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THE AILERON AS AN AID TO RECOVERY FROM THE SPIN

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SUMMARY

As part of a general investigation by the NACA of factors that affect the spin, the use of the aileron as an aid to recovery from the spin was studied. Tests of 10 different models, covering a wide range of mass distribution, were made in the NACA free-spinning tunnel to determine the effects of a large downward deflection of the outboard aileron and of normal angular deflections of the ailerons upon recovery characteristics.

The results indicate that the direction of aileron setting, with or against the spin, which will aid recovery from the spin depends upon the airplane weight distribution. For monoplanes and for biplanes with lower-wing ailerons, ailerons with the spin will be favorable when the weight is distributed chiefly along the fuselage (single-engine airplanes) and ailerons against the spin will be favorable when the weight is distributed chiefly along the wings (multiengine airplanes). Downward movement of the outboard aileron through a large angle will not always be effective in aiding recovery, the effectiveness of such a movement also being dependent upon the weight distribution of the airplane.

INTRODUCTION

Numerous special devices to insure recovery from the spin have been developed from time to time. Except for the tail chute, none has been widely adopted.

A method of expediting recovery from the spin that showed particular promise on the basis of past experience consisted in deflecting the outboard aileron (left aileron in a right spin) downward through a large angle to assist the rudder in recovery. At large deflections, the outboard aileron should provide considerable antispin yawing moment to augment the moment obtainable by reversal of the rudder. A study of this method of improving spin recoveries was accordingly undertaken in the NACA free-spinning tunnel. In order to afford a means of comparison and to obtain a clear understanding of the results, a study of the effects of normal angular deflections of the ailerons, with and against the spin, was included in the investigation. Ailerons deflected with the spin means that the ailerons are deflected with right aileron up and left aileron down in a right spin. The results of the investigation are discussed in this paper.

Ten models, representing airplanes of widely different mass distributions, were tested. For one of these models, tests were made with varied mass distribution. Tests were made of recovery by rudder movement alone for the various aileron settings and also, in some cases, by simultaneous movement of both rudder and ailerons. The forces required to deflect the controls were neglected.

APPARATUS AND TESTS

Spin-testing technique in the NACA free-spinning tunnel and the construction of spin models are described in detail in reference 1. The models, constructed of balsa, are ballasted by the installation of proper weights at suitable locations. An automatic clockwork delay-action mechanism is installed to actuate the controls for recovery. The models are launched by hand into the vertical air stream and the air speed is adjusted to keep the model at a fixed height until recovery is attempted.

The models tested were all landplanes and, unless otherwise indicated, represent low-wing monoplanes. The landing gear was retracted except as noted. Table I gives a short description of the airplanes represented by the models and their moments of inertia. In order that the effect of the ailerons might be clearly demonstrated, adjustments were made to the models so that, without the use of the ailerons, slow recoveries would be obtained by use of the rudder. In some cases this result was obtained by suitable adjustment of the elevator angle or loading and in other cases by restricting the rudder travel.

The models were launched with rudder set with the spin and recoveries by rudder movement alone were investigated for each of the 10 models with the ailerons neutral. The effect of a large downward setting (60°, or more) of the outboard aileron and the effect of normal settings of the ailerons (approximately 20° up and 20° down) with or against the spin were then determined. In some cases, the tests were extended to investigate recovery by simultaneous movement of both rudder and ailerons.

Recoveries were evaluated by the number of turns the spinning model made from the time the controls were observed to move until the spinning rotation ceased. Turns for recovery, shown on the figures and in the tables, were counted visually and are believed to be accurate to within a half turn.

Steady-spin characteristics were not studied in the present investigation.

RESULTS AND DISCUSSION

The results of the investigation are tabulated in tables II to XII and are summarized in figures 1 and 2. In the figures, all the results shown for any one model are for conditions in which the ailerons were either preset at the position indicated or were moved to that position simultaneously with the rudder movement.

In the discussion, it has been found convenient to separate the models into two groups according to the relative distribution of weight along the fuselage and the wings. The first group comprises models 1 to 8 for which the weight is distributed chiefly along the fuselage ($I_Y > I_X$, where I_X and I_Y are the moments of inertia about the X and the Y axes, respectively). The results for this group are summarized in figure 1. The second group, the results for which are presented in figure 2, comprises models 9, 10, and 6R, with weight distributed chiefly along the wings ($I_X > I_Y$). The weight distribution of model 9, an unstaggered biplane, fell in the same category as that of model 10, a multiengine design. Model 6R was obtained by reballasting model 6 to simulate the mass distribution of a multiengine design. The tests of this model therefore provided a direct check on the validity of classification of the aileron effect according to the type of mass distribution.

