NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1575

THE EFFECT OF VARIATIONS IN MOMENTS OF INERTIA ON SPIN AND RECOVERY CHARACTERISTICS OF A SINGLE-ENGINE LOW-WING MONOPLANE WITH VARIOUS TAIL ARRANGEMENTS, INCLUDING A TWIN TAIL

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SUMMARY

An investigation has been conducted in the Langley 15-foot free-spinning tunnel on a research model, representative of a present-day trainer or a four-place cabin monoplane, with varied moments of inertia. The tests were made for eight different wing arrangements and four different tail arrangements, including a twin tail. The moments of inertia about the three airplane axes were increased or decreased by a constant percentage and the results were compared. Comparison is also made between these results and those previously presented for conditions with the airplane relative density varied.

The results of variation of moments of inertia indicated that, within the range of the present tests, uniformly decreasing the moments of inertia led to steeper spins, higher angular and vertical velocities, and faster recoveries. Comparison of these results with results of previous tests indicated that adding weight at the center of gravity up to 50 percent of the basic weight led to higher rates of descent and rotation, had little effect upon recoveries when the elevators were up, and generally had a somewhat adverse effect upon recoveries when the elevators were neutral or down. The results also indicated that the twin-tail configuration was a very effective arrangement as regards spin recovery.

INTRODUCTION

Spin-tunnel experience has indicated that moments of inertia may have significant effects upon the spin and recovery characteristics of an airplane. In order to make available additional results on the effects of moments of inertia, the results of an investigation conducted during 1939 on a low-wing airplane model in the Langley 15-foot free-spinning tunnel are presented in this paper. Eight different wing arrangements and four different tail arrangements, including a twin tail, were investigated. The investigation was an extension of the research conducted with the low-wing airplane model reported in references 1 to 5.

For the investigation referred to herein, moments of inertia about the three airplane axes were increased or decreased by a constant percentage. Such changes would occur on an airplane if items of load were shifted along both the wings and the fuselage. The present results are considered comparable to those previously obtained when the relative density was varied (reference 5). In reference 5, the results presented were for loadings obtained by increasing or decreasing the moments of inertia and at the same time altering the weight correspondingly in order to keep the radii of gyration constant. For the present tests, corresponding moment-of-inertia variations were made but the weight was maintained constant.

The tail arrangements varied from a short rudder above a shallow fuselage to a full-length rudder and raised horizontal tail on a deep fuselage, and also included a twin-tail design. The wing variables were: tip shape, airfoil section, plan form, thickness, and landing flaps.

SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing mean chord, inches $\left(\frac{S}{b}\right)$
x/c	ratio of distance of center of gravity rearward of leading edge of wing mean chord to wing mean chord
z/c	ratio of distance between center of gravity and thrust line to wing mean chord (positive when center of gravity is below thrust line)
m	mass of airplane, slugs
ρ	air density, slug per cubic foot
μ	airplane relative-density parameter $\left(\frac{m}{\rho S b}\right)$
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2
k_X, k_Y, k_Z	radii of gyration about X, Y, and Z body axes, respectively, feet
$\frac{I_X - I_Y}{mb^2}$	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

$\frac{I_Z - I_Y}{I_Z - I_X}$ inertia rolling-moment and yawing-moment parameter

α angle between thrust line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), degrees

φ angle between span axis and horizontal, degrees

V model rate of descent, feet per second

Ω model angular velocity about spin axis, radians per second

APPARATUS AND METHODS

The tests were conducted in the Langley 15-foot free-spinning tunnel which has since been superseded by the larger 20-foot free-spinning tunnel. A general description of model construction and testing technique in the Langley 15-foot free-spinning tunnel is given in reference 6. Use of a launching spindle has, however, been replaced by launching the model by hand into the vertically rising air stream. A photograph of a model spinning in the Langley 20-foot free-spinning tunnel is shown as figure 1.

The basic condition of the model for the present investigation was similar to the basic condition referred to in reference 5. The model is considered to represent a $\frac{1}{15}$-scale model of a current trainer or a four-place cabin monoplane. Figure 2 is a two-view drawing of the basic model, and photographs of the basic model are shown as figure 3. The wing and tail surfaces were independently removable and interchangeable to permit testing any combination. The exchange of surfaces could be made without any change in mass distribution. The mass distribution, however, could be independently varied by the relocation of weights.

The various wing configurations used are shown in figure 4 and are designated as follows:

Wing 1 - NACA 23012 section; rectangular plan form; Army tips.

Wing 2 - Same as wing 1 with 20-percent full-span split flaps deflected 60°.

Wing 3 - NACA 23012 section; rectangular plan form; rectangular tips.

Wing 4 - Same as wing 3 with faired tips.

Wing 5 - NACA 0009 section; rectangular plan form; Army tips.

Wing 6 - NACA 6718 section; rectangular plan form; Army tips.

Wing 7 - NACA 23012 section; 5:2 taper ratio; Army tips.

Wing 8 - NACA 23018-09 section (standard Army wing); 2:1 taper ratio; square center; Army tips.

Photographs of the wings are shown as figures 5 and 6. Figures 2 and 3 show the model with the basic wing (wing 1) and tail C installed. This wing is of NACA 23012 section with rectangular plan form and Army tips. In common with the other wings, it has an area of 150 square inches, a span of 30 inches, and no dihedral, twist, or sweepback. The other seven wings have varied dimensional characteristics as indicated in figures 4 and 6.

Each wing was mounted on the model at an angle of incidence equal to the angle of zero lift for the particular section.

The four tail configurations used are designated tails A, B, C, and D and are shown in figures 7 and 8. Tail C had a shallow fuselage with rudder completely above the tail cone. Tail B was derived from tail C by increasing the fuselage depth, raising the stabilizer and the elevators, and installing the original fin and rudder atop the deepened fuselage. Tail A was similar to tail B except for full-length rudder construction and slightly increased elevator cut-out. Tail D has the same areas and tail lengths as tail C. The vertical tail area was redistributed to form two vertical tails of circular plan form, each having half the original area. The dimensional characteristics of the various tail arrangements are given in table I. The tail-damping power factor was computed by the method described in reference 7. The stabilizer was set at zero incidence for each tail. There was no fin offset. A clockwork delay-action mechanism was installed in the model to actuate the controls during recovery tests.

The full-scale dimensional characteristics for this model (assumed 1/15 scale) with any one of the wings shown in figure 4 and with tail C installed would be:

Mean wing chord, inches	75
Span, feet	37.5
Wing area, square feet	234.4
Aspect ratio	6
Distance from quarter-chord point to elevator hinge, feet	16.6
Distance from quarter-chord point to rudder hinge, feet	16.9
Fin area, square feet	6.8
Rudder area, square feet	6.9
Stabilizer area, square feet	19.8
Elevator area, square feet	12.9
Control travel, degrees	
Rudder	±30
Elevator up	30
Elevator down	20

The model was ballasted by the installation of proper lead weights to represent an airplane spinning at 6000 feet altitude ($\rho = 0.001988$). If the model were arbitrarily assumed to be 1/15 scale, the corresponding characteristics for the basic loading and for the loadings with moments of inertia decreased and increased would be the values given in table II. The moments of inertia were decreased approximately 16 percent of the basic values and increased approximately 24 percent. It was noted for the present investigation that, with the moments of inertia decreased, the actual values of the moments of inertia were about the same as those for the low relative-density condition previously presented in reference 5. With the moments of inertia increased, the increases were approximately 60 percent of the corresponding increases obtained for the high relative-density condition.

PRECISION

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

α, degrees	±1
ϕ, degrees	±1
V, percent	±5
Ω, percent	±2
Turns for recovery	
when obtained from motion-picture records	$\pm\frac{1}{4}$
when obtained by visual estimate	$\pm\frac{1}{2}$

The preceding limits may have been exceeded for those spins for which it was difficult to control the model in the tunnel because the rate of descent was high or because the spin was wandering or oscillatory.

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

Weight, percent	± 1
Center-of-gravity location, percent c	± 1
Moments of inertia, percent	± 5

The controls were set with an accuracy of $\pm 1^{\circ}$.

Tests made at the basic, or normal, loading were repeat tests, and the results agreed fairly well with corresponding results of reference 5, although the agreement was not always exact as a result of inadvertent slight damages to the model resulting from testing.

TESTS

For each wing and tail combination with each set of values of the moments of inertia, spin tests were made for four control settings:

(a) Rudder 30° with the spin, elevators 30° up

(b) Rudder 30° with the spin, elevators neutral

(c) Rudder 30° with the spin, elevators 20° down

(d) Rudder neutral, elevators neutral

Recovery from (b) and (c) was attempted by reversal of the rudder, recovery from (a) by complete reversal of both controls as well as by reversal of the rudder alone, and recovery from (d) by moving the rudder full against the spin and the elevator full down. Ailerons were not deflected during the investigation.

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented in tables III to XI. Tables XII to XIX present a comparison of results obtained with the moments of inertia decreased with the corresponding results previously obtained with the relative density decreased and thus afford a determination of the effect of variation in weight at the center of gravity. All results are presented in terms of model values. Conversion to full-scale values may be obtained by methods described in reference 6.

Effects of Moment-of-Inertia Variations

Tables III to X indicate that, when the rudder was initially with the spin, the qualitative effects upon the spin and recovery characteristics of variation in the moments of inertia were generally the same for each of the tail and wing arrangements tested. In general, decreasing the moments of inertia led to steeper spins and more rapid recoveries; whereas increasing the moments of inertia led to somewhat flatter spins and slower recoveries. The angular and vertical velocities in the spin increased as the moments of inertia decreased, and vice versa.

Table XI presents the results of tests for decreased, basic, and increased values of moments of inertia when all the controls, including rudder, were neutral. When the twin tail, tail D, was installed, no spin was obtained for any wing arrangement or any moment-of-inertia condition.

As previously indicated, the results presented in reference 5 were for loadings with varied relative densities which were obtained by changing the moments of inertia and at the same time changing the weight to keep the radii of gyration constant. Comparison of the current results with those presented in reference 5 indicates that, for the range of mass variation considered in this investigation, systematic changes in moments of inertia will affect the recovery characteristics in a manner similar to that brought about by changes in relative density involving similar moment-of-inertia variations, particularly when the elevators are up. It thus appears that the changes in moments of inertia associated with a change in relative density are primary factors affecting the spin recovery. In tables XII to XIX, results with moments of inertia decreased are compared with results for relative density decreased for the different wing arrangements. The condition with moments of inertia decreased represents the model with weight in at the center of gravity; whereas the condition with the relative density decreased represents the model with the weight out at the center of gravity. The difference in weight was approximately 25 percent. When the elevators were up, the recovery characteristics for the two loadings were quite similar although the rates of descent and the angular velocities in spins were higher with the weight in. When the elevators were neutral or down, the results were not always consistent, but a small adverse effect upon recovery characteristics appeared to result from adding weight at the center of gravity.

Although no comparison is presented herein, the test results with moments of inertia increased may be compared with corresponding results from reference 5 with the relative density increased. The difference in these two loadings can be considered to represent the effect of added weight at the center of gravity of approximately 50 percent of the basic weight. As previously mentioned, the moment-of-inertia changes were not so great as those made in reference 5, but the general conclusions to be drawn are quite similar to those drawn from the comparison made between decreased moments of inertia and decreased relative density.

Effects of Tail and Wing Arrangement

Comparison of the results for tails A, B, and C for any moment-of-inertia condition indicated that tail A gave the most rapid recoveries and tail B gave the steepest spins but slower recoveries; tail C gave the slowest recoveries. The effects of wing and loading variations were most apparent for tail C. With the twin tail D installed, spins for any moment-of-inertia condition were generally as steep as those for tail B, but recoveries were as good as or better than those for tail A. Tail D, as previously indicated, was formed by the use of vertical fin and rudder areas equal to those for tail C, and the improved recovery characteristics obtained with the twin-tail configuration indicates that it is a very effective arrangement as regards spin recovery. The difference in results obtained for tails A, B, C, and D are in agreement with the findings of reference 8.

For any moment-of-inertia condition, the wings with rectangular and faired tips (wings 3 and 4) gave the steepest spins, the most outward sideslip, and the most rapid recoveries. The rectangular wing with Army tips (wing 1) consistently gave flatter spins and slower recoveries. Even slower recoveries were obtained for the wing with 5:2 taper (wing 7). The wing with NACA 6718 section (wing 6) led to spins in which the inner wing was down a relatively large amount. Flaps deflected 60° (wing 2) generally retarded recovery. The Army standard wing (wing 8) generally gave more satisfactory recovery characteristics than the basic rectangular wing.

