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RESEARCH MEMORANDUM

for the

U. S. Air Force

EMERGENCY SPIN-RECOVERY DEVICE FOR THE 1/18-SCALE MODEL

OF THE RYAN X-13 AIRPLANE AS DETERMINED FROM TESTS

IN THE LANGLEY 20-FOOT FREE-SPINNING TUNNEL

By James S. Bowman, Jr.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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EMERGENCY SPIN-RECOVERY DEVICE FOR THE 1/18-SCALE MODEL OF THE RYAN X-13 AIRPLANE AS DETERMINED FROM TESTS IN THE LANGLEY 20-FOOT FREE-SPINNING TUNNEL

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/18-scale model of the Ryan X-13 airplane to determine the size parachute required for emergency-spin recovery during demonstration spins. Test results for erect spins indicate that a stable 12.75-foot-diameter parachute with a drag coefficient of 1.11 (based on the 12.75-foot projected diameter) is the minimum size required to insure satisfactory recovery in an emergency. The use of a stable parachute is recommended.

Test results for inverted spins indicate that the 12.75-foot-diameter parachute is also satisfactory to terminate inverted spins.

INTRODUCTION

In accordance with a request by the U. S. Air Force, an investigation is being conducted to determine the spin and recovery characteristics of a 1/18-scale model of the Ryan X-13 airplane. Tests have been completed to date to determine the size parachute required for emergency spin recovery during demonstration spins. Only the parachute tests are discussed in this report, inasmuch as the investigation has not been completed. For these tests, the model was loaded for the normal gross weight for vertical flight attitude with the center of gravity located at 29.1 percent of the mean aerodynamic chord.

A standard-form appendix is included which presents a general description of the model-testing technique, the precision with which model test results and mass characteristics are determined, the variations of model mass characteristics occurring during tests, and a general comparison of the results for the model and airplane.

SYMBOLS

b	wing span, ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord; x is measured in wing chord plane
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slug/cu ft
μ	relative density of airplane, $\frac{m}{\rho Sb}$
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg
ϕ	angle between span axis and horizontal, deg
V	full-scale true rate of descent, ft/sec
Ω	full-scale angular velocity about spin axis, rps

MODEL AND TEST CONDITIONS

The 1/18-scale model of the Ryan X-13 airplane was built at the Langley Laboratory of the National Advisory Committee for Aeronautics. A photograph of the model showing the normal testing configuration is shown in figure 1. The dimensional characteristics of the airplane are presented in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 25,000 feet (ρ = 0.001065 slug/cu ft). The loading conditions possible on the X-13 airplane and the loading tested on the model are shown on table II.

The parachute was attached on the model at the base of the vertical tail, on the top rearward end of the fuselage as shown in figure 1. This point corresponds to the parachute-attachment point on the corresponding airplane. The model parachute was packed at the same point, but on the airplane it will be packed inside the vertical tail.

The ailerons and elevators are combined into one control known as the elevons. (See fig. 1.) In determining the control deflection of the elevons, the movement of the ailerons and elevators are additive. The maximum control deflections used were:

Rudder, deg	25 right, 25 left
Ailerons, deg	17.5 up, 17.5 down
Elevators, deg	22.5 up, 2.5 down

RESULTS AND DISCUSSION

The results of the erect and inverted spin tests for determining the parachute size required for satisfactory spin recovery are presented in table III. The erect-spin-test results are in terms of right spins and the inverted-spin-test results are in terms of inverted spins to the pilot's right. Erect and inverted spin tests were conducted with stable parachutes. Reference 1 indicates that a stable parachute is desirable, and stable parachutes of hemispherical shape were arbitrarily used for the tests, inasmuch as they were readily available. (The stability of the parachutes used is attributable to the porosity of the material and not to the parachute shape; see ref. 1.) The results for the erect spin are presented for the criterion spin-control configuration (ailerons deflected one-third against the spin, elevators set to two-thirds of full-up deflection, and rudder full with the spin). The test results indicate that a stable 12.75-foot-diameter parachute with a drag coefficient of 1.11 (based on the 12.75-foot projected diameter) is the minimum size required to insure satisfactory recovery in an emergency. The shroud-line lengths used for the 12.75-foot-diameter parachute were 34.5 feet, and the towline length was varied from 0 to 5.1 feet. (All dimensions are full scale.) If a parachute with a different drag coefficient is used, a corresponding adjustment should be made in the parachute size, and the combined towline and shroud-line lengths should be about 35 to 40 feet.

