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THE INFLUENCE OF VERY HEAVY FUSELAGE MASS LOADINGS AND LONG NOSE LENGTHS UPON OSCILLATIONS IN THE SPIN

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SUMMARY

A study of the design and mass characteristics of several airplanes has been made to determine the basic factors which influence the tail spin in such a manner as to make the spinning motion a series of violent rolling and yawing oscillations. The study has indicated that long fuselage nose lengths, with resultant large side-area moment factors, combined with large distributions of mass along the fuselage, with resultant negative values of the inertia yawing-moment parameter, lead to this motion. A chart is presented that shows an empirical relationship between the side-area moment factor and inertia yawing-moment parameter. This chart separates the region for which steady spinning motions were obtained from the region for which violent oscillatory motions were obtained.

The accelerations encountered in these motions will be uncomfortable to the pilot but will probably not injure or seriously incapacitate him, and model results have indicated that satisfactory recovery from these extremely violent motions can generally be obtained if the tail design is adequate from a spin-recovery viewpoint.

INTRODUCTION

During recent tests in the Langley 20-foot free-spinning tunnel, a tendency has been noted for the characteristic nature of the tail spin to change somewhat for some airplane designs having relatively heavy fuselage loadings in that the usual steady spin has been replaced by an oscillatory motion. This oscillatory motion consists basically of violent rolling and yawing motions in recurring order and may or may not be termed a spin.

A preliminary study of the airplanes exhibiting this motion has been made in order to determine the basic factors which are conducive to these particular oscillations. The results of this study are presented herein.

SYMBOLS

b wing span, feet

S wing area, square feet

$\bar{c}$ 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 thrust line to mean aerodynamic chord (positive when center of gravity is below thrust line); in a few instances, vertical center-of-gravity location was measured from fuselage reference line (table II)

m mass of airplane, slugs

ρ air density, slugs per cubic foot

μ relative density of airplane $\left(\frac{m}{\rho Sb}\right)$

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

$\frac{A_2L_2}{A_1L_1}$ side-area moment factor (fig. 1)

METHODS

The spinning data used for this study were obtained from routine tests of models in the Langley 15-foot and 20-foot free-spinning tunnels. The testing technique used in performing these tests was essentially the same as that presented in reference 1, except that the model launching technique has been changed from launching from a spindle to launching by hand with spinning rotation into the vertically rising air stream. The results presented are for conventional models with unswept wings. The data used herein were taken only for model conditions for which flaps and landing gear were retracted except that models which had fixed landing gear were tested with the landing gear attached. Because preliminary analysis has indicated that the particular type of oscillation discussed herein occurs only on models having relatively large negative values of the inertia yawing-moment parameter, only results obtained for models with negative values of the inertia yawing-moment parameter were considered. All models which display the oscillatory motion have been used for this investigation. A study of all models which display the steady spinning motion has been made but only the results of a representative group of models were used.

In order to augment the visual observations made in the tunnel, motion-picture film of each model condition presented was studied to determine whether the oscillatory motion existed and, for those models that oscillated, to determine the actual nature of the oscillations.

Calculations were made of the instantaneous values of centripetal acceleration which occurred for a typical airplane during the yawing and rolling motions occurring in oscillatory spins. For these calculations, it was assumed that each separate yawing or rolling motion was made about the center of gravity of the model. The centripetal acceleration which would exist at the pilot's head was computed.

RESULTS AND DISCUSSION

Results of recent tests in the Langley 20-foot free-spinning tunnel have indicated, as previously stated, a tendency for the characteristic nature of the spin to change somewhat for some designs in that the usual steady spin has been replaced by an oscillatory motion.

The characteristic oscillatory motion consisted primarily of a series of recurring rolling and yawing motions. There was also some pitching motion involved which was less predominate than the rolling and yawing motions. These motions caused the models to assume wide variations in attitude with respect to the tunnel axes. In some cases the violence of the oscillation, particularly in roll, was so great that the model rolled over on its back and in some instances continued rolling. Figures 2 to 4 are strip photographs made up from motion-picture film of tests of one model. These photographs show the typical oscillatory motions for three control configurations.

As indicated, the oscillations encountered were rather violent and extreme, often reaching values of yaw angle of 90° or greater. It was believed, therefore, that some indication of the directional stability at these extreme angles of yaw or sideslip should be used to obtain quantitative values for separating the steady and oscillatory motions. A study was made of the dimensional characteristics of the various models as presented in table I, and the quantity termed side-area moment factor was developed inasmuch as it appears to be an approximate indication of the directional stability at extreme angles of yaw or sideslip. Further study may indicate the desirability of force and moment measurements up to 90° yaw angle in order to obtain a more direct measure of the directional stability at such extreme yaw angles.

As previously indicated, this oscillatory type of motion was noted to exist only on models for which the fuselage was more heavily loaded than the wings. It was believed, therefore, that a factor indicating the method of weight distribution in the models in connection with the side-area moment factor would lead to a separation of the steady and oscillatory motions. The mass characteristics and inertia parameters presented in table II were carefully studied, and the inertia yawing-moment factor was considered most applicable for obtaining separation of steady and oscillatory motions when used in connection with the side-area moment factor.

The side-area moment factor $\frac{A_2L_2}{A_1L_1}$ was determined by the method presented in figure 1. This factor is the ratio of the side area ahead of the model center of gravity A_2 multiplied by the distance from the centroid of this area to the model center of gravity L_2 to the side area behind the model center of gravity A_1 multiplied by the distance from the centroid of this area to the model center of gravity L_1.

The inertia yawing-moment parameter $\frac{I_X - I_Y}{mb^2}$ is an indication of how the mass is distributed in the airplane or model, that is, whether there is more mass distributed along the fuselage than along the wings or vice versa. Increasing negative values of this parameter indicate increased relative distribution of mass along the fuselage. This parameter has been used in the past to aid in predicting the effect of controls in the spin (reference 2) and to aid in determining the vertical-tail requirements for satisfactory spin recovery (reference 3).

The study was made by plotting the side-area moment factor as a function of the inertia yawing-moment parameter for each model and model condition considered. A line was then drawn on the plot which separated the points representing models that had steady or reasonably steady spins from those representing models that had violent oscillatory motions.

The results of the subject study are presented in table III and are plotted in figure 5 in terms of the inertia yawing-moment parameter and side-area moment factor. It is expected that other factors such as vertical-tail aspect ratio and horizontal-tail span and area may affect the separation somewhat, but it appears that such factors are of only secondary importance.

The plot shown in figure 5 was obtained by separating the steady and oscillatory spins for various designs and by also separating the oscillatory and steady spins for individual models which spun steadily at one loading condition but which spun in an oscillatory manner at another loading.

As shown in table III and figure 5, moving the center of gravity rearward or increasing the mass distribution along the fuselage on a given model sometimes resulted in a change from a steady spin to an oscillatory spin. Conversely, moving the center of gravity forward or decreasing the mass distribution along the fuselage on some models resulted in a change from an oscillatory spinning condition to a steady spin. Examination of figure 5 shows that mass changes made on models D, E, F, G, I, J, and P resulted in a change in their spinning behavior. Whereas movement of the center-of-gravity location changes the static margin, unpresented tests of one model show that changing the nose length produces an effect on the steadiness of the spin characteristics similar to that produced by a center-of-gravity movement. It is assumed, therefore, that the effect produced by center-of-gravity movement is probably the result of the change in side-area moment factor rather than the change in static margin.

The model test results indicated that recovery from the oscillatory-spin condition can be effected by normal method, that is, rapid full reversal of the rudder followed in about 1/2 turn by movement of the stick forward of neutral, if the airplane has a satisfactory vertical-tail design for spinning as defined by reference 3.

It is interesting to note that the present trend of airplane design is definitely toward the incorporation of long nose lengths and high fuselage mass loadings, the factors which lead to the oscillatory motions herein discussed. The present jet and rocket-propelled designs usually have wings placed far back on the fuselage with resultant long nose lengths; also, with the thin wing sections being used, little weight can be carried within the wings and most internal fuel is placed along the fuselage with a resultant increase in the relative mass distribution along the fuselage.

Computations of the radial accelerations encountered in the oscillatory motions were made for one representative model (model O) for spins with the elevator full up and with the ailerons full with, neutral, and full against the spin. As previously indicated, the motions were considered to be about the center of gravity of the model; and it was found that the maximum rolling velocity was of the order of 3.2 radians per second with an accompanying acceleration of 0.85 g acting upward at the pilot's head and that the maximum yawing velocity was about 2.5 radians per second with an accompanying acceleration of 1.5 g acting forward on the pilot's head. The normal acceleration of gravity adds or subtracts from these accelerations in an appropriate manner depending on the airplane's attitude with relation to the ground. Accelerations of these magnitudes may be quite uncomfortable to the pilot but are probably not of sufficient magnitude to injure or disable him.