The NACA 0009 section (wing 5) led to faster recoveries when the moments of inertia were decreased than did either the 23012 or the 6718 section; whereas, when the moments of inertia were increased, the NACA 6718 section (wing 6) led to the fastest recoveries. These results may be explained on the basis of reference 9, which indicates that as $\frac{I_X - I_Y}{mb^2}$ becomes more negative, downward tilt of the inboard wing during the spin is favorable, and vice versa. It was noted that when wing 5 was installed on the model, the outboard wing tip (left tip in a right spin) was tilted down; whereas when wing 6 was installed, the inboard tip was down. Also, the relative mass distribution along the fuselage was decreased $\left(\frac{I_X - I_Y}{mb^2}\text{ became less negative}\right)$ when the moments of inertia were decreased, and vice versa.

The effects of tail and wing variables were in general similar to those previously reported in reference 5.

Effects of Control Setting

Within the range tested, moment-of-inertia variations appeared to have no appreciable effect upon control effectiveness in producing recoveries. Recoveries from spins with the elevator neutral and the rudder with the spin were very similar to those from corresponding spins with the elevators down. Except for the twin-tail, tail D, holding the elevators up resulted in the steepest spins (from which the most rapid recoveries were obtained). For the twin-tail arrangement, elevators up gave somewhat flatter spins than elevators down. The simultaneous reversal of the rudder from rudder with to rudder against the spin and of the elevator from up to down gave better recovery than only rudder reversal for tails B and C (the tails with short rudders) but not for tails A and D.

CONCLUSIONS

The results of tests made on a research model with varied moments of inertia, and comparison with previous results led to the following conclusions:

1. Uniformly decreasing the moments of inertia led to steeper spins, higher angular and vertical velocities, and faster recoveries.

2. Adding weight up to 50 percent of the basic weight at the center of gravity led to higher rates of descent and higher angular velocities, had little effect upon recoveries when the elevators were up, and generally had a somewhat adverse effect upon recoveries when the elevators were neutral or down.

3. The twin-tail configuration was a very effective arrangement as regards spin recovery.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., December 31, 1947

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE VARIOUS TAIL ARRANGEMENTS

Tail	Vertical tail area (percent wing area)	Fuselage side area (back and below leading edge of stabilizer) (percent wing area)	Vertical tail length (from c/4 point of wing to rudder hinge line) (percent wing span)	Horizontal tail area (percent wing area)	Horizontal tail length (from c/4 point of wing to elevator hinge line) (percent wing span)	Tail-damping power factor
A	8 (rudder, 5; fin, 3)	3.0	45	14 (elevator, 5.5; stabilizer, 8.5)	44	136×10^{-6}
B	6 (rudder, 3; fin, 3)	4.3	45	14 (elevator, 5.5; stabilizer, 8.5)	44	5
C	6 (rudder, 3; fin, 3)	1.1	45	14 (elevator, 5.5; stabilizer, 8.5)	44	0
D	6 (rudder, 3; fin, 3)	1.1	45	14 (elevator, 5.5; stabilizer, 8.5)	44	393

TABLE II.- FULL-SCALE LOADINGS BASED ON ASSUMPTION OF $\frac{1}{15}$-SCALE MODEL

Item	Loading with moments of inertia decreased	Basic loading	Loading with moments of inertia increased
Weight, lb . . .	4720	4720	4720
I_X, slug-ft^2. . .	2310	2760	3380
I_Y, slug-ft^2. . .	3320	3970	4915
I_Z, slug-ft^2. . .	5040	6150	7700
$\frac{I_X - I_Y}{mb^2}$	-49×10^{-4}	-59×10^{-4}	-75×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-83×10^{-4}	-105×10^{-4}	-135×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	132×10^{-4}	164×10^{-4}	210×10^{-4}
$\frac{I_Z - I_Y}{I_Z - I_X}$	0.64	0.64	0.64
μ (at 6000 ft). .	8.4	8.4	8.4
x/c	0.25	0.25	0.25
z/c	0	0	0

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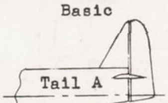
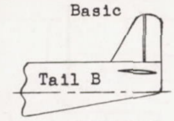
TABLE III.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 1 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]



Elevator	Moments of inertia: Decreased	Basic	Increased
Up	50.2, 1.8D	54.1, 1.3D	54.7, 2.8D
	40.9, 11.5	39.5, 10.5	40.0, 9.5
	$1\frac{1}{4}$, $1\frac{1}{4}$	$1\frac{1}{2}$, $1\frac{1}{2}$	$1\frac{1}{2}$, $1\frac{1}{2}$
	[a]1, [a]1	[a]$1\frac{1}{2}$, [a]$1\frac{3}{4}$	[a]2, [a]$2\frac{1}{4}$
Neutral	53.2, 0.6U	58.9, 0.9D	61.7, 0.8D
	36.4, 13.6	35.5, 12.5	35.0, 11.5
	$2\frac{1}{4}$, $2\frac{1}{4}$	3, $3\frac{1}{4}$	$3\frac{1}{4}$, $3\frac{1}{2}$
Down	53.1, 1.3U	59.1, 0	61.0, 1.1D
	35.9, 14.0	34.5, 12.8	35.0, 11.5
	$2\frac{3}{4}$, 3	3, 3	$3\frac{1}{2}$, $3\frac{1}{2}$



Elevator	Moments of inertia: Decreased	Basic	Increased
Up	44.7, 3.7D	44.0, 4.0D	45.6, 5.0D
	43.2, 10.7	43.2, 10.7	42.3, 8.3
	$2\frac{1}{2}$, $2\frac{1}{2}$	$1\frac{3}{4}$, $2\frac{1}{2}$	$2\frac{1}{2}$, $2\frac{1}{2}$
	[a]$1\frac{1}{4}$	[a]$1\frac{1}{2}$	[a]$1\frac{1}{2}$, [a]$1\frac{1}{2}$
Neutral	49.7, 0.3U	52.5, 0.2U	53.0, 0.8D
	38.2, 13.1	37.3, 11.9	38.2, 10.5
	$3\frac{1}{2}$, 4	[b]11	[bc]∞
Down	50.3, 0.7U	52.4, 0.3U	53.1, 0.5D
	36.8, 13.1	36.8, 12.2	37.3, 10.9
	$3\frac{1}{4}$, $3\frac{1}{4}$	[b]5, [b]11	[bc]∞

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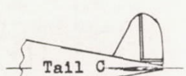
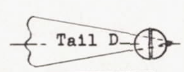


Elevator	Moments of inertia: Decreased	Basic	Increased
Up	44.4, 5.3D	45.1, 5.1D	47.2, 3.6D
	42.3, 10.8	43.2, 9.8	41.8, 8.7
	$2\frac{3}{4}$, $3\frac{1}{2}$	$3\frac{1}{2}$, $4\frac{1}{4}$	[c]∞
	[a]1, [a]$1\frac{1}{4}$	[a]$1\frac{1}{4}$, [a]$1\frac{1}{4}$	[a]$3\frac{1}{4}$
Neutral	52.8, 0.3U	56.3, 0.6D	59.6, 1.6D
	35.0, 13.1	35.5, 12.2	35.5, 11.1
	[bc]∞	[bc]∞	[bc]∞
Down	53.0, 1.7U	56.3, 0.2D	59.6, 1.6D
	35.0, 13.7	35.5, 12.6	34.5, 11.4
	[b]7, [b]9	[bc]∞	[bc]∞



Elevator	Moments of inertia: Decreased	Basic	Increased
Up	45.9, 2.7D	53.2, 0.9D	56.9, 2.0D
	40.0, 11.6	37.7, 11.0	37.7, 10.2
	$1\frac{1}{2}$, $1\frac{3}{4}$	2, 2	$2\frac{1}{4}$, $2\frac{1}{4}$
	[a]$1\frac{1}{2}$, [a]$1\frac{3}{4}$	[a]$2\frac{1}{2}$, [a]$2\frac{1}{2}$	[a]$2\frac{3}{4}$, [a]3
Neutral	47.0, 0.5D	47.4, 1.6D	55.3, 1.8D
	39.1, 14.0	38.7, 12.1	36.4, 11.4
	2, $2\frac{1}{4}$	$>2\frac{1}{4}$, $2\frac{1}{2}$	$3\frac{1}{4}$, $3\frac{1}{4}$
Down	32.6, 3.2U	47.3, 1.5D	54.4, 0.6D
	46.8, 17.1	38.1, 12.7	35.0, 11.6
	$1\frac{1}{4}$, $1\frac{1}{4}$	3, 3	$3\frac{3}{4}$, 4

[a]Recovery by reversal of both rudder and elevator.

[b]Visual estimate.

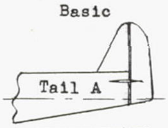
[c]∞ means model did not recover.

Model values
U inner wing up
D inner wing down

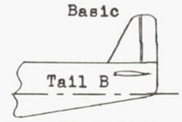
α (deg)	ϕ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

TABLE IV.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 2 INSTALLED

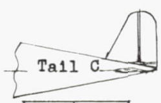
[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]



Elevator	Moments of inertia	α (deg)	ϕ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	Decreased	49.2	2.7D	36.8	11.9	$2, 2\frac{1}{4}$; [a]$1\frac{3}{4}$, [a]$1\frac{3}{4}$
Up	Basic	51.9	2.7D	36.4	10.8	$2\frac{1}{4}, 2\frac{1}{2}$; [a]3, [a]$3\frac{1}{4}$
Up	Increased	57.3	2.4D	35.9	10.0	$2\frac{3}{4}, 3$; [a]$4\frac{3}{4}$, [a]$5\frac{1}{4}$
Neutral	Decreased	54.8	1.4D	33.6	14.0	3, 3
Neutral	Basic	58.4	0.9D	33.6	12.5	$4\frac{1}{2}, 4\frac{3}{4}$
Neutral	Increased	61.6	2.0D	33.6	11.5	$>6\frac{1}{2}, 8$
Down	Decreased	51.6	0	33.2	14.2	$2\frac{1}{2}, 2\frac{1}{2}$
Down	Basic	57.2	1.9D	33.6	12.6	$4\frac{1}{4}, 4\frac{1}{2}$
Down	Increased	60.2	4.5D	33.6	11.7	[b]9, $10\frac{1}{4}$



Elevator	Moments of inertia	α (deg)	ϕ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	Decreased (d)					
Up	Basic	44.7	3.6D	39.6	9.5	[b]>2, [b]>4; [a]2, [a]$2\frac{1}{4}$
Up	Increased	46.2	3.0D	38.2	8.4	>4, [b]∞; [c]4, $4\frac{3}{4}$
Neutral	Decreased	52.4	0.4D	34.1	13.4	$4\frac{1}{4}, 4\frac{3}{4}$
Neutral	Basic	54.2	1.6D	34.6	12.1	[bc]∞
Neutral	Increased	56.8	1.0D	34.6	10.6	[bc]∞
Down	Decreased	51.0	0.8D	34.1	13.4	[b]$3\frac{1}{2}$, 4
Down	Basic	54.3	1.2D	34.1	12.4	[bc]∞
Down	Increased	55.7	0.8D	34.1	11.1	[bc]∞



Elevator	Moments of inertia	α (deg)	ϕ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	Decreased	49.8	2.5D	38.6	11.5	[b]∞, [b]∞; [a]$2\frac{1}{4}$, [a]$2\frac{3}{4}$
Up	Basic	52.0	2.6D	37.7	10.5	[b]>4, [b]∞; [a]$3\frac{1}{2}$, [a]$3\frac{1}{2}$
Up	Increased	54.9	2.6D	37.7	9.2	[bc]∞, [bc]∞; [abc]∞, [abc]∞
Neutral	Decreased	50.5	2.3D	35.4	13.4	[bc]∞, [c]∞
Neutral	Basic (e)	76.4 55.1	1.9U 1.8D	26.8 33.6	17.4 12.3	[bc]∞
Neutral	Increased (e)	60.1 76.5	2.3D 1.0D	34.6 27.2	11.3 16.0	[b]∞, [bc]∞
Down	Decreased	52.3	0.7D	34.6	13.8	[b]15, [b]25
Down	Basic (e)	76.3 57.3	1.4U 1.6D	26.8 33.2	18.0 12.7	[bc]∞
Down	Increased (e)	58.7 78.9	0.5D 0.4U	33.6 26.4	11.7 16.5	[b]∞, [b]∞

Elevator	Moments of inertia	α (deg)	ϕ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	Decreased	49.3	2.4D	36.4	12.3	$2\frac{3}{4}, 2\frac{3}{4}$; [a]$2\frac{1}{4}$, [a]$2\frac{1}{4}$
Up	Basic	54.2	1.9D	35.9	11.3	3, 3; [a]3, [a]3
Up	Increased	57.7	2.2D	35.4	10.5	$3\frac{1}{2}, 3\frac{1}{2}$; [a]$3\frac{1}{2}$, [a]4
Neutral	Decreased	47.6	1.9D	35.4	13.8	$2\frac{1}{4}, 2\frac{1}{4}$
Neutral	Basic	50.4	2.0D	35.0	12.4	$3\frac{1}{4}, 3\frac{1}{2}$
Neutral	Increased	57.0	2.1D	34.1	11.3	4, 4
Down	Decreased	No spin				
Down	Basic	44.9	1.9D	34.6	12.7	$3\frac{1}{4}, 3\frac{1}{2}$
Down	Increased	55.8	2.0D	34.1	11.6	$4\frac{1}{2}, 4\frac{3}{4}$

[a]Recovery by reversal of both rudder and elevator.
[b]Visual observation.
[c]∞ means model did not recover.
[d]The spin is steep and oscillatory.
[e]Two types of spin.

