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RESEARCH MEMORANDUM

FREE-SPINNING-TUNNEL INVESTIGATION OF A MODEL HAVING A 60° DELTA WING WITH HALF-DELTA AILERONS INSTALLED

By Walter J. Klinar and Henry A. Lee

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

March 9, 1953

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SUMMARY

An investigation has been undertaken in the Langley 20-foot free-spinning tunnel to determine the effectiveness of half-delta ailerons in terminating the spin rotation of a model having a 60° delta wing. Ailerons 15 and 5 percent of the wing area were investigated. In addition to a basic loading, tests were made with mass distribution increased along the wings by the addition of external aerodynamic shapes. The aerodynamic shapes were installed either at inboard or outboard positions and were considered to simulate either fuel tanks or engine nacelles.

The results of the investigation indicated that, for the range of conditions investigated, half-delta ailerons 15 percent of the wing area were effective in terminating the spin rotation by movement of the ailerons to full with the spin. Ailerons 5 percent of the wing area effectively terminated the spin rotation for the basic loading but were not sufficiently effective for the conditions with mass added along the wings (aerodynamic shapes installed). The changes in spin and spin-recovery characteristics brought about by installation of the aerodynamic shapes were due primarily to the changes in mass loading. Trimming the ailerons symmetrically upward prior to deflecting them differentially had little beneficial effect. The results of this investigation and the data presented in NACA RM L9L06, indicate that half-delta ailerons when deflected through ±30° from the plane of the wing or from a trimmed-up position were as effective as conventional flap-type ailerons of comparable size deflected ±20° in effecting recoveries from spins for comparable delta-wing designs.

The model trimmed at flat stalled attitudes for up settings of the elevator. On a similar airplane configuration, it will be necessary to move the stick forward of neutral in order to pitch rapidly to an unstalled attitude.

INTRODUCTION

Results of an investigation of the spin and spin-recovery characteristics of a model having a 60° delta wing and conventional flap-type controls previously conducted in the Langley 20-foot free-spinning tunnel (ref. 1) indicated that, for a configuration having a single vertical tail, the ailerons, when deflected to full with the spin, were the effective controls in terminating the spin rotation. Inasmuch as half-delta tip controls are being considered as lateral controls for triangular wings, an investigation was undertaken to determine the effectiveness of controls of this type in terminating spins. The investigation was performed in the Langley 20-foot free-spinning tunnel and the results are presented herein. The 60° delta-wing model used for this investigation was similar to that used for the investigation reported in reference 1. For the present investigation, two aileron sizes were investigated, 15 and 5 percent of the wing area. Included in the investigation were tests to determine the effectiveness of trimming both ailerons symmetrically upward and then deflecting them differentially as ailerons. The model was investigated in a basic loading condition and with aerodynamic shapes (simulating either fuel tanks or engine nacelles) alternately installed at an inboard and outboard station on the wing, the mass distribution along the wing being increased with the addition of the tanks. The longitudinal location of the center of gravity was maintained constant during the investigation.

SYMBOLS

b	wing span, ft
S	wing area, sq ft
c	wing or elevator chord at any station along the 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 fuselage 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, $\frac{m}{\rho Sb}$

α — angle between fuselage reference line and vertical (approximately equal to absolute value of 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

APPARATUS AND METHODS

Model

The model used for the spin investigation was of such proportions as to be considered representative of a $\frac{1}{20}$-scale delta-wing fighter type of airplane. The dimensional characteristics of a corresponding full-scale airplane are given in table I. The hinge lines of the half-delta ailerons investigated on the model were located at the 50-percent station of the inboard chord of the ailerons. A three-view drawing of the model as tested with flap-type elevators and half-delta ailerons is shown in figure 1, and a drawing showing the position of the aerodynamic shapes (external tanks or nacelles) as tested on the model is shown as figure 2. A photograph of the model with the 5-percent ailerons installed is shown as figure 3, and two photographs of the model with the aerodynamic shapes installed outboard and inboard are shown as figure 4.

The model was ballasted to obtain dynamic similarity to a corresponding airplane at an altitude of 15,000 feet (ρ = 0.001496 slug/cu ft). The weight, moments of inertia, and center-of-gravity location used in ballasting the model were selected on the basis of dimensions of an airplane typical of this type. The aerodynamic shapes were independently ballasted, the size and weight of the aerodynamic shapes being based on an existing configuration similar to the one being investigated and having external fuel tanks installed. If the tank is considered a nacelle housing an engine, it would be expected that the weight of the complete nacelle would be approximately half the weight investigated.

A magnetic remote-control mechanism was installed in the model to actuate the controls for the recovery attempts. Sufficient moments were exerted on the control surfaces 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 generally similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel, except that the model launching technique for the spin tests has been changed. With the controls set in the desired position, the model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, recovery is attempted by moving one or more controls by means of the remote-control mechanism. After recovery the model dives into a safety net. In those instances when the model does not recover, it is lowered into the safety net at the termination of the test. A photograph of the model during a spin is shown as figure 5.

The spin data presented were obtained and converted to corresponding full-scale values by methods described in reference 2. The turns for recovery were measured from the time the controls were moved to the time the spin rotation ceased. 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, that is as >3. A >3-turn recovery does not necessarily indicate an improvement over a >7-turn recovery. For recovery attempts in which the model did not recover, the recovery result was recorded as ∞. When the model recovered without control movement, with the rudder with the spin, the results were 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. During this investigation, recoveries were also attempted by movement of ailerons alone. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the ailerons are set at 1/3 of the full deflections in the direction conducive to slower recoveries and the elevator is set at 2/3 of its full-up deflection or full up, whichever is conducive to slower recovery. Recovery was attempted by rapidly reversing the rudder from full with the spin to full against the spin, or by movement of ailerons alone to full or half with the spin. The spin rotation of the model is considered to be adequately damped if recovery from the spin requires $2\frac{1}{4}$ turns or less. This value has been selected on the basis of full-scale airplane spin-recovery data that are available for comparison with corresponding model test results.

PRECISION

The model test results 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:	
From motion-picture records	±1/4
From visual observation	±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 wandering or oscillatory nature of the spin.

Comparison between model and full-scale results in reference 3 indicated that model tests satisfactorily predicted full-scale recovery characteristics approximately 90 percent of the time and for the remaining 10 percent of the time the model results were of value in predicting some of the details of the full-scale spins. The airplanes usually spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 3 also indicated that usually the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models; the higher rate of descent of airplane or model, however, being generally associated with the smaller angle of attack. This comparison was made primarily for conventional airplane designs, however, and may not be strictly applicable to delta-wing airplanes.

Because it is impracticable to ballast the model exactly and because of inadvertent damage to the model during tests, the measured weight and mass distribution of the model varied from the true scaled-down values within the following limits:

Weight, percent	0 to 2.5 high
Center-of-gravity location, percent $\bar{c}$	0 to 1.5 forward
Moments of inertia:	
I_X, percent	0 to 8 high
I_Y, percent	0 to 2 high
I_Z, percent	0 to 2 high

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

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls were set with an accuracy of ±1°.

TEST CONDITIONS

The mass characteristics and inertia parameters for the conditions investigated are shown in table II and plotted in figure 6. The model was tested with landing gear retracted and the cockpit closed. The following conditions were investigated with ailerons deflected differentially from the plane of the wing: basic loading, external tanks installed inboard, and external tanks installed outboard. With the ailerons trimmed symmetrically upward 30° from the plane of the wing, tests were made only for the condition with external tanks located outboard.

