NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESTRICTED BULLETIN

ANTISPIN-TAIL-PARACHUTE INSTALLATIONS

By Oscar Seidman and Robert W. Kamm

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

Although antispin tail parachutes have been used successfully in spin demonstrations for some time, very little published information is available concerning the size of parachute, the bridle-line length, and the type and location of pack to use for a particular airplane. The present paper is an attempt to supply data relating to these factors. The paper is in two parts. The first part reviews the principles of operation of the antispin parachutes, summarizes available information on actual installations, and discusses parachute loads and pack locations. The second part of the paper reports on systematic tests in the NACA 15-foot and 20-foot free-spinning tunnels at the Langley Memorial Aeronautical Laboratory to determine the minimum size and the optimum bridle-line lengths for antispin tail parachutes for current military airplanes. It is concluded that airplanes weighing between 7500 and 14,000 pounds require parachutes 8 feet in diameter and bridle-line lengths between 20 and 50 feet. A positive-ejection mechanism is desirable to throw the parachute clear of the tail and to assure rapid opening. The pack and attachment point must be so located that the equipment will not foul the tail surfaces.

INTRODUCTION

Although the use of antispin tail parachutes is widespread and they have been successfully used in effecting recovery from uncontrollable spins, very little published information is available concerning the requirements for proper installations.

It is the purpose of part I of the present paper to summarize the information that has been obtained from actual experiences with tail parachutes both in flight tests and in emergency use of the installations. On the basis of these experiences and on the basis of the general principles of operation of tail parachutes in spins, certain precautions are noted and practical recommendations are offered with regard to requirements for installations.

Part II gives the results of a spin-tunnel investigation made using models of six current military airplanes that range in weight from 7500 to 14,000 pounds. On each model, tail parachutes of various sizes were tested with several lengths of lines connecting the parachute to the airplane.

The results are analyzed to show the minimum parachute size and the optimum length of line for antispin parachute installations.

I. FULL-SCALE RESULTS

Principles of Operation

In a spin, the airplane descends rapidly and at the same time rotates about a vertical axis with the result that the flight path is a helix of small radius and of large pitch somewhat as shown in figure 1. The resultant velocity is directed almost vertically downward.

Recovery is normally obtained by reversal of the rudder. This reversal opposes the rotation and results in steepening of the spin and, in most cases, in recovery. For some airplanes, merely pushing the stick forward gives sufficient diving moment for recovery; whereas for others the elevator is ineffective. The aileron position is also frequently important. If, during the spin tests of a new airplane, the controls are ineffective or if the pilot is unable to move the controls because of high forces, the tail parachute is opened to bring the airplane out of the spin.

The tail parachute is fastened to the tail of the airplane and exerts a predominantly upward pull that tends to nose the airplane down. If the parachute is large enough, the airplane will nose down considerably and will stop rotating; that is, it will be in a dive. The parachute can then be released and normal flight resumed.

The effectiveness of the parachute depends primarily on its size, and also to some extent on the length of the bridle line (the line connecting the parachute shroud lines to the airplane).

Flight Tests of Installations

A limited amount of full-scale research on tail parachutes has been conducted. Reference 1 describes tests made with parachutes of various sizes on several airplanes. A parachute pack was fastened on each side of the rudder near the trailing edge and the bridle lines were fastened to mountings placed at the junction of the fin and stabilizer. Among the results obtained for a biplane (PT-13) weighing 2571 pounds were the following: A 3-foot-diameter parachute effected a recovery in 1 turn from a right spin even though the controls were held with the spin but did not effect recovery from a left spin. The indications were, however, that a 4-foot-diameter parachute was not effective for recovery from either right or left spins. A 6-foot-diameter parachute with a 20-foot bridle line caused immediate recovery. An attempt was made to spin the airplane with a 5-foot parachute open, but the spin could not be generated because the parachute lifted the tail and prevented the stall. The length of the bridle lines for the smaller parachutes was not specified. It was recommended, however, that this line be made as "short as possible" because of the belief that the longer the line is the nearer the parachute will tend to ride the spin axis where its yaw effect will be lost. It was also recommended that provision be made for the attachment of the parachute on each side of the rudder and that the spins be made toward the side on which the parachute is installed. This arrangement will prevent the bridle line from applying loads to the rudder opposite to the pilot's control for recovery. During preliminary tests in level flight with the parachute open, it was noted that the parachute swung violently and damaged the trailing edge of the rudder.

Reference 2 describes tests made with an 8-foot-diameter parachute with a 50-foot bridle line on the F4B-2 airplane, which weighed approximately 3000 pounds. The parachute pack was installed on a small horizontal platform above the fin and rudder. The bridle line was fastened to the platform which had bracing struts running to the stabilizer and fuselage. The central portion of the platform was cut out because experience showed this to be necessary in order that wind from below would blow the parachute free when it was unrolled on the platform. A 50-foot bridle line was used because it permitted the parachute to follow more smoothly both during the spin and when being towed behind the airplane in level flight than was possible with a short line. The parachute was not needed for emergency use but was opened once during a spin in order that its action could be observed. As a result of the action of the parachute, the airplane pitched forward rapidly until the fuselage was nearly vertical and increased greatly its rate of rotation. The pilot was surprised at the sudden increase in rotation and released the parachute immediately and executed a rapid recovery from the spin by normal control manipulation. The pilot and ground observers agreed that the airplane was in a low-angle-of-attack dive at the time the parachute was released and that the parachute would have been an effective emergency device.

Tests were also made with a 5-foot-diameter parachute installed on a small platform above the fin on another biplane (XN2Y-1) that weighed approximately 1500 pounds. When opened in spins, the parachute caused a very pronounced change in the attitude of the spin but did not produce recovery in itself.

A 5-foot-diameter parachute was tested for its effectiveness on a monoplane (SNJ-3) weighing 5195 pounds. The parachute pack was fixed to a plate that was attached to the fuselage immediately above the tail wheel. An 8-foot lead of 8/32-inch extra-flexible cable was attached to a bracket secured to the fuselage through the lift and tie-down hole in the side of the fuselage and was connected to the bridle line through a fair-lead at the after end of the fuselage. This arrangement kept the line clear of the tail surfaces. The bridle line attached to the cable lead was 40 feet long and made of four strands of standard shroud line. Three turns after the parachute was released the airplane stopped spinning and recovered with free controls. The pilot reported that he could feel oscillations caused by the steady rotation of the parachute after the airplane had recovered. The bridle line broke during the dive following recovery.

A $3\frac{1}{2}$-foot-diameter parachute was also tested on a very similar airplane (AT-6A) weighing 4932 pounds. Parachute packs were located on both sides of the rudder, somewhat rearward of the rudder hinge line and slightly above the plane of the horizontal tail. The bridle lines were made of four strands, each of 450 pounds strength. They were 7 feet 2 inches long and were fastened to fittings on the rear spar of the stabilizer. This installation was used once as an emergency device after ordinary recovery measures had proved ineffective. After an 8-turn spin to the right the pilot opened the right-hand parachute and the spin was immediately stopped. The airplane went into a vertical dive from which recovery was made. It was noted that the parachute oscillated and the bridle line repeatedly hit against the rudder. Contradictory results were obtained when the same airplane was later spun again to test the effectiveness of the parachute. After the parachute was opened, the airplane spun for two more turns with the controls neutral, after which the pilot applied recovery measures and recovered in from 3/4 to 1 turn. The pilot commented that recovery seemed slightly quicker and the control forces seemed slightly lighter than normal with the parachute open, but that he did not feel the action of the parachute except by its buffeting of the tail.

A 3-foot-diameter parachute was tested on a monoplane (P-40E) weighing 8400 pounds. The parachute installation was located as described in the preceding paragraph, and the same type of bridle line was used. The bridle line was fastened to a fitting joining the fin and stabilizer rear spars. After the parachute corresponding to the direction of spin was opened, the airplane spun 1 turn with free controls, 1 turn with controls neutral, and finally recovered in from 1/2 to 1 turn after the pilot applied recovery measures. The parachute did not appear to expedite recovery very much. It was noted that the parachute oscillated erratically and buffeted the rudder considerably during the spin and recovery. At an indicated airspeed between 170 and 180 miles per hour, the bridle line finally broke at a length corresponding to the position of the rudder trailing edge.

