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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM 1222

INVESTIGATION OF THE MODEL ME 210 IN THE SPIN WIND TUNNEL OF THE DVL

FOURTH PARTIAL REPORT - MODEL WITH LONG FUSELAGE AND WITH A VEE TAIL

By A. Huffschmid

Translation of ZWB Untersuchungen und
Mitteilungen Nr. 1288, June 1944

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ABSTRACT:

After conclusion of the spin investigation of the model Me 210 with elongated fuselage and central vertical tail surfaces (model condition III; reference 3), tests were performed on the same model with a vee tail (model condition IV). Here the entire tail surfaces consist of only one surface with pronounced dihedral. Since the blanketing of the vertical tail surfaces by the horizontal tail surfaces, which may occur in case of standard tail surfaces, does not occur here, one could expect for this type of tail surface favorable spin characteristics, particularly with

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*"Untersuchung des Me 210-Modells im Trudelwindkanal der DVL. 4. Teilbericht. Modell mit langem Rumpf und mit V-Leitwerk." Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB), Berlin-Adlershof, Untersuchungen und Mitteilungen Nr. 1288, June 15, 1944.

**NACA reviewer's note: Data obtained at the Langley Aeronautical Laboratory indicate that loading may influence the effectiveness of a vee tail in spin recovery. Inasmuch as the results presented herein were obtained with a single model at only one loading, they should not be interpreted as indicating the effects of a vee tail for all designs.

respect to rudder effectiveness for spin recovery. However, the test results did not confirm these expectations. The steady spin was shown to be very irregular; regarding rudder effectiveness the vee tail surfaces proved to be inferior even to standard tail surfaces; thus they represent the most unfavorable of the four fuselage and tail-surface combinations investigated so far.

OUTLINE:

I. PURPOSE OF THE TESTS

In the systematic spin investigation on a model Me 210 the effect of a variation in the form of fuselage and tail surfaces on the spin behavior is determined. The following model variations have already been investigated:

Short fuselage and central vertical tail surfaces:
model condition I

Short fuselage and twin vertical tail surfaces:
model condition II

Long fuselage and central vertical tail surfaces:
model condition III

The results of these three test series have already been published (references 1, 2, and 3). As a fourth variation, a model with elongated fuselage and with so-called vee tail surfaces (model condition IV) was investigated in the present test series. In this arrangement of the tail surfaces, horizontal and vertical tail surfaces were replaced by a surface of 35° dihedral (see fig. 3.) Besides other advantages, as for instance reduction of the high-speed drag, good rudder effectiveness for spin recovery was to be expected for this arrangement of the tail surfaces, since no reduction of the rudder effectiveness due to blanketing of the air flow by the horizontal tail surfaces could occur as it had been observed to occur for the central vertical tail surfaces.

II. DESCRIPTION OF THE MODEL

As in the former test series, a geometrically and dynamically similar model of the scale $\lambda = 1:16$ served as test carrier (see figs. 1 and 2); it is the same model on which the measurements of the previous test series had been performed. Details of the model are described in UM 1176; here only a few remarks concerning the vee tail surfaces will be added.

The tail surfaces consist in this case of only one surface of 35° dihedral. Due to this dihedral, moments about the transverse or vertical axis of the airplane may be produced by corresponding or opposite deflection of the two control surfaces. The angular range of each control surface is $\pm 50^{\circ}$. Therein the elevator deflection η upward is 30°, downward 20° (for standard tail surfaces $\pm 27^{\circ}$); the rudder deflection produced by superposition amounts to 20° on the up-going rudder, 30° on the down-going rudder, so that a maximum rudder deflection of $\zeta = \pm 25^{\circ}$ results (for standard tail surfaces $\zeta = \pm 35^{\circ}$).

The coupling of the elevator and rudder deflections in the control-surface deflections for vee tail surfaces is not easily defined (see fig. 3). Thus the control-surface deflections for vee tail surfaces for the investigated control measures are divided into the rudder and elevator deflections for a customary type of tail surfaces in table 1 (see also section IV). For better visualization, in the discussion of the test results, the corresponding rudder or elevator deflections for standard tail surfaces are always given instead of the total control-surface deflections for vee tail surfaces, in order to make a comparison with the former model conditions possible. The following symbols signify for vee tail surfaces: St B, starboard; BB, port side; $\eta > 0$, surface depressed. For standard tail surfaces the customary definitions are valid again: $\eta > 0$ signifies stick pushed forward; $\zeta > 0$ signifies rudder deflected toward the right (trailing edge of the rudder pointing toward port side is thus spin-promoting in left spins).

Due to the particular shape of the vee tail surfaces there result for a considerably smaller actual total surface of the tail surfaces, projections into the plane of horizontal and vertical tail surfaces which are larger than the corresponding surfaces for central vertical tail surfaces. Table 2 gives for comparison the magnitudes of the tail-surface areas and their lever arms (referred to a position of the center of gravity of $0.20l_{aer}$) for the four different model conditions; all quantities refer to full-scale airplanes.

The moments of inertia were equal to those of model condition III, except for slight deviations; they were:

$$I_x = 4785 \text{ kgms}^2; \; I_y = 3120 \text{ kgms}^2; \; I_z = 7540 \text{ kgms}^2$$

The simulated flying weight was again 7540 kilograms. The position of the center of gravity was varied in a range of 14-percent to 28-percent of the mean aerodynamic chord. In the tests with extended slats the slat configuration corresponded to the previous design (UM 1176, p. 4).

III. SYMBOLS AND DEFINITIONS

The symbols and definitions are identical with those of the previous partial reports (reference 3, p. 5.) All model values are again converted to full-scale values.

IV. TEST RESULTS

A. Steady Spin

The steady spin condition of the model with vee tail surfaces differed considerably from that of the former tail-surface combinations. Whereas for the latter the spin was very steady, the spin of the model with vee tail surfaces showed striking oscillations; the variation of the characteristics with the time shows large periodical fluctuations particularly of the pitch angle ϑ and the speed of rotation Ω; the period of oscillation of these superimposed disturbances is about

5 seconds (in the model test 1.25 sec.). As an example, the variation with time of the most important spin characteristics is represented in figure 4; the variation of the spin characteristics for the model with central vertical tail surfaces and long fuselage for the same test conditions is plotted for comparison in a dashed line. A corresponding variation of the rate of drop took place with the continuous rapid variation of the angle of attack; thereby the test performance was made more difficult inasmuch as the jet velocity of the tunnel could not be adapted sufficiently fast to the respective resultant rate of drop of the model, so that the model occasionally performed violent movements in the direction of the jet axis. On the other hand the model showed no tendency to move from the jet center.

The mean values of the spin characteristics (from several tests) are compiled for different positions of elevator and center of gravity and with slats extended and retracted in table 3. For ϑ, $\dot{\varphi}$, and α the limits of the fluctuations are indicated. The rudder was in all cases adjusted to a fully spin-promoting position ($\zeta = -25^\circ$). All values apply to a flight altitude of 4 kilometers.

Aside from the irregularity already mentioned the steady spin is slightly different from that of model condition III in other respects as well; the pitch is, on the average, 5° larger and the speed of rotation slightly higher than for the model with standard tail surfaces. For the rest, however, the mean values of the characteristics remain within the limits of the test series performed so far.

For extended slats the spin was very steady; the mean values of the spin characteristics show the same tendency found in the test series so far according to which the spin flattens and speed of rotation and rate of drop decrease somewhat when the slats are extended. As for the former model conditions the angle of sideslip and the spin radius were very small for all tests (with slats retracted and extended.)

B. Effect of Control Measures for Spin Recovery

In order to clarify the important problem of control surface effectiveness for vee tail surfaces, a number of control measures were taken and the unsteady course of motion after starting of the control measure observed. The program of the measurements corresponded, on principle, to that of the previous test series. It had been extended only inasmuch as smaller control deflections against the spin, too, were investigated because it had been found for model condition III that smaller rudder deflections are less effective. For the same reason, one of the two control surfaces or both of them simultaneously were only moved to neutral position. Table 4 shows a compilation of the tests performed for the different positions of the center of gravity (slats retracted and extended) marked by a cross (+). All results given here refer to a flight altitude of 4 kilometers; a few tests corresponding to a flight altitude of 1 kilometer were performed at random; results similar to those for 4 kilometers altitude were obtained. The simulation of an altitude of 10 kilometers was not possible due to the limited air speed of the spin wind tunnel since the model for this air density again showed an obvious tendency towards a steep spin; however, in view of the high surface loading of the model and the small air density required for such high flight altitudes, a steep spin condition cannot be maintained for any length of time. Because of the tendency toward a steep spin it may, however, safely be assumed that the spin behavior at high flight altitudes is similar to that at 4 kilometers altitude.

