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NASA TECHNICAL MEMORANDUM

FOR

BUREAU OF WEAPONS, DEPARTMENT OF THE NAVY

SPIN-TUNNEL INVESTIGATION OF A 1/30-SCALE MODEL OF THE NORTH AMERICAN A-5A AIRPLANE

TED NO. NACA AD 3140 (U)

by Henry A. Lee

Langley Research Center

Langley Station, Hampton, Va.

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

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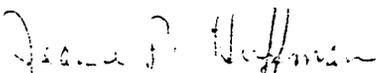
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INTRODUCTION

In accordance with a request from the Bureau of Weapons, Department of the Navy, an investigation was made in the Langley spin tunnel to determine the spin and recovery characteristics of a 1/30-scale model of the North American A-5A airplane (formerly designated the A3J-1). The A-5A airplane has a swept-back high wing and a wide flat fuselage enclosing the twin-jet engines. It has an all-movable horizontal tail for pitch control, an all-movable vertical tail for yaw control, and a wing spoiler-deflector combination for roll control. The horizontal tail also has 3° of differential movement for roll trim control. The wing has leading- and trailing-edge flaps.

The erect and inverted spin and recovery characteristics were determined for a range of center-of-gravity locations ranging from 26 percent to 40 percent of the mean aerodynamic chord. Also, full external wing tanks were tested on the model. The effects of differential deflection of the horizontal tail as a lateral control device and the effects of various other devices including strakes were determined. In addition, tests were made to determine the gyroscopic effects of jet-engine rotating parts on erect spins and recoveries. Tests to determine the effect of rockets as an emergency recovery device were performed as well as tests to determine the size of a tail parachute required for emergency spin recovery.

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

$\dfrac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

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for

Bureau of Weapons, Department of the Navy

SPIN-TUNNEL INVESTIGATION OF A 1/30-SCALE MODEL OF
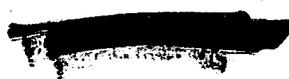
THE NORTH AMERICAN A-5A AIRPLANE*

TED NO. NACA AD 3140

By Henry A. Lee

SUMMARY

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An investigation has been made in the Langley spin tunnel to determine the erect and inverted spin and recovery characteristics of a 1/30-scale dynamic model of the North American A-5A airplane. Tests were made for the basic flight design loading with the center of gravity at 30-percent mean aerodynamic chord and also for a forward position and a rearward position with the center of gravity at 26-percent and 40-percent mean aerodynamic chord, respectively. Tests were also made to determine the effect of full external wing tanks on both wings, and of an asymmetrical condition when only one full tank is carried.

The results of the tests indicate that the airplane will not recover from a spin by any manipulation of the normal controls. Satisfactory recoveries could be obtained, however, with the configuration modified by the addition of retractable strakes to the forward part of the fuselage and an increase in the differential deflection of the horizontal tail for roll control. With these modifications, the optimum technique for satisfactory recovery from erect spins with the basic flight design loading is rudder movement to full against the spin, elevator full up (stick back), full differential movement of the horizontal tail ($\pm 6^\circ$) as ailerons with the spin (stick right in a right spin), and opening strakes (9.17 ft long, 5.6 in. wide) on both sides of the fuselage nose. A rearward center-of-gravity position will produce flatter spins than obtained for the normal center-of-gravity position and recoveries, even by the optimum recovery technique given previously, will be unsatisfactory. Recoveries with the full external tanks on will be satisfactory by the same optimum control technique except for the condition when the full tank is on the outboard wing only. In this case the tanks should be jettisoned, and then the optimum control technique will be satisfactory. The airplane may not spin when inverted, but if a spin is obtained it is recommended that all the controls should be neutralized to assure a satisfactory recovery. A 40-foot-diameter (laid-out-flat) parachute having a drag coefficient of 0.65 (based on laid-out-flat diameter) and a towline length of 26.3 feet will be satisfactory for emergency spin recovery. Also, satisfactory recoveries from emergency spins will be obtained with rockets producing an antispin yawing moment (about the body axis) of at least 62,300 foot-pounds or a rolling moment with the spin of at least 73,700 foot-pounds.

*Title, Unclassified.

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Langley Research Center

ABSTRACT

An investigation has been made to determine the erect and inverted spin and recovery characteristics of a 1/30-scale dynamic model of the North American A-5A airplane. Tests were made for the basic flight design loading with the center of gravity at 30-percent mean aerodynamic chord and also for a forward position and a rearward position with the center of gravity at 26-percent and 40-percent mean aerodynamic chord, respectively. Tests were also made to determine the effect of full external wing tanks on both wings, and of an asymmetrical condition when only one full tank is carried.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

$\dfrac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\dfrac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

ρ air density, slug/cu ft

μ relative density of airplane, $\dfrac{m}{\rho S b}$

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 1/30-scale model of the 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. The dimensions and locations of the various strakes and ventral fins tested are shown in figure 2. The strakes are long narrow flat surfaces protruding a few inches from the side of the fuselage nose and act like small-span spoiler strips. A photograph of the model 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 25,000 feet (ρ = 0.01065 slug/cu ft). The mass characteristics and mass parameters for loadings possible on the airplane and for the corresponding loading conditions tested on the model are presented in table II.

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

The angular momentum of the rotating parts of the full-scale engine was simulated by rotating a flywheel with a small battery-powered motor. The flywheel was located in the model so that the axis of the angular momentum was parallel to the longitudinal axis of the airplane. Tests were made with and without the flywheel rotating.

