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SPIN-TUNNEL INVESTIGATION OF A 1/20-SCALE MODEL OF THE NORTHROP F-5E AIRPLANE COORD NO. AF-AM-422

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16. Abstract

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SUMMARY

An investigation has been conducted in the Langley spin tunnel to determine the spin and recovery characteristics of a 1/20-scale model of the Northrop F-5E airplane. The investigation included erect and inverted spins, a range of center-of-gravity locations and moments of inertia, symmetric and asymmetric store loadings, and a determination of the parachute size required for emergency spin recovery. The effects of increased elevator trailing-edge-up deflections, of leading-edge and trailing-edge flap deflections, and of simulating the geometry of large external stores were also determined.

The test results indicate that erect spins can be obtained with the airplane for all normal loading conditions. Fast flat spins as well as slow oscillatory spins were indicated as possible. Recovery characteristics from spins will be unsatisfactory. The airplane spin and recovery characteristics will not be affected appreciably by rearward positions of the center of gravity within the limits tested or by the position of the leading-edge and trailing-edge flaps. For the forward center-of-gravity position, recovery characteristics could be even worse than those for medium or rearward center-of-gravity positions. The recommended technique for best possible recovery from fully developed erect spins on the airplane is: move the elevators to neutral (stick longitudinally neutral), the ailerons full with the spin (stick right in a spin to the pilot's right), and the rudder full against the spin. As noted, recoveries for some spin modes may be unsatisfactory.

For a wing-heavy loading with heavy wing stores, the slow oscillatory spin mode will not be present, and only fast flat spins will occur; recoveries will be unsatisfactory. The effects of a large empty external fuel tank below the fuselage center line will also be adverse in that the slow oscillatory spins will not occur; other lightweight store shapes and locations tested will have no appreciable influence on the spin and recovery characteristics. With regard to asymmetric store loadings, some spins in the direction of the lightweight wing may be encountered from which no recovery can be effected using the airplane control surfaces.

Inverted spins will be oscillatory and will have slow rotation rates. For symmetric loadings of the airplane, recoveries will be satisfactory by neutralization of all controls. For asymmetric loadings, recoveries from inverted spins will be satisfactory by moving the stick full back, the rudder full

against the spin (rudder right in an inverted spin yawing to the pilot's left), and the ailerons full against the spin (stick left in an inverted spin yawing to the pilot's left).

The parachute required for emergency spin recovery during erect and inverted spins is 6.9 m (22.8 ft) in diameter (laid out flat) with a drag coefficient of 0.50 and a riser-plus-shroud-line distance of 22.9 m (75 ft) from the attachment point on top of the fuselage at fuselage station 587 to the skirt of the parachute canopy.

INTRODUCTION

An investigation was conducted in the Langley spin tunnel at the request of the U.S. Air Force Systems Command in order to determine the spin and recovery characteristics of a 1/20-scale model of the Northrop F-5E airplane. The F-5E is a small twin-engine fighter with a wing having a swept leading edge, a long fuselage forebody, and an all-movable horizontal tail. The investigation included erect and inverted spins, various loading conditions including symmetric and asymmetric external store loadings, and a determination of the parachute size for emergency spin recovery. The effects of wing leading-edge and trailing-edge flap deflections were also determined.

Inasmuch as the F-5E has some relatively large external stores as part of its design, the effects of simulating the shapes of these stores on spin and recovery characteristics were determined, independent of the effects of the mass of the stores.

SYMBOLS

Measurements were made in U.S. Customary Units. They are presented herein in the International System of Units (SI) with the equivalent values in U.S. Customary Units given parenthetically. Factors relating the two systems are given in reference 1.

b wing span, m (ft)

C_D drag coefficient of parachute based on laid-out-flat area, $\dfrac{\text{Drag}}{\frac{1}{2}\rho V^2 S_p}$

$\bar{c}$ mean aerodynamic chord, m (ft) or cm (in.)

I_X, I_Y, I_Z moment of inertia about X, Y, and Z body axis, respectively, kg-m^2 (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

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

m mass of airplane, kg (slugs)

S wing area, m^2 (ft^2)

S_p parachute laid-out-flat area, m^2 (ft^2)

V full-scale true rate of descent, m/sec (ft/sec or fps)

x distance of center of gravity rearward of leading edge of mean aerodynamic chord, m (ft)

z distance between center of gravity and fuselage reference line (positive when center of gravity is below line), m (ft)

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

δ_a aileron deflection, deg

δ_e elevator deflection, deg

δ_f flap deflection, deg

δ_r rudder deflection, deg

μ relative density of airplane, $m/\rho Sb$

ρ air density, kg/m^3 ($slugs/ft^3$)

ϕ angle between span axis of inner wing in spin and horizontal, deg

Ω full-scale angular velocity about spin axis, rps

Abbreviations:

c.g. center of gravity

L.E. leading edge

T.E. trailing edge

MODEL

A 1/20-scale model of the Northrop F-5E airplane was built at the Langley Research Center. A three-view drawing of the model is shown in figure 1 and photographs of the model are shown in figures 2 and 3. The dimensional characteristics of the full-scale airplane are presented in table I. The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 7620 m (25 000 ft) with ρ = 0.549 kg/m^3 (0.001065 slug/ft^3). The mass characteristics and mass parameters for typical loadings of the airplane and for loadings tested on the model are presented in table II.