Actual spin tests of one airplane (model J) have verified the existence of these oscillations in full-scale spinning flight, which, in effect, duplicated the motions of the model in the spin tunnel. The accelerations caused discomfort but in no way injured or seriously incapacitated the pilot. The pilot was able to recover satisfactorily from these motions by normal use of controls.

CONCLUDING REMARKS

Analysis of the results of spin-tunnel tests of several models has indicated that certain trends in airplane design, namely long nose lengths combined with large relative distributions of mass along the fuselage will lead to violently oscillatory spinning motions instead of the more or less conventional steady spin.

The accelerations encountered during these motions will be uncomfortable but will probably not be of sufficient magnitude to injure or seriously incapacitate the pilot. If the tail design is adequate from a spin-recovery viewpoint, recovery should be satisfactory.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., September 16, 1947

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2. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation of the Recovery from a Spin. NACA ARR, Aug. 1942.

3. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN No. 1045, 1946.

TABLE I.- DIMENSIONAL CHARACTERISTICS FOR THE ORIGINAL CONFIGURATIONS OF THE VARIOUS MODELS

[Model values are presented in terms of airplane values]

Model	Model scale	Over-all length (ft)	Normal weight (lb)	Normal c.g. location (percent c̄)	Ailerons		Horizontal tail surface				Vertical tail surface		
					Total area (sq ft)	Span (percent b/2)	Total area (sq ft)	Span (ft)	Elevator area (sq ft)	Distance from normal c.g. to elevator hinge line (ft)	Total area (sq ft)	Total rudder area (sq ft)	Distance from normal c.g. to rudder hinge line (ft)
A	1/16	34.16	5,099	24.1	17.90	32.70	59.46	14.51	22.82	19.21	25.70	13.80	17.29
B	1/18	27.80	6,450	29.1	19.40	36.80	61.10	14.80	28.10	16.80	25.80	13.50	16.70
C	1/14	34.24	5,276	25.7	18.00	36.00	61.00	14.50	28.50	19.70	27.30	13.80	16.66
D	1/20	29.80	6,340	31.5	12.30	40.50	30.50	10.90	12.00	16.20	14.40	8.00	16.50
E	1/15	22.60	3,387	26.7	-----	41.09	20.90	9.00	6.50	12.88	9.63	3.04	12.75
F	1/14	37.21	7,760	20.4	9.65	37.87	56.70	14.75	19.85	18.00	45.00	13.00	19.01
G	1/15	33.50	5,596	26.0	-----	52.00	40.60	12.00	14.38	17.88	25.45	11.75	18.32
H	1/16	32.31	9,355	26.3	12.80	37.70	68.86	17.50	20.84	18.67	31.85	8.92	18.25
I	1/17	36.69	8,600	25.6	18.20	40.43	41.30	14.17	7.80	16.43	20.81	5.49	17.08
J	1/17	38.77	9,600	25.0	18.20	38.30	41.30	14.17	7.80	16.47	20.81	5.49	17.12
K	1/20	44.70	18,180	21.2	25.10	44.80	108.00	23.33	30.00	22.95	36.00	13.20	23.05
L	1/16	53.60	24,744	25.0	-----	32.80	139.00	25.00	-----	22.19	82.90	-----	22.10
M	1/20	43.70	16,378	25.0	31.30	45.30	90.40	20.00	26.80	26.90	36.60	16.40	24.40
N	1/20	36.88	12,872	27.4	29.60	45.60	48.50	14.94	13.00	19.24	30.00	7.39	20.58
O	1/20	32.83	9,025	31.0	14.20	36.10	45.80	14.30	15.00	16.19	26.60	9.40	16.51
P	1/20	33.70	12,151	22.8	18.64	36.60	59.70	17.60	15.50	17.90	30.20	7.30	16.60
Q	1/18	31.00	5,311	25.7	6.20	41.40	26.00	11.40	5.20	14.95	25.60	5.20	15.31

Model	Wing										
	Span (ft)	Area (sq ft)	Section		Incidence		Aspect ratio	Sweepback of leading edge (deg)	Dihedral (deg)	Mean aerodynamic chord, c̄ (ft)	Leading edge of c̄ rearward of leading edge of root chord (ft)
			Root	Tip	Root chord (deg)	Tip chord (deg)					
A	38.19	299.80	NACA 23015	NACA 23009	3.0	---	4.85	0	5.00	8.13	0.36
B	39.00	259.00	NACA CYH 18 percent thick	NACA CYH 11.8 percent thick	0	0	5.90	1.60	5.50	6.94	.26
C	38.00	290.00	NACA 23017	NACA 23009	3.0	---	4.98	0	4.00	8.11	.08
D	35.00	232.00	NACA 0015	NACA 23009	2.0	2.0	5.30	3.60	3.00	7.02	.47
E	27.50	100.00	NACA 65(216)-017	NACA 67,1-(1.3)15	2.0	2.0	7.56	4.50	5.00	3.99	.45
F	42.00	276.25	NACA 66,2-218	NACA 66(215)-414	0	0	6.38	0	6.00	7.05	0
G	33.00	206.00	---------	-----------	4.0	---	5.28	2.60	5.50	6.69	.74
H	40.00	275.00	NACA 65(215)-117	NACA 65_2-115	1.0	1.0	5.82	0	0 (center) 7.50 (outer)	7.29	0
I	37.00	230.00	-----------	-----------	1.0	-.5	5.95	9.60	3.82	6.71	1.26
J	39.00	235.40	-----------	-----------	1.0	-.5	6.46	9.60	3.82	6.71	1.26
K	50.35	425.00	NACA 65(112)-213	NACA 65(112)-213	2.5	2.5	6.00	0	6.00	9.58	0
L	70.50	555.00	Douglas G15	Douglas G15	4.0	2.0	8.93	10.70	4.00	8.57	2.78
M	48.00	400.00	NACA 66(215)-214	NACA 65(112)-213	1.0	-1.5	5.76	4.80	6.50	8.72	.88
N	36.42	260.00	R-4,45-1512-.9	R-4,45-1512-.9	0	-2.2	5.10	6.00	5.00	7.40	.90
O	32.83	203.50	NACA 65(215)-114	NACA 65_1-212	2.0	-1.0	5.30	4.34	4.00	6.46	.56
P	38.10	255.30	NACA 64_1-112	-----------	1.0	-1.5	5.70	3.70	5.00	7.02	.54
Q	28.00	130.00	NACA 65-110	NACA 65-110	2.5	1.5	6.00	5.05	0	4.81	.55

Weight and cg locations are actual airplane values

TABLE II.– MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING CONDITIONS OF THE VARIOUS MODELS

[Model values presented in terms of airplane values; moments of inertia given about center of gravity]

