25p

Copy 31

DECLASSIFIED [redacted]

P-25

NASA TECHNICAL MEMORANDUM

NASA TM SX-964

FOR

BUREAU OF WEAPONS,
DEPARTMENT OF THE NAVY

~~4-15006~~

(NASA-TM-SX-964) SPIN-TUNNEL INVESTIGATION OF A 1/28-SCALE MODEL OF A SUBSONIC ATTACK AIRPLANE (NASA) 25 p LIMIT USGA

X94-71135

Unclas

Restriction/Classification Cancelled

Cat 05

Z9/04 0208346

DECLASSIFIE
Authority:
memo dated

NASA TM SX-964

SPIN-TUNNEL INVESTIGATION OF A 1/28-SCALE MODEL OF A SUBSONIC ATTACK AIRPLANE

TED NO. NACA AD 3156 (U)

by Henry A. Lee and Frederick M. Healy

Langley Research Center
Langley Station, Hampton, Va.

DECLASSIFIED: Effective 2-5-65
Authority: F.G. Drobka (ATSS-A
memo dated 3-25-65: AFSDO-5197

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JULY 1964

[redacted]

~~CONFIDENTIAL~~

DECLASSIFIED

ABST IN BACK

TECHNICAL MEMORANDUM SX-964

for the

Bureau of Weapons, Department of the Navy

SPIN-TUNNEL INVESTIGATION OF A 1/28-SCALE MODEL OF A SUBSONIC ATTACK AIRPLANE

TED NO. NACA AD 3156

By Henry A. Lee and Frederick M. Healy

Langley Research Center
Langley Station, Hampton, Va.

GROUP 4
Downgraded at 3 year intervals;
declassified after 12 years

[redacted]

REVIEW COPY
This interim draft is for the official use of the initial recipient only.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

L-3839

~~CONFIDENTIAL~~

TECHNICAL MEMORANDUM SX-964

for the

Bureau of Weapons, Department of the Navy

SPIN-TUNNEL INVESTIGATION OF A 1/28-SCALE MODEL OF A SUBSONIC ATTACK AIRPLANE

TED NO. NACA AD 3156

By Henry A. Lee and Frederick M. Healy

SUMMARY

An investigation has been made in the Langley spin tunnel to determine the erect- and inverted-spin and recovery characteristics of a 1/28-scale dynamic model of a subsonic attack airplane.

The model results indicate that recovery from erect spins should be attempted by use of the extended control deflections provided on the airplane especially for spin recovery. The optimum spin recovery technique recommended for the flight design gross weight loading is rudder reversal to against the spin with the longitudinal control maintained at full up until recovery appears imminent. Even with this optimum recovery technique, however, recoveries are likely to be marginal for the clean condition. With full internal fuel and empty external fuel tanks, the rudder should be reversed to full against the spin and the slats and flaps extended simultaneously, the longitudinal control being maintained full up until recovery appears imminent.

Inverted-spin recovery should be attempted by rudder reversal to full against the spin with the lateral control maintained neutral and the longitudinal control maintained full up (stick forward) until recovery appears imminent.

Satisfactory recoveries from emergencies encountered during spin-demonstration flights should be obtained by either deploying a parachute 23.3 feet in diameter (laid out flat) with a drag coefficient of 0.65, shroud lines 31.5 feet long, attached to the airplane tail with a 51-foot towline; or by firing rockets which provide an antispin yawing moment of about 65,000 foot-pounds.

INTRODUCTION

At the request of the Bureau of Weapons, Department of the Navy, an investigation has been made of a 1/28-scale model of the Grumman A-6A airplane (formerly designated A2F-1) in the Langley spin tunnel. The A-6A is a subsonic attack airplane with swept wings and twin jet engines.

The erect spin and recovery characteristics of the model were determined for the flight design gross weight loading and for a loading with full internal fuel and empty external wing fuel tanks. The effects of extending slats and deflecting flaps were investigated. Inverted-spin and recovery characteristics of the model were determined for the flight design gross weight loading. The size of the spin-recovery tail parachute necessary to insure satisfactory spin recovery was determined, and the effect of firing wing-mounted rockets during spins was investigated.

An appendix includes a general description of the model testing technique, information on the precision with which model test results and mass characteristics are determined, and a general comparison of dynamic-model and full-scale spin tests, based on past experience with other designs.

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 fuselage reference line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-foot^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	airplane relative density coefficient, $\frac{m}{\rho Sb}$
α	angle between fuselage reference line and vertical (approx. equal to absolute value of angle of attack at plane of symmetry), deg
ϕ	angle between spin axis and horizontal, deg
V	full-scale true rate of descent, fps
Ω	full-scale angular velocity about spin axis, rps

MODEL

The 1/28-scale model of the test airplane was furnished by the Bureau of Weapons, Department of the Navy, and was prepared for testing by the Langley Research Center of the National Aeronautics and Space Administration. A three-view drawing of the model tested is shown in figure 1.

During the model test program the all-movable horizontal tail of the airplane was moved rearward a distance of 16 inches and the chord of the rudder was increased. The corresponding model modifications are shown in figures 1 and 2. A photograph of the model, with the original horizontal-tail position and the original rudder, is shown in figure 3. 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 30,000 feet ($\rho = 0.000889$ slug/cu ft). The mass characteristics and inertia parameters for the loadings of the airplane and for the loadings tested on the model are presented in table II. 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 airplane longitudinal control and rudder deflections are designated as "normal" for the cruise condition or "extended" for the approach condition (slats and flaps extended). Extended deflections are also available for spin-recovery application.

The control deflections (measured perpendicular to the hinge lines) used for the control surfaces and flaps during the test program were:

Rudder deflection:	
Normal, deg	10 right, 10 left
Extended, deg	35 right, 35 left
Lateral control deflection, deg	55 up, 0 down
Longitudinal control deflection:	
Normal, deg	9.6 up, 5 down
Extended, deg	24 up, 5 down
Single slotted flaps, deg	0, 40 down

The "criterion spin," for which deflections other than those indicated are used, is discussed in the appendix.

