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MEMORANDUM

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U. S. Air Force

FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/17-SCALE MODEL OF THE CESSNA T-37A AIRPLANE

COORD. NO. AF-AM-42

By James S. Bowman, Jr., and Frederick M. Healy

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
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ABSTRACT

Results of an investigation of a dynamic model in the Langley 20-foot free-spinning tunnel are presented. Erect spin and recovery characteristics were determined for a range of mass distributions and center-of-gravity positions. The effects of lateral displacement of the center of gravity, engine rotation, nose strakes, and increased rudder area were investigated.

INDEX HEADINGS

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SUMMARY

An investigation has been made in the Langley 20-foot free-spinning tunnel to determine the erect spin and recovery characteristics of a 1/17-scale model of the Cessna T-37A airplane.

The model results indicate satisfactory spin-recovery characteristics for the airplane. The optimum spin-recovery technique for any spins encountered by the airplane will be full rudder reversal followed approximately one-half turn subsequently by downward movement of the elevator.

Gyroscopic effect of engine rotation, replacing the normal partial-length rudder with a full-length rudder, removal of the strakes, or moderate longitudinal or lateral displacement of the center-of-gravity should have little significant influence on the spin and recovery characteristics of the airplane.

INTRODUCTION

At the request of the U. S. Air Force, an investigation has been made of a 1/17-scale model of the Cessna T-37A airplane in the Langley 20-foot free-spinning tunnel. The T-37A is a light midwing training airplane with twin jet engines.

The erect spin and recovery characteristics of the model were determined for the 25-percent-fuel loading, the 75-percent-fuel loading, and the 75-percent-fuel loading with the moments of inertia in roll and pitch increased approximately 20 percent. The effects of varying center-of-gravity position both longitudinally and laterally were determined. The influence of the gyroscopic moments of the rotating engine components on spins and recoveries was also investigated. The model was tested with and without longitudinal strakes on the nose, and with the span of the rudder extended to the lower fuselage contour.

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SYMBOLS

b	wing span, ft
S	wing area, sq 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
$z/\bar{c}$	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, fps
Ω	full-scale angular velocity about spin axis, rps

MODEL AND TESTING TECHNIQUES

The 1/17-scale model of the Cessna T-37A was constructed at the Langley Research Center of the National Aeronautics and Space Administration. A three-view drawing of the model as tested is shown in figure 1. A modified rudder configuration investigated is shown in figure 2. A photograph of the model is shown in figure 3. The dimensional characteristics of the airplane are presented in table I.

The mass characteristics for the loadings of the airplane and for the loadings tested on the model are presented in table II. The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 27,000 feet ($\rho = 0.000992$ slug/cu ft).

A remote control mechanism was installed in the model to actuate the controls for the recovery attempts. Sufficient torque was exerted on the controls for the recovery attempts to reverse them fully and rapidly.

The following normal maximum control deflections (measured perpendicular to the hinge lines) were used during the test program:

Rudder, deg:	
Right	25
Left	25
Elevator, deg:	
Up	25
Down	10
Ailerons, deg:	
Up	15
Down	15

General descriptions of model testing techniques, methods of interpreting test results, and correlation between model and airplane results are presented in reference 1.

The following techniques are included in the presentation of the data on the charts: For spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as greater than the velocity at the time the model hit the safety net; for example, >300 feet per second, full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude. For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as greater than the number of turns from the time the controls are moved to the time the model strikes the net, as >3. A >3 turn recovery, however, does not necessarily indicate an improvement over a >7 turn recovery. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin."

RESULTS AND DISCUSSION

The results of the model tests are presented in charts 1 and 2. Spins to the pilot's right and left were similar, and the data are arbitrarily presented in terms of right spins.

Effect of Mass Distribution

The model was tested with three conditions of mass distribution simulated: 25 percent fuel, 75 percent fuel, and 75 percent fuel with the moments of inertia in roll and pitch increased approximately 20 percent (referred to as 75 percent fuel with increased inertias).