Because it is impractical to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the F-5E model varied from true scaled-down values within the following limits:

Weight, percent . . . . 0.2 high to 2.8 high

Center-of-gravity location, percent $\bar{c}$. . . . . . 0.1 rearward to 0.8 rearward

Moments of inertia:
- I_X, percent . . . . 2.7 low to 6.3 high
- I_Y, percent . . . . 2.4 low to 2.7 low
- I_Z, percent . . . . 2.1 low to 0.7 high

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

The normal control deflections used for each control surface (measured perpendicular to the hinge line) were:

Pitch control:
- Elevators, deg . . . . 17 up, 5.5 down

Roll control:
- Aileron
  - Early part of test program, deg . . . . 18 up, 14 down
  - Latter part of test program, deg . . . . 35 up, 25 down

Yaw control:
- Rudder, deg . . . . 30 right, 30 left

For a few tests, the maximum elevator trailing-edge-up deflection was increased from 17° to 20° and then to 24°.

SPIN-TUNNEL TESTS

The tests were made in the Langley spin tunnel which is described in detail in reference 2. The test technique used in the tests is described in reference 2 and in the appendix to the present paper. The technique includes hand launching the model into the vertical airstream in a variety of attitudes (including a flat attitude), with spin rotation applied, and allowing the model to enter an equilibrium condition or conditions, since there are often several spin modes possible for a particular configuration and loading.

Most of the tests were conducted with the leading-edge flaps deflected down 24° and the trailing-edge flaps deflected down 20°. The model was ballasted to represent the airplane with about 55 percent internal fuel and with medium, rearward, and forward center-of-gravity locations. In addition, tests were made with a wing-heavy loading, with several asymmetric store loadings, and with the leading-edge and trailing-edge flaps at 0° deflection.

Experience with model tests in the spin tunnel has shown that the aerodynamic effects of externally mounted stores under the wing normally cause little or no change in developed spin and in recovery characteristics, whereas the mass changes caused by external stores can have a large effect on these characteristics. In view of this experience and in order to minimize loss of test time due to store damage, the store loadings were simulated by adding lead weights to the upper surfaces of the wings. However, because some of the F-5E external stores are relatively large, it was decided to conduct some brief tests to actually determine the effects of simulating the shape of these stores.

Tests were made to determine the size of the parachute and the riser-plus-shroud-line distance required for erect and inverted spin modes of the airplane. These tests were limited to one size parachute system only, inasmuch as previous tests of a 1/20-scale model of the F-5A airplane in the spin tunnel (results unpublished) had already determined a parachute system adequate for the earlier F-5A design. The tests made in the present investigation were to verify that the same system would be adequate for the F-5E airplane.

The appendix indicates the precision of measurement of the spin and recovery characteristics.

FORCE TESTS PRECEDING SPIN-TUNNEL TESTS

Spin-tunnel model tests are made at very low Reynolds numbers, whereas full-scale airplane spins occur at high Reynolds numbers. Because some airplane configurations experience marked effects of Reynolds number on spin characteristics (see ref. 2), it is sometimes required to precede Langley spin-tunnel tests with force tests in the Ames 3.7-m (12-ft) pressure tunnel to determine if configuration features (particularly fuselage nose cross-sectional shapes) result in such effects. Some airplane models require the use of nose strakes to eliminate this tendency at low values of Reynolds number.

In a previous investigation (ref. 3), force tests were made at Ames Research Center on a model of the F-5A airplane. The results (applicable to the F-5E as well) indicated that for erect spins, there was an appreciable change due to Reynolds number in the aerodynamic parameters considered to be significant to the developed spin and recovery, especially yawing moment, which tends to be the key parameter. These results indicated that yawing moments acting during 1/20-scale spin model erect spin tests would cause the model to be more prospin than the full-scale airplane. Force tests were therefore made to determine a nose strake configuration which would eliminate the prospin moments at low Reynolds number. As a result of these tests, a strake configuration was identified, and these strakes were installed on the spin model for the erect spin tests. The spin and recovery characteristics of the F-5E airplane can therefore be predicted by proper interpretation of the spin-tunnel results of the 1/20-scale model with strakes added for erect spins and with strakes off for inverted spins.