A study of the results for models 1 to 8 indicates that the use of a large downward deflection of the outboard aileron was generally favorable to the spin and the recovery characteristics. Tests with the inboard aileron neutral and the outboard aileron preset in various positions were made with models 1, 2, 3, 5, and 6. These tests showed that, as the downward deflection of the aileron increased, the steady spin tended to steepen until a condition was reached in which the rotation could no longer be maintained. The model then automatically recovered when launched into the tunnel in rotation. The tests were usually stopped when the vertical velocity became too great for the tunnel even though the nonspinning condition had not been attained. With models 4, 7, and 8, the tests were made for only the 60° downward aileron setting. The extent to which the model spins were affected by a given aileron setting varied considerably among the models. For example, the vertical velocity of model 2 became too fast for the tunnel when the outboard aileron was set down 10°; whereas, with model 3, this condition did not obtain even with a 40° setting. Four out of five models of this group tested with a 60° downward aileron setting would not spin for this control configuration.

Models 3 and 5 were not tested with 60° settings of the aileron but, for these models as was the case for model 2, smaller settings were quite effective. The indications are that, in every case, a large downward deflection of the outboard aileron would be sufficient either to prevent the spin or to steepen the spin enough so that recovery by rudder reversal would be rapid. The aileron setting required to insure a rapid recovery would probably be less than 60° for these cases. Drooped ailerons set full with the spin approximate the condition of the outboard aileron alone deflected down through a large angle. These results indicate the advantages of holding drooped ailerons full with the spin where the weight distribution is of the type represented by models 1 to 8.

When the steady spin was made with the ailerons neutral and the outboard aileron moved down simultaneously with the rudder reversal for recovery, the recoveries were not so good as when this aileron was preset. Of the six models tested on which the outboard aileron and the rudder were moved together, satisfactory recoveries were obtained for five cases. For models 1, 2, and 6, a 40° downward deflection of the outboard aileron was sufficient but for models 3 and 4 a 60° deflection was necessary. For model 5, which had a very flat attitude in the spin (approximately 80°), recovery, although showing some improvement, still took on the order of 14 turns even when the outboard aileron was deflected as much as 80° downward.

On model 4, which would not recover by rudder reversal for ailerons neutral, a test was made in which the outboard aileron was moved down after the rudder had been neutralized. This condition corresponded to the situation in which a pilot finds neutralizing of the rudder to be ineffective and follows up his initial manipulation by deflecting the outboard aileron as an added emergency device. The ensuing recovery for the case tested was rapid.

Tests on models 7 and 8 indicated that individual deflection of the outboard aileron down through a large angle was more effective than any other individual deflection of either aileron, up or down. Although the comparison was not complete for the remaining models, it was found that, in general, deflection of the outer aileron down was most effective, but in a few isolated instances other deflections appeared equally effective.

The results for models 9, 10, and 6R, models whose weight was distributed chiefly along the wings, show that presetting the outboard aileron down 60° had very little effect with these models. With model 9, it appeared that an aileron deflection larger than 60° would produce a slight favorable effect. For model 10, the spin with the outboard aileron deflected down 60° was slightly flatter than the spin with this aileron neutral and, for model 6R, there was little effect with this aileron setting.

The effect of normal angular settings of the ailerons was investigated and the results indicated that presetting the ailerons with the spin, tried for five of the first eight models, gave results consistent with those for a large downward deflection of the outboard aileron in that the spins were steeper and the recoveries were more rapid than from the aileron-neutral spins. Presetting the ailerons against the spin had the opposite effect; the spin generally became flatter and the recoveries slower. As with the larger aileron settings, the magnitudes of the effects varied considerably among models. With model 1, for example, the recovery depended critically upon the aileron setting; with model 5, the effects were barely perceptible. When the steady spins were made with the ailerons in neutral and the ailerons moved simultaneously with the rudder, similar effects were obtained; but in no case in which comparable results were available was the improvement as great as that for presetting the ailerons. Only a small effect was observed with model 5, a model that gave a very flat spin. For model 3, a biplane with ailerons on only the upper wing, there was practically no effect of normal aileron deflections.