The results of tests with 25 percent fuel (loading 1 in table II) are presented in chart 1. As indicated in the chart, the recovery characteristics are satisfactory. Recoveries from spins encountered in this loading should be attempted by full rapid rudder reversal with the stick maintained laterally neutral. Premature forward movement of the stick may result in a spin with a higher rotational rate and slower recoveries. Therefore, the stick should not be moved forward until the spin rotation has stopped or decreased appreciably, at least one-half turn following rudder reversal.

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The results of tests with 75 percent fuel (loading 3 in table II) are presented in chart 2. In this loading, mass is concentrated heavily along the wings. The spin and recovery characteristics of the T-37A model with 75 percent fuel and also with 75 percent fuel with increased inertias (not presented in chart form) are typical of airplanes with this type of mass distribution; that is, movement of elevator down assists recovery, and ailerons deflected with the spin tend to retard recovery (ref. 2). Satisfactory model recoveries were obtained by rudder reversal and simultaneous movement of elevator down from the criterion spin with 75 percent fuel (chart 2). This technique was also effective for 75 percent fuel with increased inertias. The effectiveness of the rudder is reduced by shielding when the elevator is down in an erect spin. Therefore, when downward movement of the elevator is used during a spin-recovery attempt, the rudder should be fully reversed prior to initiating elevator movement. The control technique recommended for recovery from spins of the airplane with 75 percent fuel or 75 percent fuel with increased inertias is rudder reversal to full against the spin followed approximately one-half turn subsequently by downward movement of the elevator.

Effect of Center of Gravity

The model was tested for the 75-percent-fuel loading with increased inertias with the center of gravity at 25 percent, 29 percent, and 35 percent of the mean aerodynamic chord. The results are not presented in chart form. At the most forward center-of-gravity position (25 percent $\bar{c}$), two spin conditions were usually observed for the same control disposition, that is, a steep spin and a flat spin. Recoveries from the flat spin were generally unsatisfactory which may possibly be attributed to a generally increased rate of rotation for these spins. No other significant differences in spin and recovery characteristics were noted for the range of center-of-gravity positions investigated.

Lateral Unbalance

Moderate values of lateral unbalance (approx. 27,500 inch-pounds, full scale) were tested on the model with 25 percent fuel and 75 percent fuel (lateral unbalance of 8.4 and 6.8 percent $\bar{c}$, respectively). Extreme lateral unbalance (approximately 62,500 inch-pounds or 15.6 percent $\bar{c}$, full scale) was tested with 75 percent fuel with increased inertias. These results are not presented in chart form. At the moderate values of lateral unbalance, little effect was observed on the spin and recovery characteristics of the model with either the inner wing or the outer wing heavy. Extreme lateral unbalance indicated adverse effects on recovery characteristics with the inner wing heavy. It is recommended that extreme lateral displacement of the center of gravity be avoided on the airplane.

Gyroscopic Effect of Engine Rotation

The angular momentum of the rotating components of the engines at 21,000 rpm was simulated by a flywheel mounted on the model. Clockwise and counterclockwise rotation of the flywheel was investigated in both left and right spins. The results (not presented in chart form) indicate that there was little influence on the spin and recovery characteristics of the model for either sense of flywheel rotation.

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Effect of Strakes

To evaluate the influence of the strakes on the spin characteristics of the model, brief tests were made (results not presented) with the strakes removed. These strakes were normally fixed on the nose of the model. Removal of the strakes had a tendency to increase the rate of rotation slightly but had no appreciable effect on recovery characteristics.

Rudder Modification

During most of the model test program, a partial-length rudder (the normal rudder for the T-37A) as shown in figure 1 was used. In an attempt to improve the recovery characteristics of the model by use of the rudder alone, brief tests (results not presented) were also made with the rudder extended to the lower fuselage contour (fig. 2). The results were somewhat inconsistent but, in general, there appeared to be little difference in spin recovery characteristics with either the partial-length or the full-length rudder installed.

