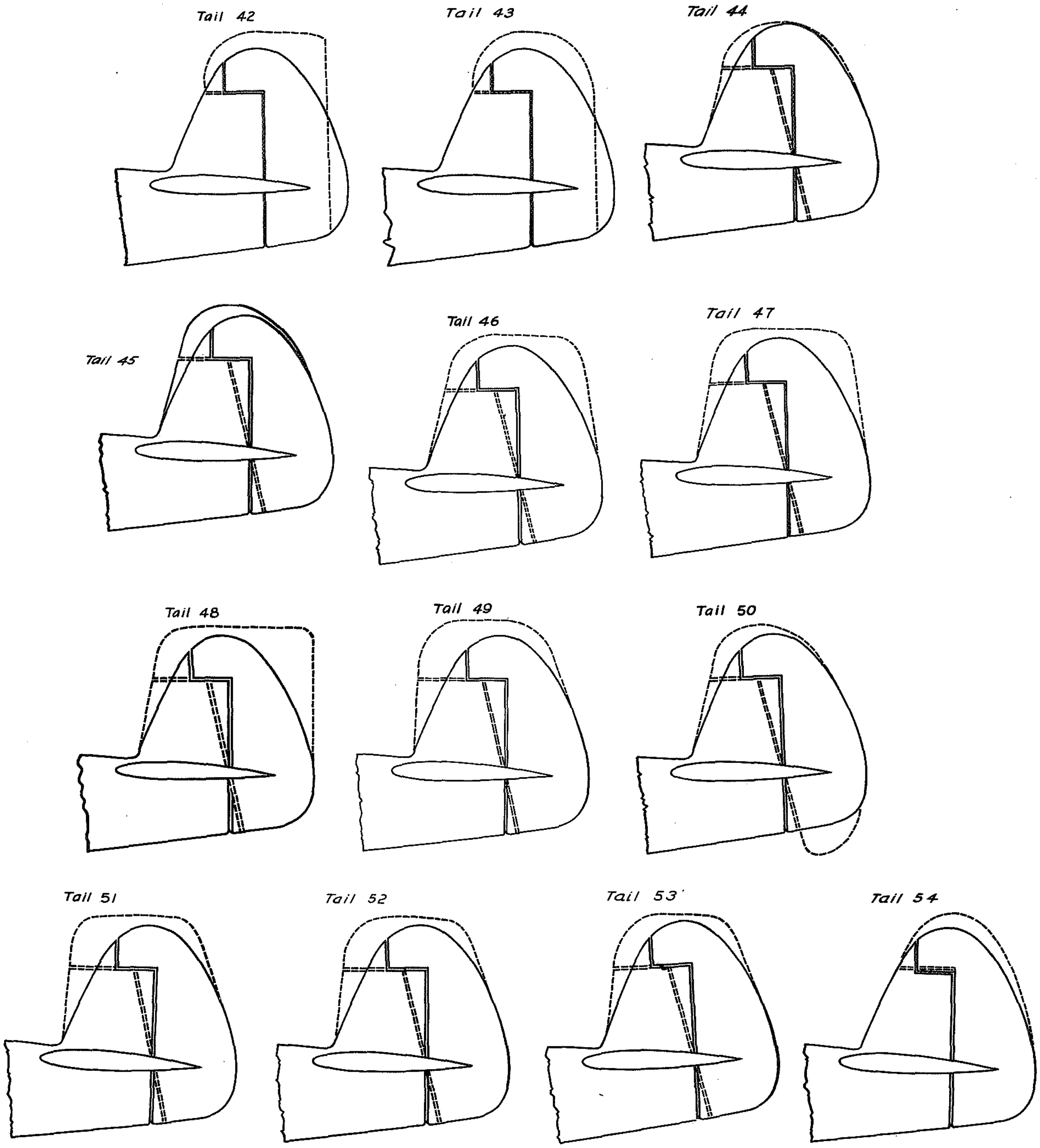
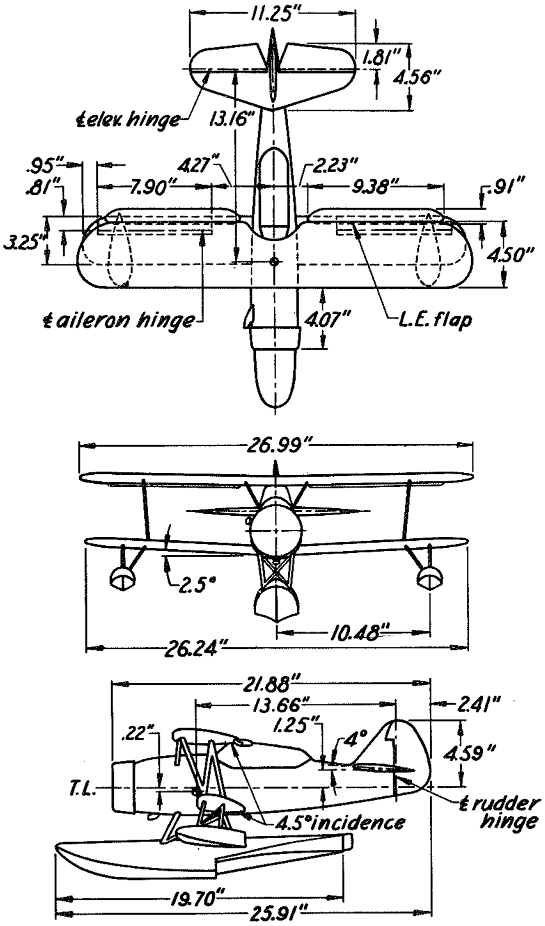
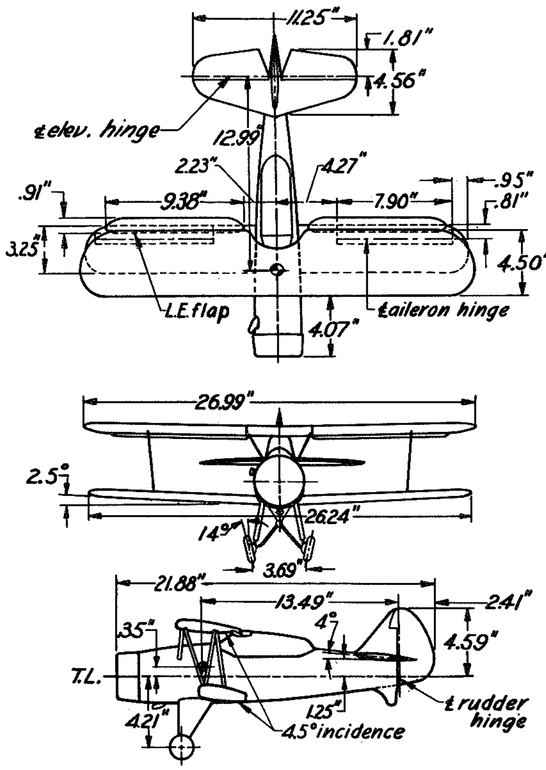

Tail 42
Tail 43
Tail 44
Tail 45
Tail 46
Tail 47
Tail 48
Tail 49
Tail 50
Tail 51
Tail 52
Tail 53
Tail 54

1/16-SCALE MODEL OF THE STEARMAN XOSS-1 SEAPLANE AND LANDPLANE



Model as tested.



Model as tested.

<u>**Dimensional Data**</u>

(Full-Scale)

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(The data for both airplanes are the same except where noted.)

b, ft (upper)	36.00
b, ft (lower)	35.00
L, ft	
Seaplane	34.55
Landplane	29.86
$\bar{c}$, in	67.23
S, sq ft	377.60
A (effective)	3.43
L.E. $\bar{c}$ aft L.E. c_r	14.94
S_h, sq ft	63.84

: For lateral movements of the stick he flaps acted as ailerons.

S_e, sq ft	25.88
S_v, sq ft	32.60
S_r, sq ft	16.94
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 20 D
δ_a	
Seaplane	25.8 U, 15.6 D
Landplane	25 U, 12 D
δ_f	30 D
TDPF, Seaplane	397×10^{-6}
TDPF, Landplane	343×10^{-6}
Landing gear	
Seaplane	float
Landplane	fixed

Mass Data

	Seaplane	Landplane
W, lb	5,356	4,790
$x/\bar{c}$	0.267	0.307
$z/\bar{c}$	0.052	-0.084
I_X, slug-ft^2	3,457	2,186
I_Y, slug-ft^2	6,554	5,777
I_Z, slug-ft^2	7,476	6,977
Test altitude, ft	12,000	12,000
μ (at sea level)	5.14	4.6
μ (12,000 ft)	7.44	6.65

	Seaplane	Landplane
$\frac{I_X - I_Y}{mb^2}$	-144×10^{-4}	-186×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-43×10^{-4}	-63×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	187×10^{-4}	249×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, the aileron-neutral, elevator-full-up spin of the seaplane model was of a wandering nature which prohibited testing. With the elevator set 10° up the wandering motion of the model became less pronounced and recovery by rapid full rudder reversal was satisfactory (1 turn). With the elevator either neutral or down recoveries by rapid full rudder reversal were slightly retarded although still satisfactory.

Lowering the flaps either 15° or 30° with the stick laterally neutral had little effect on the recovery characteristics of the model.

With the revised tail recoveries of the seaplane model from spins were slightly faster than from corresponding spins for the model with the original tail. Setting the ailerons against the spin with the flaps neutral or down (flaps disconnected from aileron) retarded recoveries slightly.

For the landplane with the revised tail the recoveries were satisfactory when the elevator was full up or neutral independent of flap and aileron deflections. Satisfactory recoveries could be obtained for elevator-down spins only when the ailerons and flaps were with the spin.

For the model representing either the seaplane or landplane extending the mass along the wings or along the fuselage or moving the center of gravity either forward or rearward (values given in the chart) had little effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE STEARMAN XOSS-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full air-rudder reversal only from right erect spins.]

Seaplane, normal loading, aileron-neutral spins

Flaps	3°U				15°D		30°D	
Elevator	30°U (a)	10°U (a)	N	D (a)	N	D (a)	N	D
α, deg	-----	41	41	40	----	41	----	42
Ø, deg	-----	2U	2U	3U	----	2U	----	3U
Ω, rps	-----	0.38	0.40	0.42	----	0.45	----	0.44
V, fps	-----	136	132	130	----	130	----	128
Turns for recovery	-----	1	$1\frac{1}{4}$	1, 2 [b]$1\frac{3}{4}$ [c]$1\frac{1}{4}$ [d]$2\frac{1}{4}$ [de]5	$1\frac{1}{2}$	2	$1\frac{1}{4}$	2

Seaplane, effect of mass variations and c.g. movements on turns for recovery from aileron-neutral spins

Flaps	3°U	
Elevator	N	D
ΔI_X and $\Delta I_Z = 0.15 I_X$	[f]1	[f]$1\frac{3}{4}$
ΔI_X and $\Delta I_Z = 0.30 I_X$	[f]$1\frac{1}{2}$	[f]$1\frac{1}{2}$
c.g. moved back $0.05\bar{c}$	$1\frac{1}{2}$	$1\frac{3}{4}$ [e]$2\frac{1}{2}$ [e]>4
Bomber loading	[f]1	$1\frac{1}{2}$ 2

Seaplane, ΔI_Y and $\Delta I_Z = 0.30 I_Y$ aileron-neutral spins

Flaps	3°U			15°D	30°D
Elevator	10°U (a)	N (a)	D (a)	D (a)	D (a)
α, deg	--	43	41	42	42
Ø, deg	--	1U	2U	2U	2U
Ω, rps	--	0.33	0.37	0.38	0.37
V, fps	--	139	134	130	130
Turns for recovery	--	$1\frac{1}{2}$	$1\frac{1}{2}$ >3	---	---

Seaplane, revised tail, normal loading

Aileron	Against 24.8°U, 15.6°D				Neutral								With 24.8°U, 15.6°D			
Flaps RT	3.7°U		34.6°D		3°U				15°D		30°D		4.8°U		17.8°D	
Flaps LT	4.8°U		17.8°D		3°U				15°D		30°D		3.7°U		34.6°D	
Elevator	N	D	N	D	30°U (a)	20°U (a)	N	D	N	D	N	D	N	D	N (gh)	D (g)
α, deg	45	44	47	49	--	42	40	42	---	39	---	41	36	34	----	21
Ø, deg	7U	7U	7U	3U	--	6U	4U	4U	---	2U	---	3U	2D	1U	----	2D
Ω, rps	0.42	0.45	0.42	0.45	--	0.31	0.40	0.44	---	0.45	---	0.43	0.45	0.50	----	0.83
V, fps	136	132	130	127	--	142	134	132	--	134	---	129	158	153	----	184
Turns for recovery	$1\frac{1}{2}$	2	$1\frac{1}{2}$	2 $3\frac{1}{2}$	--	$\frac{1}{2}$ [i]$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{3}{4}$ $1\frac{1}{4}$ [b]$1\frac{1}{2}$ [c]$1\frac{1}{2}$ [d]$1\frac{1}{2}$ [eg]$1\frac{1}{2}$	1	1	1	1	1	1	[e]1	[e]1

Seaplane revised tail. Effect of mass variations and c.g. movement on turns for recovery for aileron neutral spins

Flaps	RT. 3°U LT. 3°U
Elevator	D
ΔI_X and $\Delta I_Z = 0.30 I_X$	$1\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.30 I_Y$	[f]$1\frac{1}{4}$
c.g. moved back $0.05\bar{c}$	1
Bomber loading	$1\frac{1}{4}$

Landplane revised tail

Aileron	Against 24.8°U, 15.6°D					Neutral							With 24.8°U, 15.6°D			
Flaps RT.	3.7°U		34.6°D			3°U			15°D		30°D		4.8°U		17.8°D	
Flaps LT	4.8°U		17.8°D			3°U			15°D		30°D		3.7°U		34.6°D	
Elevator	N	D	U	N	D	U (a)	N	D	N	D	N	D	N (k)	D (k)	N	D (k)
α, deg	48	48	46	50	51	41	42	45	---	43	----	40	---	31	-	21
Ø, deg	7U	4U	6U	6U	4U	3U	1U	2U	---	2U	----	2U	---	1U	-	1U
Ω, rps	0.41	0.45	0.35	0.42	0.44	0.33	0.42	0.46	---	0.46	----	0.46	---	0.50	-	0.82
V, fps	124	117	122	117	114	150	125	119	---	119	----	119	---	141	-	162
Turns for recovery	2	$5\frac{3}{4}$ ∞	[e]$1\frac{3}{4}$ [i]$1\frac{3}{4}$	$1\frac{3}{4}$ $2\frac{1}{2}$	∞	1 $\frac{3}{4}$ [ei]$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{3}{4}$ $3\frac{1}{4}$ [ej]2	$1\frac{3}{4}$	$2\frac{1}{2}$ 3	$1\frac{1}{2}$	2 $2\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	-	$\frac{3}{4}$

Landplane, revised tail. Effect of mass variations and c.g. movements on turns for recovery for aileron neutral spins

Flaps	3°U	
Elevator	N	D
ΔI_X and $\Delta I_Z = 0.15 I_X$	$1\frac{3}{4}$	$2\frac{1}{2}$ 4
ΔI_X and $\Delta I_Z = 0.30 I_X$	$1\frac{3}{4}$	$2\frac{3}{4}$ 4
ΔI_Y and $\Delta I_Z = 0.17 I_Y$	[f]2	[f]$3\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.34 I_Y$	[f]$1\frac{1}{2}$	[f]>$2\frac{1}{2}$
c.g. moved forward $0.05\bar{c}$	$1\frac{3}{4}$	$3\frac{1}{4}$ >4
c.g. moved back $0.05\bar{c}$	$1\frac{1}{4}$	$3\frac{1}{2}$
Bomber loading	$1\frac{3}{4}$	$3\frac{1}{4}$

[a] Wandering spin.
[b] Water rudder neutral.
[c] Water rudder against.
[d] Water rudder off.
[e] Visual observation.
[f] Before recovery attempted model wandered.
[g] Wing tip floats removed.
[h] Vertical velocity too high to test.
[i] Recovery attempted by simultaneous reversal of rudder and elevator.
[j] Tail wheel on.
[k] Steep spin.

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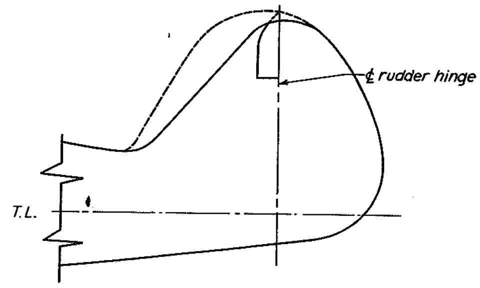
Comparison of original and revised vertical tails



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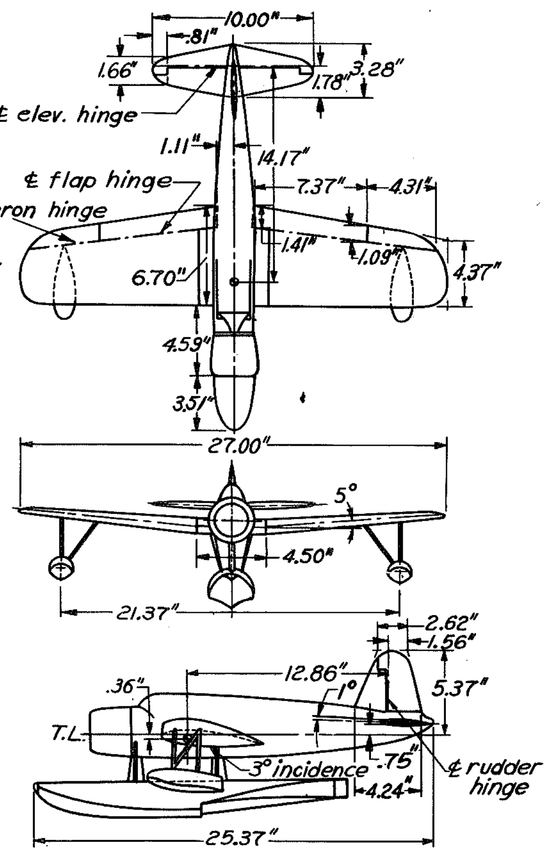
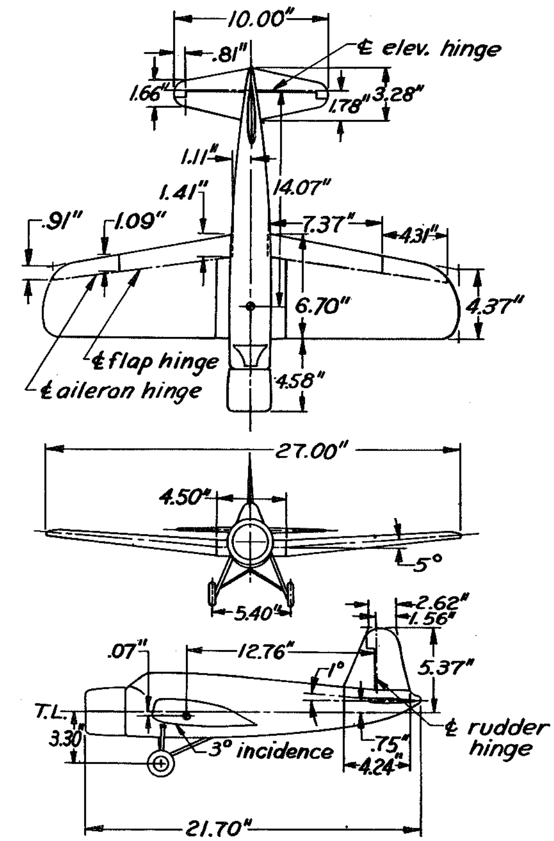
$\frac{1}{16}$-SCALE MODELS OF THE CHANCE-VOUGHT XOS2U-1 SEAPLANE AND LANDPLANE



Model as tested.



Model as tested.

Dimensional Data

(Full Scale)

(Values are the same for both landplane and seaplane except where indicated)

b, ft 36.00
L, ft
  Seaplane 33.83
  Landplane 30.08
$\bar{c}$, in. 89.50
S, sq ft 262.00
A 4.94
L.E. $\bar{c}$ aft L.E. c_r, in. . . . 0
S_h, sq ft 36.94
S_e, sq ft (inc. bal.) 16.44

S_v, sq ft 21.45
S_r, sq ft (inc. bal.) 11.45
δ_r, deg . . . . 25 R, 25 L
δ_e, deg . . . . 30 U, 20 D

TDPF . { Landplane . . 469×10^{-6}
       { Seaplane . . 480×10^{-6}

Landing gear
  Seaplane . . . . Float
  Landplane . . . . Fixed

Mass Data

Normal Loading

(Seaplane)

W, lb	4752	$\frac{I_X - I_Y}{mb^2}$	-148×10^{-4}
$x/\bar{c}$	0.261	$\frac{I_Y - I_Z}{mb^2}$	-82×10^{-4}
$z/\bar{c}$	0.066	$\frac{I_Z - I_X}{mb^2}$	230×10^{-4}
I_X, slug-ft^2	2815		
I_Y, slug-ft^2	5633		
I_Z, slug-ft^2	7208		
Test altitude, ft	12,000		
μ (at sea level)	6.58		
μ' (12,000 ft)	9.52		

(Landplane)

W, lb	4675	$\frac{I_X - I_Y}{mb^2}$	-163×10^{-4}
$x/\bar{c}$	0.278	$\frac{I_Y - I_Z}{mb^2}$	-81×10^{-4}
$z/\bar{c}$	0.013	$\frac{I_Z - I_X}{mb^2}$	244×10^{-4}
I_X, slug-ft^2	2016		
I_Y, slug-ft^2	5080		
I_Z, slug-ft^2	6597		
Test altitude, ft	12,000		
μ (at sea level)	6.46		
μ' (12,000 ft)	9.35		

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Résumé of Model Test Results

In the clean condition and normal loading, the seaplane model spun steeply with the elevator up, neutral, or down. Recoveries were satisfactory by rapid full rudder reversal. Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$), extending or retracting mass along the fuselage (ΔI_Y and $\Delta I_Z = \pm 0.16\ I_Y$), or moving the center of gravity forward or back $\pm 0.05\bar{c}$ from its normal location did not appreciably alter the recovery characteristics of the model and recoveries were still generally satisfactory.

The landplane model spun at a flatter attitude than the seaplane model and recoveries obtained were slower than those obtained with the seaplane model.

In order to improve recoveries from elevator-down spins of the landplane model, additional area (approximately 2 square feet full scale) was added below the horizontal tail surfaces to simulate possible fairing aft of the tail wheel. This additional area was quite effective and enabled recoveries to be obtained in 2 turns. (Data not presented)

With the seaplane model, brief tests were conducted with a pro-spin fin attached to the inner wing tip (see sketch) in order to obtain more extensive data for the elevator-up spins. Satisfactory recoveries by simultaneous rapid full reversal of rudder and elevator were obtained with the pro-spin fin attached to the model indicating that the recoveries from the elevator-up spins without the pro-spin fin installed would have been definitely satisfactory, inasmuch as the pro-spin fin attached to the inner wing tip promotes an increment of yawing moment tending to keep the model in the spin.

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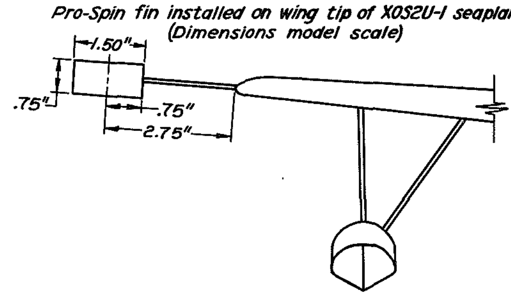
Pro-Spin fin installed on wing tip of XOS2U-1 seaplane
(Dimensions model scale)



[redacted]

SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CHANCE-VOUGHT XOS2U-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with, aileron-neutral spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Seaplane, normal loading			Seaplane, normal loading with pro-spin fin attached		
Elevator	U [a]	N [b]	D [b]	U [a]	N [b]	D
α, deg	--	22	30	43	46	49
ø, deg	--	1D	8U	1D	3U	1U
Ω, rps	--	0.52	0.45	0.31	0.41	0.43
V, fps	--	210	163	153	141	133
Turns for recovery	--	---	$1\frac{3}{4}$ $1\frac{1}{4}$ [c]$2\frac{1}{4}$ [d]$\frac{3}{4}$	$1\frac{1}{4}$ [e]$1\frac{1}{2}$	$2\frac{1}{4}$	----

Seaplane, effect of mass variations and c.g. movements on turns for recovery for elevator down conditions	
ΔI_X and ΔI_Z = 0.15 I_X	[f]1
ΔI_X and ΔI_Z = 0.30 I_X	[f]$1\frac{1}{4}$
ΔI_Y and ΔI_Z = 0.16 I_Y	[g]$\frac{1}{2}$
ΔI_Y and ΔI_Z = -0.16 I_Y	1
c.g. moved forward 0.05$\bar{c}$	[h]$2\frac{1}{2}$ [h]$1\frac{1}{4}$
c.g. moved back 0.05$\bar{c}$	$\frac{3}{4}$
Bombing loading, (ΔI_X and ΔI_Z = 0.14 I_X)	[h]$\frac{3}{4}$

Seaplane with pro-spin fin attached, c.g. moved forward 0.05$\bar{c}$			
Elevator	U	N	D
α, deg	42	48	49
ø, deg	1D	3U	2U
Ω, rps	0.25	0.45	0.45
V, fps	142	138	131
Turns for recovery	[e]2	—	—

Seaplane with pro-spin fin attached. Effect of mass variations and c.g. movements on turns for recovery for elevator-up condition	
ΔI_X and ΔI_Z = 0.15 I_X	[he]1
ΔI_X and ΔI_Z = 0.30 I_X	[e]$1\frac{1}{2}$
ΔI_Y and ΔI_Z = 0.16 I_Y	[be]2 [be]$2\frac{1}{2}$
ΔI_Y and ΔI_Z = -0.16 I_Y	[he]$1\frac{3}{4}$ [he]1
c.g. moved back 0.05$\bar{c}$	[he]$1\frac{3}{4}$

	Landplane, normal loading					Landplane, rudder neutral spins			Landplane, c.g. moved forward 0.05$\bar{c}$			
Elevator	U [i]	20°U [i]	15°U	N	D	15°U	N	D	U	15°U	N	D
α, deg	----	52	-----	54	53	----	----	37	----	49	52	53
ø, deg	----	1U	-----	1U	2U	----	----	1U	----	1U	2U	1U
Ω, rps	----	0.39	-----	0.43	0.45	----	----	0.46	----	0.41	0.45	0.47
V, fps	----	139	-----	132	130	----	----	144	----	141	134	132
Turns for recovery	[g]---	2 [e]$1\frac{1}{2}$ [e]$2\frac{1}{2}$	[j]$2\frac{1}{2}$ [ej]$3\frac{1}{2}$	3 $3\frac{1}{2}$	$3\frac{1}{2}$ 4	[g]---	[g]---	----	----	$2\frac{1}{4}$ [ej]$3\frac{1}{4}$	$3\frac{1}{4}$	4

Landplane, effect of mass variations and c.g. movements on turns for recovery.		
Elevator	15°U	D
ΔI_X and ΔI_Z = 0.20 I_X	[e]4 [j]$2\frac{1}{2}$	$4\frac{1}{4}$
ΔI_X and ΔI_Z = 0.40 I_X	[e]$2\frac{3}{4}$ [j]$2\frac{1}{4}$	$3\frac{1}{2}$
ΔI_Y and ΔI_Z = 0.20 I_Y	[e]2, [e]$3\frac{3}{4}$	$3\frac{1}{2}$
ΔI_Y and ΔI_Z = -0.20 I_Y	[e]$2\frac{1}{4}$	3
c.g. moved back 0.05$\bar{c}$	[j]2	$3\frac{1}{2}$
Bomber loading (ΔI_X and ΔI_Z = 0.19 I_X)	[e]3	$3\frac{1}{2}$

[a]Wandering spin with high vertical velocity.
[b]Wandering spin.
[c]Recovery attempted by rapid full-rudder reversal; water rudder 25° with spin.
[d]Recovery attempted by rapid full-rudder reversal; water rudder 25° against spin, high vertical velocity.
[e]Recovery attempted by simultaneous reversal of rudder and elevator.
[f]Before recovery was attempted the spin was steep and wandering.
[g]Recovery was attempted from a spin of high vertical velocity.
[h]Before recovery was attempted the spin was wandering and oscillatory.
[i]Oscillatory spin.
[j]Visual observation.

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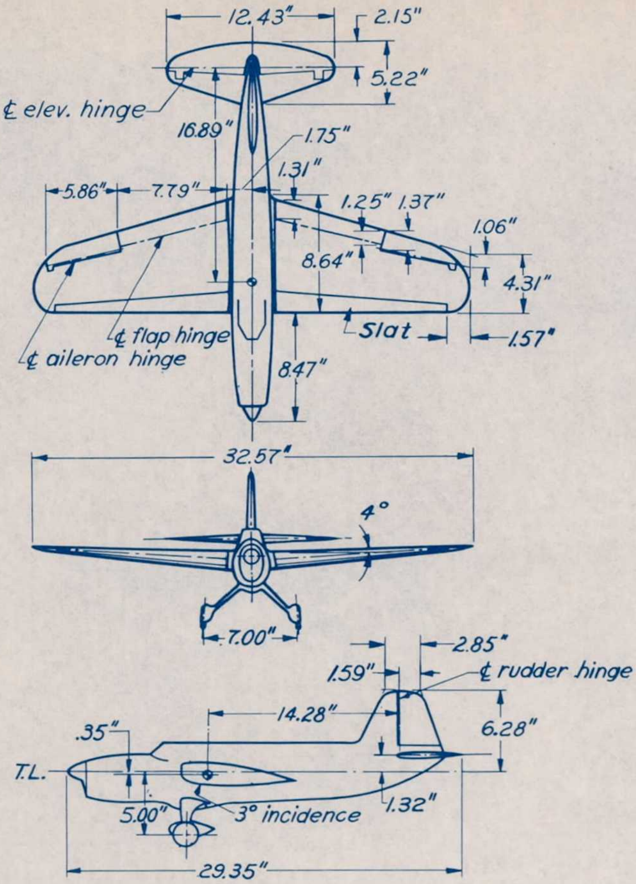
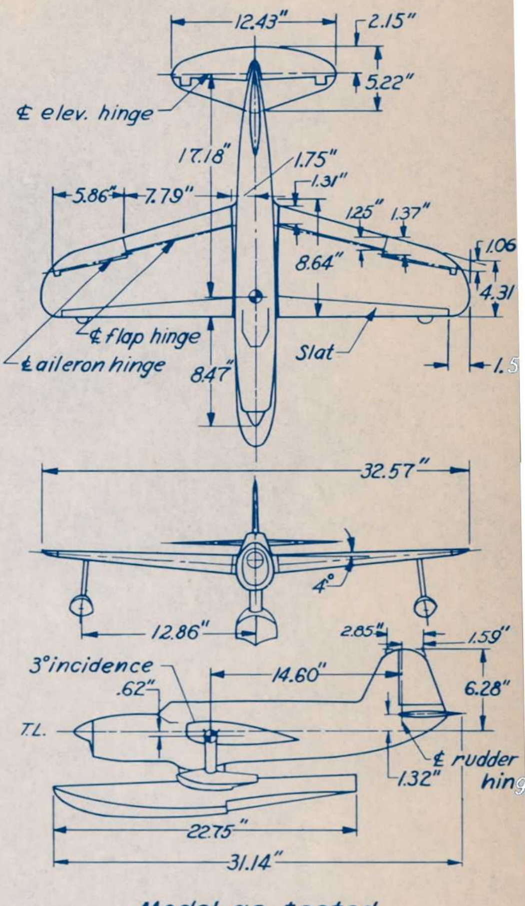
$\frac{1}{14}$-SCALE MODEL OF THE CURTISS XSO3C-1 LANDPLANE AND SEAPLANE



Model as tested.



