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RESEARCH MEMORANDUM

FREE-SPINNING-TUNNEL INVESTIGATION TO DETERMINE THE EFFECT ON SPINS AND RECOVERIES OF WING LEADING-EDGE CHORD-EXTENSIONS AND DROOPED LEADING-EDGE FLAPS ON SCALE MODELS OF TWO SWEPTBACK-WING FIGHTER AIRPLANES

By Jack H. Wilson and Walter J. Klinar

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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FREE-SPINNING-TUNNEL INVESTIGATION TO DETERMINE THE EFFECT ON SPINS AND RECOVERIES OF WING LEADING-EDGE CHORD-EXTENSIONS AND DROOPED LEADING-EDGE FLAPS ON SCALE MODELS OF TWO SWEPTBACK-WING FIGHTER AIRPLANES

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the effect of wing leading-edge chord-extensions and drooped leading-edge flaps on the spin and spin-recovery characteristics of models of two swept-wing fighter airplanes. The models were investigated at loading conditions corresponding to distributions of weight considered typical for airplanes of this type. The investigation included chord-extensions in the plane of the wing and also chord-extensions deflected in combination with drooped leading-edge flaps.

The results of the investigation indicated that the chord-extensions had no appreciable effect on spin or spin-recovery characteristics when installed in the plane of the wing. Results with chord-extensions drooped in combination with drooped leading-edge flaps indicated a beneficial effect when the droop angle was of sufficient amount. The beneficial effect obtained, however, was attributed to the drooped leading-edge flap for the loading investigated and not to the chord-extensions. For loadings with the mass heavily distributed along the wings, however, as might occur with heavy load items installed on the wings, analysis indicates that drooping the leading-edge flaps may produce an adverse effect.

INTRODUCTION

Wing leading-edge chord-extensions have been suggested as a means for improving the longitudinal stability characteristics at moderate and high lift coefficients of airplanes having sweptback wings (refs. 1, 2, and 3). Reference 1 also points out that leading-edge chord-extensions used in combination with a drooped leading-edge flap on a sweptback wing improve the maximum lift coefficient and the drag due to lift in addition to improving the longitudinal stability characteristics. Inasmuch as no information was available on the effects of chord-extensions or drooped leading-edge flaps on airplanes in spins, an investigation was undertaken in the Langley 20-foot free-spinning tunnel to provide information on this subject. The results of this investigation are reported herein. Models of two contemporary swept-wing fighter designs were used as the test vehicles for the investigation. Both models were tested with chord-extensions fixed in the chord plane of the wing and one of the models was tested with the chord-extensions drooped in combination with a drooped leading-edge flap. A drooped leading-edge flap alone was also tested on this model.

SYMBOLS

A sketch of an airplane in a spin showing positive directions of body axes and moments and other pertinent information relating to the spin is shown as figure 1.

b wing span, ft

S wing area, sq ft

c wing chord at any station along span, ft

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

$x/\bar{c}$ ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

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

m mass of airplane, slugs

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

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

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

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

ρ air density, slugs/cu ft

μ relative density of airplane, $m/\rho Sb$

α angle between fuselage reference line and vertical (approximately equal to the true angle of attack at plane of symmetry), deg

ϕ angle between span axis and horizontal, deg

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

Ω full-scale angular velocity about spin axis, rps

L,M,N roll, pitch, and yaw moments, respectively, about body axes, ft-lb

APPARATUS AND METHODS

Model

The two models used for the present investigation were constructed principally of balsa. The chord-extensions were formed by fairing circular-arc extensions of thin aluminum sheet from a point ahead of the wing to the point of maximum thickness on the airfoil. The models are considered as representative of current swept-wing fighter airplanes, model A being considered a 1/24-scale model, and model B, a 1/25-scale model. Three-view drawings of models A and B are shown as figures 2 and 3, respectively. The three undrooped chord-extensions investigated on model A are shown in figure 4 and the drooped chord-extensions investigated in combination with the drooped leading-edge flaps are shown in figure 5 (chord-extensions and leading-edge flaps deflect the same amount). Figure 6 illustrates the chord-extension (undrooped) investigated on model B. The geometric characteristics of the models scaled up to airplane values are presented in table I.

Model A was ballasted to obtain dynamic similarity to an airplane at an arbitrary altitude of 20,000 feet (ρ = 0.001267 slug/cu ft);

whereas model B was arbitrarily ballasted at an equivalent test altitude of 25,000 feet (ρ = 0.001065 slug/cu ft). A magnetic remote-control mechanism was installed in each of the models to actuate the controls for the recovery attempts and sufficient moments were exerted on the controls during the recovery attempts to reverse them fully and rapidly.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is, in general, similar to that described in reference 4 for the Langley 15-foot free-spinning tunnel, except that the model launching technique has been changed. The model is launched by hand into the vertically rising air stream with the controls set in the desired position. The airspeed is adjusted until the upward force of the air balances the weight of the model and, after a number of turns in the established spin, recovery is attempted by movement of the controls. After recovery, or after the test is completed, the model dives or is lowered into a safety net. The model is retrieved, the controls reset to the desired positions, and the next spin is made. A photograph of one of the models during a spin is shown as figure 7.

The spin data presented have been converted to corresponding full-scale values by methods described in reference 4. The turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. For the spins which had a rate of descent in excess of that which can be attained readily in the tunnel, the rate of descent was recorded as greater than the tunnel airspeed at the time the model hit the safety net, for example, >370. For these tests, the recovery was attempted before the model reached its final attitude and while the model was still descending in the tunnel. Such results are conservative; that is, recoveries will not be as fast as when the model is in the final steeper attitude. 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 were moved to the time the model struck the net, for example, >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. For recovery attempts in which the model did not recover after 10 turns, the recovery was recorded as ∞. When the model recovered without control movement with the rudder set with the spin, the result was recorded as "no spin."

Spin-tunnel tests are usually made to determine the spin and recovery characteristics of the model at the normal spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations including zero and maximum deflections. Recovery is generally attempted by rapid full rudder reversal. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For this type of test, the ailerons are set at one-third of the full deflection in the direction conducive to slower recoveries and the elevator is set at two-thirds of its full-up deflection or full up, whichever is conducive to slower recoveries. For the tests reported herein recoveries were attempted by rapid rudder reversal from full with to only two-thirds against the spin. Recovery characteristics were considered satisfactory if recovery from the spin occurred in $2\frac{1}{4}$ turns or less. This criterion was used on the basis of a correlation of available full-scale-airplane spin-recovery data and corresponding model test results.

PRECISION

The results of model tests presented are believed to be 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:

Obtained from film	$\pm\frac{1}{4}$
Obtained by visual observation	$\pm\frac{1}{2}$

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

Comparison between model and full-scale results (ref. 5) indicates that model tests satisfactorily predicted full-scale recovery characteristics approximately 90 percent of the time. For the remaining 10 percent, about half of the model results were optimistic and half were pessimistic; these results, however, were of value in predicting some of the details of the full-scale spins and recoveries. The airplane generally spun at an angle of attack closer to 45° than did the model and at a higher altitude loss per revolution than the model, although the higher rate of descent was found to be associated with the smaller angle of attack. The model generally spun with more outward sideslip than did the corresponding airplane.

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, percent $\bar{c}$	±1
Moments of inertia, percent	±5

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

TEST CONDITIONS

Three sets of chord-extensions in the plane of the wing were investigated on the outboard portion of the wing of model A and one set was investigated on model B. As is shown in figure 4, the extensions on model A were 15 and 25 percent of the chord and extended inboard from the wing tip to the 70-percent and 50-percent semispan stations. The chord-extensions investigated on model B (fig. 6) extended chordwise 0.15c and spanwise from the wing tip to 0.65b/2. Model A was also investigated with and without leading-edge chord-extensions 0.15c and 25 percent of the span attached to drooped leading-edge flaps as shown in figure 5. Because of the manner in which the wing of model A was constructed, it was not feasible to extend the leading-edge flaps and chord-extensions to the wing tip. Three different amounts of droop were investigated: 6°, 18°, and 30°. The loading condition investigated on each of the models, which corresponded to normal distributions of mass for airplane configurations of this type, is indicated in table II.

The maximum control settings (measured perpendicular to the hinge lines) used for the investigation were:

	Model A	Model B
Rudder, deg	20 right, 20 left	30 right, 30 left
Elevator, deg	25 up, 15 down	25 up, 15 down
Ailerons, deg	20 up, 20 down	16 up, 16 down

RESULTS AND DISCUSSION

The results of the investigation are presented in charts 1 to 9. In those instances where no data are presented in the charts for certain control configurations, no tests were conducted because the data were not considered necessary for the analysis presented herein. The model data are presented in terms of full-scale airplane values. Right and left spins of the models were, in general, similar, and therefore the data on the charts are arbitrarily presented in terms of right spins.

Effect of Chord-Extensions in Plane of Wing

Charts 1 to 5 illustrate the effect of installing chord-extensions in the plane of the wing on the spin and spin-recovery characteristics of models A and B. Comparison of chart 1 with charts 2, 3, and 4 shows that the three sets of chord-extensions investigated on model A had little effect on its spin or spin-recovery characteristics, the recoveries from aileron-against spins being unsatisfactory and recoveries from the aileron-neutral or aileron-with spins being satisfactory with or without chord-extensions installed. Data presented in chart 5 show also that model B was not affected by installation of the chord-extensions in that the model did not spin, or spun steeply and recovered rapidly, with chord-extensions installed or removed.