As in the previous partial report, the test results are represented chiefly on the basis of the variation with time of the pitch angle ϑ which is the primary characteristic for determining the effectiveness of a control measure. Attainment of a pitch angle of $\vartheta = -70^\circ$ is again required as criterion for spin recovery. The effects of the various control measures are compared below with one another and with the corresponding results for the model with standard tail surfaces and long fuselage.

1. Model with slats retracted.

a. Effect of a rudder actuation.

For stick held back, a full rapid rudder deflection against the spin [1] does not result in recovery for any of the investigated positions of the center of gravity (see fig. 6); the disturbance oscillation of ϑ and so forth mentioned before, already present in steady spin, continues after introduction of the rudder measure, with the oscillations continuing with the same amplitude and frequency about an only very slowly increasing mean value. For a position of the center of gravity at 20 percent the variation with time of all spin characteristics is represented in figure 5. Recovery cannot yet be established after 16 seconds, that is, 8 spin turns or 1200-meter loss of altitude; for a position of the center of gravity at 28 percent conditions are similar, whereas a somewhat more favorable behavior may be assumed for the foremost position of the center of gravity. True to expectation, results are still more unfavorable for smaller rudder deflections against the spin

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[1] This rudder measure corresponds approximately to the standard control measure suggested by Höhler (DVL) which is: a. full rapid rudder deflection against the spin; b. no pushing forward of the stick but yielding if it tends forward by itself; c. aileron in mean position.

(fig. 7). Comparing this result with that of a rudder deflection against the spin for central vertical tail surfaces one finds a pronounced deterioration of recovery characteristics for tail surfaces. It has to be noted that the rudder deflection against the spin amounts, for the vee tail surfaces, on the average to only 25° in contrast to 35° for standard tail surfaces; however, for the latter one could observe, for a position of the center of gravity at 20 percent even in case of a rudder deflection against the spin reduced to 25°, perfect spin recovery after 10 seconds (see UM 1176, fig. 6). It could also be assumed that in the continuous alternation of flat and steep spin the rudder reversal happened to take place always during flat spin and that this was the reason for the delay in recovery. Figure 6 shows, however, that the rudder was actuated in all three cases at a pitch angle of $\vartheta \approx - 50^\circ$ (that is, in steep spin). Thus it may be concluded that the effectiveness of a rudder deflection is not as good for vee as for standard tail surfaces. This falure is the more striking as the oscillatory nature of the steady spin phenomenon permits one to infer a very slight stability of the latter so that even very small tail-surface moments ought to be sufficient to disturb it.

With the stick held in neutral position or pushed forward, recovery takes place after 5.4 seconds or 3 seconds, respectively (see fig. 8). These two positions of the stick are, therefore, considerably more favorable for spin recovery than the position of stick held back. The same tendency had been established in the previous test series. However, since the elevator, due to the free-stream conditions in spin, always will float up, actuation of the rudder will probably always represent the most important control measure in case of stick held back.

Since in the former test series extension of the dive brakes had proved ineffective, they were not actuated in this test series.

b. Effect of an elevator actuation.

Pushing the stick forward from $\eta = - 30^\circ$ to $+ 20^\circ$ proved completely ineffective for the present tail-surface arrangement (fig. 9); the model could be observed spinning for an arbitrary length of time after the rudder had been actuated; recovery did not take place even after a longer lapse of time. Likewise, of course, moving the elevator to neutral position proved ineffective. This result is noteworthy inasmuch as for all types of tail surfaces investigated so far pushing forward of the stick had, under all circumstances, brought about a very rapid spin recovery. Even though the practical value of this control measure for standard tail surfaces is questionable, due to the large control forces, this observation shows very clearly the deterioration of the control effectiveness for vee tail surfaces.

c. Effect of simultaneous actuation of rudder and elevator.

If both control surfaces are fully deflected against the spin (control measure 10), spin recovery occurs very rapidly for all positions of the center of gravity (fig. 10). After not more than 0.8 second to 1.5 seconds subcritical angles of attack are attained; in the end the model overshoots the vertical ($\vartheta_{max} = -110^{\circ}$). The loss in altitude due to spin recovery amounts for this control measure only to barely 100 meters; the airplane performs, approximately, another spin half-turn. In order to examine the practical feasibility of this combined control measure, a rough calculation of the control forces was performed. A few rough assumptions had to be made (for instance concerning the c_w-values of the control surfaces); however, a comparison of calculations using the same assumptions for the Ar 96 with existing control-force measurements in spin by Höhler shows that the calculation gives the control forces with relatively high accuracy (in the case of the Ar 96, for instance, approx. 10 percent). The calculation always used the normal component of the resulting velocity vector on the control-surface area of the tail surfaces. For a steady spin condition with the following mean values of the spin characteristics

$$\vartheta_m \approx 48^{\circ}; \; \alpha_{Hl_m} \approx \alpha = 42^{\circ}; \; ws_m = 72 m/s; \; \Omega = 3.3/s; \; \varphi \approx 0^{\circ}$$

and for a control surface deflection of $\eta_{BB} = 50^{\circ}$, $\eta_{StB} = 0^{\circ}$, that is, $\eta = 30^{\circ}$, $\zeta = 25^{\circ}$ resulted in a control-surface moment of about 78 kilogram meters; if a transmission ratio in the control linkage of 1.5 and a length of the control stick of 0.5 meter are assumed, the control force is calculated to be about 230 kilograms! Performance of this control measure in practice seems impossible, even if the fact is taken into consideration that for vee tail surfaces the pilot's hand and foot pressure add up in the control operation.

If both control surfaces are moved only into neutral position (control measure 9), recovery does not take place, regardless of the position of the center of gravity (fig. 10); thus these results agree with those for standard tail surfaces.

Release of both control surfaces is absolutely ineffective; the model continues spinning without change for an arbitrary length of time.

2. Model with slats extended.

In the tests with extended slats a pronounced steadying of the spin was noticeable. The mean values of the decisive spin parameters did not show any particular variation due to the extension of the slats; however, the superimposed disturbance oscillation of ϑ, Ω, and so forth mentioned above had disappeared except for a slight normal amount which was observed for all model configurations in the current test program. With respect to control-surface effectiveness the same conditions prevailed as in the tests with slats retracted. A rudder deflection against the spin was absolutely ineffective for spin recovery whereas simultaneous elevator and rudder actuation very rapidly brought about recovery. Since the rudder deflection against the spin had been ineffective already for the model with slats retracted, the unfavorable influence of the slats noticed in the previous tests does not appear for this model condition. Figure 11 shows the variation with time of ϑ after starting of the control measures 1 and 10 for extended slats for positions of the center of gravity at 20 percent and 28 percent. Figure 12 shows for the variation with time of ϑ with slats extended and retracted the position of the center of gravity at 20 percent.

V. EVALUATION OF THE MODEL ME 210 WITH LONG FUSELAGE AND WITH VEE TAIL SURFACES

If the model test results are presupposed to be transferable to the flight test, the following statements may be made concerning the spin characteristics of the Me 210 with vee tail surfaces:

For retracted slats the steady spin is characterized by a striking oscillation; the pitch angle ϑ and the speed of rotation Ω show large periodical fluctuations so that the spin condition continuously alternates between flat and steep spin ($\vartheta = -33^{\circ}$ to -63°); the mean condition may be called moderately steep ($\vartheta = -50^{\circ}$). With respect to recovery, a relatively small control effectiveness of the vee tail surfaces became evident. Control deflections corresponding to a rudder deflection against spin for stick pulled back for standard tail surfaces proved to be completely ineffective for all positions of the center of gravity; for stick held in neutral position or pushed forward recovery takes place after 5.3 seconds and 3 seconds, respectively. Pushing forward of the stick also was completely ineffective with vee tail surfaces, in contrast to all previous types of tail surfaces. Only by reversing of both control surfaces (rudder against the spin and simultaneous pushing forward of the stick) did spin recovery occur rapidly for all positions of the center of gravity. Because of the very large control forces, however, this measure probably has no practical significance. Movement of both control surfaces merely to neutral position did not cause spin recovery in any case.