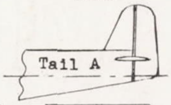
Model values
U inner wing up
D inner wing down

Key:

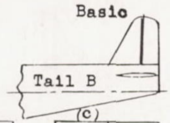
α (deg)	ϕ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

TABLE V.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 3 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]

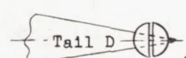


Elevator	Moments of inertia: Decreased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Basic α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Increased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	29.5	1.1D	54.6	12.1	[a]$\frac{1}{2}$; [ab]$\frac{1}{2}$	31.0	0.1D	52.3	11.0	$\frac{3}{4}$; [b]$\frac{1}{2}$, [b]$\frac{1}{2}$	51.0	2.0D	40.0	9.1	$1\frac{1}{4}$; [b]1, [b]1
Neutral	No	spin				51.4	1.7U	36.8	11.8	$1\frac{1}{2}$, $1\frac{3}{4}$	57.9	0.2U	35.0	10.9	$2\frac{1}{4}$, $2\frac{1}{4}$
Down	No	spin				49.7	2.4U	36.4	12.1	$1\frac{1}{2}$, $1\frac{1}{2}$	56.3	1.3U	35.0	11.0	$2\frac{1}{2}$, [a]$2\frac{1}{2}$



Elevator	Moments of inertia: Decreased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Basic α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Increased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	(c)					(c)					(c)				
Neutral	No	spin				25.1	5.3U	61.5	12.4	$\frac{1}{2}$	43.6	0.4U	40.9	10.5	$2\frac{1}{4}$, $2\frac{1}{4}$
Down	No	spin				34.8	1.3U	44.1	13.1	1	44.2	0.6U	39.6	10.8	$2\frac{1}{4}$, $2\frac{1}{4}$

Elevator	Moments of inertia: Decreased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Basic α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Increased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	33.0	5.3D	54.6	11.8	$\frac{1}{2}$, $\frac{1}{2}$; [b]$\frac{1}{2}$, [b]$\frac{1}{2}$	(c)					(c) 33.0	3.3D	61.5	9.0	
Neutral	34.7	1.7U	47.8	13.6	1	32.9	0.2D	51.4	12.6	$\frac{3}{4}$	35.2	0.8D	52.3	11.0	$\frac{3}{4}$
Down	38.5	4.1U	44.6	14.3	1	37.7	1.5U	45.4	13.1	$1\frac{1}{2}$	45.1	1.1U	38.6	11.1	$2\frac{3}{4}$, $3\frac{1}{2}$



Elevator	Moments of inertia: Decreased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Basic α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery	Increased α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Up	(c)		61.8			(c) 25.7	2.7D	59.1	11.8		(c)				
Neutral			50.0	14.3	$\frac{1}{2}$	24.8	10.2U	56.8	12.6	$\frac{1}{2}$	24.1	0.6D	54.6	11.6	$\frac{3}{4}$
Down			45.9	14.6	$1\frac{1}{4}$	30.2	10.8U	47.8	13.5	$1\frac{1}{4}$	29.2	5.4U	50.0	13.1	$1\frac{1}{4}$

[a]Visual estimate.

[b]Recovery by both rudder and elevator reversal.

[c]The spin is steep and oscillatory.

Model values

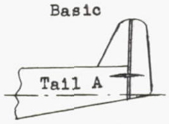
U inner wing up

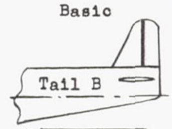
D inner wing down

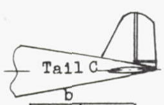
α (deg)	φ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

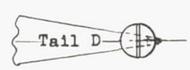
TABLE VI.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 4 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]









Tail	Elevator	Moments of inertia	α (deg)	φ (deg)	V (fps)	Ω (rad/sec)	Turns for recovery
Tail A	Up	Decreased	31.6	0.4U	52.3	11.8	$\frac{1}{2}$; [a]$<\frac{1}{2}$
Tail A	Up	Basic	45.6	1.0D	40.0	10.1	1, $1\frac{1}{4}$; [a]$\frac{3}{4}$, [a]1
Tail A	Up	Increased	53.1	0.9D	40.0	9.2	$1\frac{1}{2}$, $1\frac{1}{2}$; [a]$1\frac{1}{4}$, [a]$1\frac{1}{4}$
Tail A	Neutral	Decreased	No spin				
Tail A	Neutral	Basic	55.1	2.6U	34.1	12.2	2, 2
Tail A	Neutral	Increased	59.9	0.4U	35.0	11.0	$2\frac{3}{4}$, $2\frac{3}{4}$
Tail A	Down	Decreased	No spin				
Tail A	Down	Basic	54.7	2.1U	34.1	12.4	$1\frac{3}{4}$, 2
Tail A	Down	Increased	58.9	1.0U	35.0	11.2	$2\frac{1}{2}$, $2\frac{3}{4}$
Tail B	Up	Decreased	(b)				
Tail B	Up	Basic	(b)				
Tail B	Up	Increased	(b)				
Tail B	Neutral	Decreased	No spin				
Tail B	Neutral	Basic	34.1	0	47.8	12.6	$\frac{3}{4}$
Tail B	Neutral	Increased	46.2	0	40.9	10.6	$2\frac{1}{4}$, $2\frac{1}{2}$
Tail B	Down	Decreased	No spin				
Tail B	Down	Basic	37.2	4.3U	43.2	13.1	$1\frac{1}{4}$
Tail B	Down	Increased	47.1	0.7U	40.0	10.6	2, 2
Tail C	Up	Decreased	27.5	1.8D	61.5	12.1	$\frac{1}{2}$; [ac]$\frac{1}{4}$, [a]$\frac{1}{2}$
Tail C	Up	Basic (b)	26.6	2.0D	61.5	11.0	
Tail C	Up	Increased	27.6	3.3D	61.5	9.0	[c]$\frac{1}{4}$, [c]$\frac{1}{2}$; [ac]$\frac{1}{4}$, [ac]$\frac{1}{4}$
Tail C	Neutral	Decreased	29.6	12.1U	56.8	14.0	$\frac{1}{2}$
Tail C	Neutral	Basic	27.4	2.6U	52.3	13.1	$\frac{3}{4}$, $\frac{3}{4}$
Tail C	Neutral	Increased	28.0	1.5U	61.5	11.0	[c]$\frac{3}{4}$
Tail C	Down	Decreased	No spin				
Tail C	Down	Basic	32.0	5.2U	49.6	13.6	$\frac{1}{2}$
Tail C	Down	Increased	46.3	0.3U	38.6	11.1	$2\frac{1}{2}$, $3\frac{1}{4}$
Tail D	Up	Decreased	No data				
Tail D	Up	Basic	No data				
Tail D	Up	Increased	No data				
Tail D	Neutral	Decreased	No data				
Tail D	Neutral	Basic	26.4	8.9U	54.6	12.8	$\frac{3}{4}$
Tail D	Neutral	Increased	No data				
Tail D	Down	Decreased	No data				
Tail D	Down	Basic	31.7	7.9U	47.8	13.6	$1\frac{1}{4}$, $1\frac{1}{2}$
Tail D	Down	Increased	No data				

[a]Recovery by reversal of both rudder and elevator.
[b]The spin is steep and oscillatory.
[c]Visual observation.

Model values
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

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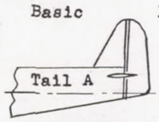
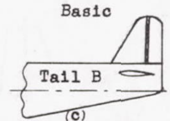
TABLE VII.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 5 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]



Moments of inertia

Elevator	Decreased	Basic	Increased
Up	46.5; 0.9D 41.4; 11.2 1, $1\frac{1}{8}$ [a]1, [a]1	50.7; 0 40.0; 9.9 1, $1\frac{1}{4}$ [a]$1\frac{1}{4}$, [a]$1\frac{1}{4}$	55.2; 0.6D 39.6; 9.2 $1\frac{1}{2}$, $1\frac{1}{2}$ [a]$1\frac{3}{4}$, [a]$1\frac{3}{4}$
Neutral	52.7; 2.7U 35.4; 13.2 $1\frac{3}{4}$, $1\frac{3}{4}$	58.4; 1.2U 35.0; 12.2 $2\frac{1}{2}$, $2\frac{3}{4}$	60.2; 0.8D 34.1; 11.2 3, $3\frac{1}{4}$
Down	52.3; 3.6U 34.6; 14.0 $1\frac{3}{4}$, $1\frac{3}{4}$	58.1; 1.3U 34.1; 12.6 $2\frac{1}{2}$, $2\frac{1}{2}$	59.6; 0.1D 34.1; 11.4 $3\frac{1}{4}$, $3\frac{1}{4}$



Moments of inertia

Elevator	Decreased	Basic	Increased
Up	(c)	(c)	45.7; 4.8D 43.2; 8.7 $1\frac{1}{4}$, $2\frac{1}{4}$ [a]1, [a]1
Neutral	41.1; 4.0U 40.9; 13.3 1, 1	52.8; 2.0U 37.7; 11.6 3, $3\frac{1}{4}$	53.1; 0.5U 37.2; 10.4 $5\frac{1}{2}$, 11
Down	43.1; 3.6U 39.1; 13.8 1, [b]1	53.3; 1.8U 36.4; 12.1 $2\frac{3}{4}$, 3	54.6; 0.7U 36.4; 10.7 6, 8

Elevator	Decreased	Basic	Increased
Up	36.5; 1.9D 47.8; 10.5 $\frac{1}{2}$ [ab]$\frac{1}{4}$, [a]$\frac{1}{2}$	41.4; 2.4D 46.8; 9.5 [b]$1\frac{1}{4}$, $1\frac{1}{2}$ [a]$\frac{3}{4}$, [a]$\frac{3}{4}$	45.9; 3.9D 42.2; 8.4 2, 2 [a]$1\frac{1}{2}$, [a]$1\frac{1}{2}$
Neutral	(d) 47.5; 1.8U 33.5; 0 40.4; 12.7 46.8; 12.6 $2\frac{1}{2}$, $3\frac{1}{2}$	56.1; 1.0U 35.9; 12.1 $8\frac{1}{2}$, [b]9	57.6; 0.4D 35.9; 10.8 [be]∞, [e]∞
Down	(d) 53.0; 3.0U 45.9; 3.1U 35.9; 13.4 40.4; 13.6 3, $3\frac{1}{2}$	56.7; 1.0U 35.4; 12.6 [b]8, [b]8	57.0; 0.4D 35.4; 11.2 [e]∞

Elevator	Decreased	Basic	Increased
Up	30.9; 2.1D 55.0; 12.6 $\frac{1}{2}$ [a]$\frac{1}{2}$	47.3; 1.3D 40.9; 10.5 [b]1, [b]1 [a]$1\frac{1}{2}$, [a]$1\frac{3}{4}$	54.0; 1.0D 38.2; 9.6 $1\frac{3}{4}$, $1\frac{3}{4}$ [a]$2\frac{1}{2}$, [a]$2\frac{1}{2}$
Neutral	32.3; 0.3U 50.4; 14.3 $\frac{3}{4}$	28.6; 3.0U 52.3; 12.7 $\frac{1}{2}$, 1	51.4; 0.4U 37.2; 10.9 $2\frac{1}{4}$, $2\frac{1}{2}$
Down	36.3; 4.1U 45.9; 15.7 $\frac{1}{2}$	33.4; 2.3U 46.8; 13.6 $1\frac{1}{4}$, $1\frac{1}{4}$	51.2; 0.1U 36.4; 11.2 $2\frac{3}{4}$, $2\frac{3}{4}$

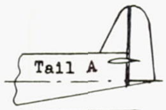
[a]Recovery by reversal of both rudder and elevator.
[b]Visual observation.
[c]The spin is steep and oscillatory.
[d]Two types of spin.
[e]∞ means model would not recover.

