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SERVICE REPORT

TECHNICAL MEMORANDUM

SX-445

for the

Bureau of Weapons

LARGE-ANGLE MOTION TESTS, INCLUDING SPINS, OF A FREE-FLYING RADIO-CONTROLLED 0.13-SCALE MODEL OF A TWIN-JET SWEPT-WING FIGHTER AIRPLANE

COORD NO. N-AM-50

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON

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SUMMARY

An investigation has been conducted with a free-flying radio-controlled 0.13-scale model of a twin-jet swept-wing fighter airplane to determine the tendency of this design to enter spins and to evaluate the nature of the spin obtained from post-stall motions.

The test results indicate that it may be difficult to obtain a developed spin on the airplane, particularly the flat-type spin. Two types of erect developed spins will be possible; one will be flat and fast rotating from which recovery may not be obtained and the other will be steeper and oscillatory from which recoveries will be satisfactory. Controls will be effective for satisfactory termination of the post-stall gyrations obtained. The recommended recovery technique from both post-stall gyrations and developed spins will be movement of the rudder to oppose the yawing rotation and simultaneous movement of the ailerons to with the rotation (stick right when turning to the right). When recovery is imminent, the stick should be moved longitudinally to neutral. It is recommended that the spin not be allowed to develop fully on this airplane. The developed-spin results obtained in the investigation were in good agreement with spin-tunnel results.

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INTRODUCTION

At the request of the Bureau of Weapons, Department of Navy, an investigation was made to determine the post-stall and developed spin-recovery characteristics of an unpowered free-flying radio-controlled 0.13-scale model of the McDonnell F4H-1 airplane using the radio-controlled dynamic model testing technique described in references 1 and 2. This airplane is a swept-low-wing, twin-jet-engine fighter aircraft with an all-movable horizontal tail (or stabilator) for pitch control and an aileron-spoiler combination for roll control. Spin-tunnel tests on a 1/30-scale dynamic model of the airplane (ref. 3) indicated the possibility of two types of spins, one of which was steep and oscillatory from which recoveries were satisfactory, and the other was flat and fast rotating from which recovery was difficult or impossible. It was felt that the flat spinning attitude which could be obtained readily in the spin tunnel could be due at least in part to the tunnel launching technique (ref. 4) and that therefore the tendency for the airplane to enter the flat spin could not be predicted accurately solely on the basis of the tunnel tests. In order to determine whether it was likely, or even possible, that this airplane could enter the flat spin from more likely spin-entry techniques for the airplane, it was considered desirable to determine the post-stall characteristics of this design. The present tests, therefore, were made to augment the spin-tunnel tests and to obtain a more realistic evaluation of spin-entry and spinning characteristics of the airplane.

The post-stall and erect-developed-spin recovery characteristics of the radio-controlled model were determined for the combat-loading condition with the center of gravity located at 30.3 percent of the mean aerodynamic chord. The model was tested in the clean condition, that is, no external stores or armament were attached to the model. For some tests, the model was prerotated to determine the spinning characteristics in a manner similar to that used in the spin tunnel whereas for other tests the model was launched in forward flight to determine the post-stall motions as well as to compare the resulting spinning motions with those obtained by prerotation tests.

SYMBOLS

The orientation of the model relative to the earth is defined by the set of Euler angles ψ_e, ϕ_e, and θ_e illustrated in figure 1.

b wing span, ft [redacted]

S wing area, sq ft

[redacted]

[redacted]

$\bar{c}$	mean aerodynamic chord, ft
c	local 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 perpendicular distances 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
W	weight of airplane, lb
X,Y,Z	body axes
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
$\dfrac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\dfrac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slugs/cu ft
μ	relative density of airplane, $m/\rho Sb$
V_R	resultant velocity, ft/sec
α	angle of attack at nose boom, deg
Ω	angular velocity about spin axis, rps
β	angle of sideslip at nose boom, deg
ψ_e	Euler angle of yaw or azimuth angle, deg
ϕ_e	Euler angle of roll, deg
θ_e	Euler angle of pitch, deg
δ_r	rudder deflection, positive with trailing edge to left, deg
δ_h	deflection of all-movable horizontal tail (stabilator) positive with trailing edge down, deg

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δ_a	aileron deflection, deg
δ_s	spoiler deflection, deg
t	simulated full-scale time, sec
L	left stick or pedal movement to produce control deflection, deg
R	right stick or pedal movement to produce control deflection, deg
U	up (trailing edge)
D	down (trailing edge)

MODEL FLIGHT-TEST TECHNIQUE

In general, the investigation was made by using basically the same technique as presented in references 1 and 2. In brief, this technique consisted of launching, generally in forward flight, an unpowered dynamically scaled radio-controlled model from a helicopter, and controlling the model remotely from ground stations during the flight. Evaluation of the flight behavior is based on the model pilot's observations and the quantitative measurements obtained from motion-picture records.

An additional technique was utilized for part of the present investigation in an attempt to obtain a developed spin more readily and also in an attempt to obtain the flat spin. This technique consisted of prerotating the model on the launch rig (maximum rate of rotation, 0.25 revolution per second, full scale) before it was released in a flat attitude with the helicopter flying in a hovering condition. Based on results obtained in the spin tunnel, on a 1/30-scale model of this airplane (ref. 3), however, it appeared that a rate of rotation somewhat above 0.25 revolution per second full scale might be required to achieve the flat-spin condition. Therefore, for some flights, a detachable flat metal plate was attached to the wing tip of the model (see fig. 2) in an attempt to force the model to higher rates of rotation than could normally be obtained on the launch rig. This plate, or pro-spin vane, was attached to the inner wing tip of the model in a spin (right wing tip in right spin). When the model appeared to be rotating sufficiently fast after release, the vane was jettisoned by the model pilot, at the same time moving the ailerons against the spin to help promote the spin. The model was allowed to spin for several turns in order to obtain a developed-spin condition, after which recovery controls generally were applied.

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Facility

The flight tests were performed at an isolated airport with three 5,000-foot runways forming an equilateral triangle. Two ground control stations were used for controlling the model, one for the pilot who operated the pitch controls and one for the pilot who operated the roll and yaw controls. (See fig. 3.) Each ground station was provided with a radio-control transmitter, communication equipment, and a motorized tracking unit equipped with a telephoto motion-picture camera and binoculars to assist the pilots and trackers in viewing the flight of the model. All phases of the operation were directed by a coordinator located near the ground stations. Magnetic tape recorders were used to record control signals and all voice communications among the helicopter, coordinator, and tracking units to assist in analysis of the test results.

Model Construction and Instrumentation

A three-view drawing of the 0.13-scale model of the test airplane is presented in figure 4 and a photograph of the model is shown in figure 5. A list of the pertinent geometric characteristics of the airplane is given in table I. Two identical models were furnished by the manufacturer and were constructed primarily of fiber-glass-reinforced plastic. The wings and tail surfaces had solid balsa cores with a covering of fiber glass whereas the fuselage was a 1/4-inch-thick hollow shell. During the course of flight testing, the models were revised from the original configuration which included a slender nose and small canopy to a final configuration which had a larger nose and canopy. (See fig. 6.) In addition, the full-up stabilator deflection was changed from -17° to -21° at the time the configuration was revised. Unless otherwise indicated the model results presented will be for the final revised configuration. The small housing for the infrared seeker device and the nose strakes originally on the model were not used in this investigation.

The model was provided with electric-motor-powered actuators which moved the aileron-spoiler combination and rudder rapidly through prefixed angular deflections in either direction from the neutral position in response to control signal. This type of control is referred to as a flicker or "bang-bang" type of control action. The aileron and spoiler actuators were connected electrically such that the left aileron and right spoiler operated simultaneously as did the right aileron and left spoiler; the ailerons deflected down only and the spoilers up only. The all-movable horizontal tail or stabilator was moved continuously by an electric actuator as long as a radio signal was being given. The normal maximum control deflections used in the flight tests were: $\delta_r = \pm 30^\circ$, $\delta_a = 30^\circ$; $\delta_s = -45^\circ$, and $\delta_h = 9^\circ$ to -21°.

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Simplified instrumentation was used in the model to provide sufficient data for a qualitative analysis of the motions of the model. A 16-millimeter motion-picture camera using a 17-millimeter wide-angle lens was mounted in the canopy of the model. It was positioned so as to photograph flow-direction vanes attached to a nose boom on the model and also to photograph control-position indicators and a timing light which were mounted on a photo panel in the canopy. The flow-direction vanes were attached to the boom with swivel joints which allowed each vane to aline itself with the airstream direction. At the beginning of the investigation, a system utilizing three flow-direction vanes (see ref. 1) was used to obtain the angle of attack and sideslip. This system was replaced early in the program with a simpler system using one vane to measure both the angle of attack and sideslip and another vane to measure the resultant airstream velocity. (See fig. 7.) The latter vane had canted fins attached to a torque rod and the angular displacement of the fins was the measure of the resultant velocity. The vanes were located 5.19 feet forward of and 0.20 feet above the center of gravity of the model.

Ground and Air Equipment

The radio-control and tracking equipment used in the present investigation were similar to those described in references 1 and 2. A photograph of the tracking equipment is shown in figure 8. A U.S. Navy HRS-1 helicopter equipped with a special launching rig was used to launch the models. In the early part of the investigation, the launching rig was mounted beneath the helicopter; a detailed description of this rig is presented in references 1 and 2. Later in the investigation this rig was replaced with a side-mounted launch rig which greatly facilitated the handling of the model. This launching rig was mounted on the side of the helicopter near the door (see fig. 9(a)) and was raised and lowered by a hydraulic hoist. When the helicopter was on the ground, the rig was in the raised position and when the model was ready to be launched the rig was lowered so that the model was below the helicopter. (See fig. 9(b).) The rig was constructed so that the model could be held stationary for forward launches or prerotated by an electric motor for spinning launches.

Retrieving Equipment

The model was retrieved at the termination of the flight by means of a parachute. In the early part of the investigation, a 21-foot (laid-out-flat) diameter ring-slot parachute was used, but the rate of descent of the model was too great with this parachute. Since the amount of space in the model available for the parachute was fixed, a larger ring-slot parachute could not be installed; however, for the same volume, a

24-foot-diameter (laid-out-flat) flat-circular parachute could be used. Although a flat-circular parachute generally is more unstable than a ring-slot type, the larger diameter and greater drag coefficient of the flat-circular parachute more than compensated for the slight loss of stability. Thus, for the remainder of the tests, the flat-circular parachute was used with good results.

The parachute was packed in a bag and installed in the fuselage near the canopy. A pyrotechnic device was used to eject the hatch covering the parachute. This hatch was attached by a length of cord to the pilot parachute so that, when the hatch was ejected, it pulled the pilot parachute into the free airstream and thus extracted the main parachute quickly and positively.

FLIGHT TESTS

The model was ballasted to simulate dynamically the full-scale airplane flying at an approximate altitude of 28,000 feet ($\rho = 0.000950$ slug/cu ft) with a gross weight of 34,700 pounds. For this condition, the total flying weight of the model was 187 pounds. The model was tested only for the combat loading condition and in the clean condition (no armament or stores simulated) with the center of gravity at 30.3 percent of the mean aerodynamic chord. A comparison of the model and airplane mass characteristics is shown in table II. The Reynolds number for these tests based on the mean aerodynamic chord averaged about 1,500,000.

For most of the flights, the model was launched in an attempt to obtain a flat spin from which recovery would be attempted, but, if a flat spin was not obtained, a recovery generally was attempted from whatever motion was obtained. Spins generally were attempted both to the right and left initially to determine the direction in which the model was most prone to spin; then the remainder of the spins were conducted in this direction. Basically, the test program was divided into two parts. One part of the program consisted of prerotating the model on the launch rig while the helicopter hovered at an altitude of 3,000 feet and releasing the model with the rudder with the spin, ailerons neutral, and the stabilator full up. The other part of the test program consisted of launching the model in forward flight at an airspeed of about 40 knots and an altitude of 3,000 feet. At instant of launch, the rudder and ailerons generally were neutral and the stabilator set to trim the model at a relatively low angle of attack. A few seconds after release, back stick was applied to stall the model. The rate at which the stabilator was deflected up was varied to produce both gentle and rapid stalls.

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After the model began to turn, it was allowed to rotate a few turns and then the ailerons were moved to against the spin to promote the spin (stick left in right spin); after the spin-developed or post-stall motion ensued, controls were applied to attempt recovery. Spin-tunnel experience has shown (ref. 4) that for airplanes with the mass distributed primarily along the fuselage, as is the case for the test airplane, the ailerons will be the primary recovery control and the rudder will aid in the termination of the spin rotation. Therefore, for most of the spin-recovery attempts in the present investigation, the ailerons were moved with the spin (stick right in a right spin) and the rudder against the spin.