SUMMARY OF RESULTS

From a free-spinning tunnel investigation of a 1/17-scale model of the Cessna T-37A airplane, the following results are considered applicable to the spin and recovery characteristics of the airplane at 27,000 feet:

1. The spin-recovery characteristics will be satisfactory. The control movement most conducive to recoveries from any spins encountered with the airplane will be full rudder reversal to against the spin followed approximately one-half turn subsequently by downward movement of the elevator.

2. Engine rotation, increasing the span of the rudder, removal of the strakes, or moderate longitudinal or lateral displacement of the

center of gravity should have little effect on the spin and recovery characteristics of the airplane.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., December 12, 1958.

REFERENCES

1. Neihouse, Anshal I., Klinar, Walter J., and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NACA RM L57F12, 1957.

2. 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.)

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TABLE I

DIMENSIONAL CHARACTERISTICS OF THE CESSNA T-37A AIRPLANE

Overall length, ft	29.28
Wing:	
Span, ft	33.78
Area, sq ft	183.9
Root chord, in.	79.37
Tip chord, in.	53.97
Mean aerodynamic chord, in.	67.0
Leading edge of $\bar{c}$ rearward of leading edge of root chord, in.	2.78
Aspect ratio	6.23
Taper ratio	0.68
Dihedral, deg	3
Incidence, deg -	
Root	3
Tip	1
Airfoil section -	
Root	NACA 2418
Tip	NACA 2412
Ailerons:	
Total area, sq ft	11.30
Span of one aileron, percent of b/2	36.2
Horizontal tail:	
Span, ft	13.96
Area, sq ft	46.57
Root chord in.	54.20
Tip chord, in.	29.03
Aspect ratio	4.18
Dihedral, deg	0
Airfoil section -	
Root	NACA 0010 (modified)
Tip	NACA 0010 (modified)
Vertical tail:	
Height, ft	4.80
Total area (including dorsal), sq ft	17.78
Rudder area (behind hinge line), sq ft	5.86
Tip chord, in.	32.40
Aspect ratio	1.30
Airfoil section -	
Root	NACA 0010 (modified)
Tip	NACA 0009 (modified)

TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE CESSNA T-37A AIRPLANE AND FOR LOADINGS TESTED ON THE 1/17-SCALE MODEL

[Values given are full scale, and moments of inertia are given about the center of gravity]