A number of installations have been tested in straight flight at the Naval Air Station at Anacostia to check the strength of the towing gear. In all cases the parachute gyrated considerably but, in most cases, the airplanes were easily controllable and no importance was attached to this characteristic. This Naval Air Station has recommended that the towline cable be as long as can be conveniently installed.

Emergency Use of Installations

Tail parachutes have been used on several airplanes in emergencies. The case of the AT-6A has already been noted. On one monoplane (XF4U-1) that weighed 9699 pounds an 8-foot diameter parachute with a 50-foot bridle line was used on two separate occasions to aid recovery. The parachute was packed in a cylindrical tube that was mounted in the tail cone, and a spring was used to eject the parachute to the rear from the tail. The bridle line was made of

5/32-inch extra-flexible cable and was fastened to the arresting hook attachment. The pilot reapplied stick and rudder hard against the spin as soon as he opened the parachute. A slight tug was felt, the tail appeared to be raised slightly, and the rotation slowed momentarily. The parachute appeared to move in an arc greater than the spin radius. In both cases the airplane recovered in a dive after approximately $1\frac{1}{2}$ turns and the bridle line broke during the dive following recovery.

Another monoplane (F2A-3) that weighed 6637 pounds had a 6-foot-diameter parachute fastened to a plate on the under side of the fuselage rearward of the tail wheel. A bridle line made of four strands of standard parachute shroud line was fastened directly to the arresting hook attachment. The bridle-line length was not specified. When standard recovery methods had failed to effect recovery from a spin, the parachute was opened. The tail of the airplane was raised, and the pilot effected recovery by normal control manipulation 2 turns later.

A 7-foot-diameter parachute was installed on a biplane (XN3N-1) weighing 2725 pounds. The parachute was fastened to the left side of the fuselage ahead of the full-length rudder and below the stabilizer. The bridle line was 20 feet long and was made of 600-pound shroud line. It was fastened to the tie-down fitting that was located on the bottom of the fuselage rearward of the tail wheel. In an emergency the pilot was able, by opening the parachute, to regain control of the airplane and to maneuver out of the spin in $2\frac{1}{2}$ turns.

Two 4-foot-diameter parachutes were installed, one on the right and one on the left side of the vertical fin, on a monoplane (P-40E) weighing 7730 pounds. The parachute packs were mounted about 1 foot above the plane of the horizontal tail, and the bridle lines, which were 7.2 feet long, were fastened to the airplane at the stabilizer-fuselage junction. After $1\frac{1}{2}$ turns in a flat, erect spin, the airplane suddenly whipped into an inverted spin that persisted for $4\frac{1}{2}$ turns. The pilot effected recovery by opening the left parachute. No abrupt jerk or high acceleration was observed when the parachute opened.

It is understood that antispin parachutes have been successfully used in emergencies in several other instances but information concerning their size and installation is not available at this time.

Discussion

Unfortunately the full-scale results are not sufficiently complete to form the basis for specific rules regarding the required parachute diameter or optimum bridle-line length. Table I summarizes the results obtained for the various installations.

Certain inferences can be made. It appears that the 6-, 7-, and 8-foot parachutes were quite effective on the airplanes on which they were tested, but that parachutes less than 5 feet in diameter were often ineffective. Bridle-line lengths on satisfactory installations included values of 20, 40, and 50 feet. Correlation between the weight of the airplane and the size of the effective parachute is not apparent. The need for systematic research is evident.

Practical Aspects of Parachute Installation

In order for the parachute to be effective it must open immediately, clear the airplane without fouling the control surfaces, exert a strong pull on the tail without breaking either the tail or the bridle line, and be releasable when the airplane has recovered from the spin. The bridle line should be fastened as far rearward as practicable and should not foul the control surfaces.

Past experiences have indicated certain precautions to be observed in making the installations. Reference 1 states, for example, "Parachute locations ahead of the fin, below the fuselage, or under the tail surfaces are unsafe because of the possibility of fouling." Reference 2 mentions that the alternative of having the pilot throw the parachute out from the cockpit is bad as the parachute may foul the rudder or fall on top of the stabilizer.

Figure 2 shows possible (good and bad) locations for the parachute pack designated by the numbers 1 to 10. A parachute mounted on top of the stabilizer or on the lower part of the fin (locations 1 and 2) would not blow off when the parachute pack is opened because the air on top of the stabilizer is stagnant (reference 3). As a guide in determining the part of the vertical tail blanketed by the horizontal surfaces, it can be assumed that the relative wind strikes the horizontal tail surfaces from below and that the air flow diverges after passing tail plane, somewhat as shown by the limits LL' in figure 2. A parachute pack installed on the vertical tail between these limits probably would not be exposed to the air stream. Use of a positive-ejection system to throw the parachute clear of the airplane is desirable for cases where the parachute pack is not exposed to the air stream.

For airplanes that have partial-length rudders, that is, fixed fuselage below the rudder, the parachute should be installed in the tail cone (location 3) with an ejecting device, and the bridle line should be attached to a fitting on the tail cone. For airplanes that have full-length rudders, it appears that the most desirable location for the parachute pack would be at the top of the fin (location 4) with the bridle line fastened near the top of the fin, but this arrangement may present structural difficulties. For this installation, the parachute pack can be mounted on a platform that has a cut-out, in order that the air from below can blow the pack free. The top of the fin could be externally braced to support the parachute load or, as an alternative, the bridle line could be fastened to the fuselage near the base of the fin. A parachute location such as location 5 with spring ejection rearward could be used provided a fair-lead carries the bridle line clear of the lower rudder.

Parachute packs have been mounted on the rear portion of the rudder (location 6) with bridle lines fastened at the fin-fuselage juncture. This arrangement requires duplicate installations, one on the right side to be used in right spins and one on the left side for left spins. If the wrong parachute is opened it will probably hold the rudder with the spin and retard recovery.

A location such as 7, with positive upward ejection would probably be satisfactory. Locations such as 1, 8, 9, and 10 are questionable because of the possibility either of fouling or of failure of the parachute to open as a result of blanketing of air flow. Small weights, a "rat-trap" spring, or coil springs in the pack have been suggested as a means of facilitating positive ejection.

For Navy airplanes the bridle line can frequently be fastened to the arresting hook attachment. On one Navy airplane (F3F-2) the parachute-pack mounting was on a rod that replaced the arresting hook and by normal use of the arresting-hook mechanism the pack could be moved rearward to clear the airplane before the parachute was opened.

For inverted spins, locations such as 3 or 5 with positive ejection should prove satisfactory.

The steady load in the bridle line can be estimated from the approximate formula for circular parachutes given in reference 1

$$L = \frac{1.28 \times D^2 \times V^2}{391 \times 1.6}$$

where

L — load on parachute, pounds

D — diameter of parachute spread flat, feet

V — indicated airspeed, miles per hour

From this formula it is apparent that the effective drag coefficient based on flat area was 1.02. It should be appreciated that the drag coefficient may vary somewhat with the type of silk used. In estimating the required bridle-line strength, some allowance should be made for inertia loads associated with the mass of the parachute and attachments and the additional mass of air, and for the fact that the velocity toward the end of the recovery will be higher than the initial velocity in the spin.

The mechanism to cut the parachute loose from the airplane, that is, the release pin equipment, must be operable from the cockpit under load but the handle should be so located that it will not be operated inadvertently. In several instances this mechanism has operated concurrently with the mechanism to open the parachute, and the parachute has floated away without affecting the spin.

Before a spin recovery is attempted, the entire system should be tested thoroughly on the ground with loads acting and in level flight at the maximum speed at which the airplane is expected to spin.

II. SPIN-TUNNEL TESTS

Apparatus

The spin-testing technique used in the NACA free-spinning tunnels and the construction of spin models are described in detail in reference 4. Briefly, the models, constructed of balsa, are ballasted for dynamic similarity to the corresponding airplane by the installation of proper weights at suitable locations. A magnetic remote-control mechanism is installed in the models to actuate the controls for recovery. The models are launched by hand in a spinning attitude into the vertical air stream of the tunnel with the rudder set for the spin. The airspeed is adjusted to equal the normal rate of descent of the model. Recovery was attempted in the present tests by merely opening the parachute. The rudder was kept with the spin during recovery attempts in order that the effect of the various size parachutes could be more easily evaluated. The ailerons were kept neutral and tests were run with the elevator full up, neutral, and down. Parachutes of three different sizes were generally tested on each model, and tests were usually run with bridle lines of four different lengths on each parachute. Models of six airplanes representing current military types were tested. The airplanes are described briefly in table II.