The results obtained from inverted spins (table III) indicate that the 12.75-foot-diameter stable parachute is also satisfactory for inverted-spin emergency recoveries. The model was reluctant to spin inverted unless the ailerons were full against the spin and the elevators were full up (with respect to the airplane) and, therefore, inverted-parachute tests were made for this configuration.

CONCLUSIONS

Based on the results of tests of a 1/18-scale model of the Ryan X-13 airplane, the following conclusions regarding the emergency spin-recovery parachute tests are made:

1. A stable 12.75-foot-diameter parachute with a drag coefficient of 1.11 (based on the 12.75-foot projected diameter) is the minimum size required to insure satisfactory emergency spin recovery.

2. A stable parachute should be used.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 10, 1955.

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Approved: Thomas A. Harris
Chief of Stability Research Division

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APPENDIX

METHODS AND PRECISION

Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising airstream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 2.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning-control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with moving of the ailerons to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model (refs. 3 and 4). Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator is set at either full up or two-thirds of its full-up deflection and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which may be either against the spin (stick left in a right spin) or with the spin, depending primarily on the mass characteristics of the particular model. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin and movement of the elevator to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and stick movement to two-thirds with the spin. These control configurations amd manipulations are collectively referred to as the "criterion spin," with the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

For spin-recovery parachute tests, the minimum-size tail parachute required to effect recovery within $2\frac{1}{4}$ turns is determined generally from the criterion spin. The parachute is opened for the recovery attempts by actuating the remote-control mechanism and the rudder is held with the spin so that recovery is due to the parachute action alone. The folded spin-recovery parachute is placed on the model in such a position that it does not seriously influence the established spin. A rubber band holds the packed parachute to the model and when released it allows the parachute to be blown free of the model. On full-scale parachute installations, it is desirable to mount the parachute pack within the airplane structure, if possible, and it is recommended that a mechanism be employed for positive ejection of the parachute.

Turns for recovery are measured from the time recovery is attempted to the time the spin rotation ceases. Recovery characteristics of a model are generally considered satisfactory if recovery attempted from the criterion spin in any of the manner previously described is accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model-test results.

Precision

Results determined in free-spinning tunnel tests are believed to be true values given by models within the following limits:

α, deg	±1
ϕ, deg	±1
V, percent	±5
Ω, percent	±2
Turns for recovery obtained from motion-picture records	±1/4
Turns for recovery obtained visually	±1/2

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls are set with an accuracy of ±1°.

Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the Ryan X-13 model varied from the true scaled-down values within the following limits:

Weight, percent	0.5
Center-of-gravity location, percent $\bar{c}$	1.54 ahead of most forward c.g. position
Moments of inertia:	
I_X, percent	2.8 high
I_Y, percent	0.4 low
I_Z, percent	11.6 low

Comparison Between Model and Airplane Results

Comparison between model and full-scale results in reference 5 indicated that model tests accurately predicted full-scale recovery characteristics approximately 90 percent of the time and that, for the remaining 10 percent of the time, the model results were of value in predicting some of the details of the full-scale spins, such as motions in the developed spin and proper recovery techniques. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 5 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models.

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2. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. 557, 1936.

3. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery From a Spin. NACA WR L-168, 1942. (Formerly NACA ARR, Aug. 1942.)

4. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN 1045, 1946.