MODEL ROCKETS

The model rockets used in this investigation were designed and developed by the Langley Research Center. The rockets are precision built and made of steel. A typical thrust-time curve showing the characteristics of the rocket is shown in figure 4. The rockets were designed to produce approximately 3 ounces of thrust for 2 seconds. Based on the simulated test altitude (30,000 ft) and scale of the model used in the present investigation, the full-scale equivalent of 3 ounces of thrust is 1,539 pounds and the corresponding full-scale thrust duration is 10.5 seconds. A more detailed description of this rocket is given in reference 1.

TESTS, RESULTS, AND DISCUSSION

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

Erect Spins

Three rudder configurations were investigated during the model test program. (See fig. 2.) Test results indicated that the original rudder (least area) and a larger rudder (intermediate area) were both inadequate to assure consistently satisfactory recoveries from erect spins of the model. Therefore, all data presented for erect spins are for the final tail configuration.

In an attempt to improve the spin-recovery characteristics by decreasing the rate of rotation of the model, the effects of various ventral fins were evaluated. (See fig. 2.) Very little influence on the recovery characteristics of the model was observed from any of the fins tested; therefore, no results with ventral fins are presented.

Flight design gross weight loading.- The results of tests of the model with the final tail configuration and with the flight design gross weight loading (loading 1 in table II) are presented in table III. The lateral controls used on the airplane (upper surface slotted spoilers) were found to have very little influence on spin and recovery characteristics; therefore, only spins with lateral controls neutral are presented.

Normal longitudinal control deflection: Tests made with the normal longitudinal control deflection (trailing edge 9.6° up) included the clean and approach configurations. For the clean configuration (maximum rudder deflection, 10°), recoveries attempted by deflecting the rudder to full against the spin were unsatisfactory and, even by increasing the maximum rudder movement to 25°, the recoveries were still unsatisfactory. For the approach configuration (maximum rudder deflection, 35°), results were similar. These model results included tests made with the criterion rudder deflection only, that is, recovery attempts were made by reversing the rudder from full with to 2/3 full against the spin, and these results were unsatisfactory. Unsatisfactory recovery characteristics, therefore, are indicated for both normal and extended rudder throws for the normal longitudinal control condition.

Extended longitudinal control deflection: Tests made with the extended longitudinal control deflection (trailing edge 24° up) included the clean and approach configurations. For the clean configuration (maximum rudder deflection, 10°) unsatisfactory recovery characteristics were obtained by full rudder deflection. Recovery characteristics were still considered marginal by full rudder movement when the maximum rudder deflection was increased to 25°. Satisfactory recoveries were obtained on the model when the rudder was moved to a full 35° deflection. However, even though satisfactory recoveries were obtained, the recovery characteristics are still considered marginal since the final results are based on the criterion rudder deflection of 2/3 maximum. (See appendix.)

For the approach configuration (maximum rudder deflection ±35°), only the criterion rudder deflections were investigated; that is, recovery attempts were made by reversing the rudder from full with to 2/3 full against. Satisfactory recovery characteristics were obtained in this manner when the longitudinal control was full up (24°).

Recoveries from model spins were also obtained by simultaneously reversing the rudder to the normal (10°) deflection against the spin and rapidly extending upper and lower wing-tip speed brakes on both wings. (These results are not presented.) However, wing-tip speed brakes on the airplane are deflected at a relatively slow rate, and their deflection would probably not be as effective on the full-scale airplane as on the model.

Recommended recovery technique: Based on the foregoing results of the model spin tests, the optimum technique recommended for attempting recovery from erect spins of the airplane in the flight design gross weight loading is the use of extended control deflections, with the rudder reversed to full against the spin and the longitudinal control maintained at full up (stick back) until recovery appears imminent. The pilot should then apply stick as required to regain normal flight.

It should be reiterated, however, that recoveries with this optimum technique are likely to be marginal for the clean condition.

Full-internal fuel and empty external fuel tanks.- Spin test results with the model ballasted to represent the airplane with full-internal fuel and empty external fuel tanks (loading 4 in table II) and with the final tail configuration are presented in table IV. For these tests, four simulated 300-gallon wing fuel tanks were installed on the model as shown in figure 1. Extended rudder control deflections were used for all of these tests.

The results presented in table IV indicate that the model in the clean configuration would not recover from spins satisfactorily by reversal of rudder alone with the longitudinal control up 16° or 24°. Recoveries attempted from spins in the approach condition indicate a substantially better spin recovery, but it appears possible that the recovery characteristics may not be consistently satisfactory.

Information presented in references 2 and 3 indicates that extension of slats generally provides a favorable effect on spin recovery for designs in the category of the full-scale airplane and that the effect of extended flaps is generally unfavorable. Therefore, if slat extension independent of flap deflection is possible on the airplane, the extension of slats in conjunction with rudder reversal would be helpful in spin-recovery attempts.

Based on the results of the model tests, satisfactory recovery may not be possible from spins of the airplane with full internal fuel and empty external wing fuel tanks. If inadvertent spins are encountered, however, recovery should be attempted by use of extended control deflections with the rudder reversed to full against the spin and with simultaneous extension of the slats and flaps. The longitudinal control should be maintained at full up until recovery appears imminent. The pilot should then apply stick as required to regain normal flight.

Inverted Spins

The results of model inverted-spin tests in the flight design gross weight loading (loading 1 in table II) are presented in chart 1. For inverted spins, the "controls-crossed" condition for the developed spin (right rudder pedal forward and stick to the pilot's left for a spin to the pilot's right) is presented to the right of the chart and the "stick back" condition is presented at the bottom of the chart. Controls-crossed conditions were presented because when the controls are crossed in the developed spin, the lateral controls aid the rolling motion which has a favorable effect on recovery for airplanes in which the loading is distributed predominantly along the fuselage. The angle ϕ and the longitudinal control position in the chart (and text) are given as up or down relative to the ground.

The inverted-spin tests were made with the horizontal tail in the original (forward) position and with the original rudder (least area). (See figs. 1 and 2.) It is considered that the changes in tail geometry of the final model version would have little significant influence on inverted-spin characteristics.