The model parachutes used were made of parachute silk. They were circular and when spread on a flat surface formed a disk. The nominal diameters, that is, the diameters when the parachutes were spread flat, were 3, 4.2, and 5.3 inches, corresponding to 5, 7, and 8.8 feet for 1/20-scale models. Circular vent openings were cut in the center of the parachutes and were made one-twelfth the full diameter. Eight shroud lines of equal length were evenly spaced on the periphery of the parachute, and their length was 1.35 times the diameter of the parachute. The bridle lines were 7, 13, 26, and 49 inches long corresponding to 11.8, 21.8, 43.3, and 81.8 feet for 1/20-scale models. The drag coefficient of the parachutes was found, by measurement in the tunnel at various airspeeds, to have an average value based on flat area of 0.73.

The parachutes were positively ejected rearward from a tube on the side of the fuselage, below the horizontal tail plane. (See fig. 3.) The pack installation shown was convenient for the model but is not considered suitable for an airplane. The point of attachment of the bridle line to the model was as far rearward on the fuselage as was practical. Typical locations for a model with a partial-length and with a full-length rudder are shown in figures 4 and 5, respectively. It is believed that the location shown for the full-length rudder (fig. 5) would not be practicable for flight because the bridle line might foul the tail surfaces. As all controls were securely fastened in place for the current investigation of parachute-size requirements, this fouling was considered unimportant.

Results and Precision

The results of the investigation are summarized in table III and figures 6 to 9. The steady-spin parameters presented in table III describe the characteristics of the spin just prior to the release of the parachute.

The symbols used are:

α acute angle between thrust axis and vertical (approximately equal to angle of attack), degrees

ϕ angle between lateral, that is, span axis and horizontal, degrees

V full-scale true rate of descent, feet per second

Ω full-scale angular velocity about spin, that is, vertical axis, radians per second

All data are for right spins.

All the models had been previously tested and repaired extensively and in some respects the dimensions exceeded the normal constructional tolerances. Inasmuch as increases in weight resulted in the course of early repairs, the actual conditions tested were somewhat different from the normal loadings of the airplanes presented in table II.

The test results presented in table III are believed to be the true values given by the model within the following limits:

α, degrees . . . . ±1
ϕ, degrees . . . . ±1
V, percent . . . . ±2
Ω, percent . . . . ±2

As elevator-up settings sometimes led to spins that were wandering or oscillatory or had high rates of descent, fewer data were obtained for the spins with the elevator up than for the spins with the elevator neutral or down.

The variation of turns for recovery with parachute diameter for elevator down, neutral, and up is presented in figures 6, 7, and 8, respectively, and the variation of turns for recovery with bridle-line length is presented in figure 9. The turns for recovery are believed to be the true values given by the model within ±1/4 turn.

Discussion

It can be seen from figures 6, 7, and 8 that for all models and for all elevator settings the turns for recovery decreased as the parachute diameter increased. In general, larger parachutes were required to effect recovery from spins with the elevator up than from spins with the elevator neutral or down. In the figures the parachute diameters are plotted on two separate scales. The lower scale gives the diameter obtained by dividing the model-parachute diameter by the scale of the airplane model. As mentioned previously, the value of the drag coefficient of the model parachutes used in the current investigation was found to be 0.73 and, from the formula given in reference 1, it appears that the full-scale parachutes will have a drag coefficient based on flat area of 1.02. The upper scale in the figures gives the corrected full-scale diameters obtained taking account of this difference in drag coefficients. In the following discussion and in figures 10 to 12 the diameters referred to are the corrected diameters.

The results indicate that a parachute with a nominal diameter of at least 8 feet can be relied upon to effect recovery from a spin but that a 6-foot parachute is frequently inadequate. Spins with elevator up require larger parachutes than spins with elevator down. Results (unpublished) of brief tests conducted in the spin tunnel in 1936 of a model of a modified P-30 airplane with tail parachutes installed were in general agreement with the findings of the present investigation.

The results of the tests made to determine the effect of bridle-line length upon recovery are presented in figure 9. With one exception, it appears that a full-scale bridle-line length of from 20 to 50 feet is the most effective. Both longer or shorter bridle lines seem to have an adverse effect.

As a matter of interest, a few special tests were made with the bridle lines attached at the center of gravity of the model and also halfway between the center of gravity and the tail of the model. It was found that a fairly large parachute (nominal diam. of 7.5 ft) with bridle lines either 21.8 or 43.3 feet long was entirely ineffective in producing recovery from spins.

A study of the motion-picture records of the tunnel tests has indicated several interesting characteristics of the motion of the parachutes. Some of the photographs are reproduced as figures 10 to 12. In these figures the bridle lines have been accentuated for clarity.

With recommended full-scale bridle lines from 20 to 50 feet long, the parachutes tend to ride almost vertically over the tail of the airplane, although they may oscillate and be inclined either toward or away from the spin axis. They also usually incline away from the plane of symmetry toward the inner wing and contribute an appreciable antispin yawing moment. The parachutes usually have approximately the same rate of rotation as the model.

With a bridle line less than 20 feet in length, the parachute usually inclines away from the spin axis and away from the plane of symmetry toward the inner wing but frequently tends to remain alined with the fuselage axis and does not contribute much pitching or yawing moment. (See fig. 10, frames 21 and 33.)

With a bridle line longer than 50 feet, the parachute invariably inclines toward the spin axis.

During the course of the previously mentioned tests conducted in 1936, the shroud lines of the parachute were fastened directly to the tail of the model; that is, no bridle line was used. It was noted that the parachute merely fluttered in the wake without opening properly.

As a matter of interest, the estimated pitching and yawing moments contributed by the parachute were compared with corresponding moments contributed by elevator and rudder reversal, respectively. The moments resulting from elevator and rudder reversal were computed using average moment-coefficient values obtained from balance tests on other models. For cases in which the parachutes were effective the estimated initial pitching moment due to the parachute was smaller than the increment to be expected from moving the elevator from full up to full down; whereas for many cases the estimated initial yawing moment due to the parachute as a result of the mean lateral inclination of the bridle line was of the same order of magnitude or greater than the increment that would be expected for reversal of the rudder. This result suggests that the effectiveness of the parachutes results more from the yawing than from the pitching moments produced.

The results obtained in the current investigation are for small-scale models and should be checked by a flight investigation. It is to be noted that the results are not inconsistent with the limited flight data described in part I of the present paper.

CONCLUSIONS

The results of the model tests may be summarized as follows:

1. The nominal parachute diameter recommended for airplanes weighing from 7500 pounds to 14,000 pounds is 8 feet.

2. Bridle lines of from 20 to 50 feet in length are most effective and should be fastened as far rearward as practicable.

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

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TABLE I

EFFECTIVENESS OF VARIOUS TAIL-PARACHUTE INSTALLATIONS

Airplane	Weight (lb)	c.g. (percent M.A.C.)	Parachute diameter (ft)	Bridle-line length (ft)	Bridle-line construction	Effectiveness of parachute		
						Effective	Ineffective	Questionable
PT-13	2571	--	3	----	---------------			✓
Do	-do-	--	4	----	---------------		✓	
Do	-do-	--	6	20	---------------	✓		
F4B-2	3000	--	8	50	---------------	✓		
XN2Y-1	1500	--	5	----	---------------		✓	
SNJ-3	5195	26	5	40	Four strands of standard shroud line	✓		
AT-6A	4932	--	3.5	7.2	Four strands, each of 450 pound strength			✓
P-40E	8400	--	3	7.2	------do------		✓	
XF4U-1	9699	27	8	50	5/32-inch extra flexible cable	✓		
F2A-3	6637	25	6	----	Four strands of standard shroud line	✓		
XN3N-1	2725	--	7	20	600-pound shroud line	✓		
P-40E	7730	29	4	7.2	---------------	✓[a]		

[a] Parachute effective when airplane was in inverted spin.