For extended slats a considerable steadying and stabilization of the spin phenomenon occurs. However, the spin does not become noticeably flatter by the extension of the slats. With respect to spin recovery a rudder deflection against the spin alone proves ineffective whereas it brings about a very rapid spin recovery if in connection with simultaneous pushing forward of the stick.

By installation of vee tail surfaces the spin characteristics of the model Me 210, therefore, deteriorated in comparison with the design with standard tail surfaces. This result is in agreement with the sole spin investigation of vee tail surfaces known in foreign literature where the vee tail surfaces also proved inferior to central vertical tail surfaces, the effectiveness of which was reduced by interference (reference 4). In these English tests two vee tail surfaces with 24° and 45° dihedral were investigated. In the case of the tail surfaces with 24° dihedral, the projection of the tail-surface areas into the plane of the vertical tail surfaces corresponded to the magnitude of the central vertical tail surfaces referred to for comparison, whereas it was 130 percent larger for the model with 45° dihedral. Only for these last tail surfaces, with the pronounced dihedral, did spin recovery occur more rapidly than for the model with standard tail surfaces. However, for the vee tail surfaces of the Me 210 the enlargement of the vertical-tail-surface area compared to that of the central vertical tail surfaces amounts to only about 20 percent; thus according to the English tests, too, an improvement of the spin behavior cannot be expected.

No definite explanation can be given for the failure of the vee tail surfaces which a priori (because of the absence of interference) would be expected to lead to favorable spin behavior. The reason probably lies in the additional yawing and rolling moments due to side slip caused by the pronounced dihedral of the tail surfaces; however, their effect cannot be determined in detail. Due to the great number of parameters and especially due to the lack of aerodynamic data (in spin one has mostly to deal with separated flow) these influences cannot be calculated.

VI. SUMMARY AND COMPARISON WITH THE MODEL CONDITIONS INVESTIGATED SO FAR

(See also reference 3, p. 14.)

A model with elongated fuselage and with vee tail surfaces was investigated as the fourth fuselage and tail-surface combination in the systematic investigation of the model Me 210 (model condition IV). Following, the results are briefly summarized and, with respect to the most essential points, compared with those of the previous test series (see fig. 13). All data are valid for 4 kilometers flight altitude and always are full-scale values.

1. The spin was for the model conditions I to III moderately steep and characterized by steadiness. The angle of attack was, with slight deviations, 40° to 45°; the speed of rotation was 0.5 turns per second; the rate of drop was 70 to 80 meters per second. It is true that about the same mean values appeared for model condition IV; however, a strong disturbance oscillation was superimposed on the main motion so that the angle of attack was subjected to fluctuations of ±15° and that speed of rotation and rate of drop varied accordingly.

For model condition I the spin at high flight altitudes became very flat ($\alpha \approx 65^\circ$); for the model conditions II to IV a spin similarly steep as at 4 kilometers altitude is to be expected.

Extending of the slats increased the angle of attack by about 6° to 10° for model conditions I to III, but did not have any further significant influence. For model condition IV the spin with extended slats became very steady and uniform; a variation of the mean values of the spin characteristics did not occur.

2. The investigated four models showed very different behavior with respect to control-surface effectiveness. For the model with slats retracted, for the model conditions I and III, a rudder deflection against the spin with stick held back resulted in recovery after about 500 meters loss of altitude whereas for model condition II recovery occurred with about half this loss of altitude. For the model with vee tail surfaces the same recovery measure does not cause spin recovery at all. Independently of the form of the tail surfaces spin recovery takes place faster for stick in neutral position or pushed forward than for stick held back.

Pushing forward of the stick with rudder fixed in pro-spin position always led to very rapid recovery for model conditions I to III, but failed completely for the vee tail surfaces (IV).

By simultaneous actuation of rudder and elevator, spin recovery occurs for all four model conditions investigated after less than one half turn.

If one of the two control surfaces or both simultaneously are moved merely to neutral position, recovery does not take place in any case.

3. For extended slats all control measures failed for model condition I. For model condition II a rudder deflection against spin caused spin recovery after 6 seconds, for model condition III only after about 15 seconds; for model condition IV, however, this control measure failed completely. Rudder deflection against the spin with simultaneous

pushing forward of the stick led to spin recovery in about the same time – approximately 2 seconds – for the model conditions II to IV. Due to the large control forces required for this control measure, however, it would probably have no practical value.

With respect to control–surface effectiveness for spin recovery, the following sequence may be set up for the investigated fuselage and tail–surface combinations:

1. Model with short fuselage and twin vertical tail surfaces (most favorable case)
2. Model with long fuselage and central vertical tail surfaces
3. Model with short fuselage and central vertical tail surfaces
4. Model with long fuselage and vee tail surfaces (most unfavorable case)

Thus the expectations of improving the spin characteristics by use of vee tail surfaces were not fulfilled in any way. The reason for the failure of the dihedral tail surfaces probably lies in the yawing and rolling moments due to side slip which appear in spin.

For further fuselage and tail–surface combinations the following model conditions are being prepared in the systematic spin investigation of the model Me 210:

Long fuselage and central vertical tail surfaces with horizontal tail surfaces moved to a high position: model condition V

Long fuselage and central vertical tail surfaces, with horizontal tail surfaces moved toward the front: model condition VI

These tail units for which the arrangement of the tail–surface areas was chosen particularly with respect to minimum interference in spin, and also the use of twin vertical tail surfaces in combination with the long fuselage seem to promise good spin characteristics.

Translated by Mary L. Mahler
National Advisory Committee
for Aeronautics

VII. REFERENCES

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2. Untersuchung des Me 210-Modells im Trudelwindkanal der DVL.
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   Industriebericht J 800/4.2.

3. Untersuchung des Me 210-Modells im Trudelwindkanal der DVL.
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4. The Vee-Tail in Spin. Aircraft Engeneering 1936, p. 302. (Stephens).

TABLE I

Control Measure No.		1	2	3	4	5	6	7	8	9	10	11	12
Vee tail surfaces	$\eta_{St\ B}$ (deg)	0 to −50	0 to −50	0 to −40	0 to −30	30 to −20	50 to 0	0 to 50	0 to 30	0 to 0	0 to 0	0 to 20	0 to Release
	η_{BB} (deg)	−50 to 0	−50 to −10	−50 to −20	−50 to −30	−20 to 30	0 to 50	−50 to 0	−50 to −20	−50 to 0	−50 to 50	−50 to 20	−50 to Release
Standard tail surfaces	η (deg)	−30				0	20	−30 to 20	−30 to 0	−30 to 0	−30 to 20	−30 to 20	−30 to Release
	ζ (deg)	−25 to 25	−25 to 20	−25 to 10	−25 to 0	−25 to 25		− 25		−25 to 0	−25 to 25	−25 to 0	−25 to Release

TABLE 2

Model condition	Total tail-surface area (m^2)	Horizontal tail surfaces				Vertical tail surfaces			
		Total (m^2)	Lever arm (m)	Stabilizer (m^2)	Elevator (m^2)	Total (m^2)	Lever arm (m)	Fin (m^2)	Rudder (m^2)
I Short fuselage, central vertical tail surfaces	10.33	6.52	7.25	4.29	2.23	3.81	7.0	2.58	1.23
II Short fuselage, twin vertical tail surfaces	8.88	5.60	7.25	3.54	2.06	3.28	7.0	2.08	1.20
III Long fuselage, central vertical tail surfaces	10.33	6.52	8.30	4.29	2.23	3.81	8.05	2.58	1.23
IV Long fuselage, vee tail surfaces	7.76	6.35	8.30	4.22	2.13	4.45	8.30	2.95	1.50