The results of the model inverted-spin investigation indicate that satisfactory recoveries were obtained for all spins except those for which the longitudinal control was down (stick back). On the basis of the model results, the recovery technique recommended for airplane inverted spins is rudder reversal to full against the spin with the stick maintained laterally neutral. The stick should be maintained full forward until recovery appears imminent. The pilot should then apply stick as required to regain normal flight.

Spin-Recovery Parachute Tests

The results of model tests made to determine the size of tail parachute required to give satisfactory recoveries of the airplane during the emergencies in spin demonstrations are presented in table V. The diameter given for the parachute canopies in the table is the laid-out-flat diameter, the drag coefficient is based on laid-out-flat area, and the shroud-line lengths are 1.35 times canopy diameter. The tail boom to which the parachute towline was attached for some of the parachute recovery tests is shown in figure 1. It was determined that this modification had no significant effect on the developed spin and recovery characteristics of the model.

The data of table V show that a flat-type stable parachute of a diameter of 23.3 feet with a drag coefficient of approximately 0.65 and a towline length of 51 feet should be adequate for recoveries from spins with either the flight design gross weight loading (loading 1 in table II) or full internal fuel and empty external fuel tanks (loading 4 in table II).

If a parachute with a different drag coefficient is used, a corresponding adjustment should be made in canopy size. The results of table V also indicate that variations in tail geometry, towline attachment point, control deflections, and slat and flap configuration had little influence on the spin-recovery characteristics of the model.

Spin-Recovery Rocket Tests

The results of tests to evaluate the use of rockets for emergency recovery from demonstration spins are presented in table VI. The rockets were mounted on the wings at various distances from the model center line to provide the yawing moments indicated in the table.

The results of the tests indicate that the effectiveness of the applied yawing moment due to rocket thrust is dependent on the orientation of the rocket thrust line with respect to the fuselage reference line. The maximum inclination of the principal axes to the body axes on this airplane was about 5°. With the thrust lines of the rockets parallel to the fuselage reference line of the model, which results in a rolling-moment component about the principal longitudinal axis against the spin, satisfactory recoveries were not obtained. Satisfactory recoveries were obtained, however, when the rocket thrust axis was tilted as much as or more than the inclination of the principal axis.

As indicated in table VI, satisfactory recoveries were obtained at inclinations of either 5° or 10° by the application of approximately 65,000 foot-pounds of full-scale yawing moment.

SUMMARY OF RESULTS

From a spin-tunnel investigation of a 1/28-scale model of a subsonic attack airplane at a simulated test altitude of 30,000 feet, the following results are considered to be applicable to the spin and recovery characteristics of the corresponding airplane:

1. Recovery from erect spins should be attempted by utilizing extended control deflections. For spins in the flight design gross weight loading, the rudder should be reversed to full against the spin, the lateral controls should be maintained neutral, and the longitudinal control should be maintained at full up (stick full back) until recovery appears imminent. Even with this optimum recovery technique, however, recoveries are likely to be marginal for the clean condition. With full internal fuel and empty external fuel tanks, the rudder should be reversed to full against the spin, the slats and flaps extended simultaneously, the lateral controls maintained neutral, and the longitudinal control maintained at full up until recovery appears imminent.

2. Satisfactory recovery from airplane inverted spins should be obtained by rudder reversal to full against the spin with the lateral controls maintained neutral. The longitudinal control should be maintained full up (stick forward) until recovery appears imminent.

3. A spin-recovery tail parachute of 23.3-foot diameter (laid out flat) with a drag coefficient of approximately 0.65, a shroud line length of 31.5 feet, and attached to the airplane with a 51-foot towline should be adequate to provide satisfactory spin recovery in emergencies during spin-demonstration flights.

4. Rockets for emergency spin recovery should be mounted with the thrust lines oriented parallel to the principal longitudinal axis of inertia rather than parallel to the body axis. The rockets should provide a full-scale antispin yawing moment of approximately 65,000 foot-pounds for a duration of approximately 11 seconds, full scale, to obtain a satisfactory recovery.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., April 27, 1964.

APPENDIX

TEST METHODS AND PRECISION

General descriptions of model testing techniques used in the Langley spin tunnel, methods of interpreting test results, and correlation between model and airplane results are presented 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 (longitudinal control full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and longitudinal control 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 longitudinal control, or by rapid full reversal of the rudder simultaneously with movement of the lateral controls to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model. (See ref. 2.) 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 longitudinal control is set at either full-up deflection 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, or simultaneous rudder reversal to two-thirds against the spin, and movement of the longitudinal control 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. This control configuration and manipulation is referred to as the "criterion spin," the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. Based on comparison of available full-scale-airplane spin-recovery data with corresponding model test results, recovery characteristics of a model are generally considered satisfactory if recovery is obtained from normal-spinning-control-configuration spins in 2 turns or less, and if, for the criterion spin, turns required for recovery do not increase beyond $2\frac{1}{4}$ turns.

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 to be 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 were moved to the time the model struck 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."

For spin-recovery parachute or rocket tests, the minimum-size tail parachute or minimum moment due to rocket thrust required to effect recovery within $2\frac{1}{4}$ turns from the criterion spin is determined. 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 parachute towline is generally attached to the bottom rear of the fuselage. 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 the band is released, the parachute is 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.

Results determined in spin-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	$\pm\frac{1}{4}$
Turns for recovery obtained visually	$\pm\frac{1}{2}$

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°.

REFERENCES

1. Burk, Sanger M., Jr., and Healy, Frederick M.: Comparison of Model and Full-Scale Spin Recoveries Obtained by Use of Rockets. NACA TN 3068, 1954.

2. Neihouse, Anshal I., Klinar, Walter J., and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NASA TR R-57, 1960. (Supersedes NACA RM L57F12.)

3. Gale, Lawrence J.: Effect of Landing Flaps and Landing Gear on the Spin and Recovery Characteristics of Airplanes. NACA TN 1643, 1948.