The normal maximum control deflections used on the model during the tests (measured perpendicular to the hinge lines) were:

Rudder:
   With wing flaps down, deg . . . . .10 right, 10 left
   With wing flaps up, deg . . . . 3 right, 3 left

Horizontal tail for longitudinal control (trailing edge),
   deg . . . . 18 up, 12 down

Horizontal tail for lateral control (trailing edge), deg . . .   3 up, 3 down

Spoiler deflector settings for lateral control:
   Outboard upper surface, hinged at trailing edge, deg . . . .   45 up
   Inboard upper surface, hinged at forward edge, deg . . . .   70 up
   Outboard lower surface, hinged at forward edge, deg . . . . 70 down
   Inboard lower surface, hinged at trailing edge, deg . . . . 35 down

Wing flap deflections:
   Trailing edge, deg . . . . 50 down
   Leading edge:
      Outboard, deg . . . . 30 down
      Inboard, deg . . . . 20 down

When the horizontal tail was used as a combined lateral and longitudinal control, the deflections were superimposed with a maximum up movement of 18°. For example, with elevator full up and differential movement of ±3° for ailerons, right roll would require the elevator setting to be 18° up for the right side and 12° for the left side. For some of the tests, however, control settings greater than normal were used for the horizontal tail for the longitudinal and lateral control.

An appendix includes a general description of the model testing technique and information on the precision of model test results and mass characteristics. In addition, variations of the model mass characteristics occurring during the tests are presented.

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented in chart 1 and tables III to V. The model data are presented in terms of full-scale values. Inasmuch as the results for right and left spins were generally similar, the data are presented arbitrarily in terms of right spins.

Effect of Low Reynolds Number on Spin Model

Results of unpublished force tests reported by North American Aviation, Inc. at high angles of attack and various Reynolds numbers on a 0.07-scale static model of the A-5A airplane showed that the 1/30-scale model would not represent the true conditions which would exist on the full-scale airplane.

Because of the low Reynolds number of the 1/30-scale spin model in a spin attitude, the forward fuselage contributed less damping in yaw and more nose-up pitching moment than is representative of full-scale conditions. Slight modifications were made to the model so that it would give a better representation of the full-scale conditions. A set of small strakes (no. 1, fig. 2) was fixed on the forward fuselage of the model to compensate for the lack of damping in yaw, and rotation of the fixed gyroscope in the model "with" the spin (clockwise in a right spin) gave a nose-down gyroscopic moment to compensate for the lack of nose-down pitching-moment increment on the model. All the test results presented were obtained with these modifications.

Erect Spins

On spin chart 1, elevator-up (stick-back) results are presented at the top of the chart and elevator-down (stick-forward) results at the bottom of the chart; results for spoiler deflections with the spin (stick right in a right spin) are presented on the right side of the chart and results for spoiler deflections against the spin (stick left) on the left side of the chart.

Basic flight design loading.- The results of the erect spin tests in the basic flight design-loading condition are presented in chart 1 and table III. In general, the results indicate that two spin conditions were possible, either the model would spin flat and somewhat oscillatorily, or it would not spin at all. In the present investigation, recovery from a spin with elevators and spoiler-deflectors neutral was used as the criterion instead of the conventional criterion spin with elevator 2/3 up and aileron 1/3 against. This alternate criterion spin was used because it was more convenient in testing and because it seemed permissible since the results of chart 1 show that the spin was almost the same for either of these two spins. In this regard, the chart shows that the spins with elevator neutral or 2/3 up were not appreciably different and also shows the deflection of the spoiler-deflectors had very little or no effect on the spin and offered no assistance in recovery. This lack of effectiveness of the spoiler-deflectors is similar to the result shown in reference 1 for a wide variety of spoiler and spoiler-slot-deflector type controls.

Recoveries were attempted by the use of singular or combination movements of rudder, elevator, strakes, and differential movement of the horizontal tail as ailerons. The results indicate that the airplane will not recover by any manipulation of the normal controls. Satisfactory recoveries were obtained in the tests by modification of the model to incorporate movable strakes on the front of the fuselage and increased differential deflection of the horizontal tail for roll control. The optimum control movement for satisfactory recovery with these modifications was found to be rudder reversal to full against the spin, elevator full up (stick back), differential movement of the horizontal tails as ailerons ±6° (12° total) with the spin (stick right in a right spin), and opening strakes (no. 2 of fig. 2) on both sides of the fuselage nose. (See chart 1.) The increase in differential movement of the horizontal tail for roll control to ±6° was necessary since the normal movement of ±3° was ineffective in producing satisfactory recoveries even with the strakes open. Strake 2 did not seem practical, however, due to equipment location in the nose of the

airplane which limited strake location to distances greater than 3 inches (model scale) from the nose of the airplane. Strake 3 (fig. 2) was therefore tested and found to be as satisfactory as strake 2, as can be seen in table III which presents the results of other combinations of strakes and differential movement of the horizontal tail as ailerons.

Effect of flaps, dive brakes, ventral fins, access doors, and engine gyroscopic moments.- To determine the effect on the spin and recovery characteristics, tests were made in which the leading-edge and trailing-edge flaps were deflected, dive brakes extended, and ventral fins installed (fig. 2), and the engine gyroscopic moments at idle speed were simulated. Tests were also made to investigate the effect of opening the large access doors to electronic equipment in the nose of the airplane to supplement the primary flight controls for recovery. None of these conditions appreciably affected the model spin and recovery characteristics, and therefore the data from these tests are not presented.

Effect of various loadings.- Tests were made with full external fuel tanks on both wings and an asymmetrical condition with one tank full first on the inboard wing and then on the outboard wing. The results with the full tanks on both wings indicate no appreciable effect of the tanks on the spin and recovery characteristics. With a full tank on the inboard wing only, however, the model did not spin; and with a full tank on the outboard wing only, the spin was flat with a rate of rotation faster than normal, and the model would not recover from the spin. To ensure satisfactory recovery for this latter case, the tanks should be dropped and the optimum control technique used.

Tests were also made with a forward center-of-gravity position of $0.26\bar{c}$ and a rearward center-of-gravity position of $0.40\bar{c}$. The spin characteristics with the forward center of gravity were similar to the results for the 30-percent $\bar{c}$ center-of-gravity position. With the center of gravity in the rearward position, however, the model tended to spin flatter than for the $0.30\bar{c}$ center-of-gravity condition, and the recoveries were unsatisfactory even for the optimum control technique.