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DATA REDUCTION

Evaluation of the flight behavior of the model was based primarily on the model pilot's observations and comments and on quantitative measurements of the variables obtained from the motion-picture records as described in reference 2 except as previously noted for the velocity measurements. Several factors, some of which must be evaluated on the basis of experience rather than from direct measurements, are involved in determining whether the model has entered a fully developed spin. The factors which appear to be the most important in determining whether a spin is developed are as follows: The rate of rotation about the flight path is sustained either to the right or left; the average angle of attack generally is above the stall and greater than that which can be maintained with full back stick in straight flight; and the time histories of angles of attack and sideslip as well as of rotation are fairly regular, although they may be oscillatory in nature. The time or number of turns required for spin recovery is measured from the time the controls are moved until either the spin rotation ceases (even though the model may still be above the stall) or the angle of attack decreases and remains below the stall angle. The airplane recovery characteristics are considered to be satisfactory if recovery from the model spin occurs in $2\frac{1}{4}$ turns or less.

A post-stall gyration is considered to be an uncontrolled continuing large-angle motion wherein the average angle of attack generally is above the stall and there are no clearly defined spinning characteristics. In general, the time histories of post-stall gyrations will be irregular whereas for the developed spin these time histories tend to be regular. The time or number of turns for recovery from a post-stall gyration are measured from the time the controls are moved until the angle of attack goes below the stall and positive effective normal control response is restored.

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The basic time reference for the flight records was a timing light recorded by the model camera at a fixed frequency. The various other film records of a given flight were correlated with the model camera on the basis of time interval from the moment of release of the model to the instant of parachute deployment. For some flight tests, the control-position-indicator lights did not operate properly and the control deflections had to be estimated from either the film records obtained from the other cameras or the magnetic tape records. These estimated data are represented on the graphs by a dashed line.

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ACCURACY

The measurements were obtained from tests of the radio-controlled model and are presented in terms of full-scale values. It is believed that they are accurate within the following maximum limits, based on limitations of equipment and on repeatability of measurements:

α, deg	± 4
β, deg	± 4
ψ_e, deg	± 10
ϕ_e, deg	± 10
θ_e, deg	± 10
V_R, ft/sec	± 30
Ω, rps	± 0.02
δ_r, deg	± 2
δ_a, deg	± 2
δ_s, deg	± 2
δ_h, deg	± 2
t, sec	± 0.5
Turns before recovery attempted	$\pm \frac{1}{8}$
Turns for recovery	$\pm \frac{1}{8}$

The measured weight and mass distribution of this model varied from desired values within the following limits during the test program:

Weight, percent	2 low
Center-of-gravity location, percent $\bar{c}$	3 forward
Moments of inertia:	
I_X, percent	1 low to 14 high
I_Y, percent	1 low to 2 high
I_Z, percent	2 low to 6 high

[redacted]

RESULTS AND DISCUSSION

A motion-picture film supplement to this paper showing complete motion-picture records of each of the flights has been prepared and is available on loan. A request card form and a description of the film will be found at the back of this paper, on the page immediately preceding the abstract and index pages.

A summary of the complete model flight-test program conducted is as follows:

Flight motion	Number of flights	Recoveries attempted	Recoveries obtained	Recoveries not attempted
Flat spins	4	3	0	1
Steep spins	10	5	4	5
Post-stall gyrations	21	7	7	14

Of the total of 35 flights, the model was launched 15 times in a prerotated condition and the model was launched 20 times in forward flight. Satisfactory recoveries could be obtained from all post-stall gyrations and steep spins. For one flight, recovery from a steep spin was attempted by application of forward stick only, the ailerons and rudder being maintained with the spin. No recovery was obtained. Also, no recoveries could be effected from the flat spins.

The results of some of the model flight tests are presented in the form of full-scale time histories in figures 10 to 19 and are considered to be typical of all the results obtained. In these figures, U denotes trailing edge up; D denotes trailing edge down. Right and left stick or pedal movements to control deflection are denoted by R and L, respectively. For ease of comparison, the flight results are not presented in the order in which the tests were conducted. Results obtained with the original nose are arbitrarily presented last. Complete motion-picture records of each of these flights are available in a film supplement to this report.

Model Flight-Test Results

Flight 1; flat spin.- For flight 1 (fig. 10) the model was prerotated to the right with a pro-spin vane attached to the right wing tip and

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launched with rudder and ailerons neutral and the stabilator full up. After one turn, full right rudder was applied. About 6 turns later, the pro-spin vane was jettisoned, and the ailerons were moved against the spin (stick left in right spin) to promote the spin. The model continued to spin fast and very flat after the vane was ejected. The angle of attack, although slightly oscillatory, averaged about 83° and the rate of rotation was approximately 0.43 revolution per second (full scale). The rate of descent was approximately 280 feet per second (full scale); recovery was not attempted.

Flight 2; flat spin.- For flight 2 (fig. 11) the model was prerotated to the right with a pro-spin vane attached to the right wing (same condition as flight 1). At about 4 turns after the release of the model, the ailerons were moved to against the spin to promote the spin. The model continued to spin very flat (average α of 81°) and the rate of rotation was about 0.29 revolution per second (full scale). After a total of 11 turns, a spin recovery was attempted by moving the rudder against and the ailerons with the spin. A recovery was not obtained although the angle of attack decreased slightly to about 75° and the rate of rotation decreased to about 0.25 revolution per second. This spin was very similar to the flat spin obtained in flight 1 except the rate of rotation was lower.

Flight 3; flat spin.- For flight 3 (fig. 12) the model was launched in forward flight with neutral lateral controls and the stabilator deflected slightly down. A few seconds after the model was released the stabilator moved to the full up position very slowly and erratically (apparently because of radio interference) and the model approached the stall in a slight bank to the right. As the model stalled and became directionally unstable, it yawed and rolled to the left and entered a left spin. After about $1\frac{1}{2}$ turns, the stabilator moved from -10° to -21° (t = 16 seconds, full scale). The spin seemed to be fully developed after about one or two turns with a very fast rotation. Up to this time (t = 20 seconds, full scale) no lateral controls had been applied. After two turns, pro-spin controls were applied (rudder with and ailerons against the spin) and the model continued to spin very fast and flat. The angle of attack for the fully developed spin averaged about 82° and the rate of rotation was 0.45 revolution per second (full scale). A recovery was attempted but could not be obtained by moving the ailerons full with and the rudder against the spin. During the latter stage of the attempted recovery, the stabilator was moved down slightly but had no effect as expected.

Flight 4; steep spin.- For flight 4 (fig. 13) the model was released in forward flight with all controls neutral and after a few seconds, right rudder was applied briefly to keep the model on approximately a constant heading. Although the stabilator was still neutral, the model stalled a few seconds after release apparently because of the low launching airspeed. The model started turning slowly to the left and then reversed direction and started turning to the right. After about 3/4 of a turn (t = 16.5 seconds, full scale) back stick was applied in order to be sure the model remained above the stall. An instant later the rudder was deflected to the right and the ailerons moved to against the rotation (stick left in a right spin) to promote the spin. The spin was relatively steep and oscillatory and the angle of attack ranged from 40° to 60° and the angle of sideslip from approximately 20° to -20°. The variation in sideslip angle was due primarily to the rolling oscillations of the model. The spin is typical of most of the developed spins obtained with this model. After a total of $2\frac{3}{4}$ turns, a recovery was effected in approximately one turn by applying recovery controls (ailerons with and rudder against the spin). As the rate of rotation and the angle of attack decreased, forward stick was applied to unstall the model. The rotation of the model did not cease entirely during the recovery since as the model became unstalled, it continued turning in the direction that the ailerons were deflected.

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<u>Flights 5 and 6; steep spins</u>.- For flights 5 and 6 (figs. 14 and 15) the model was prerotated and then released with the stabilator deflected full up and the rudder maintained full with the rotation. The ailerons were maintained against the rotation (stick left for right rotation) for flight 5 and were kept at neutral in flight 6; a pro-spin vane was a attached to the model for flight 6 which was jettisoned after several turns. For both flights, the model entered a steep oscillatory spinning motion with the angle of attack varying between approximately 40° and 60°. The stabilator alone was moved to full down and in flight 5 resulted in terminating the spin rather quickly $\left(1\frac{1}{4}\text{ turns}\right)$; however, in flight 6 after deflecting the stabilator full down, the model continued spinning and the rate of rotation and angle of attack increased. Interpretation of these results in light of spin-tunnel experience and more complete spin-tunnel tests on this design (ref. 3) indicates that premature movement of the stabilator down (that is, before use of rudder and aileron) should be avoided.

<u>Flight 7; post-stall gyration</u>.- For flight 7 (fig. 16) the model was released in forward flight with the stabilator set at 5° down; at release, the ailerons and rudder were neutral. The stabilator was moved up slowly and the model stalled and rolled slightly to the right and entered what appeared to be a steep oscillatory spin to the right. The angle of attack, however, ranged between 30° and 50° which was somewhat low for a developed-spin condition of this model. After about 3 turns (t = 28.2 seconds, full scale), pro-spin controls were applied but instead of increasing the rotation, the rate of rotation slowed and

stopped in $2\frac{1}{4}$ turns. The angle of attack during this time oscillated between 10° and 40°. It thus appears that this motion was merely a post-stall gyration since moving the ailerons against the rotation stopped the rotation rather than promoting it, as would be the case for a developed spin.

Flight 8; post-stall gyration.- For flight 8 (fig. 17) the model was launched in forward flight with the stabilator deflected down 5°. At release and during the flight, the ailerons and rudder were neutral. After approximately 3 seconds (full scale) back stick was applied and the stabilator moved full up rather quickly. The model stalled and started rotating to the right; after $1\frac{1}{2}$ turns it reversed to the left and made about $1\frac{3}{4}$ turns. During this time, the lateral controls had not been moved. The angle of attack ranged between approximately 12° to 60°. This appeared to be a post-stall gyration. No recovery was attempted.

Flight 9; post-stall gyration.- For flight 9 (fig. 18) the model had the original slender nose and small canopy. As the model was released in forward flight, it pitched up and stalled; the model then rolled and yawed to the right, and during this time, back stick was applied to move the stabilator full up (-17°). The model then rolled and yawed to the left until it was erect again (t = 12 seconds, full scale). No lateral-control movements had been given during this motion. Since the model pilot wanted to obtain a right spin, he applied left stick and right rudder. Upon application of the controls, the model started rotating to the right with large oscillations in roll and pitch. The angle of attack ranged from approximately 12° to 50° and the angle of sideslip from 20° to -20°. As indicated, by the change in heading ψ_e, the rotation was a hesitant type of motion. Since the model trims around an angle of attack of 25° to 30° with full back stick according to static-force data, it appears the model was trimmed at a high angle of attack and was oscillating about this approximate trim point. The model was rotating to the right because of the adverse yaw produced by the ailerons which were deflected against the rotation (stick left). Thus, although the motion has the appearance of a spin, the motion is believed to be a post-stall gyration. No recovery was attempted.

Flight 10; post-stall gyration.- For flight 10 (fig. 19) the model had the slender nose and small canopy and was prerotated on the launch rig to the right as fast as possible and the stabilator full-up deflection was increased from -17° (used in flight 9) to -30° in an effort to make the model spin more readily. The model was launched with right rudder, ailerons against the rotation (stick left for right rotation), and stabilator full up; after approximately two turns, left stick was

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applied to promote right rotation. A post-stall gyration ensued similar to that obtained in flight 9. The angle of attack ranged between 8° and 50°. A recovery was obtained in slightly less than one turn by moving only the ailerons in the direction of the rotation. Although the rotation ceased, the angle of attack did not go below the stall because the stick was held full back (-30°). However, it is felt that, if the stick had been pushed forward at this time, the model would have become unstalled.

Interpretation of Model Flight Results

Model flight results indicate that, although two types of developed spins are possible on the airplane, the likelihood of obtaining the flat fast-rotating spin appears to be remote. However, specific instructions should be provided pilots to help them recognize the onset of such a spin so that immediate steps can be taken to avoid it; recovery from such a spin by existing controls may be impossible. A steeper-type, more oscillatory spin will be more readily obtainable and termination of this spin will be possible by the recommended recovery technique. In many instances, post-stall gyrations (incipient spin motions) will be obtained which may or may not develop into a spin.

The recommended airplane recovery technique from erect developed spins or from post-stall gyrations is simultaneous movement of the ailerons to full with the rotation (stick right for right rotation) and rudder full against the rotation; when recovery is imminent, the stick should be moved longitudinally to neutral. Because there is no technique which will insure a satisfactory recovery from the flat-spin condition, it is recommended that recovery be made in the post-stall condition before a flat spin could develop.

As previously stated, the likelihood of obtaining a flat fast-rotating spin on the airplane appears to be remote; nevertheless, if deliberately attempted (for example, during spin demonstration tests) such a spin might be more readily obtainable on the airplane than it was on the model since the pilot of the airplane has more precise control and "feel." If a flat spin is obtained inadvertently, it probably would be from a condition immediately after a stall with wing drop and sideslip in one direction followed by a directional divergence in the opposite direction, particularly if the stick is pulled full back quickly at this time. It is strongly recommended that the pilot be cautioned on the rapidity with which the flat spin, if it should occur, could develop (two turns or less) and that he be instructed to move the stick longitudinally to neutral when stalling of the airplane is indicated. If the stall persists and rotation starts, the stabilator should be kept neutral and the ailerons moved full with the rotation simultaneously with rudder movement full against the rotation.

