MR No. L5G31a

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

August 1945 as
Memorandum Report L5G31a

SPIN TESTS OF A 0.059-SCALE MODEL OF THE CURTISS-WRIGHT XP-55 AIRPLANE

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NACA

WASHINGTON

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Air Technical Service Command, Army Air Forces

SPIN TESTS OF A 0.059-SCALE MODEL OF THE CURTISS-WRIGHT XP-55 AIRPLANE

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SUMMARY

Spin tests have been performed in the Langley 20-foot free-spinning tunnel on a 0.059-scale model of the Curtiss-Wright XP-55 airplane. For the tests, the model was modified as recommended by the NACA to improve the longitudinal-trim characteristics by installing a large elevator with increased deflections and large wing tips with extensions to the wing-tip trimmers.

The spins were oscillatory in pitch and roll at a large average angle of attack and reversal of the rudders fully and rapidly stopped the rotation. After the rotation stopped, the model nosed down into a dive when the stick was forward or free longitudinally for erect spins and when the stick was back or free longitudinally for inverted spins.

INTRODUCTION

As requested by the Air Technical Service Command, Army Air Forces, a 0.059-scale model of the XP-55 airplane was tested in the Langley 15-foot free-spinning tunnel to determine modifications in airplane design which would prevent the airplane from trimming at flat attitudes. The XP-55 is a low-wing, canard-type, pusher airplane with a large amount of sweepback in the wing. The possibility of attaining trim at either large negative or large positive angles of attack with this airplane was previously indicated by spin tests of a model of the Curtiss-Wright 24-B airplane - a light-weight, full-scale, flying mock-up of the XP-55 airplane. The model of the XP-55 was modified to include modifications which prevented trim at flat attitudes as determined by the longitudinal-trim tests and as recommended in reference 1, and was then tested in the Langley 20-foot free-spinning tunnel to determine whether the modified model had satisfactory spin and recovery characteristics. The results of the spin tests are presented herein.

The erect-spin characteristics of the model in the clean condition were determined for the normal loading and for various loading conditions. The effects of extending the flaps and landing gear both individually and together were investigated for the normal loading. The inverted-spin characteristics of the model were determined for the clean condition, normal loading. Tests were also performed for the clean condition, normal loading, to determine the effect on the spin and recovery characteristics of linking the extensions of the wing-tip trimmers with the elevator, rudders, or ailerons.

SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing or elevator chord
$\bar{c}$	mean aerodynamic chord, feet
$x/\bar{c}$	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 fuselage reference line)
m	mass of airplane, slugs

$\mu = \frac{m}{\rho S b}$	relative density of airplane
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slug per cubic foot
α	angle between fuselage reference 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	full-scale true rate of descent, feet per second
Ω	full-scale angular velocity about spin axis, revolutions per second
σ	helix angle, angle between flight path and vertical, degrees (For this model, the average absolute value of the helix angle was approximately 3°.)
β	approximate angle of sideslip at center of gravity, degrees (Sideslip is inward when inner wing is down by an amount greater than the helix angle.)

APPARATUS AND METHODS

Model

The 0.059-scale model of the XP-55 airplane modified as a result of the longitudinal-trim tests reported in reference 1 was used for the spin tests. A three-view drawing of the model as tested is shown as figure 1. The modifications to the model were as follows:

(a) Removal of the leading-edge wing-root spoilers (fig. 2).

(b) Removal of the original (small) elevator and installation of the alternate (large) elevator (fig. 3).

(c) Increase in the elevator deflection from trailing edge 17° down and 60° up to trailing edge 60° down and 60° up.

(d) Removal of the original (small) wing tips and installation of the alternate (large) wing tips (fig. 4).

(e) Installation of 5/8-inch (model-scale) extensions of the wing-tip trimmers (fig. 5).

Photographs of the original model (small elevator, small wing tips, and without the extensions of the wing-tip trimmers) in the clean and landing conditions are shown in figure 6.

The dimensional characteristics of the airplane with the original and with the alternate elevator, and with the original and with the alternate wing tips are given in table I.

The model was ballasted to maintain dynamic similarity to the airplane at an altitude of 10,000 feet (ρ = 0.001756 slug per cubic foot). When the landing gear and split flaps were installed, small ballast weights were moved to new locations so that the mass distribution of the model would represent the mass distribution of the airplane in the landing condition. A remote-control mechanism was installed in the model to actuate the controls for recovery attempts. The moments exerted on the control surfaces were sufficient to reverse the controls fully and rapidly. The propeller was not simulated on the XP-55 model inasmuch as tests with a model of the Curtiss-Wright 24-B airplane showed that a freely rotating propeller would have little effect on the spin characteristics of the model.

The elevator was mass-balanced when the tests were started. Because of the difficulty of testing the model with the mass-balance weights installed and because the results obtained from preliminary tests with and without mass-balance weights installed were similar, the mass weights were removed early in the test program. The main portion of the tests were therefore performed without mass balance on the elevator.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 2 for the 15-foot free-spinning tunnel except that the model-launching technique has been changed from launching with a spindle to launching by hand with spinning rotation. Methods of obtaining spin-test data and of converting these data to the corresponding full-scale values presented on the charts are also described in reference 2.

Spin-tunnel tests were performed to determine the spin and recovery characteristics of the model for the normal control configuration for spinning (stick full back longitudinally and neutral laterally, and rudders full with the spin) and for various other stick deflection combinations including neutral and maximum deflections of the stick for various model loadings and configurations. The turns for recovery were measured from the time the controls are moved to the time the spin rotation ceases; based primarily on the loss of altitude of the airplane during the recovery and subsequent dive, the criterion for a satisfactory recovery from a spin for the model has been adopted as 2 turns or less. The path followed by the fuselage reference line after the rotation ceased is also shown on the charts. For the conditions in which the model stopped spinning without control movement when launched in a spinning attitude with the rudders set with the rotation, the motion of the model after the spin rotation stopped is described and the results are recorded on the chart as "No spin."

Tests were also performed to determine the effect of linking the extensions of the wing-tip trimmers with the ailerons, elevator, or rudder. Inasmuch as the ailerons or elevator were not moved (except for elevator-free tests) during any individual test, the extensions were not actually linked with the ailerons or with the elevator but were fixed at neutral, up, or down depending upon the deflection of the ailerons or elevator. No arrangement was made for tests with a free elevator linked with free extensions of the wing-tip trimmers. The extensions were linked with the rudders, however, and moved with them when they were reversed for recovery.

PRECISION

The results presented were measured within the following limits:

α, degree	±1
ϕ, degree	±1
V, percent	±5
Ω, percent	±3
Turns for recovery: when obtained from motion-picture record, turn	$\pm\frac{1}{4}$
Turns for recovery: when obtained from visual estimate, turn	$\pm\frac{1}{2}$

Many of the spins had rapid oscillations of large magnitude in pitch and roll. Inasmuch as the spin-tunnel records permit ready measurement of the angles of attack and bank for only every half revolution, it appears probable that the magnitude of the oscillations in pitch and roll during the spin may have been somewhat larger than that indicated on the charts.

Comparison between the spin results of models and airplanes (references 2 and 3) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. In general, the models spun at a somewhat smaller angle of attack, with a somewhat higher rate of descent, and with 5° to 10° more outward sideslip than did the airplanes. The comparison made in reference 3 showed that 80 percent of the model recovery tests predicted satisfactorily the corresponding airplane recovery characteristics and that 10 percent overestimated and 10 percent underestimated the airplane recovery characteristics.

Because of inadvertent damage to the model during the spin tests, the weight and mass distribution of the model varied from the true scaled-down values within the following limits:

Weight, percent	0 low, 2 high
Center-of-gravity location, percent $\bar{c}$ . . .	0 forward to 2 rearward of normal
Moments of inertia: I_X, percent	2 low, 33 high
Moments of inertia: I_Y, percent	1 low, 11 high
Moments of inertia: I_Z, percent	1 high, 23 high

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

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
I_X, percent; I_Y, percent; I_Z, percent	±5

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

TEST CONDITIONS

Spin tests were performed for the conditions of the model listed in table II. The values of the corresponding mass characteristics and of the inertia parameters for the model as tested are presented in table III. The mass characteristics and inertia parameters for the normal loading and the maximum possible loading changes from the normal loading on the airplane are shown in table IV. In addition, the inertia parameters for both the model and airplane have been plotted on figure 7.

The maximum control deflections used for the spin tests were:

Right rudder, degrees	40 right, 11 left
Left rudder, degrees	11 right, 40 left
Elevator, degrees	60 up, 60 down
Elevator tab, degrees	25 down when elevator was 60 up 0 when elevator was 0 25 up when elevator was 60 down 0 when elevator was free

Ailerons, degrees
When flaps were neutral . . . . 28 up, 9 down
When flaps were 45° down . . . . 38 up, 1 up
Flaps, degrees . . . . 45 down
Wing-tip trimmers, degrees 0
Extensions of wing-tip trimmers, degrees
When linked with the ailerons . . 28 up when adjacent aileron was 28 up
9 down when adjacent aileron was 9 down
When linked with the elevator . . . both 30 down when elevator was 60 up
both 0 when elevator was 0
both 30 up when elevator was 60 down
When linked with the rudders
Extension of right wing-tip trimmer . . . . 40 up when right rudder was 40 right
11 down when right rudder was 11 left
Extension of left wing-tip trimmer . . . . 11 down when left rudder was 11 right
40 up when left rudder was 40 left

The elevator on the airplane is connected with the stick in such a manner that the trailing edge of the elevator moves up when the stick moves forward. This elevator movement with stick movement is opposite to that for conventional airplanes. The stick movement to climb or dive, however, is the same as that for conventional airplanes, that is, the stick is pushed forward to dive and is pulled rearward to climb. Although there was no stick in the model, elevator deflections and movements are generally referred to herein in terms of stick location and movement in order to avoid confusion.

Variations in mass distribution and center-of-gravity location were made for the clean condition (landing gear retracted and flaps neutral), in order to allow for the limits of accuracy of the computed airplane and model values and also to allow for a possible rearrangement of loading that might lead to a spinning condition from which recovery might be slower than for the normal loading. In an attempt to show only the effect of a single change at one time, the weight and center-of-gravity location of the model were held approximately constant when the mass distribution of the model was changed. Similarly, the weight and mass distribution of the model around the normal center-of-gravity location were held approximately constant when the center-of-gravity location was changed.

Tests were performed only for the normal loading when the model was in the landing condition (flaps deflected 45° down, ailerons deflected 10° up for trim, and tricycle landing gear installed).

RESULTS AND DISCUSSION

A key to the results presented and a list of the footnotes used on the subsequent charts are given on chart 1. The results of the spin tests are presented on charts 2 to 9. The model data are presented in terms of full-scale values for the airplane at a test altitude of 10,000 feet. Both right and left erect spins were tested for the normal loading, clean condition, and showed that the model was slightly asymmetric in that spins to the pilot's right were flatter and had more rapid rates of rotation, somewhat slower recoveries, and less tendency to nose down rapidly into a dive after the spin rotation stopped than spins to the pilot's left for corresponding control configurations. The remainder of the tests with the model erect were, therefore, performed with spins to the pilot's right in order to obtain conservative results. The tests with the model inverted were performed with spins to both the pilot's right and left.

Clean Condition

Normal loading.- The test results for erect spins of the model in the clean condition to both the pilot's right and left are presented on chart 2. This condition is represented by loading 1 on table III and point 1 on figure 7. The results show the same general effect of control deflections for both directions of spin. The discussion is arbitrarily based on the slightly conservative results obtained from spins to the pilot's right.

The spins were generally flat with oscillations of rather large magnitude in both pitch and roll for all aileron deflections when the stick was back or neutral longitudinally, the spins with ailerons deflected against the spin (stick left in a right spin) being violently oscillatory. A portion of a motion-picture record of a typical oscillatory spin with the stick back is shown in figure 8. Although rapid full rudder reversal satisfactorily stopped the rotation for all spins, the model always remained horizontal thereafter indicating nearly vertical descent at an extremely flat attitude.