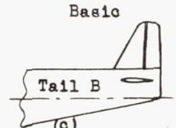
Model values
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

TABLE VIII.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 6 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]





Elevator	Tail A, Moments of inertia: Decreased	Tail A: Basic	Tail A: Increased	Tail B, Moments of inertia: Decreased	Tail B: Basic	Tail B: Increased
Up	45.6, 5.3D 41.4, 12.1 [b]1, 1$\frac{1}{4}$ [a]1, [a]1	47.8, 5.4D 40.0, 10.6 [b]1, 1$\frac{1}{4}$ [a]1, [a]1	53.7, 3.7D 38.2, 9.7 1$\frac{1}{2}$, 1$\frac{1}{2}$ [a]1$\frac{1}{4}$, [a]<1$\frac{1}{2}$	(c)	(c)	(c)
Neutral	49.4, 1.8D 38.2, 13.8 1$\frac{3}{4}$	53.0, 2.7D 35.4, 12.4 2$\frac{1}{4}$, 2$\frac{1}{4}$	58.7, 2.6D 35.0, 11.1 2$\frac{1}{4}$, 2$\frac{1}{4}$	45.1, 6.4D 38.6, 13.3 2, 2	47.1, 4.3D 38.6, 12.1 2$\frac{1}{2}$, [b]3	51.4, 3.8D 38.2, 10.5 3$\frac{3}{4}$, 4$\frac{1}{4}$
Down	49.7, 2.1D 37.7, 14.4 1$\frac{1}{2}$, 1$\frac{1}{2}$	53.6, 2.7D 35.9, 12.7 2$\frac{1}{4}$, 2$\frac{1}{4}$	57.2, 2.3D 35.4, 11.3 2$\frac{1}{2}$, 2$\frac{1}{2}$	44.6, 3.0D 37.7, 13.9 1$\frac{1}{2}$, 2$\frac{1}{4}$	47.0, 2.7D 37.7, 12.5 2$\frac{1}{2}$, 4$\frac{3}{4}$	49.5, 4.0D 37.2, 11.2 3$\frac{1}{2}$, 3$\frac{3}{4}$

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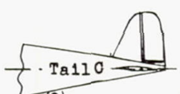


Elevator	Tail C: Decreased	Tail C: Basic	Tail C: Increased	Tail D: Decreased	Tail D: Basic	Tail D: Increased
Up	(c)	(c)	(c)	(e) 49.0, 7.7D 40.9, 12.6 1$\frac{1}{4}$ [ab]1$\frac{1}{4}$, [a]1$\frac{1}{2}$	(c)	47.7, 6.1D 40.9, 9.8 1$\frac{1}{4}$ [a]1$\frac{1}{4}$
Neutral	44.2, 6.1D 39.1, 13.6 4, 5$\frac{1}{2}$	44.7, 6.0D 40.4, 12.1 8$\frac{1}{2}$	47.2, 4.8D 40.4, 10.6 [bd]∞	(e) 45.8, 7.7D 37.7, 13.9 1$\frac{1}{2}$, [b]1$\frac{1}{2}$	(e) 45.2, 10.0D 38.2, 12.9 [b]1$\frac{3}{4}$, [b]1$\frac{3}{4}$	44.8, 5.7D 40.9, 11.1 1$\frac{1}{2}$, 1$\frac{3}{4}$
Down	46.0, 5.8D 39.1, 14.3 2, 2$\frac{3}{4}$	46.2, 4.3D 39.1, 12.9 9	50.5, 3.1D 38.2, 11.3 [b]>5, [bd]∞	(e) 43.3, 7.0D 37.2, 14.8 1$\frac{1}{2}$, 1$\frac{1}{2}$	(e) 45.6, 6.9D 38.2, 13.1 2, 2	44.5, 9.3D 40.9, 11.9 1$\frac{1}{2}$, 2

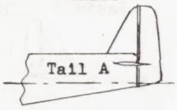
[a]Recovery by reversal of both rudder and elevator.
[b]Visual observation.
[c]The spin is steep and oscillatory.
[d]∞ means model would not recover.
[e]Very oscillatory.

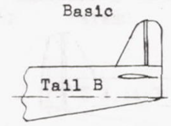
Model values
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

TABLE IX.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 7 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]





Elevator		Tail A, Moments of inertia: Decreased	Tail A: Basic	Tail A: Increased	Tail B, Moments of inertia: Decreased [d]	Tail B: Basic	Tail B: Increased
Up	α / φ	53.0 / 0.7D	54.7 / 0	56.2 / 0.8D		44.2 / 2.5D	49.7 / 1.0D
	V / Ω	39.1 / 11.8	37.2 / 10.7	38.6 / 9.8		43.2 / 9.8	41.4 / 8.5
	Turns for recovery	[a]$1\frac{1}{2}$, $1\frac{3}{4}$	$1\frac{1}{2}$, $1\frac{3}{4}$	2, 2			4, $5\frac{1}{2}$
	Turns for recovery	[b]$1\frac{1}{2}$, [b]$1\frac{1}{2}$	[b]$1\frac{3}{4}$, [b]$2\frac{1}{4}$	[b]$2\frac{3}{4}$, [b]3			[b]3, [b]$4\frac{1}{2}$
Neutral	α / φ	59.3 / 0.1D	59.8 / 0.2D	62.7 / 0.3D	54.6 / 1.3U	53.5 / 1.3U	55.4 / 0.4D
	V / Ω	34.1 / 14.0	34.1 / 12.6	35.4 / 11.3	35.4 / 12.8	36.4 / 11.8	38.6 / 10.5
	Turns for recovery	$3\frac{1}{2}$, $3\frac{3}{4}$	$3\frac{1}{2}$, $3\frac{1}{2}$	$3\frac{1}{2}$, $3\frac{3}{4}$	$6\frac{1}{2}$, $7\frac{3}{4}$	[ac]20, [ac]∞	[ac]∞
Down	α / φ	58.2 / 0.4U	59.0 / 0.9D	62.9 / 0.9D	53.6 / 1.3U	53.7 / 0.2D	55.2 / 0.3D
	V / Ω	34.1 / 14.3	34.1 / 13.0	35.0 / 11.7	35.0 / 13.2	35.9 / 12.3	35.9 / 11.0
	Turns for recovery	$2\frac{3}{4}$, 3	$3\frac{1}{2}$, $3\frac{1}{2}$	[a]$4\frac{1}{2}$, $4\frac{1}{2}$	$5\frac{1}{4}$, $6\frac{1}{2}$	[a]10, [a]11	[ac]∞

Elevator		Tail C: Decreased	Tail C: Basic	Tail C: Increased	Tail D: Decreased	Tail D: Basic	Tail D: Increased
Up	α / φ	59.0 / 1.1D	51.4 / 1.2D	53.5 / 0.8D	42.6 / 1.3D	51.3 / 0.5D	54.8 / 2.4D
	V / Ω	39.6 / 11.5	40.4 / 10.2	39.6 / 9.2	43.2 / 10.8	38.6 / 10.9	38.2 / 9.9
	Turns for recovery	$4\frac{1}{4}$, $4\frac{1}{2}$	10, 10	∞, [a]∞	1, $1\frac{1}{4}$	$1\frac{1}{2}$, $2\frac{1}{4}$	$1\frac{3}{4}$, $1\frac{3}{4}$
	Turns for recovery	[b]$2\frac{1}{4}$, [b]4	[b]3, [bc]∞	[ab]∞, [b]∞	[b]$1\frac{3}{4}$, [b]2	[b]2, [ab]$2\frac{1}{2}$	[b]$2\frac{1}{2}$, [b]$2\frac{3}{4}$
Neutral	α / φ	56.0 / 0.2D	59.4 / 1.0D	60.5 / 1.0D	33.9 / 2.5D	49.7 / 1.0U	54.1 / 0.4D
	V / Ω	35.4 / 13.6	34.6 / 12.9	35.0 / 11.5	48.6 / 14.8	37.7 / 12.3	35.9 / 11.1
	Turns for recovery	[a]∞	[ac]∞	[ac]∞, [c]∞	$1\frac{1}{4}$, $1\frac{1}{4}$	$2\frac{1}{2}$, $2\frac{1}{2}$	$2\frac{1}{2}$, 3
Down	α / φ	57.8 / 0.3D	61.3 / 1.0D	63.2 / 1.6D	31.5 / 0.9U	42.8 / 1.2U	53.9 / 1.3D
	V / Ω	35.0 / 14.3	34.1 / 13.2	34.1 / 12.0	49.6 / 17.2	45.9 / 14.3	35.9 / 11.5
	Turns for recovery	[a]∞	[ac]∞	[ac]∞, [c]∞	1	$1\frac{1}{2}$, 2	$3\frac{1}{2}$, $3\frac{3}{4}$

[a]Visual observation.
[b]Recovery by reversal of both rudder and elevator.
[c]∞ means model would not recover.
[d]The spin is steep and oscillatory.

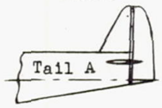
Model values
U inner wing up
D inner wing down

Key:

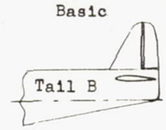
α (deg)	φ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

TABLE X.- SPIN AND RECOVERY CHARACTERISTICS OF A RESEARCH MODEL WITH WING 8 INSTALLED

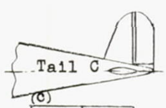
[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]



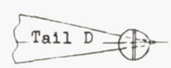
Elevator		Moments of inertia: Decreased	Basic	Increased
Up	α, ϕ	43.5, 0.5D	51.2, 1.2D	52.8, 1.6D
	V, Ω	44.10, 11.0	40.9, 10.2	39.6, 9.4
	Turns for recovery	1	$1\frac{1}{4}$, $1\frac{1}{4}$	$1\frac{1}{4}$, $1\frac{1}{4}$
		[a]$\frac{1}{4}$	[a]$1\frac{1}{4}$, [a]$1\frac{1}{4}$	[a]$1\frac{1}{2}$, [a]2
Neutral	α, ϕ	55.1, 0.7U	55.7, 0.2D	60.5, 0.5D
	V, Ω	35.9, 13.6	36.4, 12.1	36.4, 11.2
	Turns for recovery	$2\frac{1}{4}$, $2\frac{1}{4}$	$2\frac{1}{2}$, $2\frac{1}{2}$	$2\frac{3}{4}$, 3
Down	α, ϕ	52.9, 2.1U	54.4, 0.4U	60.5, 0.5D
	V, Ω	35.9, 14.2	36.4, 12.5	36.4, 11.5
	Turns for recovery	$2\frac{1}{4}$, $2\frac{1}{4}$	$2\frac{1}{2}$, $2\frac{1}{2}$	[b]$3\frac{1}{4}$, $3\frac{1}{4}$



Elevator		Moments of inertia: Decreased	Basic	Increased
Up	α, ϕ	(c)	(c)	(c)
	V, Ω			
	Turns for recovery			
Neutral	α, ϕ	(c) 46.2, 2.2U	46.5, 1.1D	52.2, 0.4D
	V, Ω	40.4, 13.1	38.6, 11.2	39.1, 10.3
	Turns for recovery		$3\frac{1}{4}$, $3\frac{1}{2}$	$4\frac{1}{2}$, $4\frac{3}{4}$
Down	α, ϕ	47.7, 2.7U	45.3, 2.0D	50.0, 0.3U
	V, Ω	40.0, 13.1	38.2, 12.1	38.6, 10.8
	Turns for recovery	2, $2\frac{1}{4}$	$3\frac{1}{4}$, $3\frac{1}{2}$	5, $5\frac{1}{2}$



Elevator		Moments of inertia: Decreased	Basic	Increased
Up	α, ϕ	(c)	(c)	40.4, 3.9D
	V, Ω			49.6, 8.5
	Turns for recovery			1
				[a]1
Neutral	α, ϕ	48.2, 1.6U	52.3, 0.3U	55.3, 1.0D
	V, Ω	37.7, 13.4	37.7, 12.2	37.2, 10.9
	Turns for recovery	$3\frac{1}{4}$, 4	[b]8, [b]12	[b]20, [d]∞
Down	α, ϕ	51.1, 1.9U	54.4, 0.5U	56.8, 1.0D
	V, Ω	37.2, 14.2	36.8, 12.7	36.8, 11.4
	Turns for recovery	5, 5	$14\frac{1}{2}$, [b]18	[bd]∞



Elevator		Moments of inertia: Decreased	Basic	Increased
Up	α, ϕ	29.9, 6.3D	47.3, 5.8D	49.3, 1.7D
	V, Ω	52.3, 12.6	47.8, 10.5	40.9, 9.5
	Turns for recovery	1	$\frac{3}{4}$	$1\frac{1}{2}$, $1\frac{1}{2}$
		[a]$\frac{1}{2}$	[a]$\frac{1}{2}$	[a]2, [a]2
Neutral	α, ϕ	(c)	(c)	32.1, 5.5D
	V, Ω	52.3		38.6, 10.9
	Turns for recovery			$2\frac{1}{4}$, $2\frac{1}{2}$
Down	α, ϕ	(c) 33.3, 1.0D	(c)	(c) 5.7D
	V, Ω	52.3, 15.0		
	Turns for recovery			

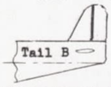
[a]Recovery by reversal of both rudder and elevator.
[b]Visual observation.
[c]The spin is steep and oscillatory.
[d]∞ means model would recover.