The results for models 9, 10, and 6R, which were obtained only with preset ailerons, show that the direction of the aileron effect for normal angular settings was reversed from that for models 1 to 8 in that ailerons set against the spin now gave a favorable effect. For models 10 and 6R, normal angular settings of the ailerons against the spin prevented the spin even when both rudder and elevators were set full with the spin. The down-elevator setting also tended to prevent the spin for these two models.

CONCLUDING REMARKS

The data presented indicate that weight distribution of the model is an important factor in determining the direction of aileron effect, that is, whether ailerons deflected with or against the spin are favorable to recovery characteristics. Figure 1, which gives results for models whose weight is distributed chiefly along the fuselage $(I_Y > I_X)$, shows that ailerons with the spin, including the special case of the outboard aileron down through a large angle, are generally favorable to recovery characteristics and that ailerons against the spin give an adverse effect. Only for a biplane model that has ailerons on only the upper wing was the effect of normal angular deflections of the ailerons indefinite. Setting the outboard aileron down through a large angle is generally superior to normal angular settings of the ailerons with the spin for this condition. Rapid recovery from a very flat spin, however, cannot always be secured. When the weight is distributed chiefly along the wings $(I_X > I_Y)$, the direction of the effect of normal angular deflection of the ailerons is reversed and a large downward setting of the outboard aileron becomes relatively ineffective. The scope of the present investigation is not complete enough to indicate definitely at what value of $I_X - I_Y$ the aileron effect reverses.

The results indicate that use of normal angular deflections of the ailerons, in the direction determined by the airplane weight distribution will generally be very effective in aiding recovery from the spin. Special aileron installation, to allow for a large downward deflection of the outboard aileron, is not generally recommended because it does not offer a dependable aid for recovery from spins of all airplanes, such as very flat-spinning single-engine airplanes or multiengine airplanes.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 13, 1940.

REFERENCE

1. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. Rep. No. 557, NACA, 1936.

TABLE I

Moments of Inertia of Airplanes Represented by Models

Model	Type airplane represented[a]	Full-scale moments of inertia (slug-ft^2)		
		I_X	I_Y	I_Z
1	Pursuit (landing gear extended)	1,500	4800	5,950
2	Scout-bomber	3,250	7025	9,575
3	Pursuit (staggered biplane)	1,525	2950	3,825
4	Attack	4,950	9225	12,725
5	Pursuit	2,875	4200	6,375
6	Pursuit (midwing)	1,825	4450	5,900
7	Trainer (staggered biplane)	1,575	3075	4,200
8	Trainer	1,750	4875	6,300
9	Trainer (unstaggered biplane)	3,125	2250	4,825
10	Pursuit (twin-engine, twin-tail)	10,800	9300	19,400
6R	Pursuit (midwing - heavily weighted along wings)	4,825	3450	7,850

[a] Unless otherwise indicated, models represent single-engine, single-tail, low-wing monoplanes with landing gear retracted.

TABLE II

Effect of Ailerons on Recoveries from Spins. Model 1: Right Spins
V, rate of descent; W, with spin; A, against spin; U, up; D, down

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	0	0	$4\frac{3}{4}$
20D	20D	20U	20U	30W	30A	0	0	∞
0	0	10D	10D	30W	30A	0	0	3
0	-	20D	-	30W	-	0	-	[a]Steep; V too great
0	-	40D	-	30W	-	0	-	Would not spin
0	-	60D	-	30W	-	0	-	Would not spin
20U	-	20D	-	30W	-	0	-	[a]Steep; V too great
0	20D	0	0	30W	30A	0	0	7
0	20U	0	0	30W	30A	0	0	$2\frac{3}{4}$
0	0	0	20D	30W	30A	0	0	$2\frac{1}{2}$
0	0	0	40D	30W	30A	0	0	$2\frac{1}{4}$
0	20U	0	20D	30W	30A	0	0	$2\frac{1}{4}$

[a] Indications are that recovery would probably be rapid.