TABLE II.- COMPARISON OF FULL-SCALE DESIGN

CHARACTERISTICS OF MODELS TESTED

Airplane	Gross weight (lb)	c.g. (percent M.A.C.)	Span (ft)	Wing loading, W/S	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)
XTBU-1	13,216	25.2	57.2	30.1	12,543	23,969	34,911
XTBF-1	13,975	25.2	54.2	27.0	11,800	23,600	33,600
XF4U-1	9,500	26.2	41.0	30.2	9,166	8,615	16,730
XP-47B	11,860	25.9	40.8	39.6	13,867	13,047	25,841
SBD-1	7,615	26.7	41.5	23.5	4,800	8,700	12,500
XP-60	9,270	26.8	41.4	33.3	8,900	9,200	17,200

TABLE III.- STEADY-SPIN CHARACTERISTICS

Airplane	Control setting (deg) (a)				α	∅	V	Ω
	Ailerons		Rudder	Elevator	(deg)	(deg) (b)	(fps)	(radians/sec)
	Right	Left						
XTBU-1	N	N	W	U	--	--	---	---
Do--	N	N	W	N	21	3u	247	3.5
Do--	N	N	W	D	27	5u	229	3.4
XTBF-1	N	N	W	U	--	--	---	---
Do--	N	N	W	N	26	4u	203	3.7
Do--	N	N	W	D	32	4u	198	3.5
XF4U-1	N	N	W	U	24	7d	239	3.3
Do--	N	N	W	N	42	1d	193	3.3
Do--	N	N	W	D	49	1d	185	3.4
XP-47B	N	N	W	U	41	2d	226	2.7
Do--	N	N	W	N	39	3d	214	3.2
Do--	N	N	W	D	38	4d	207	3.4
SBD-1	N	N	W	U	--	--	---	---
Do--	N	N	W	N	64	0	126	3.3
Do--	N	N	W	D	64	0	126	3.1
XP-60	N	N	W	U	36	2d	239	2.3
Do--	N	N	W	N	38	0	226	3.1
Do--	N	N	W	D	34	1u	222	3.3

[a]Neutral is designated N; with, W; up, U; down, D.
[b]In describing ∅, u means inner wing up; d, inner wing down.

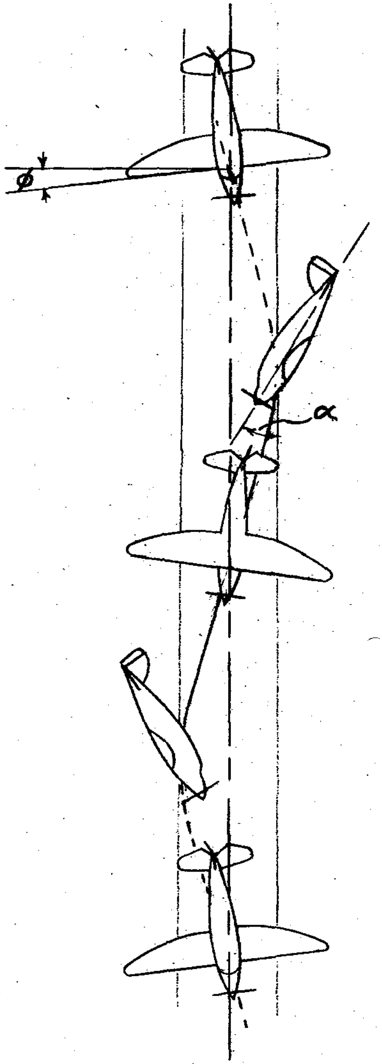

FIGURE 1.- FLIGHT PATH IN A SPIN.

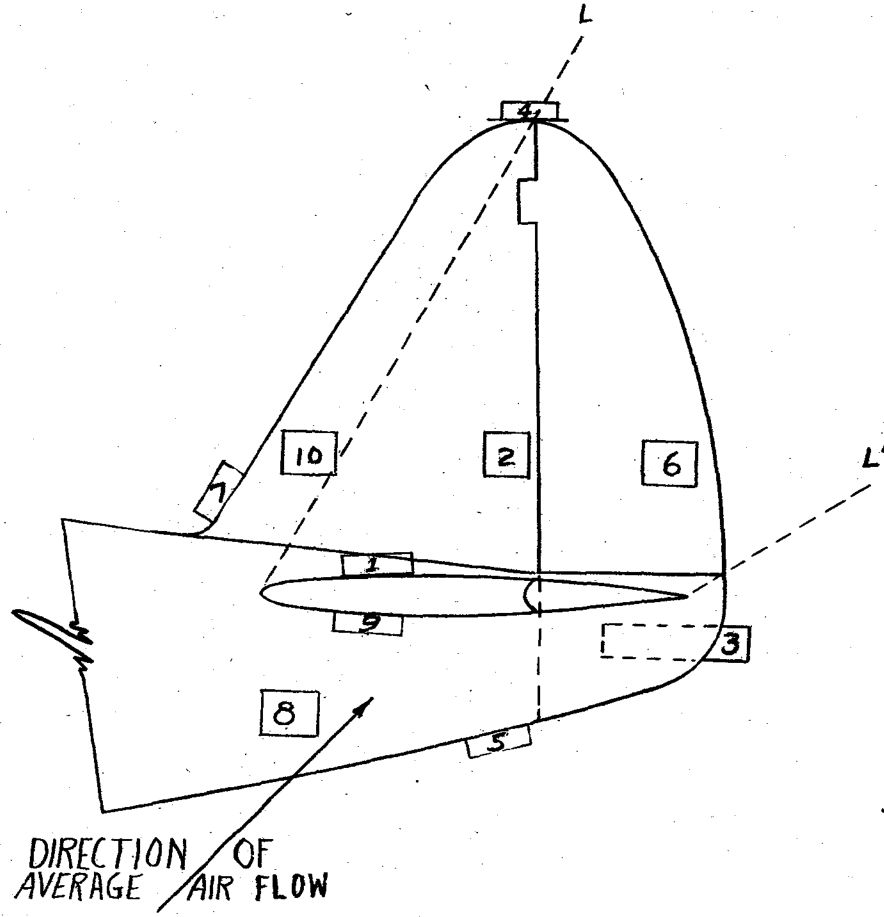

FIGURE 2.- POSSIBLE LOCATIONS FOR THE PARACHUTE PACK.

