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EFFECT OF LANDING FLAPS AND LANDING GEAR ON THE SPIN AND RECOVERY CHARACTERISTICS OF AIRPLANES

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SUMMARY

The effect of landing flaps and landing gear on the spin and recovery characteristics of airplanes has been determined from investigations of the spinning characteristics of 58 models in the Langley 15-foot and 20-foot free-spinning tunnels.

The analysis indicated that generally an adverse effect on recovery characteristics was obtained when the flaps were in an extended position during the fully developed spin. An exception to this effect occurred when the model was heavily loaded along the fuselage and the ailerons were set with the spin, for which condition there was either no effect or a favorable effect on recovery characteristics. It thus appears that if a spin is entered inadvertently with the landing flaps extended, the flaps should usually be retracted immediately.

Lowering flaps generally caused an increase in inward sideslip, an increase in the angle of attack, and a decrease in the rate of rotation of the model in the spin. Extension of the landing gear usually had a negligible effect on the spin and recovery characteristics.

INTRODUCTION

During approximately 13 years of operation of the Langley 15-foot and 20-foot free-spinning tunnels, model tests have been made for almost 200 different military designs of airplanes to determine their spin and recovery characteristics. During these tests the various flying characteristics of an airplane were investigated; the investigation included a determination of the effect of extending landing flaps and landing gear upon the spin and recovery characteristics. Because present military specifications do not require airplanes to demonstrate recovery from fully developed spins when in the landing condition, investigations of spin models with landing flaps and gear extended have been discontinued. Data for 58 models are available at the Langley Laboratory, however, from which the independent effects of either landing flaps or landing gear may be ascertained. In order to determine the independent effects, these data have been analyzed, and the results obtained are presented herein. The aerodynamic effect of landing flaps upon spin characteristics as determined from spin-balance data for a single monoplane model have been presented in reference 1.

SYMBOLS

b	wing span, feet
m	mass of airplane, slugs
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2
μ	airplane relative-density coefficient
TDPF	tail-damping power factor (reference 2)
TDR	tail-damping ratio (reference 2)
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter (positive when mass is distributed chiefly along the wings; negative when mass is distributed chiefly along the fuselage)
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 (positive when right, or inboard wing, is below horizontal in a right spin), degrees
Ω	full-scale angular velocity about spin axis, revolutions per second

TESTS

The steady-spin and recovery data used for the analysis in the present paper were obtained from routine tests made in the Langley 15-foot and 20-foot free-spinning tunnels during the last 13 years. Data from a total of 58 different models of military airplanes are considered in this analysis from which the independent effects of the landing flaps were determined for 53 models and the independent effects of the landing gear, for 38 models.

The methods used for making spin-tunnel tests are described in reference 3, although in recent years the model launching technique has been changed from launching from a spindle to launching by hand. Briefly, a model ballasted by means of lead weights to obtain dynamic similarity to the full-scale airplane at some spin altitude is launched by hand with rotation into a vertically rising air stream with the controls set in a desired position. After a number of turns, the model assumes its spin attitude and is maintained at a specified level in the tunnel by adjusting the airspeed so that the model drag equals its weight. After a number of turns in the established spin have been photographed and timed, a recovery attempt is made by moving one or more of the control surfaces by means of a remote-control mechanism; if recovery is effected, the model dives or glides into a safety net. The spin data obtained from the tests are then converted to corresponding full-scale values by methods described in reference 3.

The data considered have been obtained from results of tests for numerous airplane models in the Langley 15-foot and 20-foot free-spinning tunnels. Some of the data presented are from tests with landing flaps and landing gear extended in conjunction with an open canopy. Results of unpublished data, however, have indicated that canopy opening alone has a negligible effect on model spin and recovery characteristics.

RESULTS AND METHODS

The results of the present investigation are given in figures 1 to 6. Figures 1 to 3 indicate the effect of flaps upon spin-recovery characteristics, whereas figures 4 to 6 indicate the effect of flaps upon the angle of wing inclination, angle of attack, and rate of rotation, respectively. The model numbers associated with the points in figures 1 to 6 for all elevator-up control settings correspond to the numbers in table I. Table I presents some of the principal mass and dimensional characteristics of the models used in this investigation. Extension of the landing gear had only a small effect on the spin and recovery characteristics of the models; and, consequently, no plots pertaining to the effects of landing-gear extension are presented.

Spin-tunnel experience (references 4 and 5) has indicated that the inertia yawing-moment parameter $\frac{I_X - I_Y}{mb^2}$ may greatly influence the effect of rudder, elevator, ailerons, and slots on the spin and on the recovery. Since flaps seemed to show a dependence on this parameter and no relation to several other important mass and dimensional parameters considered, the effects of landing flaps were therefore examined in relation to the inertia yawing-moment parameter. Accordingly, the number of turns required for recovery by rudder reversal with flaps in a retracted position and with flaps in an extended position were compared as a function of the inertia yawing-moment parameter.