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Comparison of Model Flight and Spin-Tunnel Results

The developed spin results of the radio-controlled model flight tests were in good agreement with spin-tunnel results (ref. 3) both as regards the nature of spin obtained and the recoveries therefrom. The model flight tests indicated that the tunnel technique of launching the models with a high rate of rotation was conducive of obtaining the flat-type spin. The tendency to enter the flat-type spin from level flight was very slight and, even when the model was launched with moderate rotation from the helicopter, the model had little or no tendency to enter the flat spin. Use of a pro-spin vane to produce a high rate of rotation that could be maintained until the normal rate of descent of the model was reached, increased the tendency to obtain a flat spin, and thereby resulted in a flat spin on the model in a few instances.

CONCLUSIONS

On the basis of tests of a 0.13-scale radio-controlled model of a twin-jet swept-wing fighter airplane simulating the combat-loading condition at an approximate altitude of 28,000 feet, the following conclusions may be made:

1. Two types of spins are possible on the airplane although the likelihood of obtaining a flat fast-rotating spin is somewhat remote. A steeper-type, more oscillatory spin will be more readily obtainable and satisfactory termination of this spin will be possible by recommended control technique. In many instances, post-stall gyrations will be obtained which will not necessarily develop into spins.

2. The recommended airplane recovery technique from erect developed spins or from post-stall gyrations is simultaneous movement of the ailerons to full with the rotation (stick right for right rotation) and rudder full against the rotation; when recovery is imminent, the stick should be moved longitudinally to neutral. Because there is no technique which will insure a satisfactory recovery from the flat-spin condition, it is recommended that recovery be made in the post-stall condition before a flat spin could develop.

3. It is strongly recommended that the pilot be cautioned on the rapidity with which the flat spin, if it should occur, could develop (two turns or less) and that he be instructed to move the stick longitudinally to neutral when stalling of the airplane is indicated. If the stall persists and rotation starts, the stabilator should be kept neutral and the ailerons moved full with the rotation simultaneously with rudder movement full against the rotation.

4. It is recommended that the spin not be allowed to develop fully on this airplane and that the pilot be instructed to terminate any turning tendency after the stall by the recommended control technique.

5. Developed spin results of model flight tests are in good agreement with spin-tunnel results.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., October 26, 1960.

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REFERENCES

1. Libbey, Charles E., and Burk, Sanger M., Jr.: A Technique Utilizing Free-Flying Radio-Controlled Models To Study the Incipient- and Developed-Spin Characteristics of Airplanes. NASA MEMO 2-6-59L, 1959.

2. Hewes, Donald E., and Hassell, James L., Jr.: Subsonic Flight Tests of a 1/7-Scale Radio-Controlled Model of the North American X-15 Airplane With Particular Reference to High Angle-of-Attack Conditions. NASA TM X-283, 1960.

3. Bowman, James S., Jr., and Healy, Frederick M.: Free-Spinning-Tunnel Investigation of a Twin-Jet Swept-Wing Fighter Airplane - Clearance No. N5154. NASA TM SX-446, Bur. Weapons, 1960.

4. Neihouse, Anshal I., Klinar, Walter J., and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NASA TR R-57, 1960.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE TEST AIRPLANE

AS SIMULATED ON THE MODEL

Overall length, ft	57.59
Wing:	
Span, ft	38.41
Area (theoretical), sq ft	530
Area (including leading-edge extension), sq ft	538.34
Root chord (center line of airplane), ft	23.50
Tip chord (theoretical tip), ft	3.92
Mean aerodynamic chord, ft	16.04
Leading edge of $\bar{c}$ rearward of leading edge of root chord, ft	9.23
Aspect ratio	2.82
Taper ratio	0.167
Sweepback of 25-percent chord, deg	45
Dihedral (inboard 13.33 ft of semispan), deg	0
Dihedral (outboard 13.33 ft of semispan), deg	12
Incidence, deg	1.0
Airfoil section:	
Root (center line of airplane)	Modified NACA 0006.4-64
Tip (theoretical)	Modified NACA 0003.0-64
Aileron:	
Area (one side) rearward of hinge line, sq ft	13.08
Span (one aileron) (from 44.5 percent b/2 to 67.0 percent b/2), ft	4.35 (22.5 percent b/2)
Inboard-end chord (8.60 ft of semispan), ft	3.15 (21.3 percent c)
Outboard-end chord (12.95 ft of semispan), ft	2.86 (27.6 percent c)
Spoiler:	
Area (one side), sq ft	5.44
Span (from 45.3 percent b/2 to 67.0 percent b/2), ft	4.19 (21.7 percent b/2)
Inboard-end chord, ft	1.39 (10.0 percent c)
Outboard-end chord, ft	1.04 (10.0 percent c)
Horizontal tail:	
Area (in chord plane), sq ft	94.7
Movable area, sq ft	77.4
Span, ft	8.85
Aspect ratio	3.30
Taper ratio	0.20
Sweepback of 25-percent chord, deg	35.5
Dihedral, deg	-23.00
Root chord (at airplane center line), ft	8.92
Tip chord (theoretical), ft	1.78
Hinge-line location, percent $\bar{c}$ tail	41.00
Airfoil section:	
Root (airplane center line)	Modified NACA 0003.7-64
Tip (theoretical)	Modified NACA 0003.0-64
Vertical tail:	
Area (theoretical above water line 5.54), sq ft	67.5
Span (water line 5.54 to water line 11.92), ft	6.375
Taper ratio	0.227
Root chord (water line 5.54), ft	207.15
Tip chord (water line 11.92), ft	3.93
Sweepback of 25-percent chord, deg	4.85
Airfoil section:	
Root	Modified NACA 0004.0-64
Tip	Modified NACA 0002.5-64
Rudder:	
Area (rearward of hinge line), sq ft	11.07
Hinge-line location, percent of water line chords	80.00

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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS OF THE LOADINGS OF THE TEST AIRPLANE AND THE LOADING TESTED ON THE 0.13-SCALE MODEL

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

Loading	W, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	Altitude 28,200 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						
Combat	34,473	0.321	0.015	21.76	54.48	20,335	109,172	121.904	-562×10^{-4}	-81×10^{-4}	643×10^{-4}
Landing	28,029	.299	.046	17.70	44.32	20,130	102,990	115,872	-645	-100	745
					Model						
Combat	33,824	0.303	0.040	21.35	53.46	20,208	109,968	124,287	-579×10^{-4}	-92×10^{-4}	671×10^{-4}

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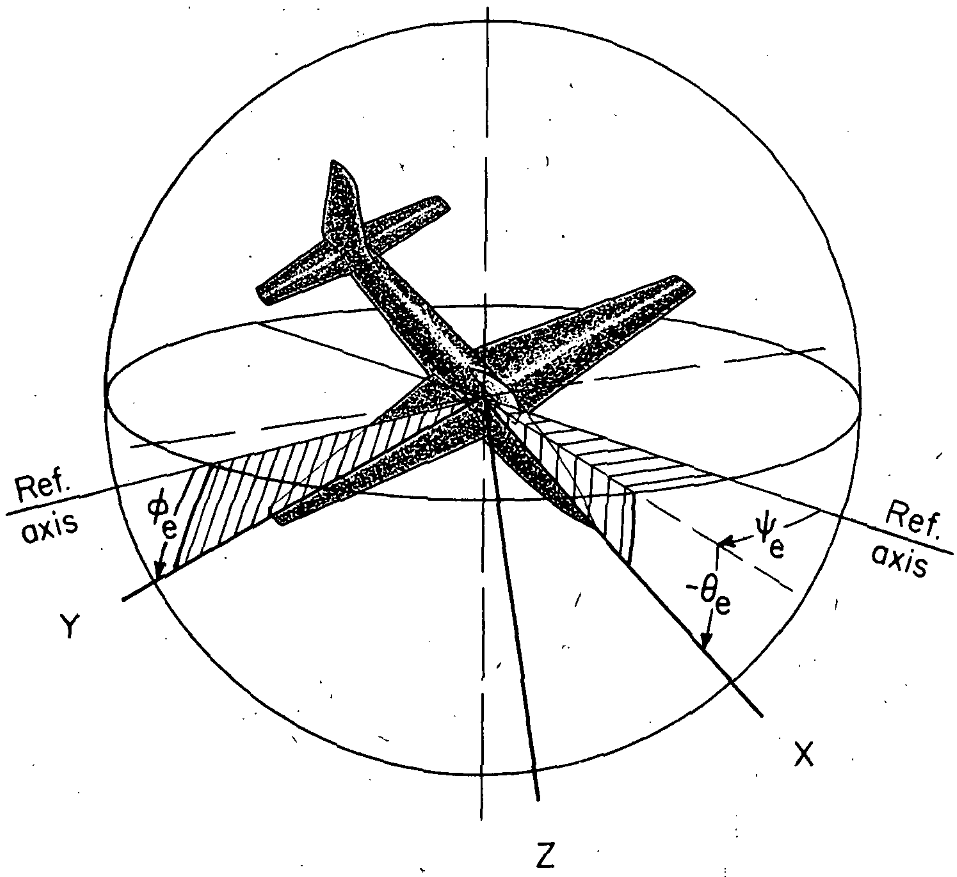

Figure 1.- Sketch illustrating Euler angles.

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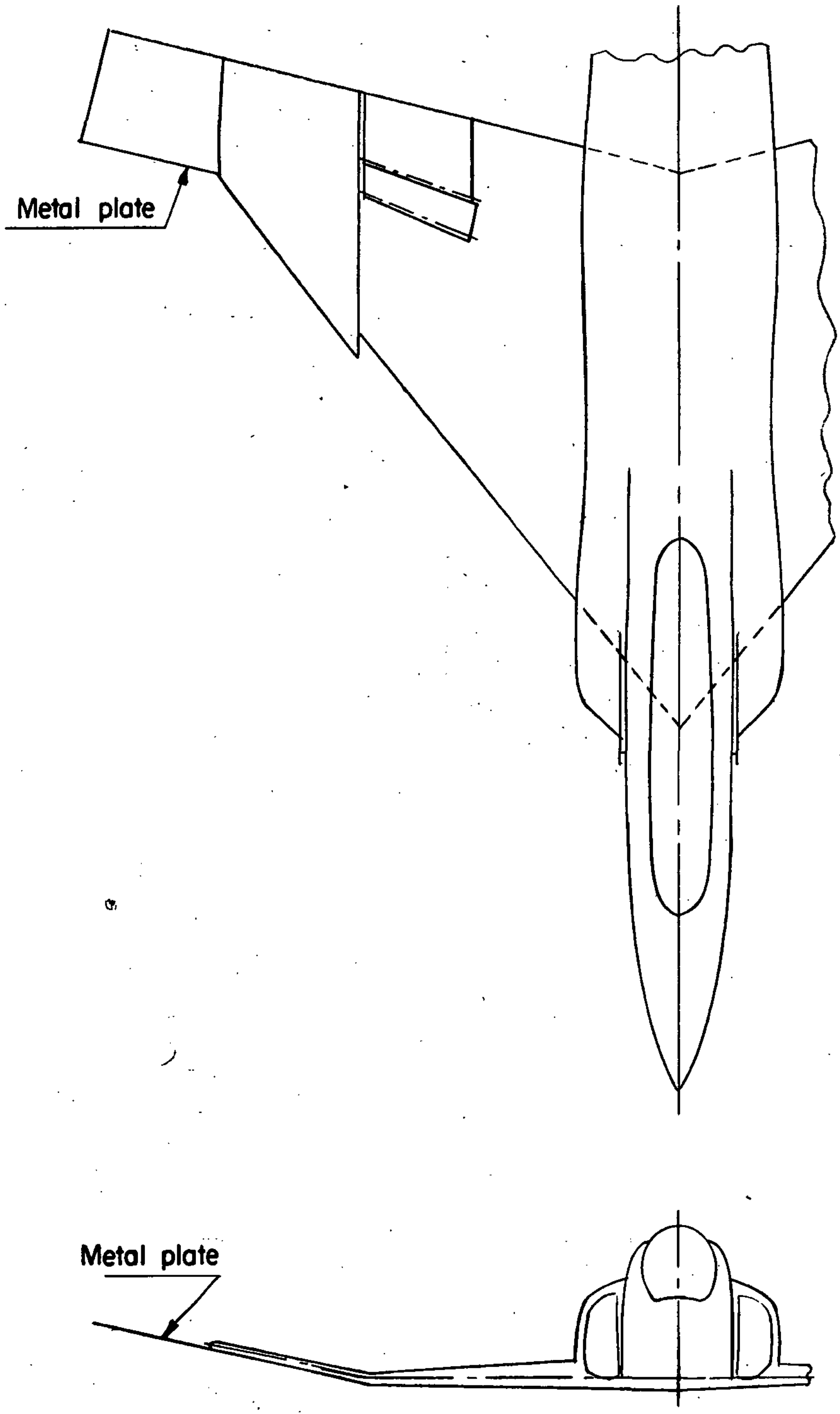

Figure 2.- Sketch showing position of detachable flat metal plate (pro-spin vane) on model.