RESULTS AND DISCUSSION

The results of the spin tests are presented in charts 1 to 4 and in tables III to XIV. The data are presented in terms of full-scale values for the airplane at an altitude of 7620 m (25 000 ft). The results for left spins were generally somewhat more conservative than the results for right spins, and for convenience the data are presented in terms of left spins; when applied to the airplane, the data represent either left or right spins.

On the charts presenting erect-spin data, results for elevators up (stick back) are presented at the top of the chart and results for elevators down (stick forward), at the bottom; results for ailerons with the spin (stick left in a left spin) are presented on the right side of the chart, and results for ailerons against (stick right), on the left side. For inverted-spin data, a different chart format is used, as will be subsequently discussed.

The "spin block" symbol in the charts and in tables III through VII and IX through XIV is used to show, at a glance, the positions of the elevators and roll control for the spin for a given test. Within the spin block symbol, the dot indicates the control positions for the developed spin, and the arrow indicates the movement of the ailerons and elevators for the attempted recoveries. The rudder was moved from with the spin to against the spin for attempted recoveries unless otherwise indicated.

For steep and/or oscillatory slow rotating spins, model spin recoveries requiring approximately two turns or less are considered satisfactory. For high-angle-of-attack spins (flat spins), where the spin rate is relatively fast, consistent recoveries of four turns or less are considered acceptable since the time and altitude lost during such recoveries are of the same order of magnitude as the time and altitude required for two-turn recoveries from slower spins. Also, four turns or less are considered acceptable only when the model exhibits an immediate response when the controls are moved for recovery; that is, on recovery control movement the rate of rotation starts to gradually slow down and the angle of attack starts to decrease.

For recoveries that require slightly more than four turns from fast flat spins, model results indicate that an airplane would probably recover, though slowly, with the resultant loss of too much altitude. Recoveries that require considerably more than four turns would be unsatisfactory, since altitude loss would be very high if recovery should be obtained, or recovery may not be obtained at all.

These criteria evolved from considerations of altitude lost in spins and correlations between model and full-scale tests for many fighter configurations.

Erect Spin and Recovery Tests

<u>Medium center-of-gravity locations (0.165$\bar{c}$ and 0.158$\bar{c}$)</u>.- The test results for loadings 1a and 1b in table II (medium center-of-gravity loadings) are presented in chart 1 and in table III, respectively. Based on these results, the airplane will have two basic erect spin modes. One mode will be a fast flat

spin at an angle of attack of about 85° and a spin rate of about 2.0 sec/turn. The second mode will be slow and oscillatory, with a rate of about 4.5 sec/turn and oscillations in angle of attack from about 45° to about 95°. Recoveries from the fast flat spin will be unsatisfactory even when use is made of the recommended spin-recovery control technique (elevators moved to neutral, ailerons deflected to full with the spin, that is, 35° up and 25° down, and rudder deflected to full against the spin). Recovery from the slow oscillatory spins of the airplane will also be unsatisfactory (although only satisfactory recoveries are shown in chart 1). This prediction of possible unsatisfactory recovery characteristics from slow oscillatory spins of the airplane with medium center-of-gravity loadings is based on unsatisfactory recovery characteristics noted from model tests at both rearward and forward center-of-gravity loadings (results presented in charts 2 and 3 and in table III).

As indicated by the test results, aileron deflections against the spin are adverse to recovery characteristics, and aileron deflections with the spin are favorable. Using elevator-up settings of 24° or 20° instead of 17° had no appreciable effect on spins and recoveries. (See table III.)

Rearward (0.199$\bar{c}$ and 0.214$\bar{c}$) center-of-gravity locations.- Test results obtained for the 0.199$\bar{c}$ and 0.214$\bar{c}$ center-of-gravity locations are presented in chart 2 and in table III. The airplane spin and recovery characteristics with these rearward center-of-gravity locations (loadings 2a and 2b in table II) will be essentially the same as those for the medium center-of-gravity loadings.

Forward (0.115$\bar{c}$) center-of-gravity location.- Test results obtained for the 0.115$\bar{c}$ center-of-gravity location (loading 3 in table II) are presented in chart 3 and in table III. With this center-of-gravity location, the airplane spin recovery characteristics will be unsatisfactory, and it appears that they could be even worse than for the medium and rearward center-of-gravity positions.