TABLE III

Effect of Ailerons on Recoveries from Spins. Model 2: Right Spins
(V, rate of descent; W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	20D	20D	5½
0	0	20U	20U	30W	30A	20D	20D	∞
0	-	10D	-	30W	-	20D	-	[a]Steep; V too great
0	-	20D	-	30W	-	20D	-	[a]Steep; V too great
0	20D	0	20U	30W	30A	20D	20D	∞
0	20U	0	0	30W	30A	20D	20D	4½
0	0	0	20D	30W	30A	20D	20D	2¼
0	0	0	40D	30W	30A	20D	20D	1¾
0	0	0	60D	30W	30A	20D	20D	1¾
0	20U	0	20D	30W	30A	20D	20D	2½

[a] Indications are that recovery would probably be rapid.

TABLE IV

Effect of Ailerons on Recoveries from Spins
Model 3: (biplane with ailerons on upper wing)
Right Spins

(W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	0	25D	25D	9
10D	10D	0	0	30W	0	25D	25D	Not in 10
20D	20D	0	0	30W	0	25D	25D	∞
40D	40D	0	0	30W	0	25D	25D	∞
0	0	60U	60U	30W	0	25D	25D	4
0	0	10D	10D	30W	0	25D	25D	8
0	0	20D	20D	30W	0	25D	25D	5
0	0	40D	40D	30W	0	25D	25D	3
0	20D	0	0	30W	0	25D	25D	∞
0	0	0	20U	30W	0	25D	25D	Not in 5
0	20D	0	20U	30W	0	25D	25D	8
0	20U	0	0	30W	0	25D	25D	Not in 10
0	0	0	20D	30W	0	25D	25D	$5\frac{1}{4}$
0	0	0	40D	30W	0	25D	25D	$3\frac{3}{4}$
0	0	0	60D	30W	0	25D	25D	$2\frac{3}{4}$
0	0	0	60D	30W	30W	25D	25D	[a]Not in 15
0	20U	0	20D	30W	0	25D	25D	8

[a]Goes into very steep spin when control moves.

TABLE V

Effect of Ailerons on Recoveries from Spins. Model 4: Right Spins
(V, rate of descent; W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	25D	25D	[a]∞
60D	60D	0	0	30W	30A	25D	25D	[a]∞
0	0	60U	60U	30W	30A	25D	25D	[a]∞
20D	20D	20U	20U	30W	30A	25D	25D	[a]∞
0	-	60D	-	30W	-	25D	-	[b]Steep; V too great
20U	20U	20D	20D	30W	30A	25D	25D	[c]1
0	20D	0	20U	30W	30A	25D	25D	[a]∞
0	20U	0	0	30W	30A	25D	25D	[a]$12\frac{1}{2}$
0	0	0	20D	30W	30A	25D	25D	[a]7
0	0	0	40D	30W	30A	25D	25D	[a]$4\frac{1}{2}$
0	0	0	60D	30W	30A	25D	25D	[a]3
0	20U	0	20D	30W	30A	25D	25D	[a]$5\frac{1}{2}$
0	0	0	60D	30W	30W	25D	25D	[d]∞
0	0	0	0	0	30A	25D	25D	∞
0	0	0	60D	0	0	25D	25D	$2\frac{1}{2}$

[a] Flat spin.

[b] Indications are that recovery would probably be rapid.

[c] Steep spin.

[d] Goes into very steep spin when control moves.

TABLE VI

Effect of Ailerons on Recoveries from Spins
Model 5: Right Spins
(V, rate of descent; W, with spin;
A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	0	0	[a]∞
23D	23D	27U	27U	30W	30A	0	0	[a]∞
0	0	20D	20D	30W	30A	0	0	[a]∞
0	-	40D	-	30W	-	0	-	[b]Steep; V too great
27U	27U	23D	23D	30W	30A	0	0	20
0	40D	0	0	30W	30A	0	0	[a]∞
0	0	0	40D	30W	30A	0	0	[a]20
0	0	0	60D	30W	30A	0	0	[a]14
0	0	0	80D	30W	30A	0	0	[a]14
0	0	0	80D	30W	30A	30U	30U	[a]14
0	20U.	0	20D	30W	30A	0	0	[a]∞

[a] Very flat spin.

[b] Indications are that recovery would probably be rapid.