When the model entered a steep high-velocity spin which could not be controlled in the tunnel, recovery was estimated to be rapid and a point was arbitrarily plotted as requiring 1/4 turn for the recovery by rudder reversal. For recovery attempts in which the model struck the safety net before recovery could be effected, the number of turns from the time the rudder was reversed to the time the model struck the safety net was recorded. This number indicates that the model required more turns to recover from the spin than shown. A greater than $2\frac{1}{2}$-turn recovery, however, does not necessarily indicate an improvement when compared with a greater than 4-turn recovery. For recovery attempts in which the model recovered of its own accord, without a reversal of the rudder, the condition known as "no spin" was plotted at zero turns for recovery. The symbol ∞ indicates that the model required 10 turns or more for recovery or did not recover at all.

Preliminary analysis indicated that there was no characteristic difference in the results obtained with the various types of landing flaps tested, and, consequently, no differentiation is made in this paper for the various types of landing flaps.

DISCUSSION

The results presented in figure 1 indicate that for the normal control configuration for spinning (rudder with the spin, ailerons neutral, and elevator up) either an adverse effect or no effect on model recovery characteristics was usually obtained if the flaps were down during the spin regardless of the loading condition. Similar results (not presented) were obtained with the elevator either neutral or down.

The results presented in figure 2 indicate the effects obtained when the ailerons were set against the spin with the elevator up. These effects are similar to those presented in figure 1. Other similar results (not presented) were also obtained with the elevator either neutral or down when the mass was distributed chiefly along the fuselage, whereas with the mass distributed chiefly along the wings the results (not presented) indicated little effect due to lowering the flaps.

The results presented in figure 3 indicate that when the ailerons were set with the spin with the elevator up the effect of extending flaps was generally similar to that obtained when ailerons were neutral, except when the mass was distributed chiefly along the fuselage, in which case either a favorable effect or no effect was usually noted. Similar results (not presented) were obtained when the elevator was either neutral or down.

The results presented in figure 4 indicate that extending flaps generally led to a downward inclination of the inner wing. The helix angle in the spin remained fairly constant (approximately 4°) for all conditions; it may therefore be concluded that lowering the flaps usually caused an increase in inward sideslip. (Sideslip angle equals ϕ minus helix angle.)

The results presented in figure 5 indicate that the angle of attack of the spinning airplane in most of the cases increased when the landing flaps were extended in the spin. Figure 6 indicates that generally for the models tested the rate of rotation decreased when the flaps were extended.

It should be noted that the elevator-neutral and elevator-down data were presented in figures 4 to 6 merely to substantiate the conclusions reached for the elevator-up data.

Brief tests were made for a contemporary low-wing fighter-type airplane attached to a rotary balance in the Langley 20-foot free-spinning tunnel. The forces and moments acting on the model were measured with flaps extended and with flaps retracted while in a simulated spin. The results of these tests indicated that usually the increment in antispin yawing moment coefficient due to reversing the rudder was appreciably less when flaps were extended than when they were retracted. These results are in agreement with free-spinning tests which indicate an adverse effect of extended flaps on recovery by rudder reversal. The results also indicated that for spins of moderate angles of attack (α between 35° and 55°), the aerodynamic diving-moment coefficient increased when the flaps were extended. Results obtained for the rolling-moment coefficient indicated small changes due to lowering flaps, and no general trend was indicated.

It appears that recoveries from fully developed spins may be seriously retarded if landing flaps are in the down position, and, accordingly, fully developed spins in the landing condition should be avoided. If a spin is inadvertently entered with flaps down, the flaps should be retracted immediately. At the present time, military airplanes are required to recover from 1-turn demonstration spins with flaps down. Experience has indicated that an airplane does not enter a fully developed spin in 1 turn; and, therefore, for this case the effect of flaps will probably be small.

With the advent of jet airplanes with the relative mass distribution along the fuselage greatly increased, the observation has been made in many instances that the spinning motion consists primarily of a sequence of rolling and yawing oscillations, particularly for a design incorporating a long nose length (reference 6). It is believed, however, that in general the conclusions reached in this report are also applicable to these jet airplanes.

As previously indicated, although not presented in chart form, the results indicated that an extension of the landing gear seldom had an effect on the spin-recovery characteristics of models. Where effects were noted they were usually favorable and recoveries were hastened slightly. Occasionally, adverse effects were noted, probably due to a critical change in mass distribution caused by the extension of the gear.

CONCLUSIONS

On the basis of the analysis presented of the effect of landing flaps and landing gear on the spin and recovery characteristics of 58 airplane models, the following conclusions may be drawn:

1. Extended landing flaps usually had an adverse effect on the spin recovery characteristics of an airplane. An exception occurred when the model was heavily loaded along the fuselage and the ailerons were set with the spin, for which condition there was either no effect or a favorable effect on recovery characteristics. It thus appears that if a spin is entered inadvertently with the landing flaps extended the flaps should usually be retracted immediately.

2. Lowering flaps generally caused an increase in inward sideslip, an increase in the angle of attack, and a decrease in the rate of rotation of the model in the spin.