It would be anticipated that the addition of chord-extensions should produce an anti-spin rolling moment or an aileron-against effect in a spin (rolling moment to the left in a right spin) in light of the fact that the chord-extension on the inboard wing (right wing in a right spin) is operating at a higher angle of attack, and thus at a greater normal-force coefficient, than the chord-extension on the outboard wing. On this basis it would be expected that adding chord-extensions would have a more pronounced effect on the spin-recovery characteristics of model A than those of model B because the spin-recovery characteristics of model A were greatly affected by aileron setting whereas those of model B were not. Inasmuch as the chord-extensions investigated produced little effect, however, the rolling moment contributed by them must have been very small. The chord-extensions investigated on the models are within the range of practical chord-extensions that might be installed on airplanes of this type, and thus it would appear that chord-extensions installed in the plane of the wing should have little effect on spin or spin-recovery characteristics of airplane configurations similar to the models that were investigated.

Effect of Drooped Leading-Edge Flaps and of Drooped Chord-Extensions in Combination With Drooped Leading-Edge Flaps

Results of tests performed with drooped leading-edge flaps alone and in combination with drooped chord-extensions are presented in charts 6 to 9. As has been stated previously, these tests were conducted only for model A and only for one set of chord-extensions (0.15 chord-extension extending inboard from near the tip to the 70-percent-semispan station). Drooped chord-extensions alone were not investigated inasmuch as static-force data presented in reference 1 for a wing similar to the one installed on model A had indicated that it was necessary to droop a considerable portion of the nose flap along with the chord-extensions to obtain substantial gains in maximum lift coefficient and drag due to lift while still maintaining satisfactory stability characteristics.

Comparison of chart 6 with chart 1 indicates that with the leading-edge flaps drooped 30° (no chord-extensions installed) there was an appreciable change in the spin characteristics of the model. Although poor recoveries had been obtained from the aileron-against spins with the leading-edge flaps undrooped, with the leading-edge flaps drooped 30°, the model did not spin for this setting of the ailerons. The results also indicated that with leading-edge flaps drooped 30° the model would probably not spin for neutral and down elevator settings with ailerons neutral. Although the aileron-full-with spins were not investigated with flaps drooped, no adverse effect would be anticipated for these control settings inasmuch as the increase in camber brought about by deflecting leading-edge flaps acts in a manner to increase the pro-spin rolling moment (right rolling moment in a right spin), as do aileron-with settings. In fact, the beneficial effect of the drooped leading-edge flaps for the loading condition investigated appears to be attributed to the increased pro-spin rolling moment brought about by drooping the flaps. It should be noted, however, that, if the model had been loaded more heavily along the wing such that the inertia yawing-moment parameter $\frac{I_X - I_Y}{mb^2}$ approached 0 or became positive, drooped leading-edge flaps may have had an adverse effect. Such loadings are unlikely on airplanes of this type, however, unless very large fuel tanks or very heavy stores are installed on or within the wing. The effect of drooping leading-edge flaps appears to be similar to the effect of leading-edge slots as indicated by unpresented test results of swept-wing models and as noted in reference 6 for models of straight-wing airplanes.

Comparison of data presented in chart 7 with the data presented in chart 6 shows that installing chord-extensions on the drooped leading-edge flaps (flaps and chord-extensions drooped 30°) did not impair the effectiveness of drooped leading-edge flaps; therefore, the changes in the aerodynamic forces and moments at spinning attitudes brought about by the addition of the chord-extensions were probably small. With the leading-edge flap and chord-extension configuration deflected only 6°, results somewhat similar to those with undrooped flaps were obtained in that recoveries from aileron-against spins were unsatisfactory; whereas with chord-extensions and flaps drooped 18°, results similar in nature to those obtained with flaps drooped 30° were obtained. (See charts 1, 7, 8, and 9.) Results of the foregoing tests thus show that the leading-edge flaps and chord-extensions had to be drooped approximately 18° to obtain a beneficial effect. It should be pointed out that drooped chord-extensions alone may be beneficial in spins for airplanes having geometric and mass characteristics similar to those of the model tested, for chord-extensions having large spans. As has been stated previously, had the model been investigated with the mass heavily distributed along the wings, the drooped leading-edge flaps may have had an adverse effect.

CONCLUSIONS

Based upon the results of the spin-tunnel investigation of the effect of wing chord-extensions and drooped leading-edge flaps on the spin and spin-recovery characteristics of models of two swept-wing fighter designs, the following conclusions are made:

1. Undrooped chord-extensions had no appreciable effect upon the model spin or spin-recovery characteristics.

2. Drooped chord-extensions in combination with drooped leading-edge flaps had a beneficial effect on the spin characteristics, provided the amount of droop was approximately as much as 18°. The improvement in spin characteristics was due to the drooped leading-edge flaps for the loading investigated (mass distributed chiefly along the fuselage). For loadings such that the mass is heavily distributed along the wings, however, drooped leading-edge flaps may have an adverse effect.

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TABLE I.- FULL-SCALE DIMENSIONAL CHARACTERISTICS AS

REPRESENTED BY THE MODELS

	Model A	Model B
Over-all length, ft	54.25	44.71
Center-of-gravity location, percent $\bar{c}$	23.0	25.9
Wing:		
Span, ft	39.67	32.28
Area, sq ft	350	260.40
Sweepback at c/4, deg	35	40
Incidence, deg	1	3
Dihedral, deg	0	3
Section	NACA 65-009	Circular arc
Aspect ratio	4.5	4.0
Mean aerodynamic chord, ft	9.8	8.4
Leading edge of $\bar{c}$ rearward of leading edge at root chord, ft	6.8	6.6
Ailerons:		
Area, sq ft	18.4	21.6
Span, percent b/2	37.8	50.4
Hinge-line location, percent c	75	80
Horizontal tail surfaces:		
Total area, sq ft	66.8	43.7
Span, ft	15.3	12.8
Elevator area, rearward of hinge line, sq ft	15.6	8.4
Distance from center of gravity to elevator hinge line at fuselage center line, ft	26.3	20.8
Incidence, deg	0	0
Sweepback at c/4, deg	35	40
Vertical tail surfaces:		
Total area, sq ft	46.6	38.6
Rudder area, sq ft	10.7	4.8
Distance from center of gravity to rudder hinge line at base of rudder, ft	27.4	20.7

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE TWO MODELS INVESTIGATED

[Values given as corresponding full-scale values of a 1/24-scale model for model A and of a 1/25-scale model for model B; moments of inertia are given about center of gravity]

Model	Weight, lb	μ		Center-of-gravity location		Moments of inertia, slug-ft^2			Mass parameters		
		Sea level	Simulated test altitude	$x/\bar{c}$	$z/\bar{c}$	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
A	17,107	16.1	30.2 at 20,000 ft	0.230	-0.058	20,120	54,920	72,268	-416×10^{-4}	-207×10^{-4}	623×10^{-4}
B	16,667	25.9	57.9 at 25,000 ft	.259	.012	7,478	67,929	73,010	-1120	-94	1214

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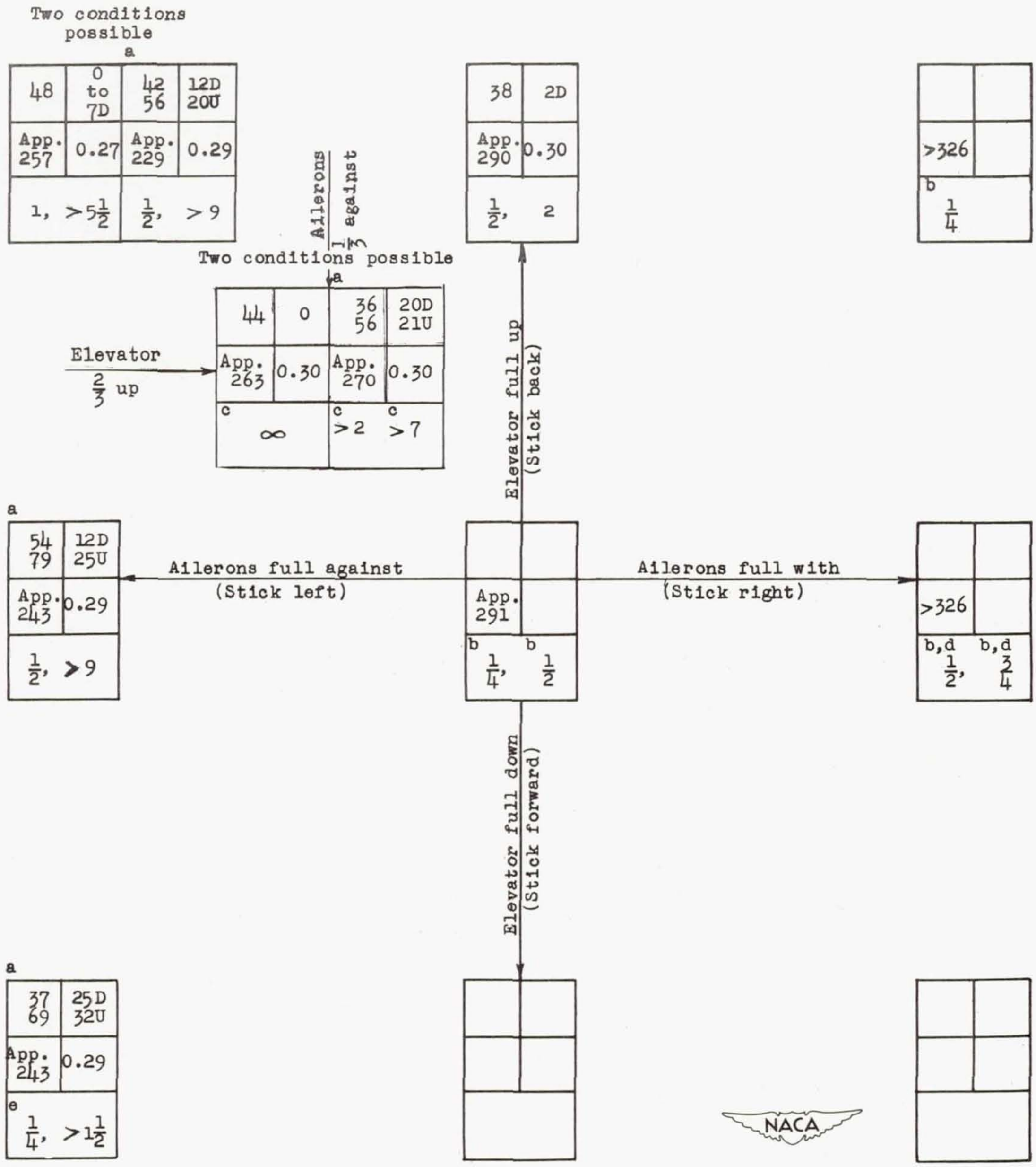
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A IN THE CLEAN CONDITION

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from and steady-spin data presented for rudder-full-with spins); right erect spins]



[a]Wandering, extremely oscillatory spin; range of values given.