TABLE 3

	η (deg)	$\frac{x_s}{l_{aer}}$	ϑ (deg)	Ω (s)	w_s (ms)	φ (deg)	R (m)	γ (deg)	$\frac{\Omega b}{2w_s}$	α (deg)	β (deg)
Slats retracted	−30	0.14	-50^{+13}_{-15}	3.65	69	$5^{\pm 10}$	1.0	−87	0.434	40^{+15}_{-13}	~0
		0.20	$-48^{\pm 15}$	3.34	71	$5^{\pm 10}$	0.9	−87.5	0.386	$42^{\pm 15}$	~0
		0.28	-50^{+8}_{-15}	2.92	77.5	5^{+4}_{-8}	1.2	−87.5	0.309	40^{+15}_{-8}	−1
	20	0.20	-45^{+13}_{-7}	3.50	69	$6^{\pm 6}$	0.9	−87.5	0.416	45^{+7}_{-13}	−1.5
		0.28	$-51^{\pm 6}$	3.33	73.5	$5^{\pm 6}$	1.0	−87.5	0.370	$39^{\pm 6}$	~0
Slats extended	−30	0.20	$-48.5^{\pm 4}$	3.0	67	$5.3^{\pm 3}$	1.2	−87	0.367	$41.5^{\pm 4}$	~0
		0.28	$-43^{\pm 3}$	2.54	65	$5.5^{\pm 5}$	1.15	−87.5	0.321	$47.0^{\pm 3}$	−1.5

TABLE 4

Control Measure	Type	Rudder						Elevator		Rudder and Elevator			
	No.	1	2	3	4	5	6	7	8	9	10	11	12
Elevator	η (deg)	−30				0	20	−30 to 20	−30 to 0	−30 to 0	−30 to 20		−30 to Release
Rudder	ζ (deg)	−25 to 25	−25 to 20	−25 to 10	−25 to 0	−25 to 25		−25		−25 to 0	−25 to 25	−25 to 0	−25 to Release
Flap deflection for vee tail surfaces	$\eta_{St\ B}$	0 to −50	0 to −50	0 to −40	0 to −30	30 to −20	50 to 0	0 to 50	0 to 30	0 to 0	0 to 0	0 to 20	0 to Release
	η_{HB}	−50 to 0	−50 to −10	−50 to −20	−50 to −30	−20 to 30	0 to 50	−50 to 0	−50 to −20	−50 to 0	−50 to 50	−50 to 20	−50 to Release
Slats retracted	$\frac{x_s}{l_{aer}}$ = 0.14	+					+			+	+		
	.20	+	+	+	+	+	+	+	+	+	+	+	+
	.28	+				+	+	+		+	+		+
Slats extended	.20	+						+			+		
	.28	+						+			+		

Figure 1

Figure 2

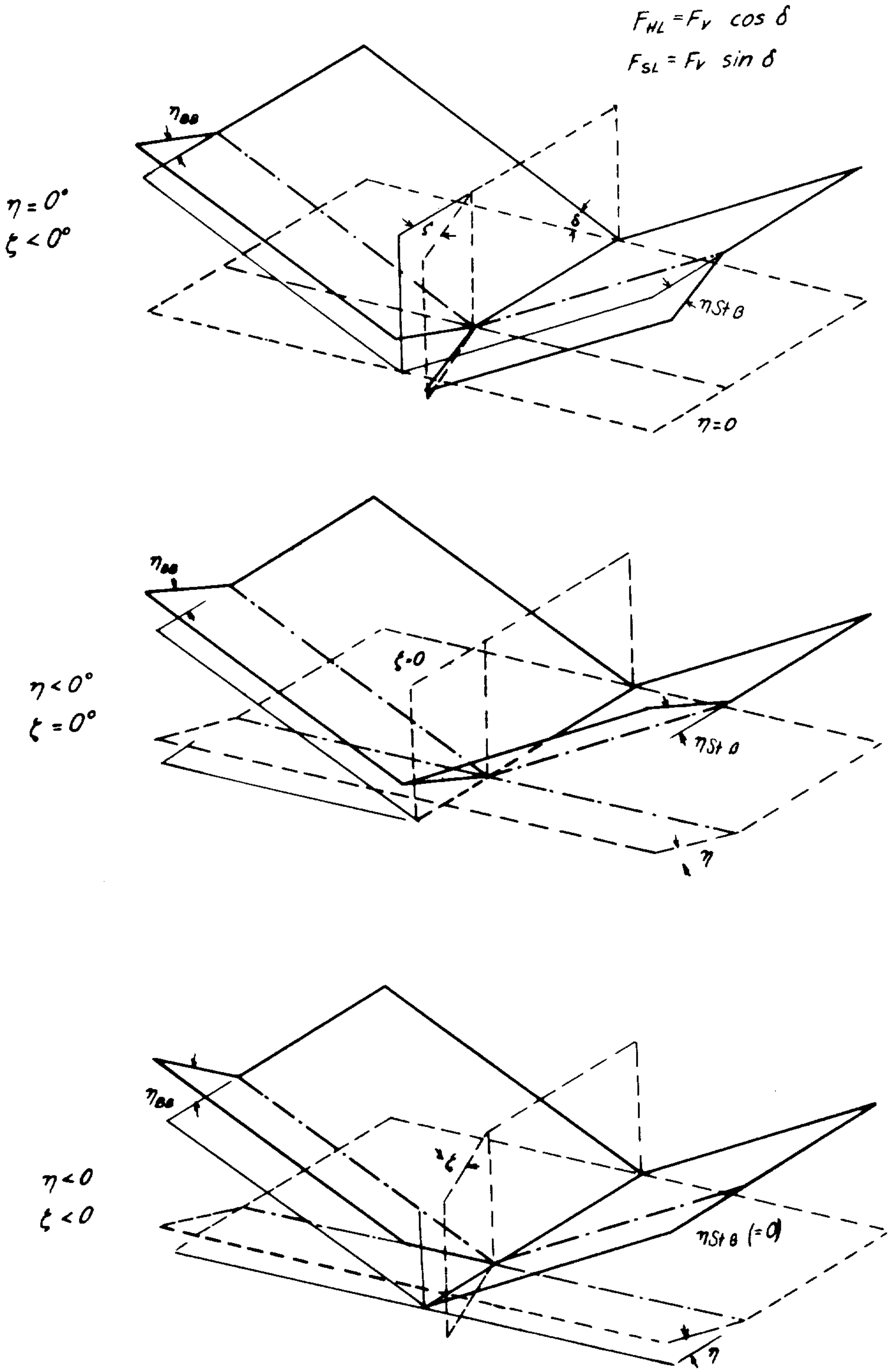

Figure 3.- Coupling of the rudder and elevator deflection for standard tail surfaces (– – – – – –) with the flap deflections of vee tail surfaces (————).