TABLE VII

Effect of Ailerons on Recoveries from Spins
Model 6 (midwing monoplane): Right Spins

(W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	20D	20D	$2\frac{1}{2}$
0	0	0	0	30W	0	20D	20D	$7\frac{1}{2}$
10D	10D	0	0	30W	0	20D	20D	Not in 9
60D	60D	0	0	30W	0	20D	20D	∞
0	0	20U	20U	30W	0	20D	20D	Not in 12
0	0	60U	60U	30W	0	20D	20D	5
0	0	10D	10D	30W	0	20D	20D	2
0	-	60D	-	30W	-	20D	-	Would not spin
0	20D	0	20U	30W	0	20D	20D	∞
0	20U	0	0	30W	0	20D	20D	$3\frac{1}{2}$
0	0	0	20D	30W	0	20D	20D	6
0	0	0	40D	30W	0	20D	20D	$1\frac{1}{2}$
0	0	0	60D	30W	0	20D	20D	1
0	0	0	60D	30W	30W	20D	20D	$1\frac{3}{4}$
0	20U	0	20D	30W	0	20D	20D	$2\frac{1}{4}$

TABLE VIII

Effect of Ailerons on Recoveries from Spins

Model 7 (biplane with ailerons on both wings): Right Spins

(W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	0	0	2
60D	60D	0	0	30W	30A	0	0	∞
0	0	60U	60U	30W	30A	0	0	1¼
11D	11D	13U	13U	30W	30A	0	0	2
18D	18D	28U	28U	30W	30A	0	0	2½
60U	60U	0	0	30W	30A	0	0	1½
0	-	60D	-	30W	-	0	-	Would not spin
13U	13U	11D	11D	30W	30A	0	0	1
28U	28U	18D	18D	30W	30A	0	0	3/4

TABLE IX

Effect of Ailerons on Recoveries from Spins
Model 8: Right Spins

(W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for re-covery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	0	0	$2\frac{3}{4}$
60D	60D	0	0	30W	30A	0	0	∞
0	-	60U	-	30W	-	0	-	Would not spin
15D	15D	30U	30U	30W	30A	0	0	3
60U	60U	0	0	30W	30A	0	0	3
0	-	60D	-	30W	-	0	-	Would not spin
30U	-	15D	-	30W	-	0	-	Would not spin

TABLE X

Effect of Ailerons on Recoveries from Spins

Model 9 (biplane with ailerons on both wings): Right Spins
(W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	20U	20U	∞
15D	15D	0	0	30W	30A	20U	20U	∞
30D	30D	0	0	30W	30A	20U	20U	∞
60D	60D	0	0	30W	30A	20U	20U	∞
0	0	15U	15U	30W	30A	20U	20U	$4\frac{1}{4}$
0	0	40U	40U	30W	30A	20U	20U	$4\frac{1}{4}$
15D	15D	15U	15U	30W	30A	20U	20U	$4\frac{1}{4}$
15U	15U	0	0	30W	30A	20U	20U	∞
0	0	15D	15D	30W	30A	20U	20U	∞
0	0	60D	60D	30W	30A	20U	20U	∞
0	0	70D	70D	30W	30A	20U	20U	$7\frac{1}{2}$
15U	15U	15D	15D	30W	30A	20U	20U	∞
0	0	60D	60D	30W	30A	20U	20U	[a]∞, [b]5

[a] Upper ailerons only used.

[b] Lower ailerons only used.

TABLE XI

Effect of Ailerons on Recoveries from Spins
Model 10: Right Spins

(W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	-	0	-	30W	-	30U	-	[a]Too steep and oscillatory
15D	-	22U	-	30W	-	30U	-	Would not spin
0	0	60D	60D	30W	30A	30U	30U	3/4
22U	22U	15D	15D	30W	30A	30U	30U	$1\frac{1}{2}$
22U	22U	0	0	30W	30A	30U	30U	3/4
22U	22U	0	0	40W	20A	30U	30U	$1\frac{1}{2}$
22U	22U	90D	90D	40W	20A	30U	30U	$1\frac{1}{2}$
22U	-	0	-	40W	-	20D	-	Would not spin
22U	22U	60D	60D	40W	20A	20D	20D	$1\frac{1}{4}$
22U	-	90D	-	40W	-	20D	-	Would not spin

[a] Indications are that recovery would probably be rapid.