Effect of leading-edge and trailing-edge flap settings.- Tests were made to investigate the effects of 0° deflection of the leading-edge and trailing-edge flaps on the spin and recovery characteristics. The test results are presented in table IV and indicate that with the flaps at 0° deflection, the airplane spin and recovery characteristics will be essentially the same as with the flaps deflected.

Wing-heavy loading.- The test results obtained for the wing-heavy loading condition (loadings 4 and 5 in table II) are presented in table V. The model loading condition simulated the weight and moments of inertia of the airplane with four 387-kg (854-lbm) external stores.

The test results indicate that only fast flat spins will occur on the airplane in this loading and that the slow oscillatory spin mode will not be present. Recoveries will be unsatisfactory.

As indicated by the results in table V, there were no appreciable effects on spins and recoveries of adding the lightweight shapes to represent the 387-kg (854-lbm) stores on the model. (For a photograph of the model with these stores, see fig. 3(a).)

Aerodynamic effects of external fuel tanks.- Tests were made to determine whether the relatively large 1.04-m^3 (275-gal) external fuel tanks of the F-5E (see fig. 3(b)) would have any effect on the nature of spins and recoveries obtained. Lightweight shapes were used to simulate empty fuel tanks. Tests were made for three different configurations: (1) one tank below the airplane fuselage center line, (2) two tanks mounted below the wing at wing stations ±2.37 m (7.79 ft) full scale, and (3) all three tanks on the model.

The test results are presented in table VI, and the model loadings during these tests were 1b, 6, 7, and 8 in table II. The results in table VI indicate that the major effect of the external fuel tanks is that the tank below the fuselage has an adverse effect in that it prevents the occurrence of slow oscillatory spins. That spin mode will not be present in the airplane for either the one-tank or the three-tank configurations, but slow oscillatory spins will occur for the two-tank configuration, just as they will for the clean (no tank) configuration.

The presence of either one, two, or three tanks will have no appreciable effect on the fast flat spins of the airplane or on the poor recoveries therefrom.

Asymmetric store loading conditions.- Spin and recovery characteristics were investigated for medium, rearward, and forward center-of-gravity locations and for small, moderate, and large asymmetric loadings. The asymmetric loadings used were 4053 N-m (2989 ft-lb), 11 869 N-m (8754 ft-lb), and 19 659 N-m (14 500 ft-lb). The results of these tests are presented in table VII, and the loadings used were 9 through 15 in table II.

As may be seen from the detailed results presented in table VII and the summary information presented in table VIII, spins of the airplane in the direction of the lightweight wing (outboard wing heavy) may lead either to fast flat spins with no recovery possible or to poststall gyrations lasting enough turns to be considered unsatisfactory. In the model tests, the fast flat spins occurred at medium and large asymmetric loading conditions when the center of gravity was forward, and at a small asymmetric loading condition when the center of gravity was rearward.

Only a few tests were made in which the model was launched in the direction of the heavyweight wing (outboard wing lightweight). As is usual for such loadings, the model did not spin (see table VII) and no spins would be expected on the airplane in that direction.

Inverted Spin and Recovery Tests

Inverted spin tests were made for symmetric and asymmetric loadings. The results of symmetric loading tests (loadings 1b and 2b in table II) are presented in chart 4 and in table IX, respectively. The results of asymmetric loading tests (loadings 16 and 17 in table II) are presented in tables X and XI. Loadings 16 and 17 had asymmetric moments of 3390 N-m (2500 ft-lb) and 6780 N-m (5000 ft-lb), respectively.

For inverted spins, the order used for presenting the data on a chart, such as chart 4, is different from that normally used for erect spins. For inverted spins, data for the ailerons with the spin condition (controls crossed, that is, left rudder pedal forward and stick to the pilot's right for a spin yawing to the pilot's left and rolling to his right) are presented on the right side of the chart; data for the ailerons against the spin condition (controls together, that is, left rudder pedal forward and stick to the pilot's left for a spin yawing to the pilot's left) are presented on the left side of the chart. When the controls are crossed in an inverted spin, the ailerons aid the rolling motion; when the controls are together, the ailerons oppose the rolling motion. The angle of wing tilt in the chart is given as up (U) or down (D) relative to the ground. The elevators up or down deflection is also given in relation to the ground; therefore, the results for elevators up (stick forward) are presented at the top of the chart and elevators down (stick back) at the bottom of the chart.

The test results in chart 4 and in table IX indicate that for symmetric loadings of the airplane, inverted spins will be oscillatory and will have slow rotation rates. The angle of attack will oscillate from about -35° to about -80° and the spin rate will be about 5 or 6 sec/turn. Recoveries will be satisfactory by neutralizing all controls.