Model as tested.

Dimensional Data

(Full Scale)

(Values are the same for both landplane and seaplane except where indicated)

b, ft	38.00
L, ft	
Seaplane	36.33
Landplane	34.24
$\bar{c}$, in	97.40
S, sq ft	290.00
A	4.98
L.E. $\bar{c}$ aft L.E. c_r, in	1.00
S_h, sq ft	61.00
S_e, sq ft (inc. bal.)	28.50
S_v, sq ft	27.30
S_r, sq ft (inc. bal.)	13.80

δ_r, deg	30 R, 3
δ_e, deg	30 U, 2
δ_a, deg	
Seaplane	25 U, 1
Landplane	23 U, 1
δ_f, deg	5
TDPF	
Seaplane	460 x 1
Landplane	446 x 1
Landing gear	
Seaplane	Large float wing ponto
Landplane	Fi

Mass Data

Normal Loading

(Seaplane)

W, lb	5403	$\frac{I_X - I_Y}{mb^2}$	-233×10^{-4}
$x/\bar{c}$	0.234		
$z/\bar{c}$	0.089		
I_X, slug-ft^2	3855	$\frac{I_Y - I_Z}{mb^2}$	-95×10^{-4}
I_Y, slug-ft^2	9500		
I_Z, slug-ft^2	11,800		
Test altitude, ft	6000	$\frac{I_Z - I_X}{mb^2}$	328×10^{-4}
μ (at sea level)	6.40		
μ'(6,000 ft)	7.66		

(Landplane)

W, lb	5276	$\frac{I_X - I_Y}{mb^2}$	-244×10^{-4}
$x/\bar{c}$	0.257		
$z/\bar{c}$	0.051		
I_X, slug-ft^2	2958	$\frac{I_Y - I_Z}{mb^2}$	-83×10^{-4}
I_Y, slug-ft^2	8739		
I_Z, slug-ft^2	10,715		
Test altitude, ft	6000	$\frac{I_Z - I_X}{mb^2}$	327×10^{-4}
μ (at sea level)	6.25		
μ'(6,000 ft)	7.49		

Résumé of Model Test Results

For the landplane model in the clean condition, normal loading, the normal control configuration for spinning or small deviations from this control position the recovery characteristics of the model were satisfactory by rapid full rudder reversal.

Extending mass along the wings $(\Delta I_X$ and $\Delta I_Z = 0.30\ I_X)$ or moving the center of gravity forward or back $0.05\bar{c}$ from its normal location did not appreciably alter the recovery characteristics of the model. Extending mass along the fuselage $(\Delta I_Y$ and $\Delta I_Z = 0.30\ I_Y)$ retarded recoveries particularly for the elevator neutral and down spins.

For the normal loading condition drooping the ailerons 15° did not appreciably affect recoveries of the model; however, drooping the ailerons 15° while deflecting the flaps 50° (and open cockpit) led to spins from which recoveries could not be obtained when the ailerons were set full against the spin. The recovery characteristics of the model were very satisfactory with the slots open for all control configurations except the aileron-against, elevator-neutral or elevator-down settings.

With the ventral fin (modification 1) installed on the model, recoveries from all spins obtained for the normal loading condition were generally satisfactory.

The steady spin and recovery characteristics of the seaplane model were in general similar to those obtained for the landplane model.

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[redacted]

SPIN DATA OBTAINED WITH THE $\frac{1}{14}$-SCALE MODELS OF THE CURTISS XSO3C-1 LANDPLANE AND SEAPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Landplane, normal loading

Ailerons	Against Full			Against 1/2			Against 3°U, 3°D		Neutral			With 3°U, 3°D		With 1/2			With Full		
Elevator	U	N	D	U	N	D	N	D	U	N	D	N (a)	D	U	N (a)	D (a)	U	N (a)	D (a)
α, deg	53	53	54	No spin	53	51	45	46	No spin	23	42	-	28	No spin	-	-	No spin	-	-
ϕ, deg	6U	6U	6U		5U	4U	2U	3U		1U	2U	-	3U		-	-		-	-
Ω, rps	0.32	0.36	0.40		0.39	0.41	0.40	0.42		0.58	0.43	-	0.56		-	-		-	-
V, fps	136	129	126		124	126	133	134		199	143	-	170		-	-		-	-
Turns for recovery	$1\frac{1}{4}$	$3\frac{1}{2}$	6		$3\frac{1}{4}$	5	3	4		1	$3\frac{3}{4}$	-	$1\frac{1}{2}$		-	-		-	-

Ailerons	Landplane, normal loading, rudder neutral spins: Against			Neutral			With			Landplane, ailerons drooped 15°, normal loading: Against			Neutral		
Elevator	U	N	D	U	N (a)	D (a)	U	N (a)	D (a)	U	N	D	U	N	D
α, deg	No spin	48	47	No spin	-	-	No spin	-	-	55	55	53	No spin	---	47
ϕ, deg		8U	7U		-	-		-	-	6U	5U	5U		---	1U
Ω, rps		0.39	0.41		-	-		-	-	0.35	0.40	0.40		---	0.41
V, fps		134	131		-	-		-	-	133	128	126		216	133
Turns for recovery		---	---		-	-		-	-	1	3	$3\frac{1}{2}$		---	---

Landplane, effect of mass changes and c.g. movements on turns for recovery for aileron-against spins

Elevator	U	N	D
ΔI_X and $\Delta I_Z = 0.30\, I_X$	$\frac{3}{4}$	$3\frac{1}{2}$	5
ΔI_Y and $\Delta I_Z = 0.15\, I_Y$	$1\frac{3}{4}$	$5\frac{1}{2}$	9
ΔI_Y and $\Delta I_Z = 0.30\, I_Y$	2	6	∞
c.g. moved forward $0.05\bar{c}$	$1\frac{1}{2}$	$3\frac{1}{2}$	5
c.g. moved back $0.05\bar{c}$	$1\frac{1}{4}$	>4	>7

Ailerons	Landplane, flaps down 50°, cockpits covered, ailerons drooped 15°, normal loading: Against			Neutral			With			Landplane, slots open, normal loading: Against			Neutral			With			Landplane, modification 1, normal loading: Against			Neutral		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N (a)	D (a)
α, deg	51	51	51	No spin	No spin	16	-	-	No spin	55	52	50	No spin	No spin	No spin	No spin	No spin	No spin	No spin	-	--	No spin	-	-
ϕ, deg	3U	2U	3U			3U	-	-		2U	3U	0								-	--		-	-
Ω, rps	0.33	0.39	0.41			0.58	-	-		0.30	0.37	0.39								-	--		-	-
V, fps	126	119	117			177	-	-		128	124	121								-	--		-	-
Turns for recovery	∞	∞	∞			$\frac{1}{2}$	-	-		$1\frac{3}{4}$	$2\frac{1}{4}$	$3\frac{3}{4}$								2	$2\frac{1}{4}$		-	-

Seaplane, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (b)	N	D	U (b)	N	D	U (b)	N (a)	D (a)
α, deg	-	49	48	-	41	42	-	-	-
ϕ, deg	-	6U	6U	-	4U	3U	-	-	-
Ω, rps	-	0.38	0.41	-	0.39	0.40	-	-	-
V, fps	-	133	124	-	136	134	-	-	-
Turns for recovery	-	$2\frac{1}{2}$	$3\frac{3}{4}$	-	---	---	-	-	-

Seaplane, normal loading; only main float attached

Ailerons	Against Full			Against 1/2			Neutral			With 1/2			With Full		
Elevator	U (b)	N	D	U (b)	N	D	U (b)	N (c)	D (c)	U (a)	N (a)	D (a)	U (b)	N (a)	D (a)
α, deg	-	53	54	-	48	48	-	43	-	-	-	-	-	-	-
ϕ, deg	-	7U	6U	-	6U	6U	-	4U	-	-	-	-	-	-	-
Ω, rps	-	0.39	0.42	-	0.40	0.42	-	0.39	0.42	-	-	-	-	-	-
V, fps	-	124	121	-	131	124	-	138	128	-	-	-	-	-	-
Turns for recovery	-	$2\frac{1}{2}$	$3\frac{3}{4}$	-	$2\frac{1}{2}$	$3\frac{3}{4}$	-	2	$3\frac{1}{2}$	-	-	-	-	-	-
							-	$2\frac{1}{2}$		-	-	-	-	-	-

Seaplane, effect of mass changes and c.g. movements on turns for recovery; only main float attached

Ailerons	Against		Neutral		
Elevator	N	D	U	N	D
ΔI_X and $\Delta I_Z = 0.15\, I_X$	$2\frac{1}{2}$	$3\frac{1}{2}$	--	--	--
ΔI_X and $\Delta I_Z = 0.30\, I_X$	$2\frac{1}{2}$	$2\frac{3}{4}$	--	--	$2\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.15\, I_Y$	$3\frac{3}{4}$	$6\frac{1}{2}$	--	--	--
ΔI_Y and $\Delta I_Z = 0.30\, I_Y$	4	>7	d-	a-	$4\frac{1}{4}$
c.g. moved forward $0.38\bar{c}$	$3\frac{3}{4}$	5	--	--	--
c.g. moved back $0.07\bar{c}$	$3\frac{3}{4}$	$4\frac{3}{4}$	--	--	--

Ailerons	Seaplane, landing condition; only main float attached, normal loading: Against			Neutral			With			Seaplane, gross weight increased 20 percent; only main float attached: Against			Neutral				Down		
Elevator	U	N	D	U	N	D	U	N	D	U (b)	N	D	U	N (a)	10°D	20°D	U	N (a)	D (a)
α, deg	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	-	56	52	No spin	-	32	34	No spin	-	-
ϕ, deg										-	7U	8U		-	3U	2U		-	-
Ω, rps										-	0.39	0.40		-	0.42	0.44		-	-
V, fps										-	138	134		-	155	168		-	-
Turns for recovery										-	$3\frac{3}{4}$	5		-	----	4		-	-

[a]Velocity too high to test.

[b]Large radius of spin, too oscillatory to test.

[c]Model capable of two types of spin, other type has velocity too high to test.

[d]No spin.

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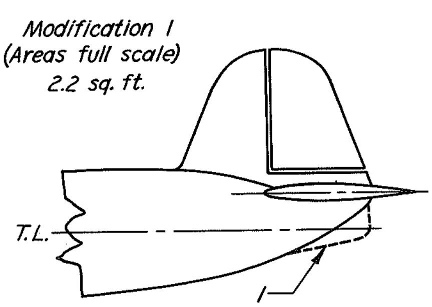
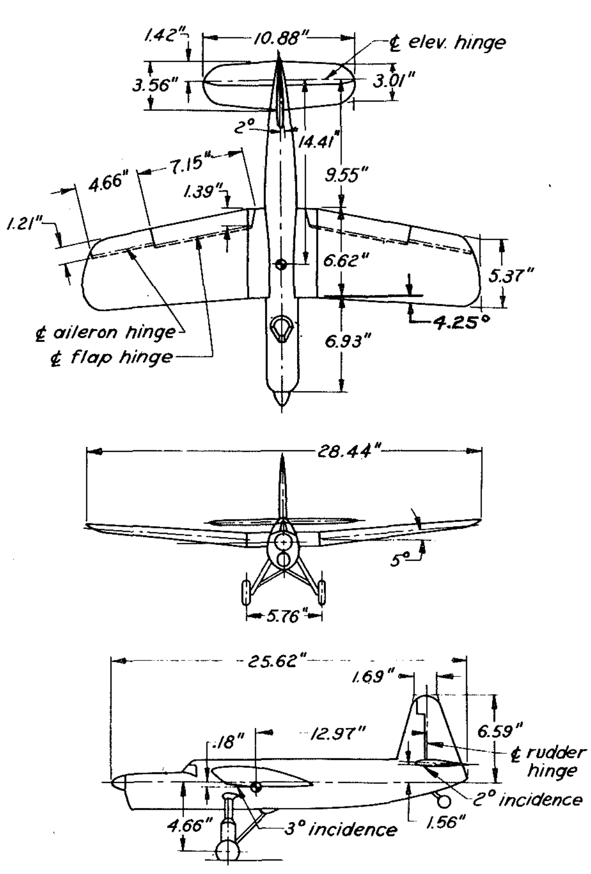
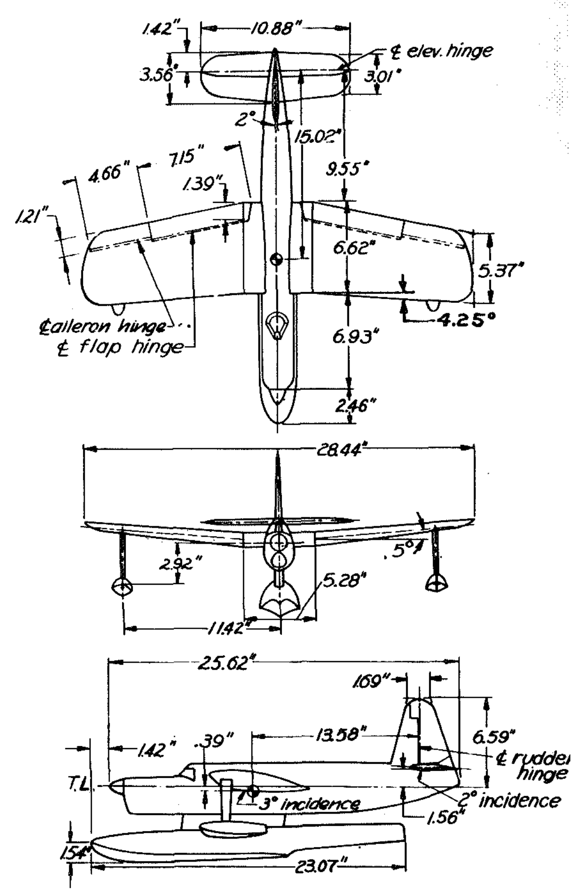
Modification 1
(Areas full scale)
2.2 sq. ft.



$\frac{1}{16}$-SCALE MODEL OF THE CHANCE-VOUGHT XSO2U-1 LANDPLANE AND SEAPLANE



Model as tested.



Model as tested.

Dimensional Data

(Full Scale)

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(Dimensions are the same for both landplane and seaplane except where noted.)

b, ft	38.19	S_r, sq ft	13.80
L, ft		δ_r, deg	25 R, 25 L
Landplane	34.16	δ_e, deg	30 U, 20 D
Seaplane	36.05	δ_a, deg	30 U, 20 D
$\bar{c}$, in.	97.60	δ_a, deg (drooped)	35 D
S, sq ft	299.80	δ_f, deg	50 D
A	4.85	δ_s (differential spoilers), deg	50 U, 3 D
L.E. $\bar{c}$ aft L.E. c_r, in.	4.30	TDPF	880×10^{-6}
S_h, sq ft	59.46	Landing gear	
S_e, sq ft	22.82	Landplane	Fixed
S_v, sq ft	25.70	Seaplane	Pontoons

Mass Data

Normal Loading

	Landplane	Seaplane
W, lb	5099	5336
$x/\bar{c}$	0.241	0.231
$z/\bar{c}$	0.028	0.063
I_X, slug-ft^2 . . .	2586	3412
I_Y, slug-ft^2 . . .	8160	8815
I_Z, slug-ft^2 . .	10,150	11,170
Test altitude, ft,	12,000	12,000
μ (at sea level). .	5.82	6.10
μ' (12,000 ft) . .	8.42	8.82

	Landplane	Seaplane
$\frac{I_X - I_Y}{mb^2}$ . .	-241×10^{-4}	-224×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$ . .	-86×10^{-4}	-97×10^{-4}
$\frac{I_Z - I_X}{mb^2}$ . . .	327×10^{-4}	321×10^{-4}

Résumé of Model Test Results

For the clean condition, normal loading, normal control configuration for spinning, the landplane model wandered continuously and descended at a rate too high to test (data not presented). The addition of a pro-spin fin to the inner wing tip of the model made it possible to obtain a slow steady spin, and a satisfactory recovery was obtained for the normal control setting for spinning indicating that recovery for this spin without the pro-spin fin attached to the model would probably be satisfactory. Deflecting the elevator partly or full down produced unsatisfactory recoveries. Test results indicated that setting the ailerons full against the rotation had no appreciable effect on the recovery characteristics, whereas setting the ailerons with the rotation steepened the spins of the model.

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.30\ I_X$), extending or retracting mass along the fuselage (ΔI_Y and $\Delta I_Z = \pm 0.20\ I_Y$), or moving the center of gravity forward or back $0.04\bar{c}$ from its normal position had little effect upon the recovery characteristics of the landplane model.

Test results (not presented) indicated that the addition of a large ventral fin (modification 3) to the model was more effective in improving the recovery characteristics than the addition of area to the fin and rudder (modifications 1 and 2).

Tests of the seaplane model in the normal loading configuration were conducted with the pro-spin fin attached to the model. A comparison of results of the seaplane and landplane tests (with pro-spin fin attached) indicated that the recovery characteristics of the seaplane are somewhat better than the recovery characteristics of the landplane.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE XS02U-1 AIRPLANE USING A PRO-SPIN FIN

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading, pro-spin fin removed									Normal loading							
Ailerons	Against			Neutral				With		Against			Neutral			With	
Elevator	U (a)	N (a)	D	N (b)	D 10° (a)	D Full (a)	D 30° (a)	N	D (b)	U (b)	N	D	U	N	D	N (b)	D (b)
α, deg	--	43	47	--	---	44	---	-	--	--	---	---	---	---	---	--	--
φ, deg	--	70	90	--	---	20	---	-	--	--	---	---	---	---	---	--	--
Ω, rps	--	0.40	0.40	--	0.41	0.43	0.40	-	--	--	0.37	0.39	0.31	0.38	0.41	--	--
V, fps	--	151	137	--	158	140	140	-	--	--	135	131	147	135	139	--	--
Turns for recovery	--	2	3	--	$2\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{3}{4}$	-	--	--	∞	∞	$\frac{3}{4}$	5	∞	--	--

Effect of mass variation and c.g. movements on turns for recovery. Pro-spin fin removed. Elevator down.

Loading condition	Landplane, Ailerons: Against	Landplane, Ailerons: Neutral	Seaplane, Ailerons: Against
ΔI_X and ΔI_Z = $0.30 I_X$	$2\frac{1}{2}$ 3	3	[a,c] $1\frac{1}{2}$
ΔI_Y and ΔI_Z = $0.20 I_Y$	$3\frac{3}{4}$ >5	$3\frac{1}{2}$	[a,c] $>2\frac{1}{2}$
ΔI_Y and ΔI_Z = $-0.20 I_Y$	2	2	[c,d] 1
c.g. moved forward $0.04\bar{c}$	3	3	[c] $1\frac{3}{4}$
c.g. moved back $0.04\bar{c}$	$2\frac{1}{4}$	3	[c] $1\frac{3}{4}$

	Rudder neutral spins, normal loading							
Ailerons	Against			Neutral			With	
Elevator	U	N	D	U	N (b)	D	N	D (b)
α, deg	No spin	----	----	No spin	--	----	-	---
φ, deg		----	----		--	----	-	---
Ω, rps		0.39	0.30		--	0.43	-	---
V, fps		140	142		--	146	-	---
Turns for recovery		∞	∞		--	∞	-	---

	Landing condition, normal loading. Ailerons drooped 35°					
Spoilers	Against		Neutral		With	
Elevator	N	D	N	D	N	D
Turns for recovery	$5\frac{1}{2}$	∞	$4\frac{1}{2}$	7	$2\frac{1}{2}$ 4	∞

	Seaplane, normal loading				
Ailerons	Against		Neutral		With
Elevator	N (a)	D (a)	N (a)	D	D (b)
Turns for recovery	$1\frac{1}{4}$	2	$2\frac{1}{2}$	$>4\frac{1}{2}$	----

[a]Wandering spin.
[b]Vertical velocity too high to test.
[c]Pro-spin fin attached for seaplane tests.
[d]Steep spin.

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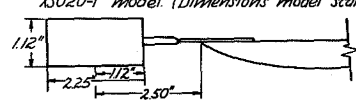
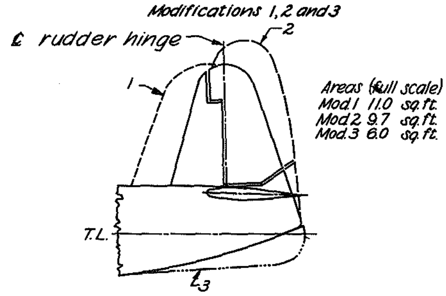
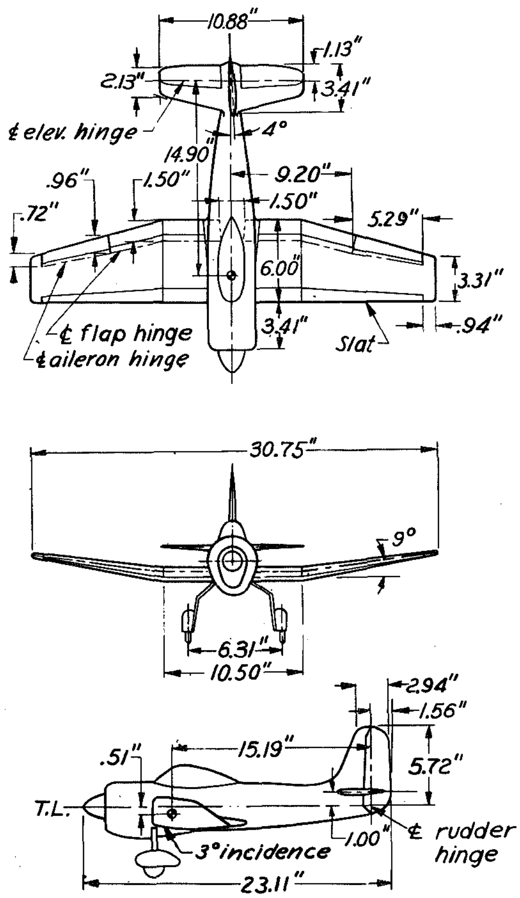
Pro-spin fin installed on wing tip of XS02U-1 model. (Dimensions model scale)



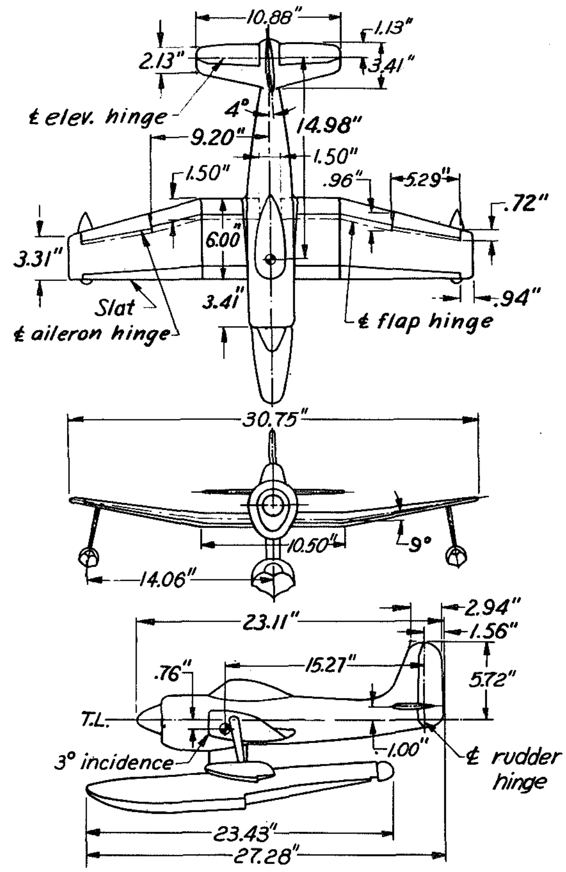
Modifications 1,2 and 3



$\frac{1}{16}$-SCALE MODEL OF THE CURTISS-WRIGHT XSC-1 LANDPLANE AND SEAPLANE



Model as tested.



Model as tested.

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Dimensional Data

(Full Scale)

(Dimensions are the same for landplane and seaplane except where noted)

b, ft	41.00
L, ft	
Landplane	31.21
Seaplane	36.38
$\bar{c}$, in	81.61
S, sq ft	281.57
A	5.97
L.E. $\bar{c}$ aft L.E. c_r, in	1.02
S_h, sq ft	51.95
S_e, sq ft	22.95
S_v, sq ft	30.93

S_r, sq ft	18.75
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	23 U, 17 D
δ_f, deg	50 D
TDPF	
Landplane	278×10^{-6}
Seaplane	291×10^{-6}
Landing gear	
Landplane	Fixed
Seaplane	Single float

Mass Data

Normal Loading

(Landplane)

W, lb	7350	$\frac{I_X - I_Y}{mb^2}$	-84×10^{-4}
$x/\bar{c}$	0.231	$\frac{I_Y - I_Z}{mb^2}$	-99×10^{-4}
$z/\bar{c}$	0.091	$\frac{I_Z - I_X}{mb^2}$	183×10^{-4}
I_X, slug-ft^2	4767		
I_Y, slug-ft^2	8007		
I_Z, slug-ft^2	11,729		
Test altitude, ft	18,000		
μ (at sea level)	8.33		
μ' (18,000 ft)	14.55		

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(Seaplane)

Loadings

	Normal	Flight		Normal	Flight
W, lb	7625	8674	$\frac{I_X - I_Y}{mb^2}$	-62×10^{-4}	-70×10^{-4}
$x/\bar{c}$	0.213	0.180	$\frac{I_Y - I_Z}{mb^2}$	-94×10^{-4}	-80×10^{-4}
$z/\bar{c}$	0.148	0.210	$\frac{I_Z - I_X}{mb^2}$	156×10^{-4}	150×10^{-4}
I_X, slug-ft^2	6739	7740			
I_Y, slug-ft^2	9206	10,917			
I_Z, slug-ft^2	12,945	14,557			
Test altitude, ft	18,000	18,000			
μ (at sea level)	8.64	9.81			
μ' (18,000 ft)	15.00	17.22			

Résumé of Model Test Results

For the seaplane model in the normal loading, clean condition, with the wing slots closed, the model recovered in one and one-half turns or less from all elevator-up and elevator-neutral spins by rapid full reversal of both the air and water rudders. Recovery by rapid full reversal of the air rudder alone was slightly slower.

Extending the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.20\ I_X\right)$ or along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ had no appreciable effect on the recovery characteristics of the model.

With the center of gravity moved rearward 0.10c, recoveries from elevator-down spins were retarded whereas there was no apparent effect on the recoveries from elevator-up or elevator-neutral spins.

In the landing condition (slots open, flaps 50° down), recoveries by reversal of the air and water rudders were generally unsatisfactory.

For the normal loading condition with the wing slots open, recoveries were generally satisfactory. Occasionally, a flat-type spin from which recovery was unsatisfactory would be obtained when the elevator was down and the ailerons neutral. With the slot on the outboard wing fully opened and the slot on the inboard wing closed, recovery by reversal of the air and water rudders was unsatisfactory from all control settings. With the slot positions reversed, the model would not spin for any control settings.

For the flight loading condition with the slots open, the seaplane model recovered satisfactorily when the elevator was up and the ailerons neutral. With the elevators full down, two types of spin were obtained. Recovery from the flat-type spin was unsatisfactory whereas recovery from the steeper spin was marginal. The slots had little effect if both slots were open symmetrically. If the slot on the outboard wing were opened more than the slots on the inboard wing, recoveries were retarded.

The addition of a dorsal fin and keel strip (modification 1) had little effect on the recovery characteristics of the model.

The addition of a ventral fin and rudder extension (modification 2) prevented the flat type elevator-down spin, and recovery from the spin obtained was satisfactory. The addition of a larger ventral fin and rudder extension (modification 3) was slightly more effective, however, recoveries were unsatisfactory with the outboard slot opened more than the inboard slot.

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The recovery characteristics of the seaplane model were satisfactory for all inverted spins for the normal loading, clean condition.

The landplane model exhibited poorer spinning characteristics than the seaplane model. In general, the recovery characteristics of the landplane model were marginal. When the elevator was neutral or down on the landplane model, aileron-against settings retarded recoveries and when the elevator was full up, aileron-with settings retarded recoveries; whereas, on the seaplane model, aileron setting had had little effect.