Inverted Spins

The results of the inverted spin tests indicated that the model would not spin when inverted. Experience has indicated, however, that for airplanes of this type, spin recovery from inverted spins by neutralization of all controls has been effective. It is therefore recommended that, if an inverted spin should occur for this airplane, all controls should be neutralized.

Spin-Recovery-Parachute Tests

Typical results of tests made to determine the size of the tail parachute which should be satisfactory as an emergency spin-recovery device are presented in table IV. The data presented are representative of results obtained for the loading range investigated on the model. For these tests the towline was

attached at the rear of the fuselage between the two engine exhausts. The results of these tests indicate that satisfactory spin recoveries from erect spins can be obtained in emergencies by opening a 40-foot-diameter (full-scale, laid-out-flat) tail parachute with a drag coefficient of 0.65 (based on the laid-out-flat diameter) and with a 26.3-foot towline length. If a parachute with a different drag coefficient is used, a corresponding adjustment will be required in parachute size.

Rocket Tests

The results of tests to evaluate the use of rockets as emergency recovery devices in demonstration spins are presented in table V. A rocket was mounted in the nose of the model to give an antispin yawing moment and the results indicate that a yawing moment of 62,300 foot-pounds (full scale) about the body axis gave satisfactory recoveries from the spin for the basic flight design loading. For recovery attempts with a roll rocket, a rocket was mounted on each wing and the results indicate that a rolling moment "with" the spin of 73,700 foot-pounds (full scale) about the body axis was required for satisfactory recoveries. Tests with tanks added to the model with the basic flight design loading showed that the tanks should be dropped to obtain satisfactory recoveries with the above specified rocket induced moments.

Significance of Results

Interpretation of spin-tunnel model test results may be affected by tunnel testing technique, particularly for some modern high-speed designs. The tunnel testing technique, as pointed out in reference 2, involves launching the model by hand into the tunnel in a flat attitude with a high rate of rotation. In this technique, a flat spin would be more readily obtainable in the tunnel than would be likely for the airplane using flight spin-entry techniques. Therefore, in order to get a more realistic evaluation of the spin-entry characteristics, a 1/9-scale nonpowered radio-controlled model was dropped from a helicopter and flown into the spin. The results of these tests, which are presented in reference 3, indicate that the results obtained from spin-tunnel model tests are indicative of the full-scale spin-recovery characteristics. The drop-model tests did not include the use of differential tail deflection which was found in the present tests to be necessary for satisfactory recoveries; therefore, these tests did not actually verify the tunnel results for the satisfactory recovery condition.

CONCLUSIONS

Based on the results of tests of a 1/30-scale model of the North American A-5A airplane, the following conclusions regarding the spin and recovery characteristics of the airplane at 25,000 feet are made:

1. For the basic flight design loading, the airplane will spin at a flat attitude somewhat oscillatorily and will not recover by normal control movement.

Satisfactory recoveries can be obtained with the configuration modified by the addition of retractable strakes to the forward part of the fuselage and an increase in the differential deflection of the horizontal tail for roll control. With these modifications, the optimum recovery technique from the developed spin is simultaneous movement of the rudder to full against the spin, elevator full up (stick back), differential movement of the horizontal tail as ailerons $\pm 6^\circ$ (12° total movement) with the spin (stick right in a right spin), and opening strakes (9.17 ft long, 5.6 in. wide) on both sides of the fuselage nose.

2. No appreciable effect on the spin and recovery characteristics of the airplane was obtained from the following: Deflection of the leading-edge and trailing-edge flaps, dive brakes extended, ventral fins installed, access doors in the nose of the airplane, or gyroscopic moments of the engine rotation at idling speed.

3. Full external fuel tanks on both wings will not appreciably affect the spin and recovery characteristics; however, in an asymmetrical condition with a full tank on only the outboard wing, the spin attitude will be flatter with a faster rate of rotation than normal and recoveries may not be obtained. For recovery the tanks should be dropped and the optimum recovery technique applied.

4. A rearward center-of-gravity position causes the spins to be flatter than the forward center-of-gravity positions and will result in unsatisfactory recoveries.

5. The airplane probably will not spin when inverted, but the recommended recovery technique in case it does spin inverted is to neutralize all controls.

6. A 40-foot-diameter tail parachute (laid-out-flat) with a drag coefficient of 0.65 (based on the laid-out-flat diameter) and with a 26.3-foot towline length will be satisfactory for emergency recoveries from any spins obtained.

7. A rocket mounted to give an antispin yawing moment of 62,300 foot-pounds about the body axis or rockets to give a rolling moment of 73,700 foot-pounds with the spin (roll to right for right spin) should be satisfactory for emergency recoveries from any spins with the model in the basic flight design loading.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., March 11, 1964.

APPENDIX

TEST METHODS AND PRECISION

Model Testing Technique

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal control configuration for spinning (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 the movement 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 (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 elevator 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, 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. This control configuration and manipulation is 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.

Turns for recovery are measured from the time the controls are moved 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 manners 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.

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 was 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, for example, >3. A >3-turn recovery, however, does not necessarily indicate

an improvement over a >7-turn recovery. A recovery of 10 or more turns is indicated by ∞. When a model recovers without control movement (rudder held with the spin), the results are recovered 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 or rocket 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; when the band is released, the parachute canopy 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.

General descriptions of model testing techniques, methods of interpreting test results, and correlation between model and airplane results are presented in reference 2.

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 . . . . $\pm\frac{1}{4}$

Turns for recovery obtained visually . . . . $\pm\frac{1}{2}$

The preceding limits may be exceeded for certain spins in which the model is difficult to control 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 c̄ . . . . ±1
Moments of inertia, percent . . . . ±5

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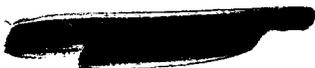
Controls are set with an accuracy of $\pm 1^{\circ}$. The rotational rate of the fly-wheel simulating the engine was maintained within ± 10 percent of the desired values.