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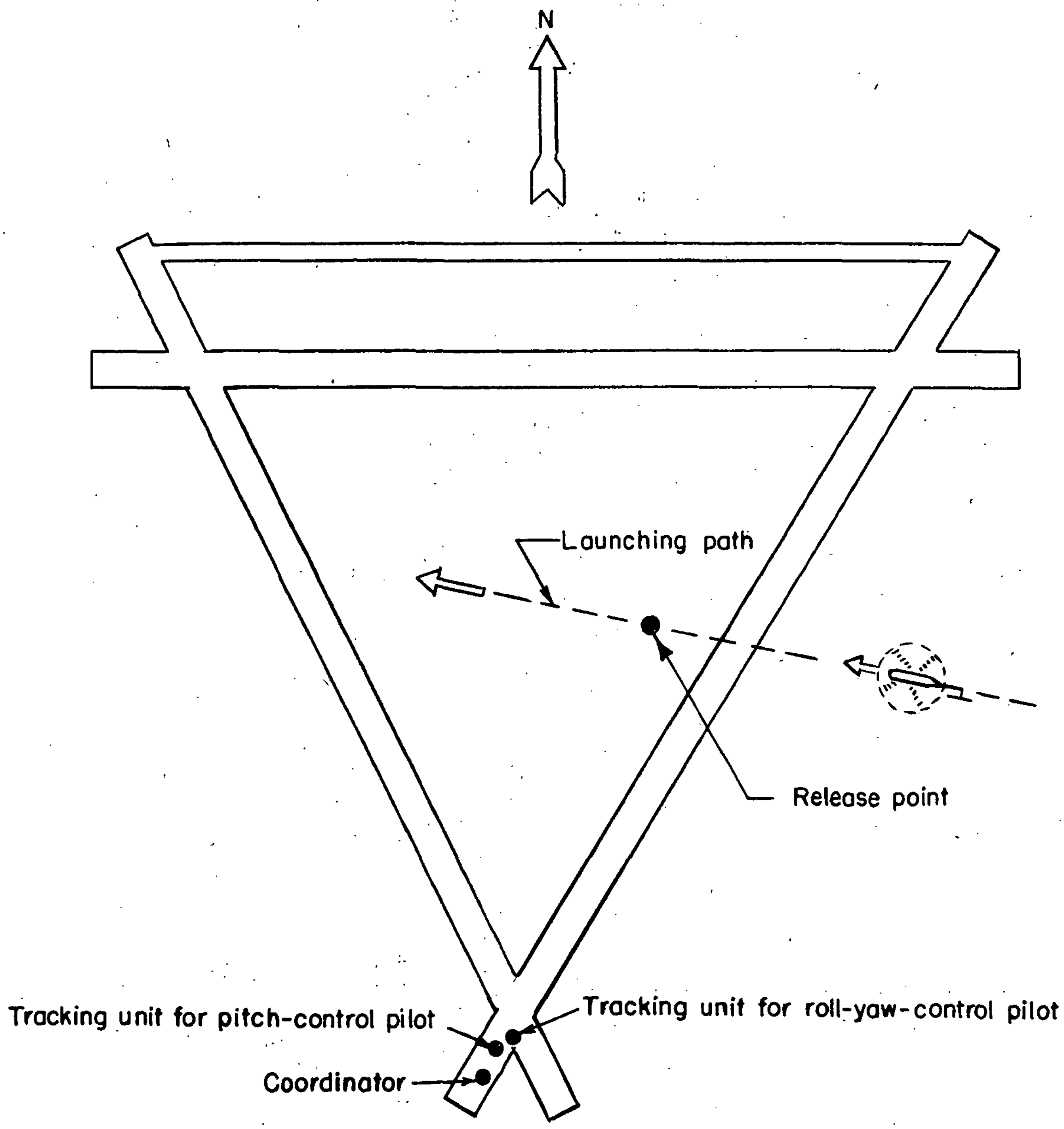

Figure 3.- Area where test program was conducted.

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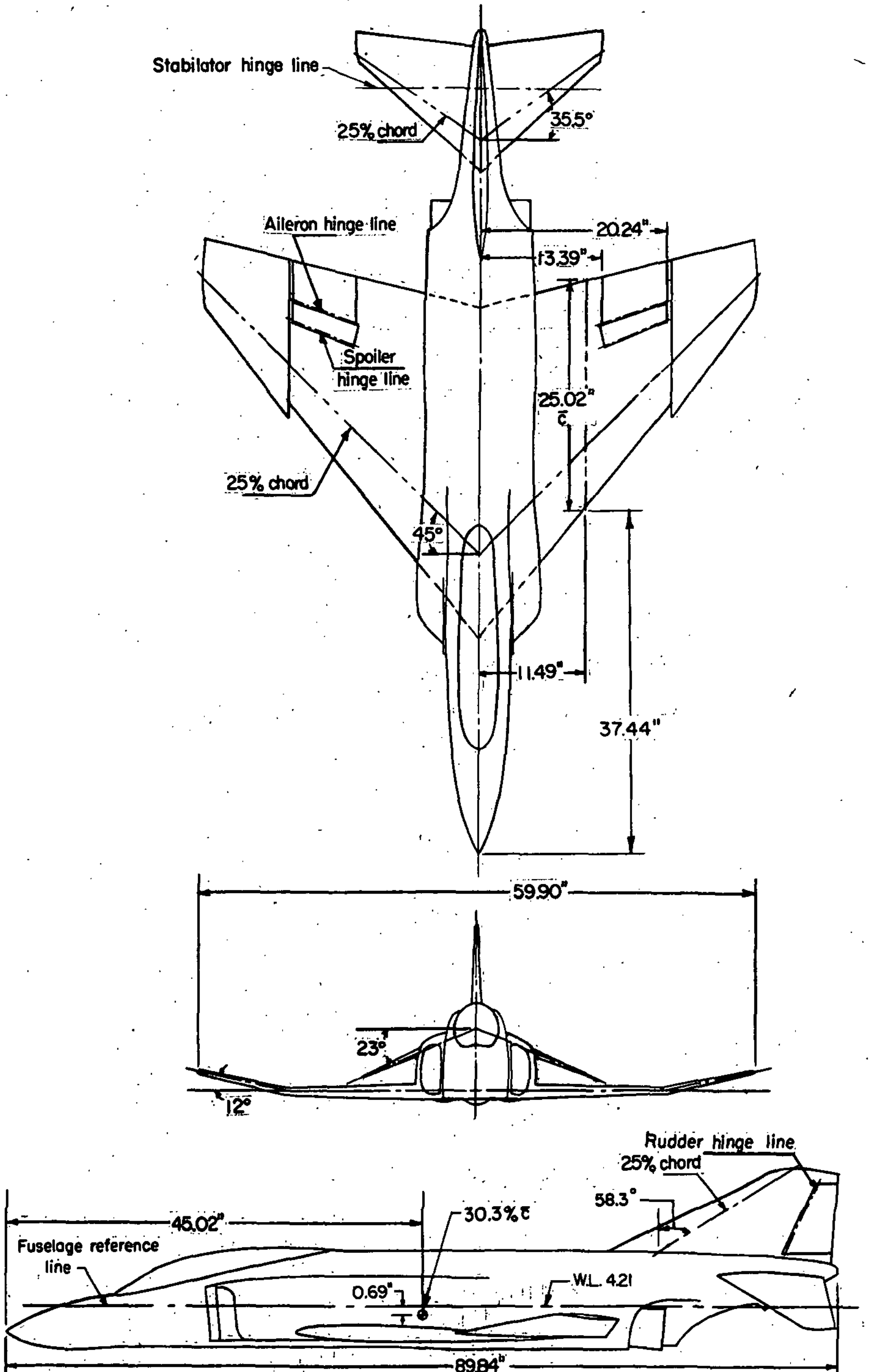

Figure 4.- Three-view drawing of the 0.13-scale model of the test airplane.

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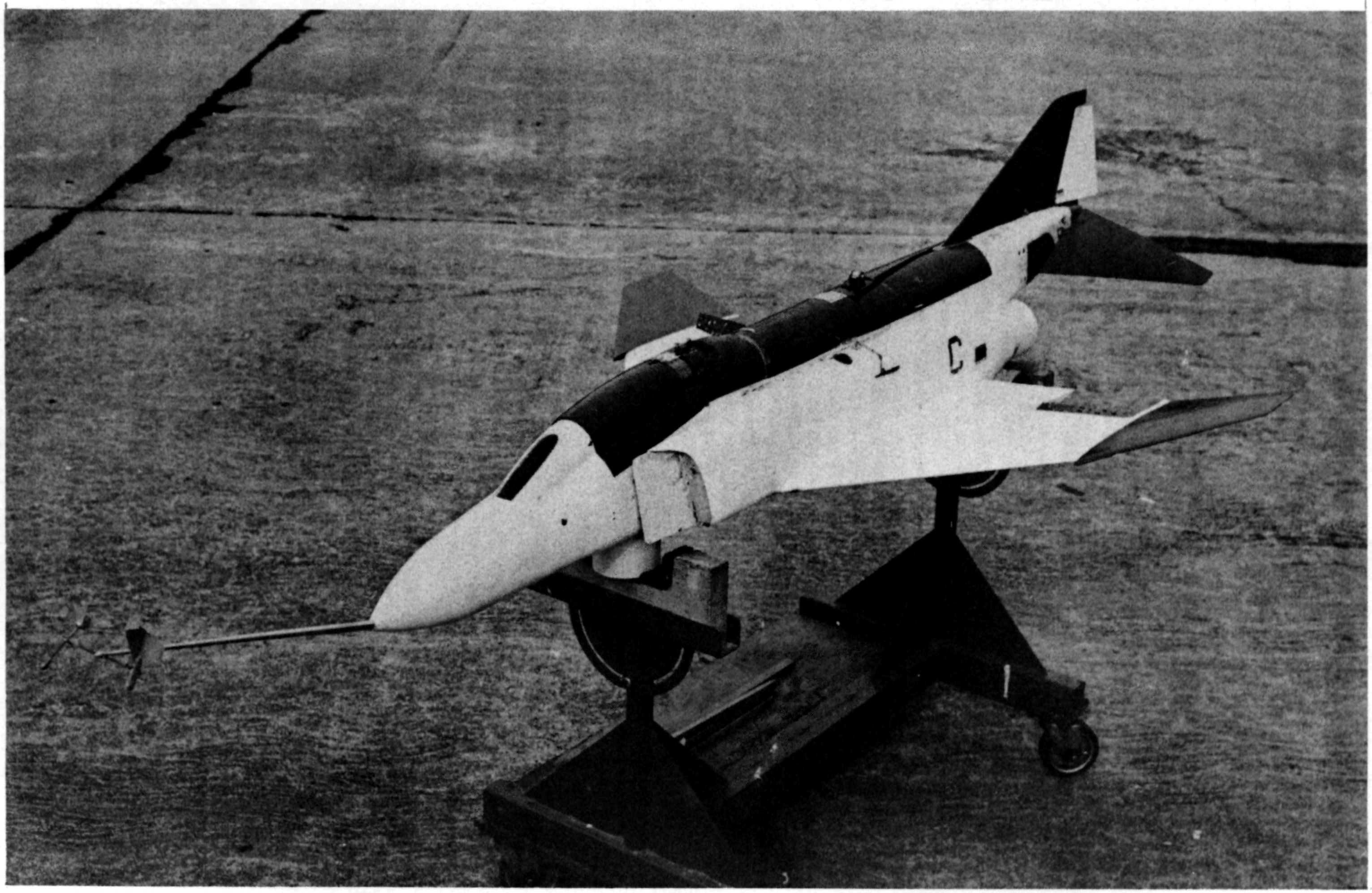