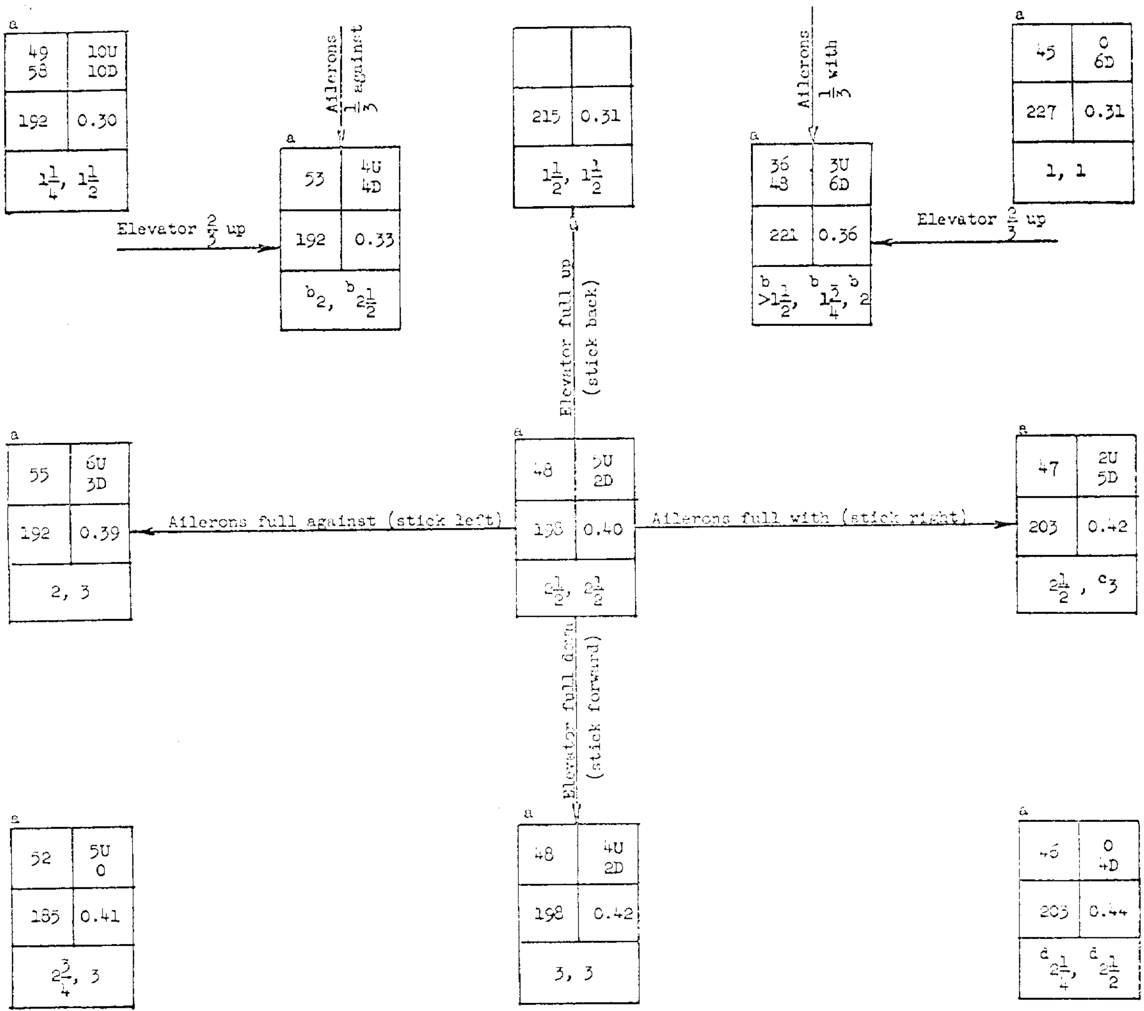
Loading		Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
			$x/\bar{c}$	$z/\bar{c}$	Sea level	27,000 ft	I_X, slug-ft^2	I_Y, slug-ft^2	I_Z, slug-ft^2	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
						Airplane						
1	25 percent fuel	4,907	0.282	-0.129	10.28	24.67	3,042	3,833	6,578	-46×10^{-4}	-158×10^{-4}	204×10^{-4}
2	50 percent fuel	5,422	.289	-.133	11.37	27.26	4,238	3,856	7,789	20	-205	185
3	75 percent fuel	5,937	.294	-.135	12.46	29.86	5,873	3,877	9,444	95	-265	170
						Model						
1	25 percent fuel	4,909	0.288	-0.116	10.32	24.75	3,298	4,158	6,889	-50×10^{-4}	-157×10^{-4}	207×10^{-4}
3	75 percent fuel	6,019	.291	-.106	12.66	30.35	6,632	4,729	10,676	89	-279	190
4	75 percent fuel with increased inertias	5,978	.296	-.085	12.59	30.19	7,746	5,656	12,596	98	-327	229

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITH 25-PERCENT-FUEL LOADING

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane: T-37A	Attitude: Erect	Spin direction: simulated Right	Loading 1 (see table II): 25 percent fuel	Strakes on
Slats ---	Altitude: 27,000 ft		Desired center-of-gravity position ± 28.8 percent $\bar{c}$	

Model values converted to full scale U-inner wing up D-inner wing down



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[a] Oscillatory spin, range of values given.
[b] Recovery attempted by reversing rudder from full with to 2/3 against the spin.
[c] Visual estimate.
[d] Recovered in an inverted dive.