Test results obtained for the landplane model indicated that the effect of slots and flaps were qualitatively the same as those for the seaplane. For the landing condition (slots open, flaps 50° down), the recovery characteristics were unsatisfactory. The addition of a ventral fin and rudder extension (modification 4) to the model enabled satisfactory recoveries to be obtained from all spins for the landing condition (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CURTISS-WRIGHT XSC-1 SEAPLANE AND LANDPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Seaplane, normal loading									Seaplane, normal loading water rudder free; recoveries attempted by rapid reversal of air rudder only									Seaplane ΔI_X and $\Delta I_Z = 0.20 I_X$,								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	N	D	U	N (a)	D	U	N	D	U (a)	N	D	U (a)	N	D	U (a)	N	D	U (a)	N (a)	D	U	N	D (a)	U (a)	N	D (a)
α, deg	31	30	36	42	29	47	32	21	---	24	38	34	42	38	34	40	39	19	28 49	28	28	45	29	20 47	37 52	40	25 40
ϕ, deg	8U	14U	15U	3U	5U	9U	5D	4D	---	9U	8U	9U	2U	4U	3U	5D	3U	4U	5U	6U	11U	2U	4U	15U 10D	4U 9D	3D	0
Ω, rps	0.33	0.51	0.52	0.35	0.62	0.64	0.36	0.69	0.69	0.37	0.84	0.53	0.36	0.44	0.37	0.40	0.59	0.97	0.36	0.50	0.61	0.39	0.50	0.76	0.35	0.48	0.62
V, fps	197 234	208	193	192	205 231	187	202	234	224	219	208	208	219	208	208	219	219	292	193	213	213	187	219	227	202	187	205
Turns for recovery	$\frac{3}{4}$	$\frac{3}{4}$	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$ $2\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$	1 $1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{2}$	2	$1\frac{1}{2}$	$2\frac{1}{2}$	1	1	1	1	$1\frac{1}{4}$	$1\frac{3}{4}$ $2\frac{1}{4}$	1 $1\frac{1}{2}$	$1\frac{1}{2}$	2	2

	Seaplane, ΔI_Y and $\Delta I_Z = 0.20 I_Y$,						Seaplane, c.g. moved back $0.10\bar{c}$,									Seaplane, landing condition, **normal loading**								
Ailerons	Against		Neutral		With		Against			Neutral			With			Against			Neutral			With		
Elevator	U (a)	D (a)	U (a)	D	U (a)	D (a)	U (a)	N (a)	D (a)	U (a)	N (a)	D	U (a)	N (a)	D (a)	U	N	D	U	N	D	U	N	D
α, deg	34 47	36 48	41 51	44	37 50	14 23	45	32 45	37 59	38 52	32 50	43	38 55	33 49	27 45	56	58	56	56	55	53	57	49	53
ϕ, deg	4U 18U	5U 19U	3U 4D	4U	6D 18D	5D 13D	10U	11U 24U	4U 22U	3U 12D	8U 9D	4U	1D 11D	5U 5D	9U 9D	6D	6D	4D	8D	6D	6D	12D	9D	8D
Ω, rps	0.30	0.42	0.30	0.40	0.32	0.59	0.22	0.37	0.38	0.30	0.41	0.44	0.29	0.35	0.55	0.42	0.48	0.46	0.42	0.48	0.47	0.42	0.45	0.50
V, fps	219	202	200	184	202	330	229	213	198	182	193	182	202	208	202	157	147	147	154	---	151	154	147	154
Turns for recovery	1	$1\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$ $2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{4}$	1	1	$1\frac{1}{2}$	2 >3	1	$1\frac{1}{4}$	[b]$2\frac{1}{2}$ [b]$3\frac{1}{2}$	3	$2\frac{1}{2}$ $3\frac{3}{4}$	3	$2\frac{1}{2}$	$2\frac{1}{4}$ $2\frac{3}{4}$	$2\frac{1}{2}$	3	[b]2 [b]3	$1\frac{3}{4}$ $2\frac{1}{4}$

	Seaplane, slots open, **normal loading**							Seaplane, slots on left wing full open, slots on right wing completely closed, **normal loading**						Seaplane, slots on left wing completely closed, slots on right wing full open, **normal loading**								
Ailerons	Against		Neutral			With		Against		Neutral			With		Against			Neutral			With		
Elevator	U (a)	D	U (a)	D (c)	D (c)	U (a)	D (a)	U	D	U	N	D	U	D	U	N	D	U	N	D	U	N	D
α, deg	56	50	58	65	48	60	42	73	70	74	73	69	68	68	No spin	---	No spin	No spin	No spin	No spin	No spin	---	No spin
ϕ, deg	3D	1D	9D	2D	4D	9D	15D	5D	5D	8D	5D	7D	13D	7D		---						---	
Ω, rps	0.33	0.39	0.35	0.54	0.42	0.32	0.40	0.58	0.57	0.56	0.59	0.60	0.51	0.57		---						---	
V, fps	162	171	167	141	176	164	176	142	137	144	137	137	154	137		---						---	
Turns for recovery	1 $1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$5\frac{3}{4}$	1 $1\frac{1}{2}$	2	$1\frac{1}{4}$	∞	∞	∞	∞	∞	∞	8 ∞									

[a]Oscillatory spin; where range of values is not given, average value is presented.
[b]Visual observation.
[c]Two types of spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CURTISS-WRIGHT XSC-1 LANDPLANE AND SEAPLANE - Continued

[Unless otherwise indicated, steady-spin data are for rudder-with spins of model in the clean condition and recoveries were attempted from right erect spins]

	Flight loading, ailerons neutral						Flight loading, modification 1, ailerons neutral																			
Slots Rt.	Open						Open				$\frac{3}{4}$ open			$\frac{1}{2}$ open			$\frac{3}{4}$ open		$\frac{1}{2}$ open		$\frac{1}{2}$ open			Closed		
Slots Lt.	Open						Open				$\frac{3}{4}$ open			$\frac{1}{2}$ open			open		open		$\frac{3}{4}$ open			Closed		
Elevator	U (d)	U	D (cd)	D (cd)	D (c)	D (c)	U (d)	$\frac{2}{3}$ U (d)	D (cd)	D (cd)	U (d)	D (cd)	D (cd)	U (d)	D (cd)	D (cd)	U (d)	D (d)	U (d)	D (d)	U (d)	D (cd)	D (cd)	U (d)	D (cd)	D (cd)
α, deg	47	51	64	47	60	48	45	45	63	41	49	60	39	44	64	43	48	69	51	67	53	66	42	40	63	36
ø, deg	1U	4D	4D	3D	3D	0	4D	5D	4D	2D	1D	2D	2D	3D	2D	1D	5D	2D	10D	5D	5D	4D	4D	2D	0	8U
Ω, rps	0.42	0.43	0.68	0.58	0.51	0.50	0.45	0.44	0.56	0.51	0.48	0.55	0.50	0.38	0.55	0.53	0.42	0.58	0.45	0.56	0.42	0.54	0.50	0.40	0.57	0.56
V, fps	194	187	153	187	159	182	211	256	159	205	188	153	205	211	---	205	188	147	182	153	187	150	205	223	161	217
Turns for recovery	$1\frac{3}{4}$	2	$5\frac{1}{4}$	$1\frac{3}{4}$ $2\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{2}$ 1	$1\frac{1}{2}$ [e]$1\frac{1}{2}$ [e]$2\frac{1}{4}$	4 5	2	$1\frac{1}{4}$ 2	$6\frac{1}{4}$	2	$1\frac{1}{4}$	$5\frac{3}{4}$	2	2	$5\frac{1}{2}$ $8\frac{3}{4}$	$3\frac{1}{2}$	9	$1\frac{3}{4}$	$5\frac{1}{4}$	2	$1\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{3}{4}$

	Flight loading, modification 2				Flight loading, modification 3				Normal loading, c.g. moved back $0.03\bar{c}$		
Slots Rt.	Open	$\frac{1}{2}$ open		Closed	Open	$\frac{1}{2}$ open			Open		
Slots Lt.	Open	Open		Closed	Open	Open			Open		
Elevator	D (d)	U (d)	D (d)	D (d)	D (d)	U (d)	D (cd)	D (cd)	U	D (c)	D (c)
α, deg	44	59	65	39	47	64	62	47	49	65	51
ø, deg	4D	8D	5D	8U	4D	7D	7D	6D	5D	2D	4D
Ω, rps	0.71	0.46	0.56	0.54	0.50	0.45	0.53	---	0.37	0.54	0.46
V, fps	205	174	147	223	205	182	159	188	182	141	187
Turns for recovery	$1\frac{3}{4}$	$3\frac{1}{4}$ 4	6 $4\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$ $3\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$5\frac{3}{4}$	$1\frac{1}{2}$

Seaplane, inverted spins, normal loading									
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	No spin	No spin	No spin	45	No spin	No spin	49	44	50
ø, deg				3D			4D	6D	2D
Ω, rps				0.37			0.42	0.44	0.46
V, fps				202			176	187	187
Turns for recovery				$\frac{1}{2}$			1	1	1

	Landplane, normal loading											
Ailerons	Against					Neutral			With			
	Full			$\frac{1}{3}$					$\frac{1}{3}$		Full		
Elevator	U	N	D	20°U	U	U	N	D	20°U	U	U (a)	N	D
α, deg	44	58	53	44	---	45	38	37	38	---	44	29	21
ø, deg	3U	1U	2U	0	---	2D	0	1U	5D	---	7D	10D	3D
Ω, rps	0.40	0.50	0.50	0.42	---	0.41	0.53	0.54	0.48	---	0.41	0.58	0.79
V, fps	190	162	167	187	---	193	192	182	197	---	197	270	250
Turns for recovery	$1\frac{3}{4}$	[f]$3\frac{1}{4}$	$3\frac{3}{4}$	[g]$2\frac{1}{2}$	---	2	2	$2\frac{1}{2}$ 3	[g]$>2\frac{1}{4}$	---	$>2\frac{1}{4}$	[h]$1\frac{1}{4}$	$1\frac{1}{4}$

[a]Oscillatory spin, where range of values is not given, average value is presented.

[c]Two types of spin.

[d]Rudder throw ±25°

[e]Recovery was attempted by reversing rudder from 25° with the spin to 16° against the spin.

[f]After recovery, model made a short glide and entered a spin in the opposite direction.

[g]Recovery attempted by reversing the rudder from 30° with to 20° against the spin.

[h]Recovery attempted before model reached final steep attitude.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE CURTISS-WRIGHT XSC-1 SEAPLANE AND LANDPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Landplane, normal loading, left spins													Landplane, landing condition, normal loading								
Ailerons	Against					Neutral			With					Against			Neutral			With		
	Full			1/3					1/3	Full												
Elevator	U	N	D	20° U (c)	20° U (c)	U	N	D	20° U	U	N (i)	D (c)	D (c)	U	N	D	U	N	D	U (a)	N	D
α, deg	24	64	64	56	24	---	55	58	26	36	52	21	46	59	68	68	54	60	58	35 57	49	60
ϕ, deg	2U	2U	1U	1U	3D	---	0	0	8D	13D	2D	4D	3D	5D	1D	1D	12D	6D	5D	1D 27D	13D	8D
Ω, rps	0.47	0.54	0.55	---	---	0.46	0.50	0.48	0.49	0.44	0.48	0.75	0.52	0.42	0.52	0.52	0.42	0.48	0.48	0.47	0.47	0.45
V, fps	250	147	157	176	261	257	162	162	257	234	171	290	176	157	146	142	157	146	151	171	157	146
Turns for recovery	[f]3/4	4	5 1/4	[g]2 1/4	[g]3/4	3/4	3	4	[g]1 3/4 [g]2 1/2	1	[j]1 3/4 [j]2 1/4	1	[j]1 [j]2	>7 1/2	∞	∞	3 1/2 4 1/2	7	5 1/4	1 1/4	1	3 3/4

	Landplane, slots open, normal loading									Landplane, slots on left wing, full open, slots on right wing **completely closed, normal loading**							Landplane, slots on left wing completely closed, slots on right wing full open, **normal loading**					
Ailerons	Against			Neutral			With			Against		Neutral			With		Against		Neutral		With	
Elevator	U	N	D	U	N	D	U (a)	N (a)	D	U	N	U	N	D	U	N	U	N	U	N	U	N
α, deg	50	56	54	43	50	49	45	43	47	73	---	70	73	---	67	---	No spin	---	No spin	No spin	No spin	---
ϕ, deg	1D	0	0	6D	4D	5D	9D	10D	7D	2D	---	2D	3D	---	6D	---		---				---
Ω, rps	0.50	0.53	0.56	0.49	0.53	0.57	0.49	0.56	0.59	0.57	---	0.52	0.58	---	0.50	---		---				---
V, fps	171	157	157	187	167	157	197	167	157	151	---	157	144	---	158	---		---				---
Turns for recovery	2 1/4 3 1/4 4 1/2	4 1/4	3 3/4	1 3/4 2 1/4	3 1/4	3	1 1/2 3 5 1/4	2 3/4	4	∞	---	∞	∞	---	∞	---		---				---

	Landplane, inverted spins, normal loading									Landplane, modification 4, normal loading			
Ailerons	Against			Neutral			With			Against		Neutral	
Elevator	U	N	D	U	N	D	U	N	D	U	D	U	D
α, deg	No spin	No spin	No spin	40	40	38	47	49	43	47	57	45	---
ϕ, deg				1D	1D	1D	2D	2D	2D	6D	1D	9D	---
Ω, rps				0.46	0.51	0.56	0.46	0.55	0.55	0.36	0.43	0.44	---
V, fps				202	202	202	197	182	176	166	166	177	---
Turns for recovery				1/2	1/2	3/4	1	3/4	3/4	1 1/2 2	2 3/4	1 1/2	---

[a]Oscillatory spin; where range of values is not fiven average value is presented.
[c]Two types of spin.
[f]After recovery, model made a short glide and entered a spin in the opposite direction.
[g]Recovery attempted by reversing the rudder from 30° with to 20° against the spin.
[i]Steeper spin also obtainable.
[j]Upon recovery, model enters right inverted spin.

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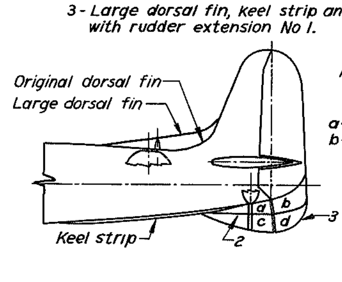
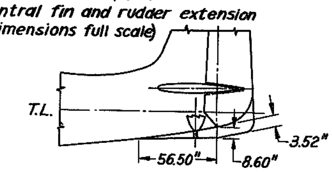
Modification 1 - Large dorsal fin and keel strip
2 - Large dorsal fin, keel strip and ventral fin with rudder extension No I.
3 - Large dorsal fin, keel strip and ventral fin with rudder extension No I.



Areas (Full scale)
a = 1.87 sq. ft.
b = 2.09 sq. ft.
a+c = 4.62 sq. ft.
b+d = 3.62 sq. ft.

Modification 4
Ventral fin and rudder extension
(Dimensions full scale)

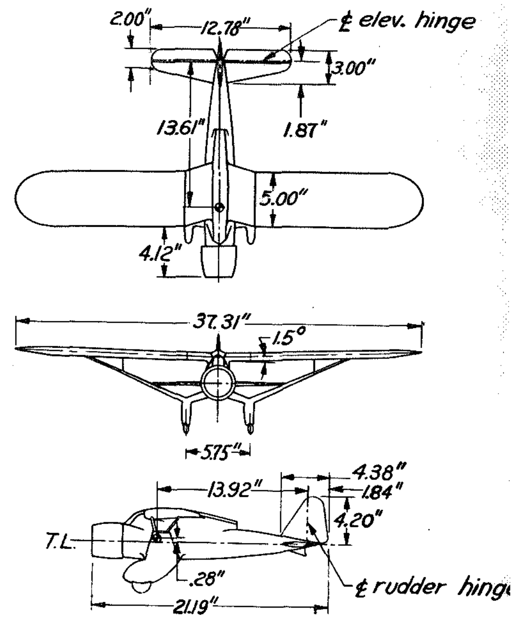


$\frac{1}{16}$-SCALE MODEL OF THE BELLANCA XSE-1 AIRPLANE

Dimensional Data

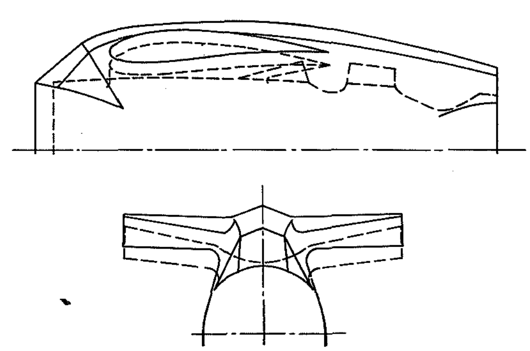
(Full Scale)

b, ft	49.75
L, ft	28.80
$\bar{c}$, in.	60.00
S, sq ft	356.00
A	8.35
S_h, sq ft	49.40
S_e, sq ft	21.20
S_v, sq ft	24.55
S_r, sq ft	13.30
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 30 D
δ_a, deg	25 U, 25 D
TDPF	18×10^{-6}
Landing gear	Fixed



Model as tested.

Comparison of cabin fuselage and open cockpit fuselage as tested on the XSE-1 airplane



Mass Data

Normal Loading

W, lb	6320
$x/\bar{c}$	0.350
$z/\bar{c}$	-0.075
I_X, slug-ft^2	7270
I_Y, slug-ft^2	7108
I_Z, slug-ft^2	11,830
Test altitude, ft	6000
μ (at sea level)	4.66
μ' (6000 ft)	5.58

$\frac{I_X - I_Y}{mb^2}$	3×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-97×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	94×10^{-4}

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Résumé of Model Test Results

In the normal loading, the spin was violently oscillatory and irregular and, accordingly, tests were made with the loading modified somewhat to permit testing in the tunnel. Mass was retracted along the wing (ΔI_X and $\Delta I_Z = -0.20\ I_Y$) and extended along the fuselage (ΔI_Y and $\Delta I_Z = 0.20\ I_Y$). The spin although fairly steep was still oscillatory when the elevator was full up. With the elevator only 10° up, neutral, or down, the spin was fairly steady and recovery was satisfactory by rapid full rudder reversal.

Various combinations of mass changes were tested for the elevator-down, aileron-neutral spin and, in general, indicated little effect.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE BELLANCA XSE-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	ΔI_X and ΔI_Z = -0.20 I_X, ΔI_Y and ΔI_Z = 0.20 I_Y, cabin fuselage																ΔI_X and ΔI_Z = -0.20 I_X, ΔI_Y and ΔI_Z = 0.20 I_Y, open cockpit fuselage		
	Against										Neutral				With		Neutral		
Ailerons	25°U 25°D	20°U 20°D	15°U 15°D	10°U 10°D	5°U 5°D	0 20°D	0 15°D	0 10°D	0 5°D	5°U 0					5°U 5°D	10°U 10°D			
Elevator	D	D	D	D	D	D	D	D	D	D	U (a)	10°U	N	D	D	D (b)	10°U	N	D
α, deg	43	42	42	43	41	42	43	40	39	39	35	36	35	39	37	34	34	36	40
ø, deg	11U	13U	13U	11U	11U	11U	6U	12U	11U	10U	5D	3D	1U	8U	7U	3D	5U	5U	11U
Ω, rps	0.44	0.43	0.44	0.45	0.45	0.45	0.45	0.45	0.46	0.46	0.33	0.40	0.43	0.45	0.48	0.50	0.40	0.42	0.45
V, fps	134	139	136	136	141	135	137	138	141	142	160	158	154	144	144	151	154	151	140
Turns for recovery	2 $1\frac{1}{2}$	2	$2\frac{1}{4}$	$1\frac{1}{2}$ $2\frac{1}{4}$	2	$2\frac{3}{4}$	3 >7	2	$1\frac{3}{4}$ $2\frac{1}{4}$	---	---	---	---	2	$1\frac{1}{2}$ 2	$1\frac{1}{2}$	1 $1\frac{1}{2}$	$1\frac{1}{4}$	1 2 [c]>4 [c]∞

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	ΔI_X and ΔI_Z = -0.20 I_X, ΔI_Y and ΔI_Z = 0.40 I_Y Cabin fuselage											
	Against								Neutral		With	
Ailerons	20°U 20°D	15°U 15°D	10°U 10°D	5°U 5°D	15°U 10°D		5°U 10°D				5°U 5°D	10°U 10°D
Elevator	D	D	D	D	D (d)	D (d)	D (d)	D (d)	U	D	D	D (b)
α, deg	45	45	46	42	47	44	58	43	----	41	37	34
ø, deg	11U	12U	12U	8U	10U	11U	10U	9U	----	7U	1U	2D
Ω, rps	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.41	----	0.42	0.44	0.46
V, fps	138	138	136	141	124	139	123	140	----	146	148	155
Turns for recovery	----	∞ [e]$1\frac{1}{2}$	∞	---	---	---	∞	----	----	4 $3\frac{1}{4}$	----	----

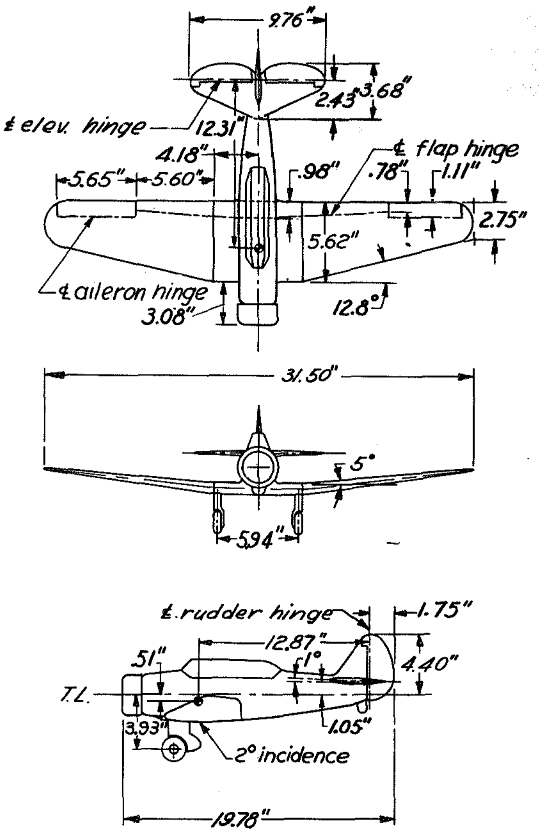
[a]Oscillatory spin.
[b]Spin oscillatory in roll.
[c]Recovery attempted by neutralizing rudder.
[d]Two types of spin.
[e]Recovery attempted by simultaneous reversal of rudder from with to full against and elevator from 30° down to 20° up.

$\frac{1}{16}$-SCALE MODEL OF THE NORTH AMERICAN BT-9

Dimensional Data

(Full Scale)

b, ft	42.00
L, ft	28.00
$\bar{c}$, in.	75.19
S, sq ft	248.30
A	7.10
L.E. $\bar{c}$ aft L.E. c_r, in.	14.81
S_h, sq ft	40.20
S_e, sq ft	20.30
S_v, sq ft	19.03
S_r, sq ft	13.57
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	30.5 U, 16.5 D
δ_f, deg	60 D
TDPF	244×10^{-6}
Landing gear	Fixed



Model as tested.

Mass Data

Normal Loading

W, lb	4296
$x/\bar{c}$	0.248
$z/\bar{c}$	0.109
I_X, slug-ft^2	2621
I_Y, slug-ft^2	3715
I_Z, slug-ft^2	5613
Test altitude, ft	7000
μ (at sea level)	5.38
μ' (7000 ft)	6.65

$\frac{I_X - I_Y}{mb^2}$	-46×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-81×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	127×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition, recoveries of the model were satisfactory for all control configurations by either rapid full rudder reversal or by simultaneous reversal of rudder and elevator.

Extending the mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$ and $0.40\ I_X$) or retracting the mass along the fuselage (ΔI_Y and $\Delta I_Z = -0.10\ I_Y$) had little effect on the recovery characteristics of the model.

With the mass extended along the fuselage (ΔI_Y and $\Delta I_Z = 0.40\ I_Y$) and with the center of gravity moved back $0.03\bar{c}$ from its normal position satisfactory recoveries could not be obtained by either rapid full rudder reversal or by simultaneous reversal of the elevator and rudder if the ailerons were set against the spin or if the ailerons were neutral with the elevator neutral or down. When the ailerons were set with the spin the model spun with a high rate of descent.

The addition of a modified rudder (see sketch) had a slight beneficial effect on the recovery characteristics of the model but was not entirely satisfactory.

Results, not presented, indicated that the most satisfactory location for additional vertical area for the improvement of the recovery characteristics of the model was in the vicinity of the tail wheel. Area added at the intersection of the fuselage and the leading edge of the vertical tail had a detrimental effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NORTH AMERICAN BT-9 AIRPLANE

[Unless otherwise indicated steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Ailerons	Against					Neutral				With			
	Full			15°U 11.7°D						15°U 11.7°D		Full	
Elevator	U	N	D	N	D	U (a)	10°U (b)	N	D	N (b)	D (c)	N (c)	D
α, deg	No spin	No spin	-	37	-	-	29	34	36	24	-	29	-
ø, deg			-	13U	-	-	13U	13U	13U	3U	-	2U	-
Ω, rps			-	0.56	-	-	0.56	0.58	0.61	0.71	-	0.62	-
V, fps			-	143	-	-	155	148	139	170	-	167	-
Turns for recovery			$\frac{3}{4}$	[d]1	$1\frac{1}{4}$	-	1	1 [d]1	$1\frac{1}{2}$	[d]1 [d]$1\frac{1}{2}$	$1\frac{1}{4}$	[d]$1\frac{1}{4}$	1 $1\frac{1}{2}$

Effect of mass variation and c.g. movements on turns for recovery

Ailerons	Neutral	
Elevator	N	D
ΔI_X and $\Delta I_Z = 0.20 I_X$	No spin	
ΔI_X and $\Delta I_Z = 0.40 I_X$	No spin	
ΔI_Y and $\Delta I_Z = 0.20 I_Y$	[d]$2\frac{1}{4}$	$2\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.40 I_Y$	[d]$3\frac{1}{2}$	$4\frac{1}{4}$
ΔI_Y and $\Delta I_Z = -0.10 I_Y$ c.g. moved forward $0.07\bar{c}$	No spin	
ΔI_Y and $\Delta I_Z = -0.10 I_Y$ c.g. moved forward $0.04\bar{c}$	-	$1\frac{1}{4}$
c.g. moved back $0.03\bar{c}$	[de]$\frac{3}{4}$	$1\frac{1}{2}$
c.g. raised $0.03\bar{c}$	[de]$1\frac{1}{4}$	$1\frac{1}{4}$
c.g. lowered $0.03\bar{c}$	[de]1	-

ΔI_Y and $\Delta I_Z = 0.40 I_Y$, c.g. moved back $0.03\bar{c}$

Ailerons	Against				Neutral			With			
	Full		15°U 11.7°D					15°U 11.7°D		Full	
Elevator	N	D	N	D	15°U (b)	N	D	N (f)	D (f)	N (f)	D (f)
α, deg	47	-	52	-	32	45		-	-	-	-
ø, deg	7U	-	8U	-	5U	4U		-	-	-	-
Ω, rps	0.43	-	0.49	-	0.43	0.46		-	-	-	-
V, fps	134	-	129	-	167	138		-	-	-	-
Turns for recovery	[d]$4\frac{1}{4}$	5	[d]$6\frac{1}{4}$	$6\frac{1}{4}$	[d]$1\frac{1}{4}$	[d]4 [dg]$2\frac{1}{4}$	$4\frac{1}{4}$ [g]$2\frac{3}{4}$	-	-	-	-

Effect of flap settings for aileron-neutral spins. ΔI_Y and $\Delta I_Z = 0.40 I_Y$, c.g. moved back $0.03\bar{c}$

Flaps	15°D	30°D	45°D	60°D
Elevator	N	N	N	N
α, deg	45	46	46	47
ø, deg	3U	4U	3U	3U
Ω, rps	0.43	0.43	0.42	0.40
V, fps	138	133	129	129
Turns for recovery	[d]$2\frac{1}{2}$ [d]3	[d]$2\frac{3}{4}$	[d]$3\frac{1}{4}$	[d]4 [d]$3\frac{1}{2}$

Modified rudder ΔI_Y and $\Delta I_Z = 0.40 I_Y$, c.g. moved back $0.03\bar{c}$

Ailerons	Neutral			
Elevator	15°U (b)	10°U	N	D
α, deg	-	43	-	47
ø, deg	-	4U	-	4U
Ω, rps	-	0.42	-	0.46
V, fps	-	146	-	133
Turns for recovery	[d]$1\frac{3}{4}$	-	[d]$3\frac{1}{4}$	$3\frac{1}{2}$

[a]Steep spiral glide.
[b]Wandering spin.
[c]Oscillatory spin
[d]Recovery attempted by simultaneous reversal of rudder from full with to full against the spin with elevator movement from initial position to full down.
[e]Model wandered before recovery was attempted.
[f]Wandering spin with high vertical velocity.
[g]Model with tail wheel attached.

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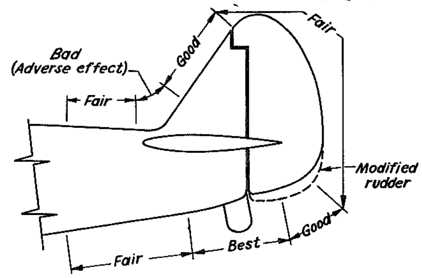
Relative effectiveness of additional vertical area.

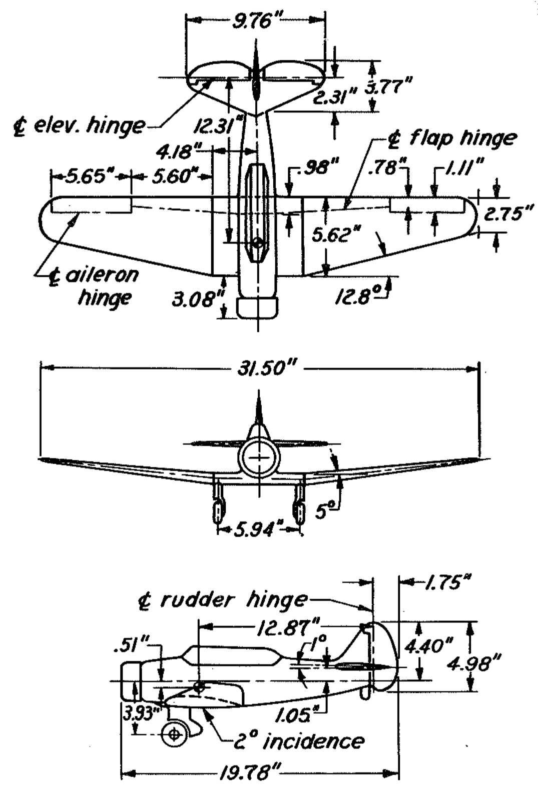


$\frac{1}{16}$-SCALE MODEL OF THE NORTH AMERICAN BT-9A AIRPLANE

Dimensional Data

(Full Scale)

b, ft	42.00
L, ft	28.00
$\bar{c}$, in.	75.19
S, sq ft	248.30
A	7.10
L.E. $\bar{c}$ aft L.E. c_r, in. . . .	14.81
S_h, sq ft	40.20
S_e, sq ft	18.99
S_v, sq ft	19.03
S_r, sq ft	13.80
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	30.5 U, 16.5 D
δ_f, deg	60 D
TDPF	330×10^{-6}
Landing gear	Fixed



Model as tested.

Mass Data

Normal Loading

W, lb	4614
$x/\bar{c}$	0.275
$z/\bar{c}$	0.101
I_X, slug-ft^2	2676
I_Y, slug-ft^2	4002
I_Z, slug-ft^2	5935
Test altitude, ft	7000
μ (at sea level)	5.38
μ' (7000 ft)	6.65

$\frac{I_X - I_Y}{mb^2}$	-52×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-77×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	129×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition satisfactory recoveries were obtained by either rapid full rudder reversal or by simultaneous reversal of the elevator and rudder.

Moving the center of gravity forward $0.035\bar{c}$ or lowering the flaps either 30° or 60° had little effect upon the recovery characteristics of the model.

Increasing the rudder deflection 5° with the spin or increasing the deflection 5° or decreasing it 5° or 10° against the spin had no appreciable effect on the recovery characteristics of the model.

With the mass extended along the fuselage (ΔI_Y and $\Delta I_Z = 0.40\ I_Y$) satisfactory recoveries could not be obtained from the elevator-down spins.

In order to improve the recovery characteristics of the model when the mass was extended along the fuselage (ΔI_Y and $\Delta I_Z = 0.40\ I_Y$), various modifications (modifications 1 to 14) were made to the tail surfaces of the model. Test results indicate that decreasing the elevator area (modification 14) or removing it (modification 11) had a favorable effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NORTH AMERICAN BT-9A AIRPLANE

[Unless otherwise indicated, steady spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading											
Ailerons	Against						Neutral					
	Full		15°U, 12°D									
Elevator	N (a)	D	N (ab)	N (a)	D (b)	D	15°U (c)	10°U (ab)	10°U (a)	N (a)	D	D (b)
α, deg	36	38	40	38	44	39	----	35	32	35	37	39
ϕ, deg	12U	12U	13U	12U	12U	11U	----	9U	9U	9U	12U	11U
Ω, rps	0.55	0.58	0.55	0.55	0.56	0.56	----	0.54	0.54	0.55	0.58	0.58
V, fps	146	139	148	146	137	138	----	156	158	152	142	141
Turns for recovery	---	---	---	---	---	---	----	---	1; [d]1	$1\frac{1}{4}$; [d]1	$1\frac{1}{2}$	$1\frac{1}{2}$

Effect of c.g. moved forward 0.035$\bar{c}$ on turns for recovery, normal loading

Ailerons	Against				Neutral		With	
	Full		15°U 12°D				15°U 12°D	Full
Elevator	N	D	N	D	N	D	D	D
Turns for recovery	[f]$1\frac{1}{4}$	$1\frac{1}{4}$; [f]$1\frac{1}{2}$; [g]$1\frac{1}{4}$	[f]$1\frac{1}{4}$	$1\frac{1}{4}$; [f]$1\frac{1}{2}$; [g]$1\frac{1}{4}$	[g]$1\frac{1}{4}$; [h]$1\frac{1}{4}$; [f]$1\frac{1}{2}$; [i]3	[h]$1\frac{3}{4}$; [f]$1\frac{1}{2}$; [g]$1\frac{1}{2}$; $1\frac{3}{4}$; [i]$3\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$

Effect of flaps on turns for recovery, normal loading

Flaps	30°		60°	
Elevator	D	D	D	D
Turns for recovery	1	[g]$\frac{3}{4}$	[j]–	[j]–

Effect of modifications on turns for recovery for aileron neutral spins, ΔI_Y and $\Delta I_Z = 0.40\ I_Y$ (Rudder reversal from 35° with to 35° against)

Elevator	10°U	D
Original	$1\frac{1}{2}$	3
Modification		
1	$1\frac{3}{4}$	$2\frac{3}{4}$
2	$2\frac{1}{2}$	$4\frac{1}{4}$
3	$1\frac{1}{2}$	3
4	$1\frac{3}{4}$	$2\frac{1}{2}$
5	$1\frac{1}{2}$	3

Elevator	10°U	D
Modification		
6	$1\frac{1}{2}$	$2\frac{1}{2}$
4 and 7	--	2
7	--	2; $2\frac{3}{4}$
7 and 8	--	$1\frac{3}{4}$
8	--	2

Elevator	D
Modification	
9	$2\frac{1}{2}$
10	$2\frac{1}{2}$
11	[k]1
12	[k]$1\frac{1}{4}$
13	5
14	2

[a]Wandering spin.
[b]Initial rudder setting 35°.
[c]Steep, wandering spin.
[d]Recovery attempted by simultaneous reversal of rudder and elevator.
[e]Recovery attempted by reversing the rudder from 35° with the spin to 25° against the spin.
[f]Recovery attempted by reversing the rudder from 35° with the spin to 20° against the spin.
[g]Recovery attempted by reversing the rudder from 30° with the spin to 25° against the spin.
[h]Recovery attempted by reversal of rudder from 30° with the spin to 20° against the spin.
[i]Recovery attempted by moving rudder from 30° with the spin to neutral.
[j]Before recovery was attempted the spin was steep and wandering.
[k]Elevator removed from model.