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 North American A-5A model varied from the true scaled-down values within the following limits:

Weight, percent . . . . 2 high to 8 high
Center-of-gravity location, percent $\bar{c}$ . . . . 0 to 1 rearward
Moments of inertia:
   I_X, percent . . . . 1 low to 3 high
   I_Y, percent . . . . 1 low to 11 high
   I_Z, percent . . . . 2 low to 7 high

REFERENCES

1. Healy, Frederick M., and Klinar, Walter J.: Comparison of Effects of Ailerons and Combinations of Spoiler-Slot-Deflector Arrangements on Spin Recovery of Sweptback-Wing Model Having Mass Distributed Along the Fuselage. NACA RM L54I14, 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. Libbey, Charles E., and Burk, Sanger M., Jr.: Large-Angle Motion Tests, Including Spins, of a Free-Flying Dynamically Scaled Radio-Controlled 1/9-Scale Model of an Attack Airplane. NASA TM X-551, 1961.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE A-5A AIRPLANE

Length (overall), ft 72.46

Wing:
  Span, b, ft 53.02
  Area, S (including spoiler-slot deflections and 203.82 sq ft covered
    by fuselage), sq ft 700.00
  Root chord (wing station 0), ft 22.05
  Tip chord (equivalent, wing station 317.5 in.), ft 4.41
  Tip chord (theoretical, wing station 318.41 in.), ft 4.36
  Mean aerodynamic chord (wing station 123.47 in), ft 15.19
  Distance from nose to L.E. of M.A.C., ft 37.63
  Aspect ratio 4.0
  Taper ratio 0.20
  Sweepback, deg -
    Leading edge 43.05
    0.25 chord 37.5
    Trailing edge 14.97

Incidence, deg 0

Airfoil:
  Root (in streamline) . . . . NACA 65A005 (modified)
  Tip (in streamline) . . . . NACA 65A005 (modified)

Spoiler-Deflector:
  Area, sq ft -
    Inboard section 5.823
    Center section 3.158
    Outboard section 3.716
    Total (one wing) 12.697
  Span (equivalent, wing stations 121.13 in. to 242.47 in.), ft 10.111
  Chord (equivalent, inboard), ft 1.44
  Chord (equivalent, outboard), ft 1.24

Horizontal tail:
  Area (exposed, including 0.912 sq ft cutout at inboard ends of trailing
    edge), sq ft 175.00
  Span (including 128 in. covered by fuselage and nacelles), ft 31.583
  Aspect ratio (exposed) 2.50
  Taper ratio (exposed) 0.20
  Root chord (exposed, horizontal-tail station 64 in.), ft 13.94
  Tip chord (equivalent, horizontal-tail station 139.499 in.), ft 2.79
  Tip chord (theoretical, horizontal-tail station 190.099 in.), ft 2.76
  Sweepback, deg -
    Leading edge 51.75
    0.25 chord 45.00
    Trailing edge 11.20

Vertical tail:
  Area (exposed, 29 in. above reference line), sq ft 101.00
  Span, ft 12.308
  Aspect ratio 1.5
  Taper ratio 0.35
  Root chord (29 in. above reference line), ft 12.16
  Tip chord (equivalent, 176.70 in. above reference line), ft 4.25
  Tip chord (theoretical, 177.536 in. above reference line), ft 4.21
  Sweepback, deg -
    Leading edge 49.25
    0.25 chord 45.00
    Trailing edge 27.36

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE LOADINGS OF THE NORTH AMERICAN A-5A AIRPLANE

AND FOR THE LOADINGS TESTED ON THE 1/30-SCALE MODEL

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

Number	Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft²			Mass parameters		
			$x/\bar{c}$	$z/\bar{c}$	Sea level	Altitude, 25,000 ft	I_X	I_Y	I_Z	$\dfrac{I_X - I_Y}{mb^2}$	$\dfrac{I_Y - I_Z}{mb^2}$	$\dfrac{I_Z - I_X}{mb^2}$
Airplane values												
1	Case 2 basic flight design gross wt.; gear up	40,953	0.3021	-0.0535	14.41	32.18	60,846	213,329	267,971	-426×10^{-4}	-153×10^{-4}	579×10^{-4}
2	Case 4 alternate take-off gross wt., gear down	50,460	0.3500	-0.0408	17.75	39.64	63,372	257,838	311,493	-411×10^{-4}	-122×10^{-4}	563×10^{-4}
3	Case 5 alternate flight gross wt.; gear up	47,278	0.3984	-0.0464	16.63	37.14	61,096	239,594	294,085	-433×10^{-4}	-132×10^{-4}	565×10^{-4}
4	Case 2 basic flight design gross wt. with full external tanks and pylons	47,397	0.2600	-0.0535	16.67	37.21	78,046	219,015	290,333	-341×10^{-4}	-172×10^{-4}	513×10^{-4}
Model values												
1	Case 2 basic flight design gross wt.; gear up	40,853	0.3109	-0.0551	14.38	32.10	60,668	208,038	254,798	-413×10^{-4}	-131×10^{-4}	544×10^{-4}
3	Case 5 alternate flight gross wt.; gear up	47,653	0.3955	0.0301	16.77	37.44	62,376	247,945	296,486	-446×10^{-4}	-117×10^{-4}	563×10^{-4}
4	Case 2 basic flight design gross wt. with full external tanks and pylons	47,840	0.2584	-0.0380	16.84	37.59	78,892	231,165	294,591	-365×10^{-4}	-152×10^{-4}	517×10^{-4}
5	Case 2 basic flight design gross wt. with a forward center-of-gravity position	44,693	0.2644	-0.0495	15.73	35.11	61,273	236,511	285,212	-449×10^{-4}	-125×10^{-4}	574×10^{-4}

TABLE III.- SPIN AND RECOVERY CHARACTERISTICS OF THE NORTH AMERICAN A-5A MODEL USING STRAKES

AND/OR DIFFERENTIAL MOVEMENT OF THE HORIZONTAL TAIL AS AILERONS

[Model loading 1 on table II. Right erect spins; model values have been converted to corresponding full-scale values.]