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE

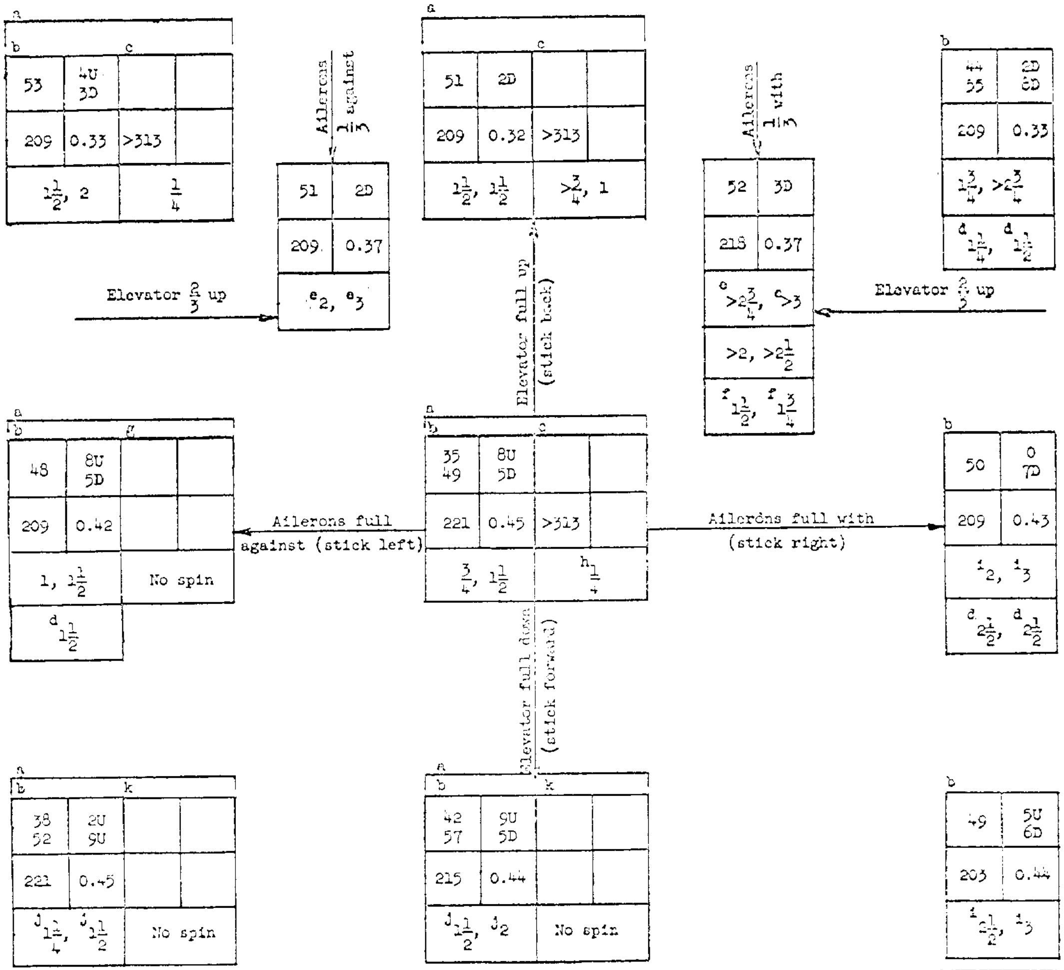
MODEL WITH 75-PERCENT-FUEL LOADING

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane: T-37A	Attitude: Erect	Spin direction simulated: Right	Loading 3 (see table II): 75 percent fuel	Strakes on
Slats ---	Altitude: 27,000 ft		Desired center-of-gravity position: 29.1 percent $\bar{c}$	

Model values converted to full scale

U-inner wing up D-inner wing down



α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

[a] Two conditions possible.
[b] Oscillatory spin, range of values given.
[c] Steep spin; recovery attempted before final attitude attained.
[d] Recovery attempted by simultaneous full rudder reversal and movement of elevator to full down.
[e] Recovery attempted by reversing rudder from full with to 2/3 against the spin.
[f] Recovery attempted by simultaneous reversal of rudder to 2/3 against the spin and movement of elevator to 2/3 down.
[g] Model entered a dive.
[h] Visual estimate.
[i] Recovered in a slowly rolling inverted dive.
[j] Recovered in an inverted dive.
[k] Model entered an inverted dive.