[b]Recovery attempted before model in final, steeper attitude.

[c]Recovery attempted by reversing rudder from full with to $\frac{2}{3}$ against the spin.

[d]Model recovered and then went into an inverted spin.

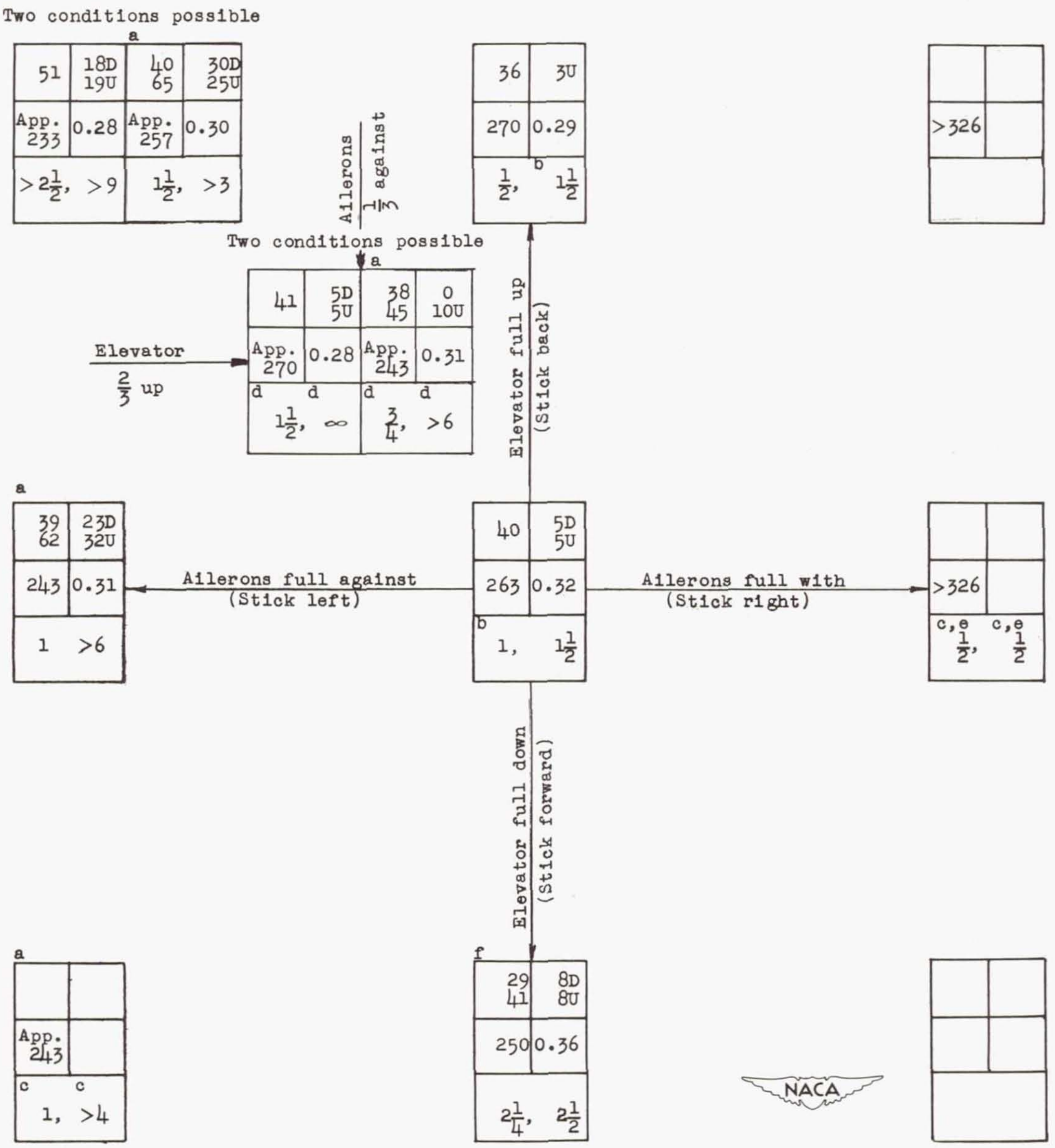
[e]Visual estimate.

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

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

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A WITH CHORD-EXTENSION 1 INSTALLED

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from and steady-spin data presented for rudder-full-with spins); right erect spins]



[a]Wandering, extremely oscillatory spin; range of values given.

[b]Visual estimate.

[c]Recovery attempted before model in final steeper attitude.

[d]Recovery attempted by reversal of rudder from full with to $\frac{2}{3}$ against the spin.

[e]Model recovered and then went into an inverted spin.

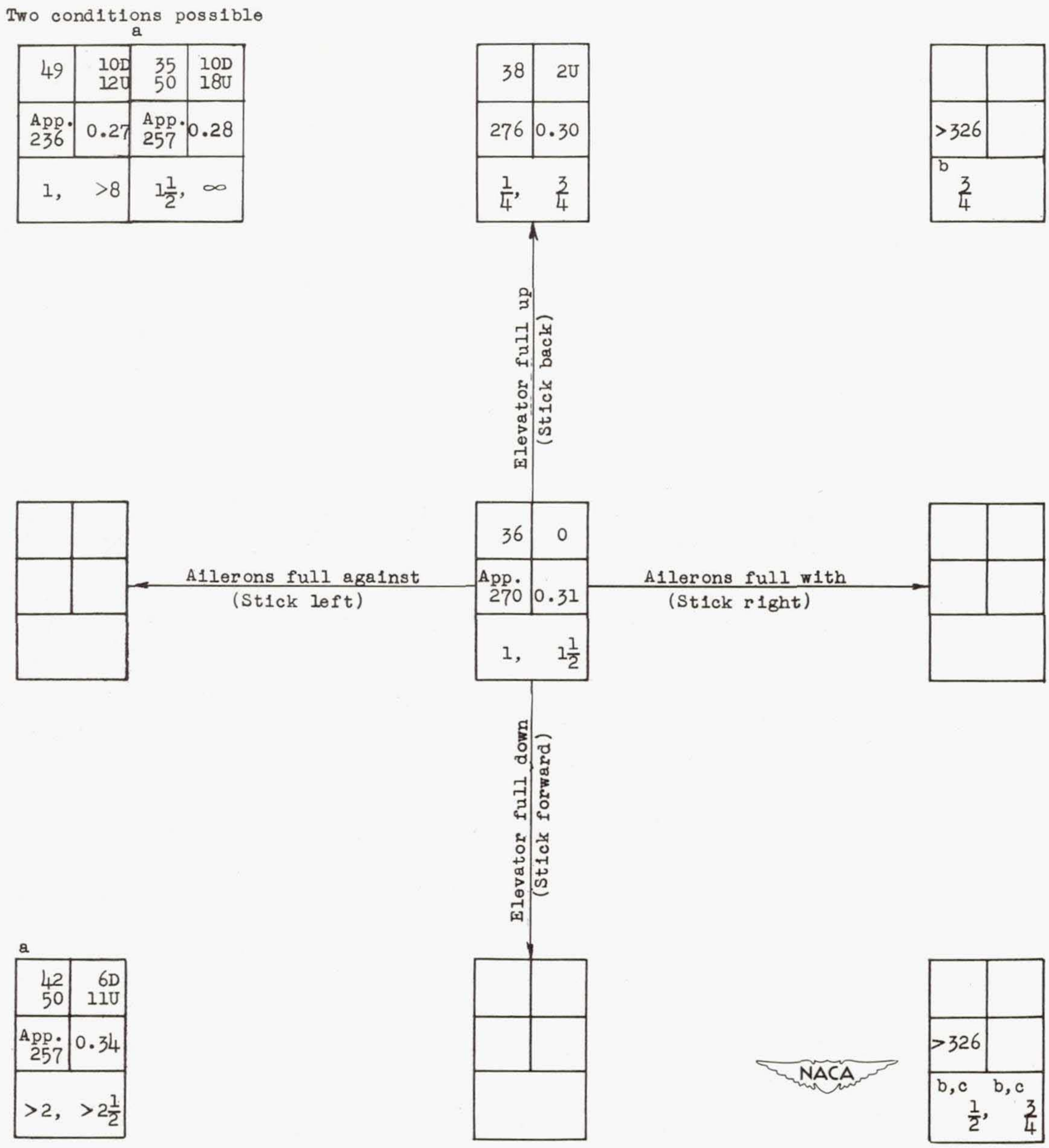
[f]Oscillatory spin, range of values given.

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

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

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A WITH CHORD-EXTENSION 2 INSTALLED

[Recovery attempted by rapid full rudder reversal (recovery attempted from and steady-spin data presented for rudder-full-with spins); right erect spins]



aWandering, extremely oscillatory spin; range of values given.

bRecovery attempted before model in final, steeper attitude.