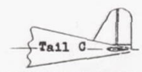
Model values
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

TABLE XI.- SPIN CHARACTERISTICS OF A RESEARCH MODEL WITH ALL CONTROLS NEUTRAL

[Turns for recovery measured when rudder is moved to full against the spin and the elevator is moved to full down; key to table given at bottom of page]





	Tail A: Moments of inertia			Tail B: Moments of inertia			Tail C: Moments of inertia			Tail D
	Decreased	Basic	Increased	Decreased	Basic	Increased	Decreased	Basic	Increased	
Wing 1		47.1, 1.5D	55.1, 1.3D	48.2, 0.6D	48.9, 0.6D	54.0, 0.8D	50.6, 0.2D	58.0, 1.3D	61.8, 0.6D	(d)
	No spin	39.6, 12.1	38.6, 10.7	38.6, 13.1	38.6, 11.8	37.7, 10.4	36.8, 13.0	35.0, 12.1	35.0, 11.3	
		$1\frac{7}{8}$, 2	3, 3	$2\frac{1}{2}$, $2\frac{1}{2}$	5, 5	[a]∞	8, 12	[a]∞	[a]∞	
Wing 2		53.1, 1.5D	56.8, 1.7D		53.9, 1.3D	56.2, 1.5D	52.9, 1.6D	(b) 75.9, 1.4D; 57.5, 1.3D	(b) 59.6, 2.3D; 77.3, 0.7D	(d)
	No spin	35.5, 12.3	35.4, 11.0	No spin	34.6, 12.0	34.6, 10.8	35.0, 13.4	27.7, 16.4; 33.6, 12.5	34.1, 11.5; 27.3, 15.7	
		$3\frac{3}{4}$, 4	$7\frac{3}{4}$, $>7\frac{3}{4}$		[a]∞	[a]∞	[a]∞ [a]∞	[a]∞	[a]∞	
Wing 3	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	(c)	(d)
Wing 4	No spin	No spin	No spin	No spin	No spin	No spin	No spin	No spin	(c)	(d)
Wing 5			52.0, 1.1U		47.3, 1.0U	53.0, 0		56.0, 0.4D	57.0, 0.2U	(d)
	No spin	No spin	38.2, 10.6	No spin	39.1, 11.6	37.7, 10.4	No spin	36.4, 12.0	35.9, 11.0	
			$2\frac{1}{2}$, $2\frac{3}{4}$		$2\frac{1}{2}$, $2\frac{1}{2}$	$5\frac{1}{4}$, 7		7, 8	[a]∞	
Wing 6					44.1, 6.6D	46.8, 5.0D	45.8, 7.8D	44.7, 8.8D	46.1, 6.7D	(d)
	No spin	No spin	No spin	No spin	38.6, 12.1	40.6, 10.5	39.1, 13.4	40.5, 12.1	40.5, 10.5	
					$1\frac{1}{4}$, 3	3, $4\frac{1}{2}$	3, 12	[a]∞	[a]∞	
Wing 7		50.6, 0.4U	52.2, 1.2D	51.7, 1.7U	52.8, 0.2U	54.7, 1.3D	54.0, 0.1U	58.0, 0.7D	62.7, 0.9D	(d)
	No spin	38.2, 12.2	38.6, 10.8	35.9, 13.1	37.2, 11.8	37.7, 10.6	35.9, 13.7	35.5, 12.8	35.8, 11.5	
		$3\frac{1}{4}$, $3\frac{1}{4}$	$3\frac{1}{4}$, $3\frac{1}{4}$	5, 5	[a]∞ [a]∞	[a]∞	[a]∞ [a]∞	[a]∞ [a]∞	[a]∞	
Wing 8					45.5, 2.0D	49.9, 0.4D		53.9, 0.1D	54.7, 0.8D	(d)
	No spin	No spin	No spin	No spin	39.1, 11.2	40.0, 10.4	No spin	37.7, 12.3	37.3, 11.1	
					$2\frac{3}{4}$, 3	6, $6\frac{1}{2}$		6, 8	[a]∞ [a]∞	

[a]∞ means model would not recover.
[b]Two types of spin.
[c]Very steep spin.
[d]No spin for any moment-of-inertia condition.

Model values
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

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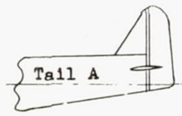
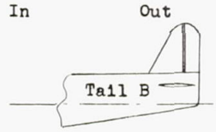
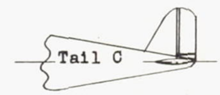
TABLE XII.- EFFECT OF WEIGHT VARIATION AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS; WING 1 INSTALLED

[Data for weight in at center of gravity obtained from current tests with moments of inertia decreased; data for weight out at center of gravity obtained from reference 5 with relative density decreased. Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]







		Tail A: Weight at center of gravity In	Tail A: Weight at center of gravity Out	Tail B: Weight at center of gravity In	Tail B: Weight at center of gravity Out	Tail C: Weight at center of gravity In	Tail C: Weight at center of gravity Out
Elevator up	α (deg)	50.2	49.5	44.7	42.3	44.4	45.2
	φ (deg)	1.8D	2.6D	3.7D	6.3D	5.3D	4.8D
	V (fps)	40.9	32.8	43.2	37.7	42.3	36.8
	Ω (rad/sec)	11.5	10.6	10.7	9.9	10.8	9.7
	Turns for recovery	$1\frac{1}{4}$, $1\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{1}{2}$, $2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{3}{4}$, $3\frac{1}{2}$	$3\frac{1}{4}$
		[a]1, [a]1	[a]1, [a]$1\frac{1}{4}$	[a]$1\frac{1}{4}$	[a]$\frac{1}{2}$	[a]1, [a]$1\frac{1}{4}$	[a]1
Elevator neutral	α (deg)	53.2	52.6	49.7	47.1	52.8	55.3
	φ (deg)	0.6U	1.0D	0.3U	0.5D	0.3U	1.5D
	V (fps)	36.4	29.7	38.2	32.7	35.0	28.7
	Ω (rad/sec)	13.6	12.3	13.1	12.2	13.1	12.7
	Turns for recovery	$2\frac{1}{4}$, $2\frac{1}{4}$	$1\frac{1}{2}$, $1\frac{3}{4}$	$3\frac{1}{2}$, 4	$1\frac{3}{4}$, 2	[c]∞	$5\frac{1}{2}$, $6\frac{1}{2}$
Elevator down	α (deg)	53.1	52.8	50.3	44.5	53.0	56.4
	φ (deg)	1.3U	0.1D	0.7U	1.4U	1.7U	0.8D
	V (fps)	35.9	29.2	36.8	33.2	35.0	28.2
	Ω (rad/sec)	14.0	12.6	13.1	13.1	13.7	13.4
	Turns for recovery	$2\frac{3}{4}$, 3	[b]$1\frac{1}{2}$, $1\frac{3}{4}$	$3\frac{1}{4}$, $3\frac{1}{4}$	1	[b]7, [b]9	6

[a]Recovery by reversal of both rudder and elevator.
[b]Visual estimate.
[c] ∞ means model did not recover.

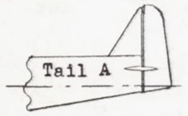
Model values
U inner wing up
D inner wing down

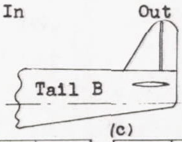
α (deg)	φ (deg)
V (fps)	Ω (rad/sec)
Turns for recovery	

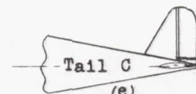
TABLE XIII.- EFFECT OF WEIGHT VARIATION AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS; WING 2 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]

Weight at center of gravity: In, Out







Tail	Elevator	Weight at center of gravity	α (deg)	ϕ (deg)	V (fps)	Ω (rps)	Turns for recovery
A	up	In	49.2	2.7D	36.8	11.9	2, $2\frac{1}{4}$; [a]$1\frac{3}{4}$, [a]$1\frac{3}{4}$
A	up	Out	49.3	2.9D	30.7	10.8	$1\frac{3}{4}$; [a]$1\frac{1}{2}$, [a]$1\frac{3}{4}$
A	neutral	In	54.8	1.4D	33.6	14.0	3, 3
A	neutral	Out	No spin				
A	down	In	51.6	0	33.2	14.2	$2\frac{1}{2}$, $2\frac{1}{2}$
A	down	Out	No spin				
B	up	In (b)					
B	up	Out (c)					
B	neutral	In	52.4	0.4D	34.1	13.4	$4\frac{1}{4}$, $4\frac{3}{4}$
B	neutral	Out	No spin				
B	down	In	51.0	0.8D	34.1	13.4	[e]$3\frac{1}{2}$, 4
B	down	Out	No spin				
C	up	In	49.8	2.5D	38.6	11.5	[d]∞, [d]∞; [a,f]$2\frac{1}{4}$, [a]$2\frac{3}{4}$
C	up	Out (e)	73.3 47.1	3.0D 4.1D	23.3 32.4	16.0 10.6	[d,f]∞, [d,f]∞, [f]25; [a,f]11, [a]$1\frac{1}{2}$, [a]2
C	neutral	In	50.5	2.3D	35.4	13.4	[f]∞, [d]∞
C	neutral	Out (e)	71.5 54.1	2.9D 2.0D	22.4 27.8	16.2 12.4	[d,f]∞, $4\frac{1}{2}$, 5
C	down	In	52.3	0.7D	34.6	13.8	[f]15, [f]25
C	down	Out	No spin				

[a]Recovery by reversal of both rudder and elevator.
[b]The spin is steep and oscillatory.
[c]Goes into a spiral glide.
[d]∞ means model would not recovery.
[e]Two types of spin.
[f]Visual observation.

Model values
U inner wing up
D inner wing down

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

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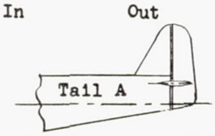
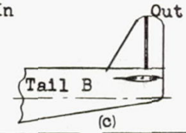
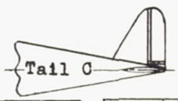
TABLE XIV.- EFFECT OF WEIGHT VARIATION AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS; WING 3 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]







Elevator	Quantity	Tail A: Weight at center of gravity In	Tail A: Weight at center of gravity Out	Tail B: Weight at center of gravity In [c]	Tail B: Weight at center of gravity Out [c]	Tail C: Weight at center of gravity In	Tail C: Weight at center of gravity Out
Elevator up	α (deg)	29.5	37.4		26.0	33.0	32.5
	ø (deg)	1.1D	3.4D		3.5D	5.3D	5.0D
	V (fps)	54.6	40.4		52.3	54.6	45.0
	Ω (rps)	12.1	10.1		9.7	11.8	10.5
	Turns for recovery	[a]$\frac{1}{2}$	$\frac{3}{4}$			$\frac{1}{2}$, $\frac{1}{2}$	1
		[ab]$\frac{1}{2}$	[b]$\frac{1}{2}$, [b]$\frac{1}{2}$			[b]$\frac{1}{2}$, [b]$\frac{1}{2}$	[ab]$\frac{1}{2}$, [b]$\frac{1}{2}$
Elevator neutral	α (deg)		36.9			34.7	37.0
	ø (deg)		1.7U			1.7U	0.3U
	V (fps)	No	38.8	No	No	47.8	37.8
	Ω (rps)	spin	12.6	spin	spin	13.6	12.3
	Turns for recovery		1, $1\frac{1}{4}$			1	$1\frac{1}{2}$, $1\frac{1}{2}$
Elevator down	α (deg)					38.5	38.2
	ø (deg)					4.1U	3.6U
	V (fps)	No	No	No	No	44.6	36.8
	Ω (rps)	spin	spin	spin	spin	14.3	13.1
	Turns for recovery					1	1, $1\frac{1}{4}$

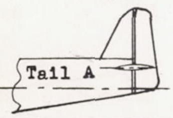
[a]Visual estimate.
[b]Recovery by both rudder and elevator reversal.
[c]The spin is steep and oscillatory.