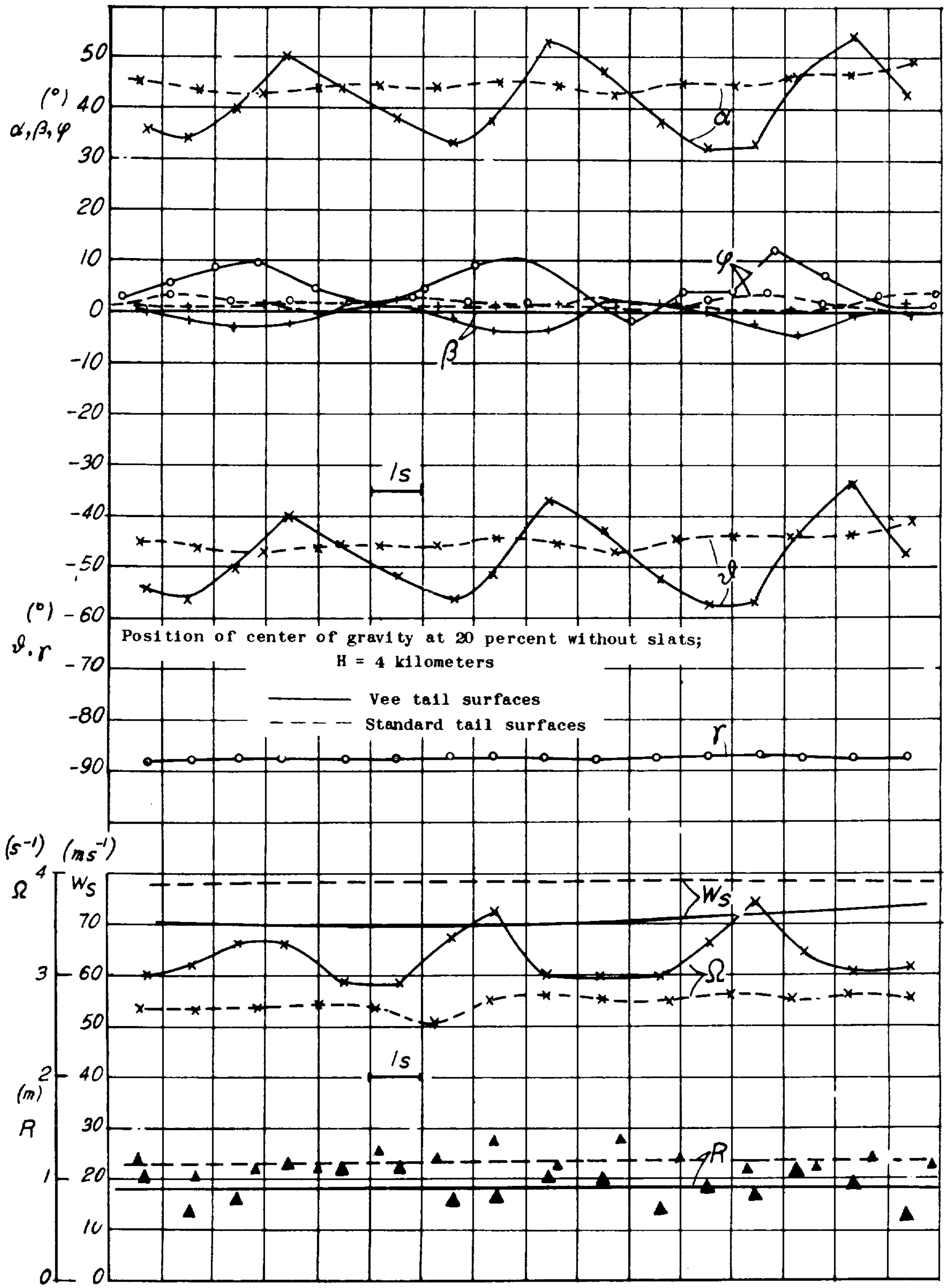

Figure 4.- Variation with time of the spin characteristics; stick pulled back, rudder in fully spin-promoting position.

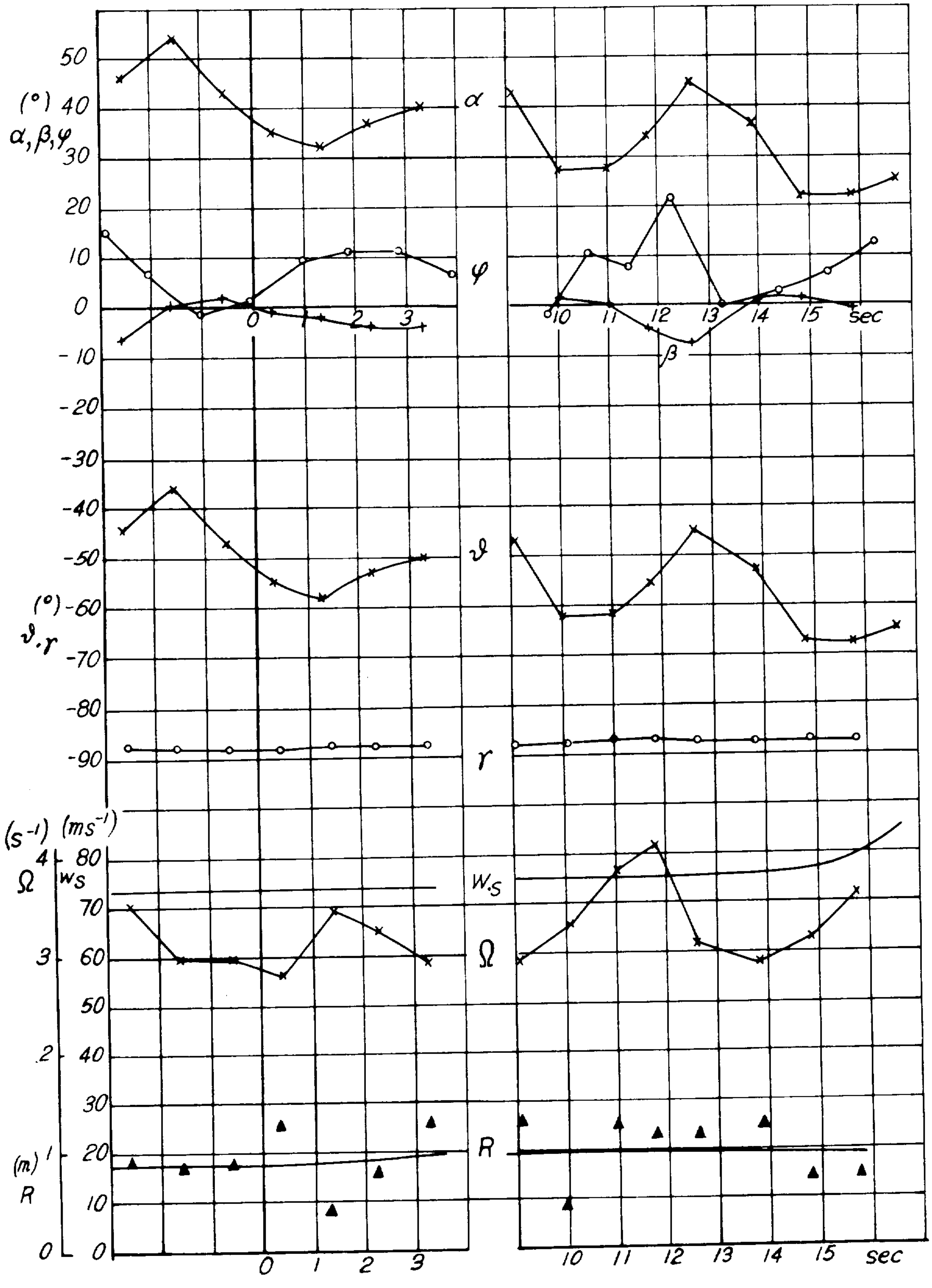

Figure 5.- Variation with time of the spin characteristics during recovery. Control measure 1: $\eta = -30^{\circ}$; $\zeta = -25^{\circ}$ to 25°.

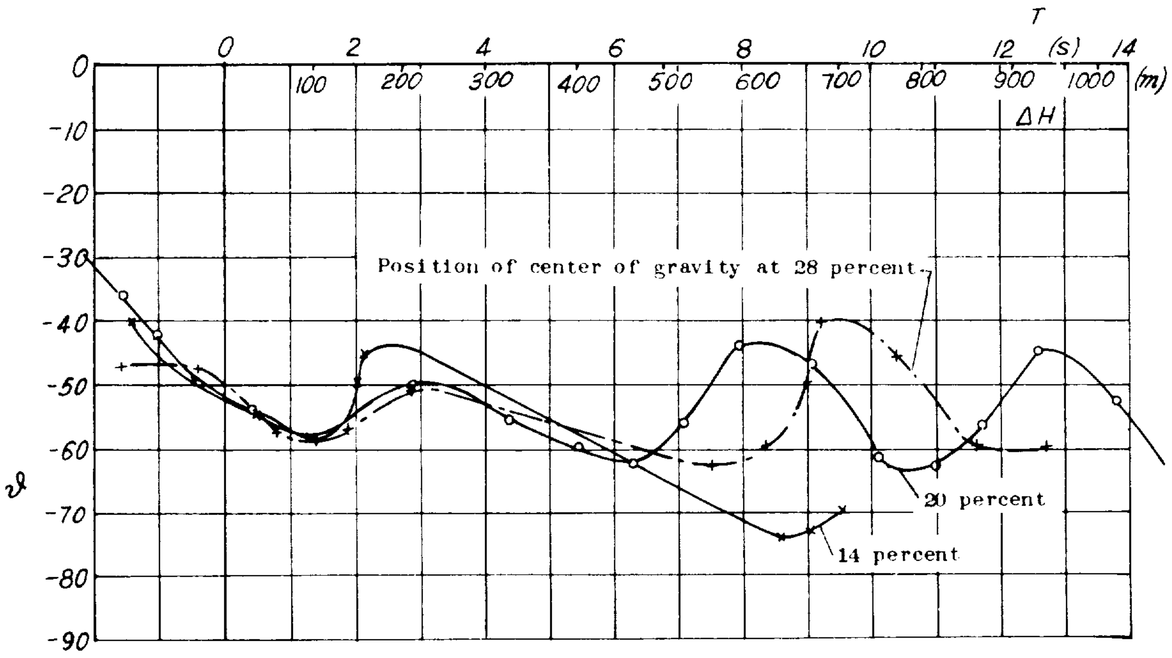

Figure 6.- Effect of a rudder deflection against the spin for various positions of the center of gravity with slats retracted; η = -30°; H = 4 kilometers.