Figure 5.- Photograph of 0.13-scale model of the test airplane. L-60-1271

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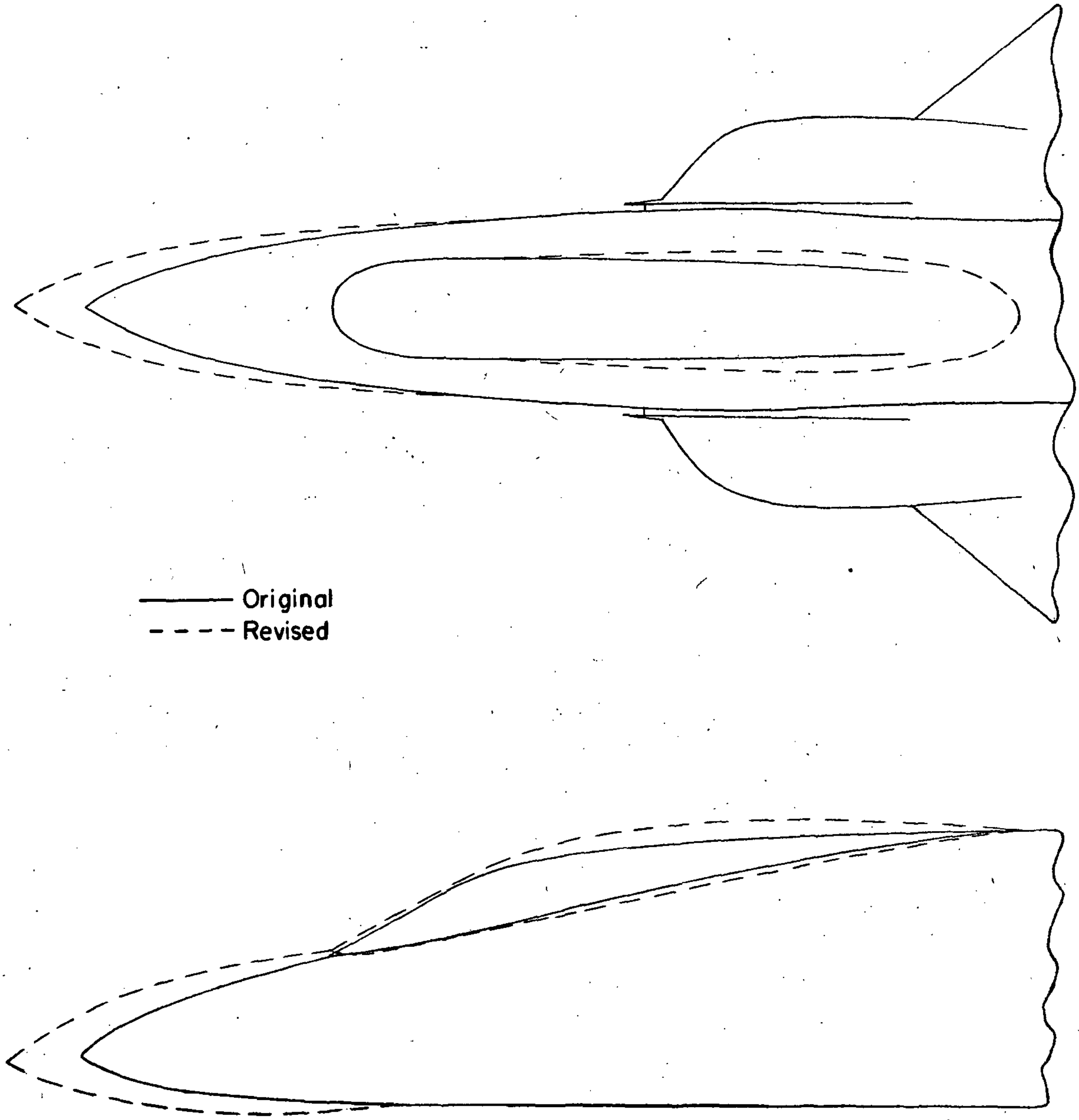

Figure 6.- Comparison of original and revised nose and canopy on the model.

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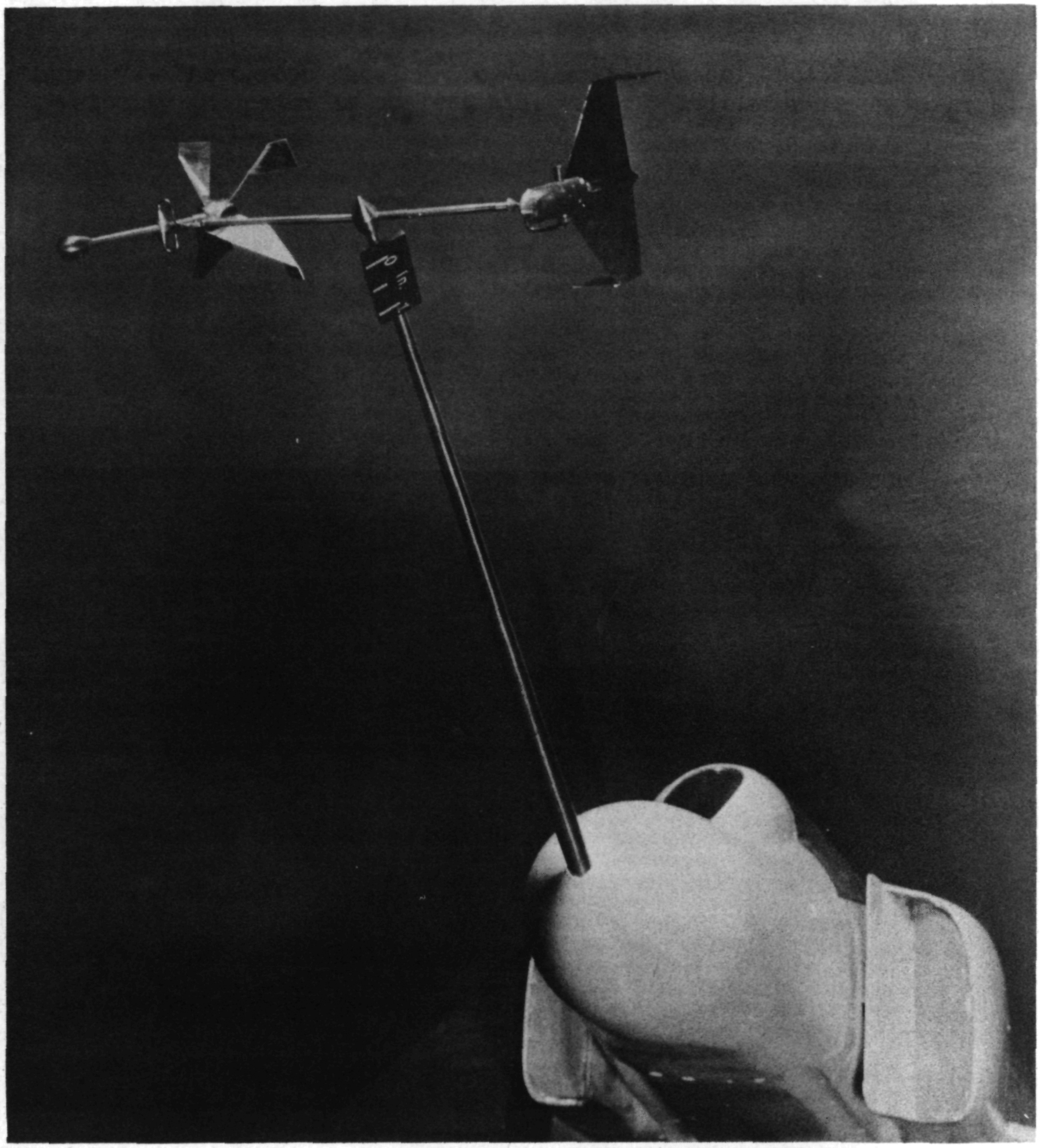

L-59-2398
Figure 7.- Photograph showing flow-direction vanes. Resultant airstream velocity indicator is on left side and α,β indicator is on right side of photograph.

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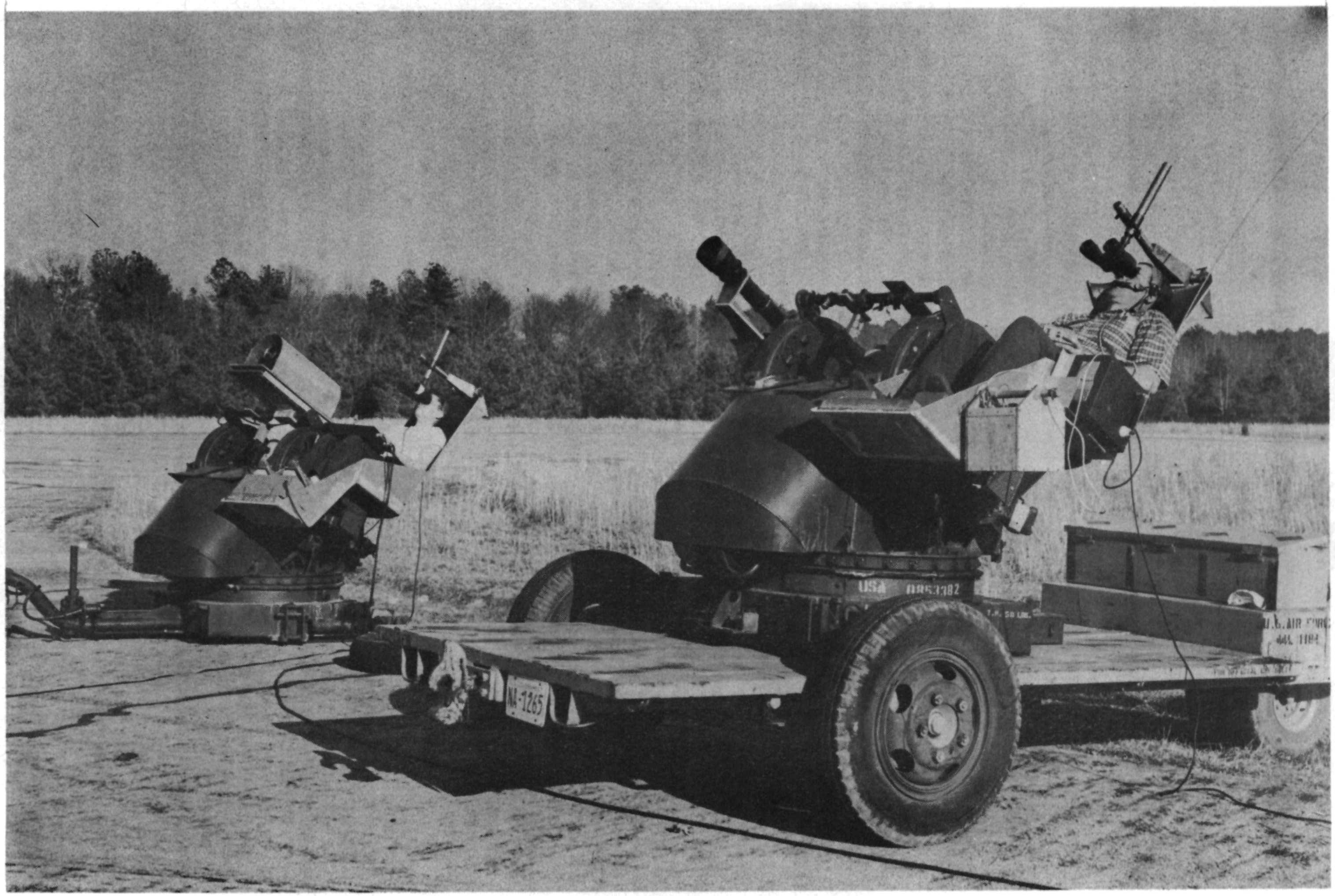

L-60-1879
Figure 8.- Photograph of ground stations showing the roll-yaw pilot and pitch pilot in position.

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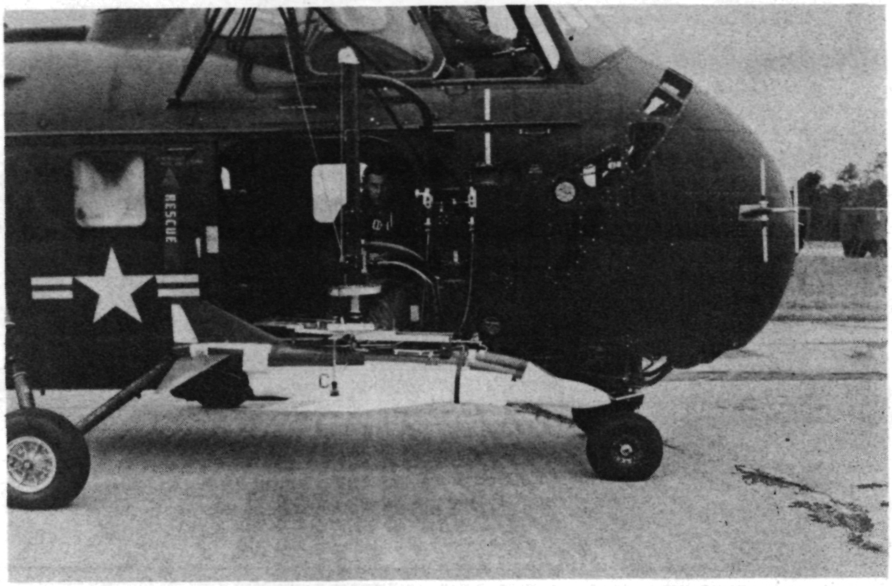

(a) Model raised. L-60-1275

(b) Model lowered. L-60-1276

Figure 9.- Photograph of model on side-mounted launch rig in raised and lowered position.