TABLE I

DIMENSIONAL CHARACTERISTICS OF THE SUBSONIC ATTACK AIRPLANE

Overall length, ft	54.60
Wing:	
Span, ft	51.00
Area (excluding fillets), sq ft	520.00
Mean aerodynamic chord, in.	132.16
Root chord, in.	182.62
Tip chord, in.	61.99
Taper ratio	0.34
Aspect ratio	5.00
Sweep at 0.25 chord line, deg	25
Incidence, deg	0
Dihedral, deg	-1.0
Airfoil section:	
Wing station 33	NACA 0009 Mod.
Wing station 144	NACA 64A008.4 Mod.
Wing station at tip 306	NACA 64A006 Mod.
Flap area (total), sq ft	101.96
Spoiler area (total), sq ft	50.40
Slat area (total), sq ft	47.40
Horizontal tail:	
Span, ft	20.34
Area, sq ft	120.00
Dihedral, deg	0
Incidence, deg	0
Sweep at 0.25 chord line, deg	30
Root chord, in.	99.40
Tip chord, in.	39.79
Airfoil section	NACA 64A008
Vertical tail:	
Area with original rudder, sq ft	68.40
Sweep at 0.25 chord line, deg	40
Airfoil section:	
Root	NACA 64A009
Tip	NACA 64A006
Rudder area, original, sq ft	10.60

TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE SUBSONIC ATTACK AIRPLANE AND FOR THE LOADINGS TESTED ON THE 1/28-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	30,000 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											
1 (Flight design gross weight; normal center of gravity)	35,051	0.252	0.0242	17.26	46.18	32,143	80,881	106,374	-172×10^{-4}	-90×10^{-4}	262×10^{-4}
2 (Flight design gross weight; most forward center of gravity)	35,051	0.240	0.0287	17.26	46.18	32,254	78,757	104,094	-164×10^{-4}	-89×10^{-4}	253×10^{-4}
3 (Flight design gross weight; most aft center of gravity)	35,051	0.280	0.0287	17.26	46.18	32,355	75,946	101,211	-154×10^{-4}	-89×10^{-4}	243×10^{-4}
4 (Full internal fuel; empty external tanks)	42,805	0.267		21.08	56.36	61,937	95,149	150,437	-96×10^{-4}	-160×10^{-4}	256×10^{-4}
Model											
1 (Flight design gross weight; normal center of gravity)	34,919	0.252	0.0365	17.19	45.97	33,439	88,007	111,437	-194×10^{-4}	-83×10^{-4}	277×10^{-4}
4 (Full internal fuel; empty external tanks)	42,929	0.258	0.0587	21.14	56.53	69,413	102,626	158,361	-96×10^{-4}	-161×10^{-4}	257×10^{-4}

TABLE III

ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE 1/28-SCALE MODEL FOR THE FLIGHT DESIGN GROSS WEIGHT LOADING

[Model loading 1 in table II; model values converted to full scale; U, inner wing up; D, inner wing down]

Condition	Control positions for developed spin			Developed spin characteristics				Rudder deflection for recovery attempts, deg	Turns for recovery	
	Rudder, deg	Lateral control, deg	Longitudinal control, deg	α, deg	ϕ, deg	V, fps	Ω, rps		Recovery attempted by rudder reversal	Recovery attempted by rudder reversal and movement of longitudinal control
Clean	10 with	0	9.6 up	[a]58 74	[a]10U 7D	328	0.31	10 against	$1\frac{1}{4}$, >2, $3\frac{1}{2}$	
Clean	10 with	0	24 up			≈440	0.35	10 against	$\frac{1}{2}$, >2, $2\frac{1}{4}$	
Clean	25 with	0	9.6 up	[a]62 72	[a]7U 8D	[b]309	0.33	25 against	>$4\frac{1}{2}$, >5	
						[b]>381			>$2\frac{1}{2}$, >3	
Clean	25 with	0	24 up	43	[a]4U 6D	[a]394 422	0.34	25 against	$\frac{1}{4}$, $1\frac{1}{2}$, >$2\frac{1}{4}$	[c,d]>$2\frac{1}{2}$, [c,e]3
								35 against	$\frac{1}{4}$, 1, 2	
Slats open; flaps extended	35 with	0	9.6 up	80	5U 2D	[b]275	0.45	[f]23.3 against	$4\frac{1}{4}$, $5\frac{1}{2}$	
						[b]349			1, $1\frac{1}{4}$	
Slats open; flaps extended	35 with	0	16 up	50	[a]5U 8D	349	0.35	[f]23.3 against	1, $1\frac{1}{4}$, $1\frac{1}{2}$	
				No spin						
Slats open; flaps extended	35 with	0	24 up	45	[a]4U 4D	349	0.35	[f]23.3 against	$\frac{3}{4}$, 1, 1	
Slats open	35 with	0	16 up	[a]42 58	[a]4U 5D	403	0.32	[f]23.3 against	$\frac{1}{2}$, [g]2	

[a] Oscillatory spin, range of values given.
[b] Two conditions possible.
[c] Longitudinal control deflected to 5° down for recovery attempts.
[d] Rudder and longitudinal control deflected simultaneously.
[e] Longitudinal control deflected approximately 1 turn after rudder.
[f] Two thirds of full deflection.
[g] Visual estimate.

TABLE IV

ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE 1/28-SCALE MODEL WITH FULL INTERNAL FUEL AND EMPTY EXTERNAL FUEL TANKS

[Model loading 4 in table II, four 300-gallon wing external fuel tanks on; recovery attempted by reversing rudder from full with to 2/3 against the spin; model values converted to full scale; U, inner wing up; D, inner wing down]

Condition	Control positions for developed spin			Developed spin characteristics				Rudder deflection for recovery attempts, deg	Turns for recovery
	Rudder, deg	Lateral control, deg	Longitudinal control, deg	α, deg	ϕ, deg	V, fps	Ω, rps		
Clean	35 with	0	16 up	[a]39 54	[a]8U 12D	403	0.35	23.3 against	>2,>3
Clean	35 with	0	24 up	45	[a]8U 7D	413	0.33	23.3 against	>2
Slats open; flaps extended	35 with	0	24 up	49	[a]9U 9D	349	0.34	23.3 against	$1\frac{1}{4}$, $1\frac{1}{2}$, $2\frac{1}{4}$

[a] Oscillatory spin, range of values given.