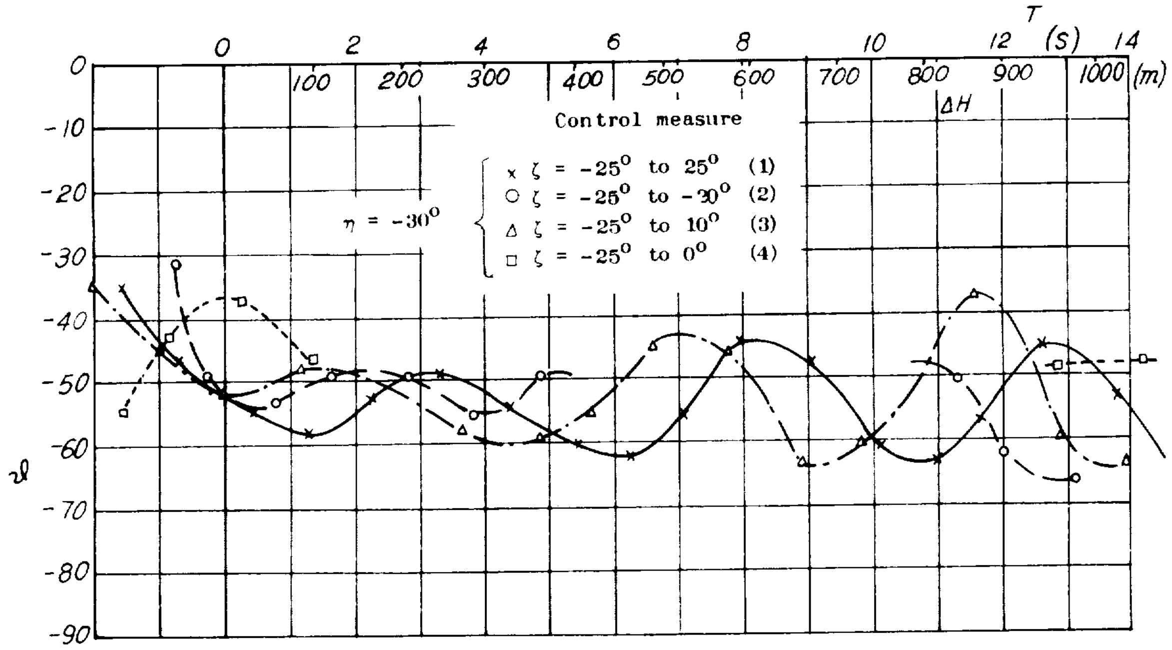

Figure 7.- Effect of various rudder deflections for stick held back, position of the center of gravity at 20 percent, with slats retracted; H = 4 kilometers.

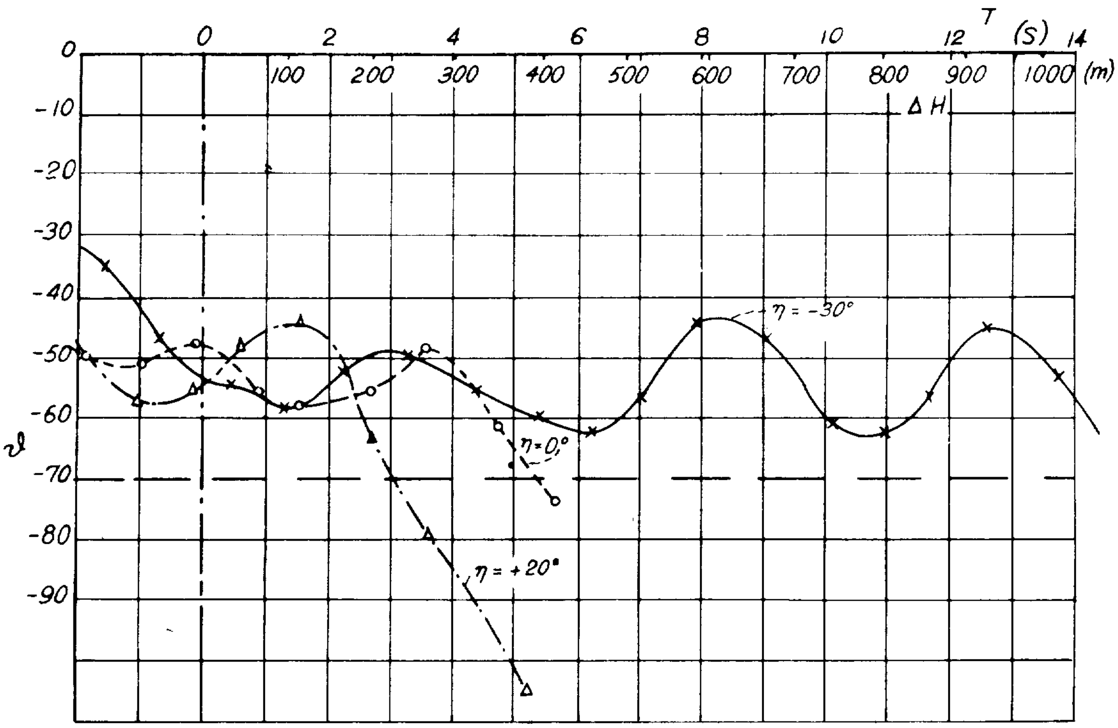

Figure 8.- Effect of a rudder deflection against spin for various elevator positions; position of the center of gravity at 20 percent with slats retracted; H = 4 kilometers.

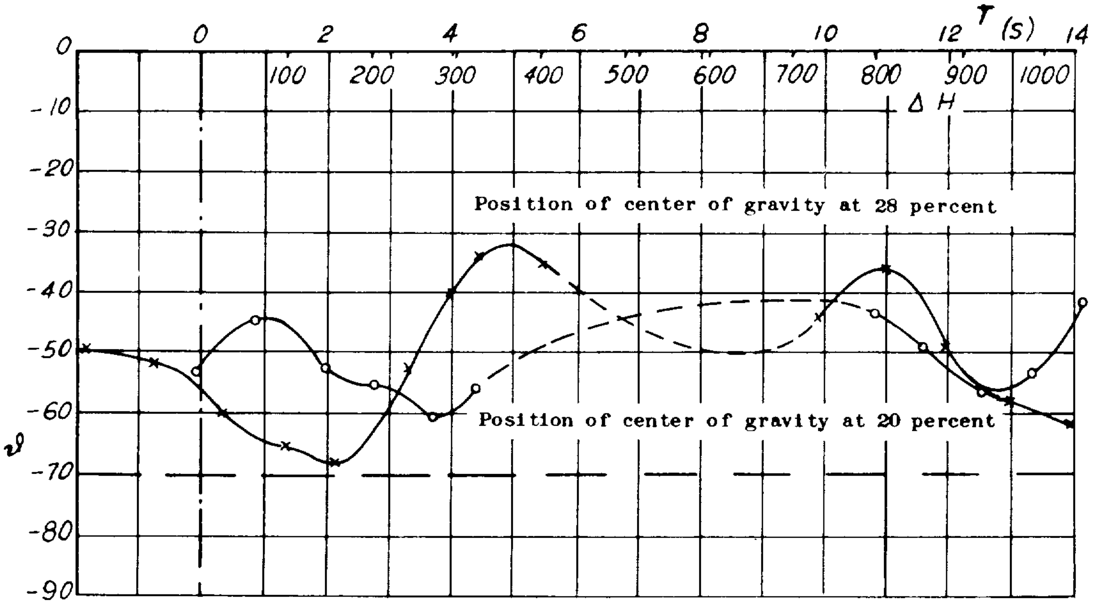

Figure 9.- Effect of an elevator actuation; maneuver 7: $\eta = -30^{\circ}$ to 20°; $\zeta = -25^{\circ}$; with slats retracted; H = 4 kilometers.