5. Berman, Theodore: Comparison of Model and Full-Scale Spin Test Results for 60 Airplane Designs. NACA TN 2134, 1950.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE RYAN X-13 AIRPLANE AS SIMULATED ON THE 1/18-SCALE SPIN MODEL

Overall length, ft	23.445
Wing:	
Span, ft	21.000
Area, sq ft	191.002
Sweep at leading edge, deg	60
Airfoil section -	
Root chord	NACA 65A008
Mean aerodynamic chord (measured in wing chord plane), in.	145.49
Leading-edge mean aerodynamic chord rearward of theoretical leading edge of wing (measured in wing chord plane), ft	6.06
Incidence (measured between wing chord plane and water line)-	
Root, deg	4
Dihedral, deg	0
Elevons:	
Total area, rear of hinge line, sq ft	22.095
Hinge line in percent of local chord -	
Root, percent	15
Tip, percent	15
Span, ft	6.135
Vertical tail:	
Total area, sq ft	47.205
Rudder, sq ft	7.065
Span, ft	9.150
Airfoil section	NACA 65A012

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE RYAN X-13 AIRPLANE AND FOR THE LOADING TESTED ON THE MODEL

[Values given are full-scale, and moments of inertia are given about the c.g.]

Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-feet^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	Altitude, 25,000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values											
Normal weight - full fuel with wheels	6,958	0.3212	-0.0767	22.65	50.57	1727.5	4325.7	5109.3	-273×10^{-4}	-82×10^{-4}	355×10^{-4}
Normal weight - full fuel with hook	6,696	.3251	-.0884	21.81	48.70	1543.0	4042.0	4832.7	-272	-86	359
Landing weight - 25 percent fuel with wheels	5,908	.3232	-.0472	19.19	42.85	1254.8	4137.7	4747.8	-357	-76	433
Landing weight - 25 percent fuel with hook	5,646	.3317	-.0630	18.35	40.97	1108.1	3902.6	4482.0	-362	-75	437
Minimum weight - 5 percent fuel with wheels	5,628	.3236	-.0423	18.35	40.97	1157.6	4116.7	4651.7	-383	-70	453
Minimum weight - 5 percent fuel with hook	5,366	.3281	-.0554	17.40	38.87	981.5	3819.7	4353.5	-388	-73	461
Model values											
Normal gross weight with hook	6,730	.2954	-.0758	21.91	48.93	1644	4064	4298	-263	-25	288

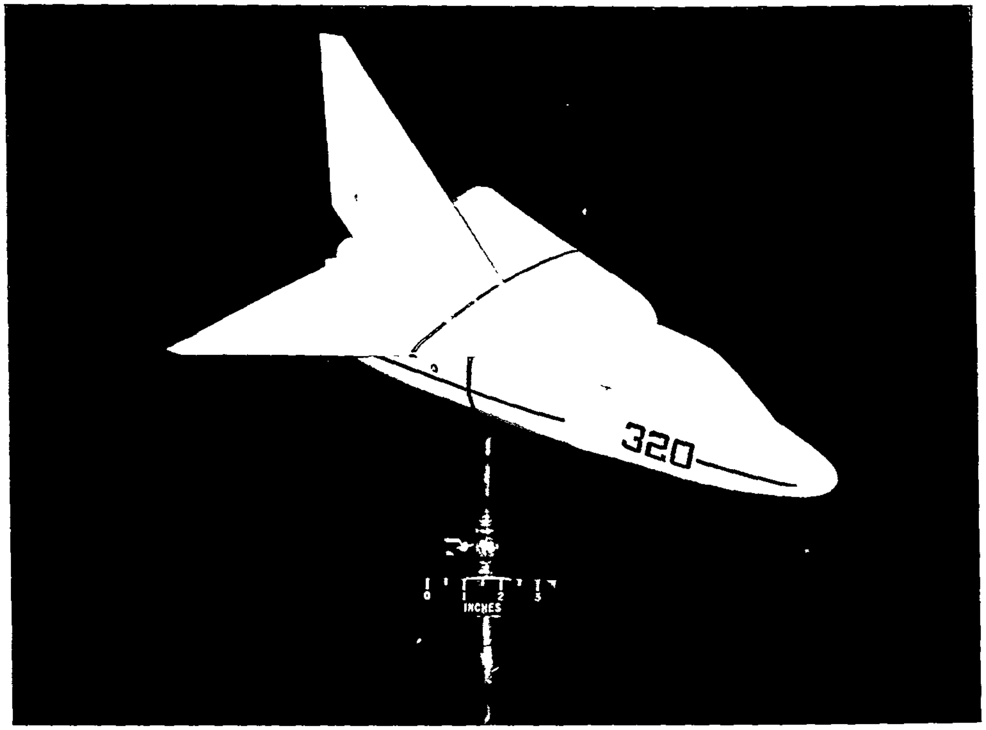
TABLE III.- SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH 1/18-SCALE MODEL