TABLE V

SPIN-RECOVERY TAIL-PARACHUTE DATA OBTAINED WITH THE 1/28-SCALE MODEL OF A SUBSONIC ATTACK AIRPLANE

[Erect spins to pilot's right; recovery attempted by opening tail parachute; drag coefficient of parachute approx. 0.65; model values converted to corresponding full-scale values]

Loading (see table II)	Tail configuration	Slats and flaps	Canopy diameter, ft	Towline length, ft	Control deflections, deg			Turns for recovery
					Rudder	Lateral controls	Longitudinal controls	
1	Original	Retracted	14.0	[a]51	25 with	0	15 up	[b]>5, [b]>6
1	Original	Retracted	18.7	[a]51	25 with	0	15 up	>1, 2, >3, >4
1	Original	Retracted	21.0	[a]51	25 with	0	15 up	$2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{1}{2}$, $2\frac{1}{2}$, $2\frac{1}{2}$, $>4\frac{1}{2}$
1	Original	Retracted	22.2	[a]51	25 with	0	15 up	$1\frac{1}{4}$, $1\frac{3}{4}$, 2, 2, 2, $2\frac{1}{4}$, $2\frac{3}{4}$
1	Original	Retracted	22.2	[c]51	25 with	0	15 up	$1\frac{1}{2}$, $1\frac{3}{4}$, 2, 2, 2
1	Final	Retracted	23.3	[c]51	7 with	0	9.6 up	$\frac{1}{2}$, $\frac{3}{4}$, $\frac{3}{4}$, 1, 1, $1\frac{1}{4}$, $1\frac{1}{4}$, $1\frac{1}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{1}{2}$, $1\frac{1}{2}$, 2
1	Original	Retracted	23.3	[a]51	25 with	0	15 up	$\frac{1}{2}$, 1, 1, 1, $1\frac{1}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{1}{2}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$
1	Original	Retracted	23.3	[c]51	25 with	0	15 up	1, $1\frac{1}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{1}{2}$, $1\frac{1}{2}$
1	Final	Extended	23.3	[c]51	35 with	0	16 up	$1\frac{3}{4}$, 2, 2, 2, 2
4	Final	Retracted	23.3	[c]51	35 with	0	16 up	1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{1}{2}$
4	Final	Extended	23.3	[c]51	35 with	0	16 up	$\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$
1	Original	Retracted	25.7	[a]51	25 with	0	15 up	$1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{1}{2}$, $1\frac{3}{4}$, $1\frac{3}{4}$

[a] Towline attached to rear fuselage.
[b] Visual estimate.
[c] Towline attached to parachute boom (see fig. 1).

TABLE VI

SPIN-RECOVERY WING-ROCKET DATA OBTAINED WITH THE 1/28-SCALE MODEL OF A SUBSONIC ATTACK AIRPLANE

[Erect spins to the pilot's right; loading 1 in table II; recovery attempted by firing wing rockets; rudder deflection as indicated, lateral and longitudinal controls neutral; model values converted to corresponding full-scale values]

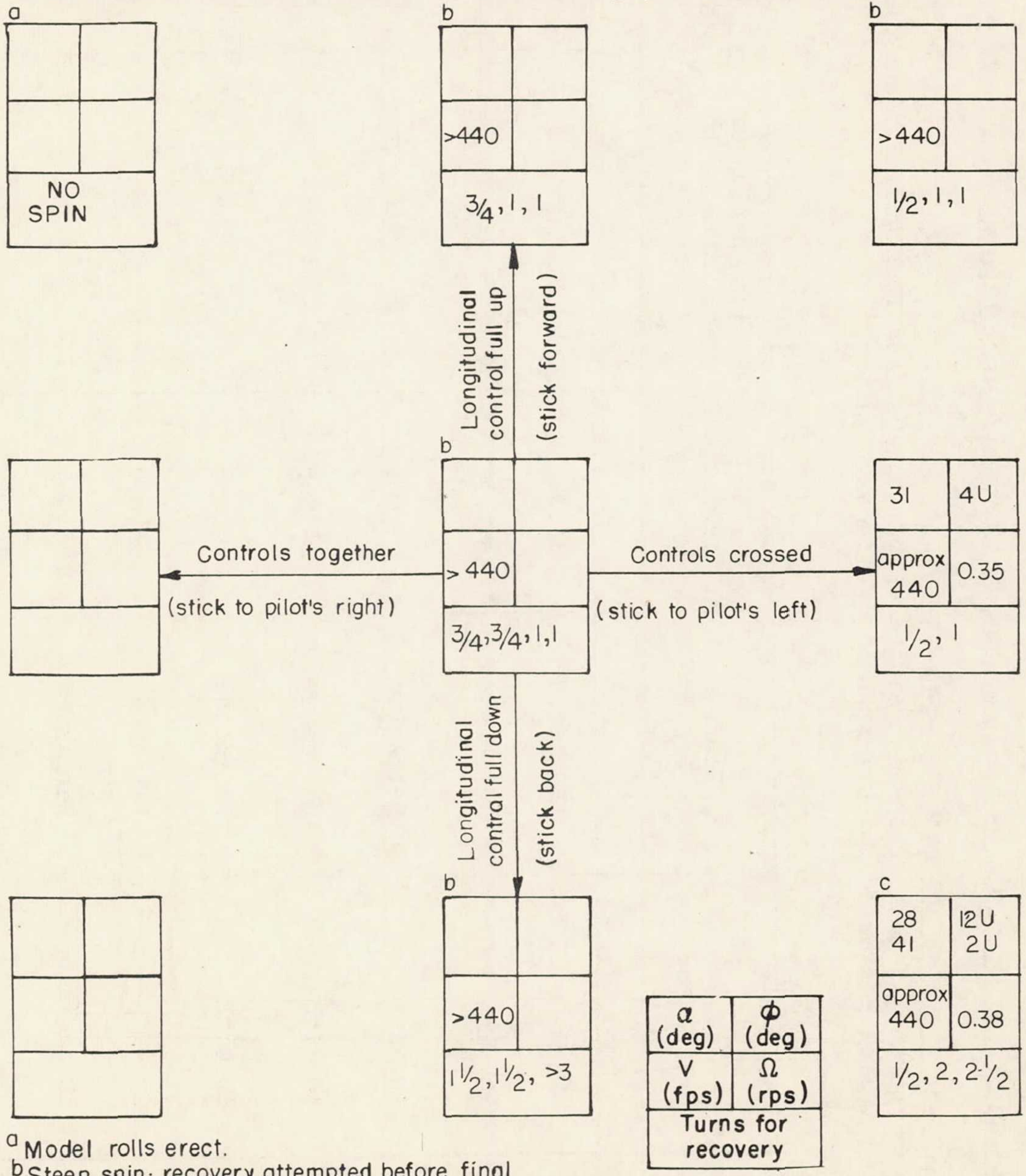
Rudder deflection, deg	Slats and flaps	Yawing moment, ft-lb	Inclination of thrust line to fuselage reference line, deg	Turns for recovery
10 with	Retracted	43,092	10	>3, >3
10 with	Retracted	57,466	10	$1\frac{3}{4}$, $>4\frac{1}{2}$
10 with	Retracted	64,638	0	$>2\frac{1}{4}$, >4
10 with	Retracted	64,638	5	$\frac{1}{2}$, 1, $>1\frac{1}{2}$
10 with	Retracted	64,638	10	$1\frac{1}{2}$, 2
25 with	Extended	64,638	5	$1\frac{1}{2}$, $1\frac{1}{2}$
10 against	Retracted	73,964	0	>3
0	Retracted	73,964	10	1, 1