The spins with the stick full forward or free longitudinally (the stick floated at or near the full forward stop) and the ailerons neutral or with the spin were generally similar to those obtained when the stick was neutral or back longitudinally. When the rudders were reversed with the stick forward or free longitudinally, however, the model stopped rotating and nosed down into a steep dive either immediately thereafter or after a short glide at a flat attitude.

When the model was launched in the tunnel with the ailerons against the spin and the stick free or forward longitudinally, the amplitude and violence of the oscillations in pitch and roll progressively increased until the model pitched and/or rolled from an erect to an inverted attitude. The oscillations and the pitching and/or rolling from erect to inverted and from inverted to erect attitudes continued until the model hit the safety net. A portion of a motion-picture record of a typical motion of the model after launching into the tunnel with ailerons deflected against the spin and the stick free or forward longitudinally is shown in figure 9. It was noted from the motion-picture records of the tests that high accelerations were frequently encountered during these violent oscillations. Inasmuch as a similar motion of the airplane would be confusing to the pilot as well as severe enough to injure him or to cause damage to the airplane structure, it is recommended that aileron-against deflections be avoided on the airplane.

The results of the erect spin tests were generally consistent with results of the longitudinal-trim tests presented in reference 1 in that when the stick was fixed at back or neutral longitudinally, the model remained at a flat attitude after rudder reversal stopped the rotation and that when the stick was forward or free longitudinally, the model nosed over into a steep dive either immediately after the spin rotation stopped or after a short glide at a flat attitude. In this connection, recoveries were occasionally attempted when the model was close to the safety net and the model then glided into the safety net before having had an opportunity to nose down into a dive. The results of these tests are the apparently inconsistent results presented on the charts which indicate that the model did not nose down into a steep dive after rudder reversal when the stick was forward or free longitudinally. It is believed, however, that the model would always have nosed down into a dive after the rotation stopped when the stick was forward or free longitudinally had sufficient space been available in the tunnel.

Mass variations.- Test results for erect spins of the model in the clean condition with the mass distribution increased along the wings (I_X and I_Z increased approximately 60 percent of I_X) and with the mass distribution decreased along the fuselage (I_Y and I_Z decreased approximately 20 percent of I_Y) are presented on chart 3. These conditions are represented by loadings 2 and 3, respectively, on table III and figure 7. The spin characteristics of the model were not appreciably affected by either change in mass distribution. The tendency of the model to dive immediately after reversal of the rudders stopped the spin rotation, however, was increased when the mass distribution was decreased along the fuselage and the stick was forward or free longitudinally. The increased rapidity with which the model nosed down after rudder reversal stopped the spin rotation when mass was retracted along the fuselage may be attributed to the reduced inertia moment that it was necessary for the aerodynamic pitching moment to overcome before the model went into a dive.

Center-of-gravity variations.- The effects of variations in the center-of-gravity location for erect spins in the clean condition are shown on chart 4. When the stick was forward or free longitudinally, moving the center of gravity forward 7 percent of the mean aerodynamic chord from the normal location (loading 4 on table III and point 4 on fig. 7) increased the rapidity with which the model nosed down into a dive after rudder reversal stopped the spin rotation; whereas, moving the center of gravity rearward approximately 8 percent of the mean aerodynamic chord from the normal location (loading 5 on table III and point 5 on fig. 7) decreased the tendency of the model to dive. These results are generally consistent with the results of the longitudinal-trim tests presented in reference 1.

Extensions of the wing-tip trimmers linked with the controls.- Charts 5 and 6 show the effects of linking the extensions of the wing-tip trimmers with the elevator, rudders, or ailerons for erect spins of the model in the clean condition, normal loading. Both the magnitude and the violence of the oscillations in pitch and roll were increased somewhat when the extensions of the wing-tip trimmers were linked with the elevator. When the stick was full forward, however, the model nosed down into a dive more rapidly after the spin rotation stopped than when the extensions of the wing-tip trimmers were maintained at neutral.

Linking the extensions of the wing-tip trimmers with the rudders decreased the tendency of the model to spin, but also decreased the tendency of the model to nose down when the stick was forward or free longitudinally.

The spin characteristics of the model were not appreciably affected when the extensions of the wing-tip trimmers were linked with the ailerons, but when the stick was forward or free longitudinally, the model would not nose down after the spin rotation had been stopped.

An analysis of the results of the tests with the extensions of the wing-tip trimmers linked with the controls indicated that the increased diving tendency obtained for stick-forward positions when the extensions were linked with the elevator can be attributed to the negative pitching moment contributed by the extensions of the wing-tip trimmers in the down position. Similarly, the analysis indicated that the reduction in diving tendency obtained when the extensions of the wing-tip trimmers were linked to either the rudders or the ailerons can be attributed to a positive pitching moment produced by the differental deflections of the extensions.

Recommended recovery technique from erect spins.- The standard technique for recovery from erect spins consists of reversal of the rudders followed approximately 1/2 turn later by movement of the stick forward (reference 4). Ailerons are maintained at neutral. Inasmuch as the XP-55 airplane will not nose down into a dive until the stick is moved nearly full forward, the altitude lost during the spin recovery will be unnecessarily increased if the standard recovery technique is employed. In order to increase the rapidity of the nosing down of the airplane and thereby decrease the altitude lost during recovery, it is strongly recommended that the stick be moved full forward or released longitudinally (to permit it to move forward towards the stop) simultaneously with reversal of the rudders. In addition, the pilot should take precaution to prevent a movement of the ailerons in a direction against the spin in order to avoid the violent oscillations associated with aileron-against deflections.

Inverted spins.- The results of inverted spin tests for the clean condition, normal loading, are presented on chart 7. The model was slightly asymmetrical for these tests but, as for the erect spins, the same general effects of control settings were observed for both spin directions. It is to be noted that the order used for plotting the data for the inverted spins is different from that used for the erect spins. For inverted spins, "controls crossed" (right rudder pedal forward and stick to left for spins to pilot's right) for the developed spin is given to the right of the chart and stick back is at the bottom. When the controls are crossed in the established inverted spin, the ailerons aid the rolling motion; when controls are together, the ailerons oppose the rolling motion. The angle of wing tilt on the chart is given as up or down relative to the ground.

The inverted spins were flat and oscillatory as were the erect spins. The magnitude of the oscillations in both pitch and roll, however, was generally greater than that for the erect spins. Rapid full rudder reversal satisfactorily stopped the spin rotation for all control configurations, but the model remained at a flat attitude thereafter when the stick was forward or neutral longitudinally. When, however, the stick was back or free (the stick floated at or near the full back stop) longitudinally, the model nosed over into a steep dive immediately after rudder reversal stopped the spin rotation.

The motion of the model when the controls were together was similar to the motion previously described for erect spins with the ailerons against the spin. For the reasons previously noted for erect aileron-against spins, it is recommended that developed inverted spins with controls together be avoided on the airplane.

The results of the inverted-spin tests also were generally consistent with the results of the longitudinal-trim tests presented in reference 1.

Recommended recovery technique from inverted spins.- In order to avoid undue loss of altitude during recovery, it is recommended that the stick be moved full back or released longitudinally simultaneously with reversal of the rudders when recovery is being attempted from an inverted spin.

Landing Condition

Test results for erect spins with the model in the landing condition and with flaps alone and landing gear alone extended are presented on charts 8 and 9. A comparison of the results presented on chart 8 for the landing condition and for the clean condition shows that the spins in the landing condition were generally similar to the spins in the clean condition when the stick was full forward, neutral, or full back. When the stick was free, the spins in the landing condition were somewhat steeper than spins in the clean condition. The model stopped rotating shortly after the rudders were reversed fully and rapidly for all control configurations. When the stick was forward or free longitudinally, the model nosed down into a dive more rapidly after the spin rotation stopped for the landing condition, or when landing gear alone was extended, than for the clean condition.

The increase in rapidity in nosing down when the flaps and landing gear were extended may be explained on the basis of an increased negative pitching moment. The results of these tests are in general agreement with the results of the longitudinal-trim tests presented in reference 1.

Recommended recovery technique from spins in the landing condition.- The technique previously recommended for recovery from erect spins in the clean condition should be followed when attempting recovery from spins in the landing condition. The flaps and landing gear should be retracted as soon as the airplane begins to dive.

Control Forces

The discussion of the results of the spin tests has been based on control effectiveness alone without regard to the forces required to move the controls. For all tests, sufficient force was applied to the rudders to reverse them fully and rapidly. The pilot must supply sufficient force to the rudder pedal to move the rudders in a similar manner in order for the model and airplane results to be similar. Although the force required to fully reverse the rudders on the model during the spin was not measured, it is believed that, because of the low rate of rotation in the spin and the high angle of attack of the airplane, the pilot will encounter little difficulty in rapidly reversing the rudders on the airplane.

The elevator on the airplane will float at or near the full-up (with respect to the ground) stop when the airplane is in a spin, and on the basis of information furnished by the manufacturer, it appears that the pilot will be unable to move the elevator from this position. Inasmuch as this is the elevator position that the model tests have shown to be conducive to rapid nosing down after rudder reversal stops the spin rotation, however, it will not be necessary for the pilot to move the elevator from this position for spin recovery.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of spin tests of a 0.059-scale model of the XP-55 airplane, the following conclusions and recommendations are made regarding the spin and recovery characteristics of the airplane at an altitude of 10.000 feet. The conclusions apply specifically to the XP-55 airplane modified to improve longitudinal-trim characteristics by the installation of a large elevator with deflections of $\pm 60^{\circ}$ and installation of large wing tips with extensions of the wing-tip trimmers as recommended by the NACA.

1. The spins for all control configurations and loadings will be flat and oscillatory. The spin rotation will stop shortly after rapid full reversal of the rudders for all control configurations.

2. Spins with ailerons deflected against the spin will be violently oscillatory and should be avoided on the airplane.

3. When the stick is neutral longitudinally or back, the airplane will remain at a flat erect attitude after the rotation stops. The airplane will nose down into a steep dive after the rotation stops, however, when the stick is forward or free longitudinally.

4. Moving the center of gravity forward, decreasing the mass distribution along the fuselage, deflecting the flaps and extending the landing gear, or linking the extensions of the wing-tip trimmers with the elevator will increase the rapidity with which the airplane noses down into a dive after the spin rotation stops.

5. Moving the center of gravity rearward or linking the extensions of the wing-tip trimmers with the rudders or ailerons will decrease the tendency of the airplane to dive after the spin rotation stops.

6. The recommended recovery technique from erect spins is rapid full reversal of the rudders accompanied by either full forward movement or release longitudinally of the stick.