OF THE RYAN X-13 AIRPLANE

[Normal gross-weight loading with center of gravity at 29.1 percent of the mean aerodynamic chord; rudder fixed full with the spin and recovery attempted by opening the parachute only; model values converted to corresponding full-scale values]

Hemishperical parachute in projected diameter, ft	Drag coefficient, C_D	Towline length, ft	Ailerons	Elevators	V, ft/sec	α, deg	Ω, rev/sec	Turns for recovery	Remarks
Right erect spins									
11.25	[a]1.13	[b]5.1	Right 5.8° down Left 5.8° up	15° up	251	68.8	0.507	$2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{3}{4}$	Model recovers in glide
12.75	[a]1.11	[c]5.1	Right 5.8° down Left 5.8° up	15° up	251	68.8	.507	$1\frac{3}{4}$, 2, 2, $2\frac{1}{4}$	Model recovers in glide
12.75	[a]1.11	[c]0	Right 5.8° down Left 5.8° up	15° up	251	68.8	.507	2, 2, 2, $2\frac{1}{4}$	Model recovers in glide
Inverted spin to pilot's right									
12.75	[a]1.11	[c]0	[d]Right 17.5° up Left 17.5° down	[d]22.5° up	251	66.1	.53	1, $\frac{1}{4}$, $\frac{1}{4}$, 1	Model recovers in erect glide

[a]Based on projected diameter.
[b]Shroud-line length is 30.8 feet.
[c]Shroud-line length is 34.5 feet.
[d]Control settings are with respect to the airplane.



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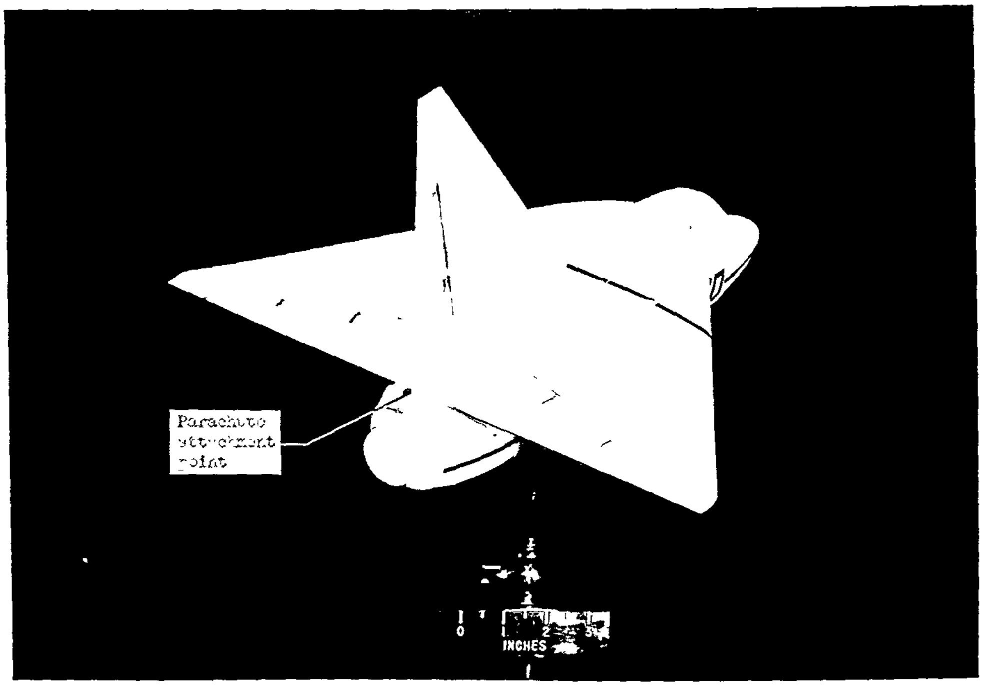

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Figure 1.- Photograph of Ryan X-13 airplane model showing normal testing configuration and point of attachment of parachute.