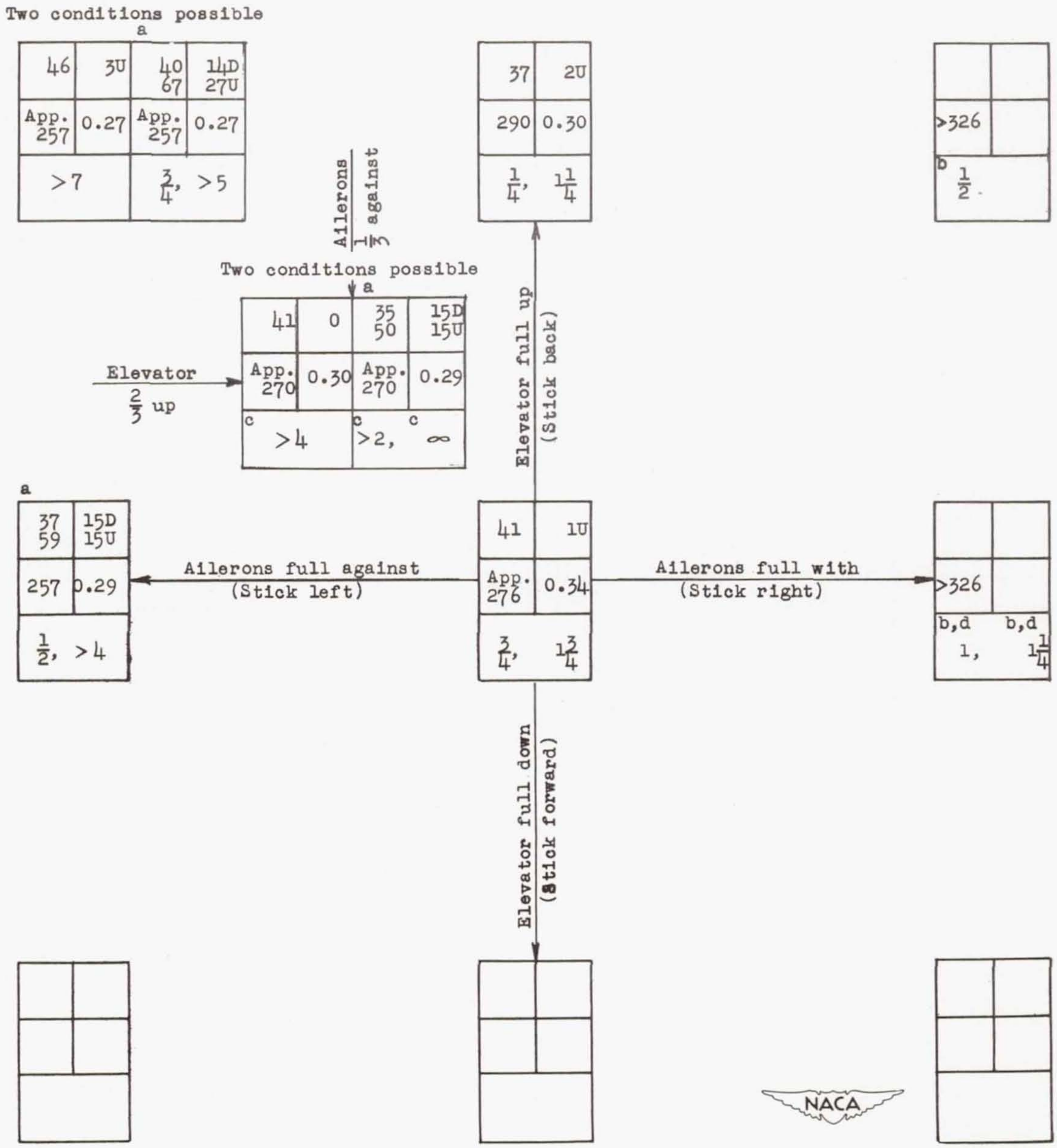
cModel recovered and then went into an inverted spin.

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

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

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A WITH CHORD-EXTENSION 3 INSTALLED

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from and steady-spin data presented for rudder-full-with spins); right erect spins]



[a] Wandering, extremely oscillatory spin; range of values given.

[b] Recovery attempted before model in final, steeper attitude.

[c] Recovery attempted by reversal of rudder from full with to $\frac{2}{3}$ against the spin.

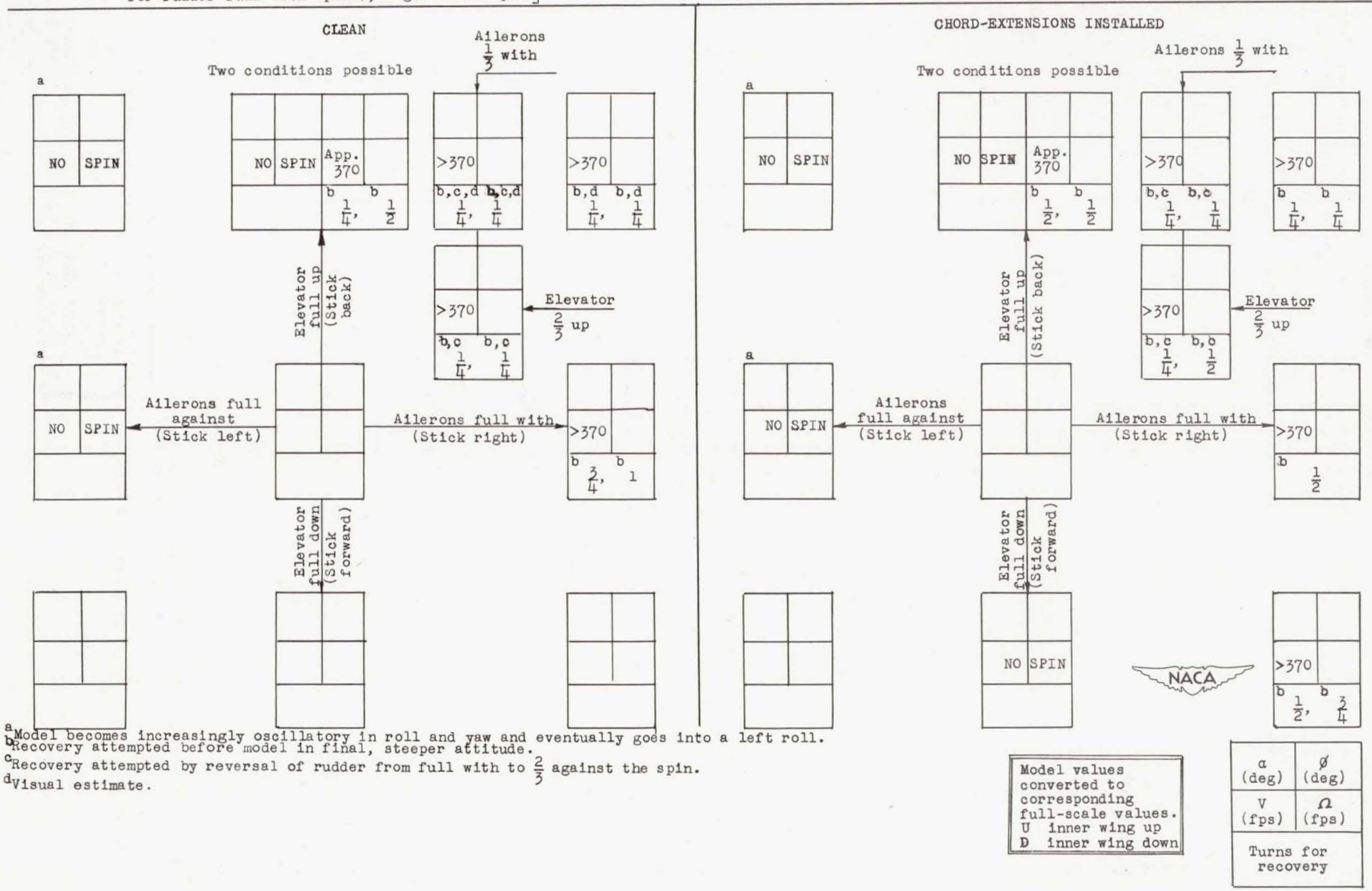
[d] Model recovered and then went into an inverted spin.

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

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

CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL B WITHOUT CHORD-EXTENSIONS INSTALLED AND WITH CHORD-EXTENSIONS INSTALLED