The maximum control deflections (measured perpendicular to the hinge lines) used in the tests were:

Rudder, degs	30 right, 30 left
Elevator, degs	30 up, 20 down
Ailerons (deflected from plane of wing), degs	30 up, 30 down
Ailerons (deflected from 30° up trim position), degs	60 up, 0 down

For the half-delta ailerons to produce approximately the same rolling moment near the stall as was obtained for ±20° deflections of the flap-type ailerons of approximately the same area which were previously investigated and reported in reference 1, it would be required to deflect the 15-percent half-delta ailerons through approximately ±30° from a 30° trimmed-up position (refs. 4 and 5). At low speed and low angles of attack the 15-percent half-delta ailerons, when deflected approximately ±30° from the plane of the wing, should provide a rolling moment equivalent to that of the flap-type controls. Although the half-delta ailerons produce larger rolling moments for comparable deflections than the flap-type controls at supersonic speeds, (ref. 6), it was believed that the low-speed condition on a corresponding airplane would be the most critical with regard to spin recovery, and accordingly the deflections tabulated above were used for the current investigation.

RESULTS AND DISCUSSION

A key to the results presented, a list of the foot notes used on the charts, and a tabulation of remarks applicable to all charts are given on chart 1. The results of the spin tests are presented on charts 2 to 6.

15-Percent Ailerons

Basic-loading condition.- The results of the tests with the model loaded to represent the assumed normal loading of a corresponding airplane (loading point 1 in table II and fig. 6) and with the 15-percent half-delta ailerons installed are presented in chart 2. This loading corresponds to the loading designated as normal in the investigation of reference 1 for which flap-type controls of approximately the same area were used.

As is indicated in chart 2, the model resisted spinning for most control settings, the spins that were obtained usually occurring for aileron settings slightly against the spin. Although rudder reversal was usually ineffective in terminating the spin rotation, aileron movement to with the spin was very effective, and movement of the ailerons to only half with the spin was sufficient to satisfactorily terminate the spinning motion. It should be noted, however, that for the center-of-gravity position investigated (approximately 25 percent of the mean aerodynamic chord) after termination of the spin rotation, the model usually trimmed in a flat stalled glide when the elevator was up. Similar results were obtained for the investigation reported in reference 1, and it was indicated that for the corresponding full-size airplane it would be necessary to move the stick forward of neutral after the spin rotation is damped in order to pitch the airplane rapidly to an unstalled attitude. Information presented in reference 1 indicates that for an airplane of this type, the center of gravity should be no farther rearward than the 25-percent station of the mean aerodynamic chord for satisfactory longitudinal trim characteristics.

Effect of installing aerodynamic shapes at an inboard and at an outboard position on the wing.- Charts 3 and 4 indicate the results obtained with the aerodynamic shapes simulating fuel tanks installed at an inboard and outboard location on the wing, respectively. As has been noted previously the mass loading of the model was altered as the tanks were installed. With no tanks installed, basic loading condition, the model was extremely heavily loaded along the fuselage; whereas with the tanks installed at an outboard position the moments of inertia about the X and Y axes were nearly equal. As is indicated on the charts, recoveries obtained with tanks installed either inboard or outboard were generally similar. Although spins were more prevalent for these conditions (loading points 2 and 3 on table II and fig. 6) than for the basic loading condition, the model still resisted spinning when the ailerons were full with the spin. Although the rudder was ineffective in terminating spins, the spin rotation of the model was adequately damped by movement of the ailerons to full with the spin. Movement of the ailerons to only one-half with the spin, however, was insufficient to insure rapid termination of the spin rotation for these conditions. Comparison of the data presented in chart 4 with the data presented in reference 1 for a similar mass loading condition indicates that the half-delta ailerons used in the present investigation having maximum deflections of $\pm 30^{\circ}$ gives results which are generally similar to those obtained with flap-type ailerons of comparable size and having maximum deflections of $\pm 20^{\circ}$.

On the basis of the results of brief tests conducted to determine the aerodynamic effects of the aerodynamic shapes on the spin characteristics of the model (not presented in the charts), and on the basis of a comparison of the results of the present investigation for loadings with the aerodynamic shapes installed for similar loading conditions investigated in reference 1, it appears that the effects obtained with the aerodynamic shapes attached are attributable primarily to changes in mass distribution. As previously noted, if the external aerodynamic shapes are considered as being nacelles housing gas turbine engines, the nacelles would be approximately half as heavy as the aerodynamic shapes investigated. On the basis of the changes in mass loading brought about by installation of nacelles of this weight, it would be expected that placing the nacelles inboard would lead to results similar to those obtained for the basic loading (chart 2); whereas placing the nacelles outboard would yield results similar to those presented on chart 3.

For the loading conditions investigated, it would be expected that a rolling moment in the direction of the spin would produce an antispin yawing moment because of inertia effects and thus be beneficial in terminating the spin. Approximate calculations indicate that the antispin aerodynamic yawing moment produced by deflecting the half-delta ailerons to with the spin was large in comparison with the pro-spin rolling moment produced. Thus, when the half-delta ailerons were deflected with the spin, the antispin aerodynamic rather than inertia yawing moment may have been the primary factor in terminating the spin rotation. Charts 2, 3, and 4 show that the model began turning to the left after termination of the imposed launching rotation to the right for the aileron full-with spins with the elevator up, possibly because of the antispin yawing moment produced.

5-Percent Ailerons

Results of tests performed with the 5-percent half-delta ailerons installed on the model are presented on chart 5. Comparison of this chart with chart 2 indicates that, for the basic loading condition, the spin rotation was satisfactorily terminated by movement of the ailerons to only one-half with the spin for either of the aileron sizes. For the loading conditions with the external aerodynamic shapes installed, however, full movement of the 5-percent ailerons did not satisfactorily damp the spin rotation; whereas full movement of the 15-percent ailerons (charts 3 and 4) had adequately damped the rotation. Results of brief tests (not presented on the charts) indicated that for these loadings, deflecting intermediate size ailerons (10 percent) to full with the spin resulted in marginal spin-recovery characteristics. Thus it would appear that, for loading conditions similar to those tested with the external aerodynamic shapes installed, the minimum-size half-delta ailerons required for satisfactory termination of the spin rotation would be approximately 15-percent of the wing area.

Ailerons Deflected From Trimmed-Up Position

Brief tests were conducted with the ailerons trimmed 30° up (both set at 30° up and deflected differentially from this position) for the condition with the aerodynamic shapes installed outboard. As has been noted previously, a rolling moment in the direction of the spin is beneficial as regards recovery for this mass condition and the data of reference 4 indicate that trimming the ailerons up should increase the rolling moment of half-delta ailerons at high angles of attack. Approximate computations also indicate that although deflecting the ailerons in this manner should increase the pro-spin rolling moment at spinning attitudes, the antispin yawing moment would be reduced. The results of the tests are presented in chart 6. Comparison of these results with the data presented in charts 4 and 5 shows that deflecting the ailerons from a trimmed-up position did not appreciably alter the spin-recovery characteristics for this loading. It appears possible, therefore, that the increased pro-spin rolling moment obtained by trimming the ailerons up may have been compensated by the decreased antispin yawing moment.

CONCLUSIONS

On the basis of the spin and recovery tests of a 60° delta-wing model equipped with half-delta ailerons, the following conclusions are made:

1. Half-delta ailerons when deflected ±30° with the spin were as effective as conventional flap-type ailerons of comparable size deflected ±20° in effecting recoveries from spins for negative values of the inertia yawing-moment parameter, $\frac{I_X - I_Y}{mb^2}$, as low negatively as approximately -80×10^{-4}.