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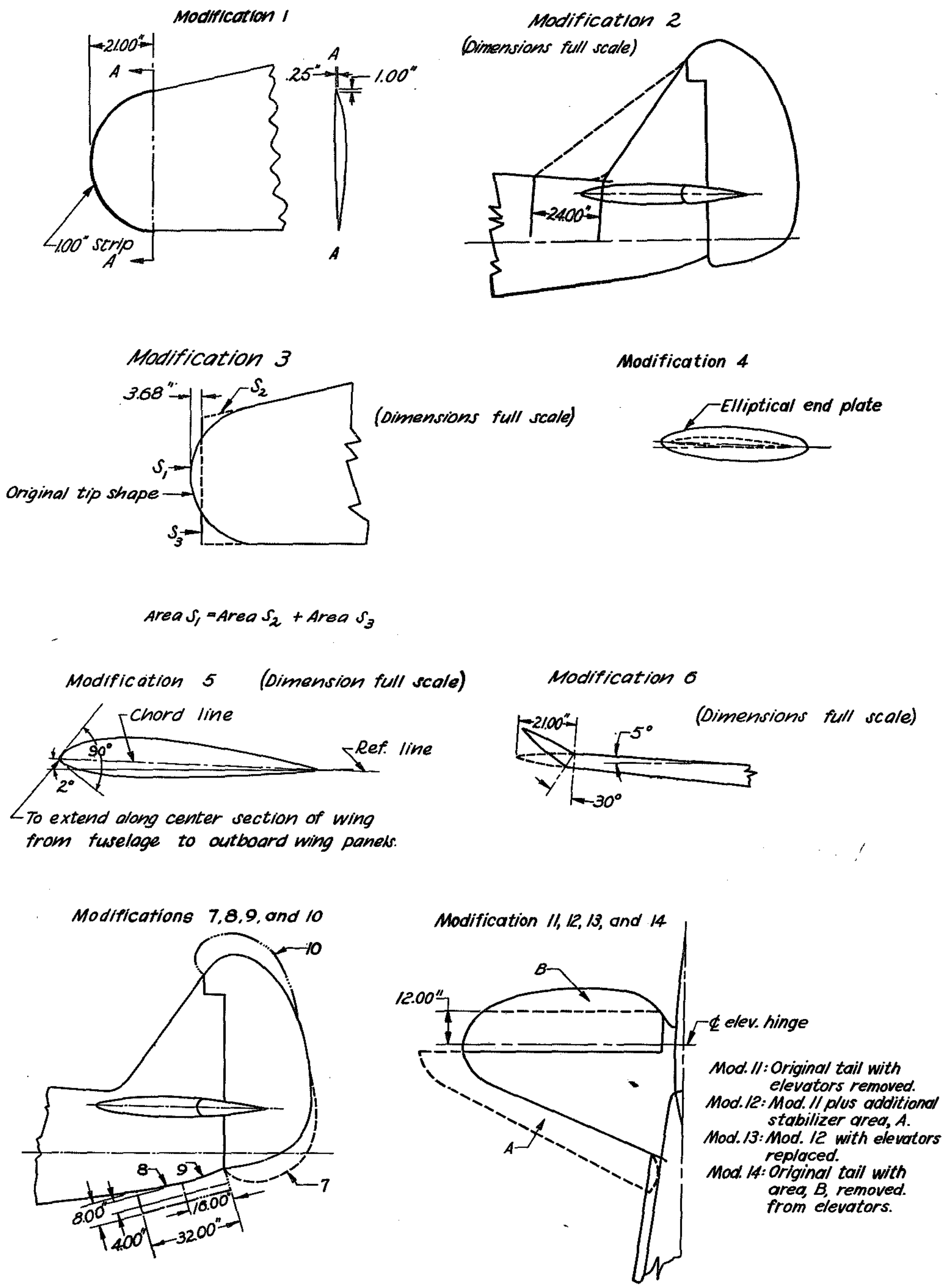

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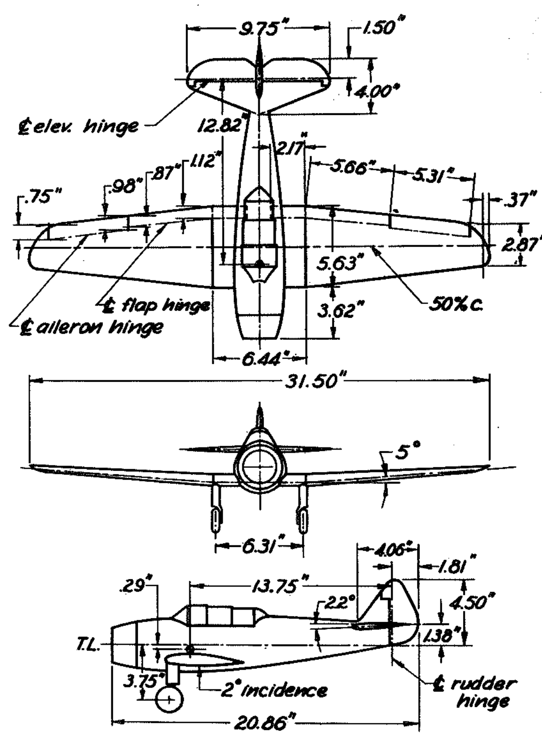
$\frac{1}{16}$-SCALE MODEL OF THE AIRCRAFT RESEARCH CORPORATION XBT-11 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	42.00
L, ft	27.81
$\bar{c}$, in.	75.60
S, sq ft	248.00
A	7.11
L.E. $\bar{c}$ aft L.E. c_r, in.	7.20
S_h, sq ft	45.10
S_e, sq ft	17.50
S_v, sq ft	20.10
S_r, sq ft	14.60
δ_r, deg	35 R, 35 L
δ_e, deg	35 U, 25 D
δ_a, deg	25 U, 25 D
δ_a, deg $\left(\frac{1}{2}\text{ stick}\right)$	12.5 U, 12.5 D
δ_f, deg	60 D
TDPF	255×10^{-6}
Landing gear	Fixed



Model as tested.

Mass Data

Normal Loading

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W, lb	4400
$x/\bar{c}$	0.258
$z/\bar{c}$	0.061
I_X, slug-ft^2	2700
I_Y, slug-ft^2	4360
I_Z, slug-ft^2	5900
Test altitude, ft	12,000
μ (at sea level)	5.51
μ' (12,000 ft)	7.97

$\frac{I_X - I_Y}{mb^2}$	-69×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-64×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	133×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun at an angle of attack of 36° and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{4}\text{ turns}\right)$. Rapid recovery was also obtained by simultaneous reversal of both elevator and rudder $\left(\frac{1}{2}\text{ turn}\right)$.

Recoveries were generally satisfactory when mass was extended along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$, from spins of the model in the landing condition, and from inverted spins.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE AIRCRAFT RESEARCH XBT-11 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading														
Ailerons	Against						Neutral			With					
	Full			$\frac{1}{2}$						$\frac{1}{2}$			Full		
Elevator	U	N	D	U	N	D	U	N	D	U (a)	N	D	U (a)	N (b)	D
α, deg	41	41	45	43	39	38	36	30	33	-	25	27	-	-	24
ϕ, deg	4U	6U	8U	2U	3U	6U	3D	1U	2U	-	1U	3U	-	-	4U
Ω, rps	0.39	0.53	0.55	0.38	0.54	0.56	0.40	0.58	0.66	-	0.62	0.70	-	-	0.74
V, fps	160	151	144	162	155	149	171	177	165	-	205	184	-	-	200
Turns for Recovery	$1\frac{1}{2}$ [c]$\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	$1\frac{1}{4}$ [d]>2 [c]$\frac{1}{2}$	$1\frac{1}{4}$ [d]$2\frac{1}{4}$	$1\frac{1}{2}$ [d]$2\frac{1}{4}$	-	1	$1\frac{1}{4}$	-	-	1

	Effect of mass variations on turns for recovery.					
Ailerons	Against			Neutral		
Elevator	U	N	D	U	N	D
ΔI_X and ΔI_Z = 0.15 I_X	-	-	-	$1\frac{1}{2}$	-	$1\frac{1}{4}$
ΔI_X and ΔI_Z = 0.30 I_X	1	No Spin	No Spin	>$3\frac{1}{2}$ [c]1	1	1

	Landing condition, normal loading										Inverted spin, normal loading								
Ailerons	Against				Neutral			With			Against			Neutral			With		
Elevator	U	N	D (e)	D (e)	U	N	D	U (a)	N	D	U	N	D	U	N	D	U	N	D
α, deg	51	46	45	29	42	19	23	-	No Spin	No Spin	No Spin	No Spin	No Spin	29	No Spin	No Spin	52	44	31
ϕ, deg	4U	5U	6U	8U	1D	1U	7U	-						3U			3D	2D	2D
Ω, rps	0.38	0.49	0.51	0.56	0.34	0.53	0.63	-						0.44			0.48	0.56	0.61
V, fps	140	169	129	156	151	198	173	-						224			147	165	176
Turns for Recovery	$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	-						$\frac{1}{2}$			>$5\frac{1}{2}$ [f]$2\frac{1}{2}$ [c]$1\frac{1}{2}$	$1\frac{1}{4}$	1

[a] Oscillatory spin.
[b] Velocity too high to test.
[c] Recovery attempted by simultaneous reversal of rudder and elevator.
[d] Recovery attempted by neutralizing the rudder.
[e] Two types of spin.
[f] Recovery attempted by simultaneously neutralizing the elevator and rudder.

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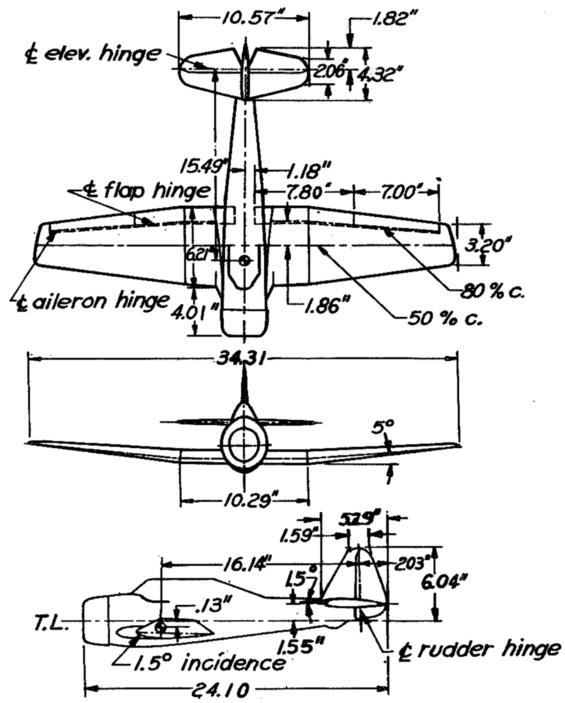
1/14-SCALE MODEL OF THE FLEETWINGS XBT-12 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	40.03
L, ft	29.16
$\bar{c}$, in.	75.00
S, sq ft	240.42
A	6.66
L.E.$\bar{c}$ aft L.E.c_r, in.	6.00
S_h, sq ft	42.39
S_e, sq ft	16.19
S_v, sq ft	23.49
S_r, sq ft	11.09
δ_r, deg	35 R, 35 L
δ_e, deg	35 U, 25 D
δ_a, deg	33 U, 17 D
δ_f, deg	50 D
TDPF	262×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

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W, lb	4282
$x/\bar{c}$	0.248
$z/\bar{c}$	0.024
I_X, slug-ft^2	2,492
I_Y, slug-ft^2	4,170
I_Z, slug-ft^2	6,293
Test altitude, ft	10,000
μ (at sea level)	5.81
μ' (10,000 ft)	7.88

$\frac{I_X - I_Y}{mb^2}$	-79×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-99×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	178×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, the model spun at a moderate angle of attack ($\alpha = 42^\circ$) and recoveries obtained either by rapid full rudder reversal or by simultaneous reversal of rudder and elevator were satisfactory $\left(1\frac{1}{2}\text{ and }1\frac{1}{4}\text{ turns, respectively}\right)$. Setting the elevator either at neutral or down had an adverse effect. Setting the ailerons fully against the spin slightly improved the recovery characteristics of the model, whereas, setting the ailerons full with spin slightly impaired the recovery characteristics of the model.

Extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$, extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_Y\right)$ or moving the center of gravity forward $0.06\bar{c}$ or back $0.03\bar{c}$ from its normal position (data not presented for center-of-gravity changes) had no great effect upon the general recovery characteristics of the model.

The recovery characteristics of the model in the landing condition were similar to those in the clean condition.

Inverted spins with the model were obtained only when the ailerons and rudder were set with the spin with the elevator set either up or neutral. The model would not spin inverted with the rudder set either neutral or against the spin (data not presented).

The installation of a smaller vertical tail on the model (see sketch) had no appreciable effect on the spin and recovery characteristics of the model (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{14}$-SCALE MODEL OF THE FLEETWINGS XBT-12 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Ailerons	Against						Neutral			With						
	Full			14°U, 10°D						14°U, 10°D				Full		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D (a)	D (a)	U	N	D
α, deg	32	56	54	42	67	61	42	54	49	51	-	44	29	61	57	54
ø, deg	5U	4U	3U	2U	3U	4U	1U	2U	3U	7D	-	0	1D	6D	4D	4D
Ω, rps	0.43	0.48	0.49	0.39	0.50	0.50	0.40	0.48	0.50	0.39	0.48	0.49	0.65	0.42	0.49	0.50
V, fps	191	128	128	168	121	121	162	129	134	153	139	138	167	138	131	133
Turns for recovery	1 [c]$\frac{3}{4}$	$1\frac{3}{4}$	2	$1\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{1}{2}$ [b]>2 [c]$1\frac{1}{4}$	$2\frac{1}{4}$ [b]$5\frac{1}{2}$	$2\frac{1}{4}$ [b]$3\frac{1}{2}$	$1\frac{3}{4}$	2	-	$1\frac{1}{2}$	$2\frac{3}{4}$ [c]$1\frac{3}{4}$	3	$3\frac{1}{2}$

ΔI_X and $\Delta I_Z = 0.30\ I_X$

Ailerons	Against					Neutral			With				
	Full			14°U 10°D					14°U 10°D		Full		
Elevator	U (d)	N	D	N	D	U	N	D	N (d)	D (d)	U	N	D
α, deg	-	No spin	No spin	No spin	No spin	44	57	53	-	-	56	61	58
ø, deg						1U	2U	1U	-	-	5D	3D	3D
Ω, rps						0.41	0.48	0.49	-	-	0.41	0.49	0.50
V, fps						160	129	135	-	-	139	131	128
Turns for recovery	-					$1\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	-	-	-	3	$4\frac{1}{2}$

ΔI_Y and $\Delta I_Z = 0.30\ I_Y$

Ailerons	Against					Neutral			With				
	Full			14°U, 10°D					14°D 10°U		Full		
Elevator	U (e)	N	D	N	D	U	N	D	N (f)	D (f)	U (g)	N	D
α, deg	-	68	60	65	62	45	61	61	-	-	-	60	58
ø, deg	-	3U	4U	3U	2U	2D	0	0	-	-	-	5D	5D
Ω, rps	-	0.44	0.44	0.44	0.43	0.34	0.43	0.44	-	-	-	0.43	0.44
V, fps	180	121	126	124	124	155	126	126	-	-	138	133	133
Turns for recovery	-	$2\frac{3}{4}$	$3\frac{1}{2}$	3	$3\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{3}{4}$	4	-	-	-	$2\frac{3}{4}$	$3\frac{1}{4}$

Landing condition, normal loading

Ailerons	Against			Neutral				With		
Elevator	U (d)	N	D	U (d)	N	D (a)	D (a)	U	N	D
α, deg	-	52	No spin	-	54	47	28	54	53	52
ø, deg	-	3U		-	1U	3U	3U	6D	5D	3U
Ω, rps	-	0.48		-	0.48	0.49	0.63	0.39	0.48	0.50
V, fps	-	126		-	121	119	158	136	129	126
Turns for recovery	-	2		-	$2\frac{1}{2}$	3	$\frac{3}{4}$	-	$3\frac{1}{4}$	$3\frac{3}{4}$

[a] Two types of spin.
[b] Recovery attempted by neutralizing the rudder.
[c] Recovery attempted by simultaneous reversal of rudder and elevator.
[d] Oscillatory spin.
[e] Oscillatory and wandering spin.
[f] Vertical velocity too high to test.
[g] Too wandering to test completely.

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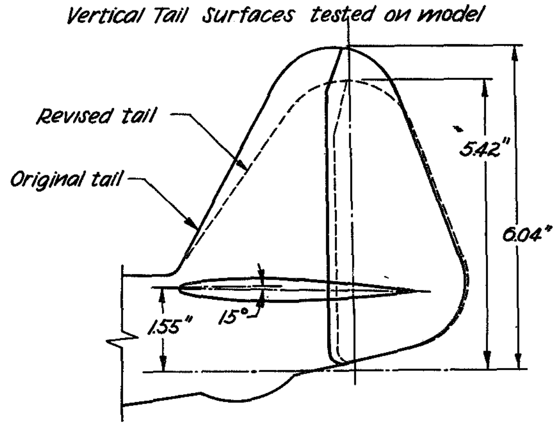
Comparison of Original and Revised Vertical Tail Surfaces tested on model

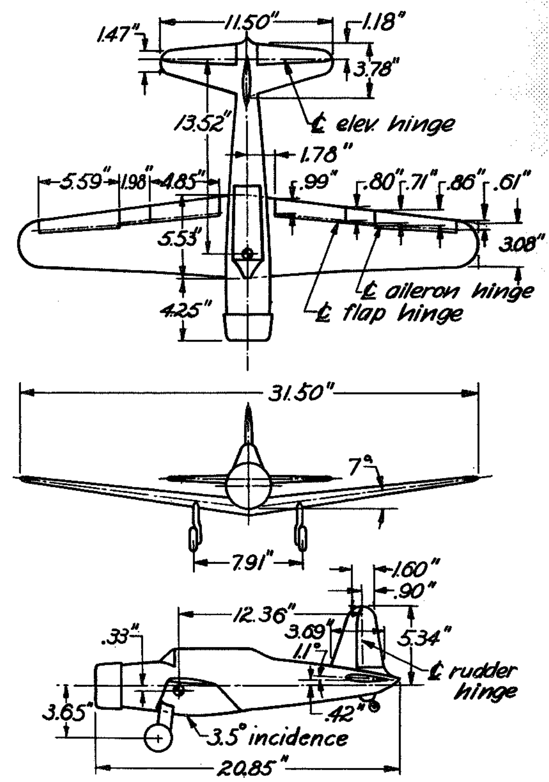


$\frac{1}{16}$-SCALE MODEL OF THE VULTEE BT-13 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	42.00
L, ft	27.80
c_r, in.	88.50
S, sq ft	239.00
A	7.28
S_h, sq ft	53.08
S_e, sq ft	19.15
S_v, sq ft	18.62
S_r, sq ft	10.68
δ_r, deg	35 R, 35 L
δ_e, deg	25 U, 25 D
δ_a, deg	30 U, 12 D
δ_f, deg	60 D
TDPF	205×10^{-6}
Landing gear	Fixed



Model as tested.

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Mass Data

Normal Loading

W, lb	4227
x/c_r	0.291
z/c_r	0.059
I_X, slug-ft^2	2659
I_Y, slug-ft^2	4122
I_Z, slug-ft^2	6201
Test altitude, ft	10,000
μ (at sea level)	5.50
μ' (10,000 ft)	7.46

$\frac{I_X - I_Y}{mb^2}$	-63×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-90×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	153×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, normal control configuration for spinning, the model spun at a moderate angle of attack ($\alpha = 46^\circ$) and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{2}\text{ turns}\right)$. An alternate spin regime, in which the spin was steeper and recovery more rapid ($\frac{3}{4}$ turn), was also obtained. The number of turns required for recovery increased by approximately 1 turn when recoveries were attempted by neutralizing the rudder rather than by completely reversing the rudder. Recoveries from elevator-neutral or elevator-down spins, although still satisfactory, were slightly slower than from the corresponding elevator up spins.

In general, extending the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$ improved the recovery characteristics, whereas extending the mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_Y\right)$ impaired the recovery characteristics of the model when the elevator was either neutral or down. Samll changes in the center-of-gravity location (±5 percent root chord) from the normal position had little effect upon recovery characteristics of the model (data not presented).

For the landing condition (flaps down 60°, cockpit open, and landing gear extended) recoveries by rapid full rudder reversal were satisfactory only from the aileron-with spins. Opening the cockpit with the model in clean condition had no effect on the spin characteristics of the model (data not presented).

Recoveries by rapid full rudder reversal from all inverted spins obtained were satisfactory (data not presented).

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE VULTEE BT-13 AIRPLANE.

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading																	ΔI_X and $\Delta I_Z = 0.30\ I_X$									
Ailerons	Against, Full				Against, 15°U, 9°D			Neutral				With, 15°U, 9°D			With, Full			Against			Neutral			With			
Elevator	U (a)	½U	N	D	U (b)	N	D	U (c)	U (c)	N	D	U	N	D	U	N	D	U	N	D	U (f)	N	D	U	N (c)	N (c)	D
α, deg	--	44	52	53	---	49	50	46	26	45	45	24	29	34	42	31	35	No spin	No spin	34	26	28	30	47	26	42	36
ø, deg	--	8U	6U	7U	---	7U	7U	3U	10U	7U	8U	1U	3U	8U	5D	1U	0			12U	---	11U	11U	4D	1U	0	1U
Ω, rps	--	0.45	0.50	0.51	---	0.49	0.51	0.38	0.45	0.50	0.52	0.47	0.56	0.57	0.43	0.53	0.57			0.55	---	0.57	0.60	0.42	0.59	0.50	0.58
V, fps	--	142	124	114	---	129	125	151	187	133	133	195	162	151	153	165	151			158	205	178	158	147	176	151	155
Turns for recovery	--	1	$2\frac{1}{4}$	$2\frac{1}{4}$	---	$1\frac{3}{4}$	2	$1\frac{1}{2}$	$\frac{3}{4}$; ${}^{d}1\frac{3}{4}$; ${}^{e}\frac{3}{4}$	2; ${}^{d}3$	2; ${}^{d}3\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	2	$1\frac{3}{4}$; ${}^{e}1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{2}$; 2			1	$\frac{1}{2}$	1	$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$; 2	$1\frac{3}{4}$

	ΔI_X and ΔI_Z = $-0.05\ I_X$			ΔI_Y and ΔI_Z = $0.15\ I_Y$			ΔI_Y and $\Delta I_Z = 0.30\ I_Y$																
Ailerons	Neutral			Neutral			Against, Full			Against, 15°U, 9°D			Neutral				With, 15°U, 9°D			With, Full			
Elevator	U (b)	N	D	U	N	D	U	N	D	U	N	D	U (c)	U (c)	N	D	U	N	D	U	N (c)	N (c)	D
α, deg	28	50	50	46	51	51	54	62	61	56	----	----	51	----	57	52	40	--	--	48	42	30	43
ø, deg	---	6U	6U	2U	3U	4U	5U	5U	5U	4U	----	----	1U	----	2U	3U	5D	--	--	5D	4D	3D	1D
Ω, rps	---	0.49	0.52	0.39	0.44	0.48	0.38	0.45	0.47	0.38	----	----	0.37	----	0.45	0.45	0.35	--	--	0.35	0.48	0.46	0.50
V, fps	180	125	129	144	125	124	129	120	118	133	----	----	152	195	131	125	191	--	--	158	154	184	165
Turns for recovery	$\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$; 3	$2\frac{1}{2}$	2; ${}^{d}5\frac{3}{4}$	$3\frac{3}{4}$; ${}^{d}\infty$	4; ${}^{d}\infty$	$2\frac{1}{4}$	3	$3\frac{3}{4}$	$2\frac{1}{4}$	1; ${}^{d}>4$	3; ${}^{d}\infty$	$3\frac{1}{2}$; ${}^{d}\infty$	1	$1\frac{3}{4}$	$2\frac{1}{2}$	2; ${}^{d}>4\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$; ${}^{d}>3\frac{1}{2}$	2; ${}^{d}\infty$

	ΔI_Y and $\Delta I_Z = 0.30\ I_Y$ Rudder neutral spins										Landing condition, normal loading								
Ailerons	Against			Neutral				With			Against			Neutral			With		
Elevator	U	N	D	U	N	D (c)	D (c)	U (gh)	N	D	U	N	D	U (b)	N	D	U (bg)	N	D
α, deg	No spin	54	54	No spin	47	47	31	----	No spin	24	44	54	56	--	51	50	----	19	27
ø, deg		5U	5U		3U	5U	9U	----		6U	4U	7U	6U	--	3U	4U	---	2U	1D
Ω, rps		0.44	0.45		0.43	0.46	0.55	----		0.67	0.40	0.50	0.51	--	0.48	0.50	----	0.61	0.62
V, fps		125	124		133	133	162	----		183	144	118	111	--	120	118	----	176	151
Turns for recovery		----	----		----	----	----	----		----	$2\frac{1}{4}$	4	$3\frac{3}{4}$	--	4	$3\frac{1}{2}$	----	1	$1\frac{3}{4}$

[a] Large radius of spin.
[b] Oscillatory and wandering spin.
[c] Two types of spin.
[d] Recovery attempted by neutralizing rudder.
[e] Recovery attempted by rapid full reversal of rudder and elevator.
[f] Wandering spin.
[g] Steep spin.
[h] Oscillatory spin.

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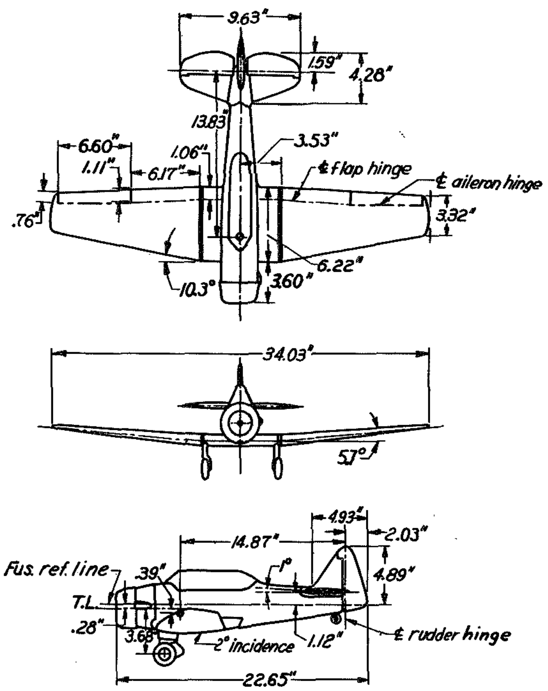
$\frac{1}{14.46}$-SCALE MODEL OF THE NORTH AMERICAN BT-14 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	41.02
L, ft	28.40
$\bar{c}$, in.	75.53
S, sq ft	246.22
A	6.83
L.E. $\bar{c}$ aft L.E. c_r, in.	0
S_h, sq ft	50.11
S_e, sq ft	21.70
S_v, sq ft	18.68
S_r, sq ft	13.35
δ_r, deg	35 R, 35 L
δ_e, deg	30 U, 20 D
δ_a, deg	30 U, 15 D
δ_f, deg	45 D
TDPF	450×10^{-6}
Landing gear	Fixed



Model as tested.

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Mass Data

Normal Loading

W, lb	4467
$x/\bar{c}$	0.262
$z/\bar{c}$	0.074
I_X, slug-ft^2	2741
I_Y, slug-ft^2	4237
I_Z, slug-ft^2	5681
Test altitude, ft	10,000
μ (at sea level)	5.79
μ' (10,000 ft)	7.81

$\frac{I_X - I_Y}{mb^2}$	-64×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-62×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	126×10^{-4}

Résumé of Model Test Results

In general, for the clean condition, normal loading, and normal control configuration for spinning, the model spun at a steep attitude ($\alpha \approx 32^{\circ}$) with a high rate of descent (175 feet per second, approximately), and satisfactory recoveries by rapid full rudder reversal were indicated from either the clean or landing condition.

Extending mass along the wings or fuselage (ΔI_X and $\Delta I_Z = 0.30\ I_X$ or ΔI_Y and $\Delta I_Z = 0.30\ I_Y$) or a center-of-gravity movement of $0.05\bar{c}$ indicated little effect.

Satisfactory recoveries by rudder reversal were indicated from inverted spins, except when the controls were crossed and the stick was forward. From this spin, simultaneous full reversal of both rudder and elevator gave satisfactory recovery.