7. The recommended recovery technique from inverted spins is rapid full reversal of the rudders accompanied by full rearward movement or release longitudinally of the stick.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE CURTISS-WRIGHT XP-55 AIRPLANE

Length over all, ft		29.58
Propeller diameter, ft		10.0
Wing:	With large wing tips	With small wing tips
Span, ft	41.02	40.57
Area, sq ft	213.2	208.3
Section, root	C-W 6500-0015	C-W 6500-0015
Section, tip	C-W 6500-0015	C-W 6500-0015
Root chord incidence, deg	4.25	4.25
Tip chord incidence, deg	0.75	0.75
Aspect ratio	7.88	7.91
Sweepback at 25 percent chord line, deg	28.5	28.5
Dihedral at 25 percent chord line, deg	4.5	4.5
Taper ratio	3.88	3.88
Mean aerodynamic chord, in.	67.44	67.69
Leading edge of M.A.C. rearward of leading edge of root chord, in.	62.88	61.08
Leading edge of root chord rearward of nose of airplane, ft	11.23	11.23
Ailerons:		
Area rearward of hinge line, percent of wing area (with large wing tips)		7.13
Span, percent of wing semispan (with large wing tips)		38.44
Chord, percent of wing chord		20.0
Flaps:		
Type		Split
Chord, ft		1.11
Span, percent of wing semispan (with large wing tips)		31.72

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TABLE I.- DIMENSIONAL CHARACTERISTICS - Concluded

Large horizontal tail surfaces:	
Total area, sq ft	21.52
Span, ft	11.31
Distance from normal center of gravity to elevator hinge line, ft	15.95
Tab chord, percent elevator chord	25.00
Small horizontal tail surface:	
Total area, sq ft	18.63
Span, ft	8.92
Vertical tail surfaces:	
Total exposed area, sq ft	27.80
Fin area forward of hinge line, sq ft	14.80
Rudder area rearward of hinge line, sq ft	13.00
Rudder area, percent of exposed vertical tail area	46.80
Over-all height, ft	4.58
Aspect ratio	1.37
Distance from normal center of gravity to rudder hinge line, ft	7.97
Distance from rudder hinge line to plane of symmetry, ft	16.56

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TABLE II

CONDITIONS OF THE CURTISS-WRIGHT XP-55 MODEL INVESTIGATION IN THE 20-FOOT FREE-SPINNING TUNNEL

No.	Configuration	Loading (a)	Type of spin	Landing gear	Flaps (deg)	Extensions of wing-tip trimmers (b)	Data on chart
1	Clean	Normal	Erect	Retracted	0	Neutral	2
2	------do-----	A	---do---	----do---	0	------do-----	3
3	------do-----	B	---do---	----do---	0	------do-----	3
4	------do-----	C	---do---	----do---	0	------do-----	4
5	------do-----	D	---do---	----do---	0	------do-----	4
6	------do-----	Normal	---do---	----do---	0	E	5
7	------do-----	--do--	---do---	----do---	0	F	6
8	------do-----	--do--	---do---	----do---	0	G	6
9	------do-----	--do--	Inverted	----do---	0	Neutral	7
10	Landing	--do--	Erect	Extended	45 down	------do-----	8
11	Flap down	--do--	---do---	Retracted	45 down	------do-----	9
12	Landing gear extended	--do--	---do---	Extended	0	------do-----	9

a. Loading:
- A. I_X and I_Z increased by 60 percent of I_X.
- B. I_Y and I_Z decreased by 20 percent of I_Y.
- C. Center of gravity 7 percent of mean aerodynamic chord forward of normal.
- D. Center of gravity 8 percent of mean aerodynamic chord rearward of normal.

b. Extensions of wing-tip trimmers:
- F. Linked with the ailerons.
- G. Linked with the rudders.
- E. Linked with the elevator.

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TABLE III. - MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS TESTED ON THE CURTISS-WRIGHT XP-55 MODEL

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

Number	Loading	Weight (pounds)	Center-of-gravity location		Moments of inertia			Mass parameters			μ (Sea level)	μ (10,000 feet)
			$x/\bar{c}$	$z/\bar{c}$	I_X (Slug-feet^2)	I_Y (Slug-feet^2)	I_Z (Slug-feet^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$		
1	Normal	7717	0.118	-0.019	4120	10,896	14,712	-168×10^{-4}	-95×10^{-4}	263×10^{-4}	11.52	15.61
2	I_X and I_Z increased 60 percent of I_X	7906	0.099	-0.008	6639	11,916	18,476	-128×10^{-4}	-159×10^{-4}	287×10^{-4}	11.80	15.99
3	I_Y and I_Z decreased 20 percent of I_Y	7851	0.109	-0.008	5657	8651	14,270	-73×10^{-4}	-137×10^{-4}	210×10^{-4}	11.72	15.88
4	Center of gravity moved forward 7 percent of M.A.C.	7811	0.048	-0.012	5063	12,672	17,718	-186×10^{-4}	-124×10^{-4}	310×10^{-4}	11.66	15.80
5	Center of gravity moved rearward 8 percent of M.A.C.	7835	0.202	-0.016	4542	9860	14,255	-130×10^{-4}	-107×10^{-4}	237×10^{-4}	11.70	15.84

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TABLE IV. - MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR VARIOUS LOADINGS POSSIBLE ON THE CURTISS-WRIGHT XP-55 AIRPLANE

[Moments of inertia are about center of gravity]

Number	Loading	Weight (pounds)	Center-of-gravity location		Moments of inertia			Mass parameters			μ (Sea level)	μ (10,000 feet)
			$x/\bar{c}$	$z/\bar{c}$	I_X (slug-feet^2)	I_Y (slug-feet^2)	I_Z (slug-feet^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$		
6	Normal	7717	0.117	-0.019	4300	11,515	15,095	-179×10^{-4}	-89×10^{-4}	268×10^{-4}	11.52	15.61
7	Maximum increase in I_X and I_Y possible	8424	0.123	-0.024	5707	11,722	16,235	-137×10^{-4}	-103×10^{-4}	240×10^{-4}	12.58	17.04
8	Maximum increase in I_Y and I_Z possible	8582	0.118	-0.021	5702	11,827	16,471	-137×10^{-4}	-103×10^{-4}	240×10^{-4}	12.81	17.35
9	Maximum decrease in I_Y and I_Z possible	6378	0.316	-0.006	4269	8449	12,027	-125×10^{-4}	-107×10^{-4}	232×10^{-4}	9.52	12.90
10	Maximum increase in I_X and I_Z and maximum decrease in I_Y and I_Z possible	7085	0.303	0.041	5620	8632	13,295	-81×10^{-4}	-126×10^{-4}	207×10^{-4}	10.58	14.33
11	Most forward center-of-gravity location possible	7732	0.105	-0.018	4298	11,531	15,141	-179×10^{-4}	-89×10^{-4}	268×10^{-4}	11.54	15.64
12	Most rearward center-of-gravity location possible	6519	0.321	-0.010	4257	8479	12,081	-124×10^{-4}	-106×10^{-4}	230×10^{-4}	9.74	13.19

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CHART 1.- KEY AND FOOTNOTES FOR CHARTS ON SPIN CHARACTERISTICS OF XP-55 MODEL

KEY

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	
Path of fuselage reference line after rotation stops	

Model values converted to corresponding full-scale values

U Inner wing up

D Inner wing down

→ Model glided forward at a flat attitude for a short distance before hitting safety net.

⟶ Model glided forward at a flat attitude for an appreciable distance before hitting safety net.

⤵ Model glided forward at a flat attitude for a short distance and then nosed down into a steep dive.

↓ Model nosed down into a steep dive immediately after the spin rotation stopped.

FOOTNOTES

[a]Oscillatory spin; range of values or average value given.

[b]Violently oscillatory in pitch and roll.

[c]Amplitude and violence of oscillations in pitch and roll progressively increased until model pitched and/or rolled inverted. The oscillations and the pitching and/or rolling erect-inverted, etc., continued until the model hit the safety net.

[d]Too oscillatory in pitch and roll to test completely.

[e]Model yawed in a circle of extremely large radius at a large angle of attack. Rotational velocity was low.

[f]Recovered in a wide spiral glide.

[g]Wandering spin.

[h]Steady oscillation in pitch. Model appeared to gallop.

[i]Model went into an inverted spin after a short vertical dive.

[j]High rate of descent. Model executed one violent oscillation in pitch per turn of spin.

[k]Too wandering to test completely.

[m]Very steep, smooth spin with too wide a radius of spin to test completely.

[n]Pitched into an inverted flat attitude after short vertical dive.

[p]Visual estimate.

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CHART 2.- EFFECT OF CONTROLS ON THE SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Normal loading; cockpit closed; landing gear retracted; flaps neutral; extensions of wing-tip trimmers at 0°; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); erect spins; direction of spin as indicated]

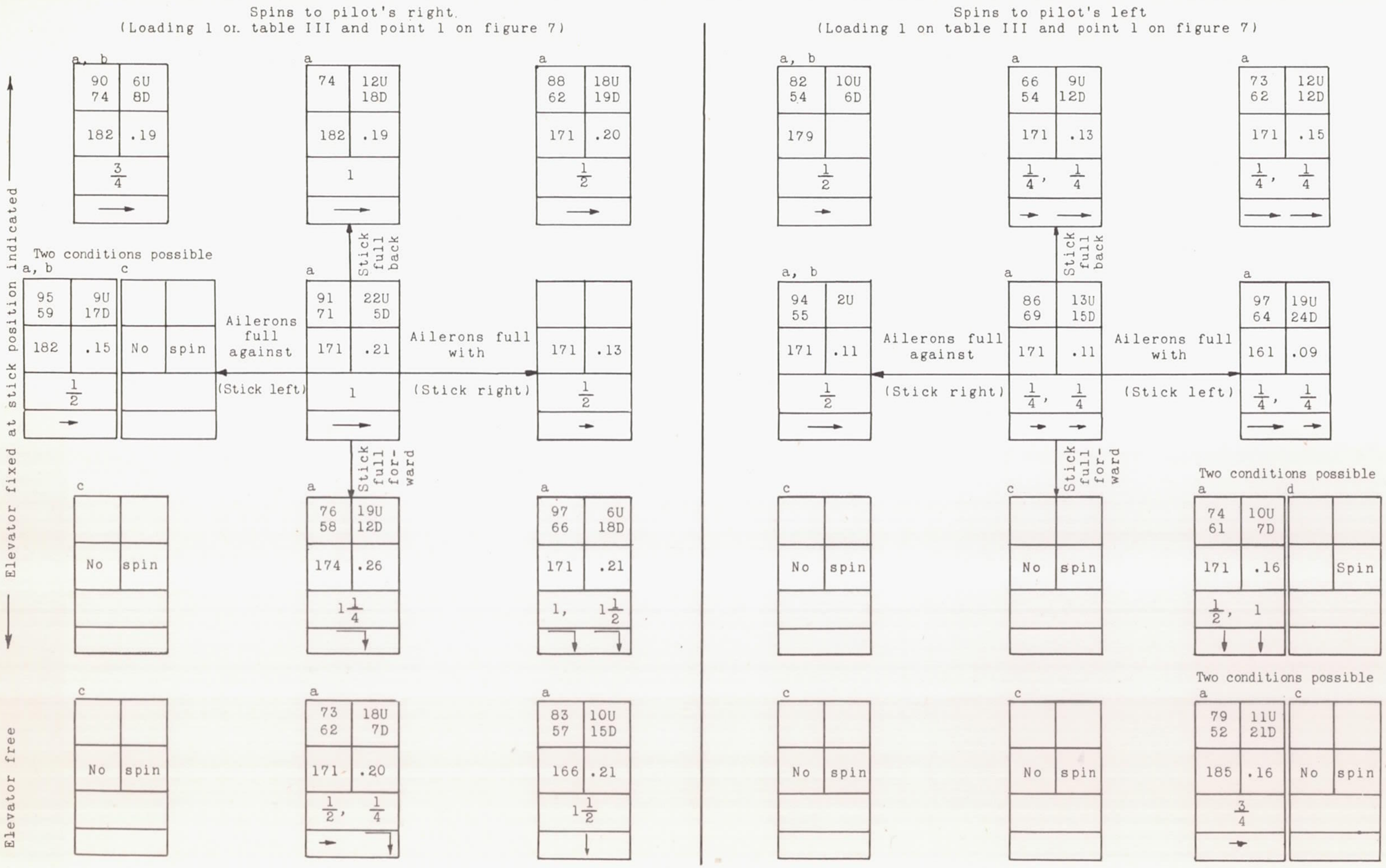

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CHART 3.- EFFECT OF MASS DISTRIBUTION ON THE SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Loading as indicated; cockpit closed; landing gear retracted; flaps neutral; extensions of wing-tip trimmers at 0°; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