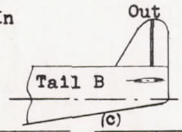
Model values
U inner wing up
D inner wing down

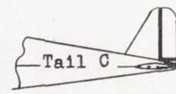
α (deg)	ø (deg)
V (fps)	Ω (rps)
Turns for recovery	

TABLE XV.- EFFECT OF WEIGHT VARIATIONS AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS; WING 4 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]







Tail	Weight at center of gravity	Elevator	α (deg)	φ (deg)	V (fps)	Ω (rps)	Turns for recovery
Tail A	In	up	31.6	0.4U	52.3	11.8	$\frac{1}{2}$; [a]$\frac{1}{2}$
Tail A	Out	up	34.6	1.3D	40.4	10.8	[b]$\frac{3}{4}$, 1; [ab]$\frac{3}{4}$, [ab]$\frac{3}{4}$
Tail B	In [c]	up					
Tail B	Out [c]	up					
Tail C	In	up	27.5	1.8D	61.5	12.1	$\frac{1}{2}$; [ab]$\frac{1}{4}$, [a]$\frac{1}{2}$
Tail C	Out	up	31.6	5.7D	45.0	10.4	$1\frac{1}{4}$; [a]$\frac{1}{2}$
Tail A	In	neutral	No spin				
Tail A	Out	neutral	38.4	0.6U	38.6	12.4	[b]1, [b]1
Tail B	In	neutral	No spin				
Tail B	Out	neutral	No spin				
Tail C	In	neutral	29.6	12.1U	56.8	14.0	$\frac{1}{2}$
Tail C	Out	neutral	36.2	0.6U	38.3	12.3	$1\frac{1}{4}$, $1\frac{1}{4}$
Tail A	In	down	No spin				
Tail A	Out	down	No spin				
Tail B	In	down	No spin				
Tail B	Out	down	No spin				
Tail C	In	down	No spin				
Tail C	Out [d]	down			37.8	13.1	

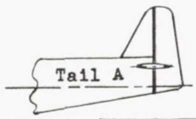
[a]Recovery by reversal of both rudder and elevator.
[b]Visual observation.
[c]The spin is steep and oscillatory.
[d]Data not obtained.

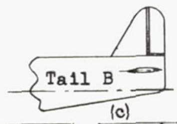
Model values
U inner wing up
D inner wing down

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

TABLE XVI.- EFFECT OF WEIGHT VARIATIONS AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS, WING 5 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]





	Tail A, weight at center of gravity In	Tail A, weight at center of gravity Out	Tail B, weight at center of gravity In	Tail B, weight at center of gravity Out	Tail C, weight at center of gravity In	Tail C, weight at center of gravity Out
Elevator up			[c]	[c]		
α (deg)	46.5	41.0			36.5	31.5
φ (deg)	0.9D	0.4D			1.9D	2.8D
V (fps)	41.4	39.1			47.8	44.1
Ω (rps)	11.2	10.6			10.5	10.1
Turns for recovery	$1, 1\frac{1}{4}$	$\frac{1}{2}$, [b]1			$\frac{1}{2}$	1
Turns for recovery	[a]1, [a]1	[ab]$\frac{1}{2}$			[ab]$\frac{1}{4}$, [a]$\frac{1}{2}$	[a]$\frac{1}{2}$
Elevator neutral					[d]	[e]
α (deg)	52.7	38.4	41.1	No spin	47.5 33.5	30.4
φ (deg)	2.7U	2.4U	4.0U		1.8U 0	1.5U
V (fps)	35.4	34.2	40.9		40.4 46.8	42.2
Ω (rps)	13.2	12.3	13.3		12.7 12.6	12.6
Turns for recovery	$1\frac{3}{4}, 1\frac{3}{4}$	1	1, 1		$2\frac{1}{2}, 3\frac{1}{2}$	1, 1
Elevator down					[d]	[c]
α (deg)	52.3	No spin	43.1	No spin	53.0 45.9	34.8
φ (deg)	3.6U		3.6U		3.0U 3.1U	3.1U
V (fps)	34.6		39.1		35.9 40.4	39.6
Ω (rps)	14.0		13.8		13.4 13.6	13.7
Turns for recovery	$1\frac{3}{4}, 1\frac{3}{4}$		1, [b]1		$3, 3\frac{1}{2}$	1, 1

[a]Recovery by reversal of both rudder and elevator.
[b]Visual observation.
[c]The spin is steep and oscillatory.
[d]Two types of spin.

Model values
U inner wing up
D inner wing down

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

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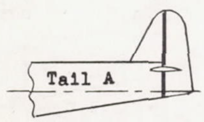
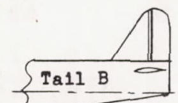
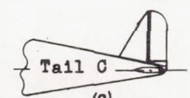
TABLE XVII.- EFFECT OF WEIGHT VARIATIONS AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS, WING 6 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]







		Tail A, weight at center of gravity: In	Tail A, weight at center of gravity: Out	Tail B, weight at center of gravity: In	Tail B, weight at center of gravity: Out	Tail C, weight at center of gravity: In	Tail C, weight at center of gravity: Out
Elevator up	α (deg)	45.6	42.9	(c)	(c)	(c)	(c)
	φ (deg)	5.3D	8.0D				
	V (fps)	41.4	36.3				
	Ω (rps)	12.1	10.9				
	Turns for recovery	[a]1, $1\frac{1}{4}$	$1\frac{1}{4}$, $1\frac{1}{2}$				
	Turns for recovery	[b]1, [b]1	[b]$\frac{3}{4}$, [ab]$\frac{3}{4}$				
Elevator neutral	α (deg)	49.4	47.0	45.1	(c)	44.2	46.5
	φ (deg)	1.8D	3.6D	6.4D		6.1D	4.9D
	V (fps)	38.2	31.4	38.6	34.1	39.1	35.4
	Ω (rps)	13.8	12.8	13.3	12.6	13.6	12.1
	Turns for recovery	$1\frac{3}{4}$	$1\frac{1}{2}$, $1\frac{1}{2}$	2, 2	2, $2\frac{1}{2}$	4, $5\frac{1}{2}$	$2\frac{1}{2}$, $2\frac{1}{2}$
Elevator down	α (deg)	49.7	45.0	44.6	41.4	46.0	46.5
	φ (deg)	2.1D	3.4D	3.0D	6.2D	5.8D	5.8D
	V (fps)	37.7	32.4	37.7	33.2	39.1	33.3
	Ω (rps)	14.4	13.3	13.9	13.0	14.3	13.4
	Turns for recovery	$1\frac{1}{2}$, $1\frac{1}{2}$	$1\frac{1}{2}$, $1\frac{1}{2}$	$1\frac{1}{2}$, $2\frac{1}{4}$	1, 1	2, $2\frac{3}{4}$	$1\frac{1}{2}$, $3\frac{1}{2}$

[a]Visual observation.
[b]Recovery by reversal of both rudder and elevator.
[c]The spin is steep and oscillatory.

Model values
U inner wing up
D inner wing down

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

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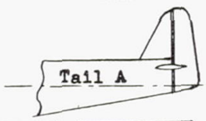
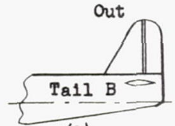
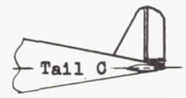
TABLE XVIII.- EFFECT OF WEIGHT VARIATIONS AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS, WING 7 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]







Elevator	Quantity	Tail A: Weight at center of gravity In	Tail A: Weight at center of gravity Out	Tail B: Weight at center of gravity In [c]	Tail B: Weight at center of gravity Out [c]	Tail C: Weight at center of gravity In	Tail C: Weight at center of gravity Out
Elevator up	α (deg)	53.0	48.5			59.0	45.3
	ϕ (deg)	0.7D	0.6D			1.1D	1.7D
	V (fps)	39.1	33.7			39.6	35.9
	Ω (rps)	11.8	10.7			11.5	10.5
	Turns for recovery	[a]$1\frac{1}{2}$, $1\frac{3}{4}$	$1\frac{1}{2}$, $1\frac{3}{4}$			$4\frac{1}{4}$, $4\frac{1}{2}$	$2\frac{1}{4}$, $2\frac{3}{4}$
	Turns for recovery	[b]$1\frac{1}{2}$, [b]$1\frac{1}{2}$	[b]1, [b]1			[b]$2\frac{1}{4}$, [b]4	[b]1, [b]$1\frac{1}{4}$
Elevator neutral	α (deg)	59.3	56.2	54.6	45.5	56.0	58.7
	ϕ (deg)	0.1D	0.5U	1.3U	0.2D	0.2D	0.6D
	V (fps)	34.1	28.7	35.4	33.6	35.4	28.7
	Ω (rps)	14.0	12.5	12.8	12.4	13.6	13.3
	Turns for recovery	$3\frac{1}{2}$, $3\frac{3}{4}$	$2\frac{1}{4}$, $2\frac{1}{2}$	$6\frac{1}{2}$, $7\frac{3}{4}$	$2\frac{1}{2}$, $2\frac{3}{4}$	[a]∞	[a]13, [a]15
Elevator down	α (deg)	58.2	53.1	53.6	46.9	57.8	57.1
	ϕ (deg)	0.4U	1.4U	1.3U	2.6U	0.3D	0.4U
	V (fps)	34.1	28.7	35.0	31.8	35.0	28.7
	Ω (rps)	14.3	13.0	13.2	13.0	14.3	13.7
	Turns for recovery	$2\frac{3}{4}$, 3	$2\frac{1}{2}$, $2\frac{3}{4}$	$5\frac{1}{4}$, $6\frac{1}{2}$	$2\frac{1}{4}$, $2\frac{1}{2}$	[a]∞	[a]11, $11\frac{1}{2}$

[a]Visual observation.
[b]Recovery by reversal of both rudder and elevator.
[c]The spin is steep and oscillatory.

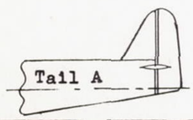
Model values
U inner wing up
D inner wing down

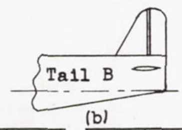
Key:

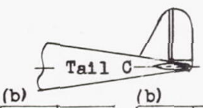
α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

TABLE XIX.- EFFECT OF WEIGHT VARIATIONS AT CENTER OF GRAVITY OF A RESEARCH MODEL UPON THE SPIN AND RECOVERY CHARACTERISTICS, WING 8 INSTALLED

[Spin data presented for ailerons neutral, rudder with the spin; turns for recovery measured when rudder alone is reversed fully and rapidly, except as noted; key to table given at bottom of page]







Elevator	Quantity	Tail A, weight at center of gravity: In	Tail A: Out	Tail B, weight at center of gravity: In	Tail B: Out	Tail C, weight at center of gravity: In	Tail C: Out
Elevator up				(b)	(b)	(b)	(b)
	α (deg)	43.5	42.4				
	φ (deg)	0.5D	2.5D				
	V (fps)	44.1	38.7				
	Ω (rps)	11.0	9.9				
	Turns for recovery	1	1				
	Turns for recovery	a 1/4	a 1/2				
Elevator neutral				(b)	(b)		
	α (deg)	55.1	48.7	46.2		48.2	50.7
	φ (deg)	0.7U	1.3U	2.2U		1.6U	0.2U
	V (fps)	35.9	30.5	40.4		37.7	31.0
	Ω (rps)	13.6	12.3	13.1		13.4	12.5
	Turns for recovery	2 1/4, 2 1/4	2, 2			3 1/4, 4	3 1/4, 3 3/4
Elevator down	α (deg)	52.9	45.1	47.7	No spin	51.1	48.9
	φ (deg)	2.1U	2.0	2.7U		1.9U	1.9U
	V (fps)	35.9	31.8	40.0		37.2	31.0
	Ω (rps)	14.2	13.0	13.1		14.2	12.9
	Turns for recovery	2 1/4, 2 1/4	1 3/4, 1 3/4	2, 2 1/4		5, 5	3, 3 1/4

[a] Recovery by reversal of both rudder and elevator.
[b] The spin is steep and oscillatory.

Model values
U inner wing up
D inner wing down

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

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Figure 1.- A model spinning in the Langley 20-foot free-spinning tunnel.