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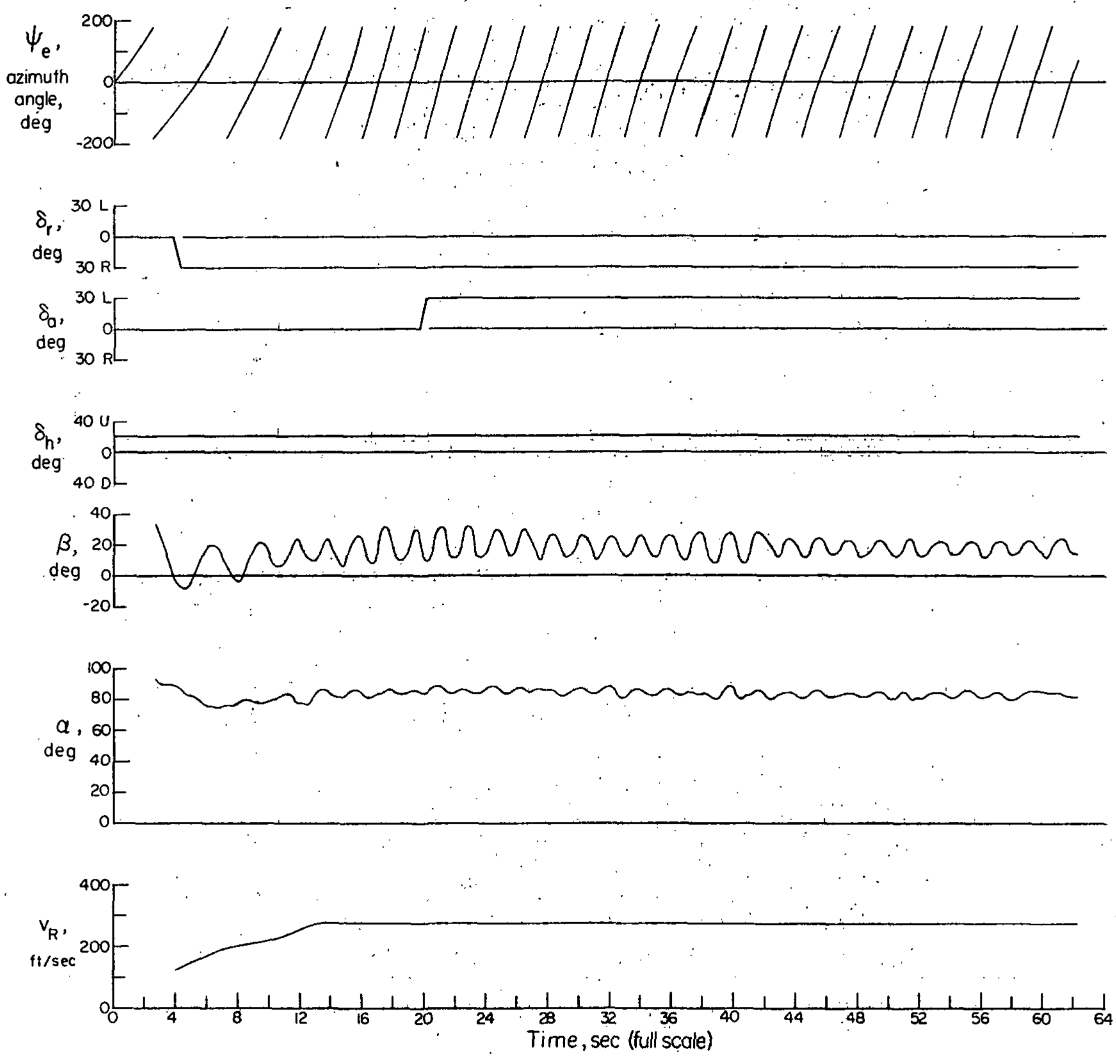

Figure 10.- Time histories of model flight tests. Flat spin; flight 1.

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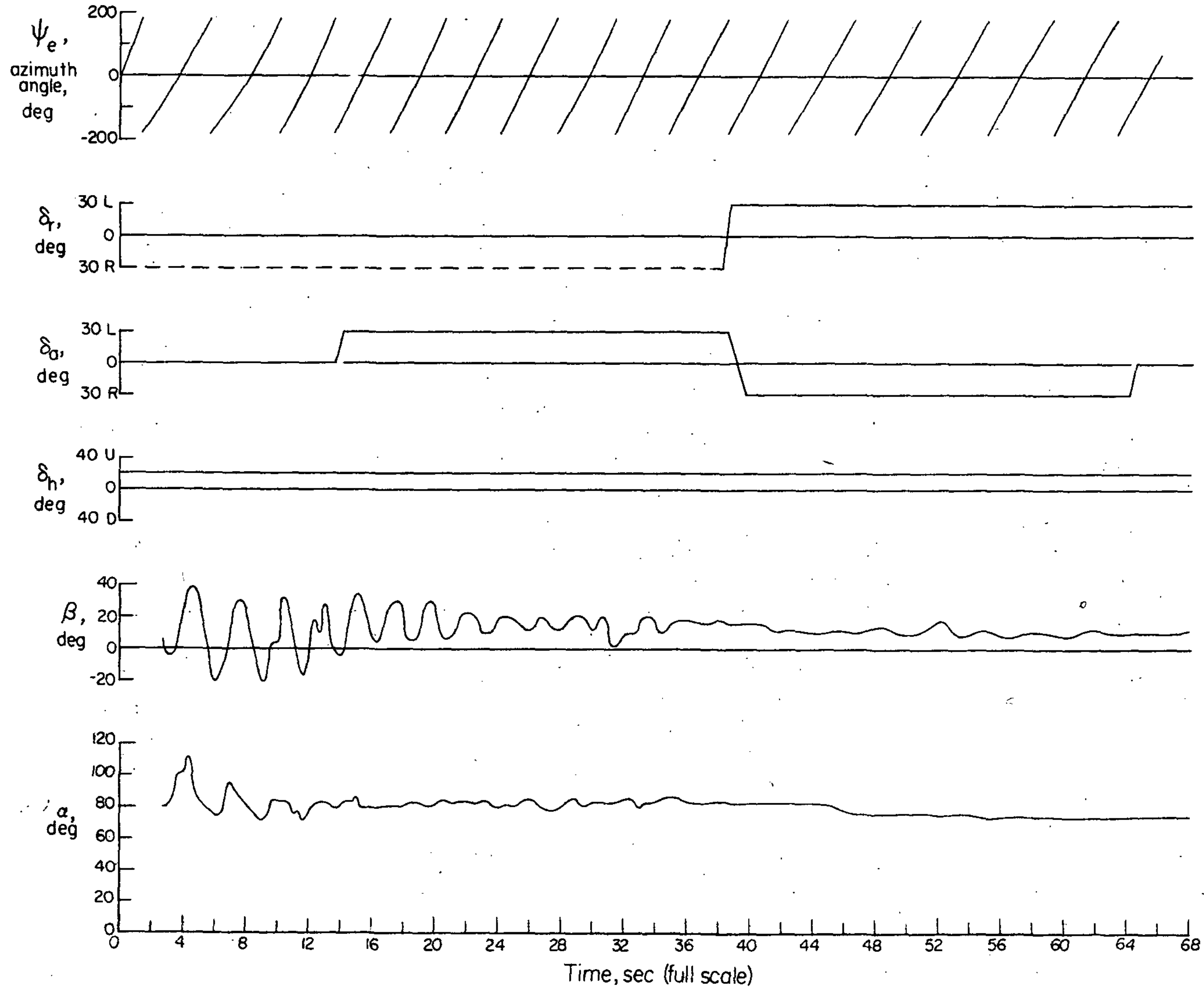

Figure 11.- Time histories of model flight tests. Flat spin; flight 2.

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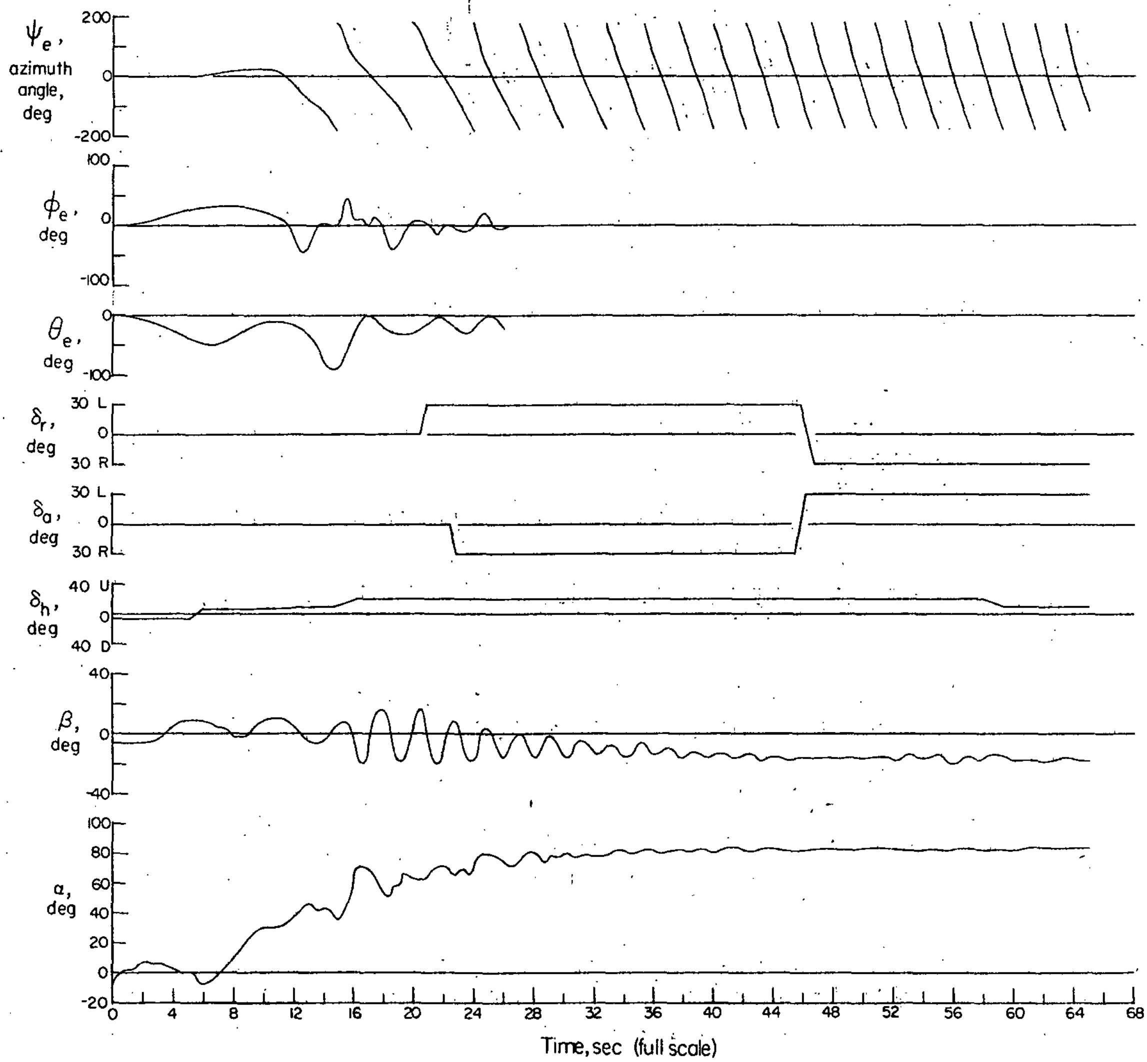

Figure 12.- Time histories of model flight tests. Flat spin; flight 3.

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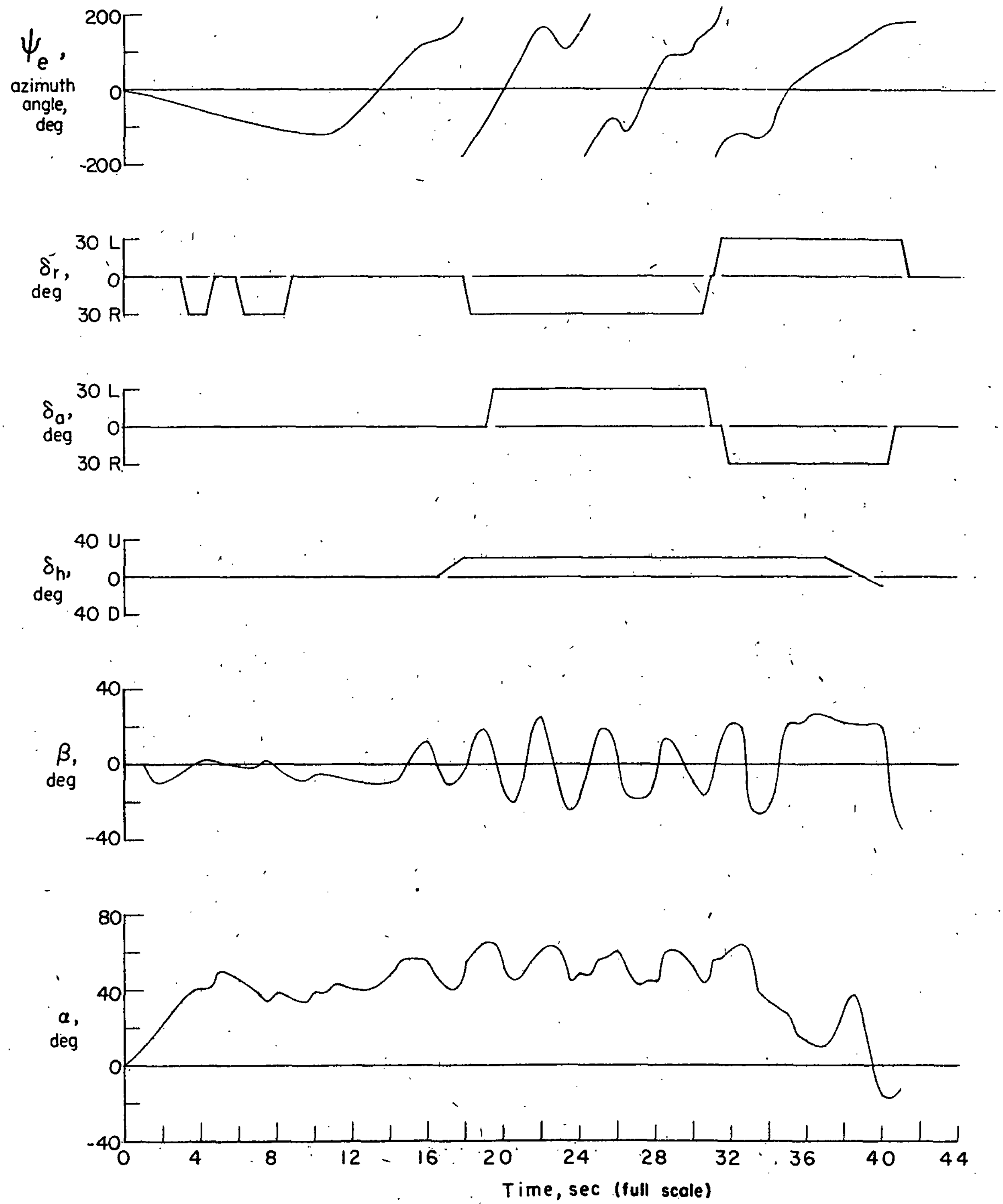

Figure 13.- Time histories of model flight tests. Steep spin; flight 4.