Model	Loading	Weight (lb)	μ		Center of gravity		Moments of inertia (slug-ft^2)			Inertia parameters		
			Sea level	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	Normal	5,099	5.82	8.42 at 12,000 ft	0.241	0.028	2,586	8,160	10,150	-240×10^{-4}	-87×10^{-4}	327×10^{-4}
B	Normal	6,450	8.34	9.98 at 6,000 ft	.291	.037	4,000	6,680	9,960	−88	−108	196
B	Mass extended along X-axis	6,450	8.34	9.98 at 6,000 ft	.291	.037	4,000	16,300	19,580	−404	−108	512
C	Normal	5,276	6.25	7.49 at 6,000 ft	.257	.051	2,958	8,739	10,715	−244	−83	327
D	Normal	6,340	10.20	12.97 at 8,000 ft	.315	.133	3,050	5,250	7,850	−91	−108	199
D	Mass extended along X-axis	6,340	10.20	12.97 at 8,000 ft	.315	.130	3,050	10,500	13,100	−309	−108	417
E	Normal	3,387	16.07	25.53 at 15,000 ft	.267	.267	652	2,224	2,650	−198	−54	252
E	Mass extended along X-axis	3,465	16.45	26.18 at 15,000 ft	.267	.267	652	2,668	3,094	−248	−52	300
E	Mass retracted along X-axis	3,304	15.75	25.06 at 15,000 ft	.267	.267	1,658	1,751	2,288	−140	−69	209
E	Center of gravity moved 12 percent $\bar{c}$ forward	3,338	15.86	25.23 at 15,000 ft	.147	.267	652	2,224	2,650	−201	−54	255
F	Normal	7,873	8.84	16.60 at 20,000 ft	.204	−.010	4,136	9,397	13,461	−122	−94	216
F	Center of gravity moved 14 percent $\bar{c}$ rearward	7,797	8.77	16.46 at 20,000 ft	.350	.010	4,420	9,920	13,980	−129	−95	224
G	Normal	5,579	10.70	20.09 at 20,000 ft	.260	[a].049	1,945	5,802	7,640	−205	−98	303
G	Mass extended along X-axis	5,738	11.00	20.67 at 20,000 ft	.260	[a].049	1,945	7,342	9,180	−278	−99	373
G	Center of gravity moved 16 percent $\bar{c}$ rearward	5,649	10.83	20.34 at 20,000 ft	.420	[a].049	1,945	5,608	7,443	−192	−96	288
G	Center of gravity moved 21 percent $\bar{c}$ forward	5,579	10.70	20.09 at 20,000 ft	.050	[a].061	1,979	5,469	7,272	−185	−96	281
H	Mass extended along Y-axis	9,514	11.28	17.92 at 15,000 ft	.268	.004	7,395	11,635	19,005	−90	−156	246
H	Center of gravity moved 5.7 percent $\bar{c}$ rearward	9,514	11.28	17.92 at 15,000 ft	.320	.004	5,720	12,237	18,537	−138	−133	271
I	Normal	8,600	13.19	20.97 at 15,000 ft	.256	.010	3,700	9,717	13,327	−165	−99	264
I	Mass extended along Y-axis and retracted along X-axis	8,785	13.47	21.42 at 15,000 ft	.287	.020	4,470	7,271	11,590	−75	−116	191
I	Center of gravity moved 5.7 percent $\bar{c}$ forward	8,660	13.28	21.12 at 15,000 ft	.199	.009	3,700	10,968	14,557	−197	−98	295
J	Normal	9,612	13.68	21.75 at 15,000 ft	.250	.014	3,696	12,659	16,775	−197	−91	288
J	Overload	12,275	17.43	27.71 at 15,000 ft	.250	.017	12,636	13,842	26,530	−21	−219	240
K	Normal	18,180	11.17	17.65 at 15,000 ft	.212	.009	17,335	37,000	55,182	−137	−126	263
L	Normal	24,744	8.25	13.12 at 15,000 ft	.250	[a].050	43,267	99,492	143,050	−148	−114	262
M	Normal, original tail	16,378	11.10	17.7 at 15,000 ft	.250	.020	11,546	33,539	42,211	−188	−74	262
M	Normal, T tail	16,922	11.50	18.30 at 15,000 ft	.290	.000	14,331	40,702	50,100	−217	−78	295
M	Mass extended along X-axis, T tail	16,900	11.40	18.20 at 15,000 ft	.300	.020	14,406	47,613	56,936	−287	−80	367
N	Normal	12,569	17.30	27.60 at 15,000 ft	.270	−.010	9,020	14,962	23,074	−115	−157	272
N	Mass retracted along Y-axis	11,970	16.50	26.20 at 15,000 ft	.270	.000	6,486	14,903	20,483	−171	−114	285
O	Normal	8,993	17.56	27.93 at 15,000 ft	.306	−.066	4,130	11,966	14,892	−261	−97	358
O	Center of gravity moved 22 percent $\bar{c}$ rearward	9,337	18.25	29.03 at 15,000 ft	.526	−.101	3,986	11,953	14,849	−255	−92	347
O	Center of gravity moved 5 percent $\bar{c}$ forward	8,990	17.56	27.93 at 15,000 ft	.256	−.076	4,020	12,308	15,146	−276	−94	370
P	Normal	11,952	16.00	25.50 at 15,000 ft	.221	.134	6,556	13,096	17,962	−121	−90	211
P	Center of gravity moved 19.3 percent $\bar{c}$ rearward	12,136	16.30	25.91 at 15,000 ft	.413	.123	6,406	13,705	18,556	−133	−89	222
Q	Minimum flying weight	5,319	19.10	30.30 at 15,000 ft	.250	[a].002	1,994	7,756	9,678	−445	−148	593

[a] Measurements made from fuselage reference line instead of thrust line.

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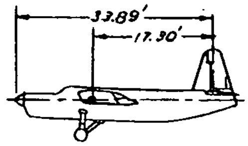
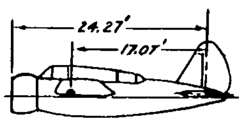
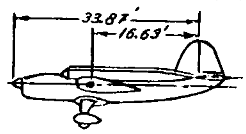
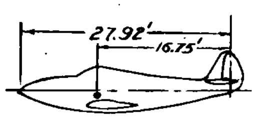
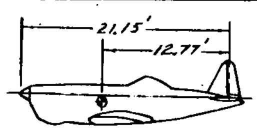
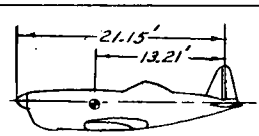
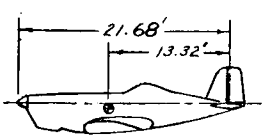
TABLE III.- NATURE OF SPINNING MOTION AS AFFECTED BY SIDE-AREA MOMENT FACTOR AND INERTIA YAWING-MOMENT PARAMETER FOR THE ORIGINAL AND MODIFIED CONFIGURATIONS OF THE VARIOUS MODELS

Model (a)	Model and loading	Loading	$\frac{I_X - I_Y}{mb^2}$	Side-area moment factor	Nature of spinning motion
	A	Normal	-240×10^{-4}	0.206	Steady
	B_1	Normal	-88	.126	Steady
	B_2	Mass extended along X-axis	-404	.126	Steady
	C	Normal	-244	.213	Steady
	D_1	Normal	-91	.280	Steady
	D_2	Mass extended along X axis	-309	.280	Oscillatory
	E_1	Normal	-198	.314	Oscillatory
	E_2	Mass extended along X-axis	-248	.314	Oscillatory
	E_3	Mass retracted along X-axis	-140	.314	Steady
	E_4	Center of gravity moved forward 12 percent mean aerodynamic chord	-201	.253	Steady
	E_5	Normal	-198	.268	Steady

[a] Model values presented in terms of airplane values.

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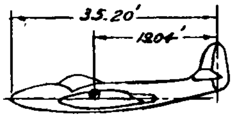
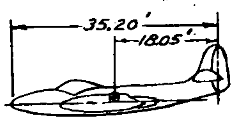
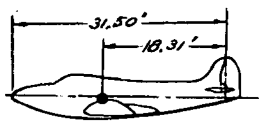
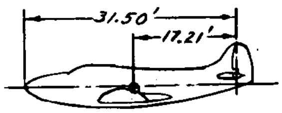
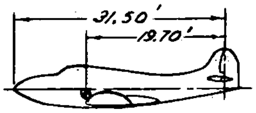
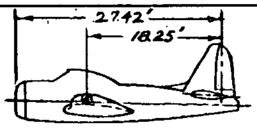
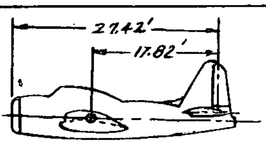
TABLE III.- NATURE OF SPINNING MOTION AS AFFECTED BY SIDE-AREA MOMENT FACTOR – Continued

Model (a)	Model and load-ing	Loading	$\frac{I_X - I_Y}{mb^2}$	Side-area moment factor	Nature of spin-ning motion
	F_1	Normal	-122×10^{-4}	0.422	Steady
	F_2	Center of gravity moved 14 percent mean aerodynamic chord rearward	-129	.536	Oscillatory
	G_1	Normal	-205	.333	Steady
	G_2	Mass extended along X-axis	-278	.333	Oscillatory
	G_3	Center of gravity moved 16 percent mean aerodynamic chord rearward	-192	.462	Oscillatory
	G_4	Center of gravity moved 21 percent mean aerodynamic chord forward	-185	.241	Steady
	H_1	Mass extended along Y-axis	-90	.160	Steady
	H_2	Center of gravity moved 5.7 percent mean aerodynamic chord rearward	-138	.175	Steady

[a] Model values presented in terms of airplane values.