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SPIN DATA OBTAINED WITH THE $\frac{1}{14.46}$-SCALE MODEL OF THE NORTH AMERICAN BT-14 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal Loading

Ailerons	Against, Full			Against, 15°U, 11°D			Neutral			With, 15°U, 11° D			With, Full		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	No spin	40	41	No spin	41	43	31	37	40	35	32	33	44	28	28
ϕ, deg		11U	10U		11U	11U	2D	8U	8U	16D	4D	2U	7D	6D	1D
Ω, rps		0.56	0.57		0.57	0.58	0.46	0.57	0.59	0.54	0.68	0.67	0.44	0.70	0.71
V, fps		150	138		147	140	175	150	140	168	168	157	152	178	166
Turns for recovery		1	$1\frac{1}{2}$		$1\frac{1}{4}$	$1\frac{1}{2}$	1	$1\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1	$1\frac{1}{8}$

Recoveries attempted by different control manipulations from rudder-with spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
Neutralizing rudder	No Spin	$1\frac{1}{2}$	$1\frac{3}{4}$	>7	$2\frac{1}{2}$	3	>4	2	$2\frac{3}{4}$
Releasing rudder	--	--	--	--	9	--	--	--	--
Releasing rudder and elevator	--	--	--	$1\frac{1}{2}$ 2	--	--	--	--	--
Simultaneous reversal of rudder and elevator	No Spin	--	--	$\frac{1}{2}$	--	--	$\frac{1}{4}$	--	--

	ΔI_X and $\Delta I_Z = 0.15 I_X$									ΔI_X and $\Delta I_Z = 0.30 I_X$									ΔI_Y and $\Delta I_Z = 0.15 I_Y$									
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With			
Elevator	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U (a)	U (a)	N	D
α, deg	No spin	No spin	No spin	33	35	34	47	37	32	No spin	No spin	No spin	32	32	No spin	46	38	35	No spin	-	43	32	-	-	42	38	-	28
ϕ, deg				1D	6U	10U	6D	10D	5D				2D	6U		8D	8D	6D		-	11U	4D	-	-	10D	24D	-	3D
Ω, rps				0.50	0.62	0.65	0.42	0.65	0.69				0.47	0.61		0.44	0.61	0.68		-	0.53	0.44	-	-	0.38	0.48	-	0.73
V, fps				175	164	154	143	154	154				178	175		150	150	150		-	140	178	-	-	164	175	-	185
Turns for recovery				$1\frac{1}{2}$	1	$1\frac{1}{4}$	2	$1\frac{3}{4}$	$1\frac{3}{4}$				1	1		$2\frac{1}{4}$	2	$1\frac{1}{2}$ 2		-	$1\frac{3}{4}$	1	-	-	2	$2\frac{1}{4}$	-	$1\frac{1}{4}$

	ΔI_Y and $\Delta I_Z = 0.30 I_Y$											c.g. moved forward 0.05 $\bar{c}$									c.g. moved back 0.05 $\bar{c}$								
Ailerons	Against				Neutral			With				Against			Neutral			With			Against			Neutral			With		
Elevator	U	U (b)	N	D	U	N	D	U (b)	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	No spin	34	-	43	31	-	-	29	48	-	27	No spin	-	40	32	-	-	32	-	29	No spin	-	40	35	-	-	52	-	30
ϕ, deg		---	-	8U	5D	-	-	25D	9D	-	2D		-	9U	2D	-	-	23D	-	2D		-	13U	3D	-	-	7D	-	4D
Ω, rps		0.47	-	0.48	0.38	-	-	0.49	0.34	-	0.67		-	0.54	0.49	-	-	---	-	0.68		-	0.54	0.42	-	-	0.40	-	0.69
V, fps		168	-	137	182	-	-	185	143	-	192		-	137	171	-	-	---	-	168		-	140	175	-	-	140	-	157
Turns for recovery		1	-	2	$\frac{3}{4}$	-	-	$\frac{1}{2}$	$1\frac{1}{2}$	-	1		-	$1\frac{1}{2}$	1	-	-	$1\frac{1}{2}$	-	$1\frac{1}{4}$		-	$1\frac{1}{4}$	$1\frac{1}{2}$	-	-	2	-	$1\frac{1}{4}$

	Landing condition, normal loading									ΔI_Y and $\Delta I_Z = 0.30 I_Y$, flaps down 45°									Inverted spins normal loading								
Ailerons	Against			Neutral			With			Against			Neutral			With			Against			Neutral			With		
Elevator	U (cd)	N	D	U (d)	N	D	U	N	D	U	N	D	U (e)	N	D	U (fe)	N	D	U	N	D	U (e)	N	D	U	N (f)	D
α, deg	---	-	28	30	-	-	39	-	22	46	-	48	-	45	-	---	-	No spin	No spin	No spin	No spin	---	No spin	No spin	29	22	No spin
ϕ, deg	---	-	10U	12D	-	-	6D	-	3U	4U	-	5U	-	4U	-	---	-					---			8D	2U	
Ω, rps	---	-	0.54	---	-	-	0.41	-	0.77	0.36	-	0.46	-	0.45	-	---	-					---			0.52	---	
V, fps	---	-	154	---	-	-	140	-	188	143	-	126	-	137	-	---	-					>233			185	212	
Turns for recovery	---	-	$\frac{3}{4}$	---	-	-	$1\frac{3}{4}$	-	$\frac{3}{4}$	1	-	$2\frac{1}{4}$	-	$1\frac{3}{4}$	-	---	-					---			>3 [g]$\frac{1}{2}$	$\frac{1}{2}$	

[a]Two types of spin.
[b]Ailerons 25°U, 15°D.
[c]Large radius of spin.
[d]Spin oscillatory in pitch.
[e]Vertical velocity too high to test.
[f]Wandering spin.
[g]Simultaneous reversal of rudder and elevator.

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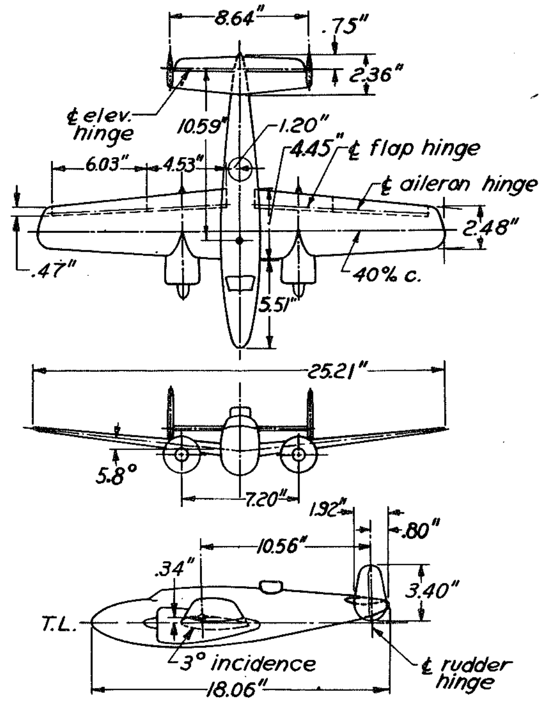
$\frac{1}{25}$-SCALE MODEL OF THE FAIRCHILD XAT-13 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	52.50
L, ft	37.58
$\bar{c}$, in.	89.43
S, sq ft	375.00
A	7.35
S_h, sq ft	72.00
S_e, sq ft	23.80
S_v, sq ft	45.00
S_r, sq ft	23.00
δ_r, deg	35 R, 35 L
δ_e, deg	35 U, 25 D
δ_a, deg	24 U, 12 D
δ_f, deg	60 D
TDPF	1360×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	10,583
$x/\bar{c}$	0.260
$z/\bar{c}$	-0.095
I_X, slug-ft^2	15,600
I_Y, slug-ft^2	11,016
I_Z, slug-ft^2	25,183
Test altitude, ft	20,000
μ (at sea level)	7.00
μ' (20,000 ft)	13.14

$\frac{I_X - I_Y}{mb^2}$	51×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-156×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	105×10^{-4}

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Résumé of Model Test Results

For the normal loading, clean condition, normal control configuration for spinning, the model spun at a steep attitude ($\alpha = 25^{\circ}$) and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{4}\text{ turns}\right)$. Merely neutralizing the rudder gave a poor recovery (>4 turns, whereas freeing the rudder and elevator simultaneously gave satisfactory recoveries (data not presented). Rapid recoveries were obtained by reversing the elevator alone.

For the normal loading condition, the model would not spin when the elevator was full down or when the ailerons were full against the spin. Setting the ailerons with the spin had a slight adverse effect upon the recovery characteristics, although the recoveries were still satisfactory.

Extending or retracting mass along the wings (ΔI_X and $\Delta I_Z = \pm 0.25\ I_X$), extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.50\ I_Y$) or moving the center of gravity forward $0.05\bar{c}$ or rearward $0.06\bar{c}$, in general, had little effect on the spin or recovery characteristics of the model.

For the landing condition, the recoveries of the model were slower than those for the clean condition, although still within the satisfactory range (≤ 2 turns) with the exception of a poor recovery (>6 turns) from the aileron-with elevator-up spin.

Recoveries from inverted spins were satisfactory by either full rapid rudder reversal or by merely neutralizing the rudder.

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SPIN DATA OBTAINED WITH THE $\frac{1}{25}$-SCALE MODEL OF THE FAIRCHILD XAT-13 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N (a)	D
α, deg	No spin	No spin	-	25	No spin	No spin	37	36	No spin
∅, deg			-	1U			2D	2D	
Ω, rps			-	0.47			0.43	0.53	
V, fps			-	264			216	225	
Turns for recovery			-	$1\frac{1}{4}$; b>4			$1\frac{3}{4}$ 3; b>4	1; b$1\frac{3}{4}$	

Turns for recovery obtained by various control manipulations for the normal loading condition						
Aileron	Neutral			With		
Elevator	U	N	D	U	N	D
Elevator reversal	c$\frac{1}{2}$	No spin	No spin	c1	-	No spin
Simultaneous reversal of rudder and neutralizing of elevator	-			$\frac{3}{4}$	-	
Simultaneous elevator and rudder reversal	-			d$\frac{1}{2}$	-	

	ΔI_X and $\Delta I_Z = 0.25 I_X$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	No spin	-	-	32	No spin	-	43	-	No spin
∅, deg		-	-	1U		-	4D	-	
Ω, rps		-	-	0.48		-	0.38	-	
V, fps		-	-	260		-	221	-	
Turns for recovery		-	-	$1\frac{1}{4}$		-	$1\frac{1}{4}$	-	

	ΔI_X and $\Delta I_Z = -0.25 I_X$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U	N	D
α, deg	No spin	-	-	27	-	-	37	-	No spin
∅, deg		-	-	1U	-	-	4D	-	
Ω, rps		-	-	0.49	-	-	0.43	-	
V, fps		-	-	260	-	-	231	-	
Turns for recovery		-	-	$\frac{3}{4}$	-	-	1	-	

	ΔI_Y and $\Delta I_Z = 0.50 I_Y$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D (e)	U	N	D (a)
α, deg	No spin	-	No spin	28	-	-	41	-	34
∅, deg		-		0	-	-	4D	-	2D
Ω, rps		-		0.40	-	-	0.33	-	0.45
V, fps		-		264	-	-	225	-	228
Turns for recovery		-		$\frac{3}{4}$	-	-	1	-	d$\frac{3}{4}$; d1

	c.g. moved forward $0.05\bar{c}$								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (a)	N	D	U (a)	N (a)	D
α, deg	No spin	-	-	26	No spin	-	36	31	No spin
∅, deg		-	-	2U		-	3D	2D	
Ω, rps		-	-	0.53		-	0.45	0.53	
V, fps		-	-	260		-	231	238	
Turns for recovery		-	-	$\frac{3}{4}$		-	1	$\frac{3}{4}$	

	c.g. moved back $0.06\bar{c}$								
Ailerons	Against			Neutral			With		
Elevator	U (f)	N	D	U (a)	N	D	U (a)	N (a)	D
α, deg	-	-	-	29	No spin	-	45	28	No spin
∅, deg	-	-	-	2U		-	4D	1U	
Ω, rps	-	-	-	0.42		-	0.36	0.38	
V, fps	-	-	-	253		-	231	238	
Turns for recovery	-	-	-	1		-	1	1	

	Landing condition, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	24	22	No spin	30	28	No spin	44	41	39
∅, deg	1D	2U		2D	2D		4D	4D	5D
Ω, rps	0.30	0.42		0.37	0.45		0.37	0.42	0.46
V, fps	249	256		231	228		197	203	203
Turns for recovery	$\frac{1}{2}$	$\frac{1}{2}$		$1\frac{3}{4}$	$1\frac{1}{4}$		>6	$1\frac{3}{4}$	2

	Inverted spins, normal loading								
Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	-	-	-	No spin	No spin	-	51	39	No spin
∅, deg	-	-	-			-	4D	3D	
Ω, rps	-	-	-			-	0.41	0.47	
V, fps	-	-	-			-	207	218	
Turns for recovery	-	-	-			-	$\frac{3}{4}$; b$\frac{3}{4}$	$1\frac{1}{4}$; b$1\frac{1}{4}$	

[a]Oscillatory spin.
[b]Recovery attempted by neutralizing rudder
[c]Model goes into inverted flight upon recovery.
[d]Model goes into inverted spin upon recovery.
[e]Steep spin.
[f]Steep spin, model recovers immediately when launched with rudder against spin.

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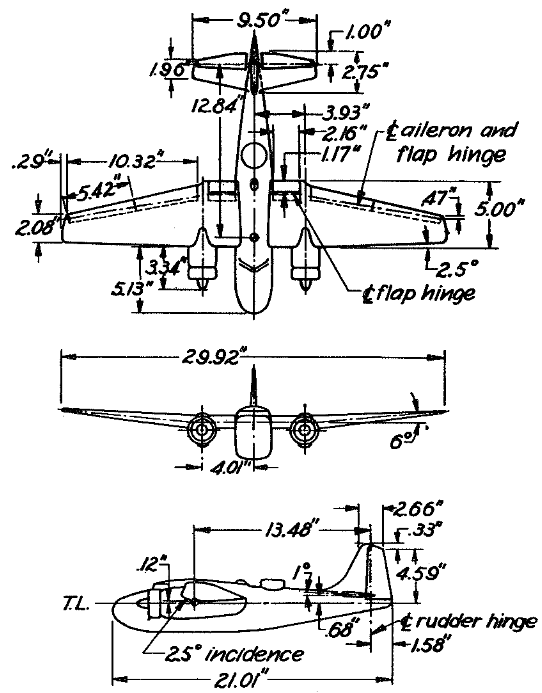
$\frac{1}{24}$-SCALE MODEL OF THE STEARMAN XAT-15 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	59.68
L, ft	42.02
$\bar{c}$, in.	98.20
S, sq ft	442.30
A	8.06
S_h, sq ft	74.15
S_e, sq ft	26.35
S_v, sq ft	43.63
S_r, sq ft	20.28
δ_r, deg	25 R, 25 L
δ_e, deg	30 U, 25 D
δ_a, deg	24 U, 16 D
δ_a, deg (take-off condition), drooped (aileron deflection measured from drooped position)	10
δ_f, deg (take-off condition)	30 D
δ_f, deg (landing condition)	50 D
TDPF	144×10^{-6}
Landing gear	Conventional



Model as tested.

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Mass Data

Normal Loading

W, lb	12,197
$x/\bar{c}$	0.192
$z/\bar{c}$	-0.029
I_X, slug-ft^2	20,370
I_Y, slug-ft^2	19,934
I_Z, slug-ft^2	37,736
Test altitude, ft	20,000
μ (at sea level)	6.04
μ' (20,000 ft)	11.32

$\frac{I_X - I_Y}{mb^2}$	3×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-133×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	130×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun at a steep attitude ($\alpha = 29^{\circ}$) with a fairly high rate of descent (248 feet per second). Recovery by rapid full rudder reversal was satisfactory although recoveries could not be obtained by merely neutralizing the rudder.

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.20\ I_X$) led to unsatisfactory recoveries by rapid full rudder reversal from all elevator-up spins. With the elevator in the neutral or down position, however, recoveries were rapid (1 turn). Retracting mass along the wings (ΔI_X and $\Delta I_Z = -0.10\ I_X$), extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.40\ I_Y$), or varying the position of the center of gravity (forward $0.04\bar{c}$ and backward $0.10\bar{c}$) had no appreciable effect on the general spin and recovery characteristics of the model.

For the take-off condition (landing gear extended, flaps down 30°, ailerons drooped 10°) and for the landing condition (landing gear extended, flaps down 50°), recoveries from spins were generally satisfactory.

Recoveries from inverted spins by rapid full rudder reversal were satisfactory.

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SPIN DATA OBTAINED WITH THE $\frac{1}{20}$-SCALE MODEL OF THE STEARMAN XAT-15

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (a)	N	D (a)	U	N	D
α, deg	26	26	No spin	29	27	27	45	34	28
ø, deg	5U	7U		2U	3U	4U	9D	6D	4D
Ω, rps	0.34	0.48		0.33	0.49	0.52	0.33	0.44	0.52
V, fps	255	248		248	248	237	213	224	230
Turns for recovery	[b]$1\frac{3}{4}$ [cd]$\frac{1}{2}$ [e]∞	$\frac{3}{4}$ [e]$1\frac{3}{4}$		2 [d]$\frac{3}{4}$ [e]∞	$1\frac{1}{4}$ [e]$7\frac{1}{2}$	$1\frac{1}{4}$ [e]$5\frac{3}{4}$	2 [d]$1\frac{1}{2}$ [e]∞	$1\frac{3}{4}$ [e]∞	[c]$1\frac{1}{2}$ [e]∞

ΔI_X and $\Delta I_Z = 0.20\,I_X$

Ailerons	Against			Neutral			With		
Elevator	U (af)	N	D	U (a)	N	D (a)	U	N	D
α, deg	27	26	No spin	30	29	31	44	33	30
ø, deg	4U	6U		1U	2U	2U	7D	3D	4D
Ω, rps	0.32	0.50		0.33	0.49	0.54	0.34	0.45	0.51
V, fps	272	262		248	248	237	213	223	233
Turns for recovery	>6	$1\frac{1}{4}$		>7	$1\frac{1}{4}$	[c]1	>3	$2\frac{1}{2}$ [g]6	[c]$2\frac{1}{4}$ [g]6

ΔI_X and $\Delta I_Z = -0.11\,I_X$

Ailerons	Against			Neutral			With		
Elevator	U	N (a)	D	U	N	D	U	N	D (a)
α, deg	27	30	28	31	30	29	43	32	29
ø, deg	4U	7U	10U	2U	3U	4U	8D	4D	4D
Ω, rps	0.31	0.44	0.50	0.32	0.45	0.51	0.33	0.45	0.51
V, fps	262	233	227	240	223	227	210	220	227
Turns for recovery	$\frac{3}{4}$ $1\frac{1}{4}$	$\frac{3}{4}$	[c]1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	[c]2

ΔI_Y and $\Delta I_Z = 0.40\,I_Y$

Ailerons	Against			Neutral			With		
Elevator	U (ε)	N (a)	D (a)	U	N	D	U	N	D (af)
α, deg	30	33	30	33	32	28	48	30	27
ø, deg	5U	6U	6U	1D	2U	3U	8D	7D	7D
Ω, rps	0.26	0.37	0.41	0.28	0.38	0.44	0.28	0.40	0.44
V, fps	258	230	233	240	237	240	213	244	248
Turns for recovery	[b]1	1	[c]$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	[c]$1\frac{3}{4}$	$1\frac{1}{2}$	1	[c]$1\frac{3}{4}$

c.g. moved forward $0.04\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D (a)	U (a)	N	D	U (a)	N	D (a)
α, deg	26	29	26	31	31	28	44	32	30
ø, deg	5U	7U	9U	1U	4U	4U	8D	1D	6D
Ω, rps	0.37	0.46	0.54	0.36	0.47	0.54	0.32	0.46	0.52
V, fps	262	233	248	248	233	233	213	230	237
Turns for recovery	[b]$1\frac{1}{2}$	$\frac{3}{4}$	[c]$\frac{3}{4}$	[b]$1\frac{1}{2}$	1	$1\frac{1}{4}$	[b]$1\frac{3}{4}$	$1\frac{1}{2}$	[c]2

c.g. moved back $0.10\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U (i)	N	D (a)	U (a)	N	D (a)	U	N	D
α, deg	-	28	26	34	29	25	48	35	30
ø, deg	-	6U	5U	2D	3U	4U	8D	5D	3D
Ω, rps	-	0.40	0.49	0.24	0.42	0.46	0.27	0.39	0.46
V, fps	-	233	240	248	248	248	213	227	233
Turns for recovery	-	1	[c]$\frac{3}{4}$	[b]$1\frac{1}{2}$	1	[c]1	[b]$1\frac{1}{2}$	$1\frac{1}{2}$	[c]$2\frac{1}{4}$

Landing gear extended, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (a)	N (a)	D	U	N	D	U (a)	N (a)	D (a)
α, deg	25	27	No spin	29	28	27	39	33	32
ø, deg	6U	8U		0	4U	5U	8D	8D	7D
Ω, rps	0.35	0.49		0.33	0.50	0.55	0.32	0.47	0.51
V, fps	264	247		247	244	244	213	220	220
Turns for recovery	[b]$1\frac{1}{2}$	$\frac{3}{4}$		[b]$1\frac{1}{2}$	$1\frac{1}{4}$	1	[b]$1\frac{1}{2}$	2	[c]$2\frac{1}{4}$

Take-off condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (fh)	N (af)	D (a)	U (h)	N (h)	D
α, deg	24	29	29	----	29	28	----	----	No spin
ø, deg	3U	6U	5U	----	2D	1D	----	----	
Ω, rps	0.36	0.46	0.55	----	0.51	0.52	----	----	
V, fps	240	216	209	----	233	216	----	----	
Turns for recovery	[b]$1\frac{1}{4}$	$1\frac{1}{2}$	1	----	$1\frac{1}{2}$	[c]$1\frac{1}{2}$	[i]$1\frac{3}{4}$	----	

Landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (h)	N	D	U (h)	N	D	U (h)	N (h)	D
α, deg	----	No spin	No spin	---	No spin	No spin	----	---	No spin
ø, deg	----			---			----	---	
Ω, rps	----			---			----	---	
V, fps	----			---			----	---	
Turns for recovery	[i]$1\frac{1}{2}$			---			[i]$2\frac{3}{4}$	---	

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Inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U (f)	N	D
α, deg	No spin	---	----	44	No spin	----	50	37	No spin
ø, deg		---	----	5D		----	6D	5D	
Ω, rps		---	----	0.32		----	0.29	0.41	
V, fps		---	----	220		----	193	220	
Turns for recovery		---	----	$\frac{3}{4}$		----	1 [e]>3	$\frac{3}{4}$ [e]$2\frac{1}{2}$	

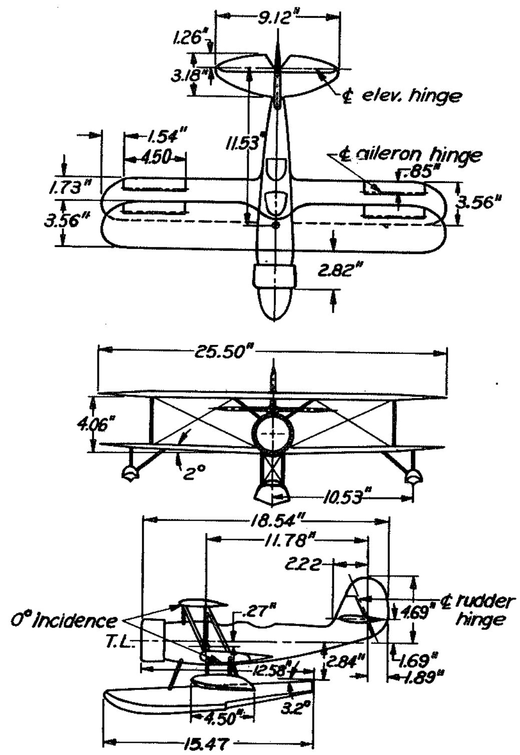
[a]Oscillatory spin.
[b]Model recovers in a glide.
[c]Model goes into inverted flight upon recovery.
[d]Recovery attempted by rudder reversal in conjunction with neutralizing the elevator.
[e]Recovery attempted by neutralizing the rudder.
[f]Wandering spin.
[g]Model occasionally requires 6 turns for recovery.
[h]Steep and oscillatory spin.
[i]Model launched with rudder against spin.

$\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY N3N-1 SEAPLANE

Dimensional Data

(Full Scale)

b, ft (upper wing)	34.00
(lower wing)	34.00
L, ft	28.60
$\bar{c}$, in.	54.00
S, sq ft	305.00
L.E. $\bar{c}$ aft L.E. c_r, in.	0
S_h, sq ft	38.50
S_e, sq ft (inc. bal.)	15.00
S_v, sq ft	23.16
S_r, sq ft (inc. bal.)	14.65
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 25 D
δ_a, deg	28 U, 18 D
TDPF	217×10^{-6}



Model as tested.

Mass Data

Normal Loading

W, lb	2820
$x/\bar{c}$	0.320
$z/\bar{c}$	0.080
I_X, slug-ft^2	2180
I_Y, slug-ft^2	2610
I_Z, slug-ft^2	3900
Test altitude, ft	8500
μ (at sea level)	3.55
μ' (8500 ft)	4.59

$\frac{I_X - I_Y}{mb^2}$ . . . . -43×10^{-4}

$\frac{I_Y - I_Z}{mb^2}$ . . . . -127×10^{-4}

$\frac{I_Z - I_X}{mb^2}$ . . . . 170×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, recoveries were generally satisfactory by rapid full rudder reversal from all spins. Recoveries attempted by a slow rudder reversal (approximately 6 seconds) were satisfactory only when the elevator was up.

Retracting mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = -0.10\ I_X\right)$, extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_Y\right)$, or moving the center of gravity forward or back $0.05\bar{c}$ from its normal position, did not appreciably alter the satisfactory recovery characteristics of the model. Extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.20\ I_X\right)$, however, caused recoveries from spins with the ailerons neutral, elevator either neutral or down and the aileron with elevator down to become unsatisfactory (>2 turns).

Raising the horizontal tail 12 inches, full scale (modification 1), appreciably improved the recovery characteristics of the model and recoveries were satisfactory by rapid full rudder reversal.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY NSN-1 SEAPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Aileron	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	51	60	53	53	55	57	53	50	49
Ø, deg	5U	2D	3U	4D	6D	5D	9D	5D	5D
Ω, rps	0.37	0.48	0.46	0.37	0.47	0.47	0.33	0.42	0.43
V, fps	100	89	95	96	89	87	100	95	91
Turns for recovery	$\frac{3}{4}$	2 $2\frac{1}{2}$	$1\frac{1}{2}$ $2\frac{1}{2}$	$1\frac{1}{4}$	2	$2\frac{1}{4}$	$\frac{3}{4}$ $1\frac{1}{4}$	$1\frac{3}{4}$	2

Effect of various control manipulations on turns for recovery, normal loading

Ailerons	Against			Neutral			With		
Elevators	U	N	D	U	N	D	U	N	D
Neutralizing rudder	$1\frac{1}{2}$	$7\frac{1}{2}$ 3	$7\frac{1}{2}$	$3\frac{1}{4}$ [a,b]∞	4	∞	[c]∞	5	$3\frac{1}{2}$
Simultaneous reversal of rudder and elevator	--	--	--	$1\frac{1}{4}$	--	--	--	--	--
Simultaneous neutralization of rudder and elevator	--	--	--	$2\frac{1}{2}$ 3	--	--	--	--	--
Simultaneous releasing rudder, elevator, and ailerons	--	--	--	∞	--	--	--	--	--
[d]Slow rudder reversal	$1\frac{1}{4}$	$3\frac{1}{4}$	$2\frac{1}{2}$ $3\frac{1}{4}$	$1\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$

Effect of mass variations and c.g. movements on turns for recovery

Ailerons	Against			Neutral			With		
Elevators	U	N	D	U	N	D	U	N	D
ΔI_X and ΔI_Z = $0.20I_X$	$1\frac{1}{2}$	-	$1\frac{1}{2}$	$1\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$1\frac{1}{4}$	-	$2\frac{3}{4}$
ΔI_X and ΔI_Z = $-0.10I_X$	--	-	--	1	$1\frac{1}{2}$	$2\frac{1}{2}$	--	-	--
ΔI_Y and ΔI_Z = $0.30I_Y$	$1\frac{1}{4}$	-	$2\frac{3}{4}$	1	2	$2\frac{1}{2}$	$\frac{3}{4}$	-	$1\frac{1}{2}$
c.g. moved forward $0.05\bar{c}$	--	-	--	$1\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	--	-	--
c.g. moved back $0.05\bar{c}$	--	-	--	1	2	$2\frac{1}{2}$	--	-	--

Modification 1, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	32	No spin	No spin	42	43	43	46	34	34
Ø, deg	1U			1D	3U	3U	12D	5D	0
Ω, rps	0.21			0.33	0.43	0.45	0.32	0.42	0.47
V, fps	102			100	98	96	102	104	116
Turns for recovery	$\frac{1}{2}$			$\frac{1}{2}$ [e]$1\frac{1}{4}$ [f]$\frac{1}{2}$	$1\frac{1}{2}$ [e]$2\frac{1}{4}$	$1\frac{1}{2}$ [e]$3\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$ $1\frac{3}{4}$

Modification 1, effect of mass variation and c.g. movement on turns for recovery

Ailerons	Against		Neutral			With		
Elevators	U	D	U	N	D	U	N	D
ΔI_X and ΔI_Z = $0.20I_X$	$\frac{1}{2}$	No spin	$\frac{1}{2}$	-	1	$1\frac{1}{2}$	-	$1\frac{3}{4}$
ΔI_X and ΔI_Z = $-0.10I_X$	-	----	1	$1\frac{3}{4}$	$1\frac{3}{4}$	--	-	--
ΔI_Y and ΔI_Z = $0.30I_Y$	$\frac{1}{2}$	2	$\frac{3}{4}$	$1\frac{3}{4}$	2	1	-	1
c.g. moved forward $0.05\bar{c}$	-	----	$1\frac{1}{4}$	$1\frac{3}{4}$	2	--	-	--
c.g. moved back $0.05\bar{c}$	-	----	1	$1\frac{3}{4}$	$1\frac{1}{2}$	--	-	--

[a]Model sensitive to rudder deflection near neutral.
[b]Model goes into spin with increasing radius after neutralizing rudder.
[c]Model goes into a spin with large radius with a whip after neutralizing rudder.
[d]Approximately 6 seconds, full scale.
[e]Recovery attempted by slow rudder reversal (approx. 6 seconds, full scale)
[f]Recovery attempted by simultaneous reversal of rudder and elevator.

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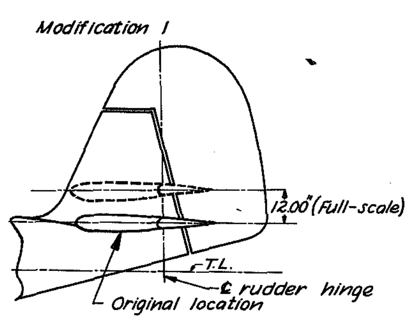
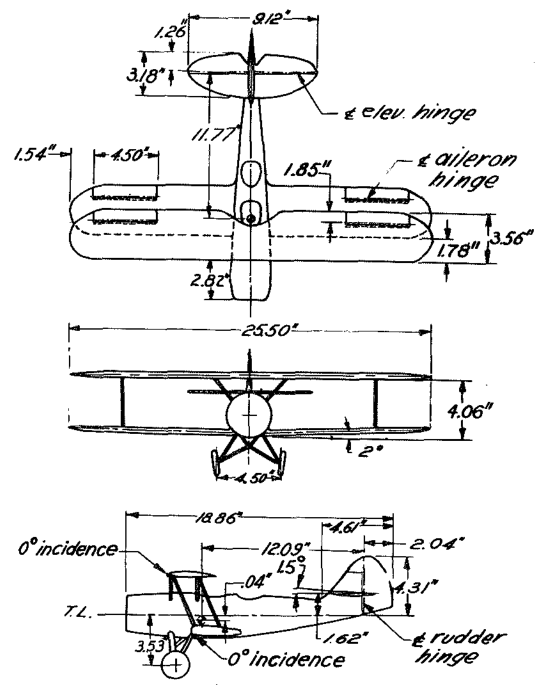


1/16-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XN3N-2 AIRPLANE

DIMENSIONAL DATA

(Full Scale)

b, ft	34.00
L, ft	25.76
$\bar{c}$, in	54.03
S, sq ft	305.00
A	7.58
L.E. $\bar{c}$ aft L. E. c_r, in	13.80
S_h, sq ft	38.08
S_e, sq ft	15.08
S_v, sq ft	21.41
S_r, sq ft	11.15
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 25 D
δ_a, deg (1/5 stick)	4.8 U, 4.5 D
δ_a, deg (2/5 stick)	10.0 U, 8.8 D
δ_a, deg (3/5 stick)	16.2 U, 12.5 D
δ_a, deg (4/5 stick)	22.5 U, 16.0 D
δ_a, deg (full stick)	30.0 U, 20.0 D
TDPF	236×10^{-6}
Landing gear	Fixed



Model as tested.

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MASS DATA

Normal

W, lb	2,704
$x/\bar{c}$	0.318
$z/\bar{c}$	0.012
I_X, slug-ft^2	1,577
I_Y, slug-ft^2	2,291
I_Z, slug-ft^2	3,416
Test altitude, ft	10,000
μ (at sea level)	3.42
μ (at 10,000 ft)	4.63

$\frac{I_X - I_Y}{mb^2}$	-74×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-116×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	190×10^{-4}

Résumé of Model Test Results

In the clean condition, normal loading, the recovery characteristics of the model were satisfactory either by rapid full rudder reversal or by simultaneous reversal of rudder and elevator.