For the two asymmetric loadings at which inverted spin tests were made on the model, some spins were obtained which indicated unsatisfactory recovery characteristics for the airplane by only neutralization of controls. These were spins with the heavy wing as the inner wing in the spin. (See tables X and XI.) Based on the model results, airplane recoveries from inverted spins in these loadings will be satisfactory if the following control technique is used: move the stick full back, rudder full against the spin (rudder right in an inverted spin yawing to the pilot's left), and the ailerons full against the spin (stick left in an inverted spin yawing to the pilot's left).

Tests were made to determine whether the empty 1.04 m^3 (275 gal) external fuel tanks would have any effects on inverted spins and recoveries, as occurred for the erect spins. The test results presented in table XII indicated that the tanks would have no effect on airplane inverted spins or recoveries.

Correlation of Model and Full-Scale Spin Modes

With regard to the spin and recovery characteristics that may be expected for the airplane, it is helpful to draw not only on the model test results, but also on experience which has been obtained on other airplane configurations with mass loading characteristics somewhat similar to those of the F-5E. For some of these other configurations, it has been possible to compare spin-tunnel model results with the results of full-scale airplane tests and/or the results of tests of larger radio-controlled models dropped from a helicopter and flown into spins.

For some of the configurations, results have indicated that in flat-attitude developed spins, the airplane spin rate may be somewhat less than that of the spin-tunnel model, and recoveries are usually faster when the spin rate is less. For other configurations, no such difference in spin rate occurs and the airplane spin rate in flat-attitude developed spins is as high as that of the model. For slow oscillatory spins, the airplane results are usually in good agreement with the oscillatory spins obtained on the model.

For the F-5E airplane, the fast flat spins and the slow oscillatory spins indicated by the model tests should be considered as possible on the airplane.

Spin-Recovery Parachute Tests

The results of tests made to determine (verify) the size of tail parachute required to give satisfactory recoveries of the airplane during emergencies in spin demonstrations are presented in tables XIII and XIV. The 6.9-m (22.8-ft) diameter given for the parachute canopy is the laid-out-flat diameter, and the drag coefficient of 0.50 is based on the laid-out-flat area. The lengths of the parachute shroud lines equaled the parachute diameter, and the riser-plus-shroud-line distance of 22.9 m (75 ft) was measured from an attachment point on top of the fuselage at fuselage station 587 to the skirt of the parachute canopy.

As may be seen from tables XIII and XIV, the tail parachute system used will provide satisfactory spin recovery from erect and inverted spins of the airplane. If a parachute with a different drag coefficient is used, a corresponding adjustment is required in parachute size. For asymmetric loading conditions of the airplane, recoveries will require more turns than for symmetric loading conditions (tables XIII and XIV).

Recommended Control Technique for Spin Recovery

It is suggested that the airplane spin-recovery control technique be a part of the overall poststall recovery procedure. The spin-recovery technique recommended, therefore, assumes that recovery was not effected during the stall/departure and that the aircraft is spinning. The recommended spin-recovery technique for best possible recoveries from erect spins of the F-5E airplane is: move the elevators to neutral (stick longitudinally neutral), then immediately move the ailerons full with the spin (stick left for a spin to the pilot's left), and move the rudder full against the spin. Even if this recommended technique is used, recoveries could be unsatisfactory.

The recommended spin-recovery technique for inverted spins is dependent upon the loading. For symmetric loading, neutralize the ailerons, elevators, and rudder; for asymmetric loadings, move the stick full back, the rudder full against the spin (rudder right in an inverted spin yawing to the pilot's left), and the ailerons full against the spin (stick left in an inverted spin yawing to the pilot's left).

CONCLUSIONS

Based on the results of tests of a 1/20-scale model of the F-5E airplane, and on other available information, the following conclusions regarding the spin and recovery characteristics of the airplane at 7620 m (25 000 ft) are drawn:

1. Two erect spin modes are possible for the airplane: a fast flat spin at an angle of attack of about 85° with a spin rate of about 2.0 sec/turn and an oscillatory spin mode with large oscillations in angle of attack from about 45° to about 95° and with a spin rate of about 4.5 sec/turn. Recovery characteristics from spins will be unsatisfactory.

2. The airplane spin and recovery characteristics will not be affected appreciably by rearward positions of the center of gravity within the limits tested, or by retracted positions of the leading-edge and trailing-edge flaps. When the center of gravity is forward, recovery characteristics could be even worse than those for medium or rearward center-of-gravity positions.

3. The following recommended recovery technique should be used to obtain the best possible recovery from all fully developed erect spins: move the elevators to neutral (stick longitudinally neutral), the ailerons full with the spin (stick left in a spin to the pilot's left), and the rudder full against the spin. Even if this recommended technique is used, recoveries could be unsatisfactory.