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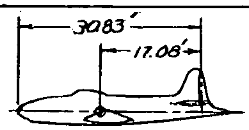
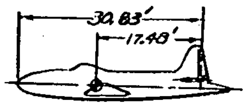
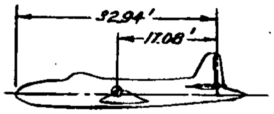
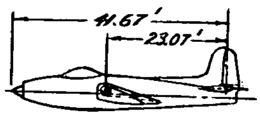
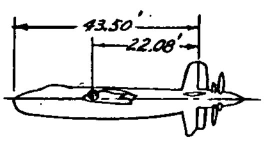
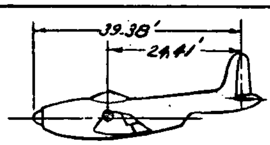
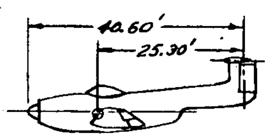
TABLE III.– NATURE OF SPINNING MOTION AS AFFECTED BY SIDE-AREA MOMENT FACTOR – Continued

Model (a)	Model and loading	Loading	$\frac{I_X - I_Y}{mb^2}$	Side-area moment factor	Nature of spinning motion
	I_1	Normal	-165×10^{-4}	0.371	Oscillatory
	I_2	Mass extended along Y-axis and retracted along X-axis	-75	.398	Steady
	I_3	Center of gravity moved 5.7 percent mean aerodynamic chord forward	-197	.329	Oscillatory
	J_1	Normal	-197	.513	Oscillatory
	J_2	Overload	-21	.513	Steady
	K	Normal	-137	.320	Steady
	L	Normal	-148	.378	Steady
 ORIGINAL TAIL	M_1	Normal	-188	.232	Steady
 T-TAIL	M_2	Normal	-217	.233	Steady
	M_3	Mass extended along X-axis	-287	.233	Steady

[a] Model values presented in terms of airplane values.

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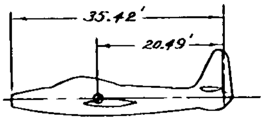
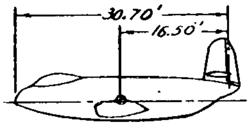
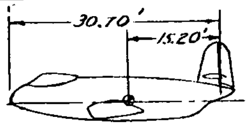
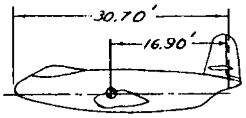
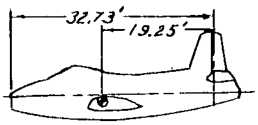
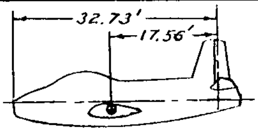
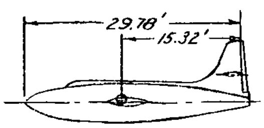
TABLE III.- NATURE OF SPINNING MOTION AS AFFECTED BY SIDE-AREA MOMENT FACTOR – Concluded

Model (a)	Model and loading	Loading	$\frac{I_X - I_Y}{mb^2}$	Side-area moment factor	Nature of spinning motion
	N_1	Normal	-115×10^{-4}	0.348	Steady
	N_2	Mass retracted along Y-axis	-171	.348	Steady
	O_1	Normal	-261	.446	Oscillatory
	O_2	Center of gravity moved rearward 22 percent mean aerodynamic chord	-255	.616	Oscillatory
	O_3	Center of gravity moved forward 5 percent mean aerodynamic chord	-276	.406	Oscillatory
	P_1	Normal	-121	.348	Steady
	P_2	Center of gravity moved rearward 19.3 percent mean aerodynamic chord	-133	.505	Oscillatory
	Q	Minimum flying weight	-445	.378	Oscillatory

[a] Model values presented in terms of airplane values.

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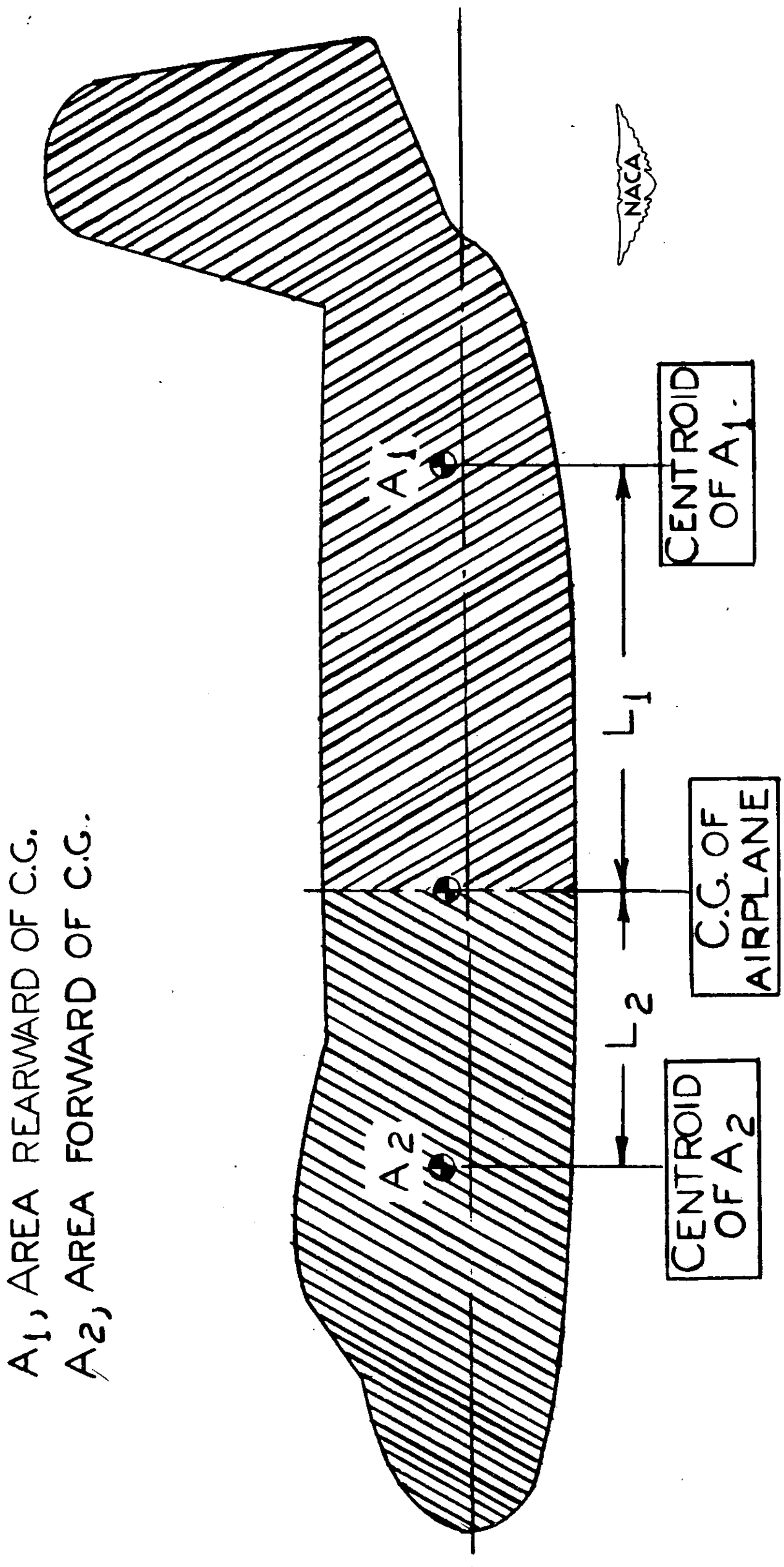

FIGURE 1.-METHOD OF COMPUTING SIDE-AREA MOMENT FACTOR $\frac{A_2 L_2}{A_1 L_1}$.

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Page 14 —— 29 (every other page blank)