For the aileron-neutral spins, extending or retracting the mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.20\ I_X \text{ or } -0.15\ I_X\right)$ or moving the center of gravity forward or back $0.05\bar{c}$ from its normal position did not appreciably alter the recovery characteristics of the model, whereas extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ led to unsatisfactory recoveries when the elevator was full down.

With mass retracted along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = -0.15\ I_X\right)$ in conjunction with mass extended along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.20\ I_Y\right)$ and center of gravity moved forward $0.05\bar{c}$ from its normal position, unsatisfactory recoveries were obtained by rapid full rudder reversal for the elevator-neutral or elevator-down settings when the ailerons were either neutral or set partly or fully against the spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XN3N-2 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading																
	Against							Neutral			With						
Ailerons	Full	4/5		3/5	2/5		1/5				1/5	2/5		3/5	4/5		Full
Elevator	U (a)	U (a)	D	U	U	D	U	U	N	D (a)	U	U	D	U	U	D	U
α, deg	35	37	---	37	40	--	41	40	42	43	38	35	--	37	40	---	40
ø, deg	10U	10U	---	12U	8U	--	5U	3U	7U	8U	1U	4D	--	8D	11D	---	14D
Ω, rps	0.32	0.33	---	0.35	0.37	--	0.36	0.36	0.47	0.48	0.36	0.36	--	0.36	0.37	---	0.36
V, fps	111	121	---	116	112	--	111	111	104	99	116	121	--	118	111	---	112
Turns for recovery	[b]1/4	[b]1/4	1	----	[b]1/2	1 1/4, 1 3/4	----	[b]3/4, 1	1 1/4	1 3/4	----	[b]1/2	1 3/4	----	[b]3/4	1 1/4	[b]1/2

	ΔI_X and $\Delta I_Z = -0.15 I_X$ ΔI_Y and $\Delta I_Z = 0.20 I_Y$ c.g. moved forward $0.05\bar{c}$															
	Against						Neutral				With					
Ailerons	Full		4/5		2/5						2/5		4/5		Full	
Elevator	U	D	U	D	U	D	U	N	D	35°D	U	D	U	D	U	D
α, deg	46	---	44	---	44	---	44	---	48	----	31	---	34	---	31	---
ø, deg	7U	---	8U	---	7U	---	1U	---	3U	----	9D	---	16D	---	15D	---
Ω, rps	0.36	---	0.35	---	0.36	---	0.35	---	0.44	----	0.36	---	0.35	---	0.35	---
V, fps	109	---	111	---	109	---	110	---	98	----	127	---	124	---	126	---
Turns for recovery	-----	4 1/4	[b]3/4	2 1/2	[b]3/4	3 3/4	[b]3/4, 1	2 1/4	5 1/4	∞	[b]1/4	2 1/2	[b]1/4	1 1/2	[b]1/4	3/4

Effect of mass variations and c.g. movements on turns for recovery		
Aileron	Neutral	
Elevator	U	D
ΔI_X and $\Delta I_Z = 0.20 I_X$	[b]1/2	1 1/4
ΔI_X and $\Delta I_Z = -0.15 I_X$	[b]1/2	2 1/4
ΔI_Y and $\Delta I_Z = 0.20 I_Y$	[b]3/4	3 1/4
c.g. moved forward $0.05\bar{c}$	[b]1/2	2
c.g. moved back 0.05c	[b]1/2	1 1/2

[a]Oscillatory spin.

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

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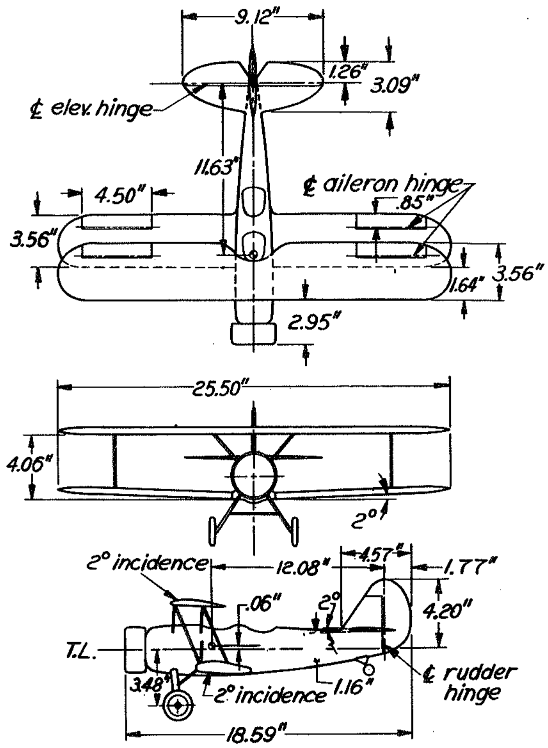
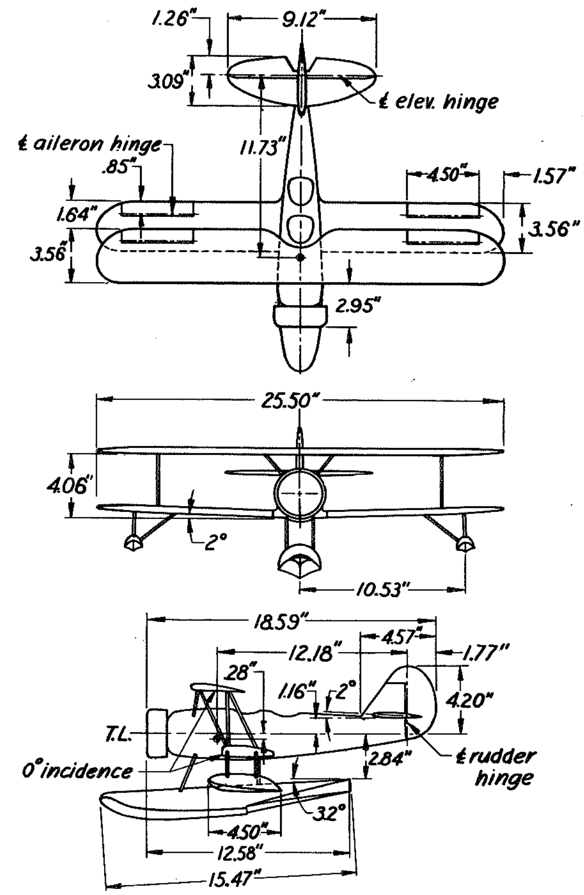
$\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY N3N-3 LANDPLANE AND SEAPLANE



Model as tested.



Model as tested.

Dimensional Data

(Full Scale)

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(Values are the same for both landplane and seaplane except where noted)

b, ft (upper and lower wing) 34.00
L, ft
  Landplane 25.58
  Seaplane 28.60
$\bar{c}$, in. 54.06
S, sq ft (total area) . . 305.00
A 7.58
L.E. $\bar{c}$ aft L.E. c_r, in. . . 0.00
S_h, sq ft 38.50
S_e, sq ft (inc. bal.) . . 15.00
S_v, sq ft 20.85

S_r, sq ft (inc. bal.) . . . 11.35
δ_r, deg . . . . 30 R, 30 L
δ_e, deg . . . . 35 U, 25 D
δ_a, deg . . . . 28 U, 18 D
δ_a, deg (1/2 stick) . 11.5 U, 10 D
TDPF . . . . 186×10^{-6}
Landing gear
  Landplane . . . . Fixed
  Seaplane . . . . Floats

Mass Data

Normal Loading

(Landplane)

W, lb	2803
$x/\bar{c}$	0.293
$z/\bar{c}$ (above T.L.)	-0.017
I_X, slug-ft^2	1583
I_Y, slug-ft^2	2363
I_Z, slug-ft^2	3487
Test altitude, ft	10,000
μ (at sea level)	3.53
μ' (10,000 ft)	4.78

$$\frac{I_X - I_Y}{mb^2} = -77 \times 10^{-4}$$

$$\frac{I_Y - I_Z}{mb^2} = -112 \times 10^{-4}$$

$$\frac{I_Z - I_X}{mb^2} = 189 \times 10^{-4}$$

(Seaplane)

W, lb	2935
$x/\bar{c}$	0.287
$z/\bar{c}$ (below T.L.)	0.080
I_X, slug-ft^2	2204
I_Y, slug-ft^2	2627
I_Z, slug-ft^2	3921
Test altitude, ft	6000
μ (at sea level)	3.70
μ' (6000 ft)	4.43

$$\frac{I_X - I_Y}{mb^2} = -41 \times 10^{-4}$$

$$\frac{I_Y - I_Z}{mb^2} = -122 \times 10^{-4}$$

$$\frac{I_Z - I_X}{mb^2} = 163 \times 10^{-4}$$

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Résumé of Model Test Results

Landplane

In the clean condition, normal loading, the recovery characteristics of the model were satisfactory by rapid full rudder reversal.

Extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$, along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.30\ I_Y\right)$, or moving the center of gravity forward or back $0.04\bar{c}$ from its normal position had little effect on the steady-spin and recovery characteristics of the model.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal.

Although the spin characteristics of the model were generally satisfactory, various modifications (1 to 4) were tested on the model to determine which locations for additional area were most effective; generally, regions along the upper and lower trailing edges of the rudder were found to be satisfactory in accelerating recoveries.

Seaplane

In general, the spin and recovery characteristics of the seaplane were qualitatively the same as those for the landplane; quantitatively, erect steady spins were somewhat steeper and recoveries were somewhat more rapid. Inverted steady spins were slightly flatter and recoveries were slightly slower.

The effect of a cowl over the engine had a negligible effect on the steady-spin and recovery characteristics of the model (data not presented).

It should be noted that a rigid comparison between the landplane and seaplane versions of the model cannot be made because the landplane model was tested at an equivalent test altitude of 10,000 feet and the seaplane model was tested at an equivalent test altitude of 6000 feet. In general, an increase in altitude tends to flatten spins and retard recoveries.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY N3N-3 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins; equivalent altitude, landplane 10,000 feet; seaplane, 6000 feet]

Normal loading

Ailerons	Against Full			Against ½			Neutral				With ½			With Full		
Elevator	U (a)	N	D	U	N	D	U	N	20°D	D	U (ab)	N	D	U	N	D
α, deg	35	58	55	53	58	57	49	48	55	53	32	41	45	31	35	45
φ, deg	12U	1D	1D	0	2D	2D	2D	1D	4D	1D	3D	3U	2U	8D	1U	1D
Ω, rps	0.35	0.48	0.50	0.41	0.49	0.51	0.39	0.48	0.51	0.50	0.39	0.48	0.51	0.40	0.48	0.49
V, fps	120	97	95	104	97	93	107	104	95	97	131	111	104	133	114	104
Turns for recovery	$\frac{1}{4}$	$1\frac{1}{4}$	2	$\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{1}{4}$	1	$1\frac{3}{4}$; c$3\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$; c$5\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$; d$1\frac{1}{4}$	$\frac{3}{4}$	1	d1

ΔI_Y and $\Delta I_Z = 0.30 I_Y$

Ailerons	Against Full			Against ½			Neutral			With ½			With Full		
Elevator	U (b)	N (a)	D (a)	U	N (a)	D	U	N	D	U	N	D	U (a)	N (ab)	D (ab)
α, deg	48	57	57	-	-	-	49	52	53	-	-	-	-	20	27
φ, deg	7U	1U	2D	-	-	-	3D	1D	1D	-	-	-	-	10D	2D
Ω, rps	0.33	0.42	0.44	-	-	-	0.33	0.41	0.42	-	-	-	-	0.52	0.50
V, fps	109	100	95	-	-	-	111	100	100	-	-	-	-	163	131
Turns for recovery	$\frac{3}{4}$	$2\frac{1}{4}$	3	-	2	$2\frac{1}{4}$	1; c2	2; c$3\frac{1}{4}$	3; c∞; e3; f$3\frac{1}{4}$	$\frac{1}{4}$	1	d$1\frac{1}{2}$	-	$\frac{3}{4}$	d1

ΔI_Y and $\Delta I_Z = 0.30 I_Y$ rudder-neutral spins

Ailerons	Against			Neutral			With		
Elevator	U	N	D (b)	U (g)	N	D	U (g)	N	D
α, deg	N	N	58	-	N	44	-	N	N
φ, deg	o	o	8U	-	o	3U	-	o	o
Ω, rps	s	s	0.42	-	s	0.42	-	s	s
V, fps	p	p	104	-	p	107	-	p	p
Turns for recovery	in	in	h$1\frac{1}{2}$; h$2\frac{1}{4}$	-	in	h$2\frac{1}{4}$	-	in	in

Effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Movement	Elevator N	Elevator D
ΔI_X and $\Delta I_Z = 0.15 I_X$	$1\frac{3}{4}$	$1\frac{3}{4}$
ΔI_X and $\Delta I_Z = 0.30 I_X$	2	$2\frac{1}{2}$
ΔI_Y and $\Delta I_Z = 0.15 I_Z$	$1\frac{3}{4}$	$2\frac{1}{4}$
c.g. moved forward $0.04\bar{c}$	2	$2\frac{1}{4}$
c.g. moved back $0.04\bar{c}$	2	2

Inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevators	U	N	D	U (b)	N	D	U (b)	N (b)	D
α, deg	N	N	N	32	N	N	50	43	N
φ, deg	o	o	o	5D	o	o	14D	14D	o
Ω, rps	s	s	s	0.50	s	s	0.39	0.52	s
V, fps	p	p	p	162	p	p	138	138	p
Turns for recovery	in	in	in	$\frac{1}{4}$	in	in	$\frac{1}{2}$	$\frac{1}{2}$	in

Effect of fin modifications on turns for recovery, ailerons neutral; elevator down, ΔI_Y and $\Delta I_Z = 0.30 I_Y$

Modification	Turns for recovery
1	c4
2	c$4\frac{1}{4}$
3	c3
4	c∞

Seaplane, normal loading

Ailerons	Against Full			Against ½			Neutral			With ½			With Full		
Elevator	U (ab)	N (i)	D (i)	U	N (i)	D (i)	U (ab)	N	D	U	N	D (i)	U (ab)	N	D
α, deg	-	-	-	46	45	-	45	47	-	42	39	45	45	26	N
φ, deg	-	-	-	7U	7U	-	3U	6U	-	1D	2D	2U	10D	2U	o
Ω, rps	-	-	-	0.38	0.49	-	0.37	0.48	-	0.35	0.48	0.49	0.35	0.55	s
V, fps	126	102	118	107	102	-	107	100	98	111	106	100	113	140	p
Turns for recovery	$\frac{1}{4}$; c1	$\frac{1}{2}$; c$3\frac{1}{4}$	d1; c$3\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	-	$\frac{1}{2}$	$1\frac{1}{4}$; c$4\frac{1}{2}$; j$3\frac{3}{4}$	1; c$7\frac{1}{4}$; j$4\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	1; $1\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	in

Seaplane, ΔI_Y and $\Delta I_Z = 0.22 I_Y$

Ailerons	Against Full			Against ½			Neutral			With ½			With Full		
Elevator	U (ab)	N	D (ab)	U	N	D	U (a)	N	D	U	N	D	U (ab)	N	D (ab)
α, deg	46	54	55	-	-	-	47	49	50	-	-	-	43	37	41
φ, deg	9U	8U	7U	-	-	-	1D	1U	1U	-	-	-	7D	1D	3U
Ω, rps	0.33	0.42	0.44	-	-	-	0.32	0.42	0.44	-	-	-	0.27	0.43	0.43
V, fps	109	98	96	-	-	-	105	100	96	-	-	-	111	140	107
Turns for recovery	$\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{4}$	$1\frac{3}{4}$	2	1	2	$2\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	1	d2

Seaplane, effect of mass variations and c.g. movements on turns for recovery for aileron-neutral spins

Movement	Elevator U	Elevator D
ΔI_X and $\Delta I_Z = 0.15 I_X$	1	1
ΔI_X and $\Delta I_Z = 0.30 I_X$	$\frac{3}{4}$	(k)
ΔI_Y and $\Delta I_Z = 0.15 I_Y$	1	2
c.g. moved forward $0.04\bar{c}$	$\frac{3}{4}$	(k)
c.g. moved back $0.04\bar{c}$	$\frac{3}{4}$	1

Seaplane, inverted spins, normal loading

Ailerons	Against			Neutral			With		
Elevator	U (a)	N (l)	D (l)	U	N	D (l)	U (b)	N	D
α, deg	-	N	N	57	N	N	53	48	N
φ, deg	-	o	o	2D	o	o	11D	13D	o
Ω, rps	-	s	s	0.27	s	s	0.30	0.46	s
V, fps	-	p	p	131	p	p	129	125	p
Turns for recovery	-	in	in	1	in	in	1	1	in

[a] Wandering spin.
[b] Oscillatory spin.
[c] Recovery attempted by neutralizing the rudder.
[d] Model goes into inverted spin upon recovery.
[e] Elevator 30° down.
[f] Elevator 35° down.
[g] Steep spiral, velocity too high to test.
[h] Recovery attempted by movement of the rudder to full against the spin.
[i] Delicate spinning equilibrium, no-spin condition also possible.
[j] Recovery attempted by releasing the rudder.
[k] No spin.
[l] Model enters right erect spin.

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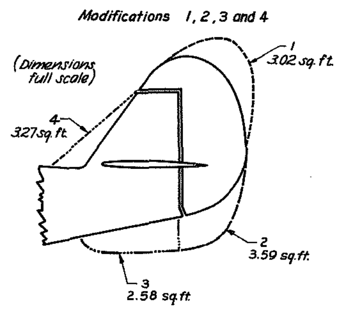

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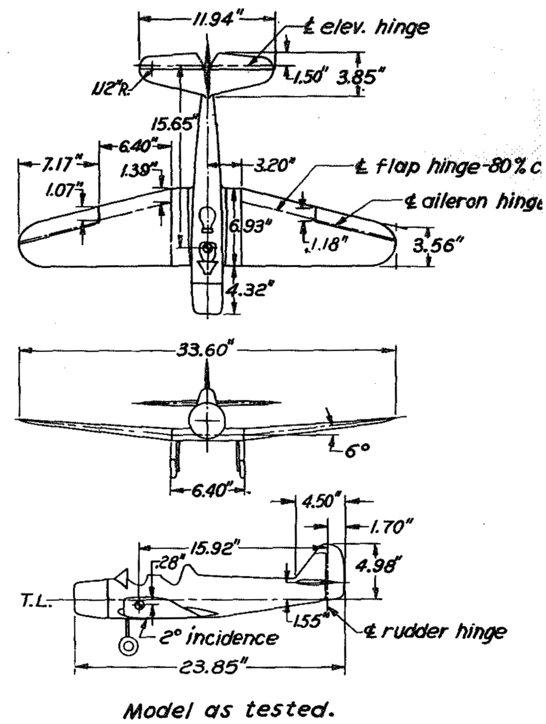
$\frac{1}{15}$-SCALE MODEL OF NAVAL AIRCRAFT FACTORY XN5N-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	42.00
L, ft	30.41
$\bar{c}$, in.	87.24
S, sq ft	290.00
A	6.08
L.E. $\bar{c}$ aft L.E. c_r, in.	0.00
S_h, sq ft	50.00
S_e, sq ft	19.70
S_v, sq ft	20.37
S_r, sq ft	11.92
δ_r, deg	30 R, 30 L
δ_e, deg	35 U, 25 D
δ_a, deg	30 U, 15 D
δ_f, deg	45 D
TDPF	238×10^{-6}
Landing gear	Fixed



Model as tested.

Mass Data

Normal Loading

W, lb	3290	$\frac{I_X - I_Y}{mb^2}$	-96×10^{-4}
$x/\bar{c}$	0.272		
$z/\bar{c}$	0.049		
I_X, slug-ft^2	1765	$\frac{I_Y - I_Z}{mb^2}$	-78×10^{-4}
I_Y, slug-ft^2	3490		
I_Z, slug-ft^2	4897	$\frac{I_Z - I_X}{mb^2}$	174×10^{-4}
Test altitude, ft	14,000		
μ (at sea level)	3.52		
μ' (14,000 ft)	5.43		

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Alternate Loading

W, lb	3352	$\frac{I_X - I_Y}{mb^2}$	-94×10^{-4}
$x/\bar{c}$	0.277		
$z/\bar{c}$	0.060		
I_X, slug-ft^2	2235	$\frac{I_Y - I_Z}{mb^2}$	-77×10^{-4}
I_Y, slug-ft^2	3484		
I_Z, slug-ft^2	5247	$\frac{I_Z - I_X}{mb^2}$	171×10^{-4}
Test altitude, ft	14,000		
μ (at sea level)	3.59		
μ' (14,000 ft)	5.53		

Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the spin was to oscillatory to permit testing. With the elevator neutral, a steady steep spin was obtained, but with the elevator full down the model would not spin. Setting the ailerons against the spin had a slight adverse effect, but recoveries by rapid full rudder reversal were satisfactory. Setting the ailerons with the spin had a favorable effect. Changes in the aileron differential had no appreciable effect on the spin or recovery characteristics of the model.

Extending mass along the wings $\left(\Delta I_X \text{ and } \Delta I_Z = 0.30\ I_X\right)$, along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.50\ I_Y\right)$, or moving the center of gravity forward $0.03\bar{c}$ or backward $0.05\bar{c}$ from its normal location had little effect upon the recovery characteristics of the model.

Extending mass along the fuselage $\left(\Delta I_Y \text{ and } \Delta I_Z = 0.40\ I_Y\right)$ in conjunction with a movement of the center of gravity backward $0.10\bar{c}$ from its normal position had a detrimental effect on the recovery characteristics of the model, inasmuch as flat spins and unsatisfactory recoveries by rapid full rudder reversal were obtained when the ailerons were either neutral or against the spin. Removing the engine cowling for this loading did not appreciably alter the spin or recovery characteristics.

The installation of a modified wing tip (see sketch) slightly improved the recovery characteristics of the model for all loadings.

An attempt was made to produce a steadier spin for the normal control configuration for spinning by relocating the horizontal tail surfaces. (See sketch.) Raising the horizontal tail surfaces $21\frac{3}{4}$ inches, full scale, led to steady spins from which recoveries were satisfactory. Moving the tail surfaces forward $19\frac{1}{2}$ inches, full scale, caused the spin to become only slightly oscillatory. Lowering the horizontal tail surfaces did not affect the spin and recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XN5N-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins; aileron differential 2:1, unless otherwise noted]

Normal loading

Ailerons	Against Full			Against $\frac{2}{3}$			Against $\frac{1}{2}$	Against $\frac{1}{3}$	Neutral			With		
Elevator	U (a)	N	D	U	N	D	D	D	U (a)	N	D	U (a)	N (b)	D (b)
α, deg	----	No spin	No spin	33	26	33	No spin	No spin	---	23	No spin	---	---	---
ϕ, deg	----			0	15U	17U			---	12U		---	---	---
Ω, rps	----			0.40	0.51	0.57			---	0.58		---	---	---
V, fps	170			171	167	151			---	203		---	---	---
Turns for recovery	----			$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$			---	----		---	---	---

Effect of 3:1 aileron differential on steady spin characteristics, normal loading

Ailerons	Against 34°U, 11°D (Full)			Against 17°U 5.5°D			Neutral					With 17°U 5.5°D	With 34°U, 11°D (Full)		
Elevator	U (a)	N	D	U	N	D	U	N (c)	N (c)	D (c)	D (c)	D (a)	U (a)	N	D
α, deg	--	No spin	No spin	30	No spin	No spin	33	No spin	---	No spin	25	---	---	----	----
ϕ, deg	--			4D			14D		---		13U	---	---	----	----
Ω, rps	--			0.41			0.47		---		0.60	---	---	----	----
V, fps	--			153			143		195		150	---	---	188	158
Turns for recovery	--			---			1		---		$\frac{1}{2}$	---	---	----	----

Effect of 1:1 aileron differential on steady spin characteristics, normal loadings

Ailerons	Against 22°U, 22°D (Full)			Against 11°U, 11°D				Neutral					With 11°U, 11°D			With 22°U, 22°D (Full)		
Elevator	U (a)	N	D	U	N (c)	N (c)	D	U	N (c)	N (c)	D (c)	D (c)	U (a)	N	D (a)	U (a)	N	D
α, deg	--	No spin	30	30	No spin	29	30	33	No spin	---	No spin	25	---	17	--	--	----	--
ϕ, deg	--		17U	1D		4U	12U	14D		---		13U	---	3U	--	--	----	--
Ω, rps	--		0.51	0.41		---	0.56	0.47		---		0.60	---	0.61	--	--	----	--
V, fps	--		128	150		142	137	143		195		150	---	211	--	--	199	--
Turns for recovery	--		$\frac{1}{2}$	$1\frac{1}{4}$		$\frac{3}{4}$	$\frac{1}{2}$	1		---		$\frac{1}{2}$	---	---	--	--	----	--

ΔI_X and $\Delta I_Z = 0.15 I_X$

Ailerons	Against Full			Against $\frac{2}{3}$		Neutral			With		
Elevator	U (a)	N	D	N	D	U	N (b)	D	U (a)	N (b)	D (b)
α, deg	--	No spin	No spin	No spin	No spin	--	--	No spin	--	--	--
ϕ, deg	--					--	--		--	--	--
Ω, rps	--					--	--		--	--	--
V, fps	--					--	--		--	--	--
Turns for recovery	--					--	--		--	--	--

ΔI_X and $\Delta I_Z = 0.30 I_X$

Ailerons	Against Full			Against $\frac{2}{3}$	Neutral		
Elevator	U (a)	N	D	N	U	N (b)	D
α, deg	--	No spin	No spin	No spin	--	--	No spin
ϕ, deg	--				--	--	
Ω, rps	--				--	--	
V, fps	--				--	--	
Turns for recovery	--				--	--	

ΔI_Y and $\Delta I_Z = 0.15 I_Y$

Ailerons	Against Full			Against $\frac{2}{3}$			Neutral		
Elevator	U	N (b)	D	U	N	D	U	N (b)	D
α, deg	-	--	33	---	---	30	-	--	---
ϕ, deg	-	--	12U	---	---	15U	-	--	---
Ω, rps	-	--	0.53	---	---	0.53	-	--	0.62
V, fps	-	--	150	---	---	153	-	--	173
Turns for recovery	-	--	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	-	--	---

ΔI_Y and $\Delta I_Z = 0.30 I_Y$

Ailerons	Against Full			Against $\frac{2}{3}$		Neutral			With		
Elevator	U (a)	N	D	N	D	U	N (b)	D	U (a)	N	D
α, deg	--	31	38	---	40	-	--	---	--	No spin	No spin
ϕ, deg	--	5U	5U	---	4U	-	--	---	--		
Ω, rps	--	0.53	0.47	---	0.45	-	--	0.62	--		
V, fps	--	150	129	---	120	-	--	160	--		
Turns for recovery	--	---	1	$\frac{3}{4}$	---	-	--	$\frac{1}{4}$	--		

ΔI_Y and $\Delta I_Z = 0.50 I_Y$

Ailerons	Neutral			
Elevator	U (a)	N (c)	N (cd)	D
α, deg	--	49	----	29
ϕ, deg	--	1U	----	2U
Ω, rps	--	0.40	---	0.56
V, fps	--	132	----	150
Turns for recovery	--	$1\frac{3}{4}$	----	$\frac{3}{4}$

Effect of c.g. movement on turns for recovery

Ailerons	Against Full			Against $\frac{2}{3}$	Neutral		
Elevator	U (a)	N	D	N	U	N (b)	D (b)
c.g. moved forward 0.03c̄	--	No spin	No spin	No spin	--	--	---
c.g. moved back 0.05c̄	--			$\frac{1}{2}$	--	--	---

ΔI_Y and $\Delta I_Z = 0.30 I_Y$, c.g. moved back 0.05c̄

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U (a)	N (b)	D
α, deg	--	65	58	41	45	29	---	---	No spin
ϕ, deg	--	7U	8U	8D	2D	1D	---	---	
Ω, rps	--	0.45	0.43	0.32	0.40	0.53	---	---	
V, fps	--	143	107	146	125	153	---	---	
Turns for recovery	--	$2\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	---	---	

ΔI_Y and $\Delta I_Z = 0.40 I_Y$, c.g. moved back 0.10c̄

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U (b)	N	D
α, deg	---	64	51	67	61	50	---	No spin	No spin
ϕ, deg	---	7U	6U	1D	1U	2U	---		
Ω, rps	---	0.40	0.39	0.37	0.40	0.39	---		
V, fps	---	111	120	115	115	123	---		
Turns for recovery	---	3	2	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{1}{4}$	---		

Engine cowling removed, ΔI_Y and $\Delta I_Z = 0.40 I_Y$, c.g. moved back 0.10c̄

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (e)	N	D	U	N	D
α, deg	--	63	61	48	51	46	--	No spin	No spin
ϕ, deg	--	8U	8U	4D	1U	1U	--		
Ω, rps	--	0.42	0.41	0.26	0.38	0.41	--		
V, fps	--	115	115	150	125	125	--		
Turns for recovery	--	----	----	----	2	2	--		

[a]Too oscillatory to test.
[b]Vertical velocity too high to test.
[c]Two conditions possible.
[d]Steep and oscillatory spin.
[e]Too wandering to attempt recovery from spin.

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SPIN DATA OBTAINED WITH THE $\frac{1}{15}$-SCALE MODEL OF THE NAVAL AIRCRAFT FACTORY XN5N-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins; aileron differential 2:1, unless otherwise noted]

Modified wing tips, alternate loading condition

Ailerons	Against Full			Against 2/3			Against 1/2		Against 1/3	Neutral			With		
Elevator	U (a)	N	D	U	N	D	N	D	D	U (a)	N (b)	D	U (a)	N (b)	D (b)
α, deg	---	No spin	No spin	31	No spin	No spin	No spin	No spin	No spin	--	--	No spin	--	--	--
ø, deg	---			3D						--	--		--	--	--
Ω, rps	---			0.40						--	--		--	--	--
V, fps	---			157						--	--		--	--	--
Turns for recovery	---			---						--	--		--	--	--

Modified wing tips, ΔIY and ΔIZ = 0.40IY c.g. moved back 0.10c̄ from alternate loading condition

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U (a)	N (ab)	D
α, deg	--	61	50	48	50	28	--	----	No spin
ø, deg	--	6U	6U	1D	2D	2D	--	----	
Ω, rps	--	0.40	0.39	0.48	0.37	----	--	----	
V, fps	--	113	123	142	125	136	--	----	
Turns for recovery	--	$2\frac{1}{2}$	$2\frac{1}{2}$	----	$1\frac{3}{4}$	----	--	----	

Modified wing tips, flaps down 45°, ΔIY and ΔIZ = 0.40IY c.g. moved back 0.10c̄ from alternate loading condition

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	--	45	45	58	51	No spin	---	---	---
ø, deg	--	5U	5U	2D	1D		---	---	---
Ω, rps	--	0.36	0.39	0.33	0.37		---	---	---
V, fps	--	120	125	116	118		---	---	---
Turns for recovery	--	1	1	2	$1\frac{1}{2}$		---	---	---

Horizontal tail surfaces raised $21\frac{3}{4}$ inches, normal loading

Ailerons	Against Full			Against 1/4	Neutral			With 1/4		
Elevator	U (a)	N	D	U	U	N	D	U	N	D
α, deg	---	-	-	35	37	No spin	No spin	37	-	-
ø, deg	---	-	-	6D	8D			11D	-	-
Ω, rps	---	-	-	0.40	0.41			0.41	-	-
V, fps	---	-	-	148	139			139	-	-
Turns for recovery	---	-	-	---	1			---	-	-

Horizontal tail surfaces lowered $4\frac{1}{2}$ inches, normal loading

Ailerons	Against			Neutral		
Elevator	U (a)	N	D	U	N	D
α, deg	--	No spin	No spin	---	No spin	No spin
ø, deg	--			---		
Ω, rps	--			0.46		
V, fps	--			141		
Turns for recovery	--			---		

Horizontal tail surfaces lowered $18\frac{3}{4}$ inches, normal loading

Ailerons	Against			Neutral			With 1/4		
Elevator	U (a)	N	D	U	N	D	U (a)	N	D
α, deg	--	--	--	30	----	No spin	--	--	--
ø, deg	--	--	--	10D	----		--	--	--
Ω, rps	--	--	--	0.43	0.62		--	--	--
V, fps	--	--	--	144	195		--	--	--
Turns for recovery	--	--	--	1	f---		--	--	--

Horizontal tail surfaces moved forward $19\frac{1}{2}$ inches, normal loading

Ailerons	Against Full			Against 1/4	Neutral			With 1/4	With Full		
Elevator	U (a)	N	D	U	U	N	D	U	U (a)	N	D
α, deg	--	No spin	No spin	31	33	19	No spin	33	--	19	19
ø, deg	--			6D	13D	8U		10D	--	0	4U
Ω, rps	--			0.39	0.41	0.58		0.41	--	0.67	0.70
V, fps	--			143	141	188		139	--	176	157
Turns for recovery	--			1	1	$\frac{1}{2}$		---	--	$\frac{1}{2}$	$\frac{1}{2}$

[a]Too oscillatory to test.
[b]Vertical velocity too high to test.
[f]Model spins steadily for a time, then recovers of own accord.