3. Extension of the landing gear generally had no appreciable effect on the spin-recovery characteristics.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., March 18, 1948

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TABLE I.- PRINCIPAL MASS AND DIMENSIONAL CHARACTERISTICS OF MODELS USED IN FLAP INVESTIGATION

[All values full scale]

Model	Wing span (ft)	Wing area (sq ft)	Weight (lb)	$x/\bar{c}$	μ (at altitude)	I_X (slug feet^2)	I_Y (slug feet^2)	I_Z (slug feet^2)	TDPF	TDR
1	42.00	303.50	10,440	0.205	15.98	13,793	7,582	21,210	2410×10^{-6}	0.0634
2	123.00	1660.00	69,600	.249	9.95	804,263	470,793	1,259,518	1160	.0465
3	51.50	455.00	17,777	.262	16.21	40,087	25,595	64,151	449	.0356
4	55.00	414.00	20,260	.154	15.73	41,989	25,596	63,625	484	.0241
5	64.00	700.00	24,500	-----	13.40	65,696	39,995	104,142	1735	.0363
6	42.00	303.50	8,616	.234	11.97	10,787	7,174	17,264	1973	.0478
7	83.00	903.20	39,578	.258	10.97	155,161	105,410	260,571	66	.0080
8	66.00	663.30	25,750	.271	14.43	53,494	35,082	83,423	1103	.0310
9	52.50	375.00	10,583	.260	13.14	15,600	11,016	25,183	1360	.0464
10	61.33	464.00	19,050	.218	16.40	33,706	24,557	55,287	367	.0280
11	91.83	1176.00	18,950	.302	3.64	105,900	93,100	137,500	34	.0030
12	40.78	300.00	11,860	.259	17.13	13,867	13,047	25,841	160	.0164
13	59.68	442.30	12,197	.192	11.32	20,370	19,934	37,736	144	.0212
14	41.44	275.00	9,277	.268	14.22	8,920	9,181	17,224	320	.0195
15	65.00	612.00	26,544	.144	11.85	63,651	69,798	129,371	517	.0411
16	40.79	210.78	5,097	.284	10.49	3,705	4,970	7,580	224	.0169
17	45.60	375.00	13,633	.246	15.05	11,920	16,545	26,164	253	.0320
18	47.70	363.00	7,311	.304	6.60	6,206	7,677	12,442	70	.0087
19	42.00	239.00	4,227	-----	7.46	2,659	4,122	6,201	205	.0140
20	42.00	248.00	4,400	.258	7.97	2,700	4,360	5,900	255	.0168
21	40.78	300.00	11,860	.259	17.13	8,736	13,047	20,710	160	.0164
22	53.65	420.00	14,545	.250	11.44	13,241	22,545	33,714	241	.0184
23	35.00	232.00	6,212	.290	12.72	2,750	4,560	6,890	175	.0171
24	35.00	208.90	4,815	.251	10.28	2,282	3,715	5,608	167	.0120
25	40.03	240.42	4,282	.248	7.88	2,492	4,170	6,293	262	.0178
26	33.50	187.00	4,341	.279	11.90	1,648	2,871	3,893	693	.0210
27	36.00	223.73	6,900	.250	13.0	3,439	5,769	8,557	0	.0144
28	41.00	281.57	7,350	.231	14.55	4,767	8,007	11,729	278	.0173
29	53.00	431.00	18,300	.235	19.66	16,159	29,198	42,499	443	.0233
30	34.33	208.00	6,750	.261	16.72	3,285	5,540	8,550	546	.0268
31	41.51	323.80	7,615	.267	10.02	4,841	8,692	12,544	4	.0206
32	39.00	258.00	5,938	.272	9.19	3,223	5,931	8,752	73	.0096
33	36.00	378.25	5,299	.286	6.89	3,610	5,710	7,070	324	.0185
34	37.28	236.00	5,531	.267	11.85	2,020	4,470	6,030	473	.0264
35	38.00	260.00	5,824	.238	11.18	2,310	4,996	6,809	73	.0079
36	42.00	248.30	4,296	.248	6.65	2,621	3,715	5,613	244	.0180
37	34.00	213.00	5,834	.264	12.7	4,358	6,113	6,000	220	.0194
38	34.00	232.10	5,386	.258	10.08	1,506	3,685	4,851	74	.0100
39	41.02	246.22	4,467	.262	7.81	2,741	4,237	5,681	450	.0204
40	36.00	378.25	5,023	.319	6.53	2,705	5,115	8,495	313	.0181
41	48.00	391.62	18,002	.274	19.90	16,975	32,576	47,686	135	.0187
42	42.00	305.00	5,575	.274	10.51	3,250	7,020	9,580	381	.0184
43	45.00	375.00	14,600	.261	15.31	13,934	25,533	37,832	32	.0213
44	40.00	275.00	9,514	.268	17.65	5,720	11,635	17,330	146	.0285
45	54.00	544.00	18,800	.230	13.29	21,655	44,586	63,263	1017	.0455
46	36.00	377.60	5,356	.267	7.44	3,457	6,554	7,476	397	.0228
47	42.00	290.00	3,290	.272	5.43	1,765	3,490	4,897	238	.0173
48	37.29	236.00	6,825	.248	14.78	2,172	6,744	8,602	452	.0251
49	47.00	379.20	10,112	.257	10.08	20,544	28,443	10,000	313	.0161
50	37.28	236.00	6,700	.287	14.41	2,062	7,387	8,842	562	.0297
51	36.00	377.60	4,790	.307	6.65	2,186	5,777	6,977	343	.0222
52	38.00	290.00	5,403	.234	7.66	3,855	9,500	11,800	460	.0219
53	38.00	290.00	5,276	.257	7.49	2,958	8,739	10,715	446	.0214