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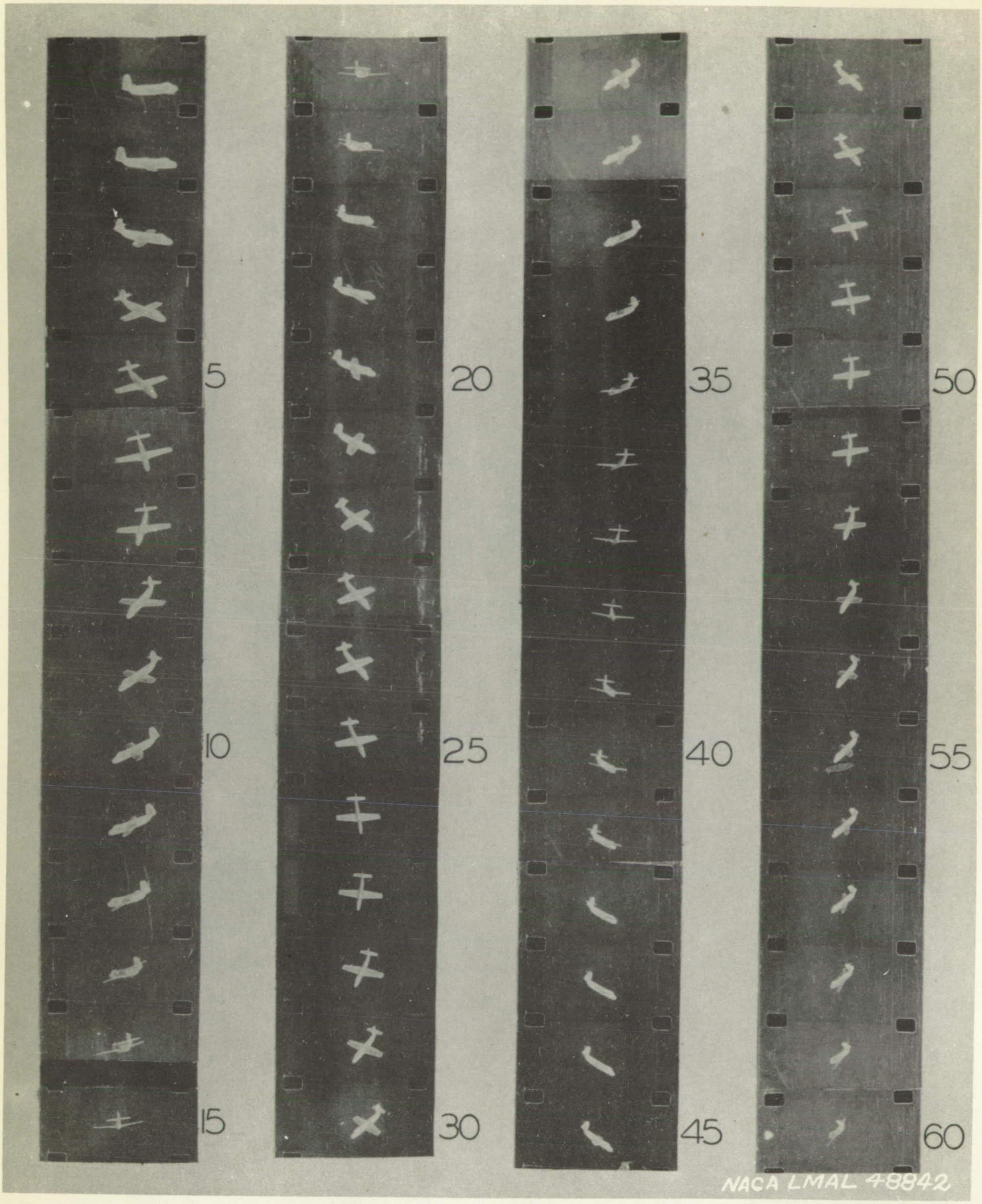

Figure 2.- Typical motion of model 0_1 with ailerons neutral, elevator full up, and rudder full with the spin. Rotation imparted to model upon launching presists through frame 45. (Pictures taken at 32 frames per second.)

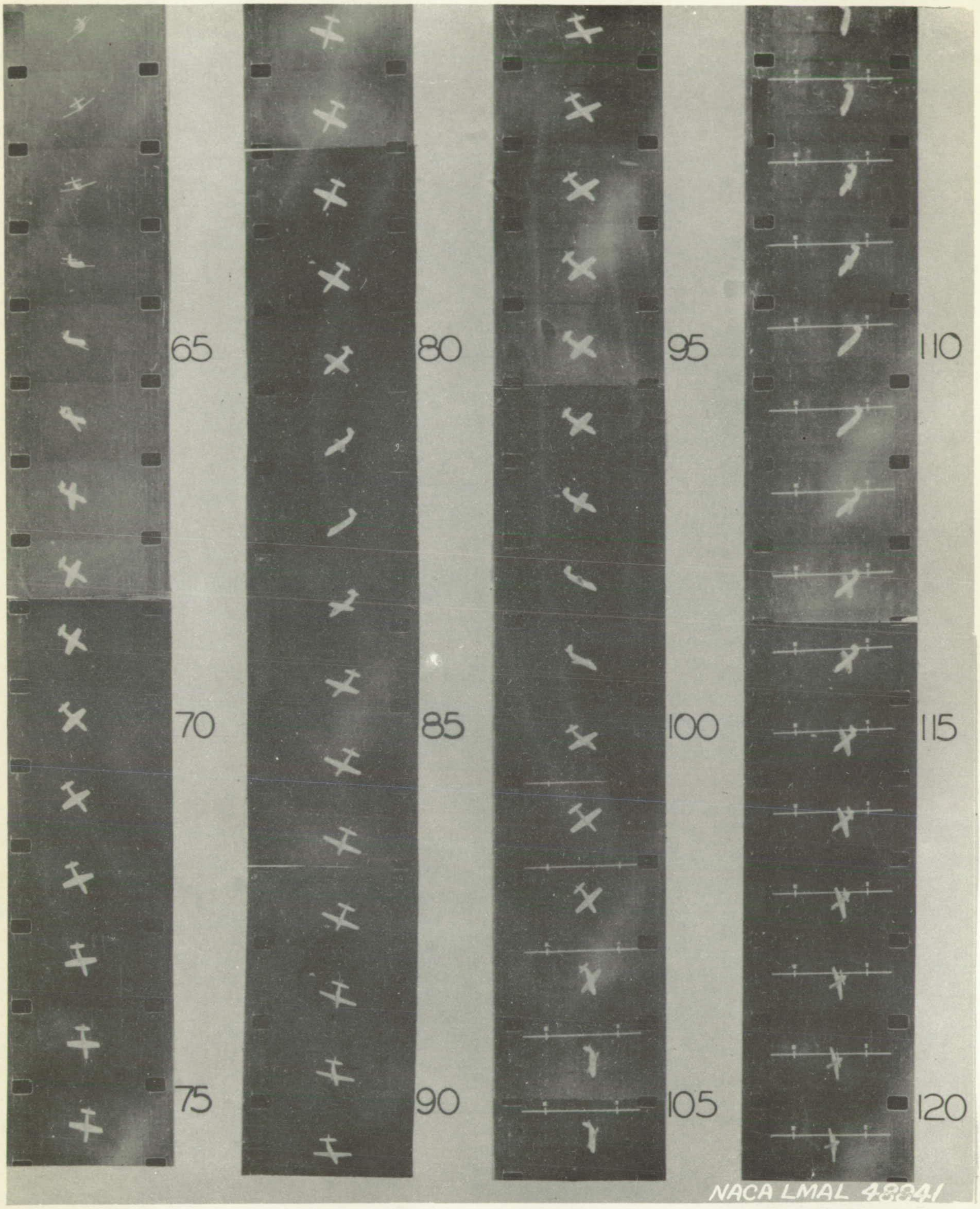

Figure 2 - Continued.