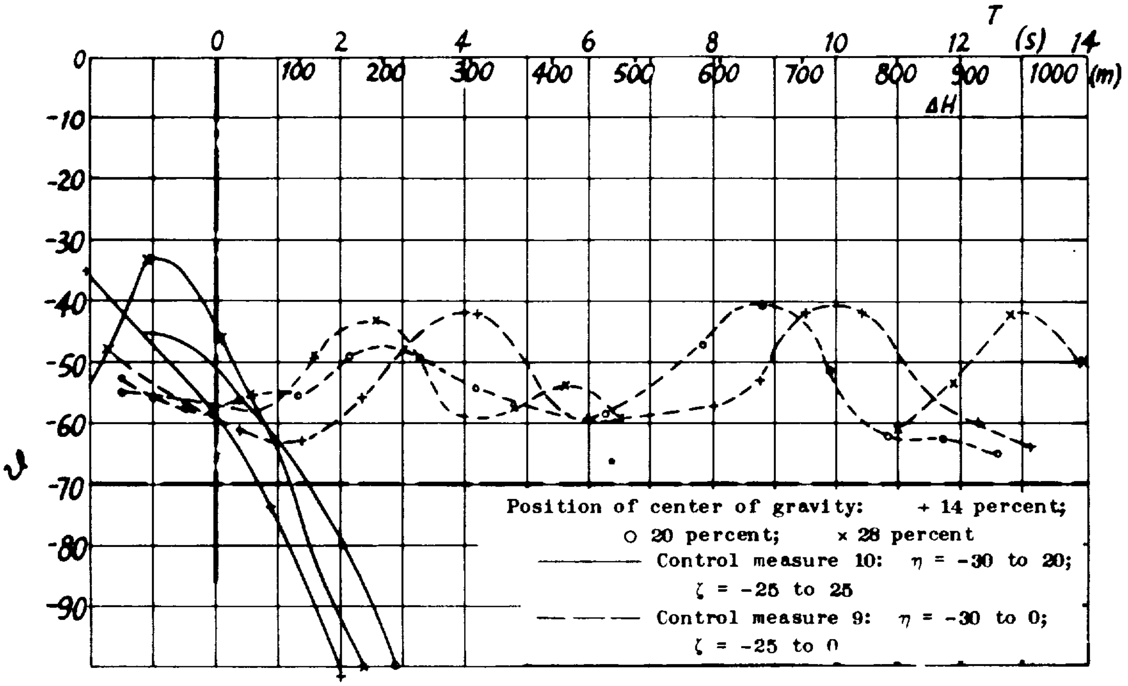

Figure 10.- Effect of simultaneous elevator and rudder actuation with slats retracted; H = 4 kilometers.

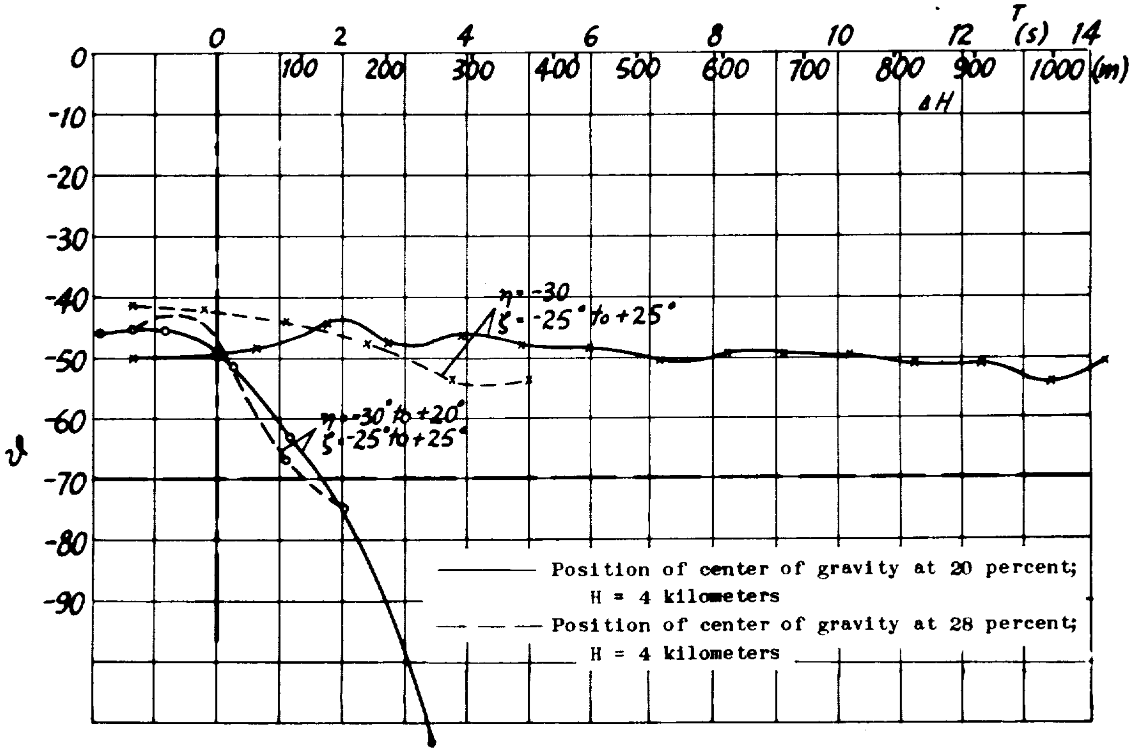

Figure 11.- Effect of control measures with slats extended.

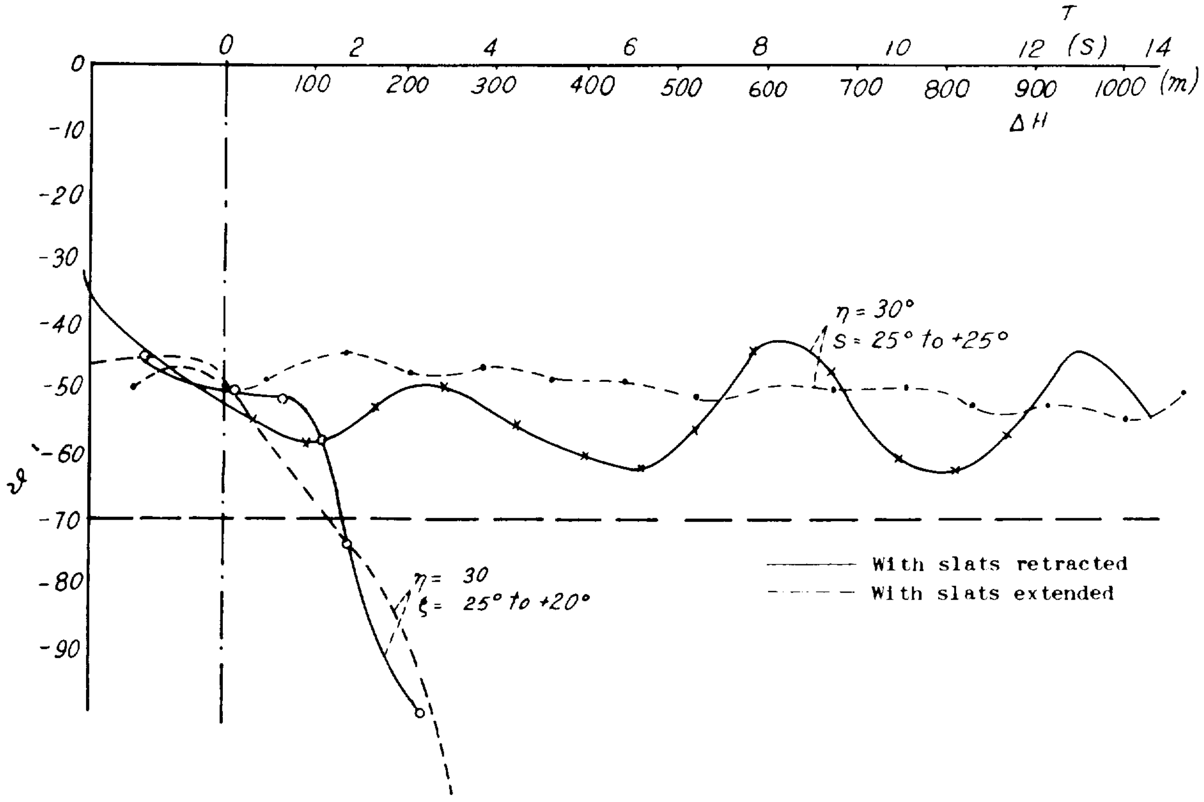

Figure 12.- Comparison of the control-surface effectiveness without and with slats extended; position of center of gravity at 20 percent; H = 4 kilometers.