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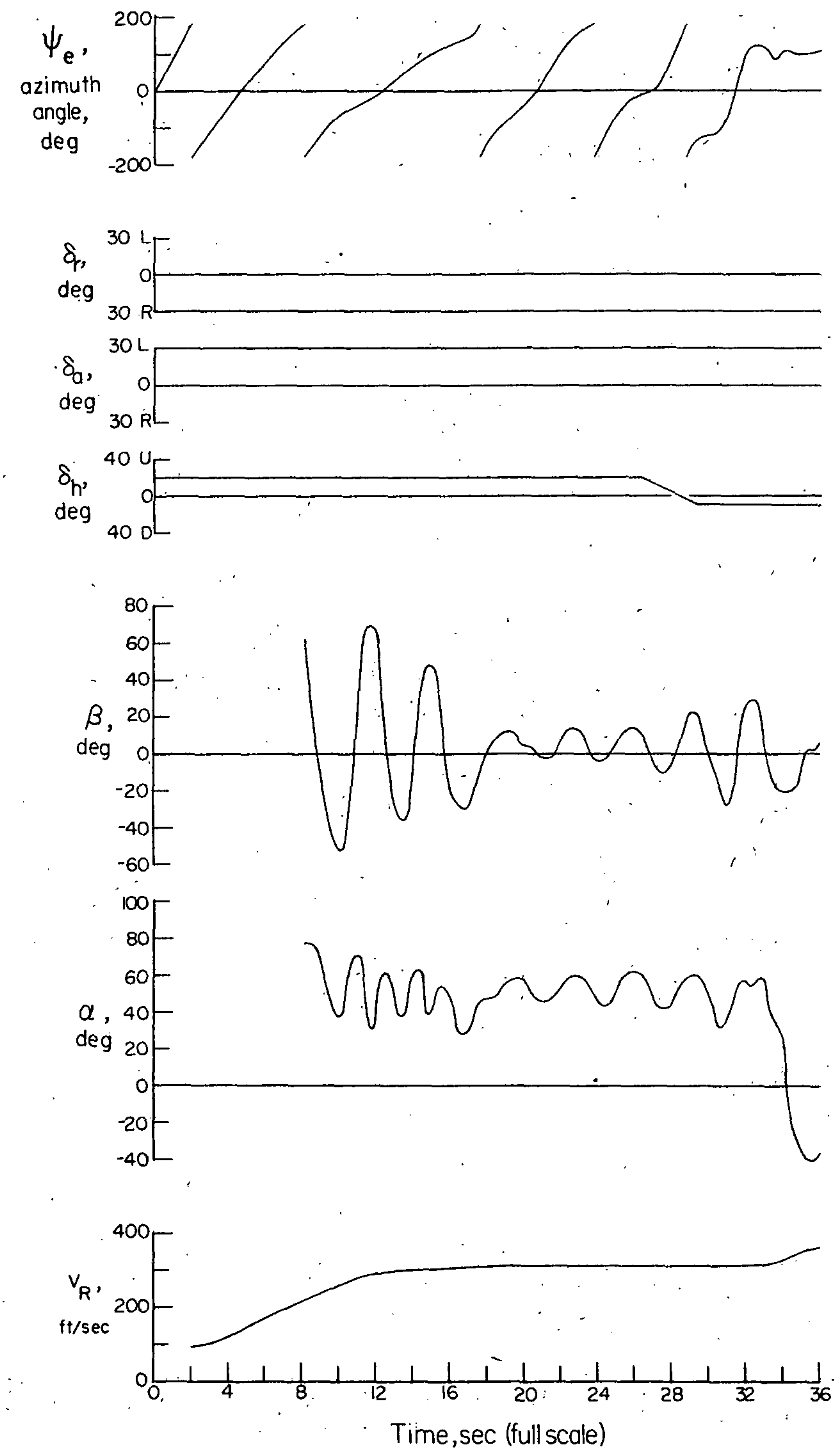

Figure 14.- Time histories of model flight tests. Steep spin; flight 5.

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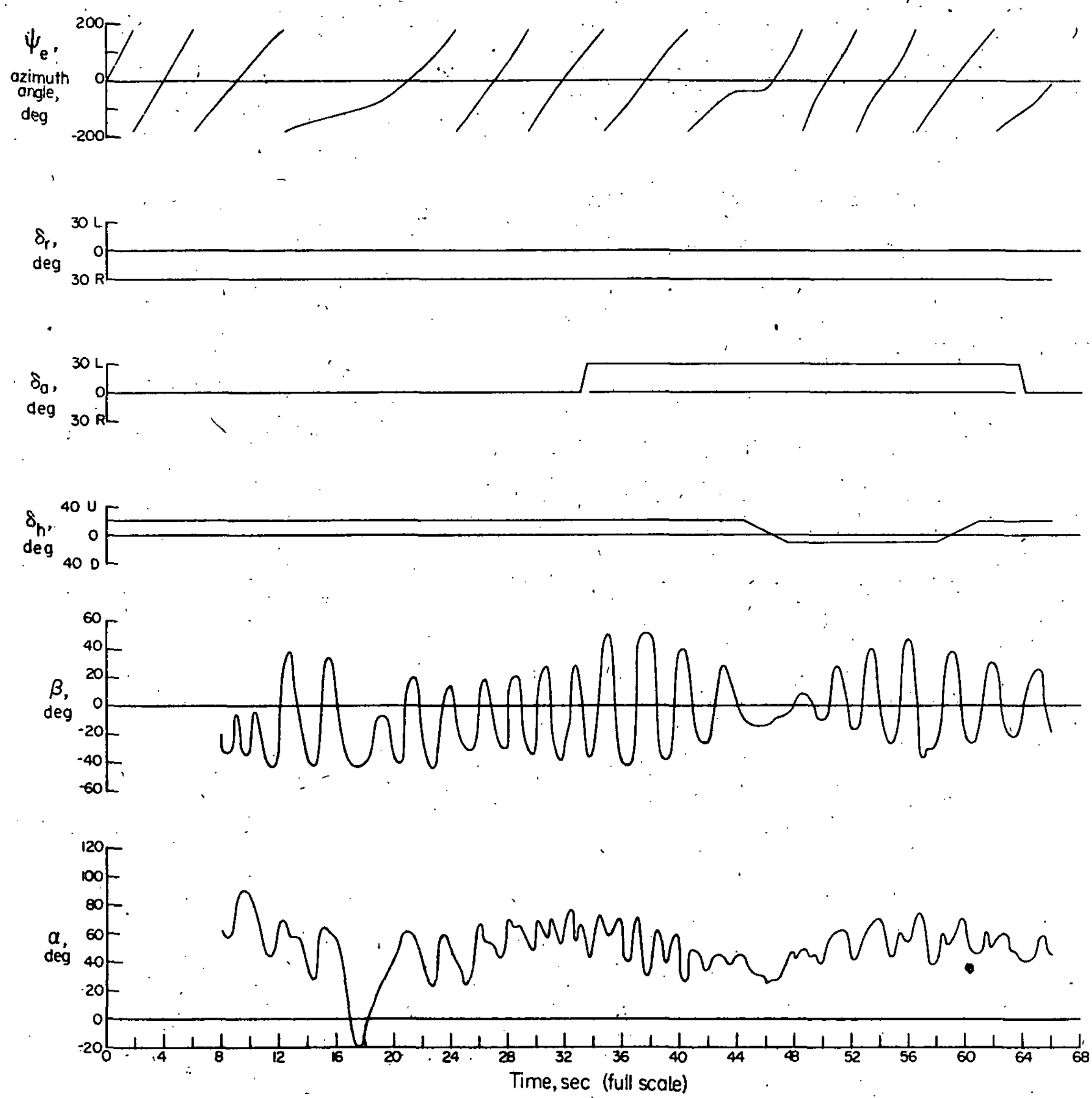

Figure 15.- Time histories of model flight tests. Steep spin; flight 6.

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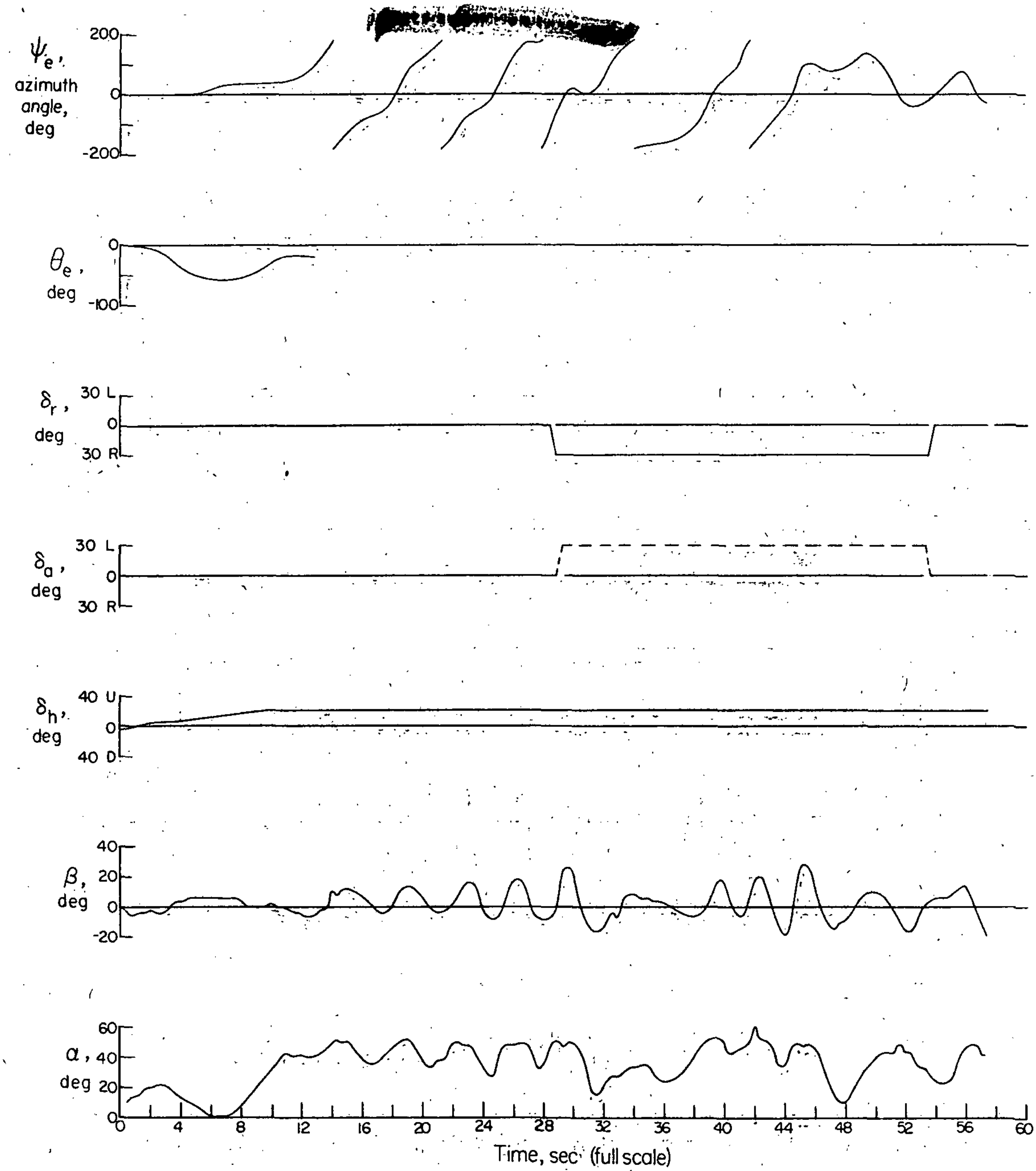

Figure 16.- Time histories of model flight tests. Post-stall gyration; flight 7.