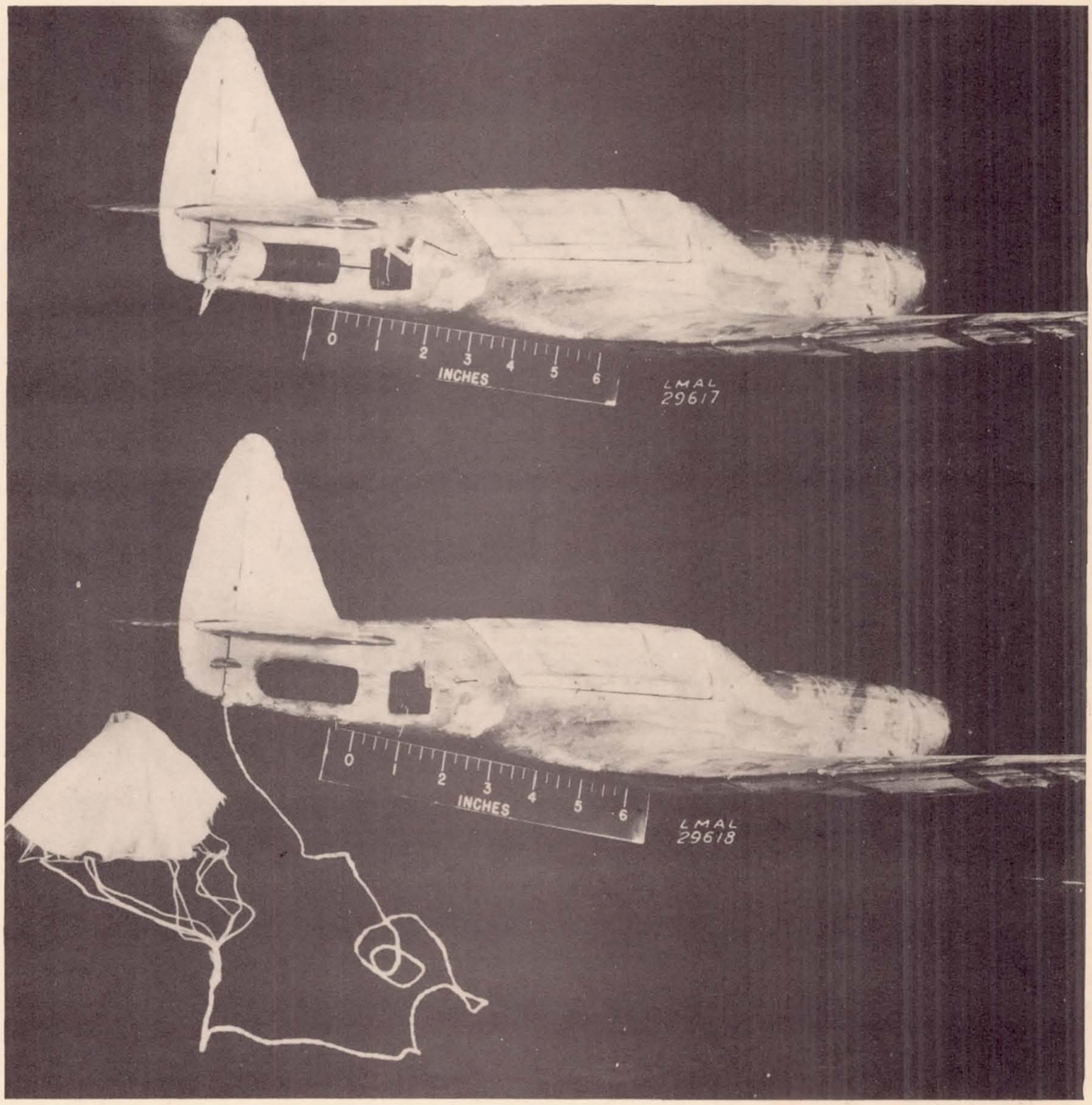

Figure 3.- Parachute-pack installation used in model tests.

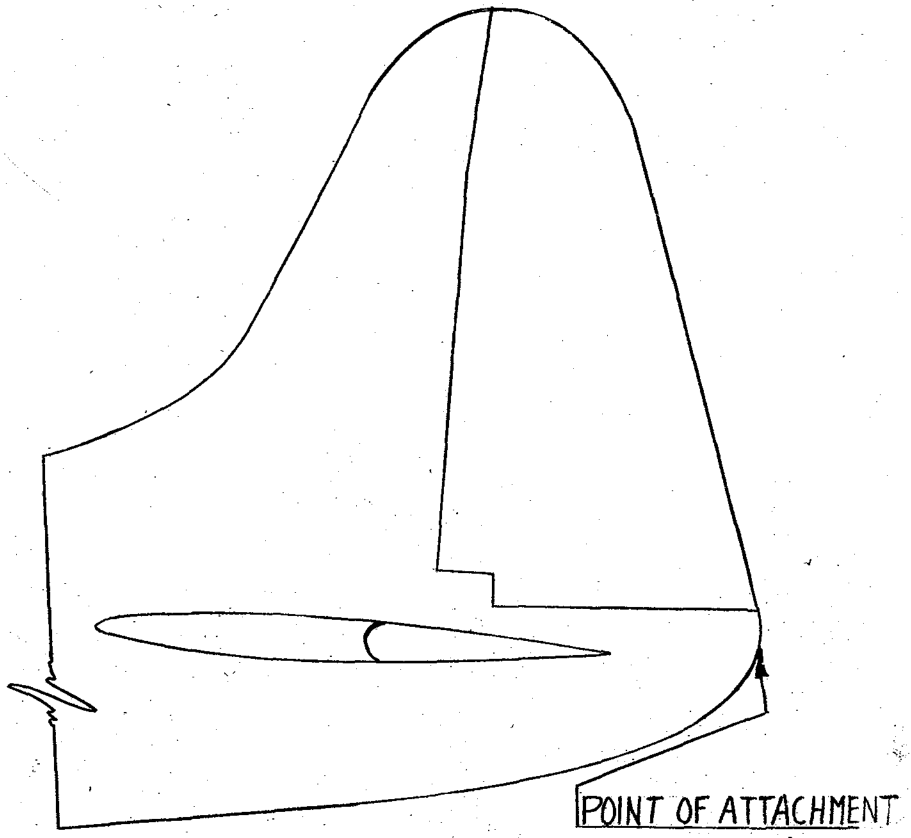

FIGURE 4.- TYPICAL POINT OF ATTACHMENT OF BRIDLE LINE ON MODELS WITH PARTIAL-LENGTH RUDDERS.

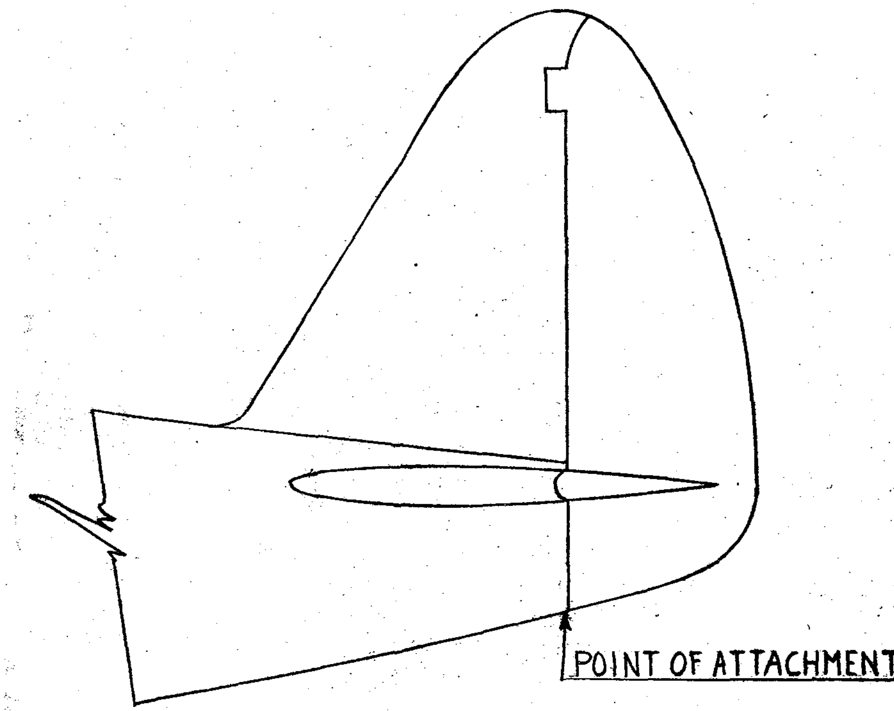

FIGURE 5.- TYPICAL POINT OF ATTACHMENT OF BRIDLE LINE ON MODELS WITH FULL-LENGTH RUDDERS.