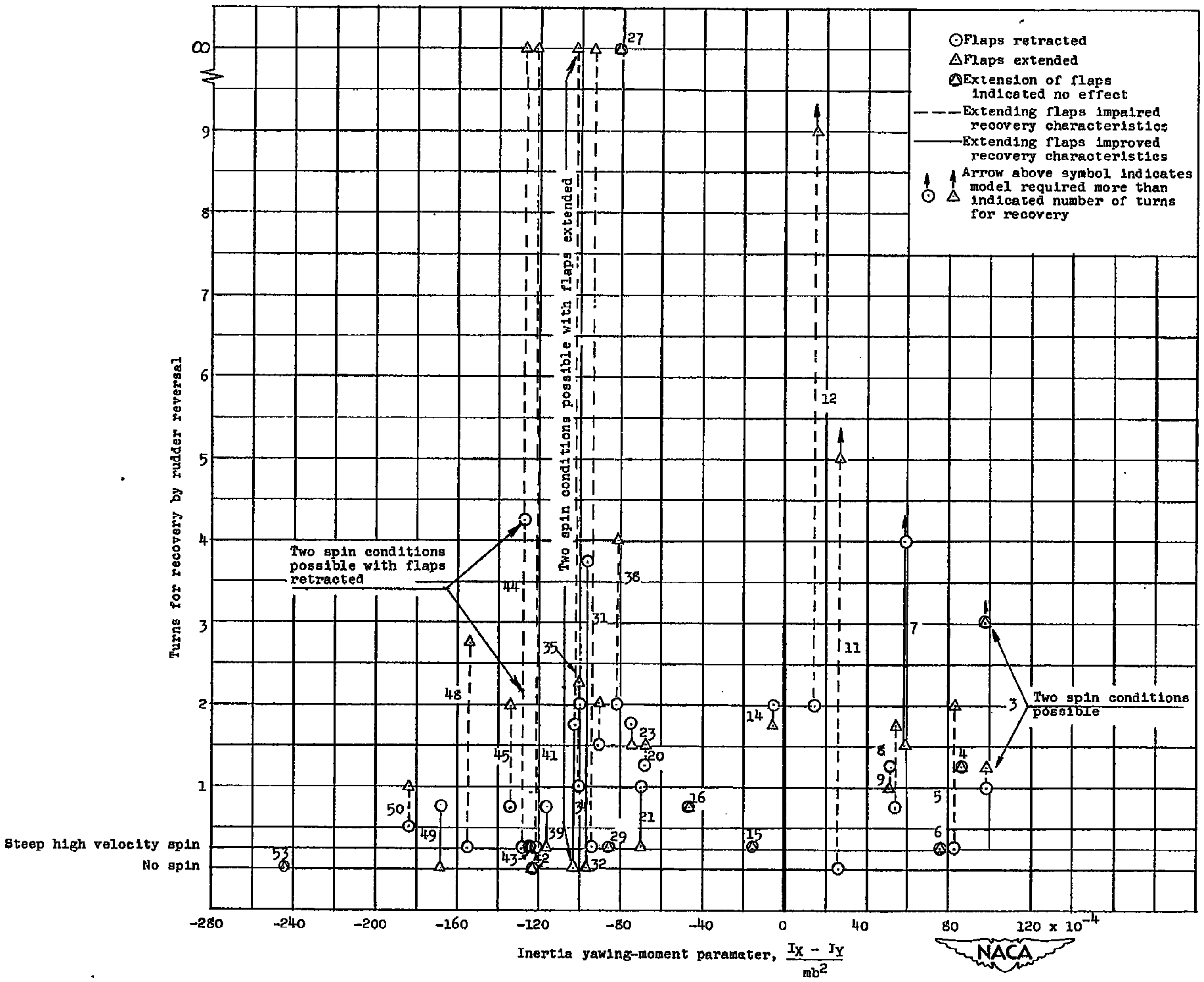

Figure 1.- Effect of landing flaps on the recovery characteristics for spin models with various inertia yawing-moment parameters with ailerons neutral and elevator up. (Numerical values placed near data refer to model numbers listed in table I.)