Test number	Control settings		Strake number (see fig. 2)	α, deg (a)	ϕ, deg	V, ft/sec	Ω, rps	Control movement for recovery				Turn for recovery
	Rudder, deg (a)	Elevator, deg						Rudder, deg (a)	Horizontal tail, deg		Opening strake number (b)	
									As elevators (a)	As ailerons (a)		
1	3 W	0	2 (both sides)	71	4 U 2 D	229	0.28	3 A	12 U	3 W	2	3, >6
2	3 W	0	------------	70	9 U 6 D	237	0.32	2 A	12 U	0	Not used	$6\frac{1}{2}$, > 6, ∞
3	3 W	0	2 (both sides)	58 71	12 U 7 D	237	0.25	2 A	12 U	0	2	2, $2\frac{3}{4}$, $2\frac{1}{2}$, $1\frac{3}{4}$
4	3 W	0	2 (both sides)	67	8 U 4 D	242	0.30	2 A	12 U	0	2	3, 2, 3, 3
5	3 W	0	3 (both sides)	68	5 U 3 D	234	0.25	3 A	12 U	0	3	$1\frac{1}{2}$, 5, $9\frac{1}{2}$, 10
6	3 W	0	3 (both sides)	66 78	8 U 4 D	235	0.23	3 A	15 U	3 W	3	$1\frac{3}{4}$, $2\frac{1}{2}$
7	3 W	0	3 (both sides)	66 78	8 U 4 D	235	0.23	3 A	15 U	3 W	Not used	$3\frac{1}{4}$, ∞
8	3 W	0	3 (both sides)	66 78	8 U 4 D	235	0.23	3 A	12 U	6 W	3	$1\frac{1}{2}$, $1\frac{1}{4}$, $1\frac{3}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$
9	3 W	0	------------	66 78	8 U 4 D	235	0.23	3 A	12 U	6 W	Not used	$2\frac{1}{4}$, $3\frac{1}{4}$, $3\frac{1}{2}$, >3

[a]W - with, A - against, U - up, D - down.
[b]For recovery the strakes were rapidly extended on both sides from a retracted position.

TABLE IV.- SPIN RECOVERY PARACHUTE TEST RESULTS ON THE 1/30-SCALE MODEL

OF THE NORTH AMERICAN A-5A AIRPLANE

[Recovery attempted by opening tail parachute; right erect spins; approximate parachute drag coefficient 0.65; parachute shroud line length 1.35 times parachute diameter; model values have been converted to corresponding full-scale values.]

Parachute diam., ft	Towline length, ft	Control settings			Turns for recovery
		Rudder, deg	Elevator, deg	Aileron, deg	
30	52.5	10 W	0	0	4, $3\frac{1}{2}$, $3\frac{1}{2}$, $4\frac{1}{4}$
35	52.5	10 W	0	0	$1\frac{1}{2}$, 3, $2\frac{1}{2}$, $2\frac{1}{4}$, 3
40	52.5	10 W	0	0	3, $2\frac{1}{4}$, 2, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, 2, 2, 2, 2
45	52.5	10 W	0	0	$1\frac{3}{4}$, $1\frac{1}{2}$, 2, 2, 2, $2\frac{1}{4}$, $1\frac{3}{4}$, 2
30	26.3	10 W	0	0	$^b\infty$
35	26.3	10 W	0	0	$2\frac{1}{2}$, 2, 2, $2\frac{1}{2}$, $2\frac{1}{2}$
40	26.3	10 W	0	0	2, $1\frac{3}{4}$, $2\frac{1}{4}$, $1\frac{1}{2}$, 2, $1\frac{3}{4}$, $2\frac{1}{2}$
30	26.3	7 W	12 U	0	2, 2, 2, >3, 2, 2, 2
35	26.3	7 W	12 U	0	2, 2, $1\frac{1}{4}$, $1\frac{1}{2}$, $\frac{1}{2}$, 2
25	26.3	10 W	18 U	0	>3, $2\frac{1}{2}$, >2, >4, $1\frac{1}{4}$, $1\frac{1}{4}$
30	26.3	10 W	18 U	0	2, $1\frac{1}{2}$, $1\frac{1}{4}$, 2, $^b2\frac{1}{4}$, $^b2\frac{1}{2}$

^{a}W - with, U - up.

^{b}Parachute fluttered in turbulent air over model.

TABLE V.- ROCKET RECOVERY SPIN TESTS ON THE 1/30-SCALE MODEL OF THE NORTH AMERICAN A-5A AIRPLANE WITH THE ROCKET SIMULATING YAWING OR ROLLING MOMENTS

[Model loading no. 1 (except as noted), table II; recovery attempted by firing rockets; right erect spins; model values have been converted to corresponding full-scale values.]

Spin number	Control settings			Moment applied, ft-lb		Approximate firing time, sec	Turns for recovery
	Rudder, deg	Elevator, deg	Ailerons, deg	Yaw	Roll		
1	3 with	0	0	56,700	-------	11	1, 2, ∞, ∞, ∞
2	3 with	0	0	62,300	------	11	$1\frac{1}{2}$, $1\frac{1}{2}$, 1, 2, $1\frac{3}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$
3	3 with	0	0	73,500	------	11	$1\frac{1}{2}$, 2, $1\frac{1}{2}$, $1\frac{3}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{1}{4}$
4	3 with	0	0	79,200	------	11	$1\frac{1}{4}$, $1\frac{1}{2}$, 1, $1\frac{1}{4}$, $1\frac{1}{4}$
[a]5	3 with	0	0	------	36,850	11	$2\frac{3}{4}$, 2, 3, $2\frac{1}{2}$, $3\frac{1}{2}$, $2\frac{3}{4}$
[b]6	3 with	0	0	------	73,700	11	$1\frac{1}{4}$, 2, $1\frac{1}{2}$
[c]7	3 with	0	0	62,300	------	11	>3, >9, [d]$2\frac{3}{4}$, [d]$2\frac{1}{2}$, [d]∞
[c]8	3 with	0	0	73,500	------	11	$1\frac{1}{2}$, $2\frac{1}{2}$, $1\frac{1}{2}$, $1\frac{1}{2}$, 2