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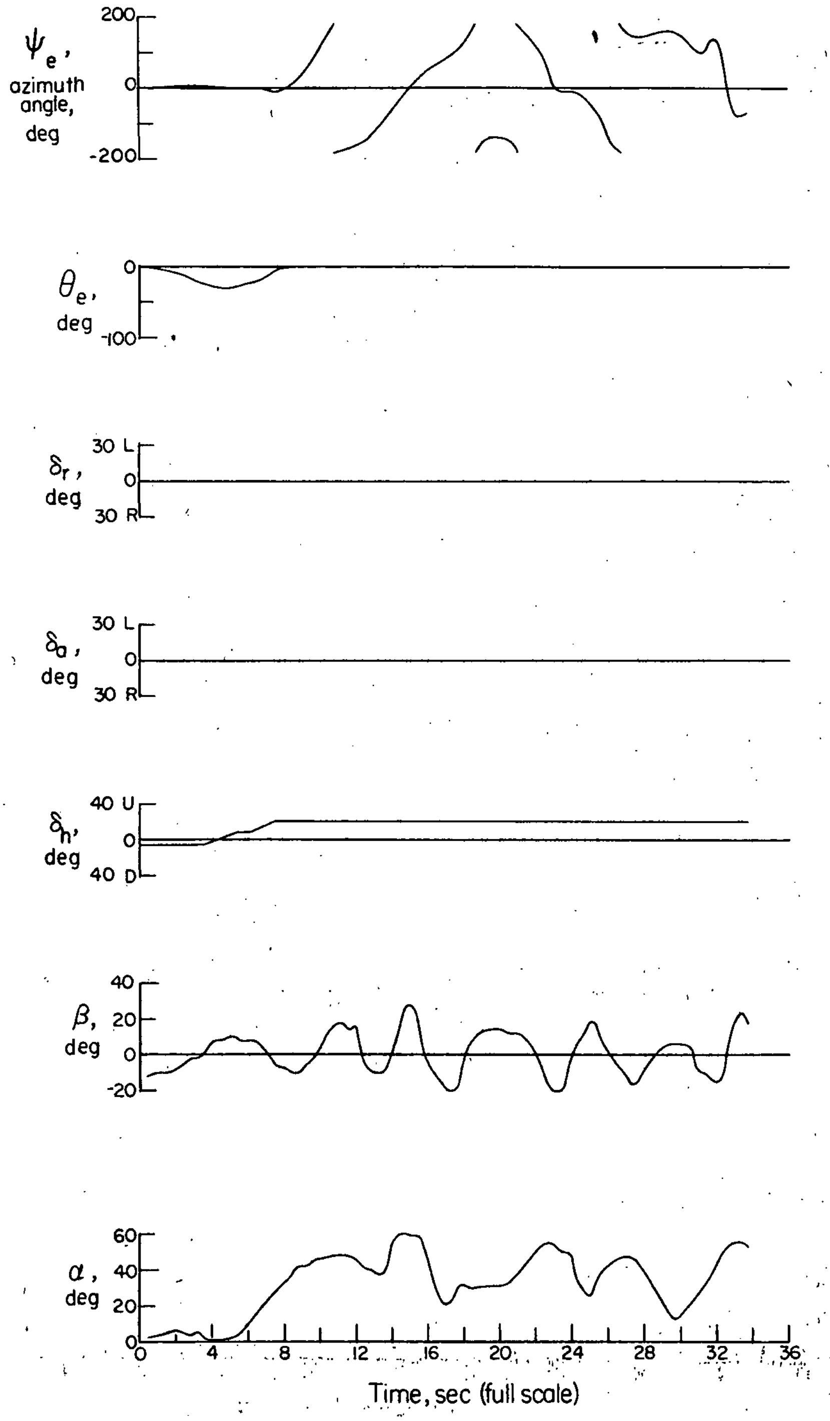

Figure 17.- Time histories of model flight tests. Post-stall gyration; flight 8.

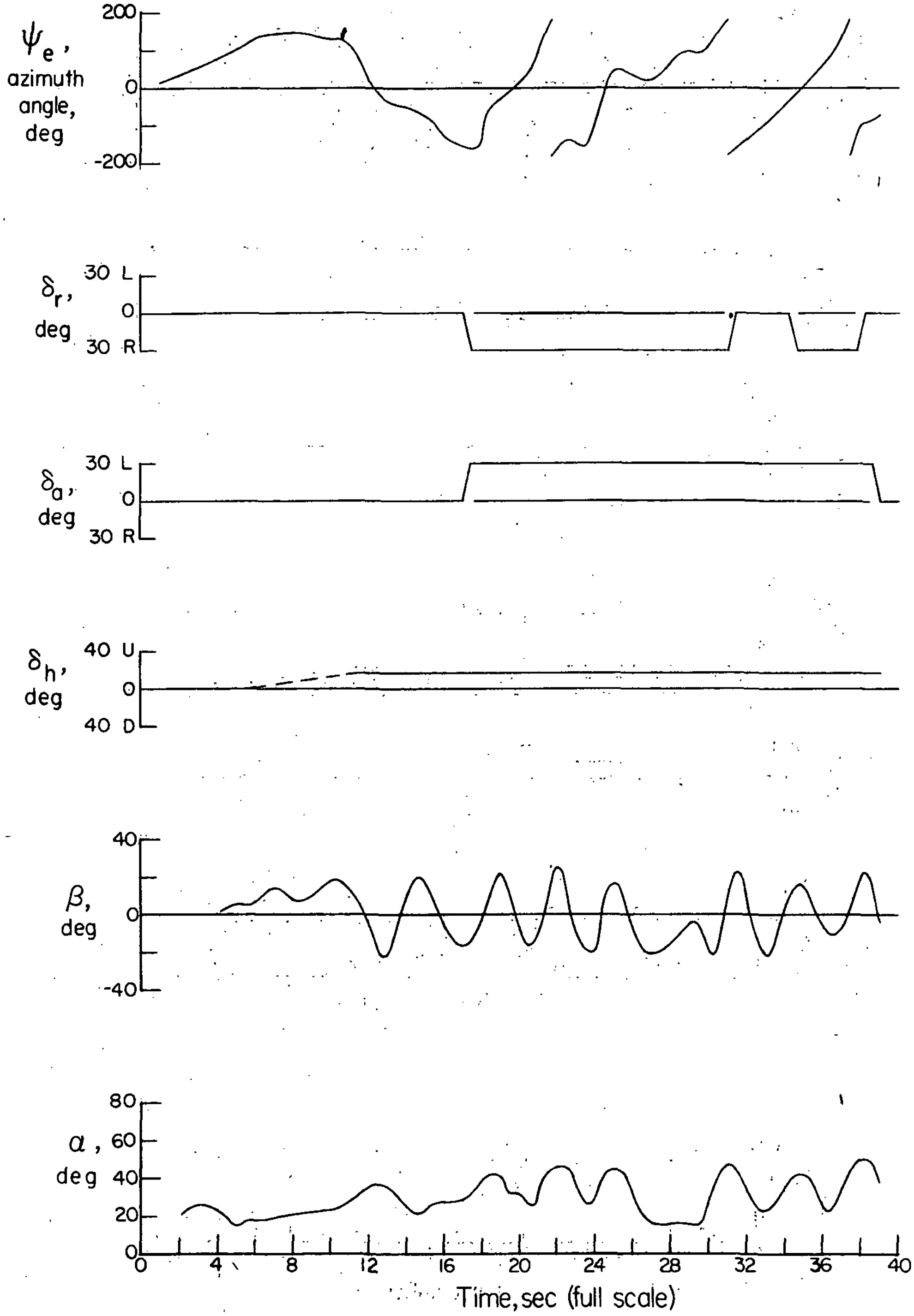

Figure 18.- Time histories of model flight tests. Post-stall gyration; flight 9.

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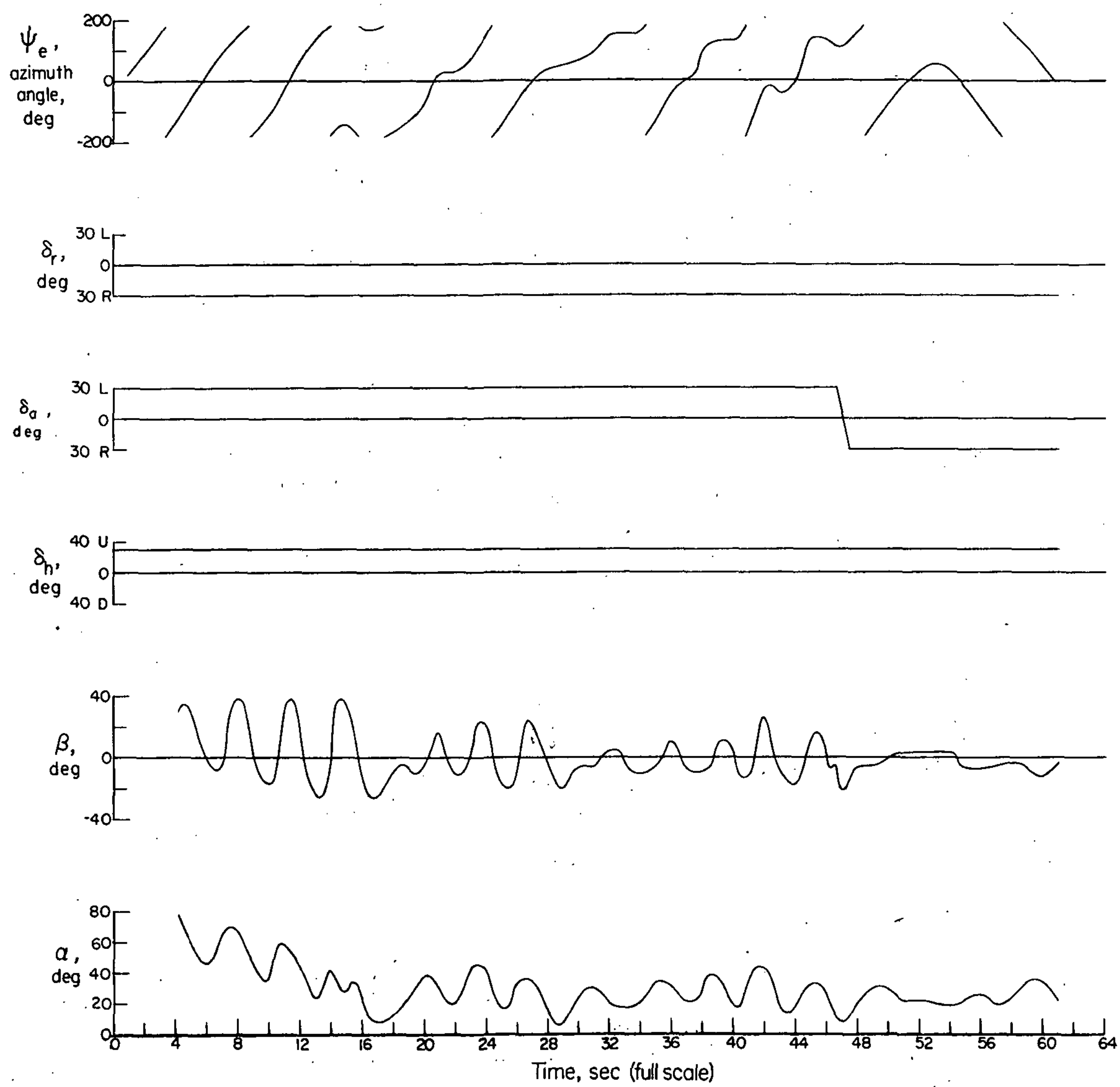

Figure 19.- Time histories of model flight tests. Post-stall gyration; flight 10.

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The film (16 mm, 35 min, color, silent) shows the tendency of the design to enter spins and the type of spin obtained from post-stall motions.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM SX-445

for the

Bureau of Weapons

LARGE-ANGLE MOTION TESTS, INCLUDING SPINS, OF A FREE-FLYING RADIO-CONTROLLED 0.13-SCALE MODEL OF A TWIN-JET SWEPT-WING FIGHTER AIRPLANE*

COORD NO. N-AM-50

By Sanger M. Burk, Jr., and Charles E. Libbey

ABSTRACT

An investigation has been conducted using a free-flying radio-controlled 0.13-scale model of the McDonnell F4H-1 airplane to determine the tendency of this design to enter spins and to evaluate the nature of the spin obtained from post-stall motions.

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