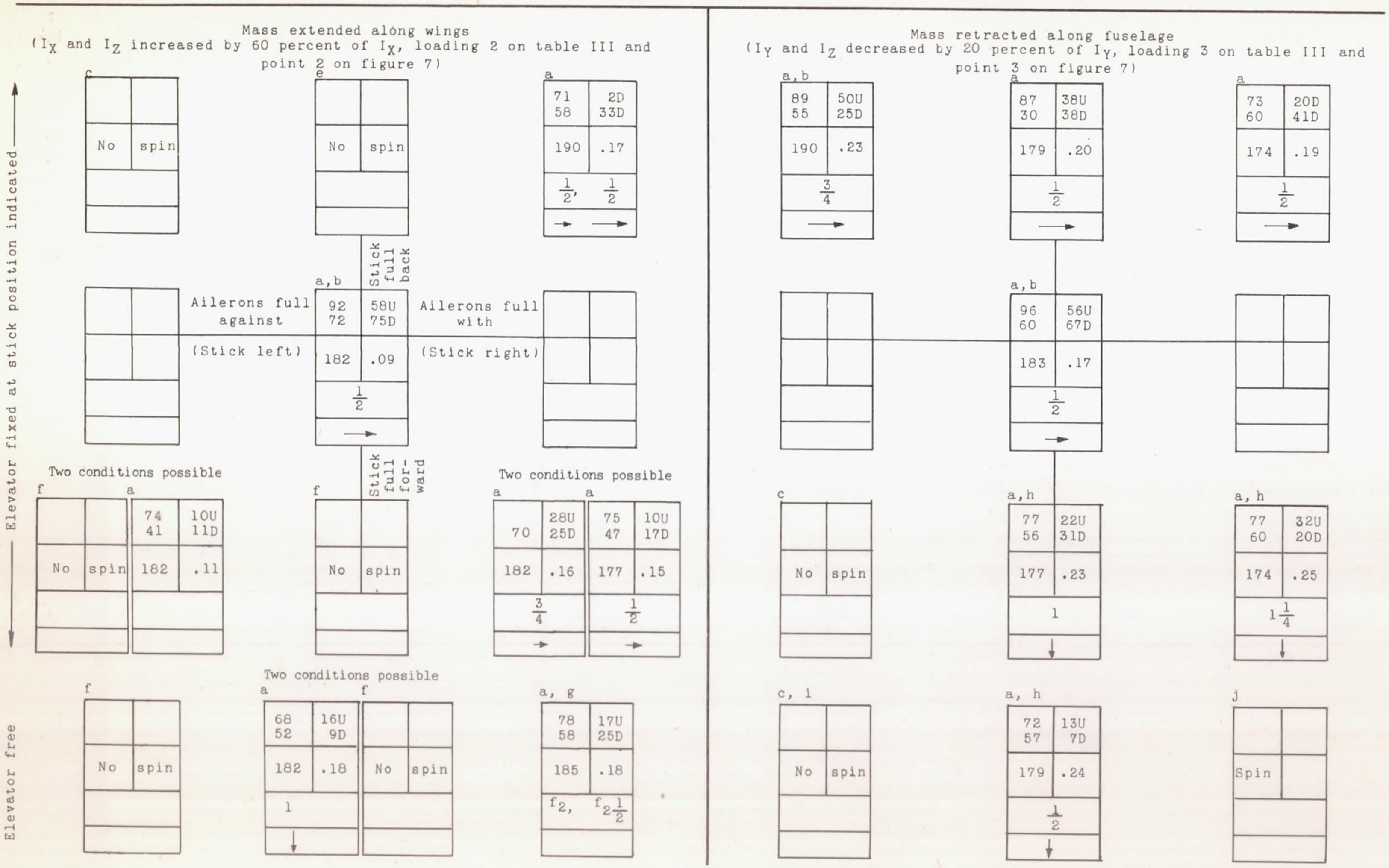

CHART 4.- EFFECT OF CENTER-OF-GRAVITY LOCATION ON THE SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Center-of-gravity location as indicated; cockpit closed; landing gear retracted; flaps neutral; extensions of wing-tip trimmers at 0°; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

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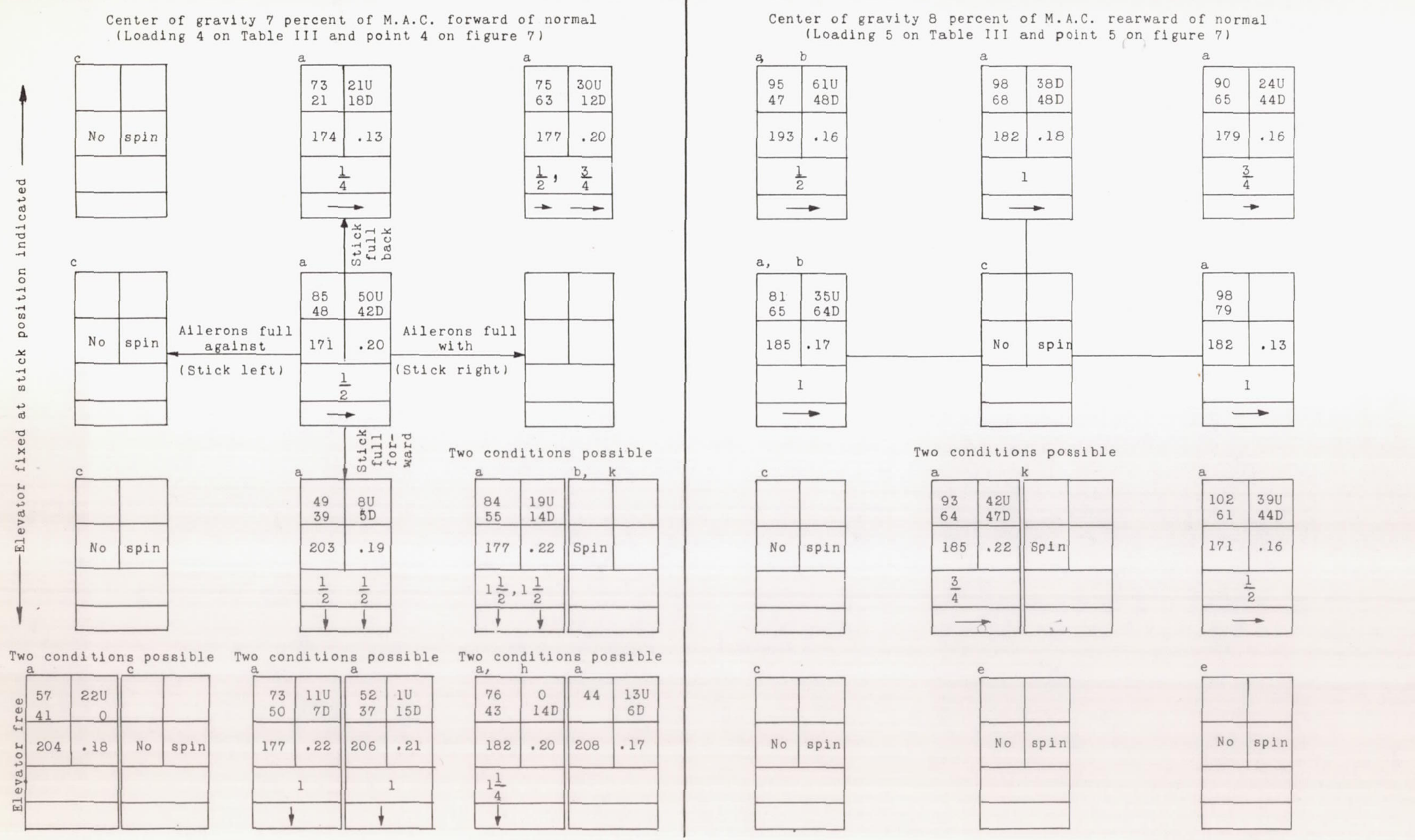

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CHART 5.- EFFECT OF LINKING THE EXTENSIONS OF THE WING-TIP TRIMMERS WITH THE ELEVATOR ON THE SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Normal loading; cockpit closed; landing gear retracted; flaps neutral; extensions of wing-tip trimmers as indicated; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

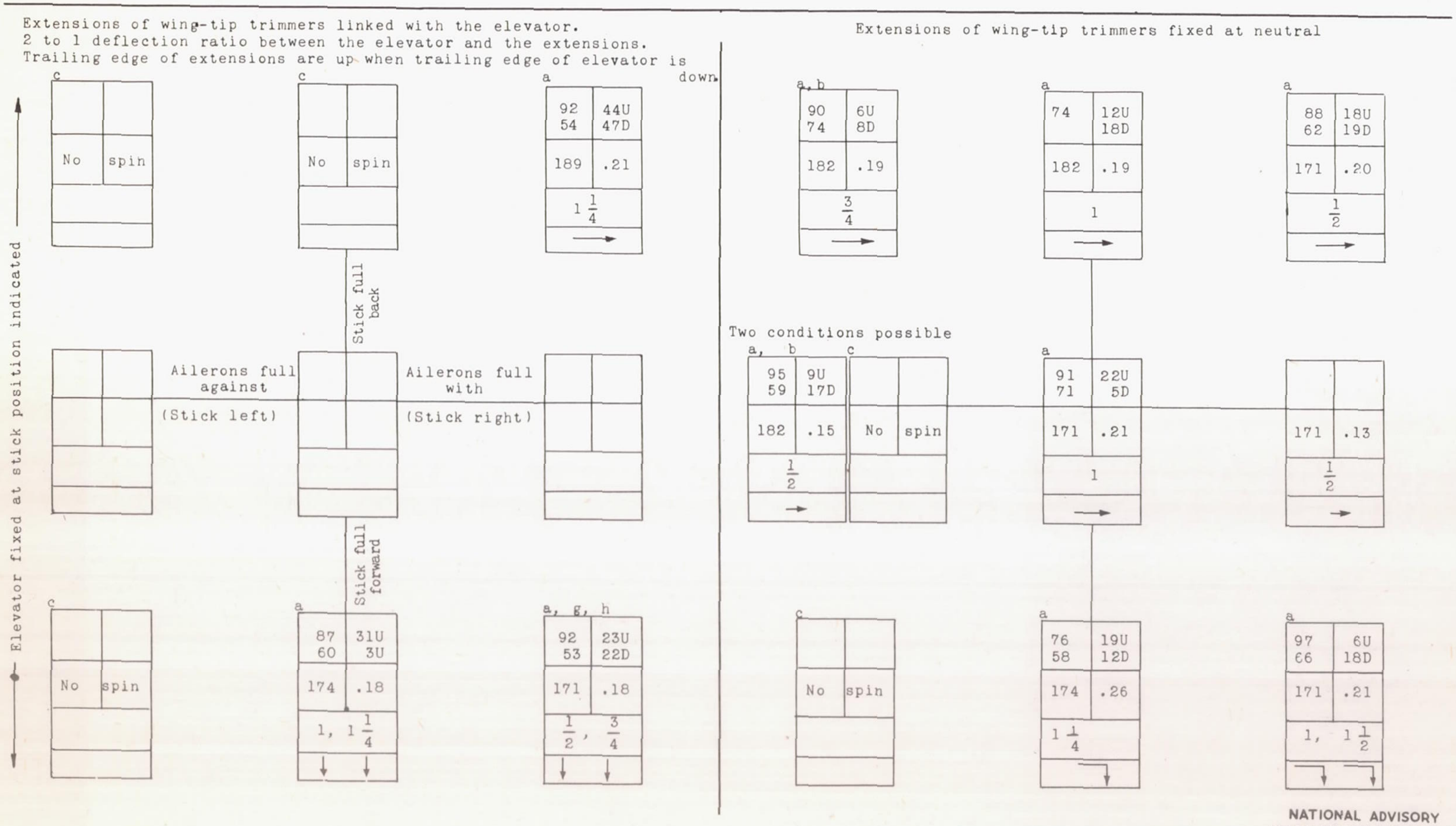

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CHART 6.- EFFECT OF LINKING THE EXTENSIONS OF THE WING-TIP TRIMMERS WITH THE AILERONS AND WITH THE RUDDERS ON THE SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Normal loading; cockpit closed; landing gear retracted; flaps neutral; extensions of wing-tip trimmers linked as indicated; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