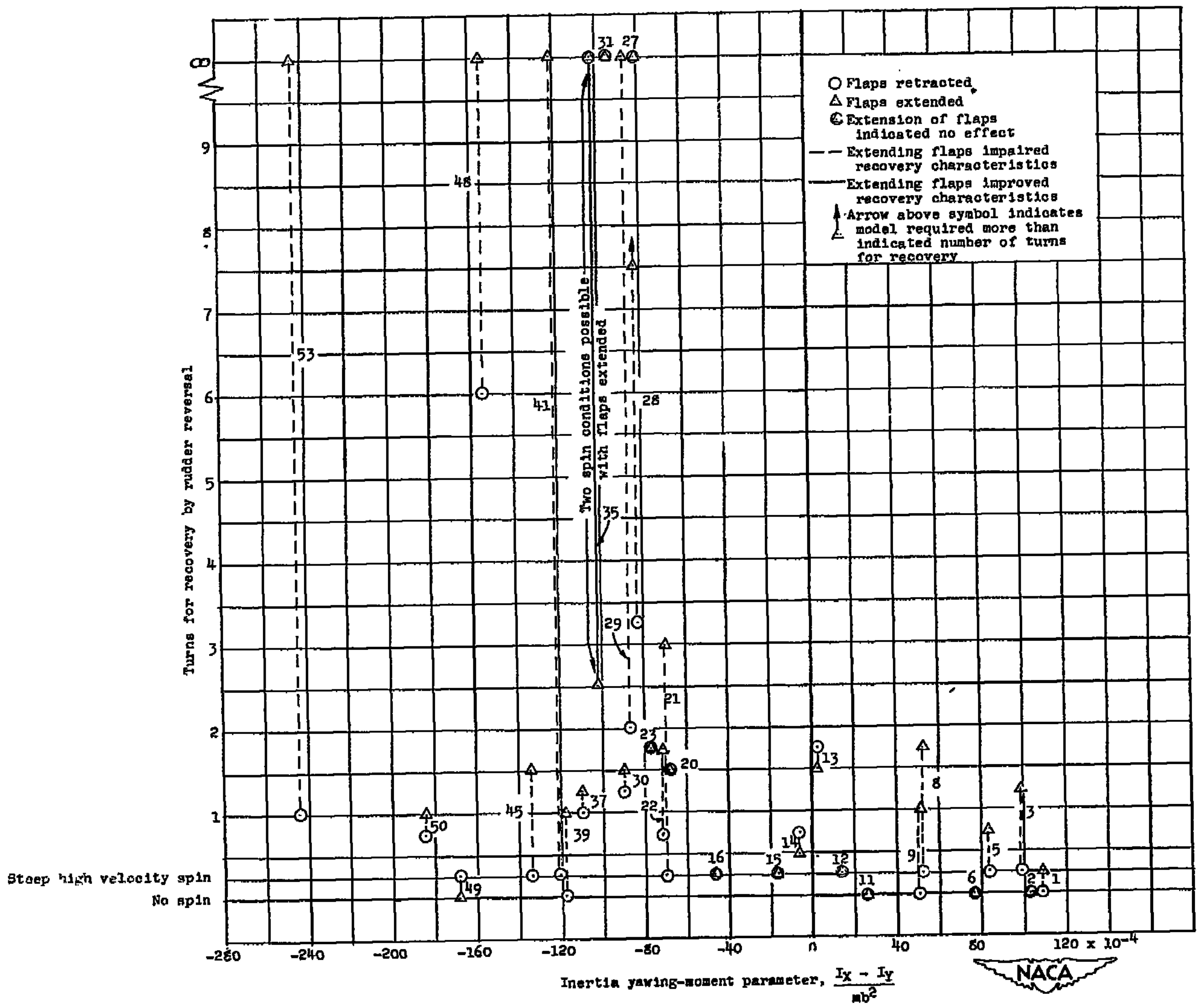

Figure 2.- Effect of landing flaps on the recovery characteristics for spin models with various inertia yawing-moment parameters with ailerons against the spin and elevator up. (Numerical values placed near data refer to model numbers listed in table I.)