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

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

Airplane A-6A	Attitude Inverted	Direction To pilot's right	Loading (see table II) 1. Flight design gross weight $\frac{I_X - I_Y}{mb^2} = -158 \times 10^{-4}$	
Slats Closed	Flaps Retracted	Stabilizer	Center-of-gravity position 25.2 percent $\bar{c}$	Original horizontal tail and rudder

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



[a] Model rolls erect.

[b] Steep spin; recovery attempted before final attitude attained.

[c] Oscillatory spin, range of values given.

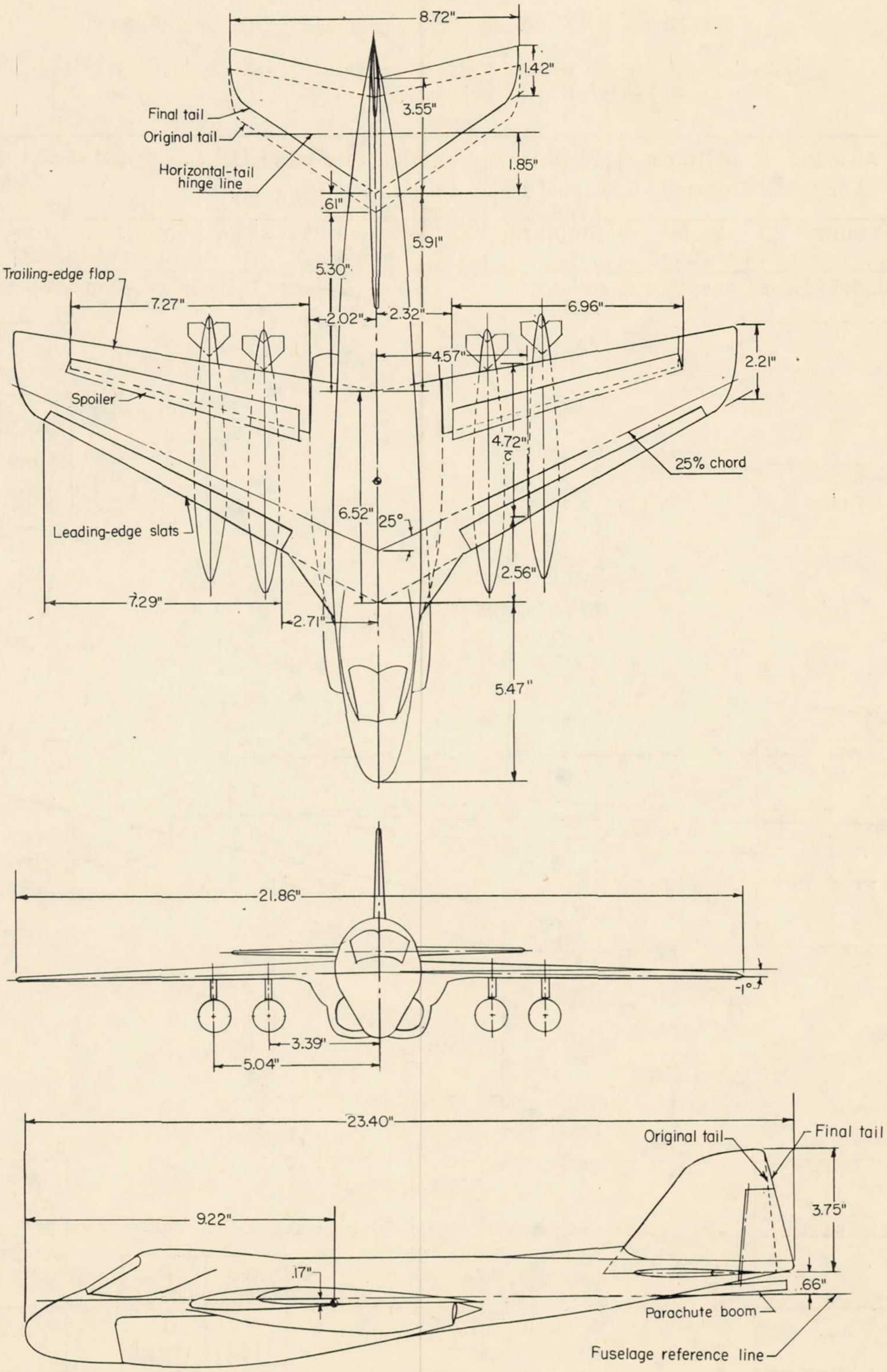


Figure 1.- Three-view drawing of the 1/28-scale model of the subsonic attack airplane. Center-of-gravity position is for the flight design gross weight with normal center of gravity.