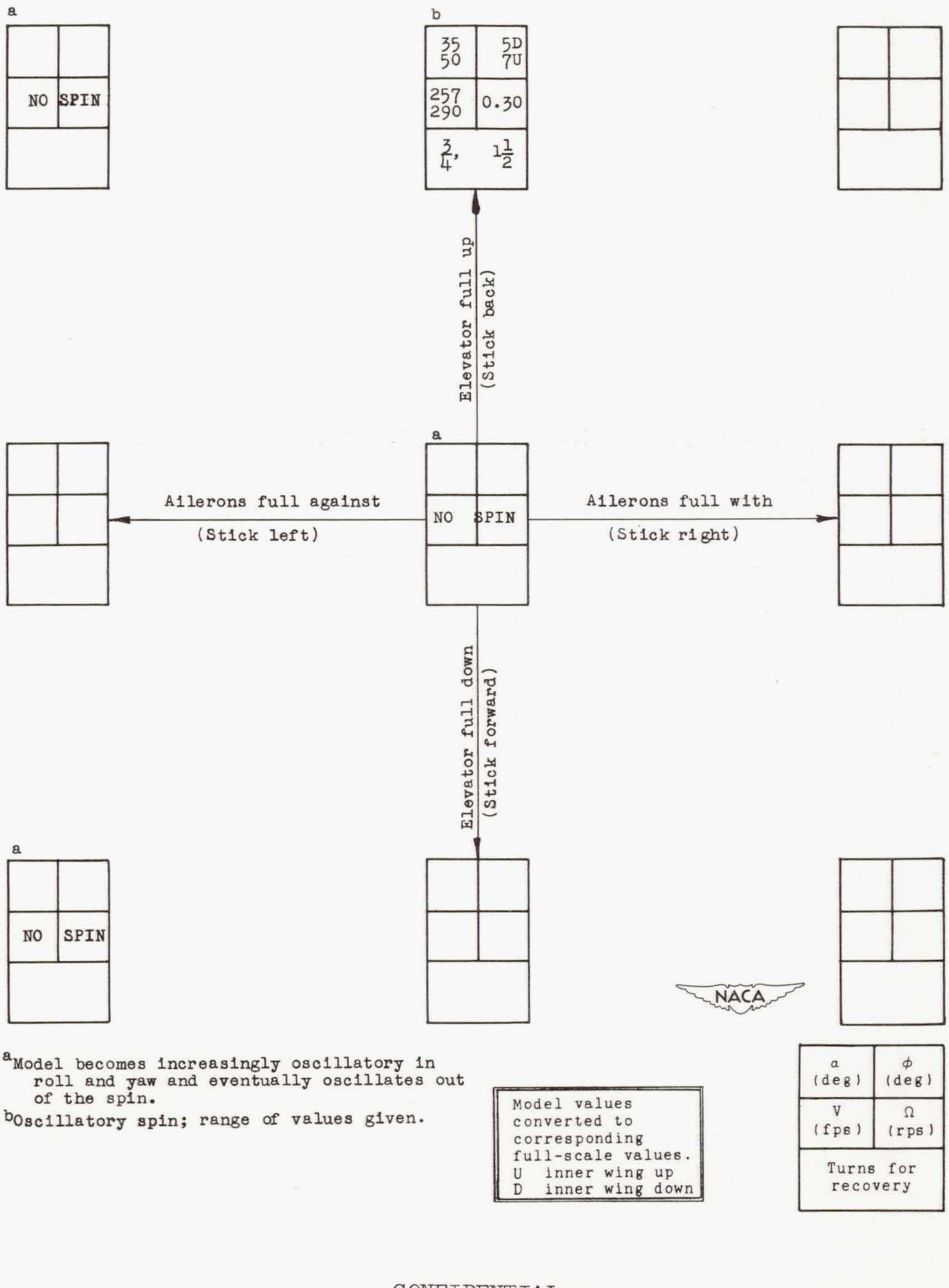
[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from and steady-spin data presented for rudder-full-with spins); right erect spins]



[a]Model becomes increasingly oscillatory in roll and yaw and eventually goes into a left roll.
[b]Recovery attempted before model in final, steeper attitude.
[c]Recovery attempted by reversal of rudder from full with to $\frac{2}{3}$ against the spin.
[d]Visual estimate.

CHART 6.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A WITH LEADING-EDGE FLAPS DROOPED 30°

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from and steady-spin data presented for rudder-full-with spins); right erect spins]

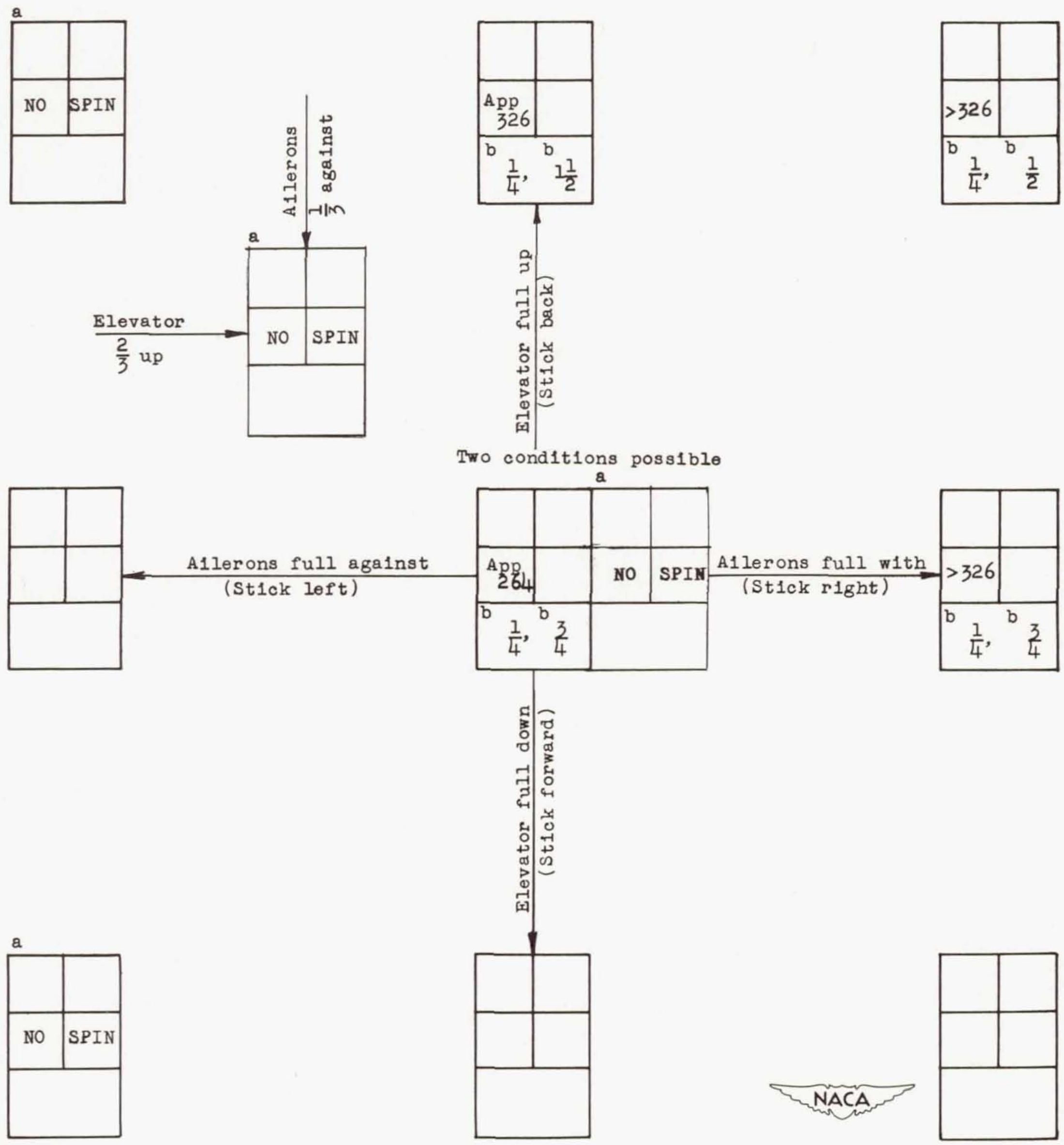


[a]Model becomes increasingly oscillatory in roll and yaw and eventually oscillates out of the spin.

[b]Oscillatory spin; range of values given.

CHART 7.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A WITH LEADING-EDGE FLAPS AND CHORD-EXTENSION DROOPED 30°

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from and steady-spin data presented for rudder-full-with spins); right erect spins]



[a]Model becomes increasingly oscillatory in roll and yaw and eventually oscillates out of the spin.

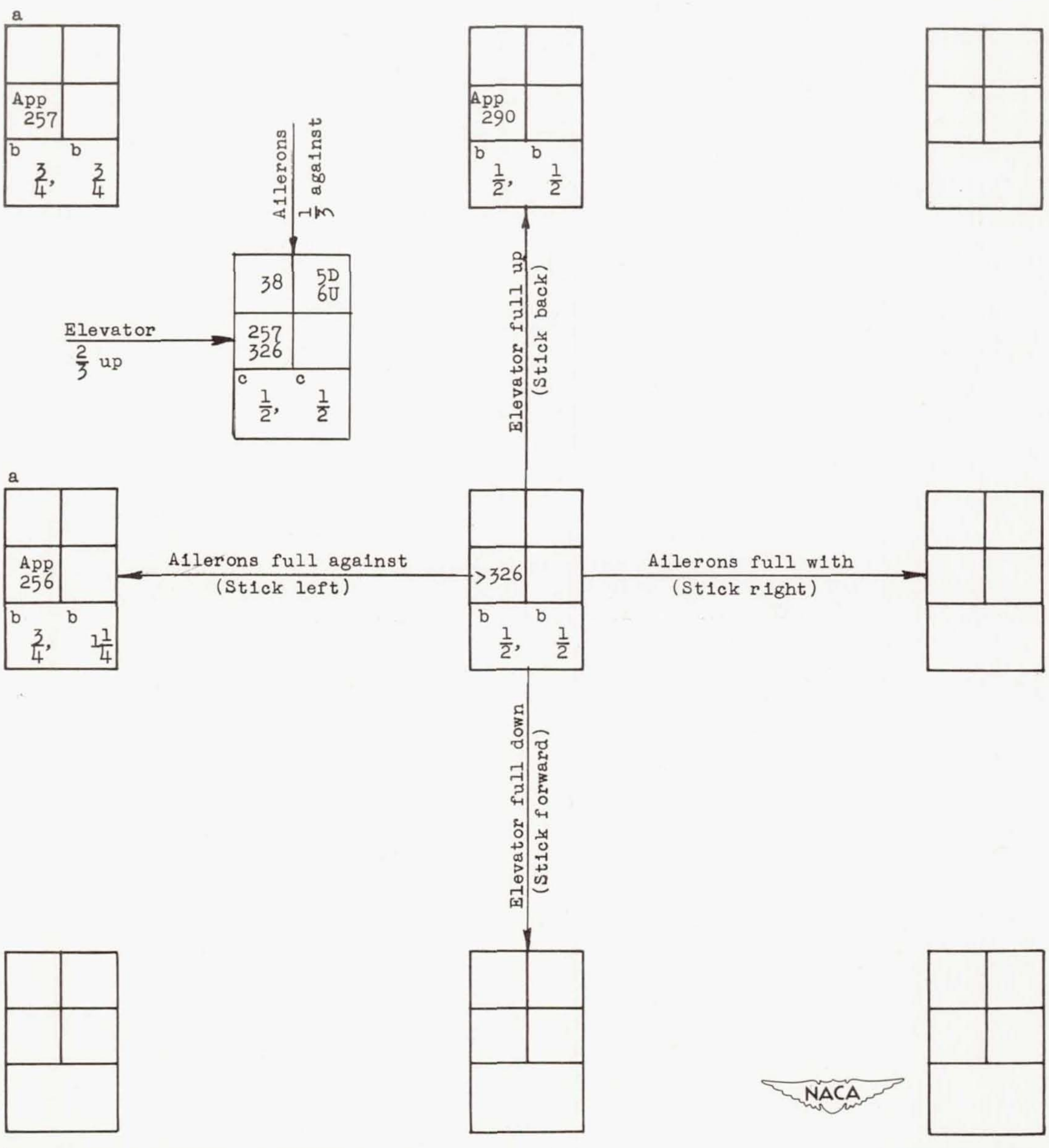
[b]Recovery attempted before model in final steeper attitude.