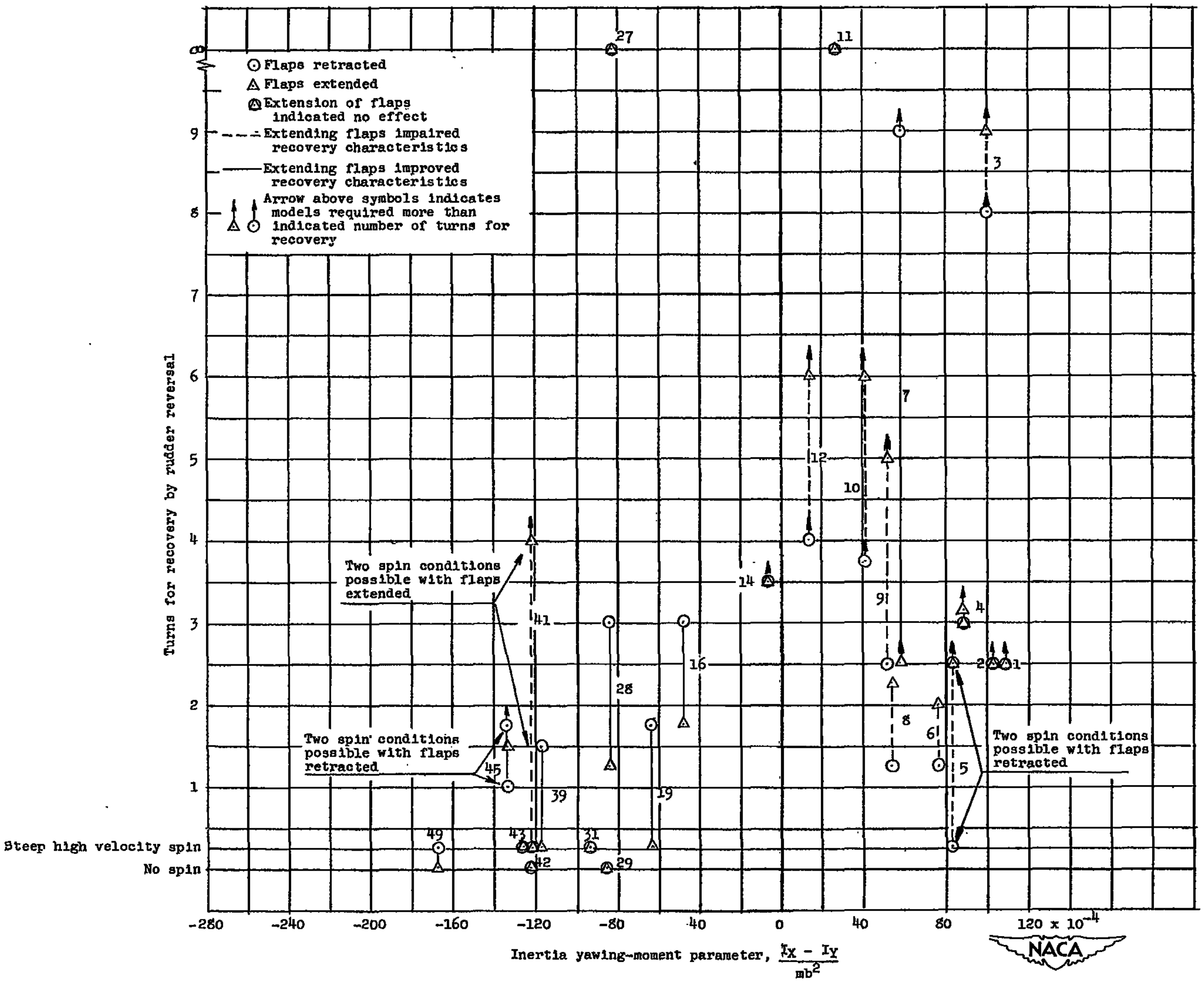

Figure 3.- Effect of landing flaps on the recovery characteristics for spin models with various inertia yawing-moment parameters with ailerons with the spin and elevator up. (Numerical values placed near data refer to model numbers listed in table I.)