2. Half-delta ailerons 15 percent of the wing area were effective in terminating the spin rotation when deflected full with the spin for the three loadings investigated $\left(\frac{I_X - I_Y}{mb^2}\right.$ equivalent to approximately $\left.-750 \times 10^{-4}, -340 \times 10^{-4}, \text{ and } -80 \times 10^{-4}\right)$; whereas ailerons 5 percent of the wing area were effective only for the basic loading condition $\left(\frac{I_X - I_Y}{mb^2} \text{ approximately } -750 \times 10^{-4}\right)$.

3. Trimming the lateral controls symmetrically upward prior to deflecting them as ailerons had only little effect on recoveries.

4. The changes in spin and spin-recovery characteristics brought about by installing the aerodynamic shapes were due primarily to changes in the mass distribution.

5. The model trimmed at flat stalled attitudes for up settings of the elevator. On a similar airplane configuration, it will be necessary to more the stick forward of neutral in order to pitch rapidly to an unstalled attitude.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

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1. Klinar, Walter J., and Jones, Ira P., Jr.: Spin-Tunnel Investigation of a Model of a 60° Delta-Wing Airplane to Determine the Spin, Recovery, and Longitudinal Trim Characteristics Throughout an Extensive Range of Mass Loadings. NACA RM L9L06, 1950.

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4. Jaquet, Byron M., and Queijo, M. J.: Low-Speed Wind-Tunnel Investigation of Lateral Control Characteristics of a 60° Triangular-Wing Model Having Half-Delta Tip Controls. NACA RM L51I10, 1951.

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6. Sandahl, Carl A., and Strass, H. Kurt: Comparative Tests of the Rolling Effectiveness of Constant-Chord, Full-Delta, and Half-Delta Ailerons on Delta Wings at Transonic and Supersonic Speeds. NACA RM L9J26, 1949.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF AIRPLANE

SIMULATED BY THE $\frac{1}{20}$ - SCALE SPIN MODEL

Length, over-all, ft	41.37
Wing:	
Span, ft	29.42
Area, sq ft	375
Section, parallel to airplane center line	NACA 65(06)-006.5
Mean aerodynamic chord, $\bar{c}$, ft	16.99
Leading edge $\bar{c}$ behind wing apex, in.	101.98
Sweepback of leading edge of wing, deg	60
Tip chord, in.	0
Root chord, in.	305.8
Wing dihedral, deg	0
Taper ratio	0
Distance from center of gravity to elevator hinge line, ft	9.88
Distance from center of gravity to rudder hinge line, ft	11.15
Elevator:	
Chord behind hinge line (constant), in.	34.4
Area of each elevator behind hinge line, sq ft	11.54
Ailerons:	
15 percent half-delta area (both ailerons), sq ft	56.25
5 percent half-delta area (both ailerons), sq ft	18.75
Vertical tail:	
Total area, sq ft	67.0
Rudder area behind hinge line, sq ft	13.4
Chord behind hinge line (constant), in.	19.2
Aspect ratio	1.15

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TABLE II.- MASS CHARACTERISTICS AND MOMENTS OF INERTIA FOR LOADINGS INVESTIGATED ON MODEL

[Model values converted to corresponding full-scale values; moments of inertia given about center of gravity]

No.	Loading	Weight, lb	Center of gravity		Relative density, μ		Moments of inertia, slug/ft^2			Inertia parameters		
			$\frac{x}{c}$	$\frac{z}{c}$	Sea level	Altitude 15,000 feet	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1	Basic loading	11655	0.246	0	13.80	21.94	4246	27611	30198	-746×10^{-4}	-82×10^{-4}	828×10^{-4}
2	Basic loading with external tanks inboard	23144	0.248	0.07	27.39	43.56	9967	30880	36207	-337	-85	422
3	Basic loading with external tanks outboard	23144	0.248	0.06	27.39	43.56	25697	30622	52177	-79	-346	425

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

(a) Key

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
R	Turns for recovery by full rudder reversal
A	Turns for recovery by aileron movement alone to full with the spin
$\frac{A}{2}$	Turns for recovery by aileron movement alone to one-half with the spin

Recovery attempted from, and steady-spin data presented for, rudder full with spins.
Right erect spins.
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

(b) Footnotes

[a]Model motion becomes increasingly oscillatory in roll and yaw until model rolls over inverted. After going inverted model either rolls in the direction of the aileron setting or dives.

[b]After launching rotation damps, model trims in a flat glide.

[c]After launching rotation damps, model begins a flat gliding turn to left.

[d]Two conditions possible.

[e]Oscillatory spin. Range or avérage values given.

[f]Model motion becomes increasingly oscillatory in pitch, roll, and yaw until model pitches inverted or dives out.

[g]After launching rotation damps, model goes into a vertical aileron roll to right.

[h]Model becomes increasingly oscillatory in roll and yaw eventually going into a dive or roll to left.

[i]Model becomes increasingly oscillatory in roll and yaw until eventually the Z-axis of the model becomes horizontal, the model then continuing to rotate about this axis as it descends.

[j]Model becomes increasingly oscillatory in roll and yaw, trims at high angle of attack eventually going into a left roll.

[k]After launching rotation damps, model goes into a left spin.

[m]After launching rotation damps, model pitches inverted.

[n]Ailerons trimmed at only 20 degrees up for this control configuration.

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CHART 2.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL IN BASIC LOADING CONDITION —AILERONS 15 PER CENT OF WING AREA INSTALLED

[Loading point I on table II and figure 6 $\left(\frac{I_X - I_Y}{mb^2} = -746 \times 10^{-4}\right)$; see chart I for key and footnotes]