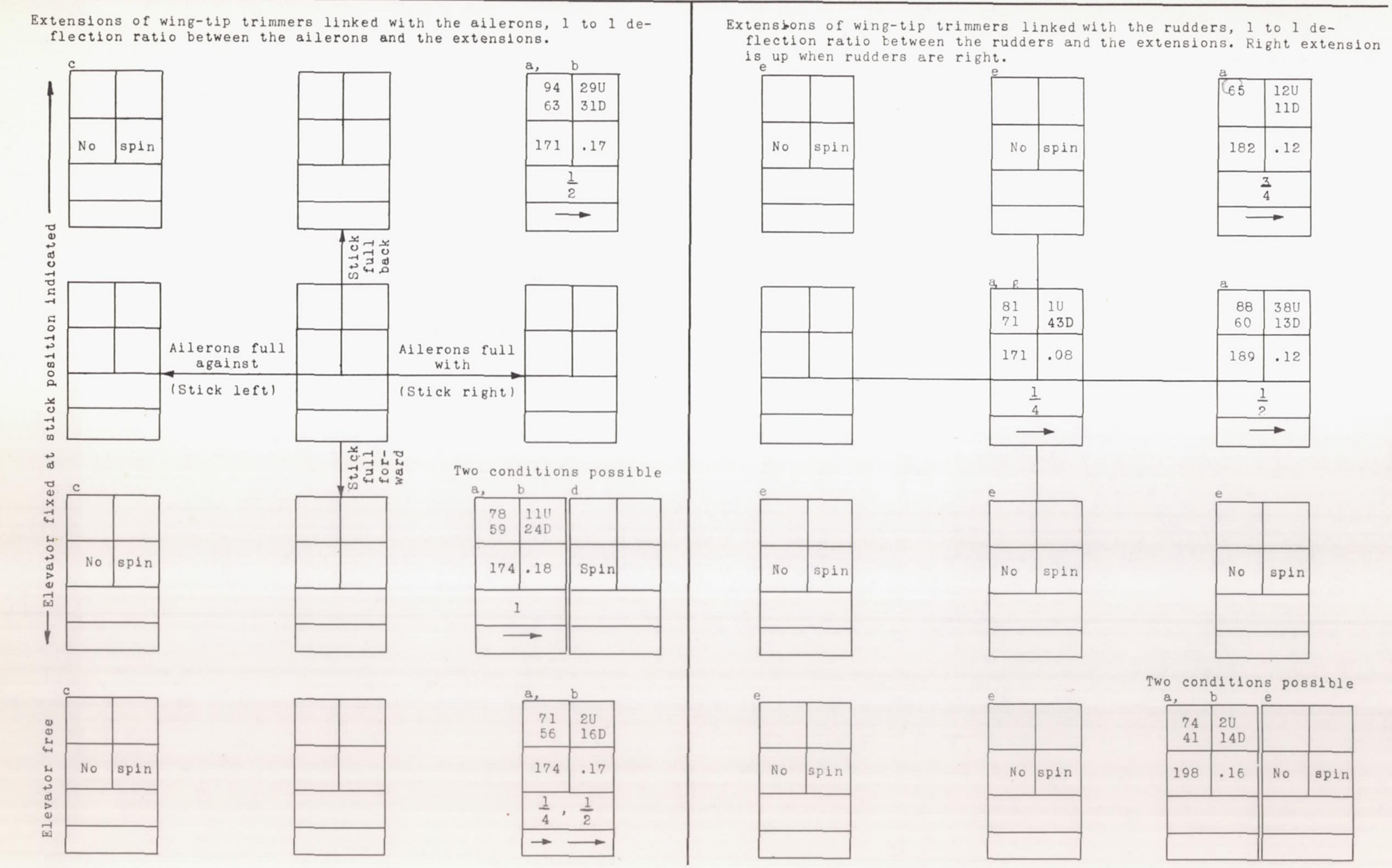

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CHART 7.- INVERTED SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Normal loading; cockpit closed; landing gear retracted; flaps neutral; extensions of the wing-tip trimmers at 0°; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); direction of spin as indicated; inverted spins]

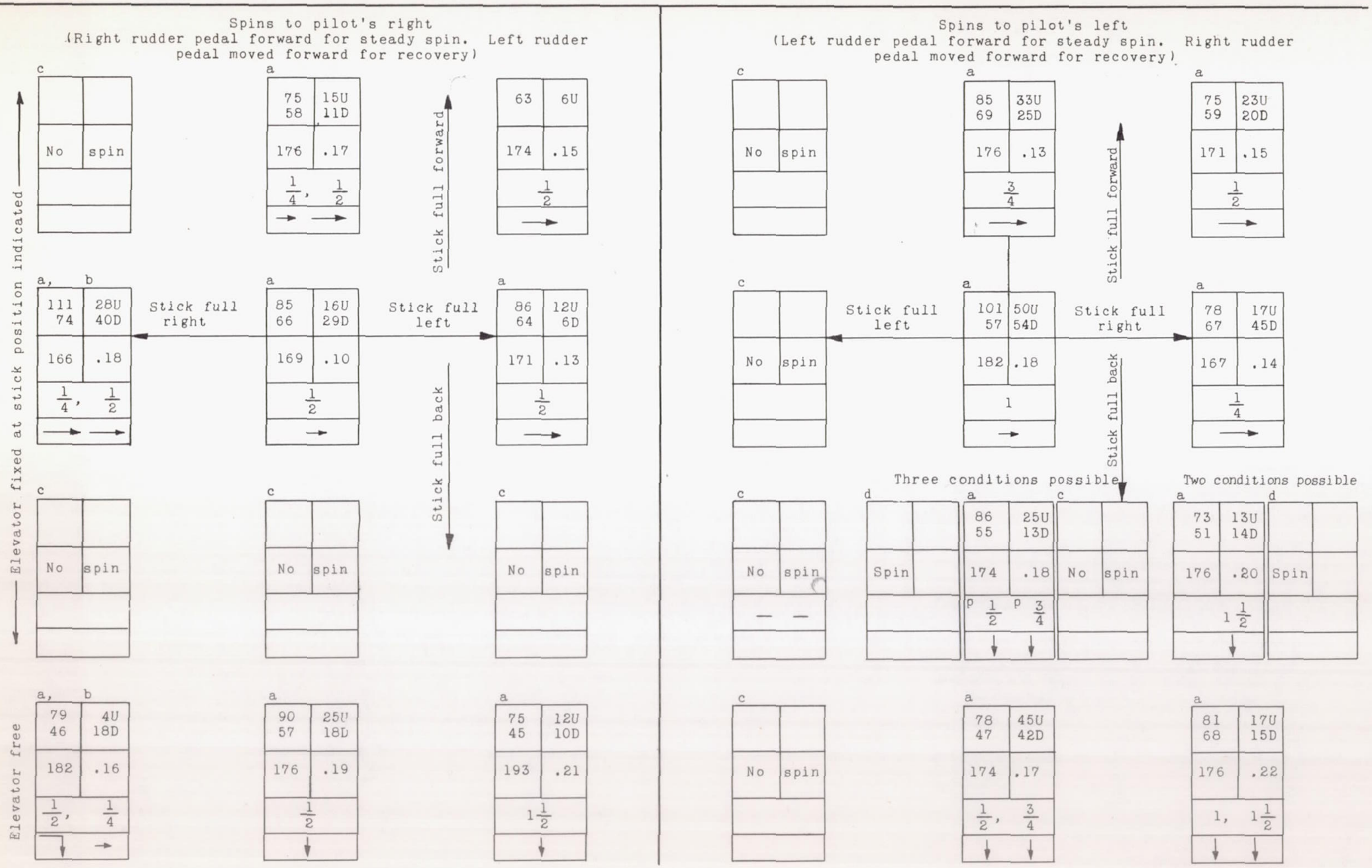

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CHART 8.- EFFECT OF FLAPS AND LANDING GEAR ON THE SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Normal loading; cockpit closed; landing gear and flaps as indicated; extensions of wing-tip trimmers at 0°; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