TABLE XII

Effect of Ailerons on Recoveries from Spins Model 6R (midwing monoplane): Right Spins

(W, with spin; A, against spin; U, up; D, down)

Control setting (deg)								Turns for recovery
Ailerons				Rudder		Elevator		
Right		Left						
Initial	Final	Initial	Final	Initial	Final	Initial	Final	
0	0	0	0	30W	30A	30U	30U	$1\frac{3}{4}$
60D	60D	0	0	30W	30A	30U	30U	$2\frac{1}{2}$
20D	-	20U	-	30W	-	30U	-	Would not spin
0	0	60D	60D	30W	30A	30U	30U	$1\frac{1}{2}$
20U	20U	20D	20D	30W	30A	30U	30U	∞
0	-	0	-	30W	-	20D	-	Would not spin
20D	-	20U	-	30W	-	20D	-	Would not spin
0	-	60D	-	30W	-	20D	-	Would not spin
20U	20U	20D	20D	30W	0	20D	20D	∞

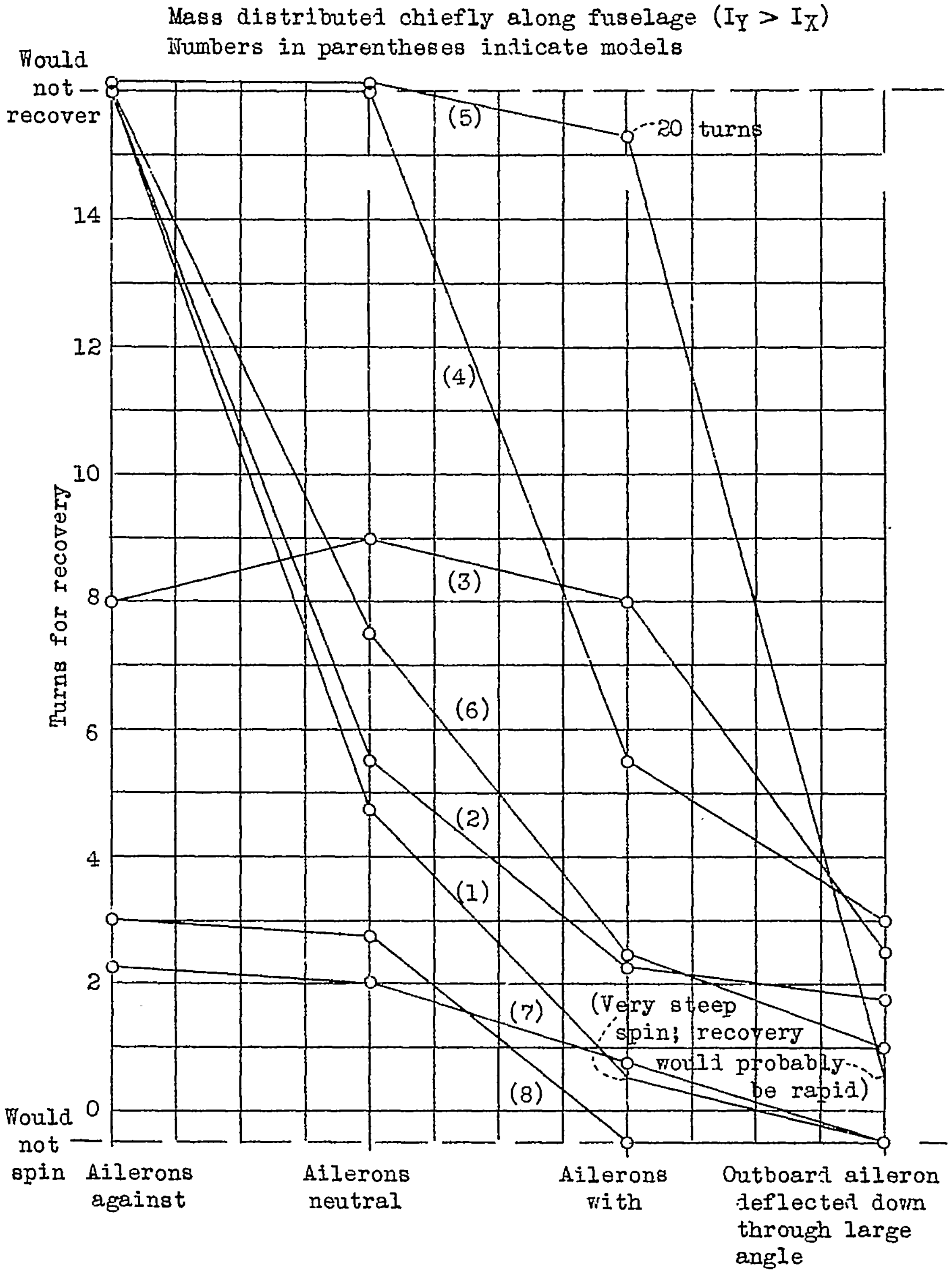

Figure 1.- Relative effectiveness of ailerons in aiding the rudder for recovery from the spin.