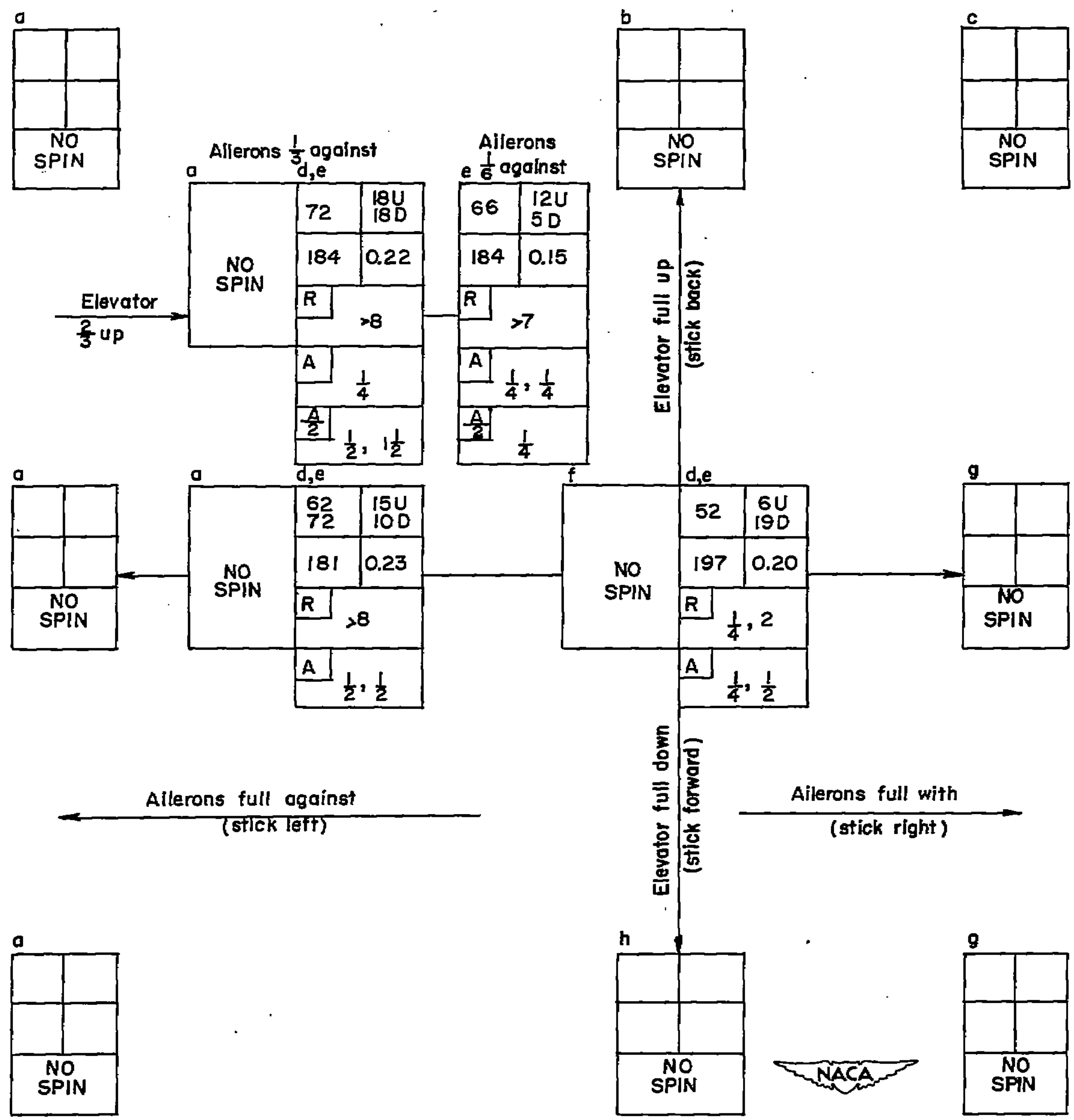

CHART 3.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH EXTERNAL TANKS INSTALLED INBOARD — AILERONS 15 PER CENT OF WING AREA INSTALLED

[Loading 2 in table II and figure 6 $\left(\frac{I_X - I_Y}{mb^2} = -337 \times 10^{-4}\right)$; see chart I for key and footnotes]

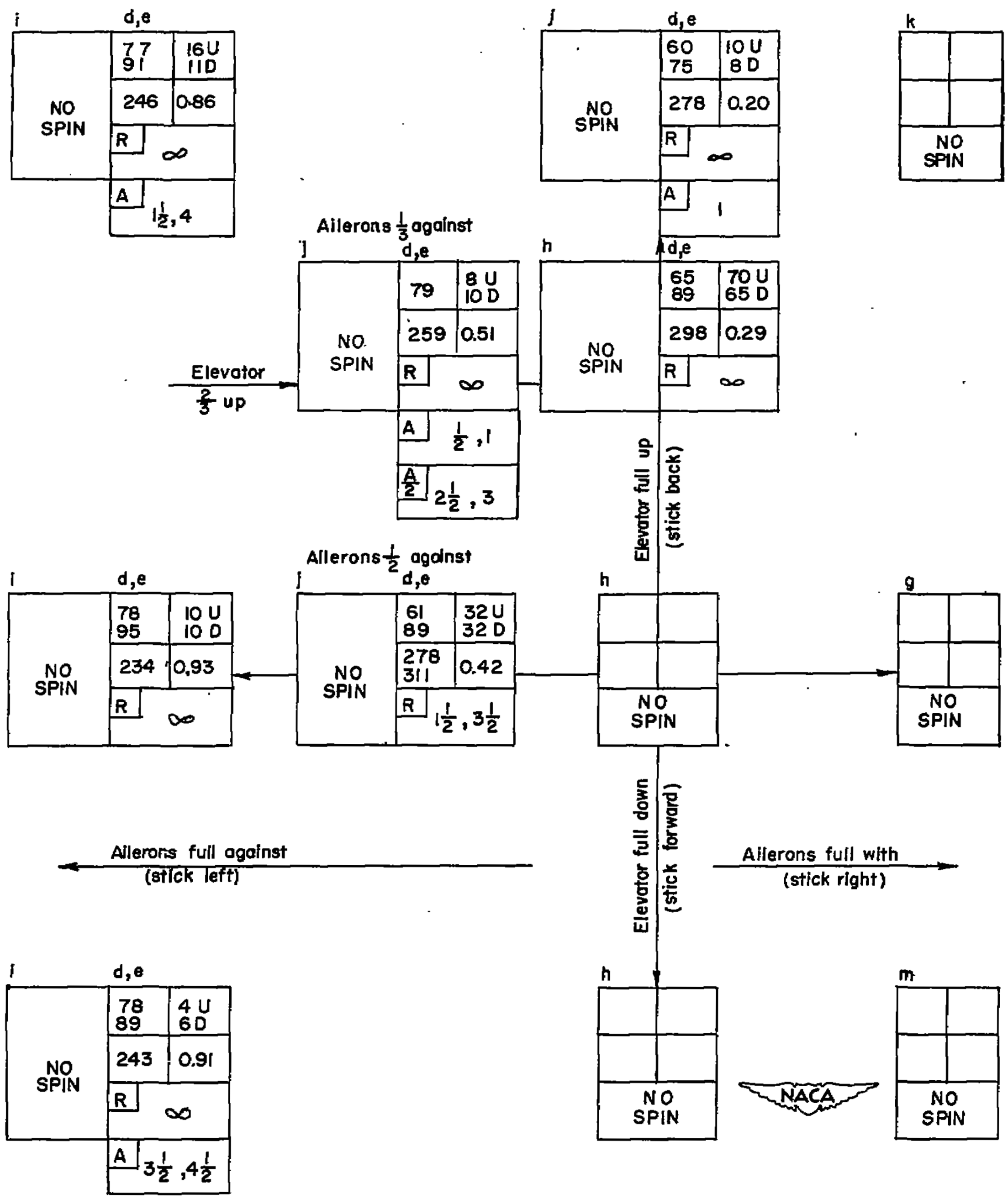

CHART 4.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH EXTERNAL TANKS INSTALLED OUTBOARD —AILERONS 15 PER CENT OF WING AREA INSTALLED

[Loading 3 in table II and figure 6 $\left(\frac{I_X - I_Y}{mb^2} = -79 \times 10^{-4}\right)$; see chart I for key and footnotes]