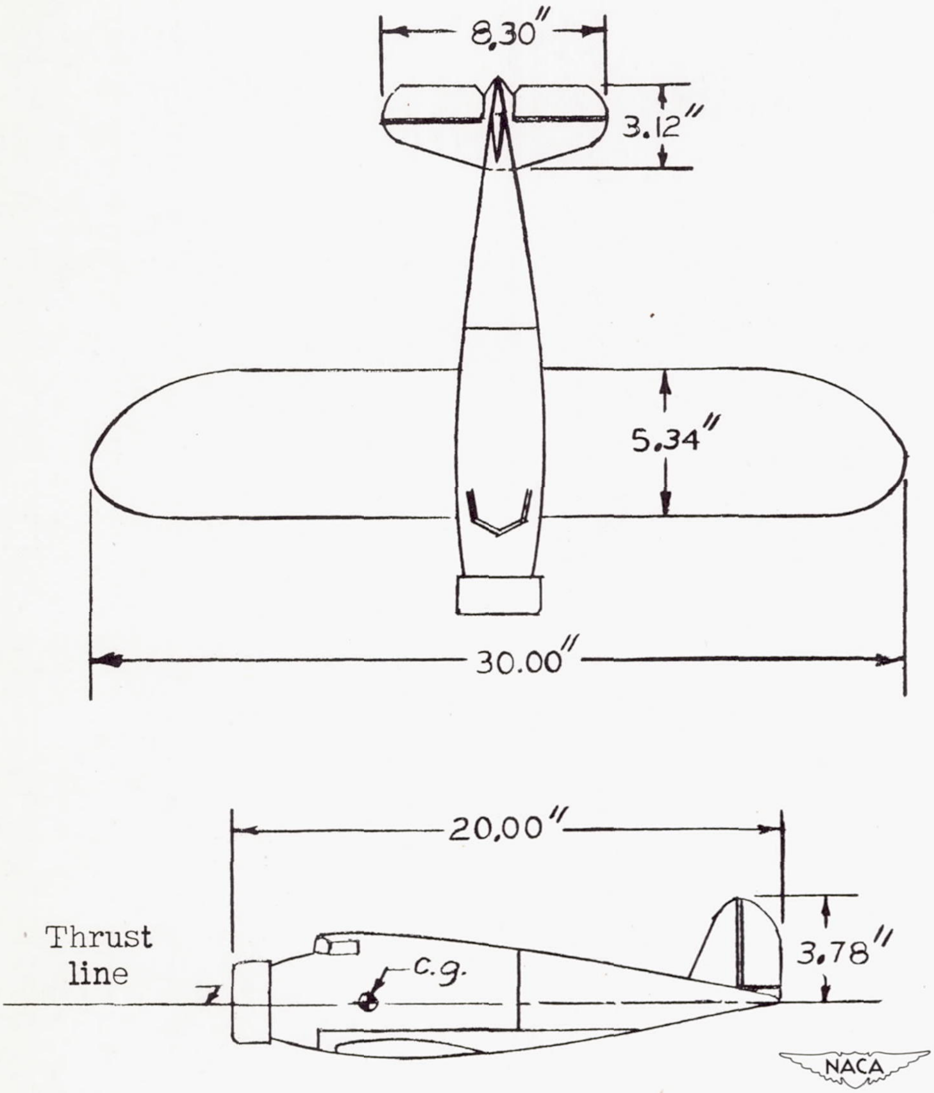


Figure 2.- Low-wing monoplane model with detachable tail and wing.

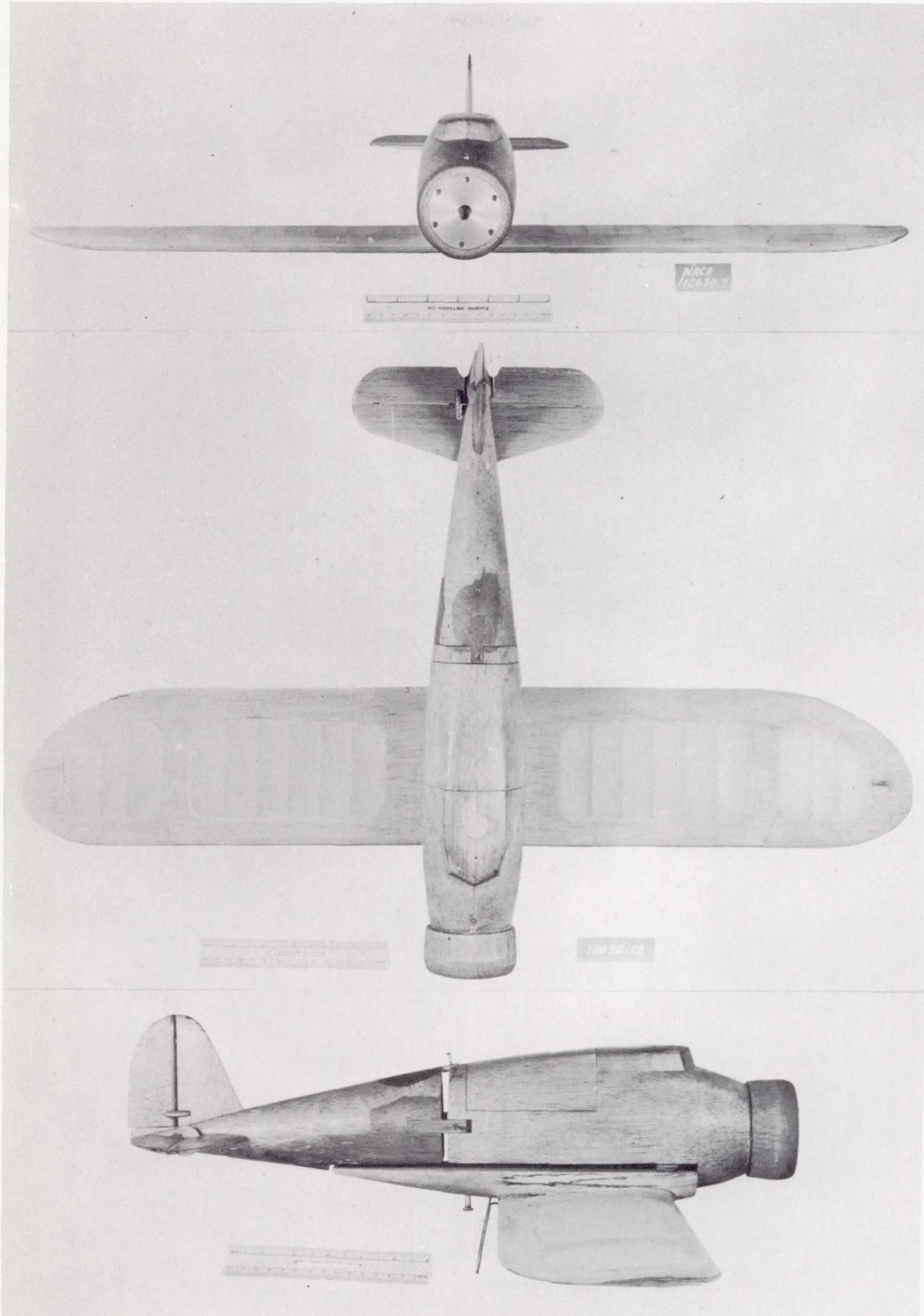


Figure 3.- Low-wing monoplane model.

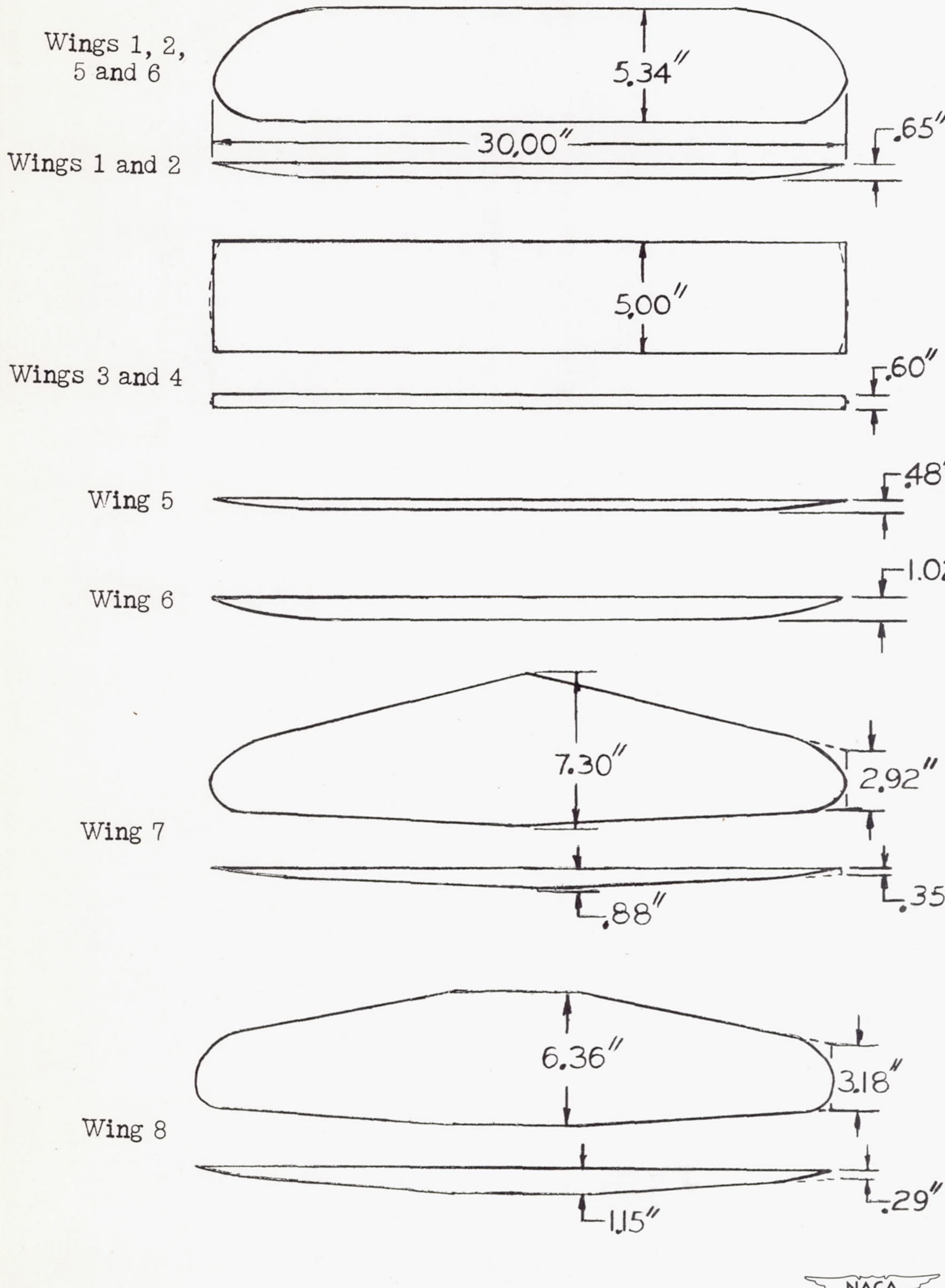
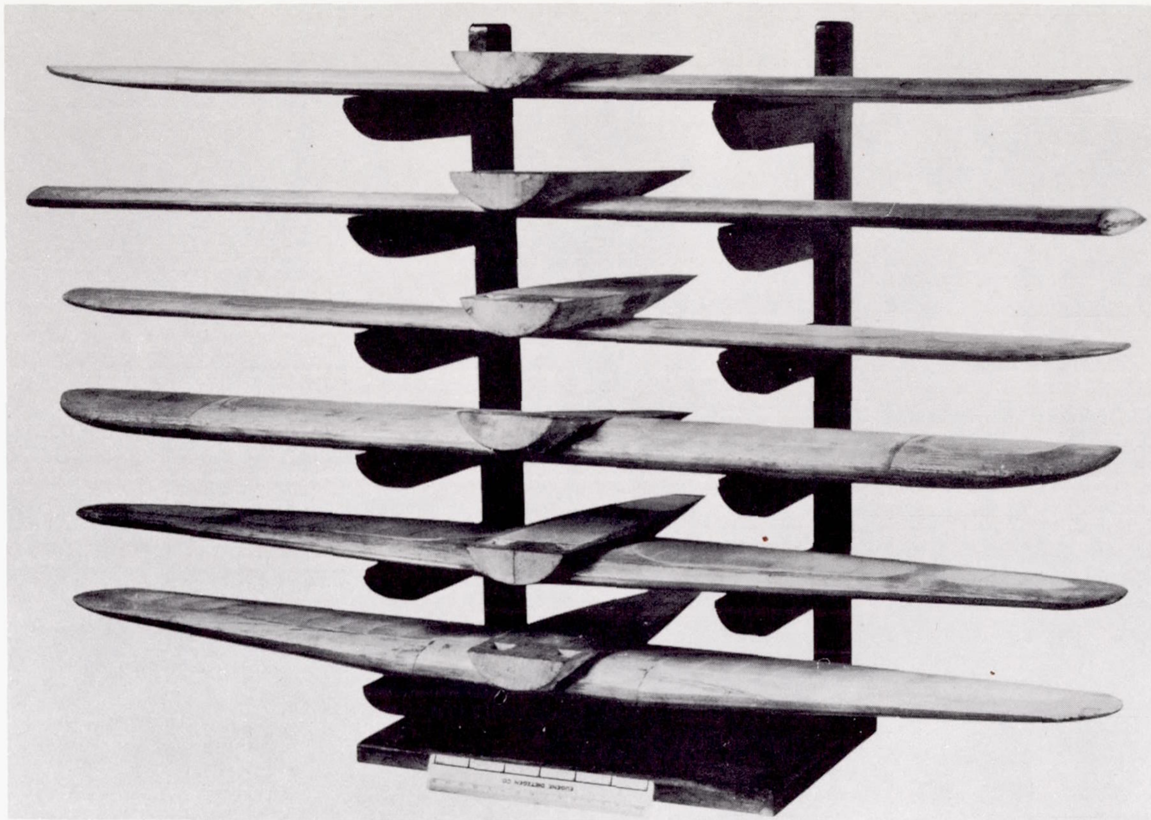


Figure 4.- Diagrams showing plan forms and frontal views of wing models.