4. With heavy wing stores added, only fast flat spins will occur on the airplane and the slow oscillatory spin mode will not be present. The presence of a large empty external fuel tank below the fuselage center line will also have an adverse effect in that only the fast flat spin mode will occur.

5. For asymmetric store loadings, some spins in the direction of the lightweight wing may be encountered for which no recovery can be effected using the airplane control surfaces.

6. Inverted spins will be oscillatory and will have slow rotation rates. For symmetric loadings, recoveries will be satisfactory if elevators, ailerons, and rudder are neutralized. For asymmetric loadings, recoveries will be satisfactory by moving the stick full back, the rudder full against the spin (rudder right in an inverted spin yawing to the pilot's left), and the ailerons full against the spin (stick left in an inverted spin yawing to the pilot's left).

7. The parachute required for emergency spin recovery during erect and inverted spins is 6.9 m (22.8 ft) in diameter (laid out flat) with a drag coefficient of 0.50 and a riser-plus-shroud-line distance of 22.9 m (75 ft) from the parachute canopy to the attachment point on top of the fuselage at fuselage station 587.

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APPENDIX

TEST METHODS AND PRECISION

Model Testing Technique

General descriptions of spin model testing techniques, 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 a matrix of control settings in various 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 elevator to neutral and the roll control to full with the spin. Tests are conducted for the various possible loading conditions of the airplane because the control manipulation required for recovery is generally dependent on the mass and geometric characteristics of the model (ref. 2).

Tests are sometimes performed to evaluate the possible adverse effects on recovery of small deviations from maximum or neutral control settings. 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 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 lateral 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 geometric 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 all spins in any of the manners previously described is accomplished within $2\frac{1}{4}$ turns. For some airplane designs, especially some high-performance fighters, recoveries that require somewhat more than $2\frac{1}{4}$ turns but that can be obtained consistently may be considered satisfactory, or at least acceptable. The results of tests of such a model have to be evaluated fully, considering the results of each such case, and no hard and fast rule stating an exact maximum number of turns allowed can be adopted in advance of the model tests. Modern high-performance fighter configurations are considerably different from the configurations studied in reference 2 wherein the $2\frac{1}{4}$ turn recovery criterion was applicable.

APPENDIX

Modern fighter aircraft are generally designed such that the fuselage has a relatively long forebody, which has an added aerodynamic influence on the spin, and a vertical tail which is usually shielded from effective airflow at high angles of attack. The mass characteristics are such that the fuselage is heavily loaded relative to the wings and the relative density μ is considerably higher than those of models referred to in reference 2. These design characteristics cause the roll control (ailerons and/or differential horizontal tail) to become the primary recovery control, rather than the rudder.

Because of the differences in airplane design, mass characteristics, and the primary control required for recovery, the $2\frac{1}{4}$ turn recovery criterion cannot be used to evaluate the recovery characteristics of present-day fighter aircraft. With fighter aircraft having roll control (ailerons and/or differential horizontal tail) as the primary recovery control, experience has indicated that model recoveries from steep and/or oscillatory spins with a relatively slow spin rate in approximately two turns are considered satisfactory. However, for high-angle-of-attack spins (flat spins), where the spin rate is relatively fast, consistent recoveries in four turns or less are considered acceptable since the time and altitude lost during such recoveries would be of the same order of magnitude as the time and altitude lost in two-turn recoveries from slower spins.

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, >91.44 m/sec (300 ft/sec) full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude. For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as greater than the number of turns from the time the controls 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 in 10 or more turns is indicated by ∞. When a model loses the rotation applied at launch within a few turns and recovers without control movement (rudder and other controls held with the spin), the results are recorded as "no spin."

For spin-recovery parachute tests, the parachute system required to effect satisfactory recovery is determined. The parachute is deployed for the recovery attempts by actuating a remote-control mechanism, and the controls are maintained prospin so that recovery is due to the parachute action alone.

Precision

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

α, deg . . . . ± 1
ϕ, deg . . . . ± 1
V, percent . . . . ± 5

Ω, percent . . . . ± 2
Turns for recovery obtained from motion-picture records . . . . $\pm 1/4$
Turns for recovery obtained visually during test . . . . $\pm 1/2$

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 $\bar{c}$ . . . . ± 1
Moments of inertia, percent . . . . ± 5

Controls are set within an accuracy of $\pm 1^{\circ}$.

REFERENCES

1. Mechtly, E. A.: The International System of Units - Physical Constants and Conversion Factors (Second Revision). NASA SP-7012, 1973.