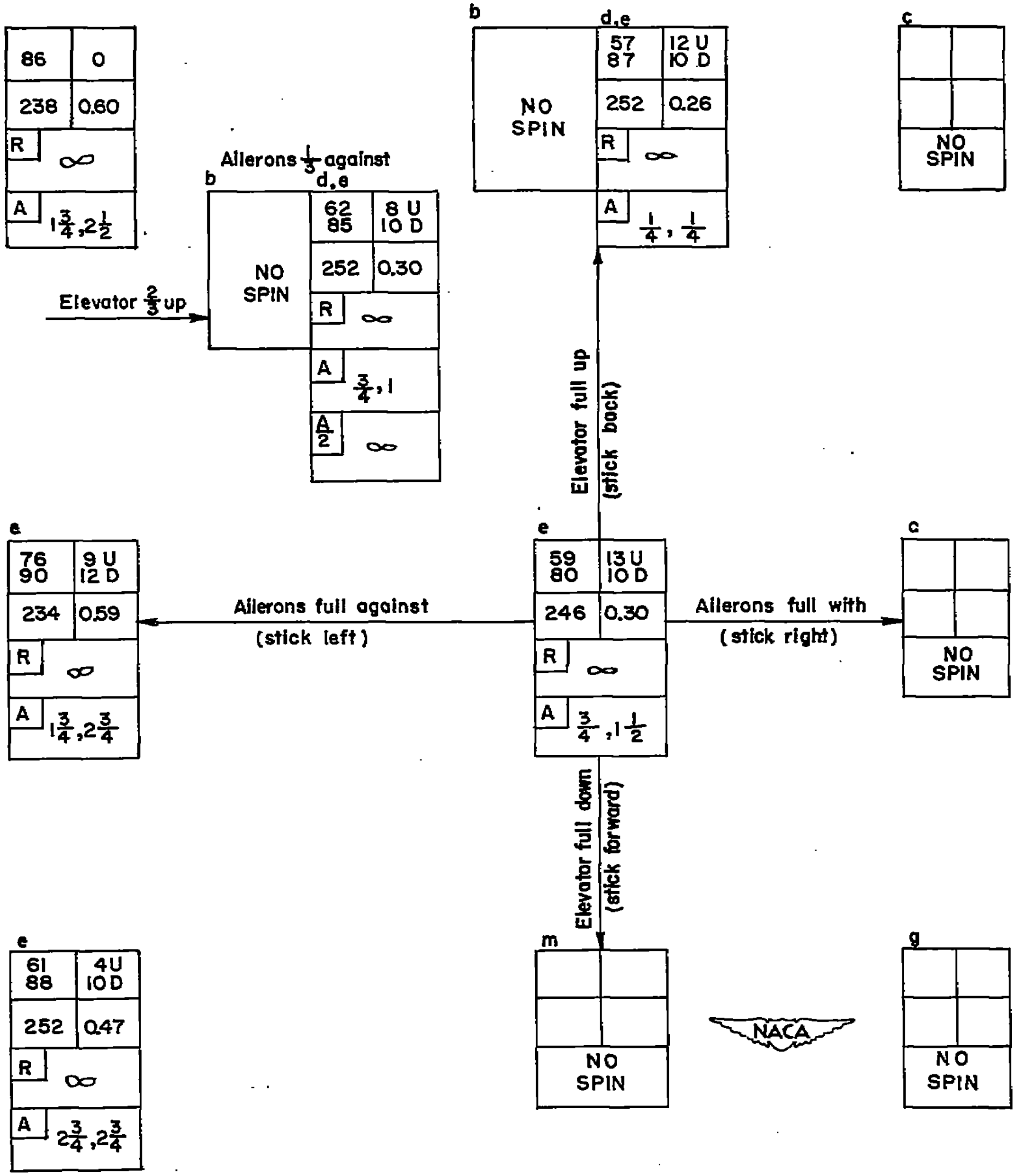

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CHART 5.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL HAVING AILERONS 5 PER CENT OF WING AREA INSTALLED

[Loading as indicated; see chart 1 for key and footnotes]