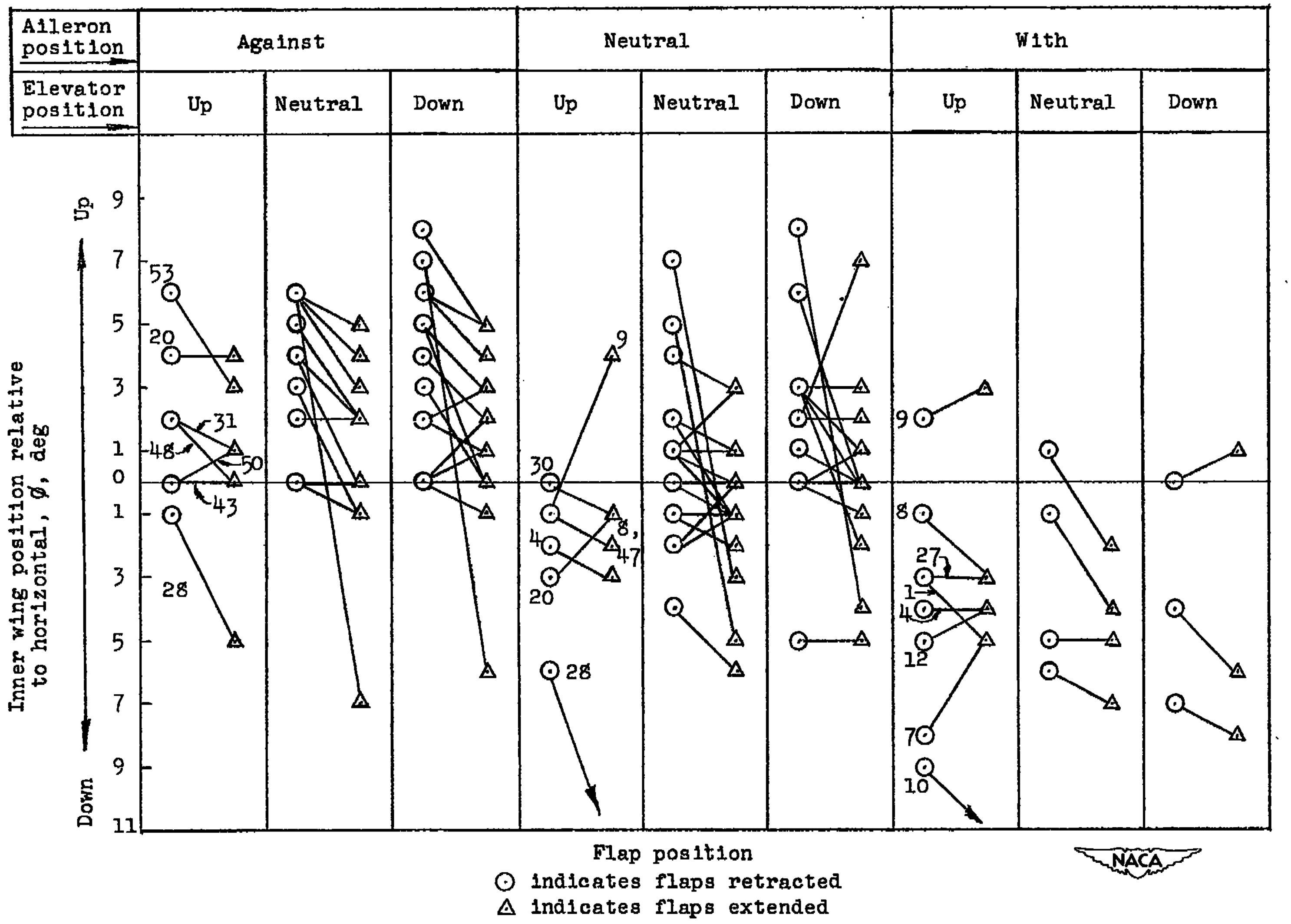

Figure 4.- Effect of flaps on the angle of wing inclination during the spin for various control settings for free-spinning-tunnel models (right erect spins). (Numerical values placed near elevator-up data refer to model numbers listed in table I.)