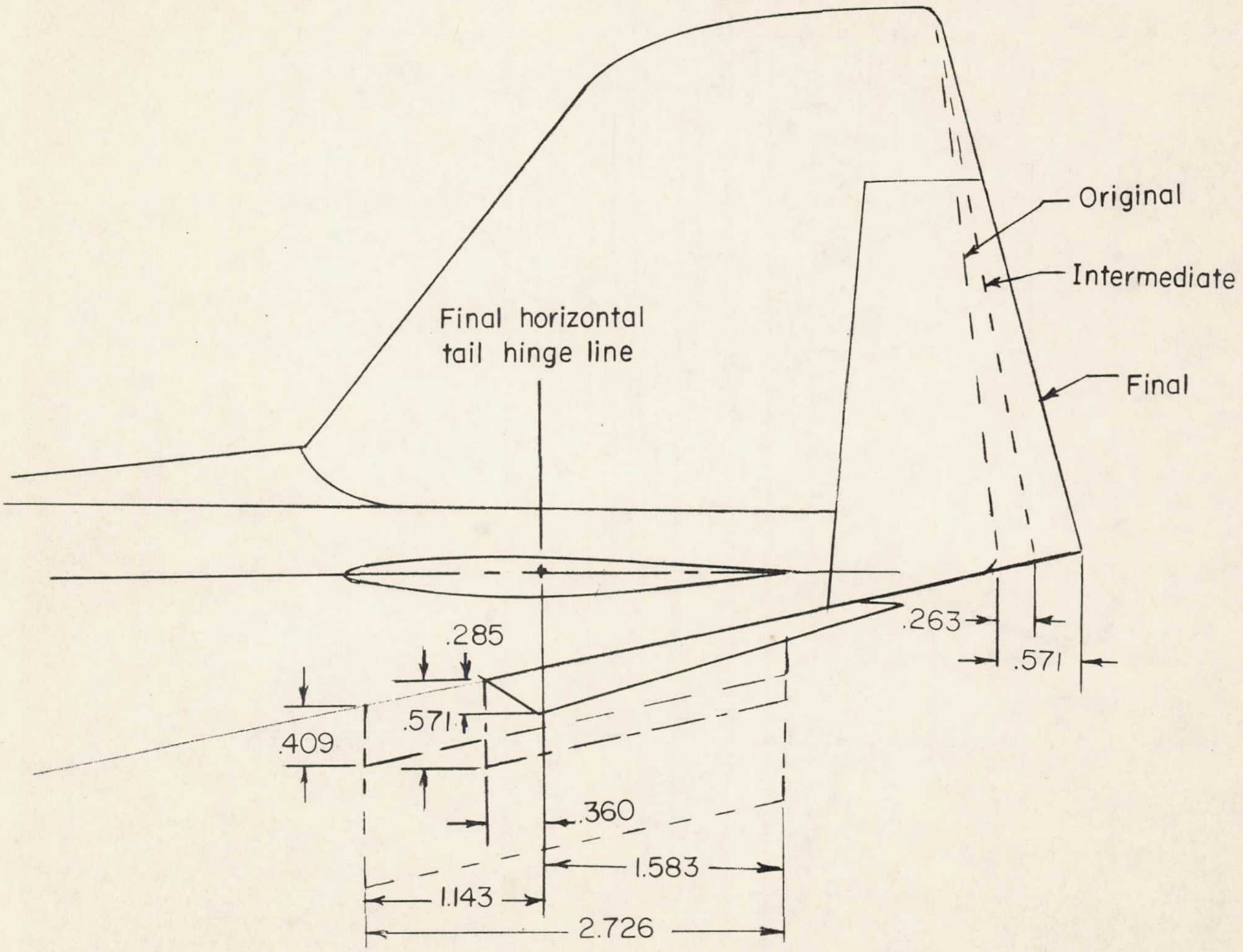
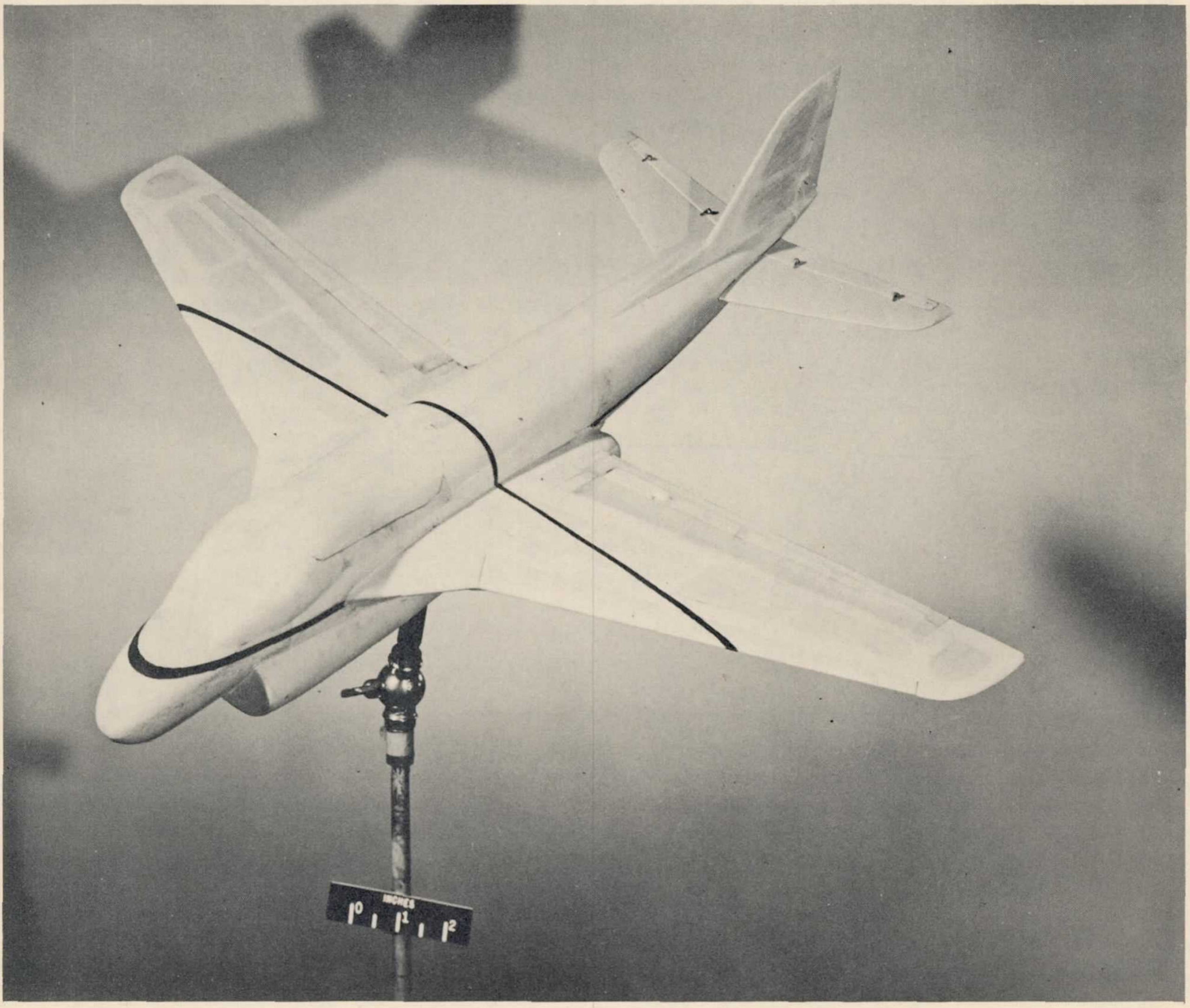