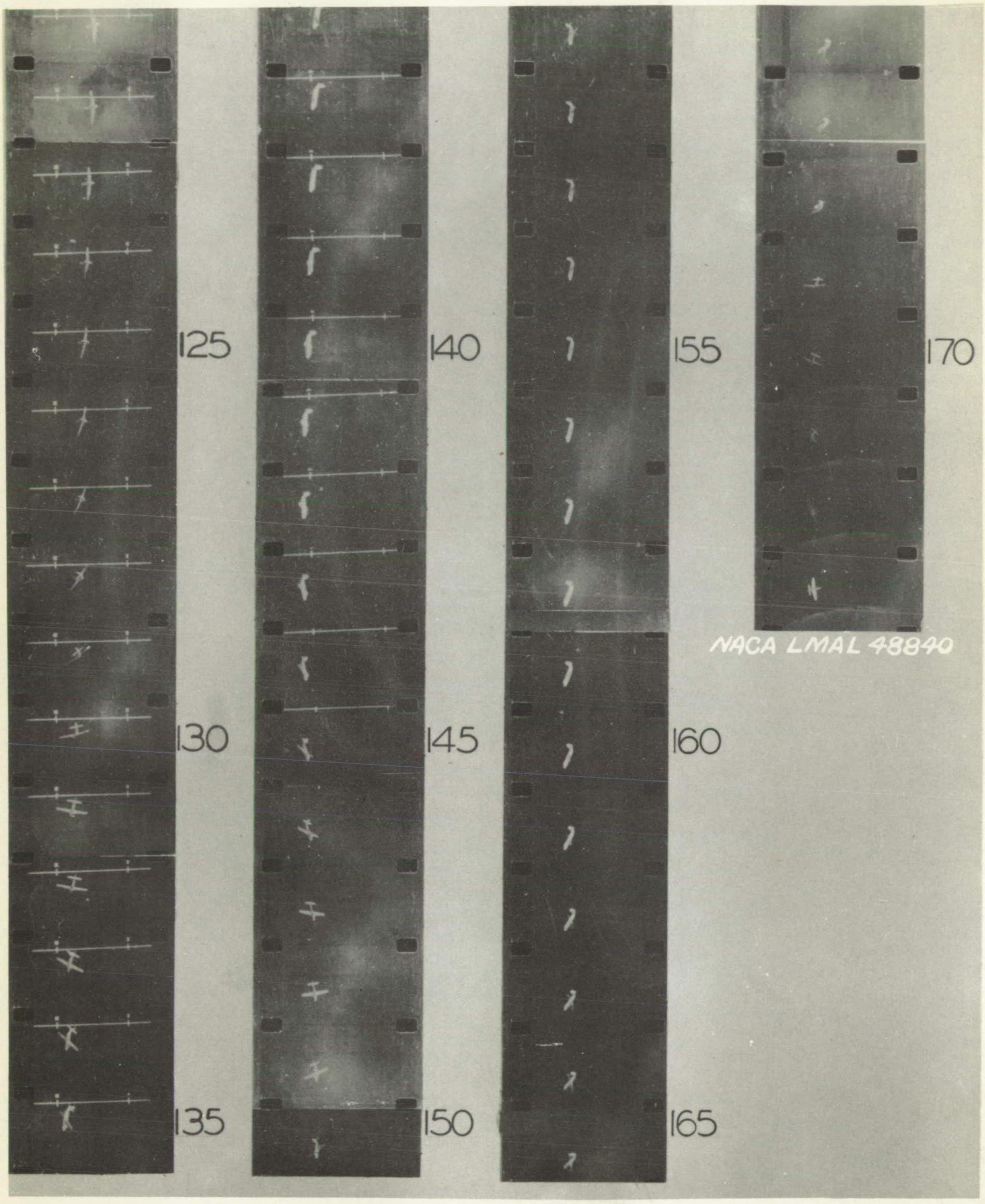

Figure 2.- Concluded.

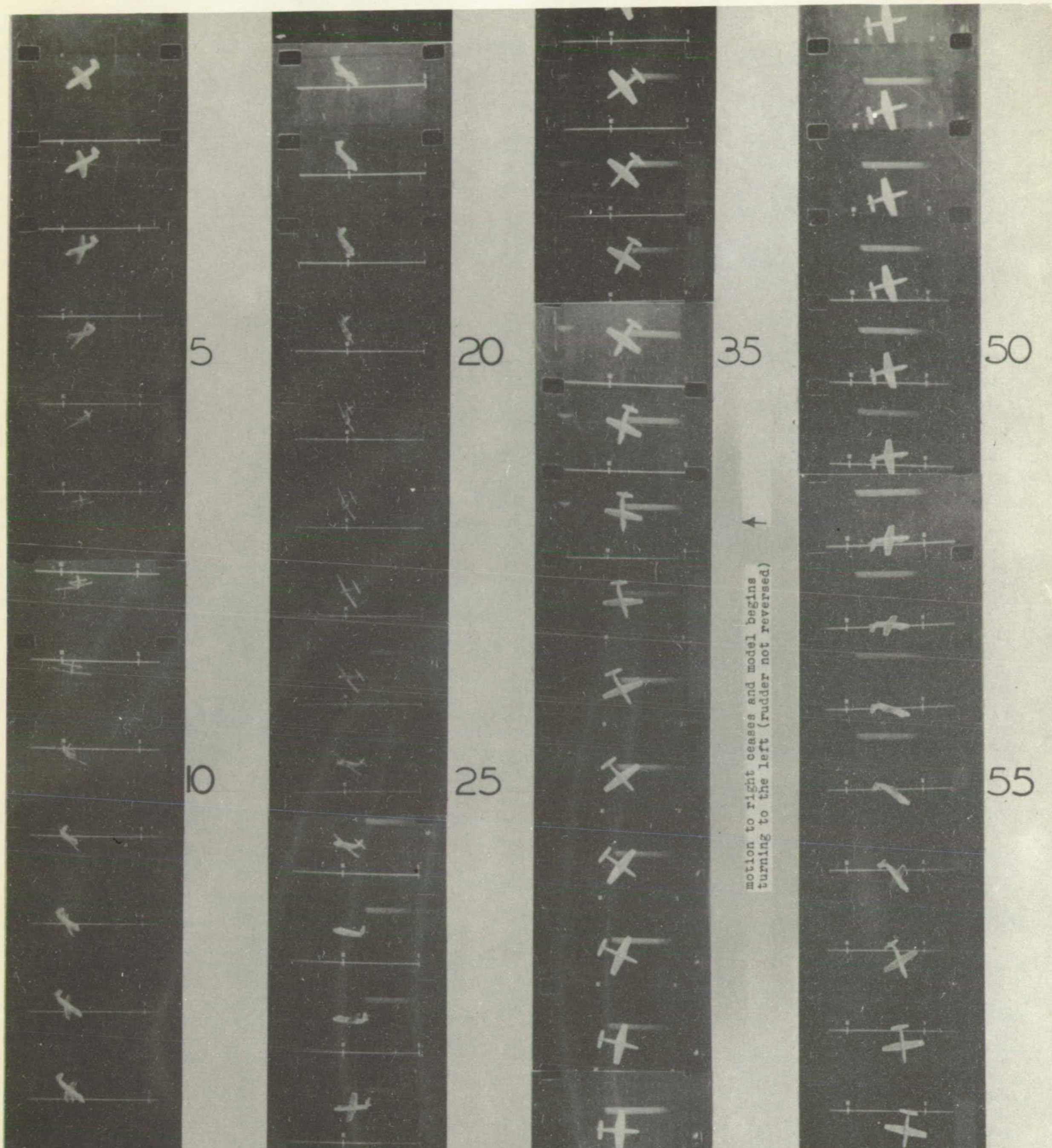

Figure 3.- Typical motion of model 0_1 with ailerons full against the spin, elevator full up, and rudder full with the spin. (Pictures taken at 64 frames per second.)

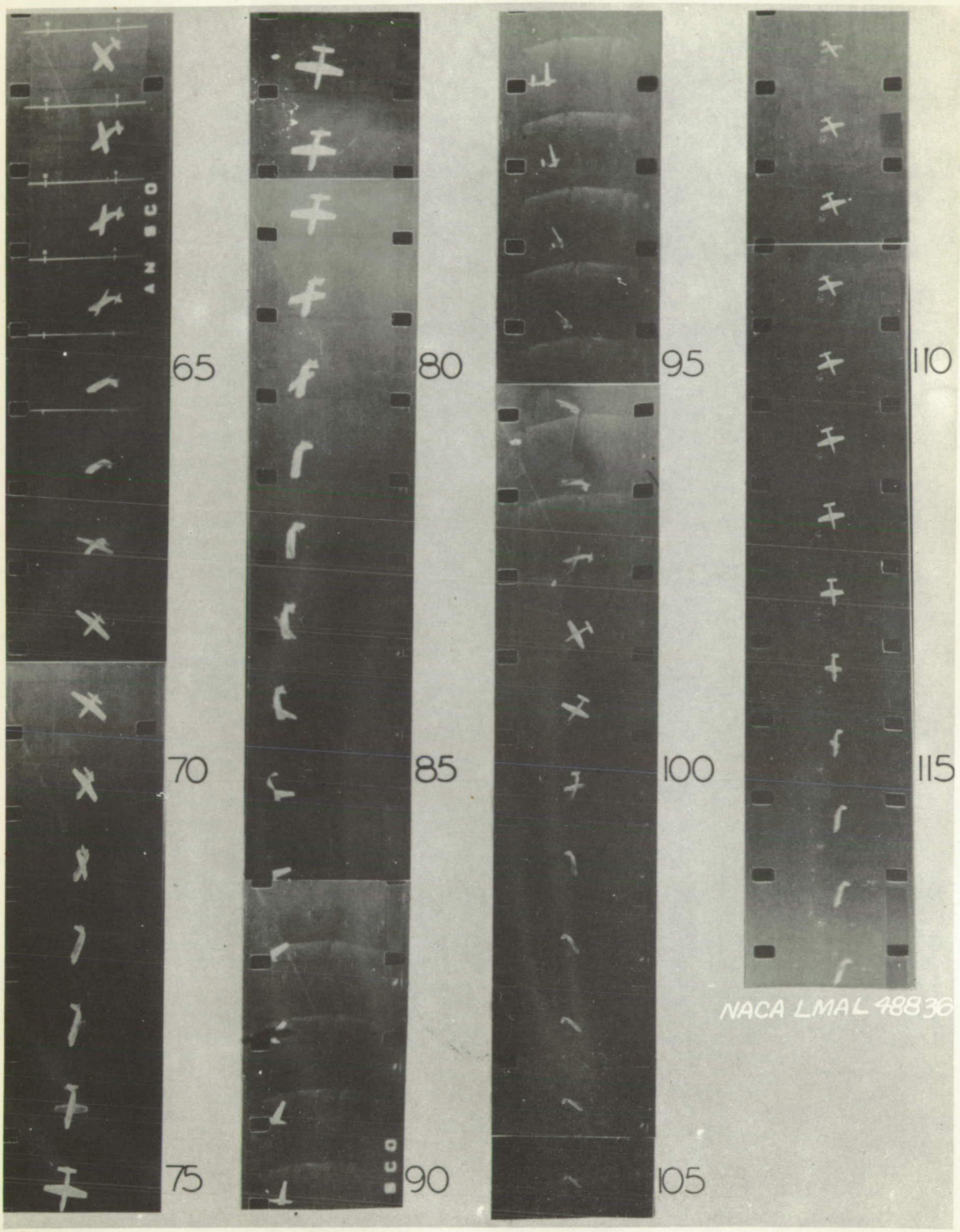

Figure 3.- Concluded.