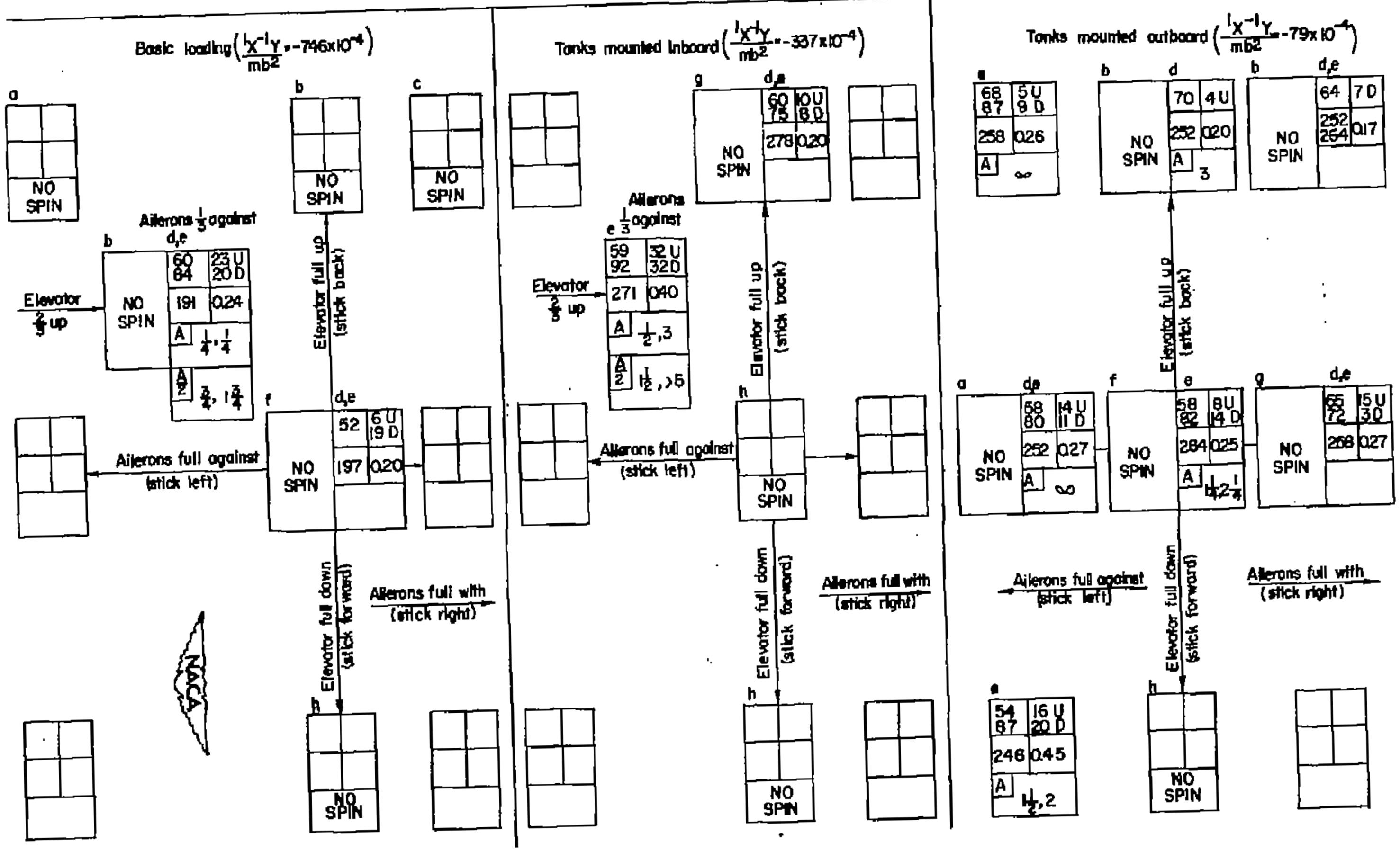

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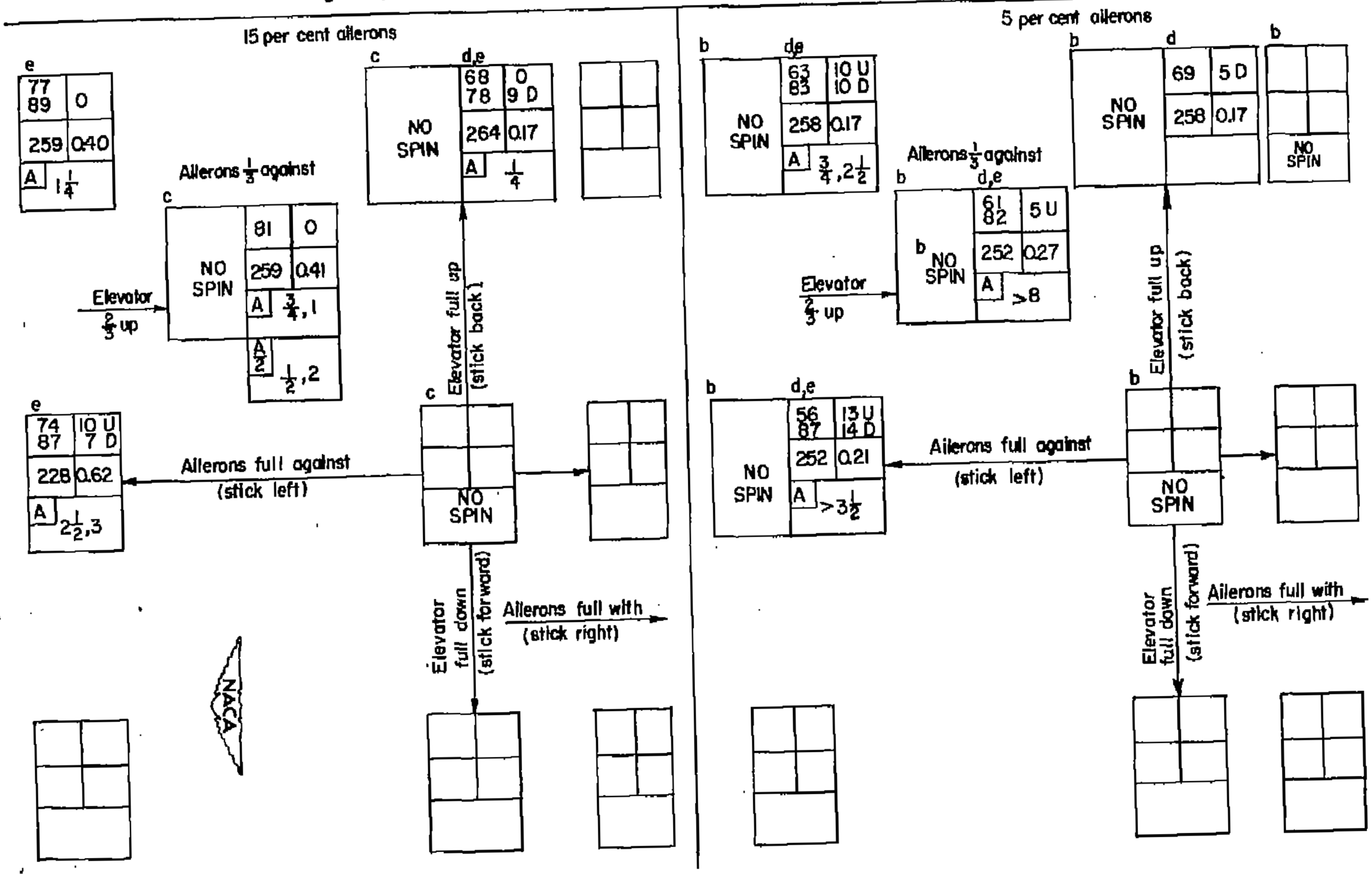
CHART 6.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL WITH AILERONS TRIMMED 30 DEGREES UP—TANKS INSTALLED OUTBOARD

[Loading 3 in table II and figure 6 $\left(\frac{I_X - I_Y}{mb^2} = -79 \times 10^{-4}\right)$; see chart I for key and footnotes]



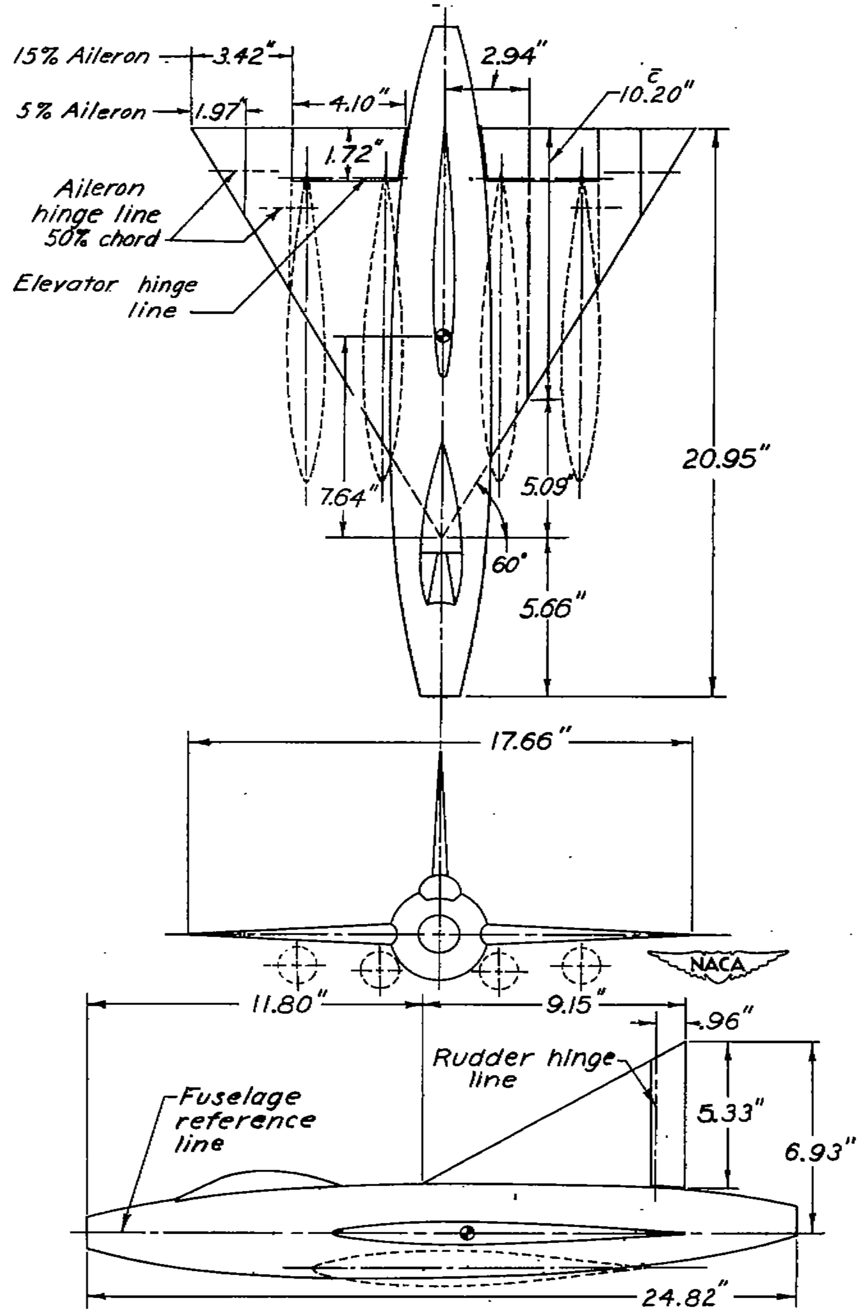


Figure 1.- Drawing of the $\frac{1}{20}$-scale model tested in the Langley 20-foot free-spinning tunnel. Center of gravity positioned at 25 percent mean aerodynamic chord, $\bar{c}$. The 15 percent ailerons and the external fuel tanks located at the outboard and inboard positions are shown in phantom.