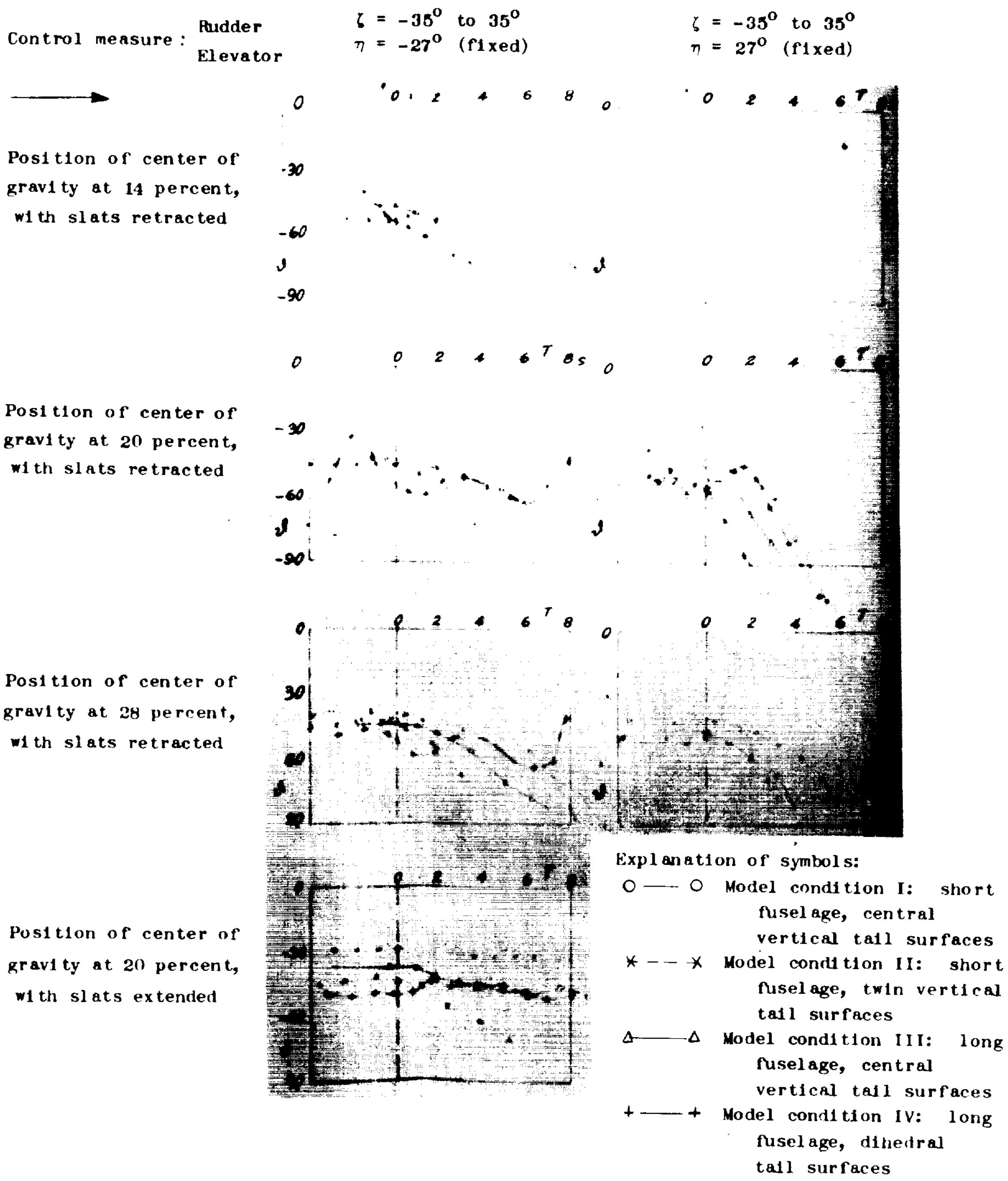

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Figure 13.- Effect of control measures for various model conditions (flight altitude H = 4 kilometers).

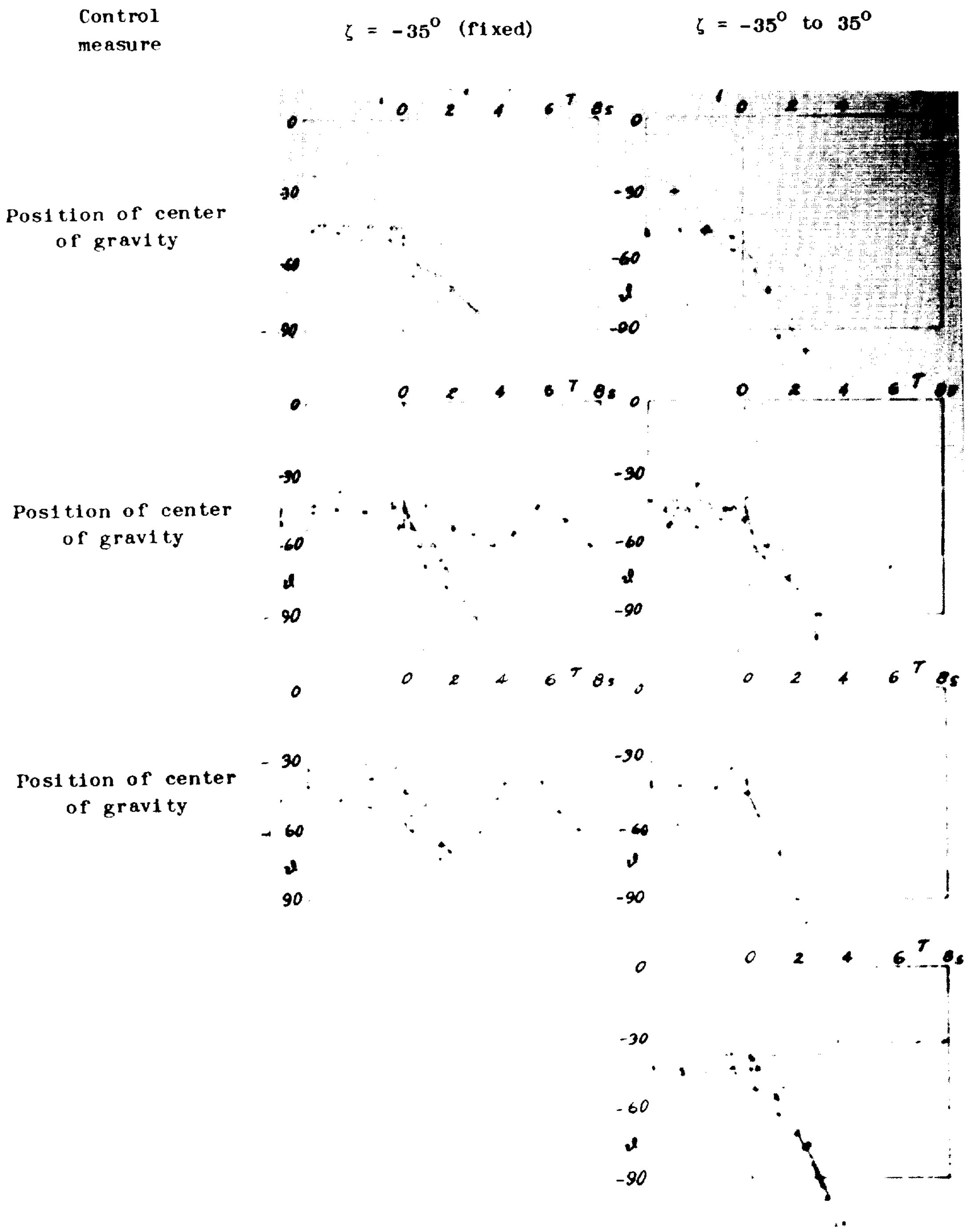

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Figure 13.- Concluded.

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