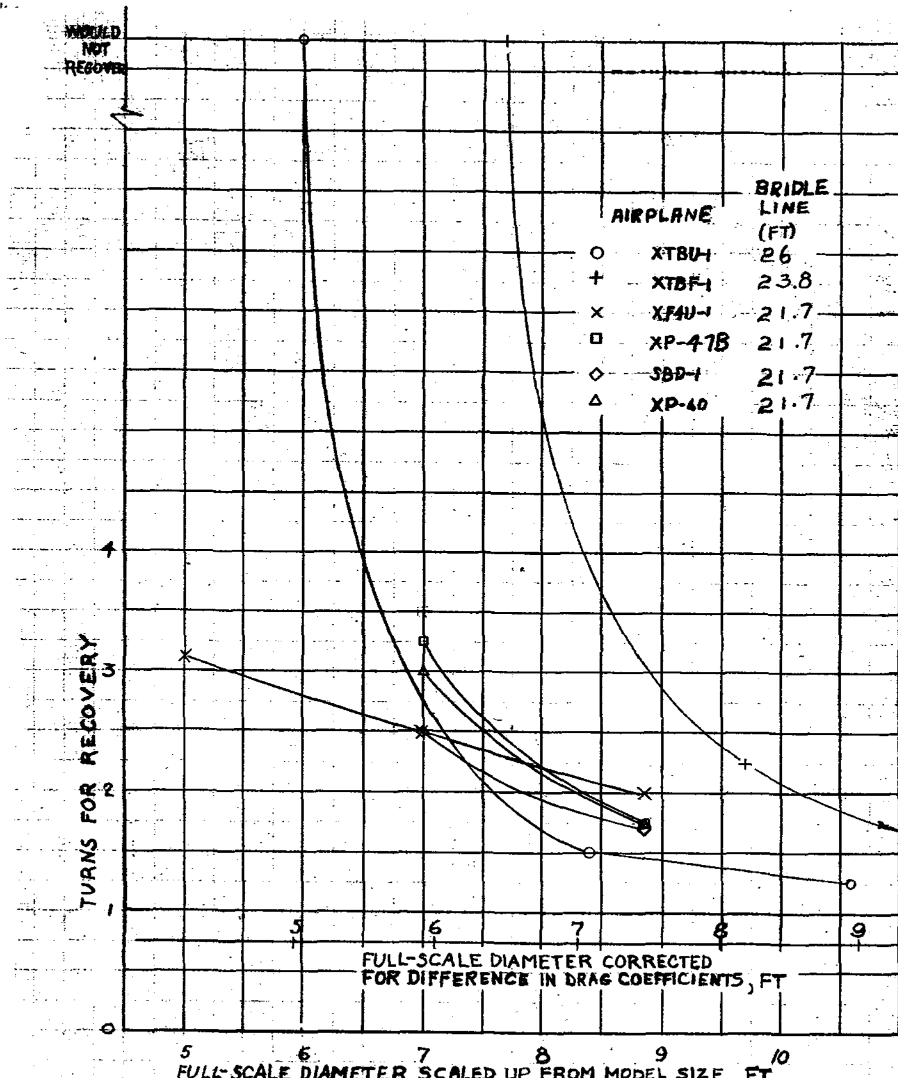

FIGURE 6.- THE VARIATION OF TURNS FOR RECOVERY WITH PARACHUTE DIAMETER. CONTROLS SET AT RUDDER WITH, AILERONS NEUTRAL, AND ELEVATOR DOWN FOR ALL TESTS.

(MEASURE WITH 5/16)

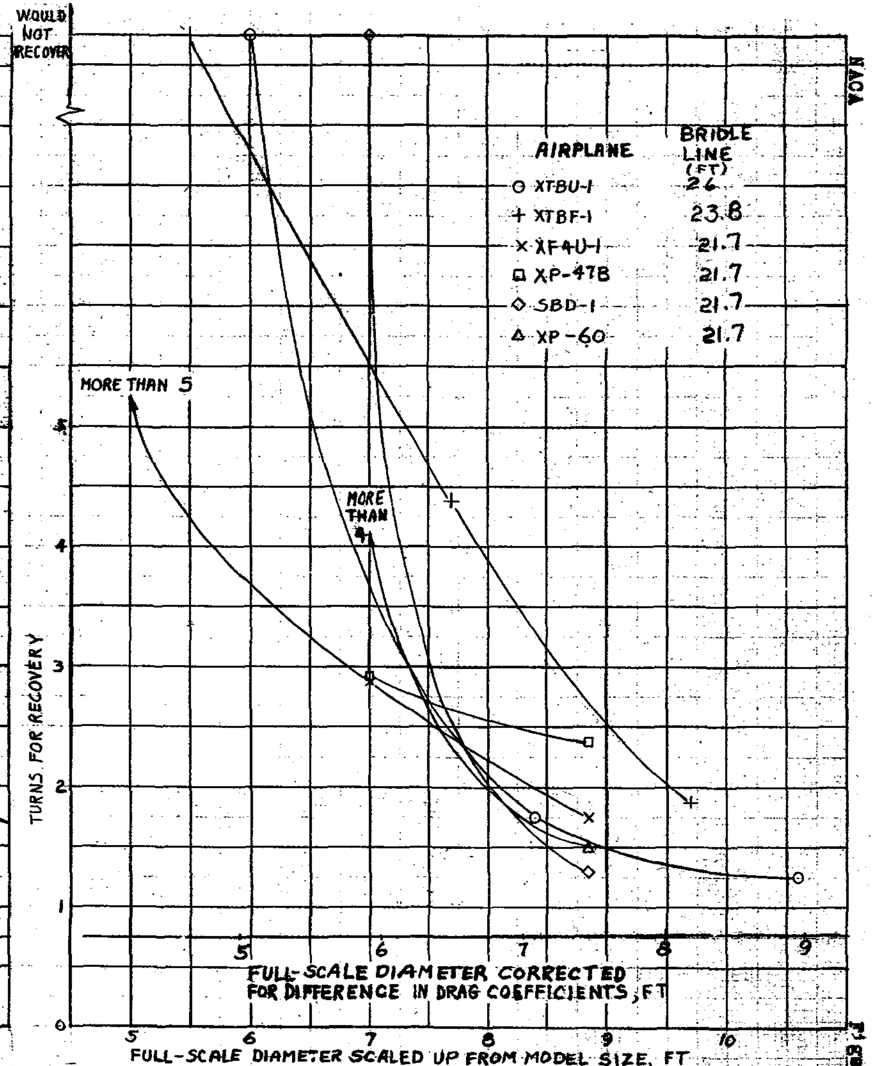

FIGURE 7.- THE VARIATION OF TURNS FOR RECOVERY WITH PARACHUTE DIAMETER. CONTROLS SET AT RUDDER WITH, AILERONS NEUTRAL, AND ELEVATOR NEUTRAL FOR ALL TESTS.

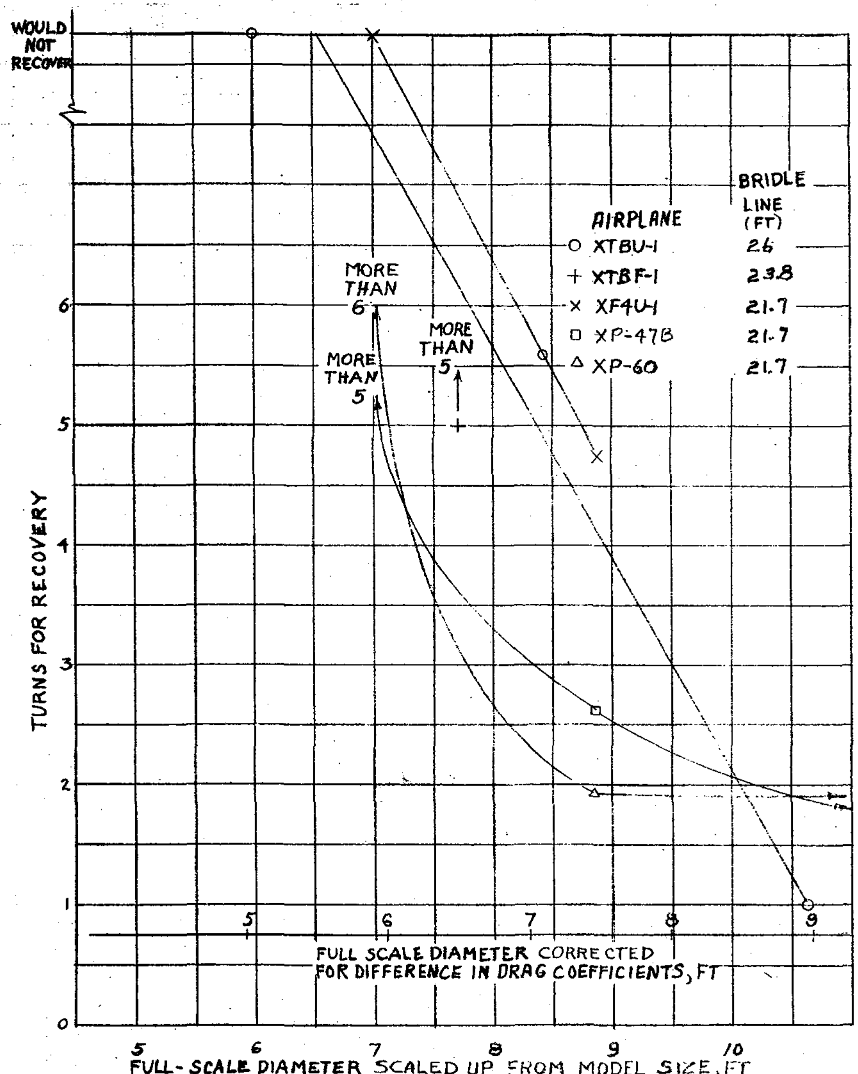

FIGURE 8.- THE VARIATION OF TURNS FOR RECOVERY WITH PARACHUTE DIAMETER. CONTROLS SET AT RUDDER WITH, AILERONS NEUTRAL, AND ELEVATOR UP FOR ALL TESTS.