[a]Rocket on right wing only to roll with.
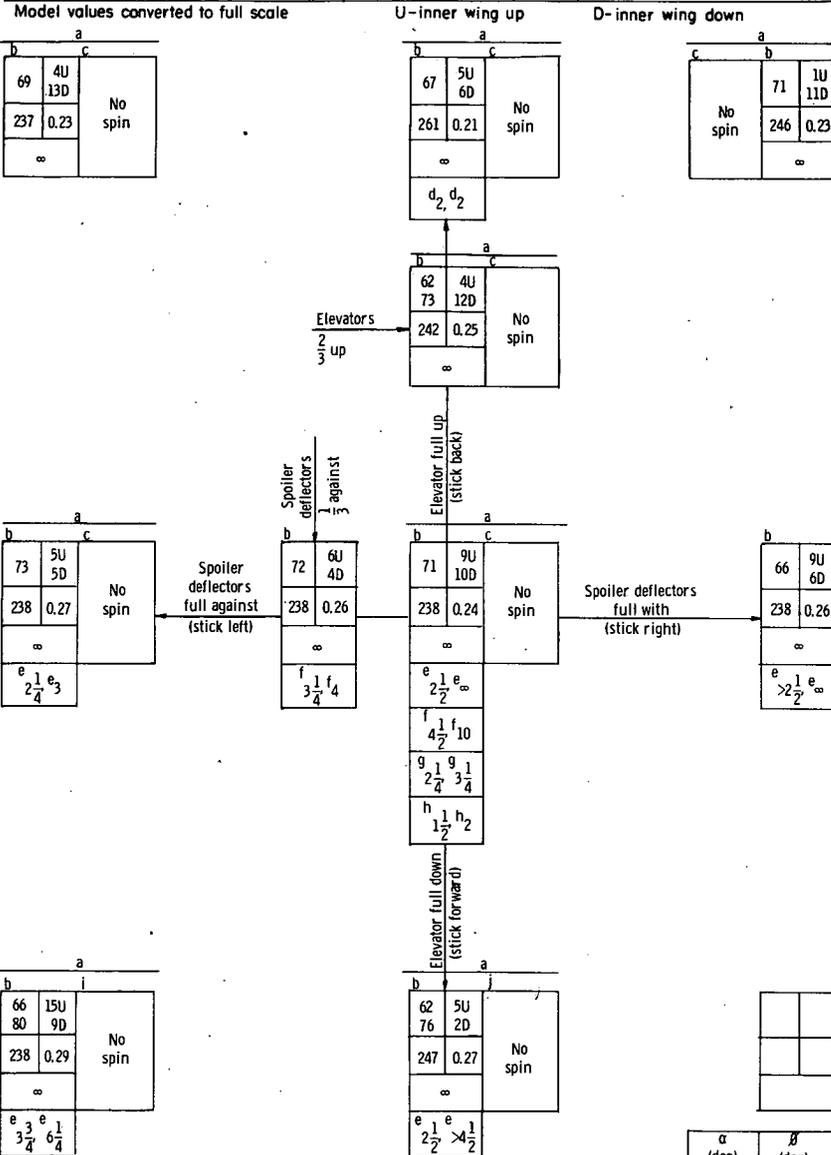[b]Rocket on both wings to roll with.
[c]Full external drop tanks on.
[d]Visual.

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

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

Airplane A-5A	Attitude Erect	Direction Right	Loading no. 1 (see table II) Basic flight design	
Slots	Flaps	Altitude 25,000 ft	Center-of-gravity position 30% c̄	Strakes No. 2 (fig. 2) used for recovery

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

b	c
69	4U .13D
237	0.23
∞	No spin

b	c
67	5U 6D
261	0.21
∞	No spin

d₂, d₂

c	b
No spin	71 1U 11D
	246 0.23
	∞

b	c
62 73	4U 12D
242	0.25
∞	No spin

Elevators ⅔ up

Spoiler deflectors ⅓ against

Elevator full up (stick back)

b	c
73	5U 5D
238	0.27
∞	No spin
e 2¼	e 3

Spoiler deflectors full against (stick left)

b	c
72	6U 4D
238	0.26
∞	
f 3¼	f 4

b	c
71	9U 10D
238	0.24
∞	No spin
e 2½	e ∞
f 4½	f 10
g 2¼	g 3¼
h 1½	h 2

Spoiler deflectors full with (stick right)

b	c
66	9U 6D
238	0.26
∞	
e >2½	e ∞

Elevator full down (stick forward)

b	i
66 80	15U 9D
238	0.29
∞	No spin
e 3¾	e 6¼

b	j
62 76	5U 2D
247	0.27
∞	No spin
e 2½	e ⍉4½

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

ᵃTwo conditions possible.

ᵇOscillatory spin; range or average values given.

ᶜModel goes into a glide.

ᵈRecovery attempted by reversal of rudder to full against and extending strakes on both sides of fuselage nose.

ᵉRecovery attempted by reversal of rudder to full against, elevator to full up and extending strakes on both sides of fuselage nose.

ᶠRecovery attempted by reversal of rudder to 2/3 against, elevator to 2/3 up, and extending strakes on both sides of fuselage nose.

ᵍRecovery attempted by reversal of rudder to 2/3 against, elevator to 2/3 up, and differential elevator as ailerons ±6° with the spin.

ʰRecovery attempted by reversal of rudder to 2/3 against, elevator to 2/3 up, differential elevator as ailerons ±6° with, and extending strakes on both sides of fuselage nose.