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

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

CHART 8.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A WITH LEADING-EDGE FLAPS AND CHORD-EXTENSION DROOPED 18°

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



[a]Wandering, extremely oscillatory spin.

[b]Recovery attempted before model in final steeper attitude.

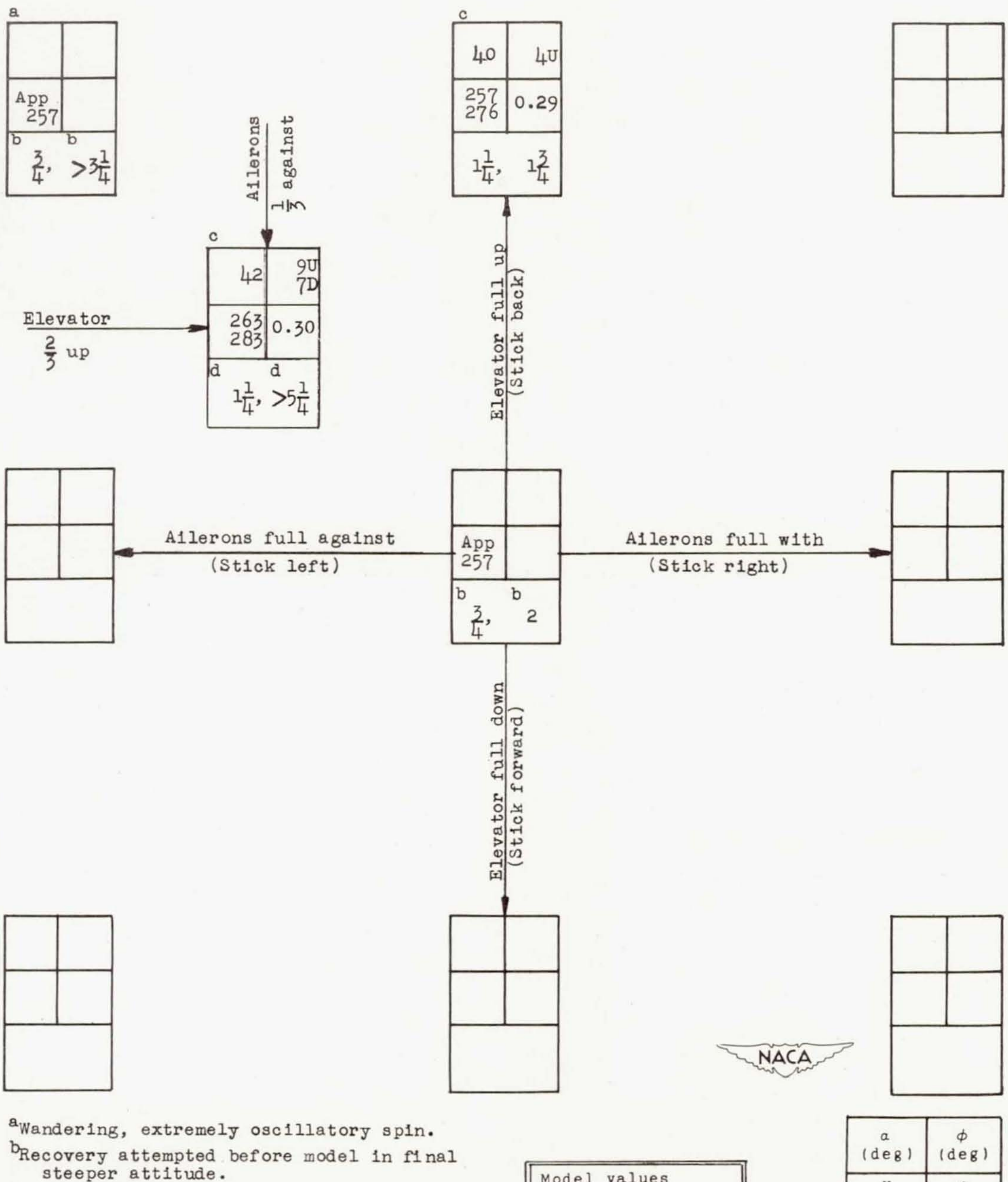
[c]Recovery attempted by reversing rudder from full with to 2/3 against the spin.

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

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

CHART 9.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL A WITH LEADING-EDGE FLAPS AND CHORD-EXTENSION DROOPED 6°

[Recovery attempted by rapid full rudder reversal unless otherwise noted (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



[a]Wandering, extremely oscillatory spin.

[b]Recovery attempted before model in final steeper attitude.

[c]Wandering and oscillatory spin; range or average values given.

[d]Recovery attempted by reversing rudder from full with to $\frac{2}{3}$ against the spin.

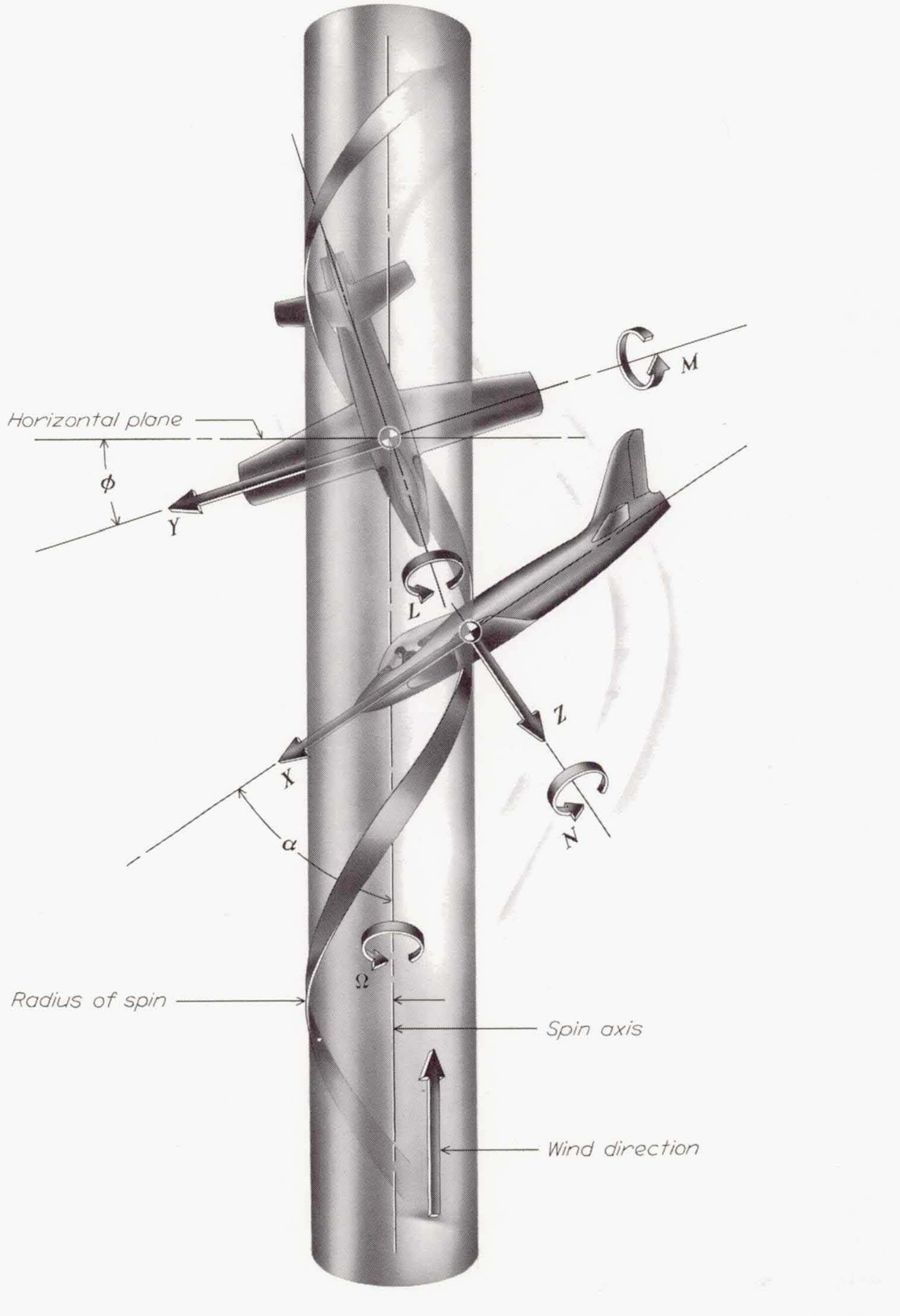


Figure 1.- Illustration of an airplane in a steady spin. Arrows indicate positive directions of body axes and moments about the body axes of the airplane.