(MEASURE WITH 5/16")

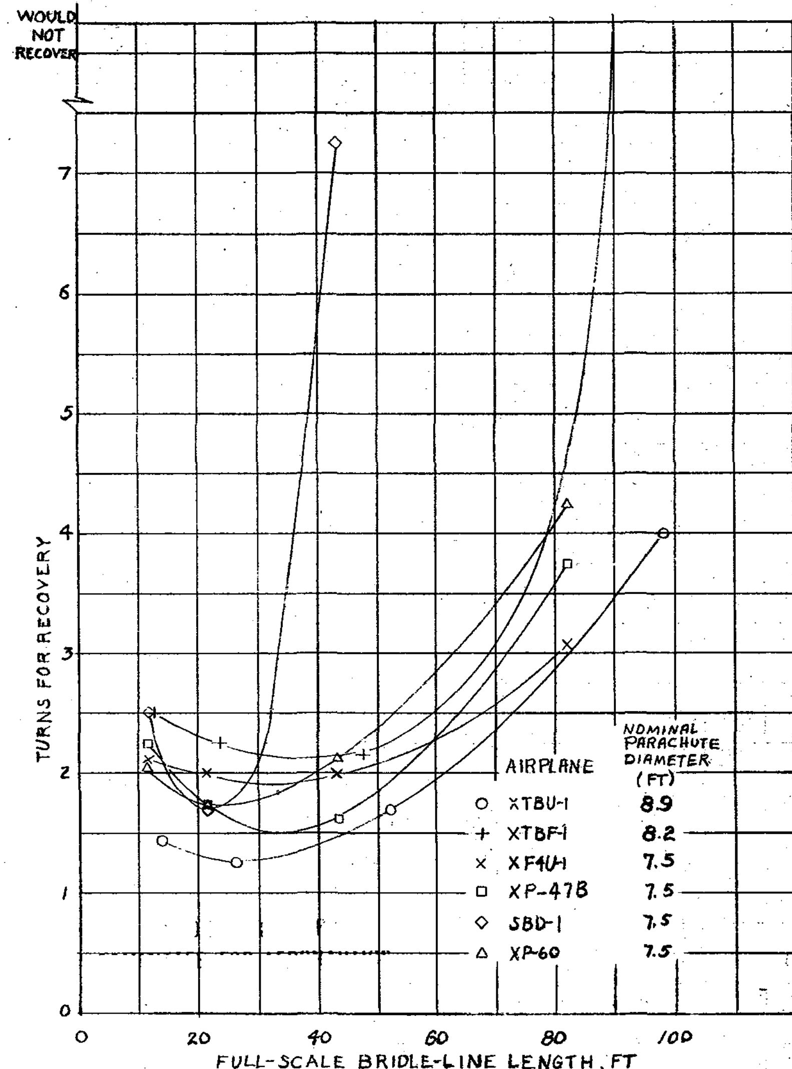

FIGURE 9.- THE VARIATION OF TURNS FOR RECOVERY WITH BRIDLE-LINE LENGTH. CONTROLS SET AT RUDDER WITH, AILERONS NEUTRAL, AND ELEVATOR DOWN FOR ALL TESTS. DIAMETERS ARE CORRECTED FOR DIFFERENCE IN DRAG COEFFICIENTS

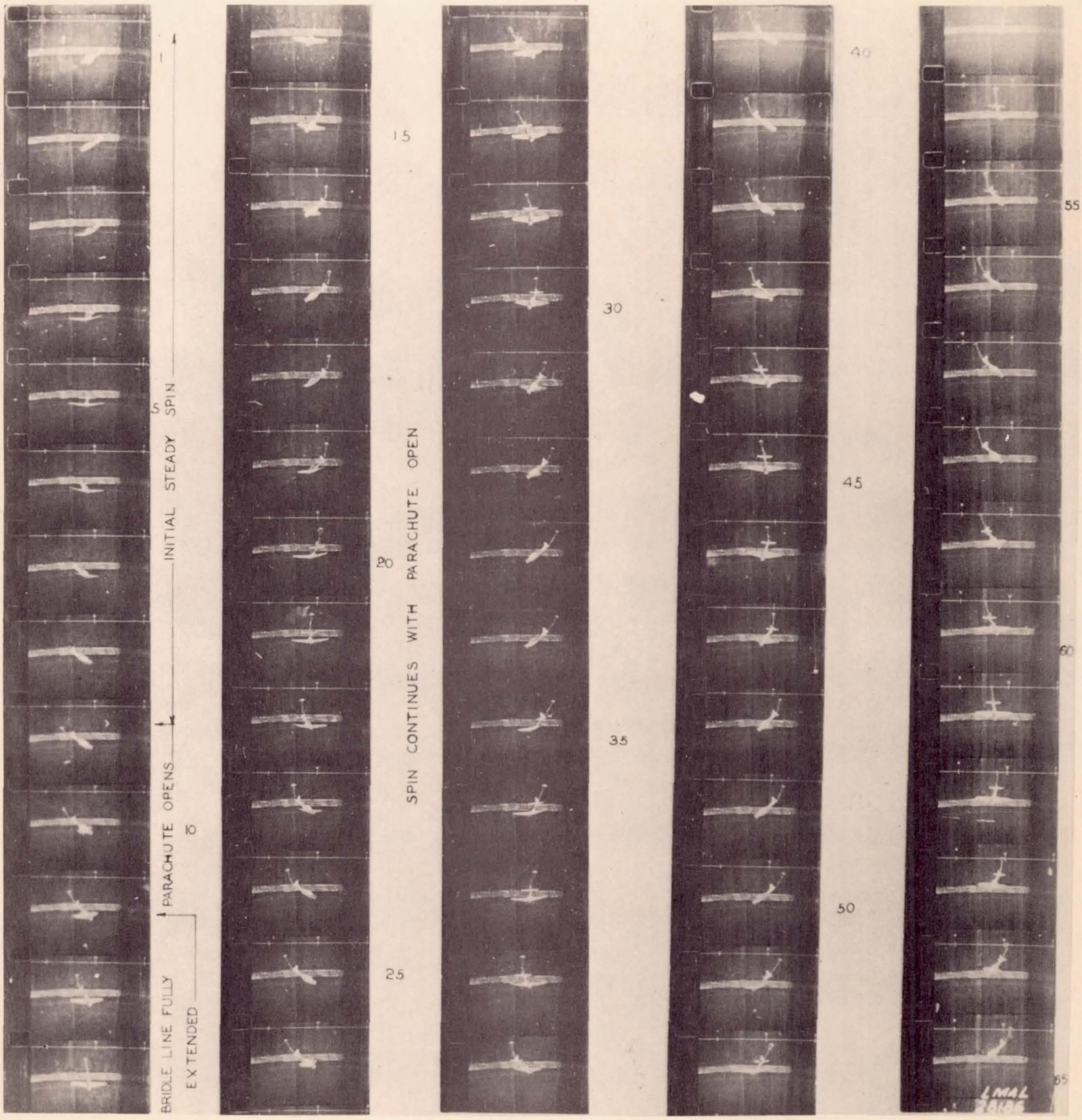

Figure 10.- Model tests of a 4.2-foot parachute with a 11.7-foot bridle line on the SBD-1 airplane. Initial full-scale steady-spin characteristics: α, 64°; ϕ, 0°; V, 126 feet per second; Ω, 3.1 radians per second; radius of spin, 1.6 feet. Control settings throughout: rudder full with the spin, elevator down, ailerons neutral.