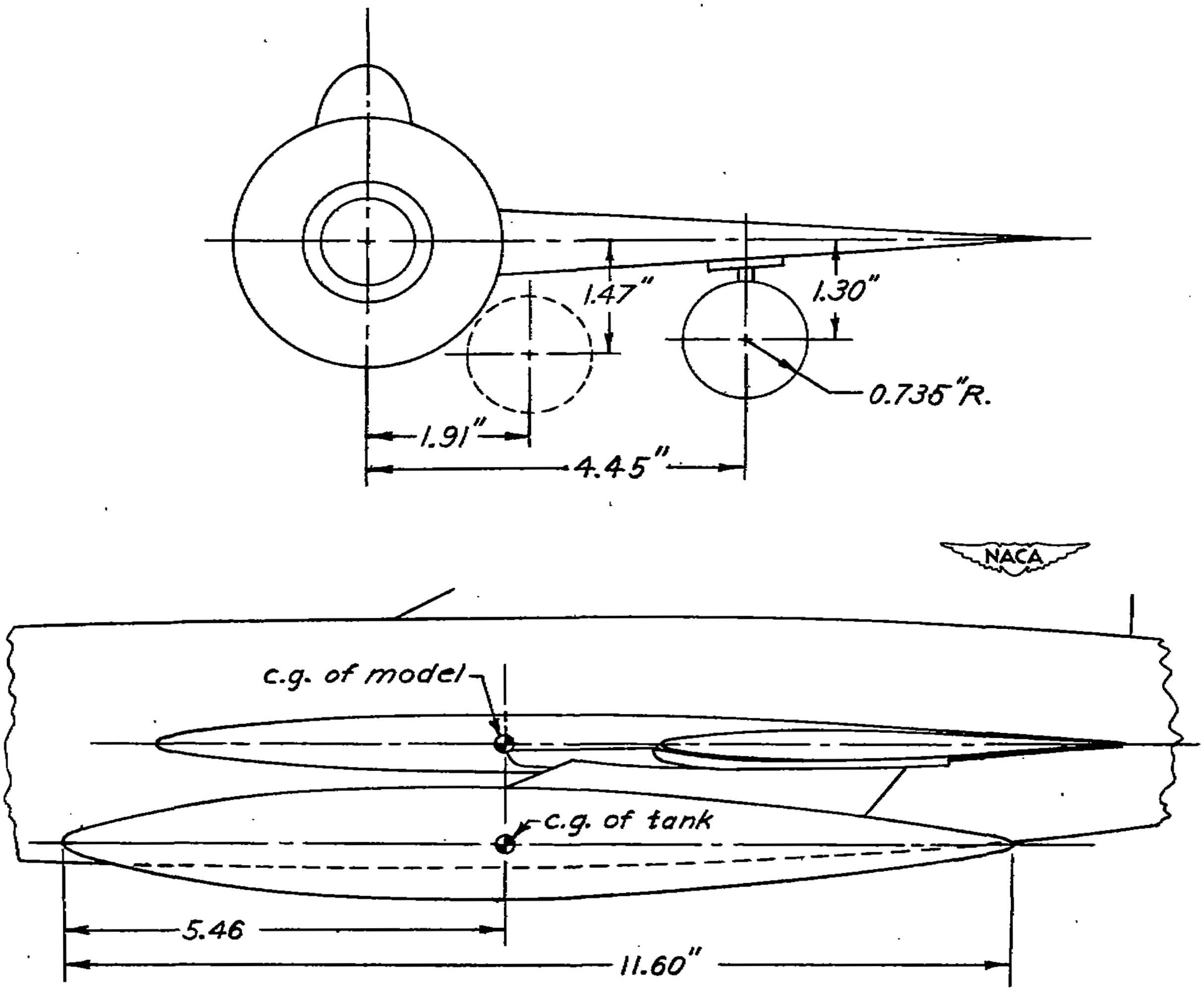


Figure 2.- Drawing of the external fuel tanks and installation on model. Inboard tank position shown in phantom.

[redacted]

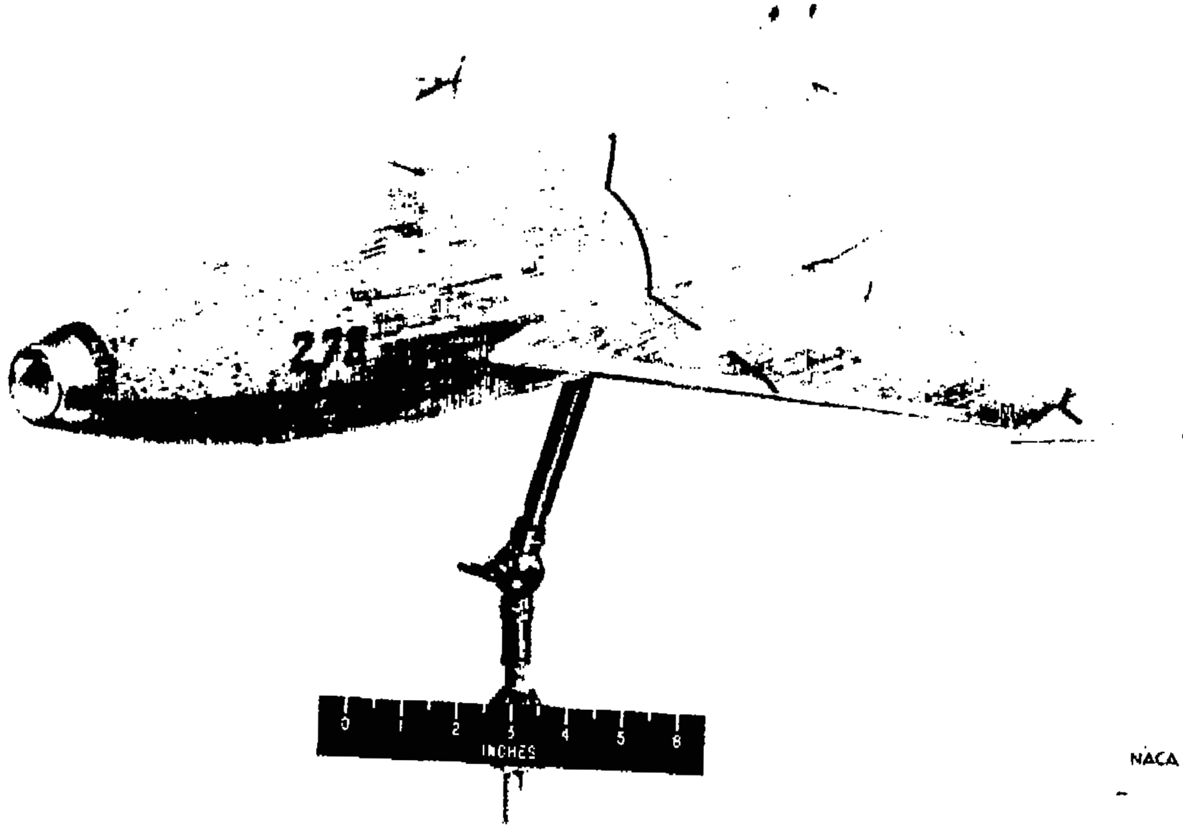
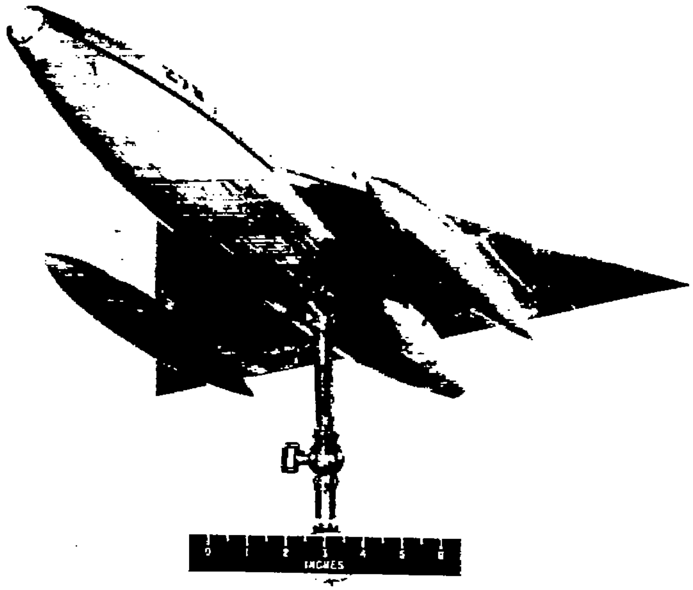
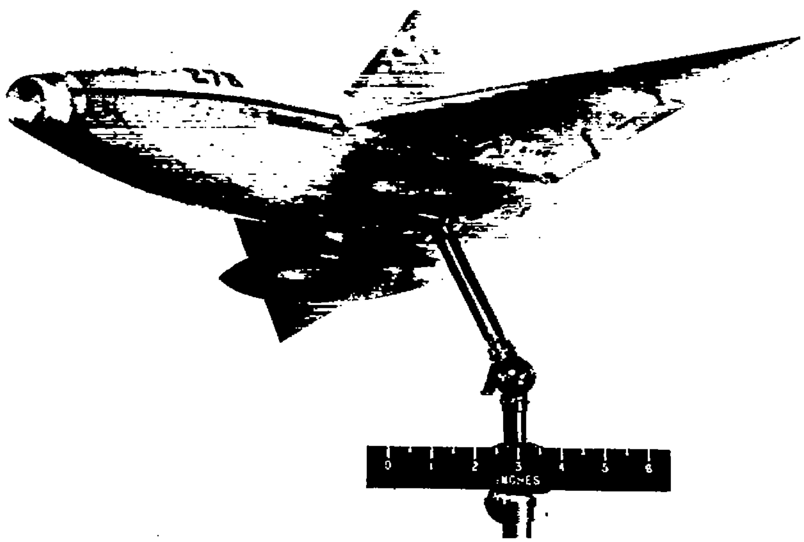