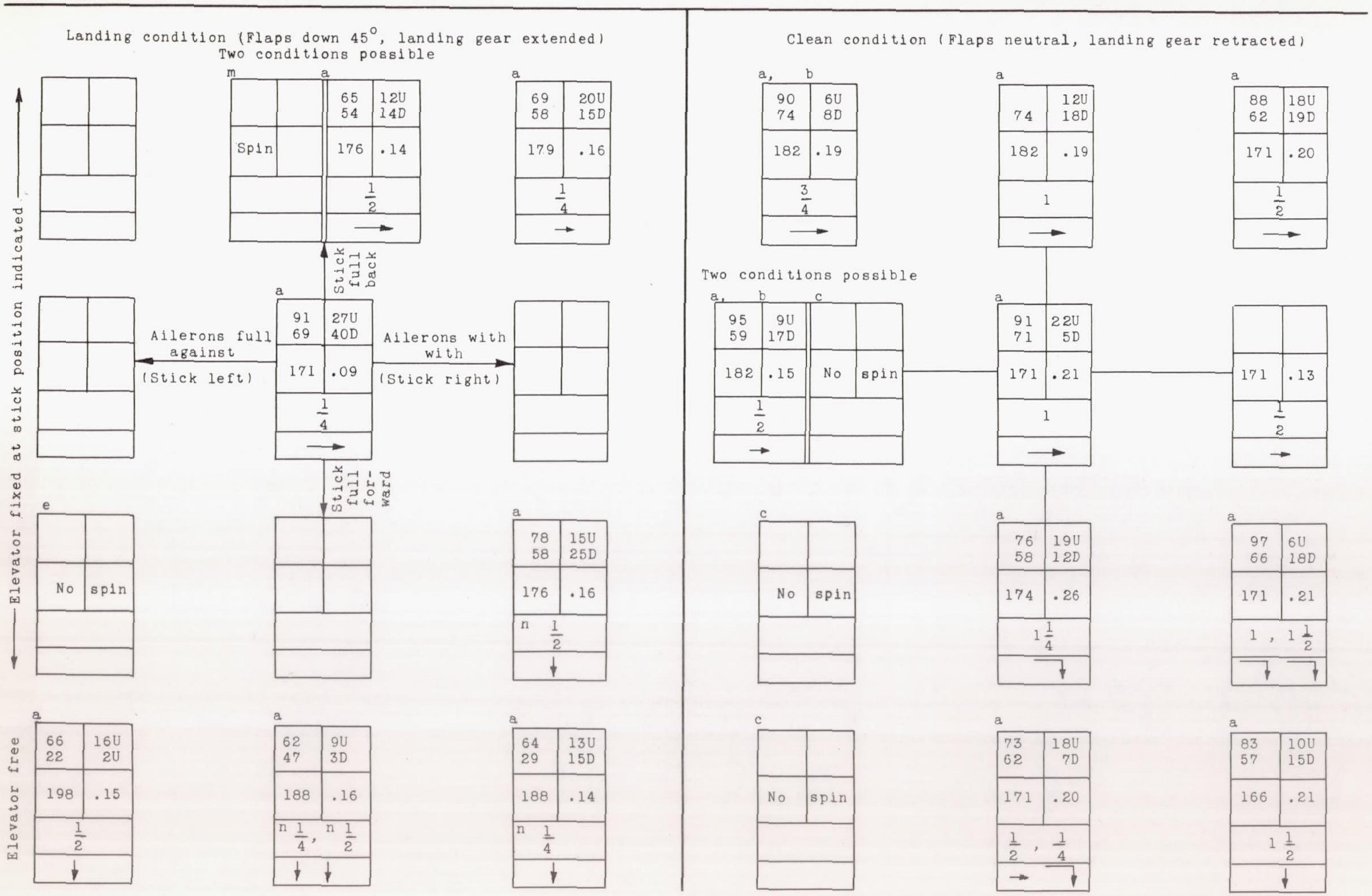

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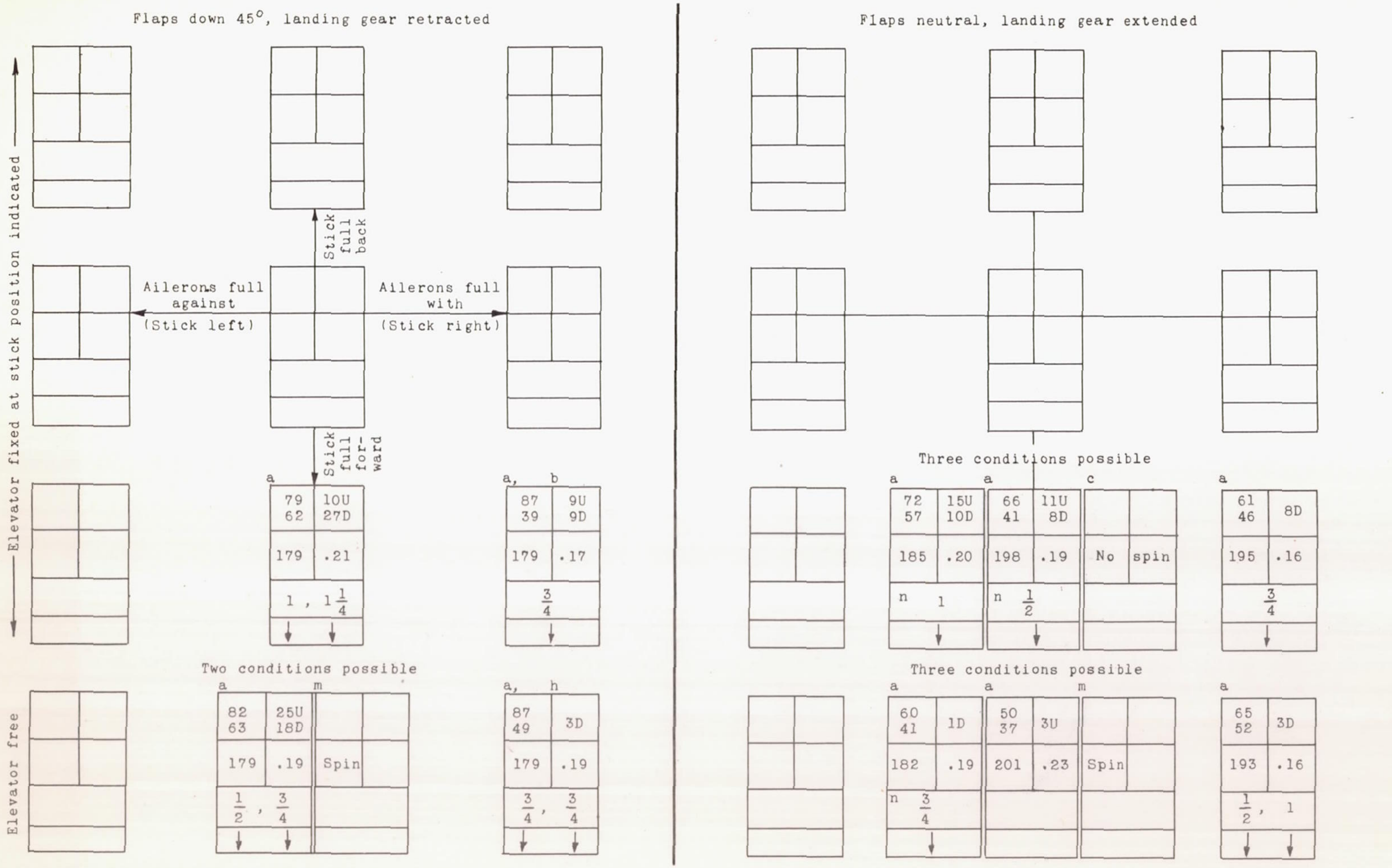
CHART 9.- EFFECT OF FLAPS AND LANDING GEAR ON THE SPIN CHARACTERISTICS OF THE XP-55 MODEL

[Normal loading; cockpit closed; landing gear and flaps as indicated; extensions of wing-tip trimmers at 0°; recovery by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



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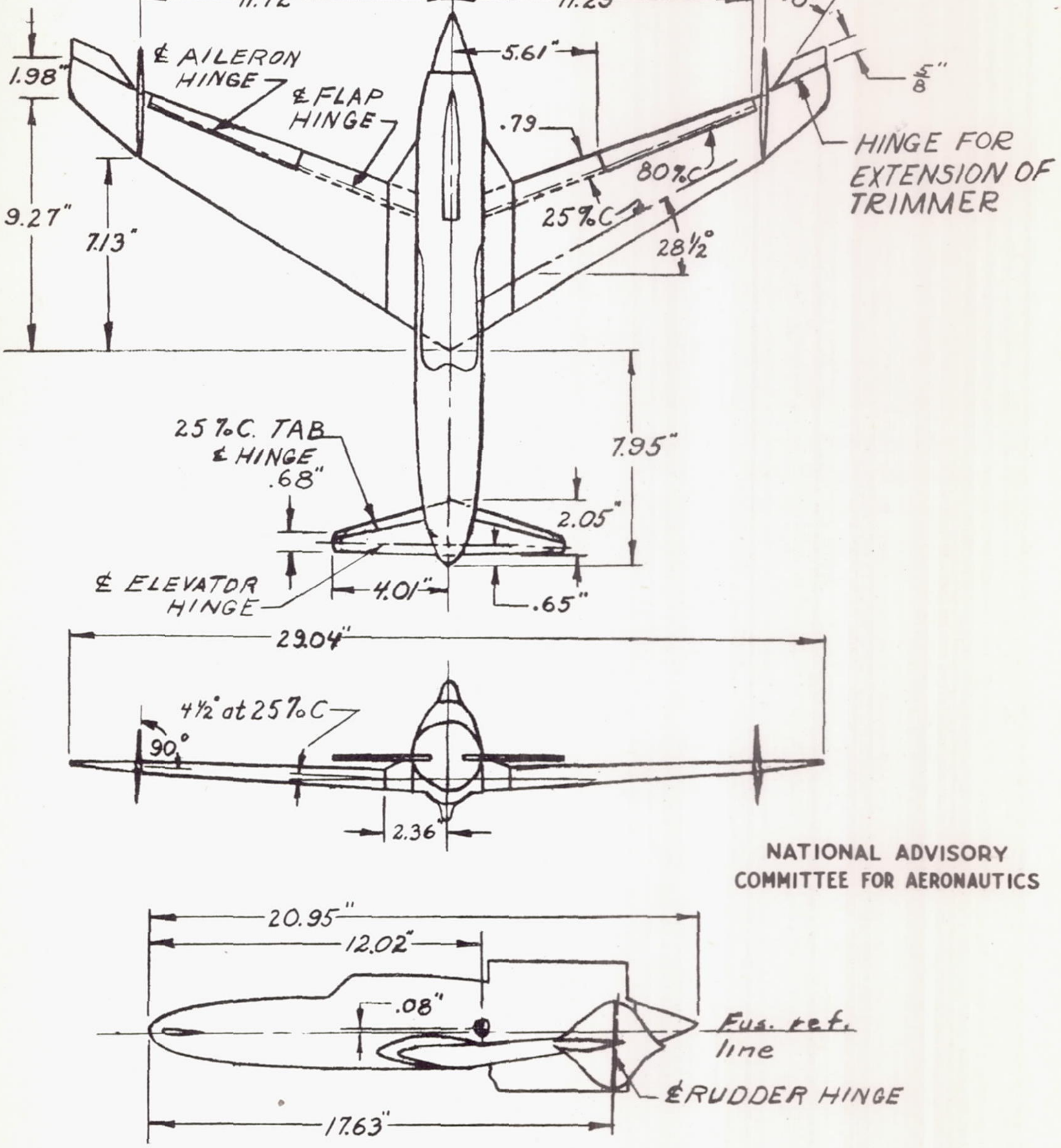

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Figure 1.- Drawing of the 0.059-scale model of the Curtiss-Wright XP-55 airplane as tested in the free-spinning tunnel. Wing root incidence, 4.25°, leading edge up. Tip chord incidence, 0.75°, leading edge up. Center-of-gravity location shown is for the normal loading with the landing gear retracted. Large elevator and large wing tips with extensions of wing-tip trimmers installed.

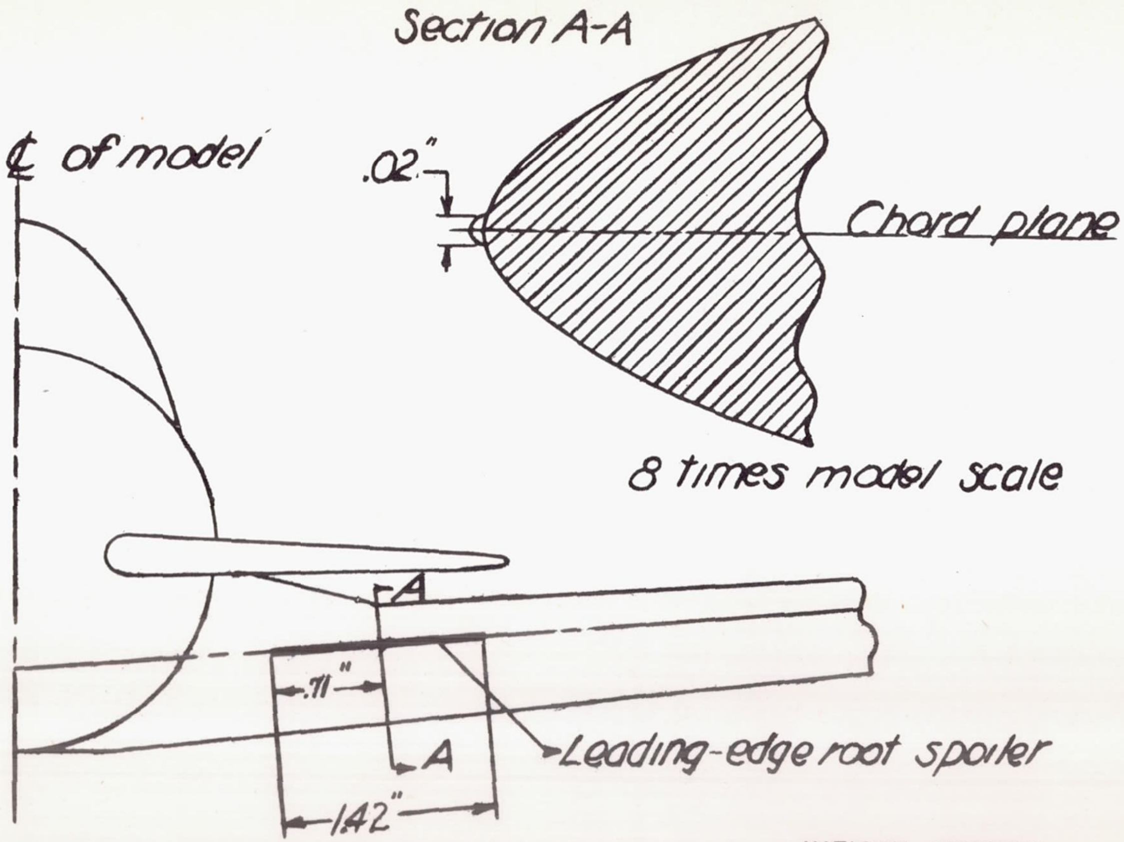

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Figure 2.- Leading-edge wing-root spoilers removed for tests of the 0.059-scale model of the XP-55 airplane in the 20-foot free-spinning tunnel.

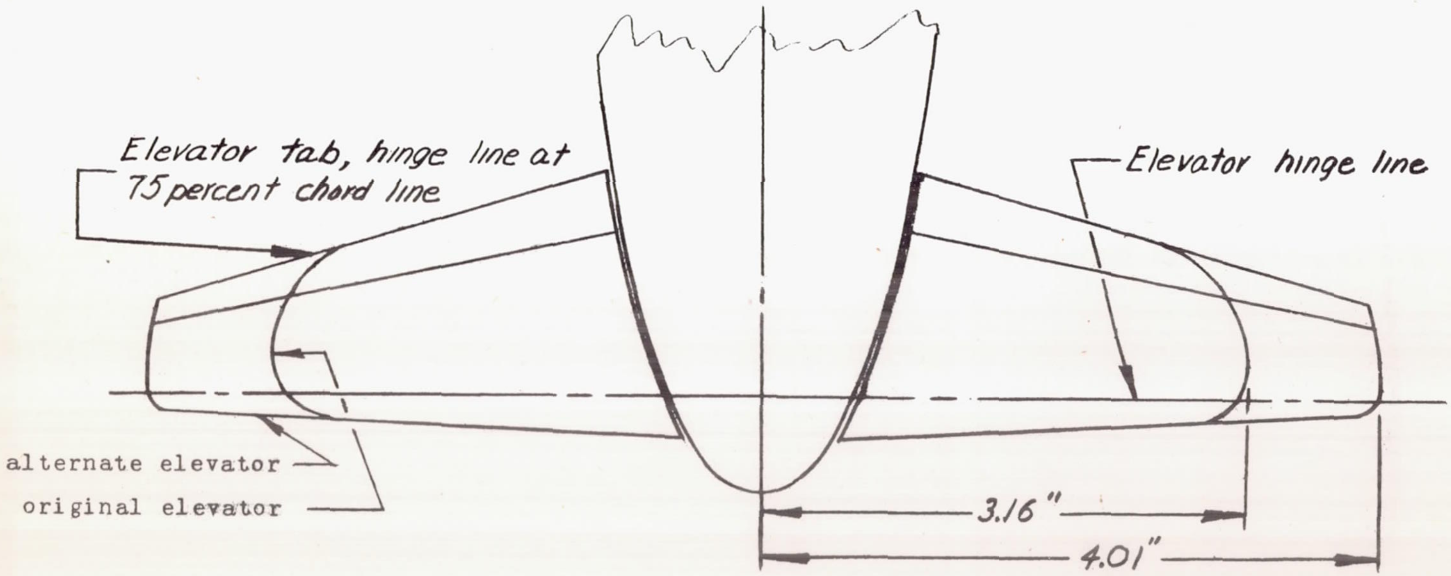

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Figure 3.- Comparison of the alternate elevator tested on the 0.059-scale model of the XP-55 airplane in the 20-foot free-spinning tunnel with the original elevator.