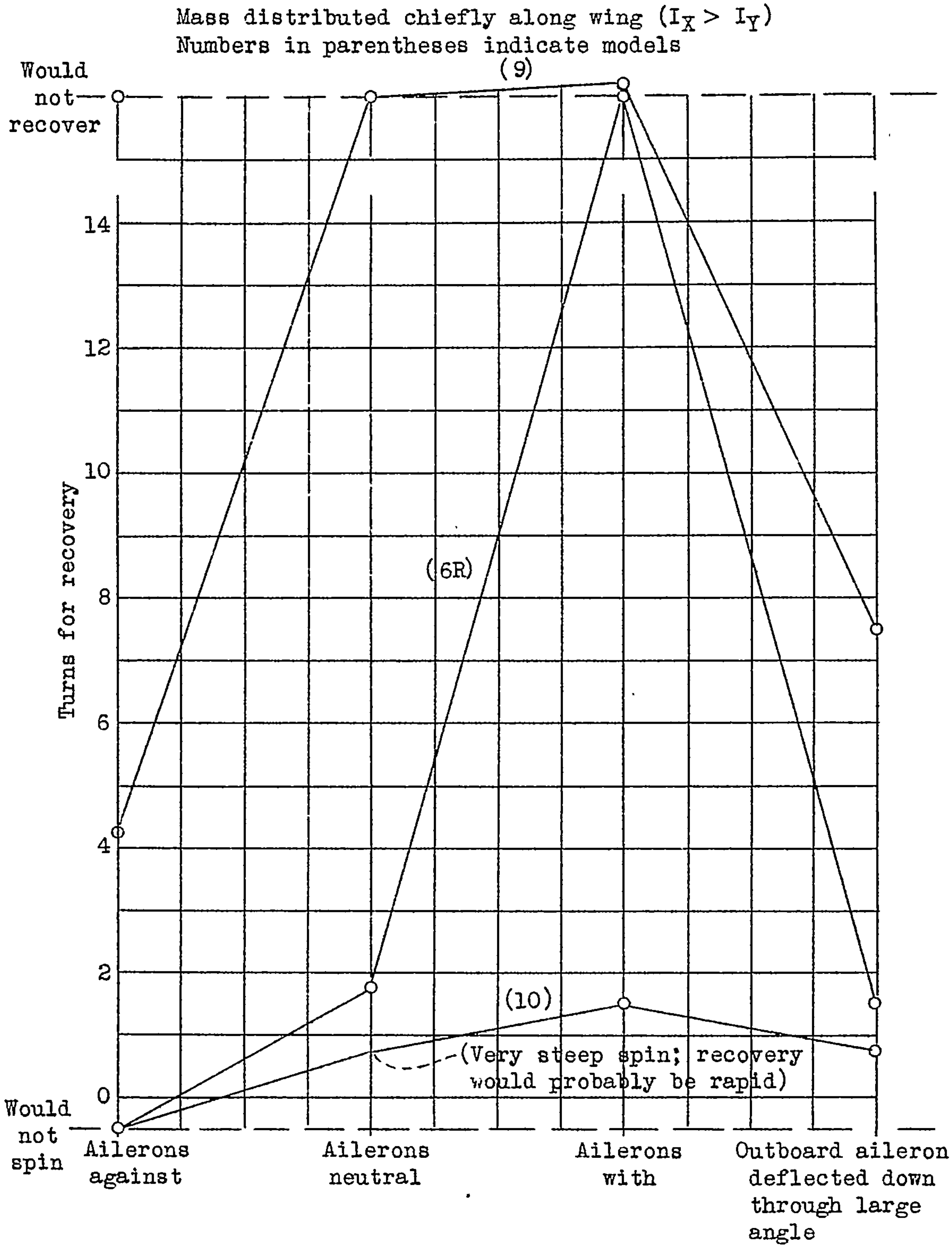

Figure 2.- Relative effectiveness of ailerons in aiding the rudder for recovery from the spin.