Figure 2.- Rudder configurations and ventral fins tested on the model. Dimensions are in inches, model scale.



L-59-3857

Figure 3.- Photograph of 1/28-scale model of the test airplane in the clean condition with the original tail configuration.

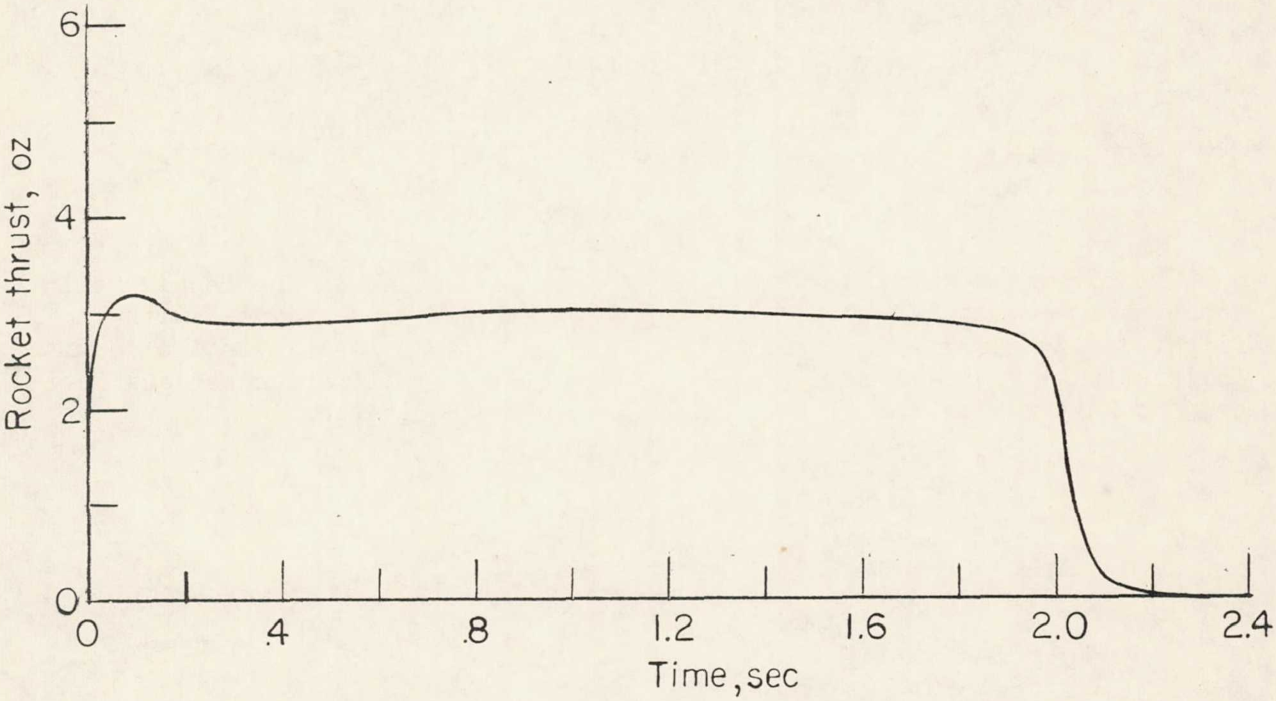


Figure 4.- Thrust-time characteristics of model rocket.

TECHNICAL MEMORANDUM SX-964

for the

Bureau of Weapons, Department of the Navy

SPIN-TUNNEL INVESTIGATION OF A 1/28-SCALE MODEL OF A SUBSONIC ATTACK AIRPLANE

TED NO. NACA AD 3156

By Henry A. Lee and Frederick M. Healy
Langley Research Center

ABSTRACT

Results of a spin investigation of a dynamic model in the Langley spin tunnel are presented. Erect and inverted spins were investigated with the flight design gross weight loading. Erect spins were also investigated with full internal fuel and empty external fuel tanks. Tail parachutes and anti-spin rockets for emergency spin recovery were investigated.

uncl.

author

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~