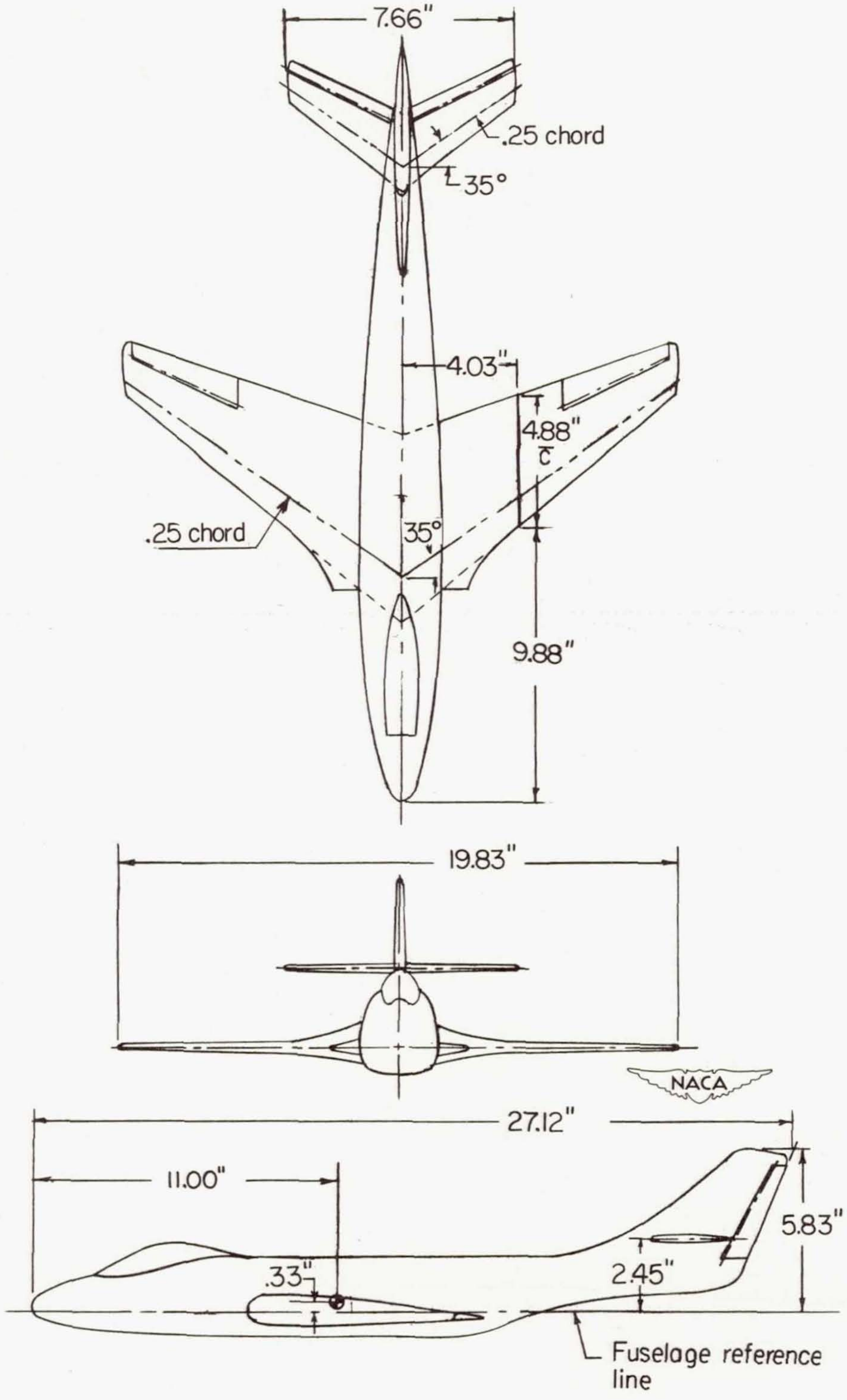


Figure 2.- Three-view drawing of model A without chord-extensions installed.

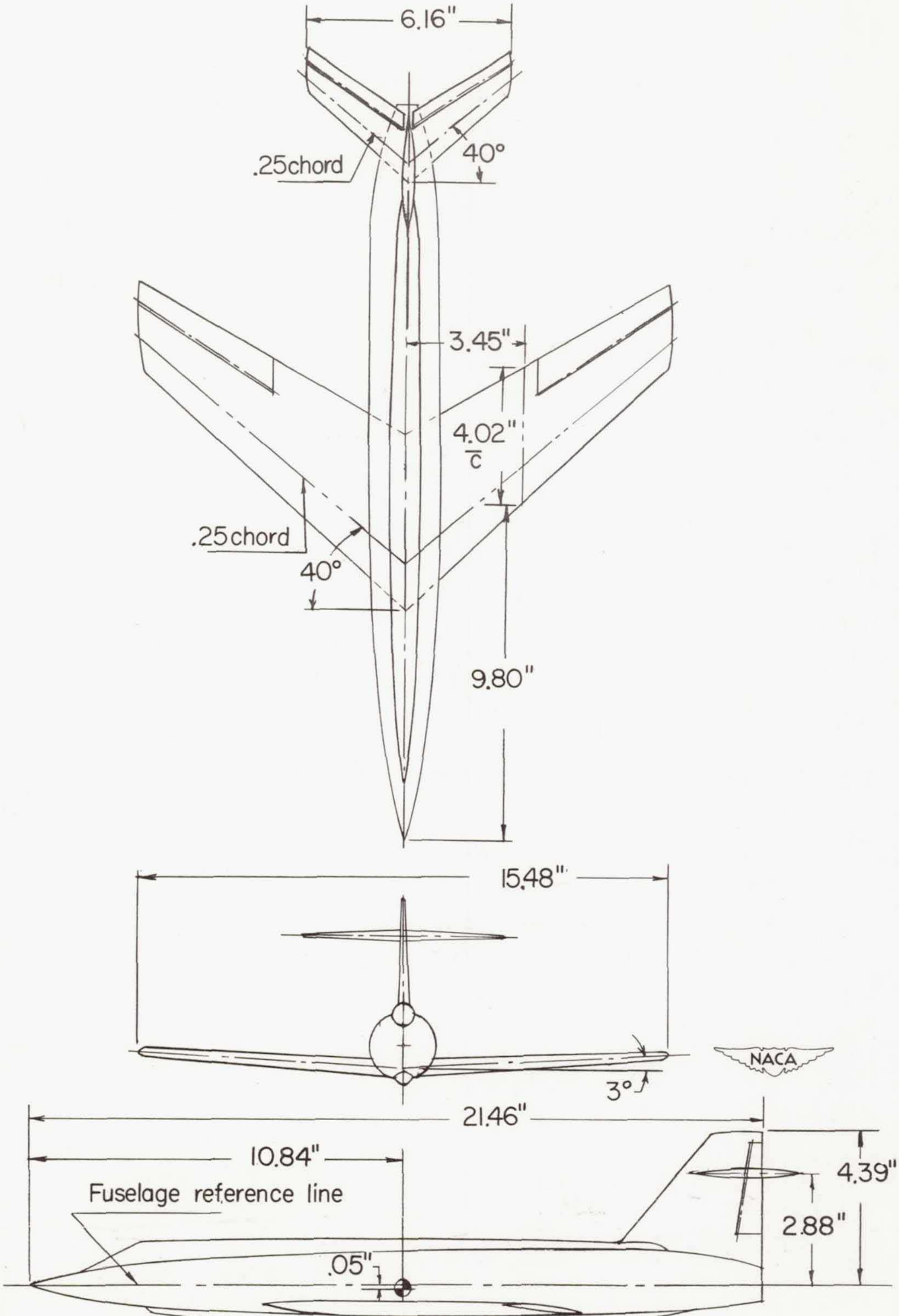


Figure 3.- Three-view drawing of model B without chord-extensions installed.