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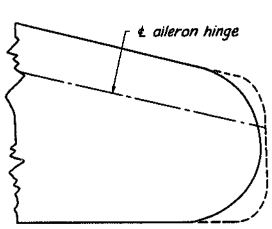
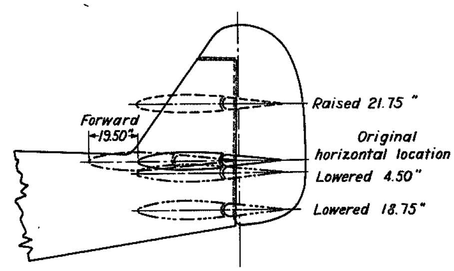
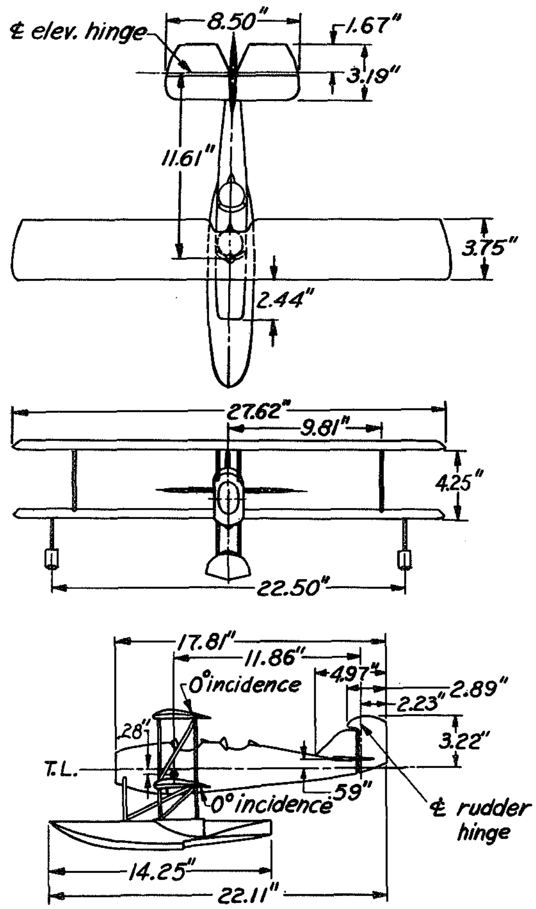
Comparison of original and modified wing-tips.



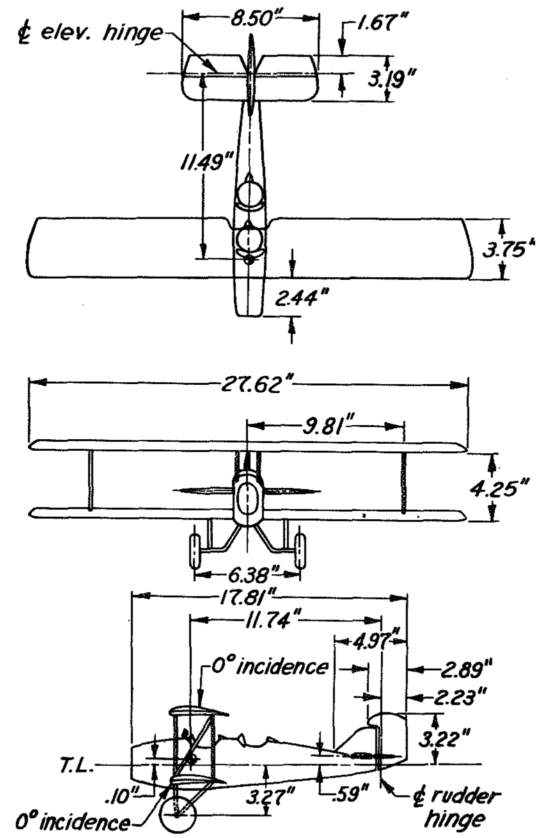
Horizontal-tail-surface locations tested on model.



$\frac{1}{16}$-SCALE MODELS OF THE BOEING NB-1 SEAPLANE AND LANDPLANE



Model as tested.



Model as tested.

<u>Dimensional Data</u>

(Full Scale)

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(Values are the same for both landplane and seaplane except where indicated)

b, ft	36.80	S_v, sq ft	16.60
L, ft		S_r, sq ft	11.35
Seaplane	28.83	δ_r, deg	±30
Landplane	24.65	δ_e, deg	30 U, 30 D
$\bar{c}_m$(mean chord), in	48.00	δ_a, deg	15 U, 15 D
S, sq ft	344	TDPF	42.2×10^{-6}
A (upper wing span)	3.94	Landing gear	
S_h, sq ft	37.80	Seaplane	Float
S_e, sq ft	17.00	Landplane	Fixed

Mass Data

Normal Loading

(Seaplane)

W, lb	2849	$\frac{I_X - I_Y}{mb^2}$	68×10^{-4}
$x/\bar{c}_m$	0.340		
$z/\bar{c}_m$	0.075		
I_X, slug-ft^2	3,342	$\frac{I_Y - I_Z}{mb^2}$	-180×10^{-4}
I_Y, slug-ft^2	2,522		
I_Z, slug-ft^2	4,690		
Test altitude, ft	6,000	$\frac{I_Z - I_X}{mb^2}$	112×10^{-4}
μ' (at sea level)	2.94		
μ' (at 6000 ft)	3.52		

(Landplane)

W, lb	2544	$\frac{I_X - I_Y}{mb^2}$	16×10^{-4}
$x/\bar{c}_m$	0.350		
$z/\bar{c}_m$	-0.026		
I_X, slug-ft^2	2,409	$\frac{I_Y - I_Z}{mb^2}$	-174×10^{-4}
I_Y, slug-ft^2	2,239		
I_Z, slug-ft^2	4,099		
Test altitude, ft	10,000	$\frac{I_Z - I_X}{mb^2}$	158×10^{-4}
μ (at sea level)	2.62		
μ' (at 10,000 ft)	3.55		

Résumé of Model Test Results

For the normal loading condition, normal control configuration for spinning, the seaplane model spun in an oscillatory manner and recovery was satisfactory by rapid full rudder reversal. With the elevator in the neutral position, recoveries were unsatisfactory. Setting the ailerons either with or against the spin had little effect on the spin and recovery characteristics of the model. Using smaller tail surfaces than originally installed on the model (see sketch) had no appreciable effect on the steady spins; however, the number of turns required for recovery increased slightly.

Extending mass along the wings with or without a center of gravity movement rearward $0.09\bar{c}$ from its normal position, led to recoveries which were generally unsatisfactory.

The recovery characteristics of the NB-1 landplane were similar to those of the seaplane model. The model spun, however, at a slightly flatter attitude.

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SPIN DATA OBTAINED WITH THE $\frac{1}{16}$-SCALE MODEL OF THE BOEING NB-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Seaplane, normal loading, large tail surface, wing tip float shingles attached											Seaplane, normal loading, small tail surfaces, wing tip float shingles attached				Seaplane, ΔI_X and ΔI_Z = 0.15 I_X, wing tip float shingles attached, large tail surface								
Ailerons	Against				Neutral			With				Neutral				Against			Neutral			With	
	15°U 15°D	10°U 10°D		5°U 5°D				5°U 5°D	10°U 10°D	15°U 15°D						15°U 15°D		10°U 10°D				15°U 15°D	10°U 10°D
Elevator	U (a)	U (a)	N	U (a)	U (a)	U (ab)	N (a)	U (a)	U (a)	U (a)	N	U	U (e)	N	D (ab)	U	N	N	U	N	D	N	D
α, deg	54	51	----	50	53	55	54	59	59	60	----	59	62	----	54	----	----	----	62	----	----	----	----
∅, deg	10D	8D	----	9D	13D	13D	14D	18D	19D	20D	----	15D	21D	----	13D	----	----	----	14D	----	----	----	----
Ω, rps	0.33	0.33	----	0.33	0.34	0.37	0.49	0.40	0.39	0.42	----	0.34	0.40	----	0.49	----	----	----	0.43	----	----	----	----
V, fps	96	95	----	95	97	93	90	91	91	88	----	97	90	----	90	----	----	----	92	----	----	----	----
Turns for Recovery	[c]$\frac{1}{2}$	----	$2\frac{1}{2}$	----	[c]$1\frac{1}{2}$	$1\frac{1}{4}$	$3\frac{1}{2}$	----	----	[c]$1\frac{1}{4}$	4	[d]$1\frac{1}{2}$	[cd]$1\frac{3}{4}$	[d]$3\frac{1}{2}$	[d]$4\frac{1}{2}$	----	----	$3\frac{1}{4}$	[bc]$1\frac{3}{4}$	----	----	[b]∞	∞

	Seaplane, ΔI_X and ΔI_Z = 0.30 I_X wing tip float shingles on, large tail surface				Seaplane, ΔI_X and ΔI_Z = 0.30 I_X, c.g. moved back $0.09\bar{c}$, large tail surface, wing tip float shingles attached									
Ailerons	Neutral		With		Against			Neutral				With		
					15°U 15°D	15°U 15°D	10°U 10°D					10°U 10°D	15°U 15°D	
Elevator	U	N	N	D	U	N	U	40° U	U	N	D	U	U	N
α, deg	63	----	----	----	66	----	66	68	66	--	60	66	66	---
∅, deg	12D	----	----	----	9D	----	10D	13D	12D	--	8D	14D	15D	---
Ω, rps	0.46	----	----	----	0.42	----	0.41	0.39	0.41	--	0.52	0.41	0.43	---
V, fps	91	----	----	----	92	----	91	93	90	--	81	92	92	---
Turns for Recovery	[cf]2	$3\frac{3}{4}$ $4\frac{1}{2}$	[d]∞	----	[c]$1\frac{1}{4}$	$2\frac{1}{2}$	----	$2\frac{1}{4}$	$3\frac{1}{4}$ [c]$1\frac{3}{4}$	∞	∞	----	[c]$2\frac{1}{4}$	∞

Seaplane, effect of mass variations and c.g. movements on the spin characteristics of the model. Elevator up, ailerons neutral, wing tip float shingles attached.

		α, deg	∅, deg	Ω, rps	V, fps	Turns for recovery
ΔI_X and ΔI_Z = 0.60 I_X large tail surface	b	64	9D	0.46	91	---------
ΔI_X and ΔI_Z = 0.60 I_X c.g. moved back $0.90\bar{c}$ large tail surface	b	66	8D	0.46	90	---------
ΔI_X and ΔI_Z = 0.30 I_X c.g. moved back $0.90\bar{c}$ small tail surface	e	68	12D	0.42	90	---------
ΔI_Y and ΔI_Z = 0.15 I_Y small tail surface	b	---	---	---	---	[c]1, [c]$\frac{3}{4}$
ΔI_Y and ΔI_Z = 0.30 I_Y small tail surface	b	---	---	---	---	[c]$\frac{1}{2}$
c.g. moved back $0.09\bar{c}$ small tail surface	b	---	---	---	---	[c]$1\frac{3}{4}$
c.g. raised $0.05\bar{c}$ small tail surface	b	---	---	---	---	[c]$1\frac{1}{4}$

	Landplane, normal loading, large tail surface								Landplane, c.g. moved back $0.05\bar{c}$, ΔI_X and ΔI_Z = 0.30 I_X								
Ailerons	Against 15°U 15°D			Neutral		With 15°U 15°D			Against 15°U 15°D			Neutral			With 15°U 15°D		
Elevator	U	N	D	U	N	U	N	D	U	N	D	U	15°U	N	U	N	D
α, deg	60	----	----	61	59	61	58	----	62	----	----	63	----	----	64	61	----
∅, deg	10D	----	----	14D	11D	19D	15D	----	7D	----	----	10D	----	----	12D	9D	----
Ω, rps	0.48	----	----	0.50	0.55	0.52	0.57	----	0.50	----	----	0.51	----	----	0.53	0.58	----
V, fps	95	----	----	92	86	92	84	----	93	----	----	88	----	----	85	84	----
Turns for Recovery	[c]$1\frac{1}{2}$	----	----	$2\frac{1}{2}$ [c]$1\frac{1}{2}$	3	2 [c]2	$4\frac{1}{2}$	5	[c]$1\frac{1}{4}$	----	----	$4\frac{1}{2}$ 8 [a]$1\frac{3}{4}$	8	----	∞ [c]$3\frac{1}{2}$	∞	8 ∞

Landplane, effect of mass variations and c.g. movements on turns for recovery. Recovery attempted by simultaneous reversal of rudder and elevator. Elevators up, ailerons neutral, large tail surface.

ΔI_X and ΔI_Z = 0.15 I_X	$1\frac{3}{4}$
ΔI_X and ΔI_Z = 0.30 I_X	$1\frac{3}{4}$
ΔI_Y and ΔI_Z = 0.15 I_Y	$1\frac{1}{4}$
ΔI_Y and ΔI_Z = 0.30 I_Y	$\frac{3}{4}$
c.g. moved forward $0.06\bar{c}$	$1\frac{1}{2}$
c.g. moved back $0.05\bar{c}$	2
c.g. moved back $0.05\bar{c}$ and raised $0.07\bar{c}$	2
c.g. moved back $0.05\bar{c}$ wt. increased 0.13	$1\frac{3}{4}$
c.g. moved back $0.05\bar{c}$ wt. decreased 0.013	2

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[a]Oscillatory spin.

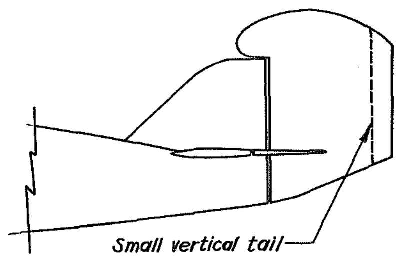
[b]Wing float shingles removed.

[c]Recovery attempted by simultaneous reversal of rudder and elevator.

[d]For attempted recoveries wing floatshingles were removed.

[e]Wing floats removed.

[f]Recovery was attempted with model equipped with small tail surface and float shingles removed.

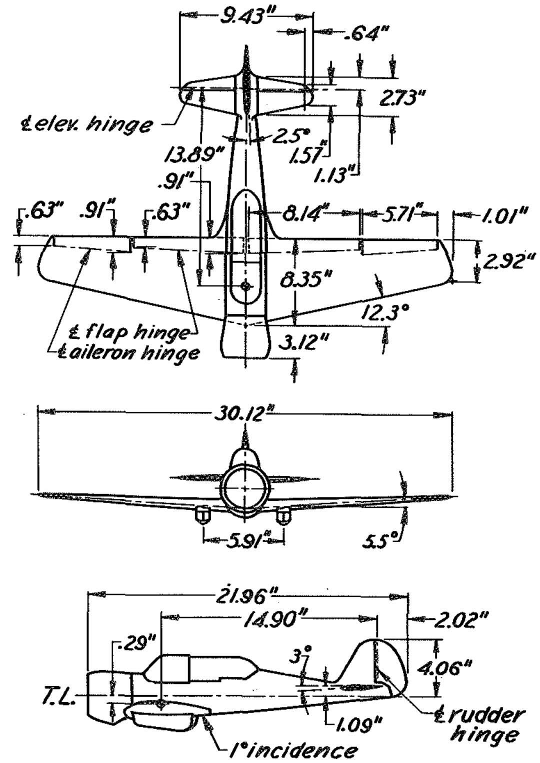

Small vertical tail

$\frac{1}{14}$-SCALE MODEL OF THE CURTISS-WRIGHT SNC-1 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	35.00
L, ft	27.00
$\bar{c}$, in.	64.01
S, sq ft	173.70
A	7.05
L.E. $\bar{c}$ aft L.E. c_r, in.	52.89
S_h, sq ft	25.53
S_e, sq ft (inc. bal.)	8.58
S_v, sq ft	16.49
S_r, sq ft (inc. bal.)	8.43
δ_r, deg	30 R, 30 L
δ_e, deg	27 U, 26.5 D
δ_a, deg	41.5 U, 9.5 D
δ_f, deg	44 D
TDPF	167×10^{-6}
Landing gear	Conventional



Model as tested.

Mass Data

Normal Loading

W, lb	3646
$x/\bar{c}$	0.304
$z/\bar{c}$	0.072
I_X, slug-ft^2	1242
I_Y, slug-ft^2	2863
I_Z, slug-ft^2	3937
Test altitude, ft	10,000
Alternate test altitude, ft	25,000
μ (at sea level)	7.83
μ' (10,000 ft)	10.60
μ'' (25,000 ft)	17.50

$\frac{I_X - I_Y}{mb^2}$	-117×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-77×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	194×10^{-4}

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Résumé of Model Test Results

In the clean condition, normal loading, and normal control configuration for spinning, the model spun steeply with an oscillatory motion. Recoveries were satisfactory either by rapid full rudder reversal (1/2 turn) or by simultaneous reversal of rudder and elevator. With the elevator either in the neutral or down position, satisfactory recoveries generally could not be obtained.

Setting the ailerons partly or full with the spin improved the recovery characteristics of the model and all recoveries attempted by rapid full rudder reversal were satisfactory, regardless of elevator setting. Setting the ailerons partly or full against the spin had a detrimental effect on the recovery characteristics of the model and satisfactory recoveries by rapid full rudder reversal could be obtained from the elevator-up spins only.

Extending or retracting the mass along the wings (ΔI_X and $\Delta I_Z = 0.25\ I_X$ or $-0.22\ I_X$), along the fuselage (ΔI_Y and $\Delta I_Z = 0.25\ I_Y$ or $-0.10\ I_Y$), or moving the center of gravity forward $0.08\bar{c}$ or back $0.10\bar{c}$ from its normal location had little effect upon the spin and recovery characteristics of the model. The recovery characteristics of the model in the landing condition (landing gear extended, flaps down 44°) were similar to those obtained for the clean condition, normal loading.

Recoveries from all inverted spins obtained were satisfactory by rapid full rudder reversal except when the ailerons were with the spin and the elevator was up.

In an endeavor to improve the recovery characteristics of the model, areas were added forward of the fin, and to the top of the original fin and rudder, and the rudder was extended downward to include the lower part of the fuselage rearward of the hinge line. (See sketches.) These modifications were generally ineffective (data not presented). The addition of antispin fillets (modifications 1 and 2) or ventral fins (modifications 3 to 7) improved the recovery characteristics of the model with best recoveries still obtained when the ailerons were full with the spin.

Recoveries from spins with the model tested at an alternate equivalent test altitude of 25,000 feet were slower than recoveries from the corresponding spins at the equivalent test altitude of 10,000 feet used for the tests previously discussed.

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SPIN DATA OBTAINED WITH THE $\frac{1}{14}$-SCALE MODEL OF THE CURTISS-WRIGHT SNC-1 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins.]

	Normal loading																									
Ailerons	Against										Neutral					With										
	Full			1/2				1/3		1/4						1/2					Full					
Elevator	U	N (a)	D	U (b)	U (b)	N (a)	D (a)	2/3U (b)	2/3U (b)	U	U (ac)	N (b)	N (b)	D (ab)	D (ab)	U	N (b)	N (bc)	D (b)	D (ab)	U (ab)	U (bc)	N (b)	N (uc)	D (ab)	D (ab)
α, deg	39	72	74	68	---	73	70	72	38	38	34	70	35	68	35	35	34	----	33	20	32	----	31	---	28	22
ϕ, deg	2U	5U	3U	3U	---	3U	2U	2U	4U	2U	2U	1U	4U	2U	5U	4D	0	----	2U	1D	1D	----	2D	---	0	1U
Ω, rps	0.43	0.58	0.55	0.48	0.43	0.60	0.54	0.55	0.45	0.41	0.42	0.54	0.54	0.52	0.56	0.48	0.56	----	0.69	0.63	0.68	----	0.76	---	0.73	---
V, fps	168	121	118	131	175	115	118	121	171	173	178	118	173	121	163	184	178	----	168	227	189	----	186	---	173	277
Turns for recovery	3/4; [d]1; [e]1/4	[d]∞; [f]7	∞; [d]∞	[f]2 1/2	1/4	∞	∞	[fg]4; [fg]4 1/2; [h]∞; [i]∞	[fg]3/4; [h]1; [i]1	3/4	[f]1/2; [d]3; [ej]1/2; [k]3 1/2	5 3/4; [d]∞	3/4; [d]2	∞; [d]∞	1 1/4; [d]4 1/2	1/2	1	----	[j]1	[j]1/2	3/4; [g]2 1/2; [ej]1/2	-	1; [d]2 1/2	[d]1	[j]1; [d]5 3/4	[dj]3/4

	ΔI_X and $\Delta I_Z = 0.25I_X$														ΔI_X and $\Delta I_Z = -0.22I_X$												
Ailerons	Against				Neutral					With					Against				Neutral					With			
Elevator	U	N (ab)	N (b)	D	U (a)	N (b)	N (b)	D (ab)	D (ab)	U (a)	N (b)	N (bc)	D (b)	D (ab)	U (b)	U (b)	N	D	U (a)	N (b)	N (ab)	D (b)	D (ab)	U (m)	N (a)	D (ab)	D (bm)
α, deg	36	71	36	72	36	70	36	67	34	34	32	---	31	22	65	38	74	74	35	73	34	70	37	32	31	31	---
ϕ, deg	5U	3U	7U	4U	4U	1U	5U	0	6U	8D	2D	---	1U	3U	5U	5U	4U	4U	4U	2U	5U	1U	5U	10D	2D	1U	---
Ω, rps	0.42	0.58	0.51	0.55	0.42	0.53	0.53	0.52	0.69	0.45	0.62	---	0.66	0.88	0.45	0.41	0.58	0.57	0.42	0.56	0.51	0.54	0.51	0.47	0.57	0.66	---
V, fps	173	121	173	121	181	123	171	121	173	197	184	---	184	233	129	173	115	115	173	118	173	118	165	200	210	189	227
Turns for recovery	[f]1/2	[f]7 1/2	[f]1	∞	1/2	6 1/2	1	∞	3/4	[i]3/4	1	---	[f]1	----	[f]2 1/2	1/2	∞	∞	[f]3/4	6 1/4	1	∞	1	---	1/2, 1	[j]1/2, [j]1	e

	ΔI_Y and $\Delta I_Z = 0.25I_Y$												ΔI_Y and $\Delta I_Z = -0.10I_Y$												
Ailerons	Against				Neutral					With			Against				Neutral					With			
Elevator	U (b)	U (b)	N (a)	D (a)	U	N (ab)	N (ab)	D (ab)	D (bm)	U (c)	N (c)	D (c)	U (a)	N (ab)	N (b)	D	U	N (b)	N (ab)	D (b)	D (b)	U (a)	N (b)	N (bc)	D (a)
α, deg	71	37	76	75	35	69	36	68	37	---	----	---	35	72	38	70	34	69	34	67	36	31	31	----	23
ϕ, deg	4U	4U	3U	4U	1U	0	3U	0	4U	---	----	---	6U	4U	7U	3U	4U	1U	5U	1U	7U	6D	2D	----	0
Ω, rps	0.44	0.36	0.56	0.51	0.43	0.46	0.49	0.53	0.58	---	----	---	0.45	0.57	0.54	0.56	0.43	0.56	0.55	0.55	0.60	0.50	0.61	----	0.90
V, fps	126	178	115	121	184	121	173	123	173	>250	>254	---	178	115	168	115	173	115	173	121	168	227	184	----	227
Turns for recovery	[f]4 1/4	[f]1/2	∞	∞	[f]1/2	5,7	1	∞	---	----	[n]1/4	---	[f]1/2	8	[f]3/4	∞	[f]3/4	5 1/2	1	8 1/4	[j]1 1/4	[l]1	1	----	[j]1/2

	c.g. moved forward 0.08$\bar{c}$													c.g. moved back 0.10$\bar{c}$													
Ailerons	Against			Neutral					With					Against					Neutral					With			
Elevator	U (a)	N	D (a)	U (a)	N (b)	N (b)	D (ab)	D (ab)	U (a)	N (b)	N (ab)	D (b)	D (bm)	U (b)	U (ab)	N (ab)	N (ab)	D (a)	U (a)	N (ab)	N (ab)	D (ab)	D (ab)	U (m)	N (a)	D (b)	D (bc)
α, deg	35	73	71	34	69	36	69	40	27	32	19	32	---	68	37	73	43	71	35	70	35	68	36	---	---	58	---
ϕ, deg	8U	3U	3U	4U	1U	6U	1U	5U	18D	1D	2D	1U	---	4U	2U	4U	4U	4U	1D	1U	5U	1U	5U	---	--	3D	---
Ω, rps	0.44	0.59	0.53	0.50	0.57	0.55	0.57	0.56	0.71	---	0.78	0.68	---	0.45	0.34	0.54	0.45	0.57	0.38	0.49	0.50	0.48	0.51	---	---	0.53	---
V, fps	181	115	121	173	115	158	118	155	254	178	238	178	210	126	173	121	158	123	189	121	165	126	165	205	>227	139	---
Turns for recovery	[f]1/2	[f]8	∞	[f]3/4	5 1/2	1	∞	[j]2, [j]4	1/2	[j]3/4	1	1 1/4	[j]1/2	2 1/2, 3	1/2	8 1/4	[f]1 1/4	∞	1/2	5 3/4	3/4	∞	1	[l]	[j]1/2	[j]6	[j]1/4

[a]Oscillatory spin.
[b]Two types of spin.
[c]Steep spin.
[d]Recovery attempted by rudder neutralization.
[e]Recovery attempted by full simultaneous reversal of rudder and elevator.
[f]Model goes into spin in opposite direction after recovery.
[g]Recovery attempted by reversal of rudder from full with to 2/3 against the spin.
[h]Recovery attempted by simultaneous movement of rudder from full with to 2/3 against the spin and elevator from 2/3 up to neutral.
[i]Recovery attempted by simultaneous movement of rudder full with to 2/3 against the spin and elevator from 2/3 up to full down.
[j]Model goes into an inverted spin after recovery from erect spin.
[k]Recovery attempted by simultaneous neutralization of rudder and elevator.
[l]Model recovers in spiral dive.
[m]Oscillatory and wandering spin.
[n]Recovery attempted before final steep attitude was attained, visual observations.

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SPIN DATA OBTAINED WITH THE $\frac{1}{45}$-SCALE MODEL OF THE CURTISS-WRIGHT SNC-1 AIRPLANE - Concluded

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full-rudder reversal from right erect spins]

	Landing condition, normal loading											
Ailerons	Against				Neutral					With		
Elevator	U (o)	U (o)	N (a)	D (a)	U	N (b)	N (bm)	D (b)	D (b)	U	N	D
α, deg	63	No spin	74	70	----	71	---	67	36	----	----	----
∅, deg	4U		3U	4U	----	2U	---	1U	5U	----	----	----
Ω, rps	0.48		0.56	0.53	----	0.56	---	0.52	0.71	----	----	----
V, fps	132		113	115	>227	115	205	121	158	>200	>200	>200
Turns for recovery	[f]3		∞	∞	[fn]$\frac{1}{4}$	$6\frac{1}{2}$	$\frac{1}{4}$	8	$1\frac{1}{4}$	[n]$\frac{1}{2}$	[n]$\frac{1}{2}$	[jn]$\frac{1}{2}$

	Inverted spins, normal loading									Normal loading, modification 1			
Ailerons	Against			Neutral			With			Against Full	Against $\frac{1}{3}$	Neutral	
Elevator	U	N	D	U (p)	N	D	U (a)	N	D	D	$\frac{2}{3}$U	U	D
α, deg	No spin	No spin	No spin	----	No spin	No spin	42	36	24	63	40	38	----
∅, deg				----			8D	10D	7D	4U	2U	3D	----
Ω, rps				----			0.43	0.51	0.68	0.50	0.45	0.42	----
V, fps				227			163	173	221	129	165	173	----
Turns for recovery				$\frac{1}{4}$; [d]$\frac{1}{2}$; [k]$\frac{1}{2}$			>$4\frac{1}{4}$; [d]∞; [r]>$2\frac{1}{4}$	[g]$1\frac{1}{4}$; [d]$4\frac{1}{4}$	[q]$\frac{1}{2}$; [d]$1\frac{1}{4}$	∞	[g]$1\frac{1}{2}$	1	----

	Normal loading, modification 2					Normal loading, modification 3					Normal loading, modification 4				
Ailerons	Against Full	Against $\frac{1}{3}$	Neutral			Against Full	Against $\frac{1}{3}$	Neutral			Against Full	Against $\frac{1}{3}$	Neutral		
Elevator	D (a)	$\frac{2}{3}$U (a)	U (a)	N	D	D	$\frac{2}{3}$U	U	N	D	D	$\frac{2}{3}$U	U (a)	N	D
α, deg	58	41	34	--	--	62	38	39	-	-	38	38	36	-	-
∅, deg	6U	2U	0	--	--	5U	4U	1D	-	-	6U	2U	0	-	-
Ω, rps	0.48	0.44	0.44	--	--	0.51	0.44	0.42	-	-	0.52	0.45	0.47	-	-
V, fps	134	158	178	--	--	129	173	173	-	-	160	168	173	-	-
Turns for recovery	∞	[g]$1\frac{1}{2}$	1	--	--	$5\frac{3}{4}$	[g]$\frac{3}{4}$	1	-	-	$1\frac{1}{4}$	[g]1	1	-	-

	Normal loading, modification 5					Normal loading, modification 6			Normal loading, modification 7				
Ailerons	Against Full	Against $\frac{1}{3}$	Neutral			Against Full		Against $\frac{1}{3}$	Against Full	Against $\frac{1}{3}$	Neutral		With
Elevator	D	$\frac{2}{3}$U	U (a)	N	D	N	D	$\frac{2}{3}$U	D	$\frac{2}{3}$U	U	D	D
α, deg	39	37	34	-	-	---	---	-------	---	---	---	---	----
∅, deg	6U	3U	2U	-	-	---	---	-------	---	---	---	---	----
Ω, rps	0.54	0.45	0.45	-	-	---	---	-------	---	---	---	---	----
V, fps	160	173	186	-	-	---	121	165	165	168	175	---	181
Turns for recovery	[j]$1\frac{1}{4}$	[g]$\frac{3}{4}$	$\frac{3}{4}$	-	-	---	$7\frac{1}{2}$	[g]$1\frac{1}{4}$	1	[g]1	1	---	1

	Normal loading, equivalent test altitude 25,000 feet											
Ailerons	Against Full			Against $\frac{1}{3}$		Neutral			With		
Elevator	U	N (a)	D (a)	$\frac{2}{3}$U (ab)	$\frac{2}{3}$U (b)	U	N	D (a)	U (s)	N (s)	D (s)
α, deg	42	70	72	69	----	38	67	62	----	----	----
∅, deg	3U	0	2U	0	----	2D	0	1D	----	----	----
Ω, rps	0.39	0.58	0.29	0.54	----	0.42	0.54	0.54	----	----	----
V, fps	218	163	168	163	210	222	168	168	>227	----	>254
Turns for recovery	$1\frac{1}{4}$	∞	∞	[g]>9	[g]$1\frac{3}{4}$	$1\frac{3}{4}$	$8\frac{1}{2}$	∞	----	----	[g]

	Normal loading, equivalent test altitude 25,000 feet modification 2						Normal loading, equivalent test altitude 25,000 feet, modification 5				
Ailerons	Against Full		Against $\frac{1}{3}$	Neutral			Against			Neutral	
Elevator	U (a)	N	$\frac{2}{3}$U	U	N	D	U (c)	N (b)	N (b)	U	N
α, deg	----	----	----	----	----	----	----	----	----	----	36
∅, deg	----	----	----	----	----	----	----	----	----	----	2U
Ω, rps	----	----	----	----	----	----	----	----	----	----	0.49
V, fps	198	173	202	216	210	----	----	173	227	227	227
Turns for recovery	$1\frac{1}{4}$; $2\frac{1}{2}$	6; 7	[g]>$4\frac{1}{4}$	$1\frac{1}{2}$	2	----	----	4	$1\frac{1}{2}$	1	$1\frac{1}{4}$

	Normal loading, equivalent test altitude 25,000 feet, modification 7							
Ailerons	Against Full				Against $\frac{1}{3}$	Neutral		
Elevator	U	N (b)	N (bc)	D	$\frac{2}{3}$U	U	N (b)	N (b)
α, deg	40	62	--	67	42	42	64	38
∅, deg	4U	5U	--	4U	2U	2D	1D	1U
Ω, rps	0.39	0.50	--	0.51	0.43	0.40	0.50	0.46
V, fps	216	178	--	173	218	222	173	216
Turns for recovery	$\frac{1}{2}$	4	--	∞	[g]$1\frac{3}{4}$	$1\frac{1}{2}$	4	$1\frac{1}{2}$

[a]Oscillatory spin.
[b]Two types of spin.
[c]Steep spin.
[d]Recovery attempted by rudder neutralization.
[e]Recovery attempted by full simultaneous reversal of rudder and elevator.
[f]Model goes into spin in opposite direction after recovery.
[g]Recovery attempted by reversal of rudder from full with to 2/3 against the spin.
[j]Model goes into an inverted spin after recovery from erect spin.
[k]Recovery attempted by simultaneous neutralization of rudder and elevator.
[m]Oscillatory and wandering spin.
[n]Recovery attempted before final steep attitude was attained, visual observations.
[o]Two conditions possible.
[p]Wandering spin.
[q]Model goes into erect spin after recovery from inverted spin.
[r]Recovery attempted by neutralization of rudder and elevator.
[s]Vertical velocity too high to test.