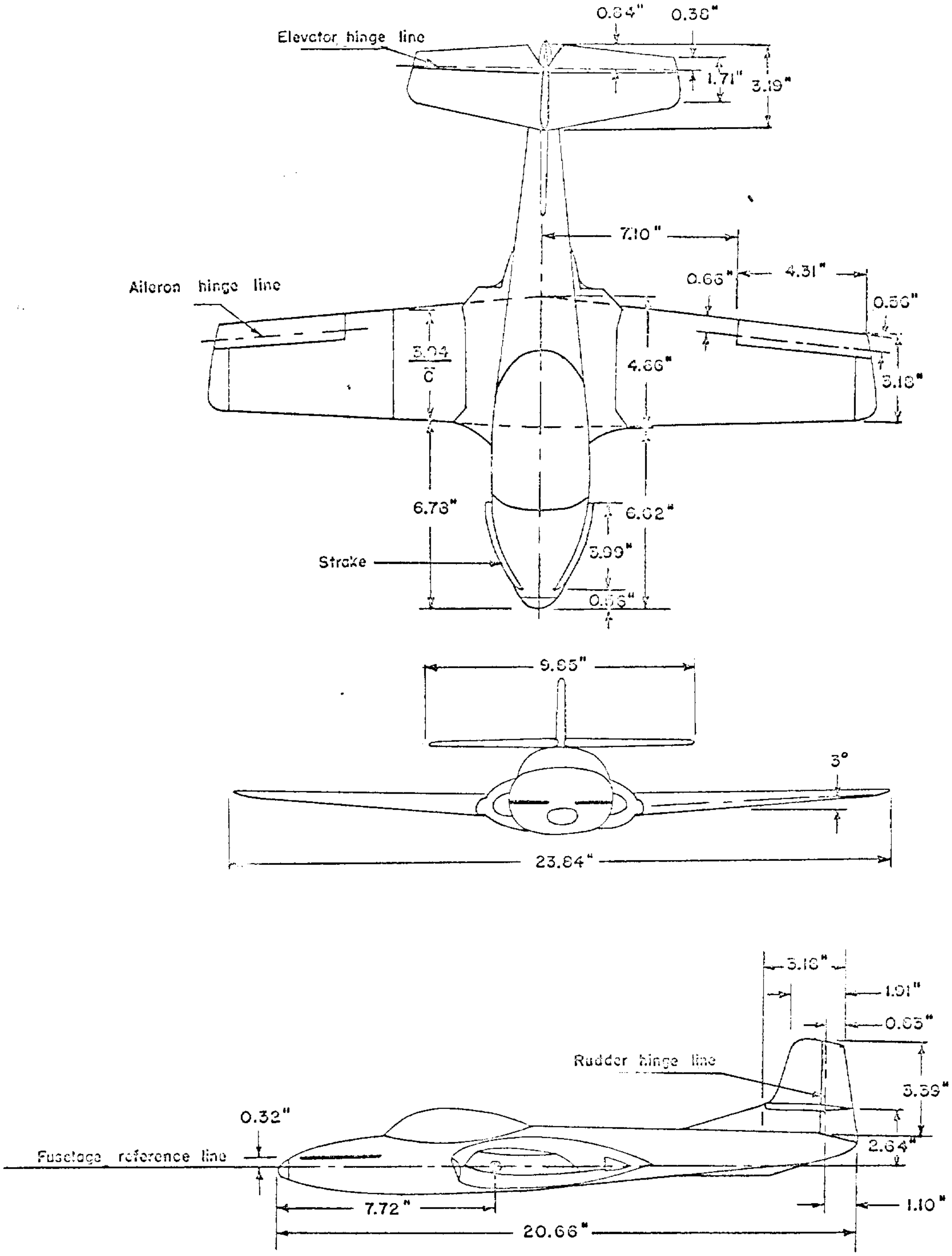


Figure 1.- Three-view drawing of the 1/17-scale model of the Cessna T-37A airplane. Center-of-gravity position indicated is for the 75-percent fuel loading.