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. Kauffman, Ronald C.; Scher, Stanley H.; and Cohen, Lee E.: Static Aerodynamic Characteristics of a 1/7-Scale Model of the F-5A Airplane at Angles of Attack From 0 to 90 Degrees and Angles of Sideslip From -10 to 30 Degrees for a Mach Number of 0.20. NASA TM X-62,339, 1974.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF NORTHROP F-5E AIRPLANE

Overall length, m (ft)	14.68 (48.16)
Wing:	
Span, m (ft)	8.13 (26.67)
Area, m^2 (ft^2)	17.30 (186.20)
Mean aerodynamic chord, cm (in.)	245.57 (96.68)
Root chord, cm (in.)	357.35 (140.69)
Tip chord, cm (in.)	68.40 (26.93)
Taper ratio	0.19
Aspect ratio	3.82
Sweep at $0.25\bar{c}$, deg	24.00
Incidence, deg	0
Dihedral, deg	0
Airfoil section	NACA 65A004.8 (modified)
Leading-edge flap area, m^2 (ft^2)	1.14 (12.30)
Trailing-edge flap area, m^2 (ft^2)	1.95 (21.00)
Aileron area, m^2 (ft^2)	0.86 (9.24)
Horizontal tail:	
Span, m (ft)	4.30 (14.10)
Area (exposed), m^2 (ft^2)	3.07 (33.03)
Tip chord, cm (in.)	50.80 (20.00)
Taper ratio (exposed)	0.33
Aspect ratio (exposed)	2.88
Sweep at $0.25\bar{c}$, deg	25.00
Dihedral, deg	-4.00
Airfoil section	NACA 65A004
Vertical tail:	
Area (exposed), m^2 (ft^2)	3.85 (41.42)
Tip chord, cm (in.)	71.12 (28.00)
Taper ratio (exposed)	0.25
Aspect ratio (exposed)	1.22
Sweep at $0.25\bar{c}$, deg	25.00
Airfoil section	NACA 65A004
Rudder area, m^2 (ft^2)	0.60 (6.42)

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS OF F-5E AIRPLANE AND FOR LOADINGS TESTED ON 1/20-SCALE MODEL

Loading	Loading description	Weight, N (lb)	Center-of-gravity location		Relative density, μ, at -		Moments of inertia, kg-m^2 (slug-ft^2)			Mass parameters		
			$x/\bar{c}$	$z/\bar{c}$	Sea level	7620 m (25 000 ft)	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
	Airplane values											
1	Clean aircraft with 55 percent internal fuel; ammo fired	57 827 (13 000)	0.166	------	34.21	76.35	4 610 (3 400)	52 063 (38 400)	55 317 (40 800)	-1219×10^{-4}	-84×10^{-4}	1303×10^{-4}
2	Aircraft with missiles and 22 percent internal fuel; ammo fired	52 489 (11 800)	0.190	------	31.06	69.32	7 118 (5 250)	50 843 (37 500)	56 673 (41 800)	-1236×10^{-4}	-165×10^{-4}	1401×10^{-4}
3	Clean aircraft with 4 percent internal fuel; ammo in	48 930 (11 000)	0.115	------	28.95	64.61	4 610 (3 400)	53 555 (39 500)	57 351 (42 300)	-1484×10^{-4}	-115×10^{-4}	1599×10^{-4}
4	Aircraft with missiles, four 387-kg (854-lbm) external stores; and 40 percent internal fuel; ammo in	75 620 (17 000)	0.164	------	44.75	99.87	21 557 (15 900)	57 622 (42 500)	76 468 (56 400)	-708×10^{-4}	-370×10^{-4}	1078×10^{-4}
	Model values											
1a	Clean aircraft with 55 percent internal fuel; medium c.g.	57 965 (13 031)	0.165	-0.051	34.27	76.48	4 481 (3 305)	51 994 (38 349)	54 145 (39 935)	-1217×10^{-4}	-55×10^{-4}	1272×10^{-4}
1b	Clean aircraft with 57 percent internal fuel; medium c.g.	59 370 (13 347)	0.158	-0.049	35.14	78.72	4 471 (3 298)	54 155 (39 943)	56 672 (41 799)	-1242×10^{-4}	-62×10^{-4}	1305×10^{-4}
2a	Clean aircraft; rearward c.g.	58 948 (13 252)	0.199	-0.044	34.89	77.87	4 558 (3 362)	52 200 (38 501)	54 404 (40 126)	-1200×10^{-4}	-55×10^{-4}	1255×10^{-4}
2b	Clean aircraft; rearward c.g.	58 877 (13 236)	0.214	-0.047	34.85	77.77	4 661 (3 438)	51 777 (38 189)	54 216 (39 988)	-1188×10^{-4}	-61×10^{-4}	1250×10^{-4}
3	Clean aircraft; forward c.g.	59 192 (13 307)	0.115	-0.051	35.03	78.19	4 674 (3 462)	52 742 (38 901)	54 783 (40 406)	-1205×10^{-4}	-51×10^{-4}	1256×10^{-4}
4	Wing-heavy loading[a]	75 469 (16 966)	0.164	-0.045	44.67	99.69	21 578 (15 915)	56 087 (41 368)	75 284 (55 527)	-679×10^{-4}	-377×10^{-4}	1056×10^{-4}