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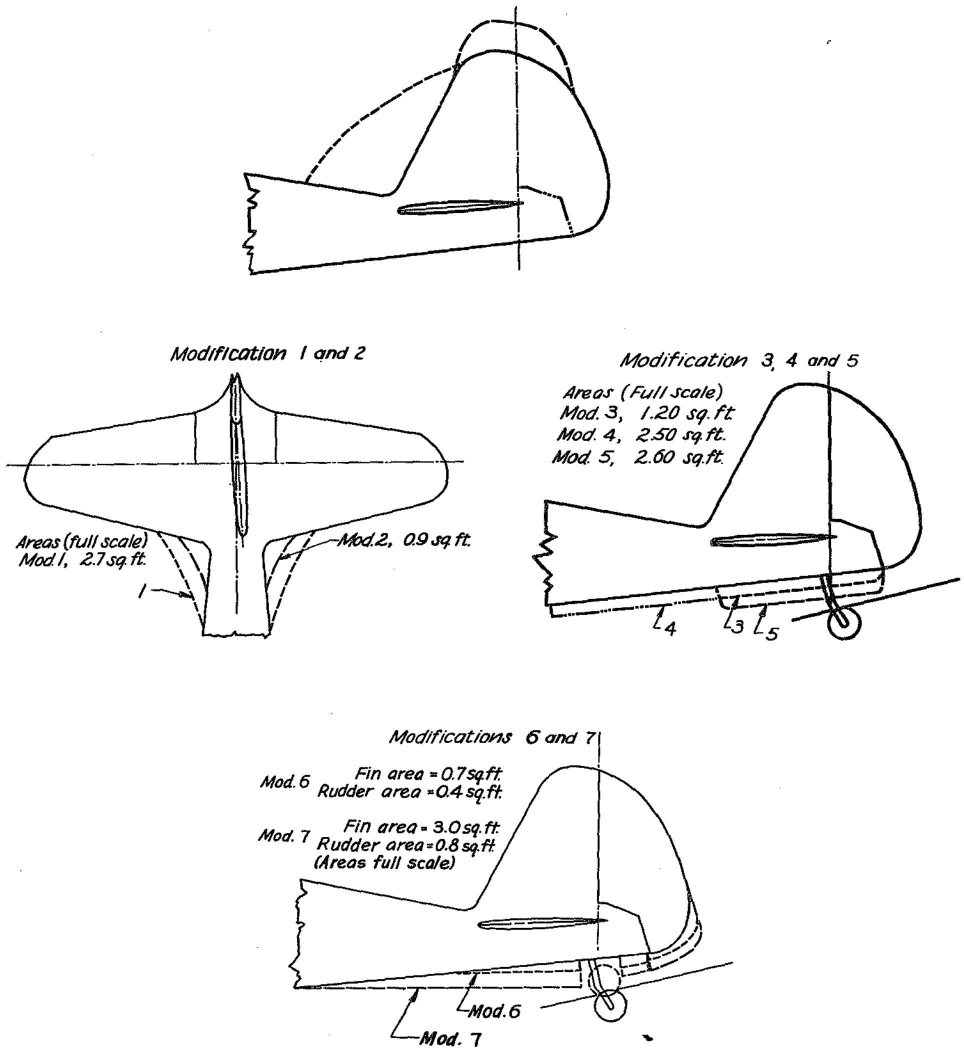
Ineffective tail modifications tested on SNC-1 model



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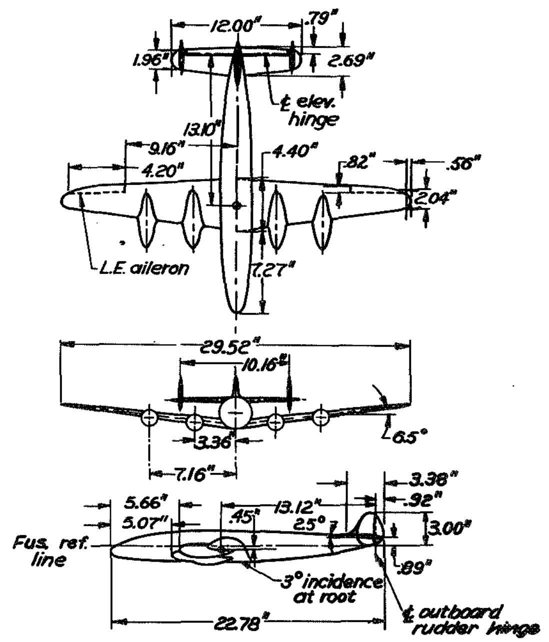
$\frac{1}{50}$-SCALE MODEL OF THE LOCKHEED XB-2 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	123.00
L, ft	94.92
$\bar{c}$, in.	177.78
S, sq ft	1660.00
A	9.11
S_h, sq ft	454.70
S_e, sq ft	112.00
S_v, sq ft (3 tails)	230.40
S_r, sq ft	87.60
δ_r, deg	30 R, 30 L
δ_e, deg	40 U, 20 D
δ_a, deg	25 U, 10 D
δ_f, deg:	
At root	39.75
At tip	42.25
TDPF	1160×10^{-6}
Landing gear	Tricycle



Model as tested.

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Mass Data

Normal Loading

W, lb	69,600
$x/\bar{c}$	0.249
$z/\bar{c}$	0.193
I_X, slug-ft^2	804,263
I_Y, slug-ft^2	470,793
I_Z, slug-ft^2	1,259,518
Test altitude, ft	25,000
μ (at sea level)	4.46
μ' (25,000 ft)	9.95

$\frac{I_X - I_Y}{mb^2}$	102×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-241×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	139×10^{-4}

Résumé of Model Test Results

For the normal loading, clean condition, and normal control configuration for spinning, the model spun at a very steep attitude ($\alpha = 24^{\circ}$) with a high rate of descent (356 feet per second, full scale) and recovery by rapid full rudder reversal was satisfactory $\left(1\frac{1}{4}\right)$turns . The model would not spin for any other aileron-elevator setting except with the elevator up and ailerons with the spin. Recovery from this spin was satisfactory only by rapid full elevator reversal or by simultaneous rapid reversal of the rudders and elevator.

Results obtained with changes in mass distribution or of the center-of-gravity position indicated no appreciable effect on the recovery characteristics of the model.

Lowering the landing gear (data not presented) or extending the flaps had little effect on the recovery characteristics of the model.

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SPIN DATA OBTAINED WITH THE $\frac{1}{50}$-SCALE MODEL OF THE LOCKHEED XB-2 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

	Normal loading											
Ailerons	Against Full			Against $\frac{1}{2}$	Neutral			With $\frac{1}{2}$	With Full			
Elevators	U	N	D	U	U	N	D	U	U (a)	U (a)	N (b)	D
α, deg	No spin	No spin	No spin	No spin	24	No spin	No spin	30	27	32	-	No spin
∅, deg					1U			2D	1D	2D	-	
Ω, rps					0.32			0.27	0.31	0.26	-	
V, fps					356			318	315	273	-	
Turns for recovery					$1\frac{1}{4}$ [c]∞ [d]∞			---	$>2\frac{1}{2}$	$>2\frac{1}{2}$	-	

Effect of various control manipulations on turns for recovery from the aileron-with, elevator-up condition, normal loading.	
Recovery attempted by:	Turns for recovery
Reversing the elevator from 40° U to 17° D	$1\frac{1}{2}$
Simultaneous reversal of rudder and movement of elevator from 40° U to 10° D	$1\frac{1}{2}$
Simultaneous neutralization of rudder and elevator	2
Neutralization of elevator	5, ∞
Releasing the rudder	∞
Releasing the elevator	∞
Rudder originally free	∞

Effect of mass changes and c.g. movements on turns for recovery			
Ailerons	With		
Elevator	U	N	D
ΔI_X and $\Delta I_Z = 0.09 I_X$	$>2\frac{1}{2}$	[e]--	--
ΔI_X and $\Delta I_Z = 0.18 I_X$	$>2\frac{1}{2}$	[e]--	--
ΔI_X and $\Delta I_Z = -0.34 I_X$	$1\frac{3}{4}$	$1\frac{1}{2}$	[f]--
ΔI_Y and $\Delta I_Z = 0.15 I_Y$	$>2\frac{1}{2}$ [g]$1\frac{1}{2}$	$1\frac{1}{2}$	[f]--
ΔI_Y and $\Delta I_Z = 0.30 I_Y$	$>2\frac{1}{2}$	$1\frac{1}{4}$	[f]--
c.g. moved forward $0.06\bar{c}$ ΔI_Y and $\Delta I_Z = 0.08 I_Y$	$>2\frac{1}{2}$	[h]--	--
c.g. moved back $0.06\bar{c}$	$>2\frac{1}{2}$	[i]$1\frac{1}{2}$	--

	Flaps down, normal loading								
Ailerons	Against			Neutral			With		
Elevators	U	N	D	U (i)	N (b)	D	U	N (i)	D
α, deg	No spin	No spin	No spin	-	No spin	No spin	40	33	No spin
∅, deg				-			5D	3D	
Ω, rps				-			0.24	0.37	
V, fps				-			241	257	
Turns for recovery							$>2\frac{3}{4}$ [j]$1\frac{1}{2}$	---	

[a]Two types of spin, flatter spin usually obtainable.
[b]Unstable spin, model generally steepens and recovers of own accord.
[c]Recovery attempted by releasing the rudder.
[d]**Model would not recovery with rudder free.**
[e]Steep spin.
[f]No spin.
[g]Recovery attempted by simultaneous reversal of rudder and elevator
[h]Velocity too high to test.
[i]Wandering and oscillatory spin.
[j]Recovery attempted by simultaneous reversal of rudder with movement of elevator from 40° U to 17° D.

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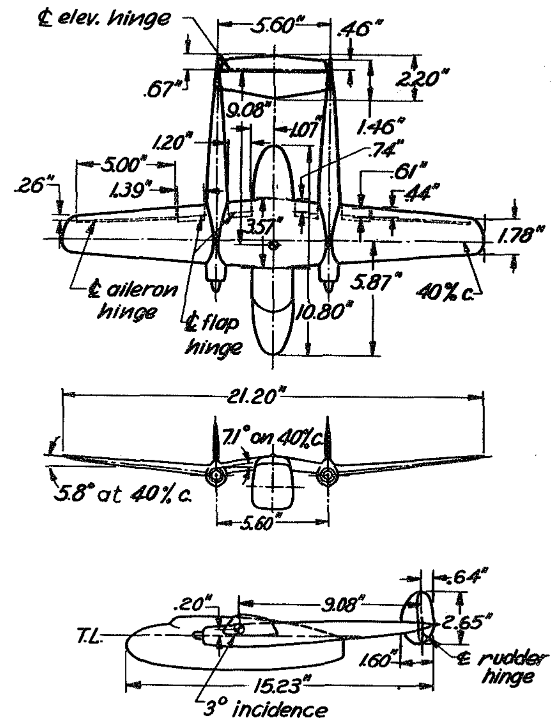
$\frac{1}{60}$-SCALE MODEL OF THE FAIRCHILD XC-82 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	106.00
L, ft	75.92
$\bar{c}$, in.	167.20
S, sq ft	1400.00
A	8.01
S_h, sq ft	250.00
S_e, sq ft	97.50
S_v, sq ft	166.00
S_r, sq ft	86.30
δ_r, deg	35 R, 35 L
δ_e, deg	35 U, 25 D
δ_a, deg	24 U, 12 D
δ_f, deg	45 D
TDPF	94×10^{-6}
Landing gear	Tricycle



Model as tested.

Mass Data

Normal Loading

W, lb	41,945
$x/\bar{c}$	0.272
$z/\bar{c}$	-0.072
I_X, slug-ft^2	285,200
I_Y, slug-ft^2	138,000
I_Z, slug-ft^2	414,500
Test altitude, ft	45,000
μ (at sea level)	3.70
μ' (45,000 ft)	19.20

$\frac{I_X - I_Y}{mb^2}$	101×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-188×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	87×10^{-4}

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Résumé of Model Test Results

For the clean condition, normal loading, normal control configuration for spinning, the model spun at a very steep angle of attack ($\alpha = 23^{\circ}$) and recovery by rapid full reversal of the rudders required $2\frac{1}{2}$ turns. Full rapid elevator reversal, or simultaneous neutralization or reversal of rudders and elevator, led to satisfactory recoveries (data not presented). The model would not spin when the elevator was either neutral or down, even though the rudders were set with the spin.

Setting the ailerons with the spin flattened the spin and impaired the recovery characteristics of the model, whereas setting ailerons against the spin steepened the spin and improved the recovery characteristics.

Extending or retracting the mass along the wings (ΔI_X and $\Delta I_Z = \pm 0.40\ I_X$) had no appreciable effect upon the recovery characteristics of the model. With the center of gravity moved back $0.10\bar{c}$ from its normal position, in conjunction with an extension of mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.52\ I_Y$), spins were obtained for all control configurations and recoveries were generally satisfactory by rapid full reversal of the rudders.

The recovery characteristics of the model in the landing condition (landing gear extended, flaps down 45°) were, in general, similar to the recovery characteristics of the model in the clean condition.

Inverted spins were conducted only for rudders with the spin, elevator full down, and controls crossed (data not presented). Recovery obtained by rapid full rudder reversal or by neutralizing the rudders was satisfactory.

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SPIN DATA OBTAINED WITH THE $\frac{1}{60}$-SCALE MODEL OF THE FAIRCHILD XC-82 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder-with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins]

Normal loading

Ailerons	Against Full			Against $\frac{1}{4}$	Neutral			With $\frac{1}{2}$	With $\frac{2}{3}$	With Full		
Elevator	U	N	D	U	U	N	D	U (a)	N (a)	U	N	D
α, deg	19	No spin	No spin	--	23	No spin	No spin	31	29	50	47	No spin
ϕ, deg	7U			--	2U			2D	2D	3D	2D	
Ω, rps	0.27			--	0.33			---	---	0.29	0.35	
V, fps	551			--	516			408	430	332	320	
Turns for recovery	$\frac{1}{4}$			$\frac{1}{2}$	$2\frac{1}{2}$; [b]>8			>$2\frac{3}{4}$	---	>$4\frac{1}{2}$; [de]$\frac{3}{4}$; [h]$2\frac{1}{2}$	3	

ΔI_X and ΔI_Z = 0.40 I_X

Ailerons	Against			Neutral			With		
Elevator	U (c)	N	D	U (a)	N (g)	D	U	N	D
α, deg	21	---	No spin	---	-	No spin	56	52	47
ϕ, deg	6U	---		---	-		3D	2D	2D
Ω, rps	0.40	---		---	-		0.30	0.40	0.36
V, fps	574	---		551	-		315	336	342
Turns for recovery	$\frac{1}{4}$	---		---	-		>4; [de]$\frac{1}{2}$	$3\frac{1}{2}$	[e]3

ΔI_X and ΔI_Z = -0.40 I_X.

Ailerons	Against Full			Against $\frac{1}{3}$	Neutral			With $\frac{1}{4}$	With Full		
Elevator	U	N (a)	D	U	U	N (c)	D (ac)	U	U	N	D (ae)
α, deg	25	23	No spin	26	25	21	---	---	53	46	24
ϕ, deg	12U	16U		9U	7U	7U	---	---	6D	5D	0
Ω, rps	0.33	0.39		0.35	0.36	0.46	---	---	0.29	0.33	0.40
V, fps	459	482		459	447	482	493	---	332	326	397
Turns for recovery	$\frac{1}{2}$	$\frac{1}{4}$		$\frac{3}{4}$	$2\frac{3}{4}$	$\frac{1}{4}$	---	>5	>3	$1\frac{3}{4}$	[e]$\frac{3}{4}$

c.g. moved back 0.10$\bar{c}$, ΔI_Y and ΔI_Z = 0.52 I_Y

Ailerons	Against			Neutral			With		
Elevator	U (af)	N (a)	D (a)	U	N	D	U	N	D
α, deg	38	28	26	54	51	44	55	54	51
ϕ, deg	6U	8U	9U	3D	2D	2D	5D	4D	4D
Ω, rps	0.19	0.31	0.36	0.22	0.24	0.28	0.22	0.25	0.26
V, fps	424	470	447	326	332	326	326	315	326
Turns for recovery	$\frac{1}{2}$	$\frac{1}{2}$	[e]$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$; 2	[e]2	$1\frac{3}{4}$	2	[e]$2\frac{1}{4}$

Landing condition, normal loading

Ailerons	Against			Neutral			With		
Elevator	U	N (g)	D	U (c)	N	D	U	N	D (g)
α, deg	22	---	No spin	22	18	No spin	50	44	---
ϕ, deg	5U	---		1U	2U		3D	3D	---
Ω, rps	0.27	---		0.47	0.44		0.29	0.32	---
V, fps	465	---		459	540		321	326	---
Turns for recovery	$\frac{1}{2}$	---		$\frac{3}{4}$	$\frac{1}{2}$		>4	2	---

[a] Oscillatory spin.

[b] Recovery attempted by neutralizing rudder.

[c] Wandering spin.

[d] Recovery attempted by simultaneous full reversal of rudder and elevator.

[e] After recovery model goes into an inverted spin.

[f] Wide radius of spin.

[g] Very steep spin, recovery would undoubtedly be rapid.

[h] Recovery attempted by simultaneous neutralization of rudder and elevator.

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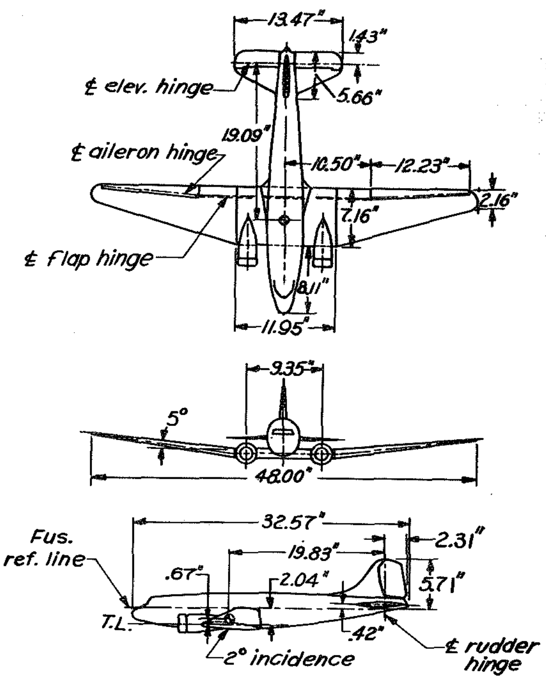
$\frac{1}{23.75}$-SCALE MODEL OF THE DOUGLAS DC-3 AIRPLANE

Dimensional Data

(Full Scale)

b, ft	95.00
L, ft	64.46
$\bar{c}$, in.	138.10
S, sq ft	987.00
A	9.15
L.E. $\bar{c}$ aft L.E. c_r, in.	31.90
S_h, sq ft	200.40
S_e, sq ft	80.00
S_v, sq ft	85.60
S_r, sq ft	46.00
δ_r, deg	30 R, 30 L
δ_e, deg	30 U, 20 D
δ_a, deg	25 U, 15 D
TDPF	13×10^{-6}
Landing gear	Retractable



Model as tested.

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Mass Data

Normal Loading

W, lb	25,554
$x/\bar{c}$	0.247
$z/\bar{c}$	-0.116
I_X, slug-ft^2	66,670
I_Y, slug-ft^2	91,690
I_Z, slug-ft^2	150,400
Test altitude, ft	10,000
μ (at sea level)	3.56
μ' (10,000 ft)	4.84

$\frac{I_X - I_Y}{mb^2}$	-35×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-82×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	117×10^{-4}

Preliminary Normal Loading

W, lb	25,554
$x/\bar{c}$	0.252
$z/\bar{c}$	-0.115
I_X, slug-ft^2	85,260
I_Y, slug-ft^2	92,310
I_Z, slug-ft^2	169,400
Test altitude, ft	2,500
μ (at sea level)	3.56
μ' (2,500 ft)	3.83

$\frac{I_X - I_Y}{mb^2}$	-10×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-107×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	117×10^{-4}

Résumé of Model Test Results

For the clean condition, normal loading, and normal control configuration for spinning, the model spun steeply ($\alpha = 35^{\circ}$) and recovery by rapid full rudder reversal was satisfactory. Neither aileron nor elevator setting had any appreciable effect on the satisfactory recovery characteristics of the model.

Extending mass along the wings (ΔI_X and $\Delta I_Z = 0.40\ I_X$) produced unsatisfactory recoveries by rapid full rudder reversal from the elevator-up spins, ailerons either neutral or full with the spin; however, with the elevator in the neutral or full-down positions, the model would not spin for any aileron setting. Extending mass along the fuselage (ΔI_Y and $\Delta I_Z = 0.25\ I_Y$) enabled satisfactory recoveries by rapid full rudder reversal to be obtained only when the ailerons were full with the spin or the elevator was full up. A forward movement of the center of gravity $0.15\bar{c}$ from its normal position caused the model to spin only for the elevator full up, aileron neutral or full-with setting. A rearward movement of the center of gravity $0.06\bar{c}$ from its normal position had little effect on the recovery characteristics of the model.

The model would not spin inverted with the ailerons in the neutral position (data not presented).

The load factor presented for each spin has been computed as the reciprocal of the sine of the angle of attack, based upon the assumption that the resultant aerodynamic force in a spin is normal to the wing chord. The test results indicated that, in general, the load factor probably would not exceed 3.

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SPIN DATA OBTAINED WITH THE $\frac{1}{23.75}$-SCALE MODEL OF THE DOUGLAS DC-3 AIRPLANE

[Unless otherwise indicated, steady-spin data are for rudder with spins of the model in the clean condition and recoveries were attempted by rapid full rudder reversal from right erect spins at an equivalent test altitude of 10,000 feet]

Normal loading

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	-	55	57	35	47	51	38	36	36
φ, deg	-	8U	8U	7U	8U	8U	4D	3U	5U
Ω, rps	-	0.34	0.36	0.29	0.34	0.36	0.28	0.36	0.40
V, fps	-	138	138	172	148	144	172	172	158
Turns for recovery	-	$1\frac{3}{4}$	$1\frac{1}{2}$	1	$1\frac{1}{4}$	$1\frac{1}{4}$	1	$1\frac{1}{4}$	1
Load factor	-	1.22	1.20	1.73	1.36	1.29	1.62	1.71	1.69

ΔI_X and ΔI_Z = 0.20 I_X

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	-	No spin	No spin	30	No spin	No spin	40	36	No spin
φ, deg	-			7U			3D	4U	
Ω, rps	-			0.29			0.28	0.38	
V, fps	-			199			172	172	
Turns for recovery	-			$\frac{3}{4}$			>2	1	
Load factor	-			2.01			1.57	1.68	

ΔI_X and ΔI_Z = 0.40 I_X

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U	N	D	U	N	D
α, deg	-	No spin	No spin	29	No spin	No spin	39	No spin	No spin
φ, deg	-			6U			3D		
Ω, rps	-			0.29			0.28		
V, fps	-			206			172		
Turns for recovery	-			$>2\frac{1}{4}$			$>2\frac{1}{4}$		
Load factor	-			2.04			1.60		

ΔI_Y and ΔI_Z = 0.25 I_Y

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U	N	D	U	N	D
α, deg	35	68	64	36	63	61	36	38	40
φ, deg	6U	6U	6U	4U	5U	5U	5D	2U	4U
Ω, rps	0.24	0.35	0.34	0.24	0.34	0.34	0.25	0.33	0.34
V, fps	190	121	121	190	121	121	182	172	161
Turns for recovery	$\frac{1}{2}$ [b]$\frac{3}{4}$ [c]>4 [d]∞	$4\frac{1}{4}$	$4\frac{1}{4}$ [b]$4\frac{1}{4}$ [c]8	1 [b]>2 [d]∞	$4\frac{3}{4}$ [b]$7\frac{3}{4}$ [c]$7\frac{1}{2}$	$2\frac{1}{2}$ [b]$5\frac{3}{4}$	$1\frac{1}{4}$ [b]>2 [c]$>5\frac{1}{2}$ [d]∞ [e]$1\frac{1}{4}$	$1\frac{1}{2}$ [b]2	$1\frac{1}{2}$ [b]$1\frac{3}{4}$ [c]$3\frac{1}{2}$
Load factor	1.76	1.08	1.11	1.71	1.12	1.14	1.69	1.62	1.56

ΔI_Y and ΔI_Z = -0.18 I_Y

Ailerons	Against			Neutral			With		
Elevator	U (a)	N	D	U (f)	N	D	U	N	D
α, deg	-	No spin	No spin	47	No spin	No spin	36	No spin	No spin
φ, deg	-			5U			1D		
Ω, rps	-			---			0.31		
V, fps	-			193			172		
Turns for recovery	-			$\frac{3}{4}$			>2		
Load factor	-			1.36			1.71		

c.g. moved forward 0.15$\bar{c}$

Ailerons	Against			Neutral			With		
Elevator	U	N	D	U (g)	N	D	U	N	D
α, deg	No spin	No spin	No spin	-	No spin	No spin	35	No spin	No spin
φ, deg				-			2U		
Ω, rps				-			0.36		
V, fps				-			178		
Turns for recovery				-			$1\frac{1}{4}$		
Load factor				-			1.73		

c.g. moved back 0.06$\bar{c}$

Ailerons	Against			Neutral		With	
Elevator	U	N	D	U	N	U	N
α, deg	32	44	44	31	46	38	35
φ, deg	6U	8U	11U	8U	10U	5D	3U
Ω, rps	0.27	---	---	0.26	0.33	0.27	0.37
V, fps	193	154	151	206	154	178	172
Turns for recovery	$\frac{1}{2}$	$1\frac{1}{2}$	---	$\frac{3}{4}$	$1\frac{1}{4}$	---	1
Load factor	1.88	1.44	1.44	1.92	1.39	1.64	1.73

Effect of control settings and mass changes on turns for recovery for the preliminary loading condition; equivalent test altitude, 2500 feet

	Preliminary normal loading				ΔI_X and ΔI_Z = 0.23 I_X			ΔI_Y and ΔI_Z = 0.40 I_Y		
Ailerons	Neutral				Neutral			Neutral		
Elevator	U (h)	U (h)	N	D	U	N	D	U	N	D
α, deg	26	36	No spin	No spin	24	No spin	No spin	36	39	40
φ, deg	9U	3U			6U			0	8U	6U
Ω, rps	0.30	0.29			---			0.23	0.31	0.32
V, fps	202	164			219			172	144	138
Turns for recovery	$\frac{1}{2}$	$\frac{3}{4}$			$\frac{1}{2}$			---	1	$\frac{1}{2}$
Load factor	2.29	1.70			2.42			1.68	1.60	1.54

	c.g. moved forward 0.06$\bar{c}$			c.g. moved forward 0.15$\bar{c}$			c.g. moved back 0.05$\bar{c}$			ΔI_Y and ΔI_Z = 0.28 I_Y; c.g. moved back 0.08$\bar{c}$		
Ailerons	Neutral			Neutral			Neutral			Neutral		
Elevator	U	N	D	U	N	D	U	N	D	U	N	D
α, deg	30	No spin	No spin	No spin	No spin	No spin	35	No spin	No spin	38	55	51
φ, deg	5U						3U			0	3U	5U
Ω, rps	---						0.25			0.20	0.29	0.30
V, fps	206						171			158	127	131
Turns for recovery	$\frac{1}{2}$						$\frac{3}{4}$			1	$1\frac{1}{4}$	$1\frac{1}{2}$
Load factor	1.99						1.73			1.62	1.22	1.29

[a]Too oscillatory to test.
[b]Recovery attempted by neutralizing the rudder.
[c]Recovery attempted by releasing the rudder.
[d]Recovery attempted by releasing the elevator.
[e]Recovery attempted by neutralizing the rudder and elevator.
[f]Model oscillatory in pitch.
[g]Steep spin or spiral.
[h]Two types of spin.

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ABSTRACT

A compilation of free-spinning-airplane model data on the spin and recovery characteristics of 111 airplanes is presented. These data were previously published in separate memorandum reports and were obtained from free-spinning tests in the Langley 15-foot and the Langley 20-foot free-spinning tunnels. The model test data presented include the steady-spin and recovery characteristics of each model for various combinations of aileron and elevator deflections and for various loadings and dimensional configurations. Dimensional data, mass data, and a three-view drawing of the corresponding free-spinning tunnel model are also presented for each airplane. The data presented should be of value to designers and should facilitate the design of airplanes incorporating satisfactory spin-recovery characteristics.