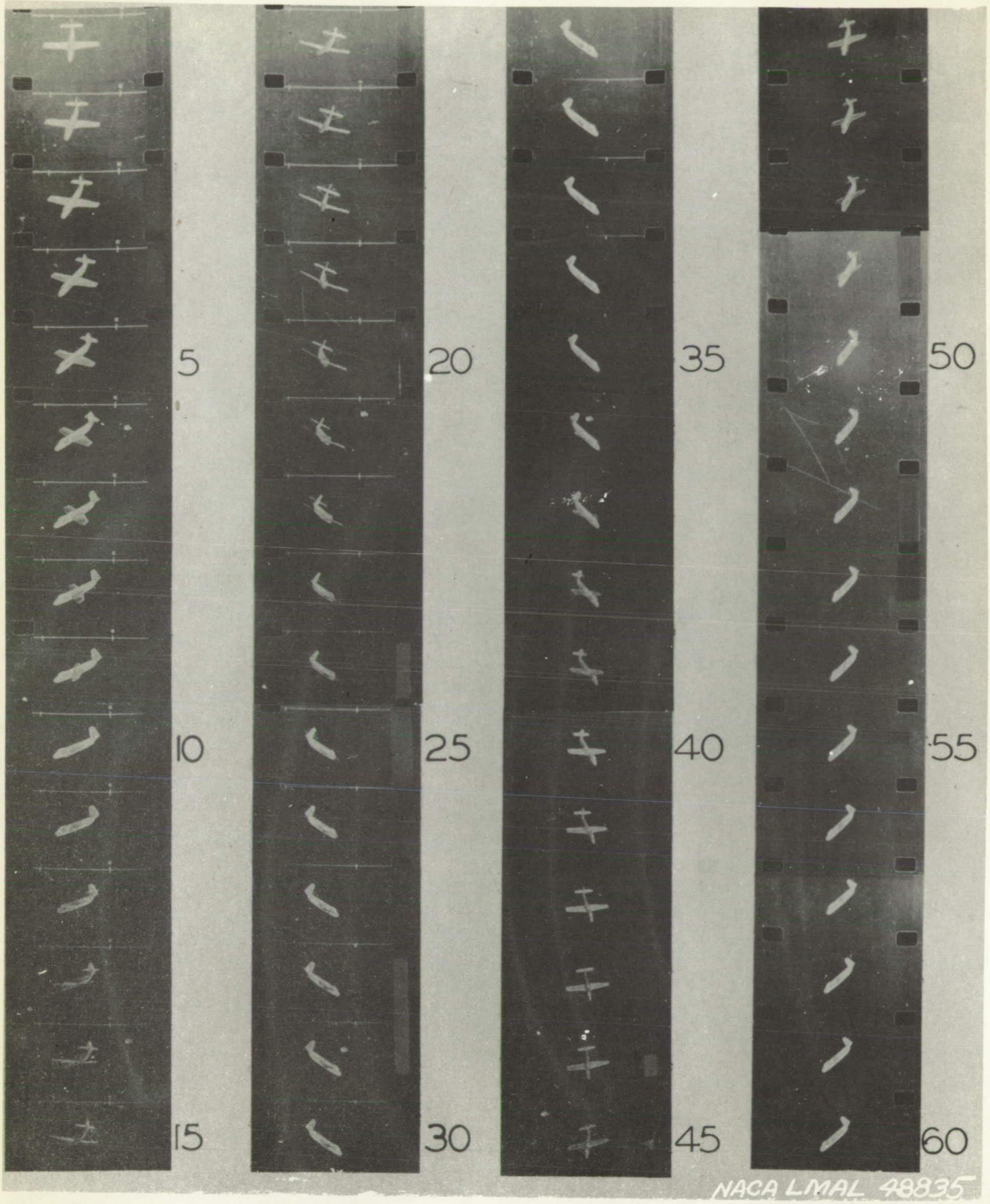

Figure 4.- Typical motion of model 0_1 with ailerons full with the spin, elevator full up, and rudder full with the spin. Rotation imparted to model upon launching presists through frame 25. (Pictures taken at 64 frames per second.)

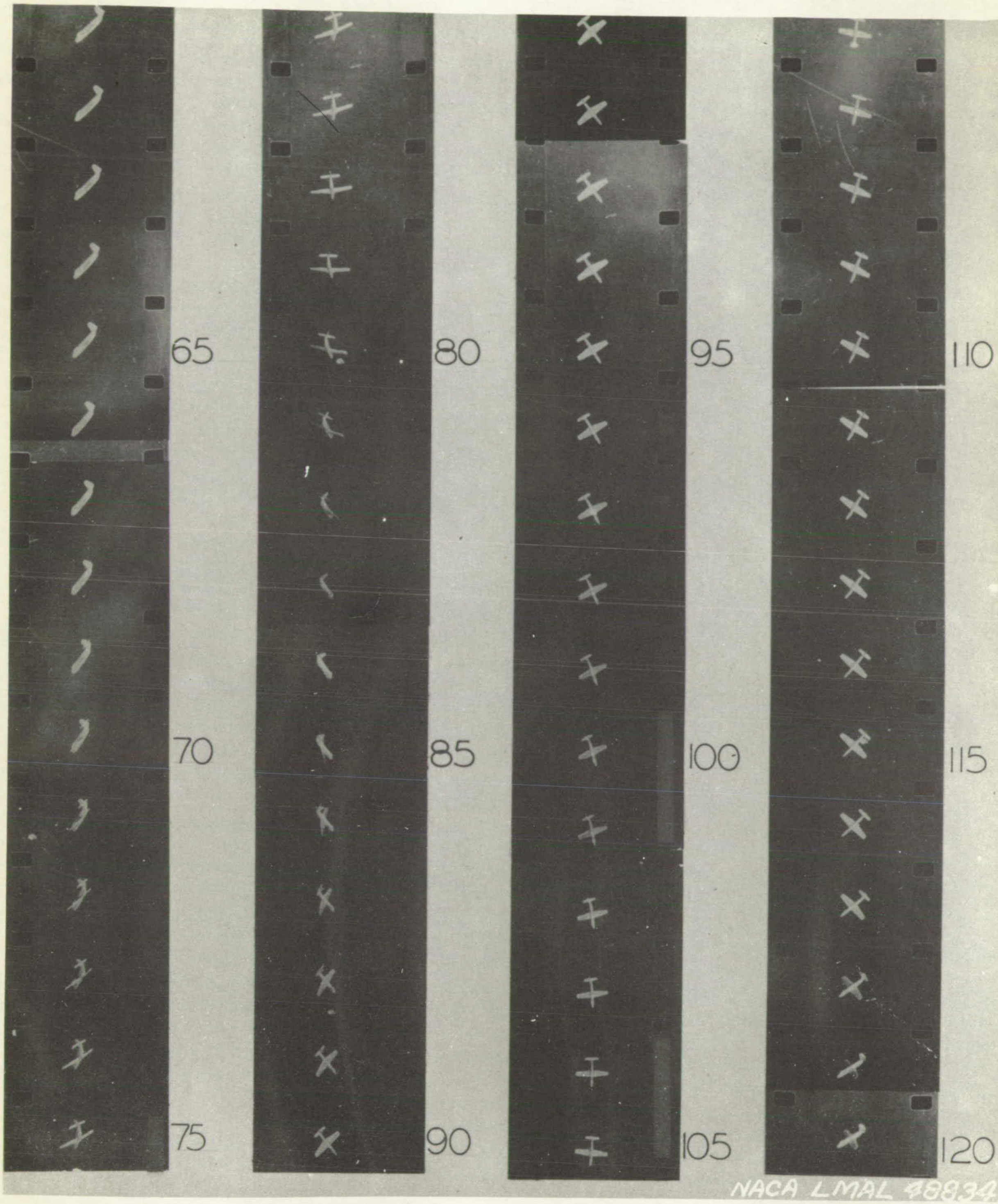

Figure 4.- Continued.