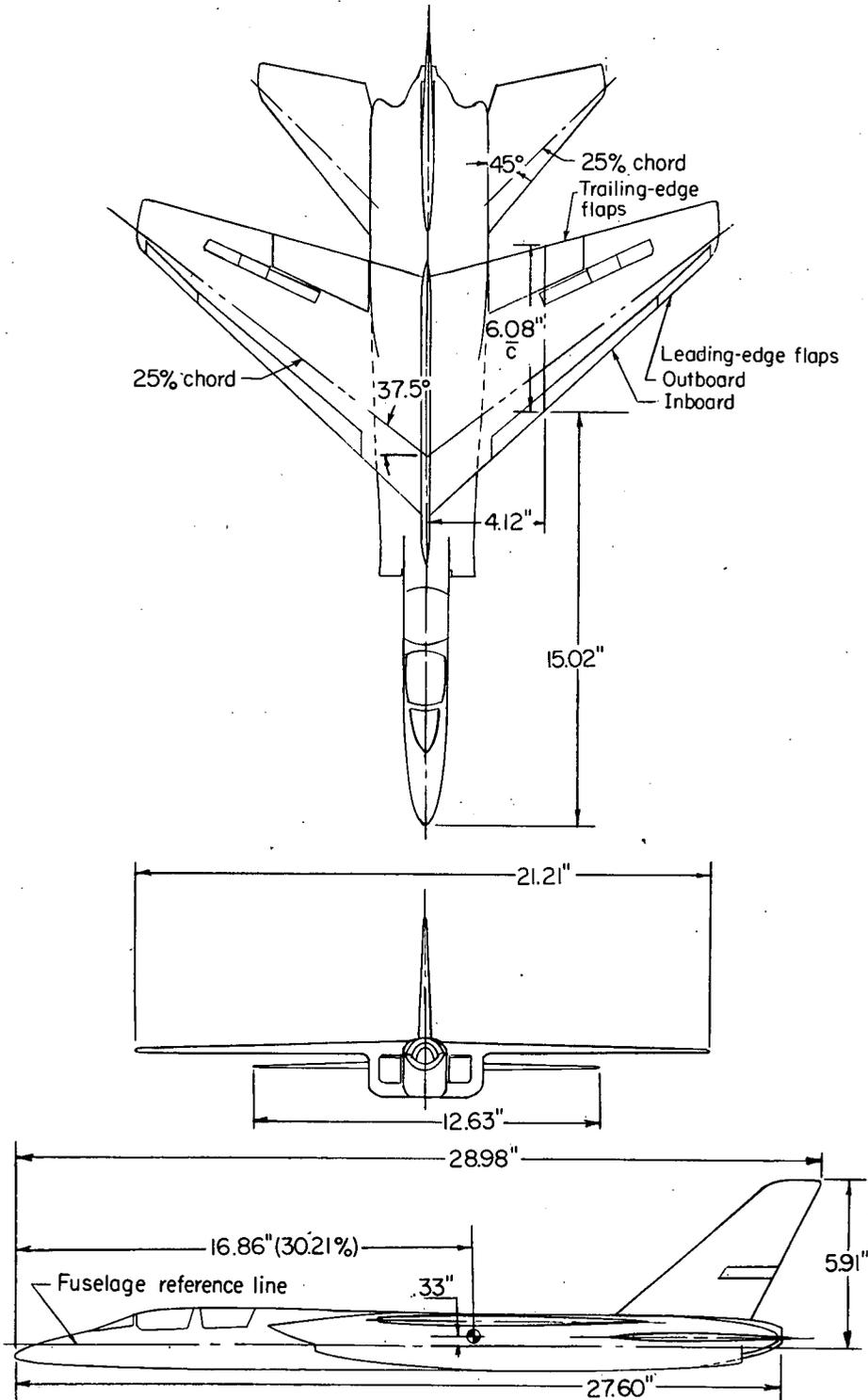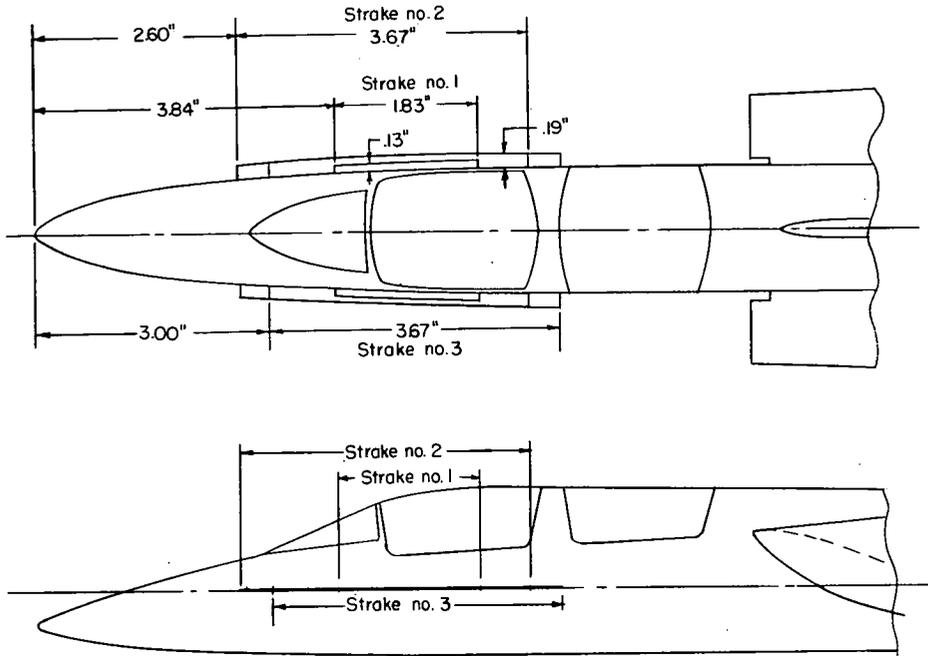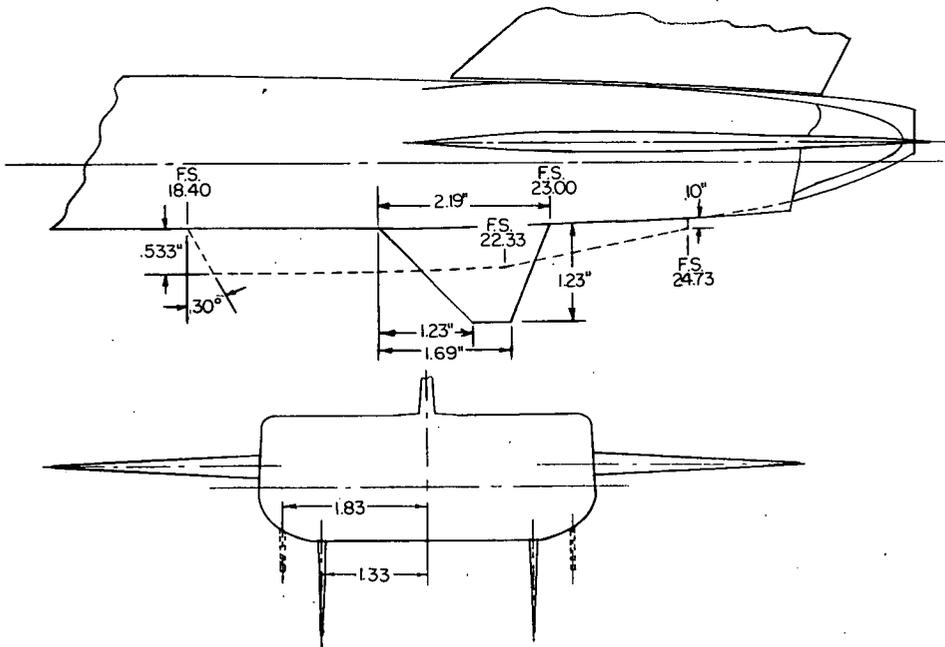ⁱGoes into an inverted glide.