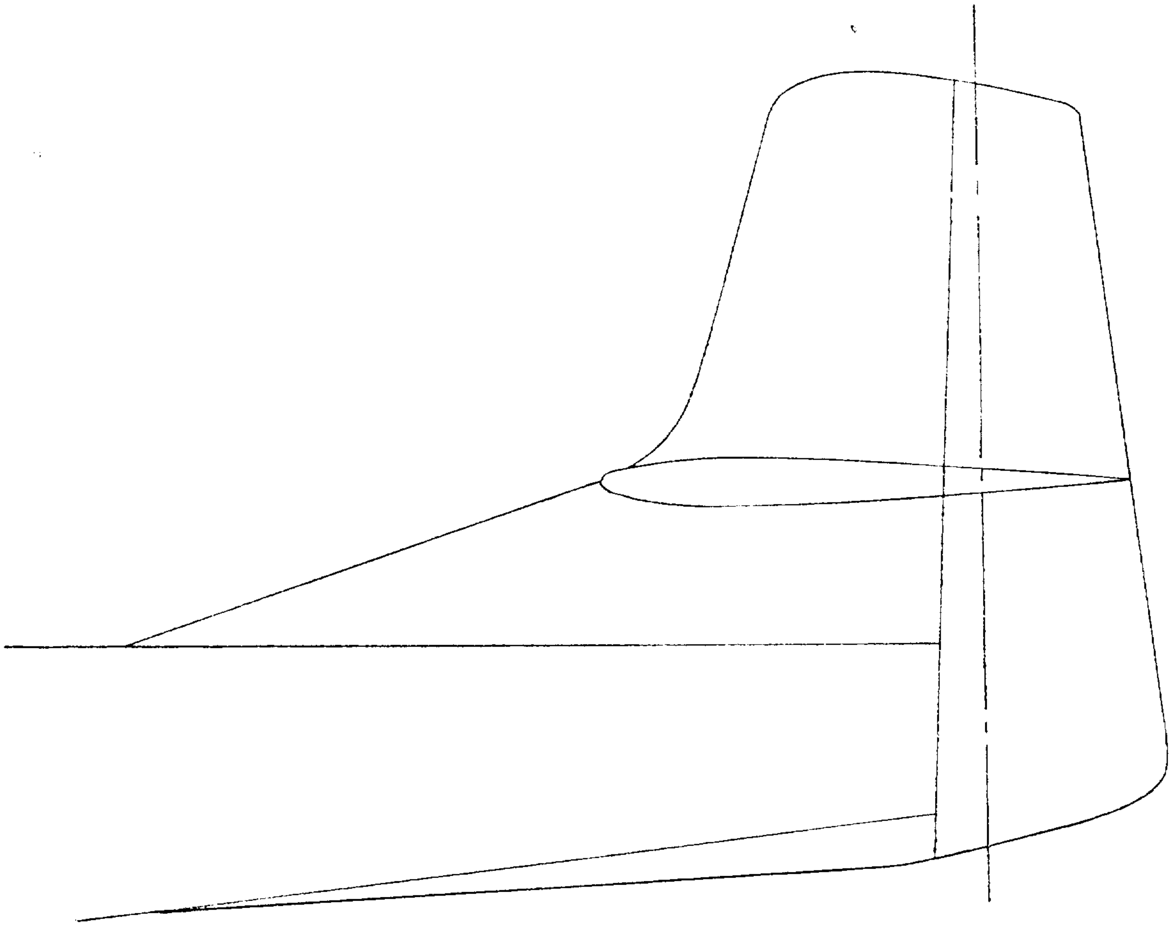


Figure 2.- Modified rudder tested on 1/17-scale Cessna T-37A model.

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Figure 3.- Photograph of the 1/17-scale model of the Cessna T-37A airplane.