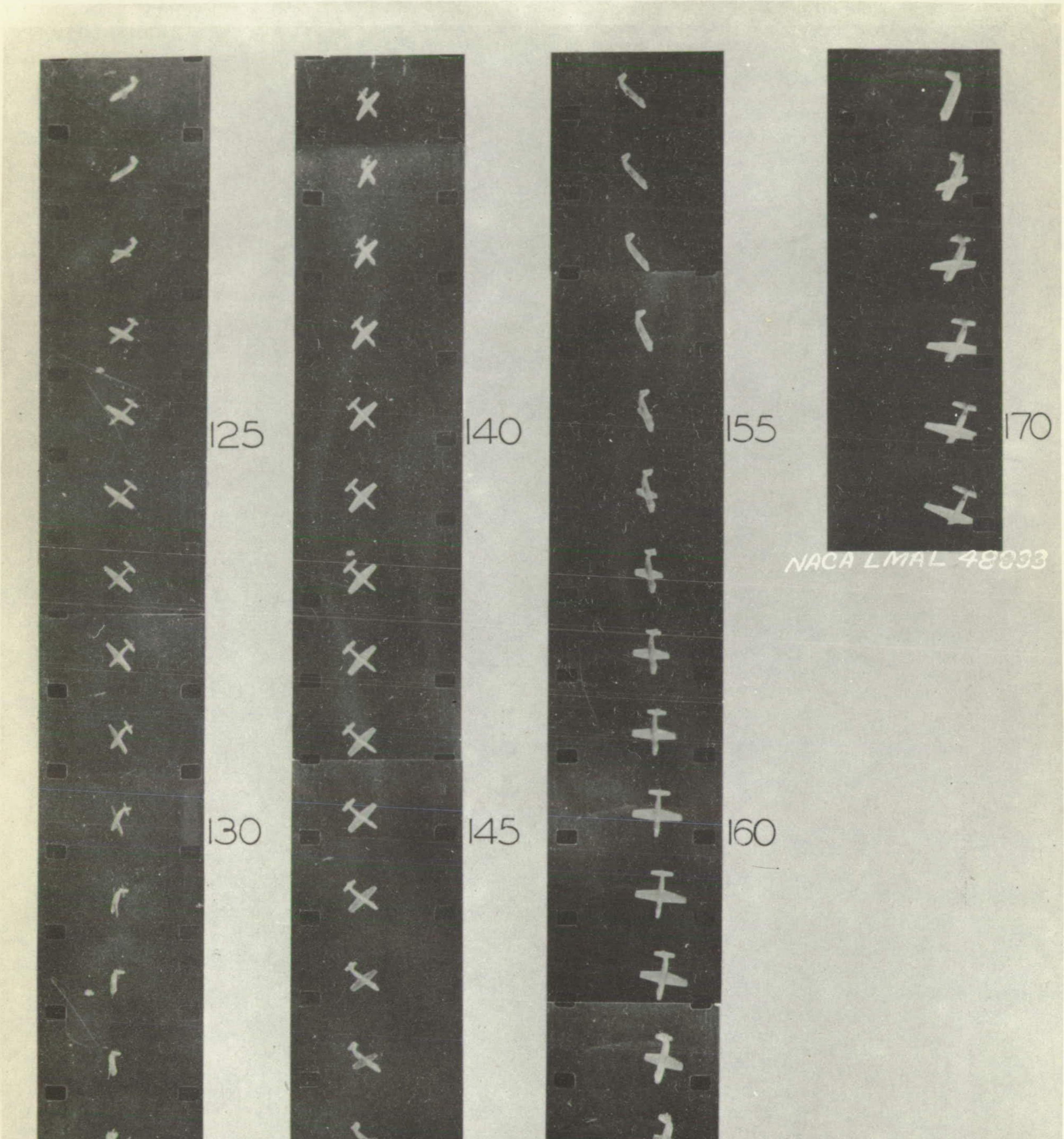

Figure 4.- Concluded.

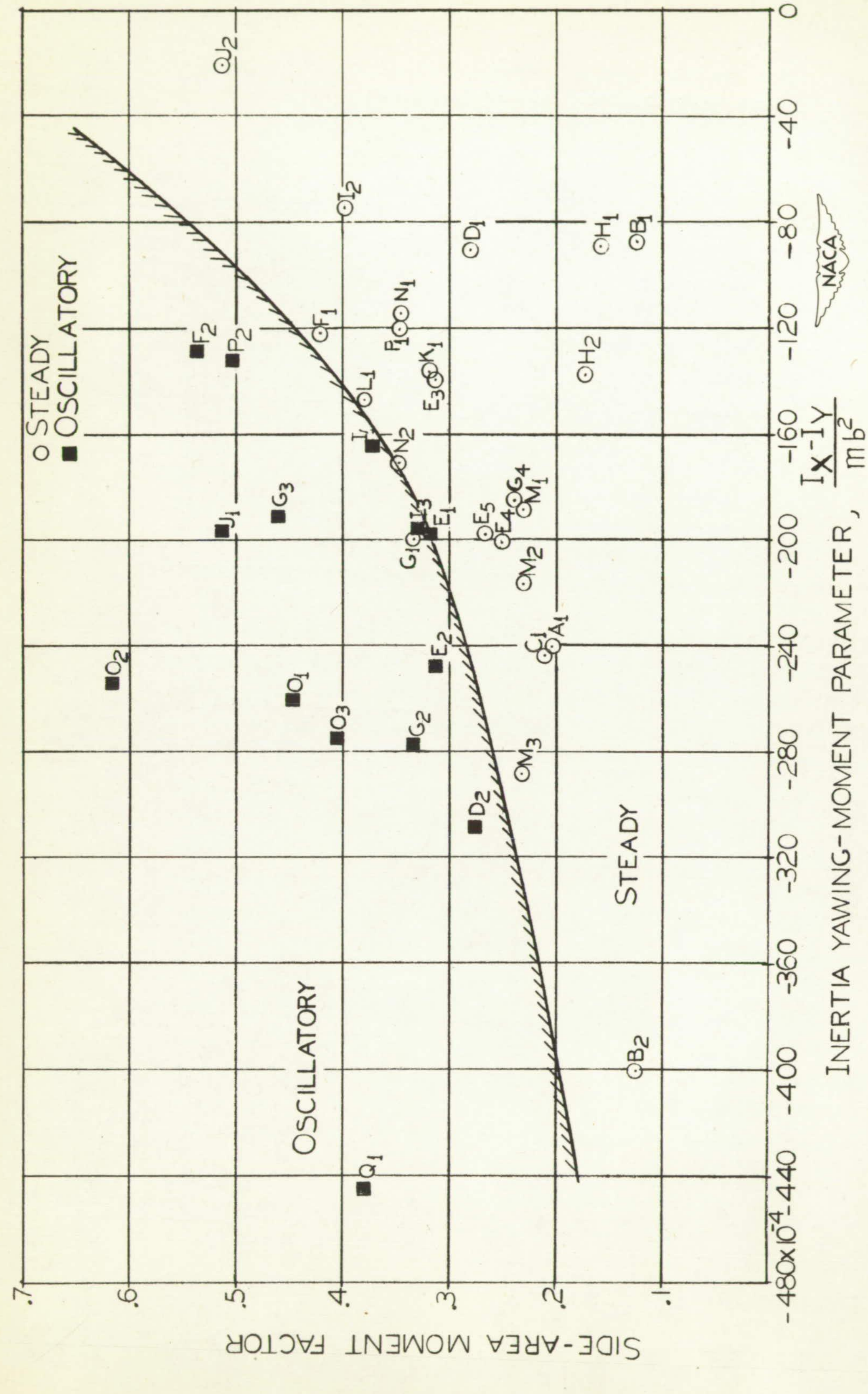

FIGURE 5.- EFFECT OF SIDE-AREA MOMENT FACTOR AND INERTIA YAWING-MOMENT PARAMETER ON THE NATURE OF THE SPIN. (LETTERS AND NUMBERS REFER TO MODELS LISTED IN TABLE III.)