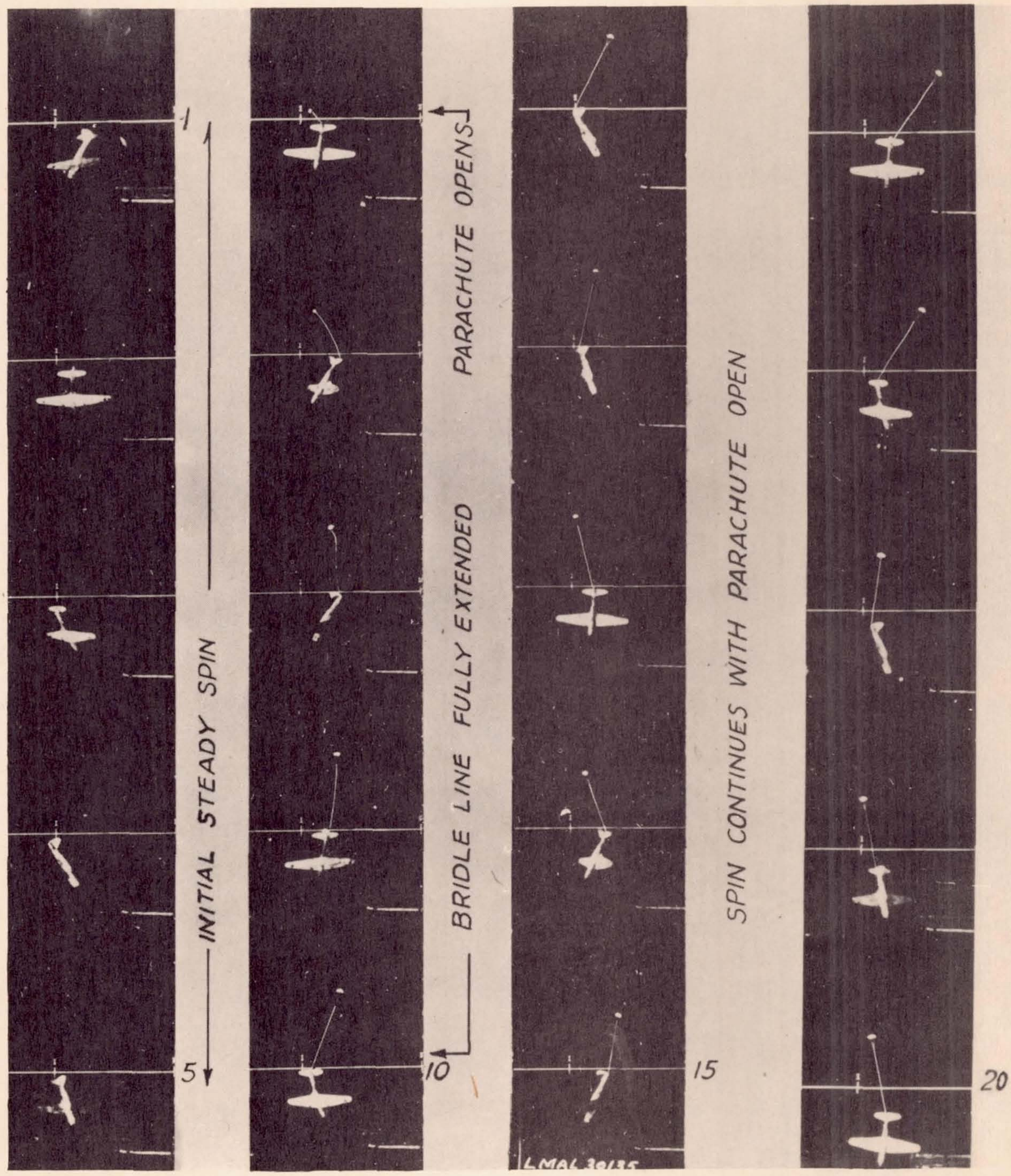

Figure 11.- Model tests of a 4.2-foot parachute with a 43.3-foot bridle line on the XP-60 airplane. Initial full-scale steady-spin characteristics: α, 38°; ϕ, 0°; V, 226 feet per second; Ω, 3.1 radians per second; radius of spin, 4.3 feet. Control settings throughout: rudder full with the spin, elevator neutral, ailerons neutral.

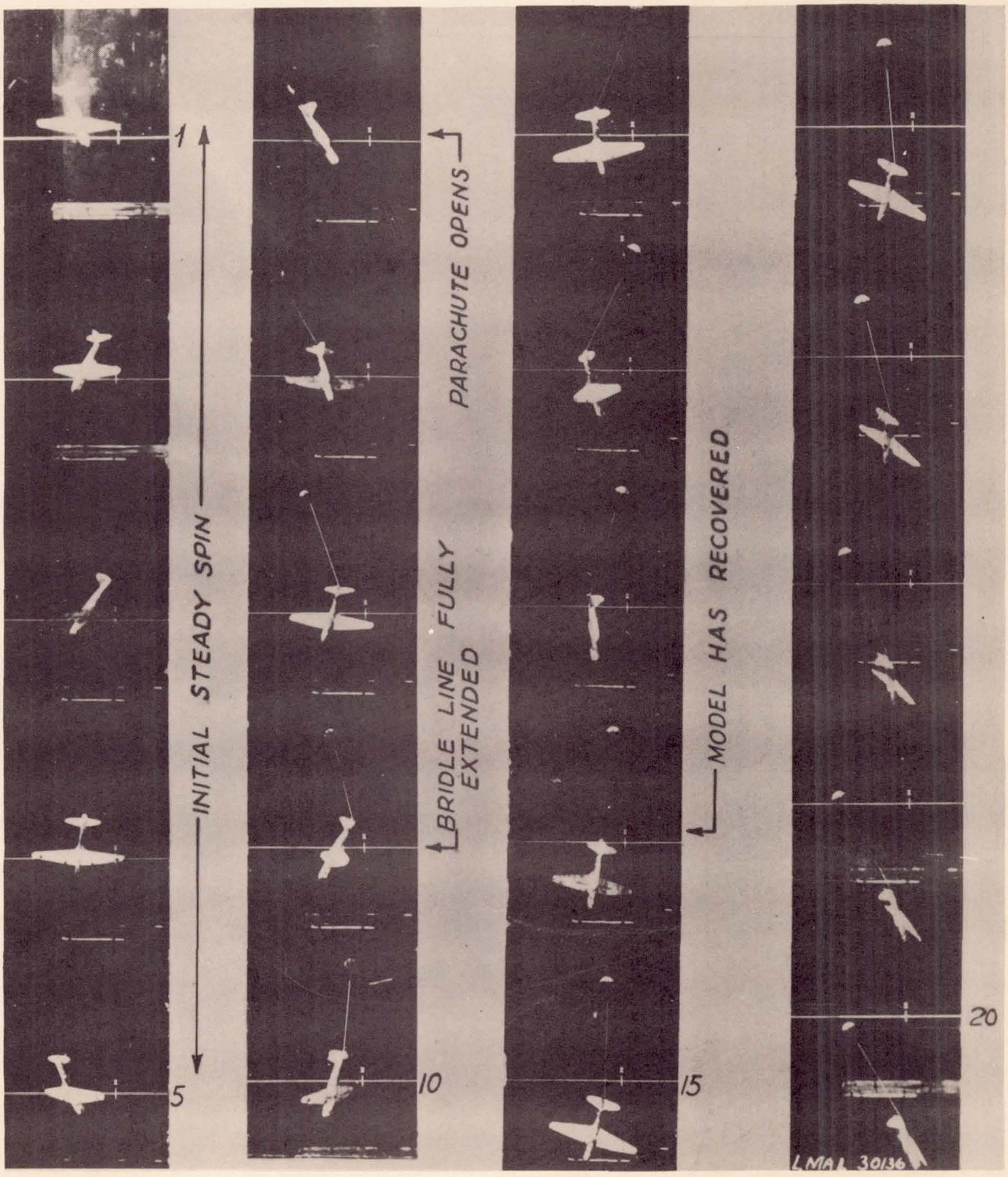

Figure 12.- Model tests of a 7.5-foot parachute with a 43.3-foot bridle line on the XP-60 airplane. Initial full-scale steady-spin characteristics: α, 38°; ϕ, 0°; V, 226 feet per second; Ω, 3.1 radians per second; radius of spin, 4.3 feet. Control settings throughout: rudder full with the spin, elevator neutral, ailerons neutral.