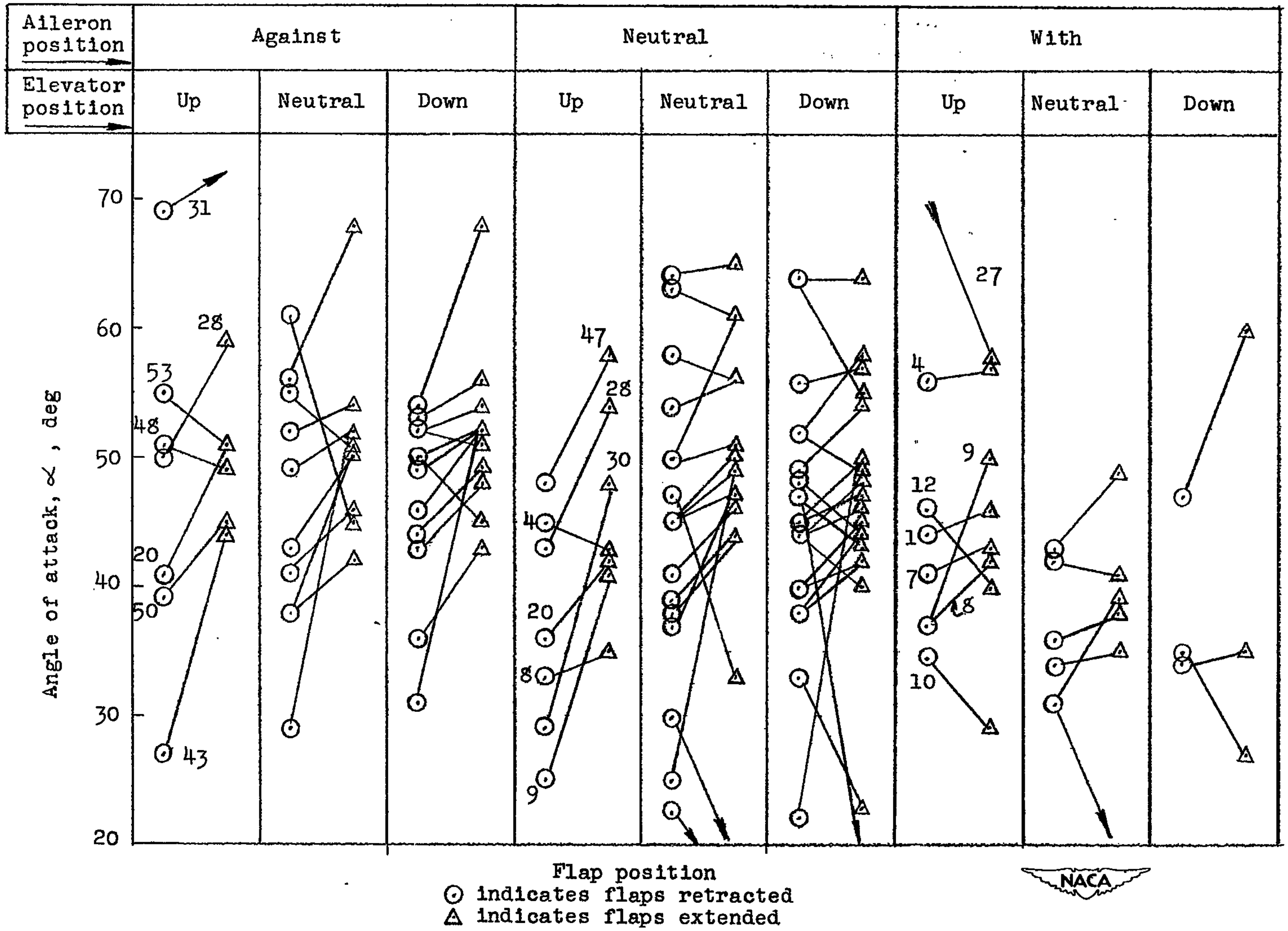

Figure 5.- Effect of flaps on the angle of attack during the spin for various control settings for free-spinning-tunnel models. (Numerical values placed near elevator-up data refer to model numbers listed in table I.)

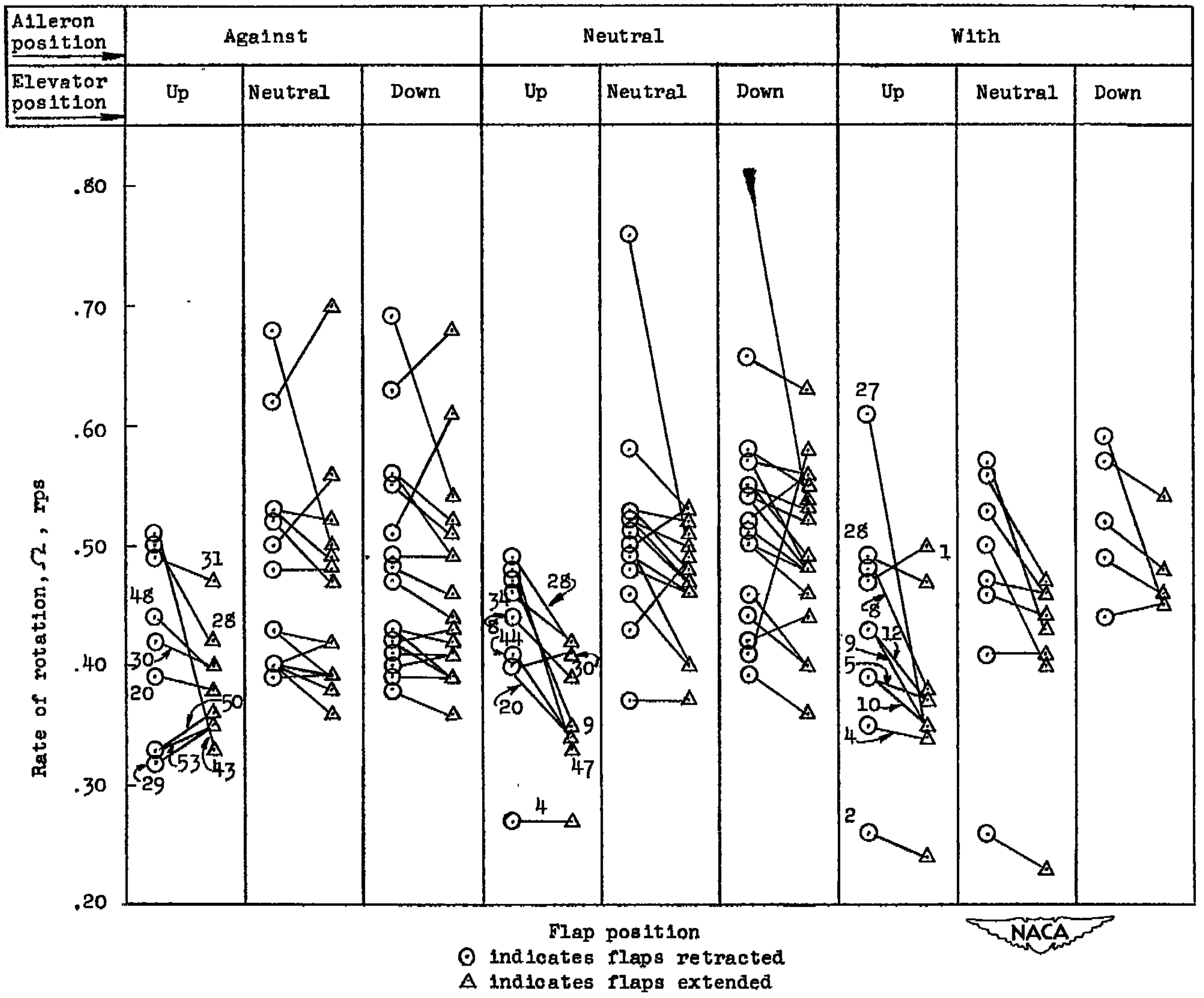

Figure 6.- Effect of landing flaps on the rate of rotation during the spin for various control settings for free-spinning-tunnel models. (Numerical values placed near elevator-up data refer to model numbers listed in table I.)