Wings 1 and 2

Wings 3 and 4

Wing 5

Wing 6

Wing 7

Wing 8

Figure 5.- Wing models used in tests.

Wings 1, 2, 5 and 6

Wings 3 and 4

Wing 7

Wing 8

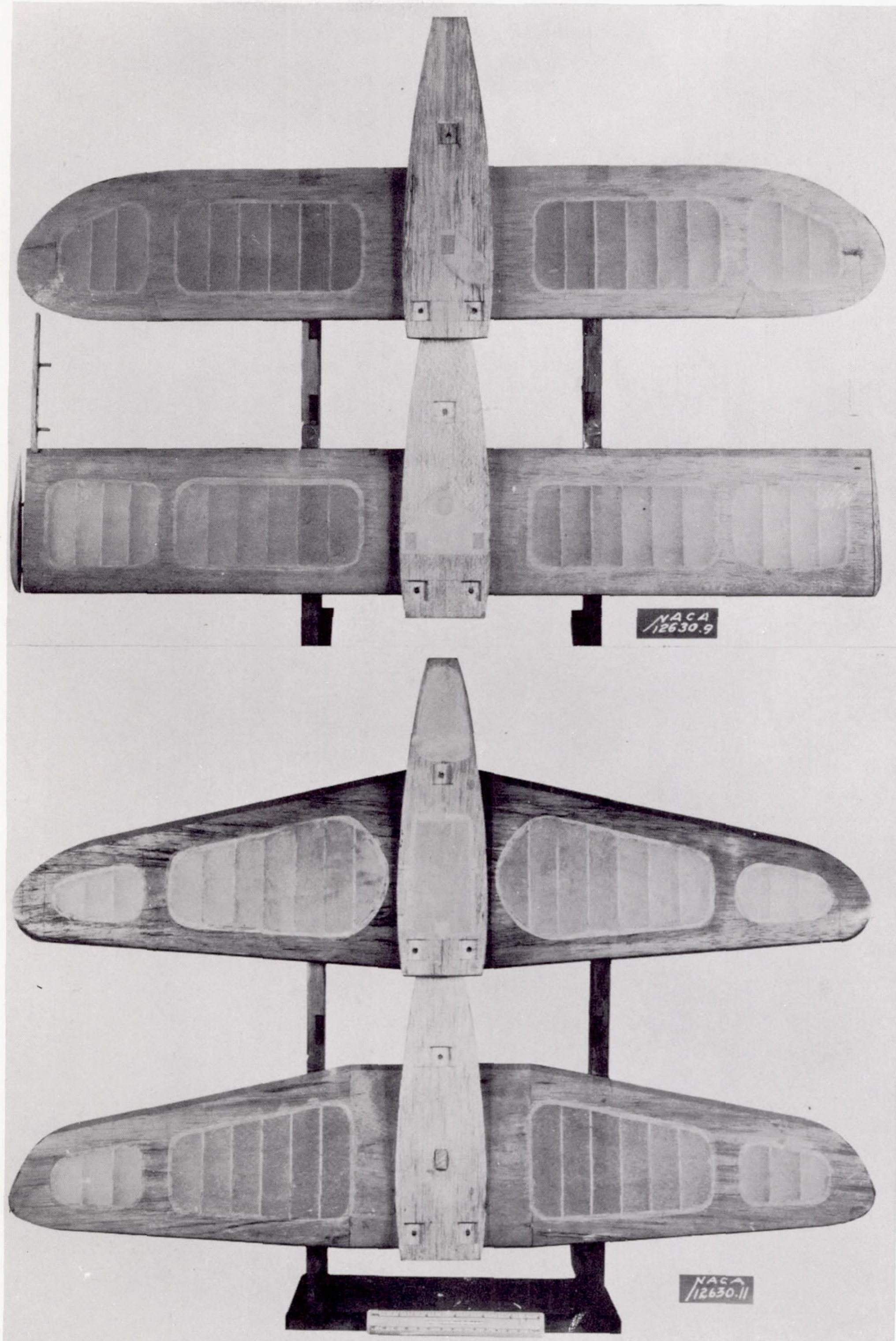


Figure 6.- Interchangeable wings of low-wing monoplane model.

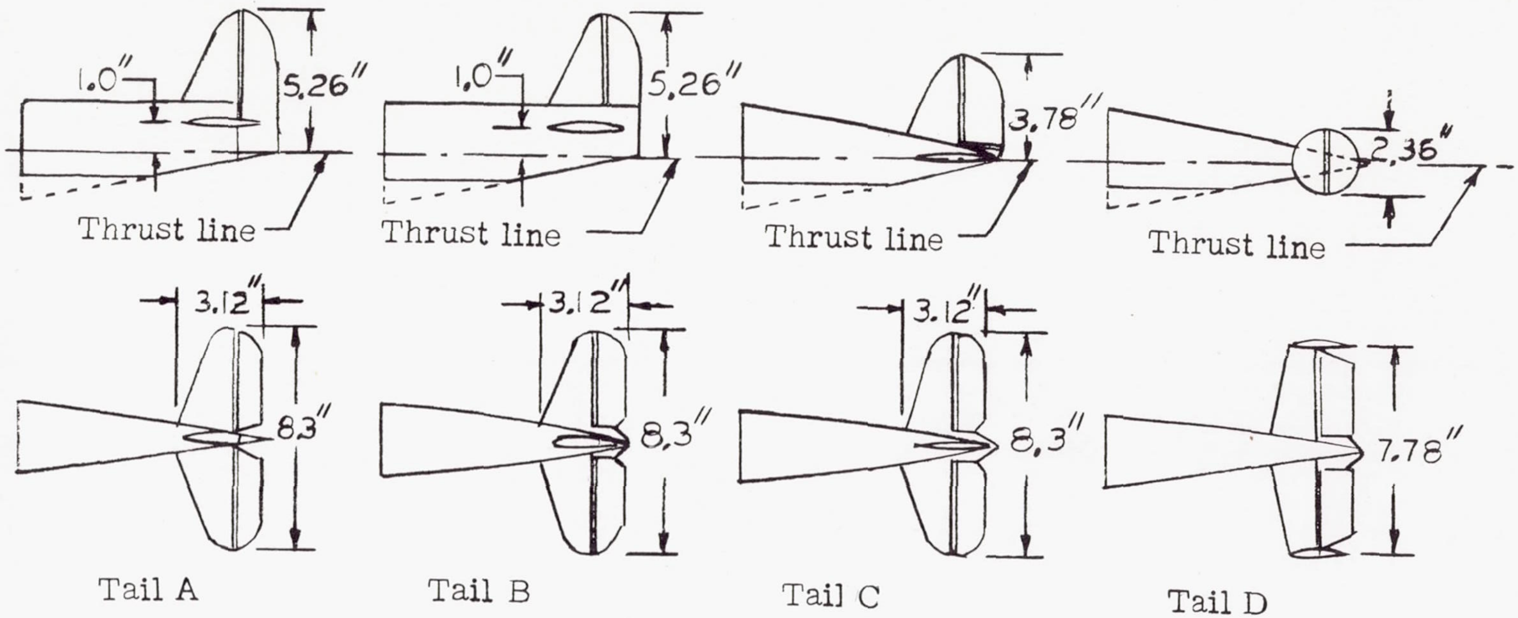


Figure 7.- Tails used on low-wing monoplane.

Tail A B C D

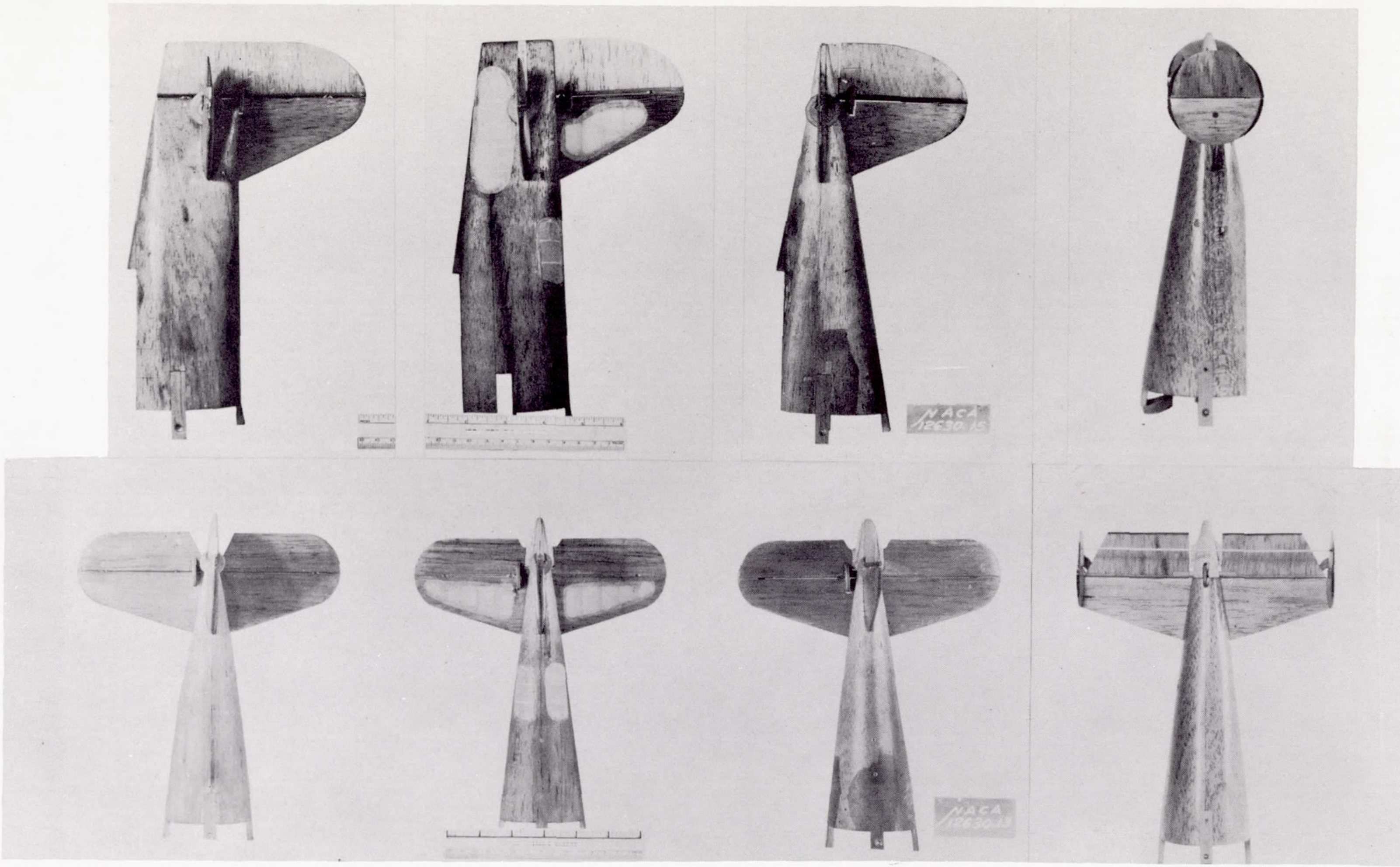


Figure 8.- Interchangeable tails of low-wing monoplane model.