ʲGoes into a dive.

Figure 1.- Three-view drawing of the 1/30-scale model of the North American A-5A airplane. Basic flight design loading with center of gravity at 30.21 percent $\bar{c}$ shown.

(a) Strakes.

(b) Ventral fins.

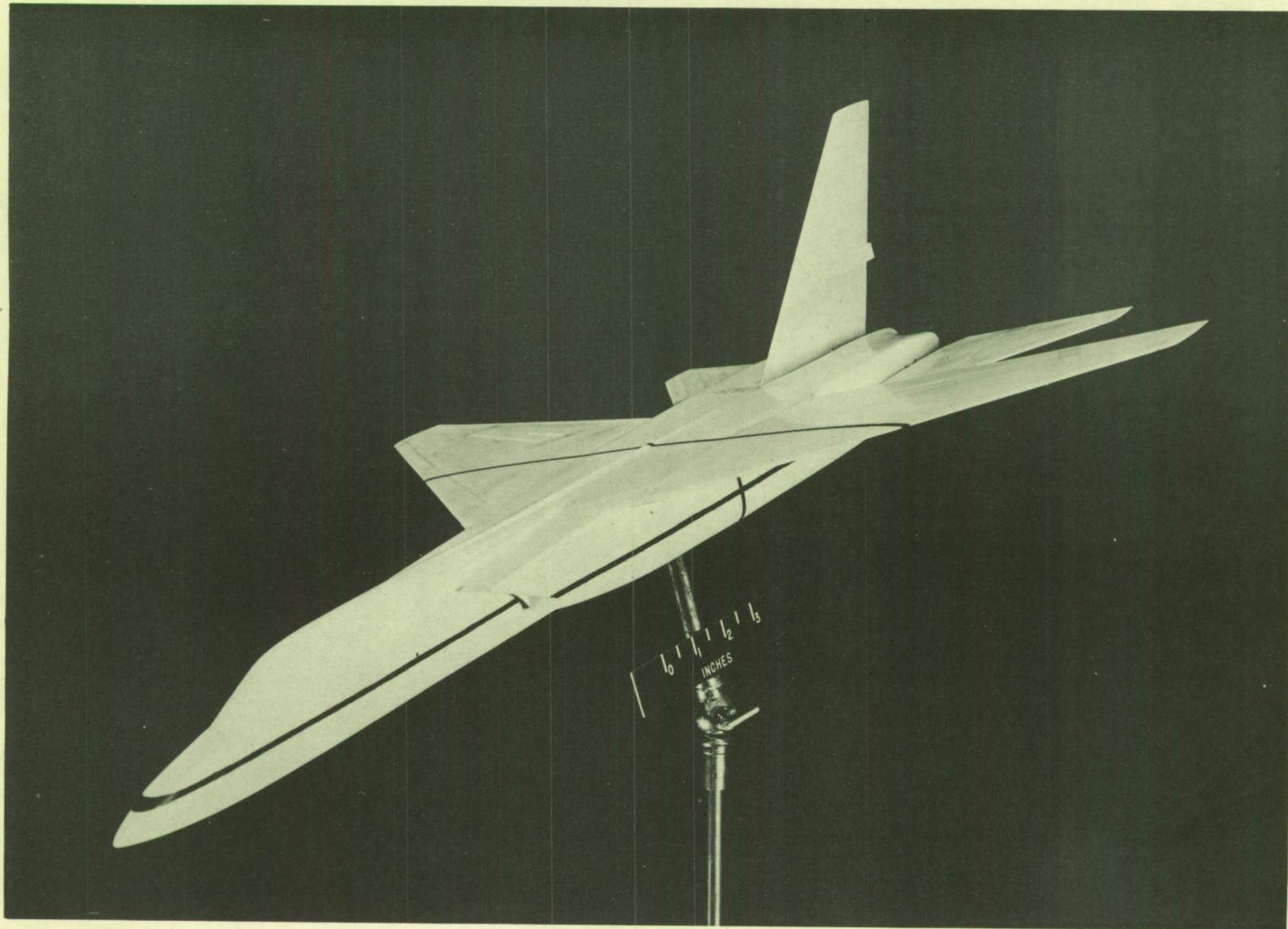Figure 2.- The 1/30-scale model of the A-5A airplane showing positions of strakes and ventral fins as tested.

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Figure 3.- The 1/30-scale model of the North American A-5A airplane as tested in the Langley 20-foot free-spinning tunnel.