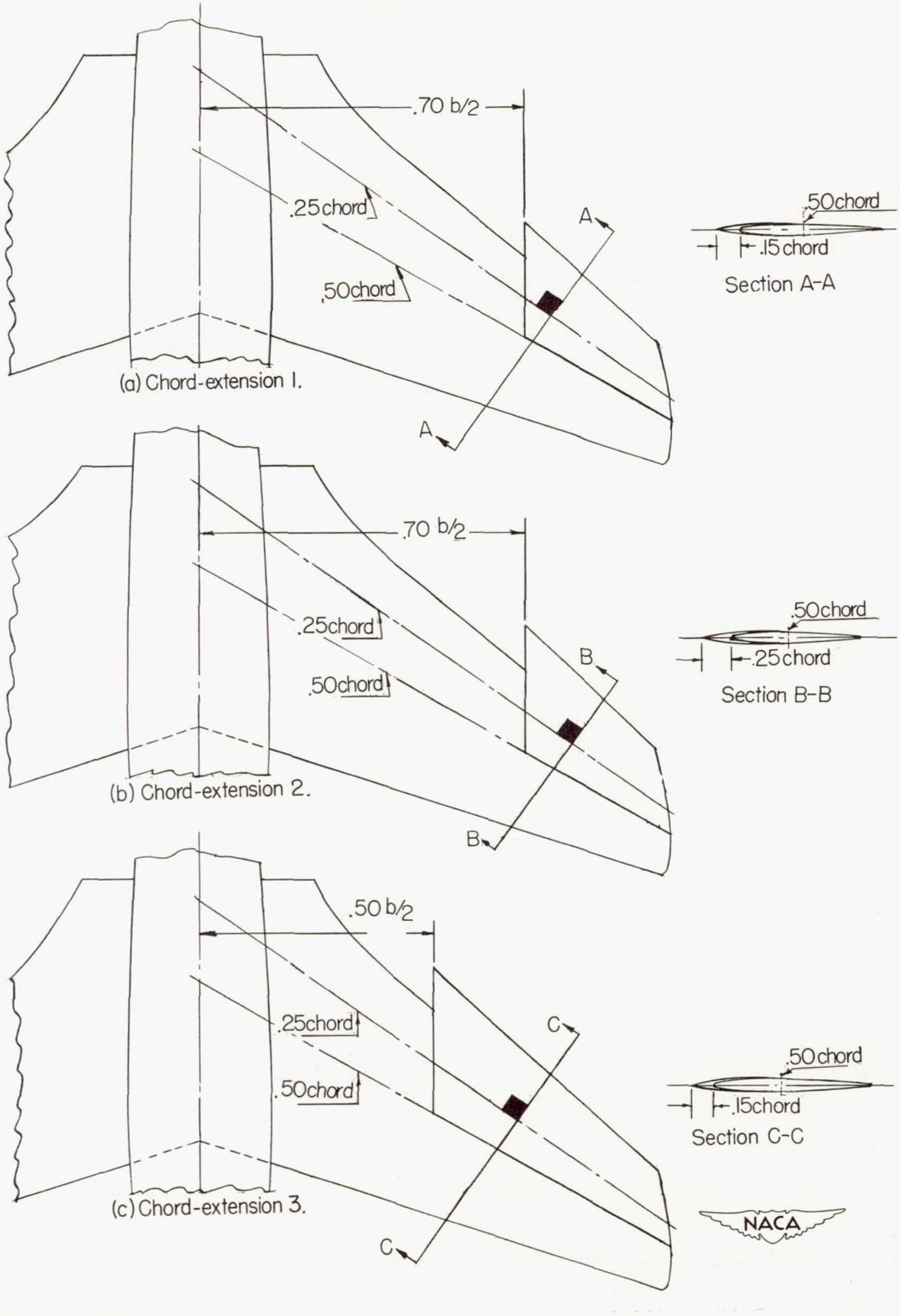
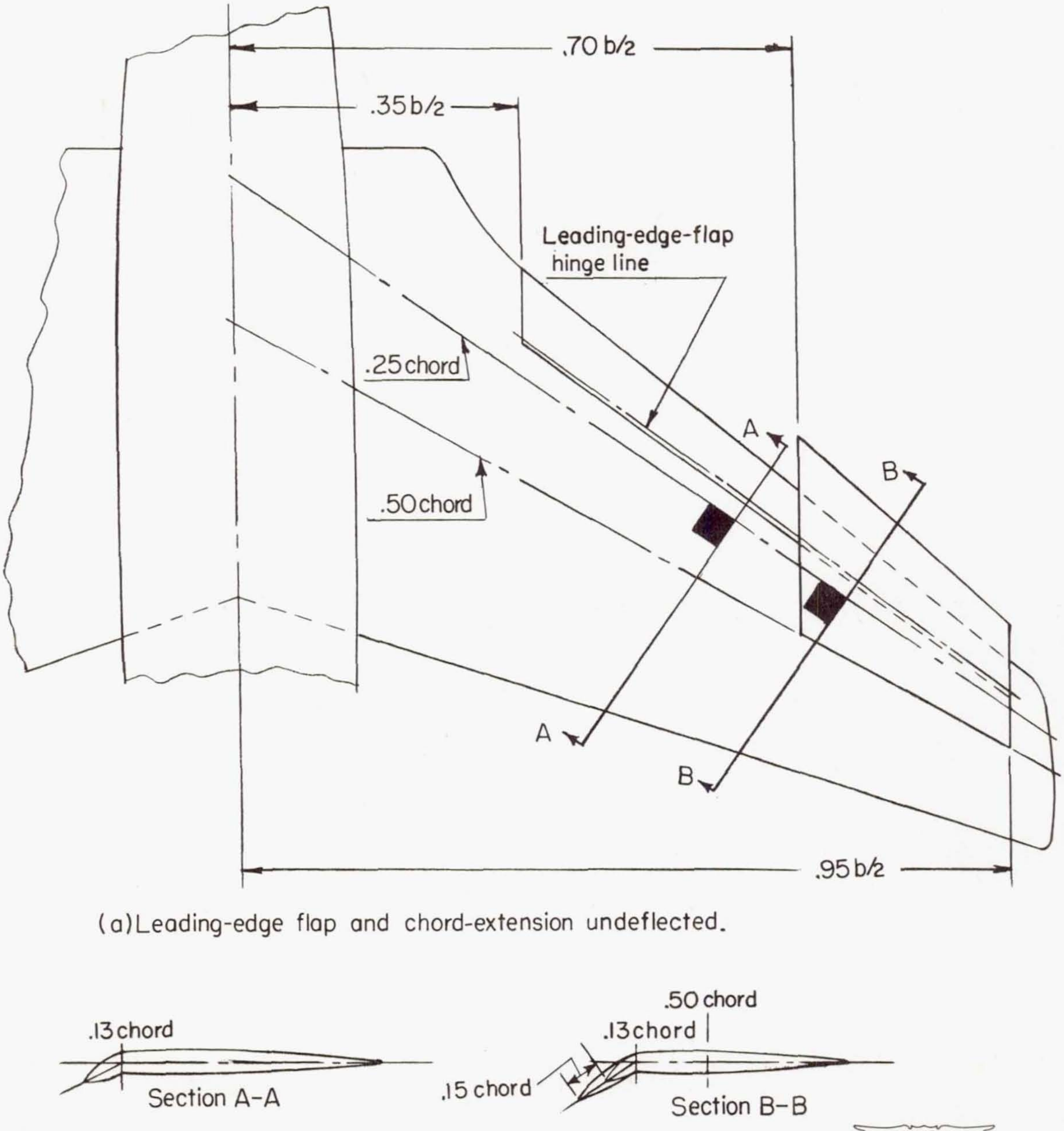
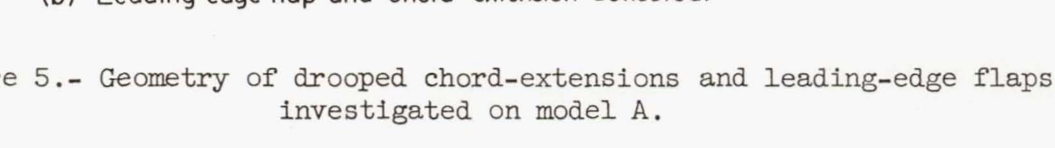


Figure 4.- Details of the undrooped chord-extensions investigated on model A.



(a) Leading-edge flap and chord-extension undeflected.



(b) Leading-edge flap and chord-extension deflected.

Figure 5.- Geometry of drooped chord-extensions and leading-edge flaps investigated on model A.

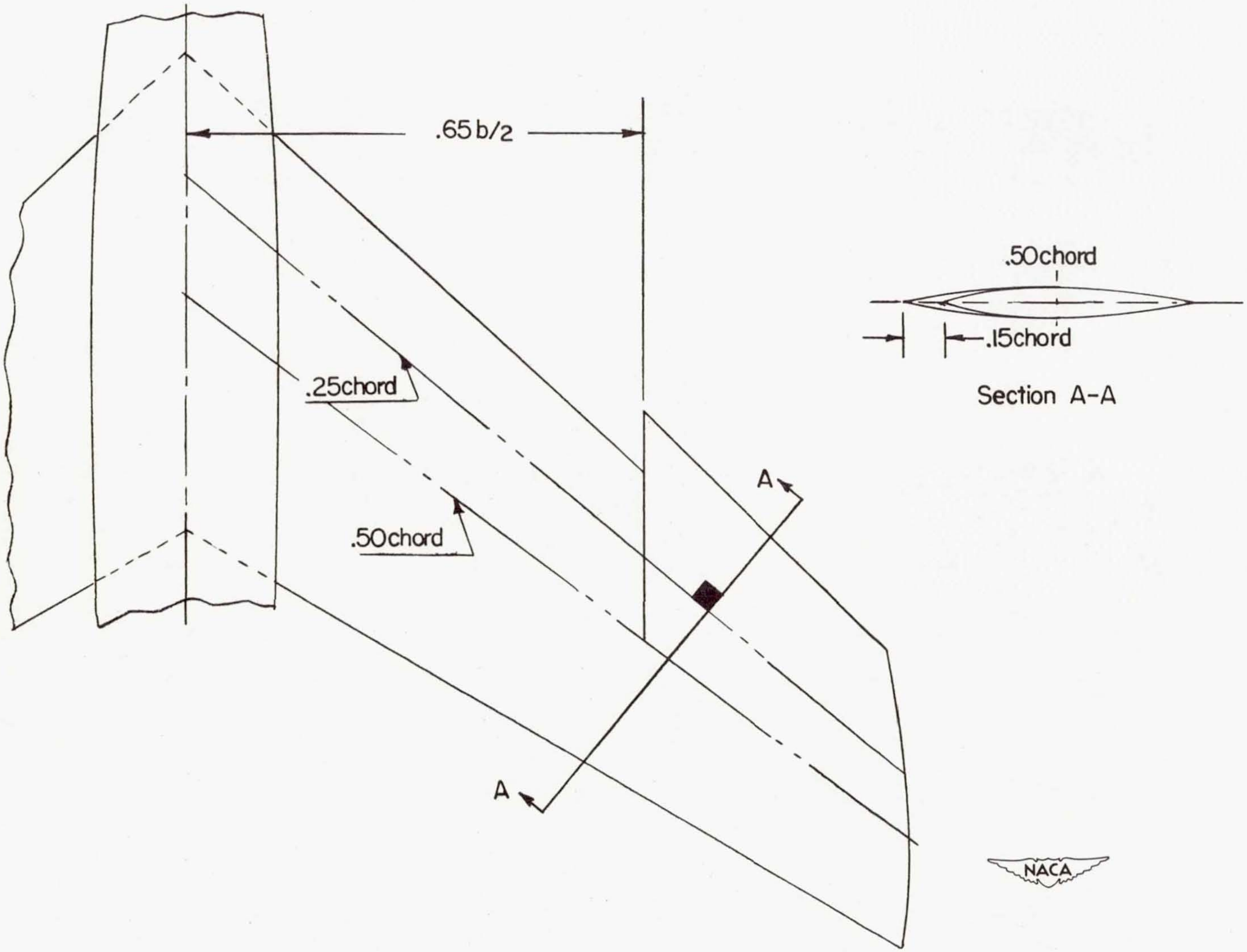


Figure 6.- Details of the chord-extensions investigated on model B.

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Figure 7.- Model A spinning in the Langley 20-foot free-spinning tunnel.

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