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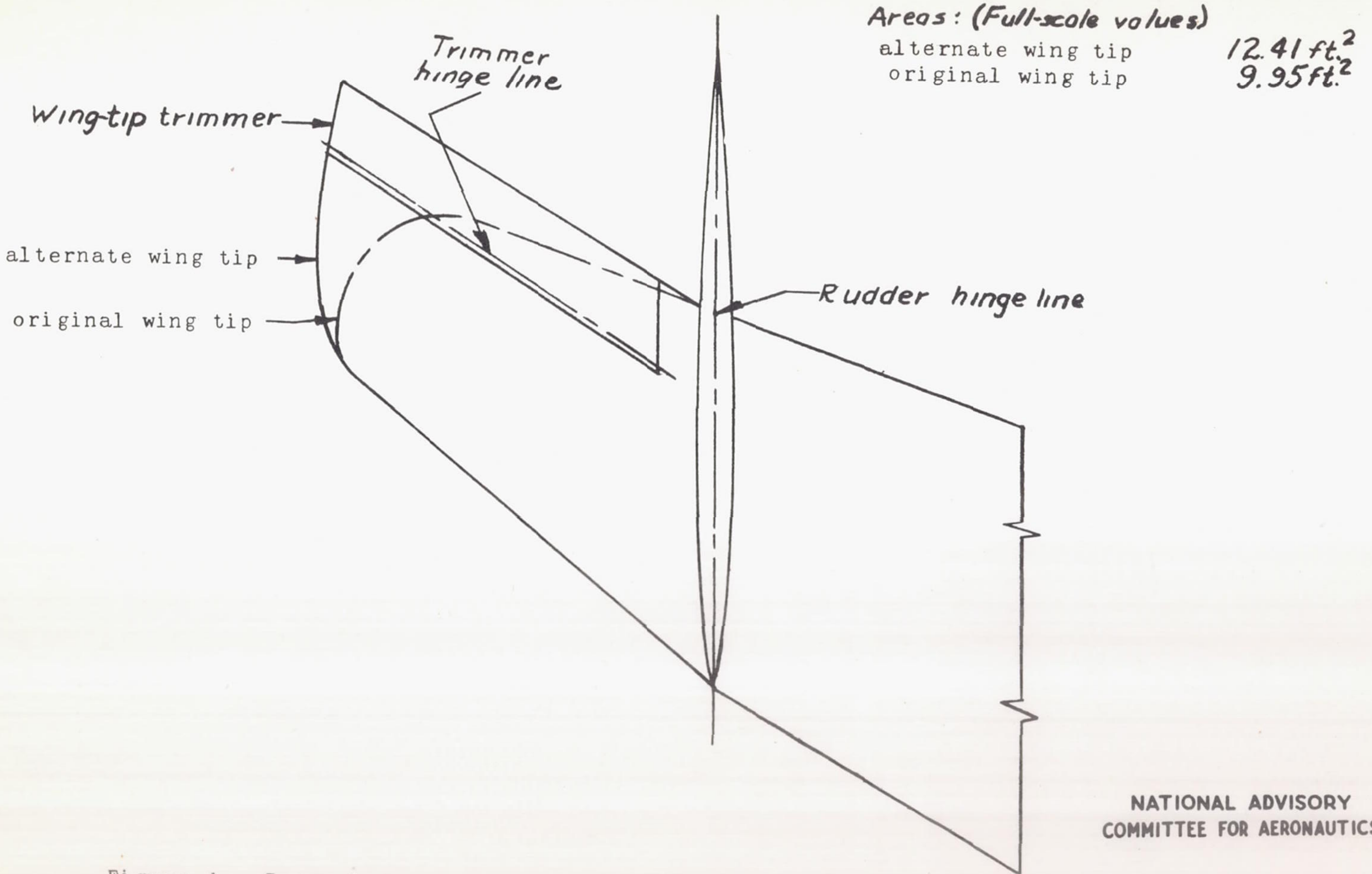

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Figure 4.- Comparison of the alternate wing tips tested on the 0.059-scale model of the XP-55 airplane in the 20-foot free-spinning tunnel with the original wing tips.

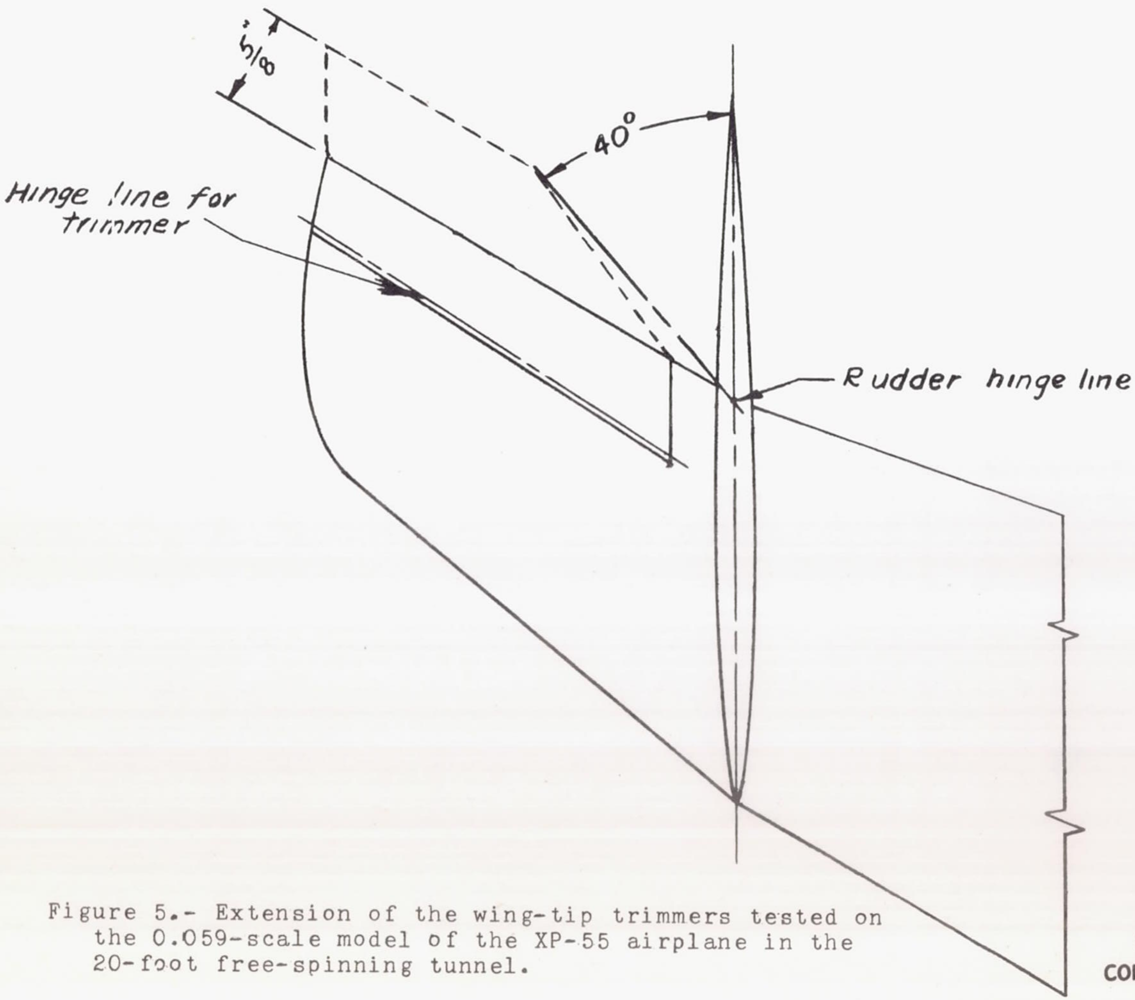

Figure 5.- Extension of the wing-tip trimmers tested on the 0.059-scale model of the XP-55 airplane in the 20-foot free-spinning tunnel.

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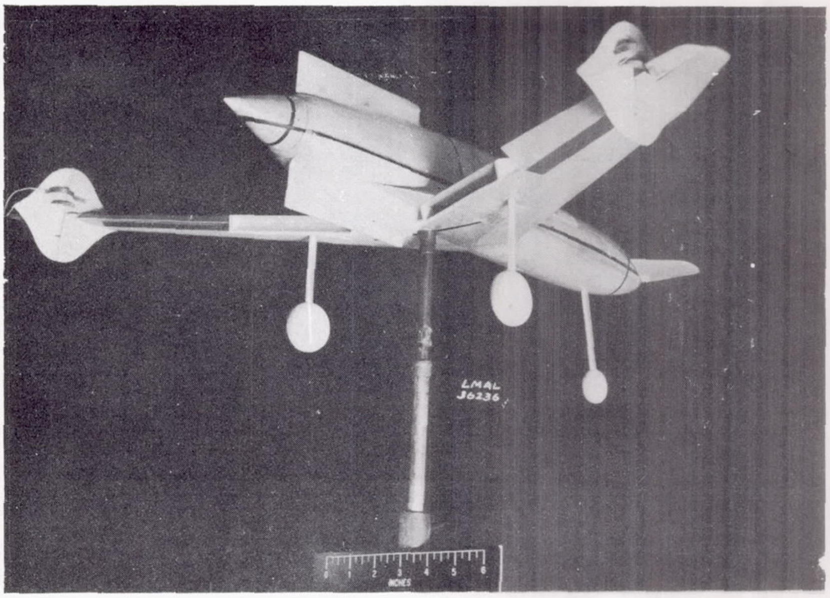

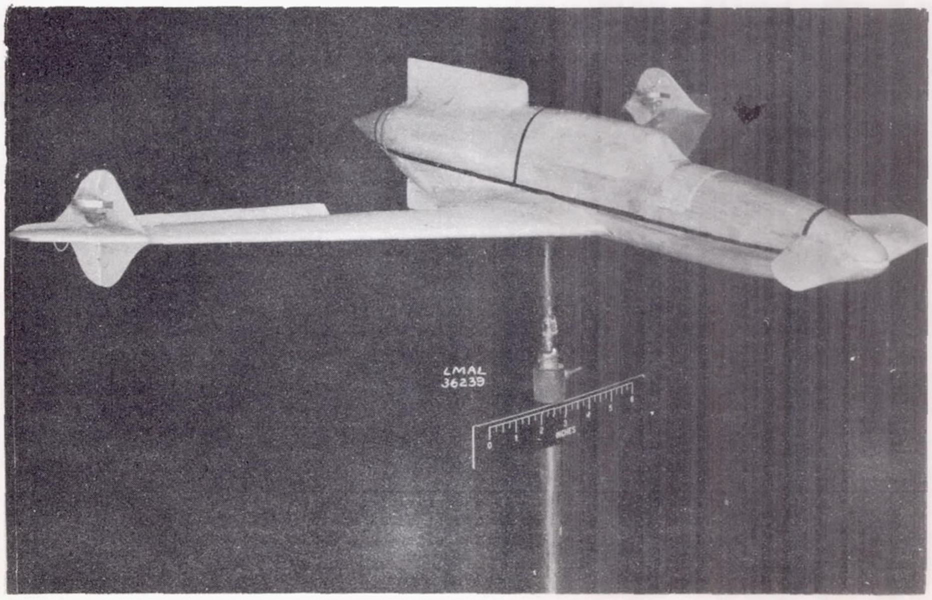

Figure 6.- The 0.059-scale model of the XP-55 airplane as tested in the 20-foot free-spinning tunnel in the clean and landing conditions.