Figure 3.- The $\frac{1}{20}$ - scale model as tested in the Langley 20-foot free-spinning tunnel.

[redacted]



(a) Tanks outboard. NACA L-70335



(b) Tanks inboard. NACA L-70336

Figure 4.- The $\frac{1}{20}$-scale model with external tanks.

Figure 5.- The $\frac{1}{20}$-scale model spinning in the Langley 20-foot free-spinning tunnel.

L-58753

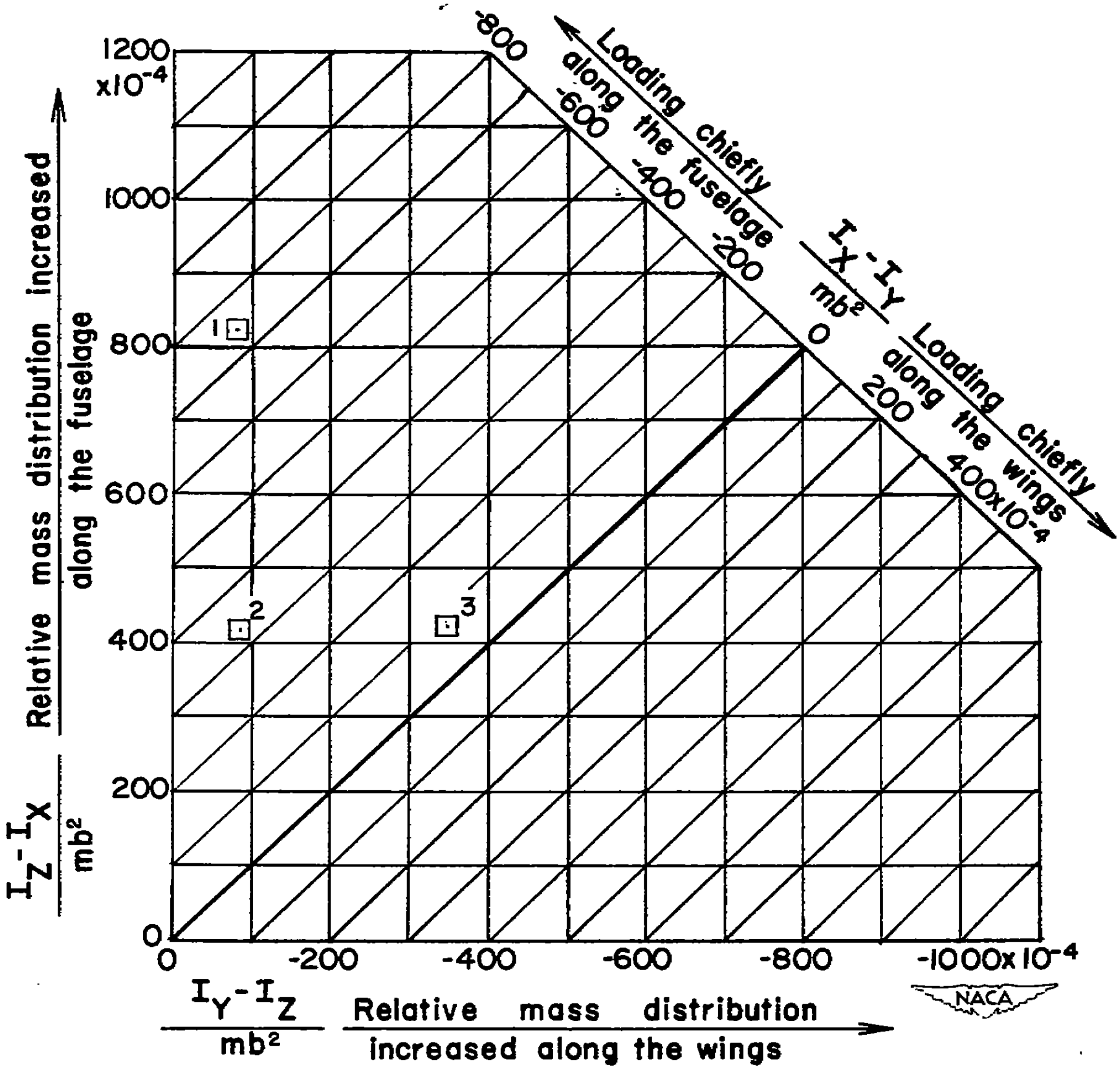


Figure 6.- Inertia parameters for loadings tested on the $\frac{1}{20}$-scale model. (Points correspond to numbered loadings in table II.)