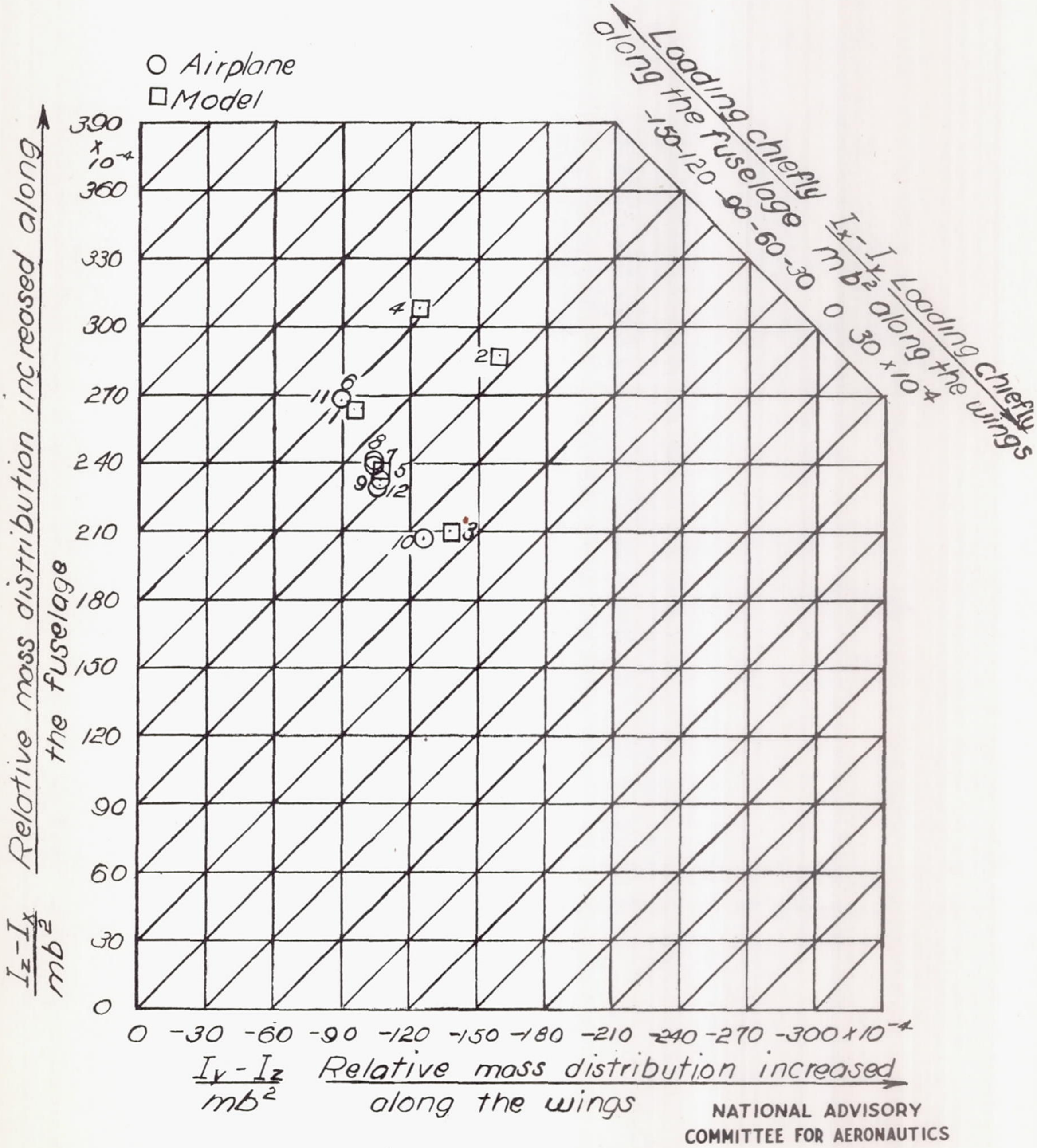

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Figure 7.-Inertia parameters for loadings possible on the XP-55 airplane and for the loadings tested on the XP-55 model. (Numbers refer to loadings listed in tables III and IV).

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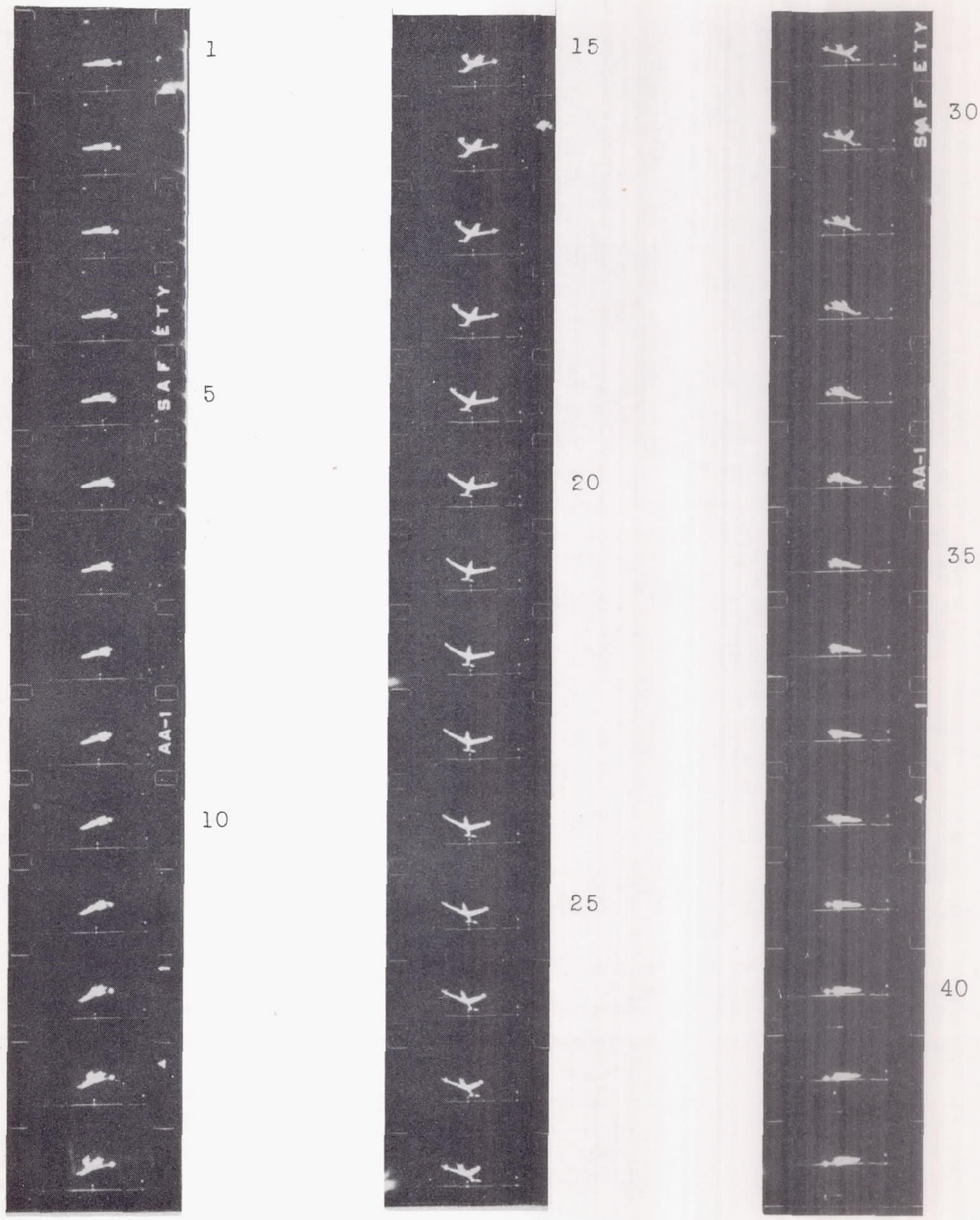

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Figure 8.- Typical spin of the 0.059-scale model of the XP-55 airplane. Camera speed: 64 frames per second.

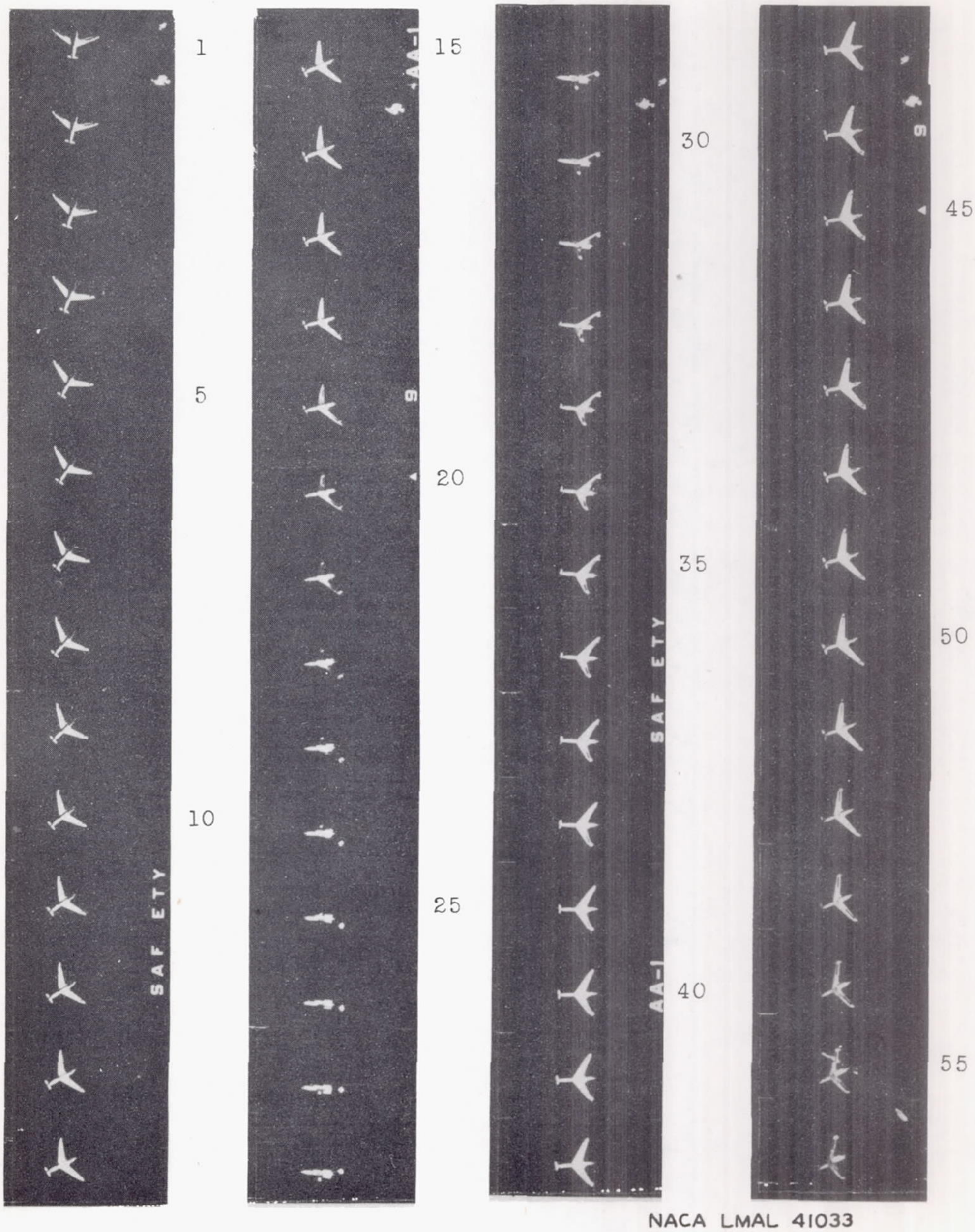

Figure 9.- Typical motion of the 0.059-scale model of the XP-55 airplane with ailerons full against the spin, rudders full with the spin, and the stick forward or free longitudinally. Camera speed: 64 frames per second.