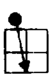
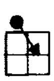
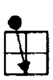
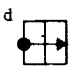
5	Wing-heavy loading with lightweight external stores added[b]	77 755 (17 480)	0.172	-0.035	46.02	102.71	22 926 (16 909)	56 268 (41 501)	76 983 (56 780)	-636×10^{-4}	-395×10^{-4}	1032×10^{-4}
6	Loading 1b plus three empty 1.04-m^3 (275-gal) external fuel tanks[c]	62 168 (13 976)	0.160	------	36.79	82.10	5 802 (4 279)	55 048 (40 601)	58 166 (42 901)	-1175×10^{-4}	-74×10^{-4}	1249×10^{-4}
7	Loading 1b plus one empty 1.04-m^3 (275-gal) external fuel tank below fuselage center line[c]	60 411 (13 581)	0.152	------	35.75	79.78	4 565 (3 367)	54 359 (40 093)	56 782 (41 880)	-1223×10^{-4}	-60×10^{-4}	1283×10^{-4}
8	Loading 1b plus two empty 1.04-m^3 (275-gal) external fuel tanks below wings[c]	61 127 (13 742)	0.168	-0.037	36.18	80.74	5 708 (4 210)	54 844 (40 451)	58 056 (42 820)	-1193×10^{-4}	-78×10^{-4}	1271×10^{-4}
9	4053 N-m (2989 ft-lb) asymmetric loading; medium c.g.	62 885 (14 137)	0.164	------	37.22	83.07	5 124 (3 779)	54 795 (40 046)	56 696 (41 817)	-1160×10^{-4}	-57×10^{-4}	1217×10^{-4}
10	11 869 N-m (8754 ft-lb) asymmetric loading; medium c.g.	62 885 (14 137)	0.164	-0.050	37.22	83.07	8 459 (6 239)	54 795 (40 046)	60 032 (44 277)	-1082×10^{-4}	-135×10^{-4}	1218×10^{-4}
11	4053 N-m (2989 ft-lb) asymmetric loading; rearward c.g.	62 747 (14 106)	0.199	------	37.13	82.87	5 201 (3 836)	54 501 (40 198)	56 957 (42 008)	-1166×10^{-4}	-58×10^{-4}	1224×10^{-4}
12	11 869 N-m (8754 ft-lb) asymmetric loading; rearward c.g.	62 747 (14 106)	0.199	------	37.13	82.87	8 536 (6 296)	54 501 (40 198)	60 290 (44 468)	-1087×10^{-4}	-136×10^{-4}	1223×10^{-4}
13	4053 N-m (2989 ft-lb) asymmetric loading; forward c.g.	62 991 (14 161)	0.115	------	37.28	83.20	4 604 (3 396)	55 043 (40 598)	57 335 (42 288)	-1171×10^{-4}	-54×10^{-4}	1225×10^{-4}
14	11 869 N-m (8754 ft-lb) asymmetric loading; forward c.g.	62 991 (14 161)	0.115	------	37.28	83.20	8 672 (6 396)	55 043 (40 598)	60 670 (44 748)	-1092×10^{-4}	-133×10^{-4}	1225×10^{-4}
15	19 659 N-m (14 500 ft-lb) asymmetric loading; forward c.g.	65 705 (14 771)	0.115	------	38.39	86.79	11 134 (8 212)	55 043 (40 598)	63 132 (46 564)	-991×10^{-4}	-183×10^{-4}	1174×10^{-4}
16	3390 N-m (2500 ft-lb) asymmetric loading; rearward c.g.	62 039 (13 947)	0.215	------	36.72	81.95	5 029 (3 709)	51 777 (38 189)	54 584 (40 259)	-1118×10^{-4}	-67×10^{-4}	1185×10^{-4}
17	6780 N-m (5000 ft-lb) asymmetric loading; rearward c.g.	65 202 (14 658)	0.216	------	38.59	86.13	5 396 (3 980)	51 777 (38 189)	54 951 (40 530)	-1056×10^{-4}	-72×10^{-4}	1128×10^{-4}

[a]Lead ballast used in lieu of external stores.
[b]Lead ballast used, plus lightweight, aerodynamically correct, external stores.
[c]Lead ballast used, plus lightweight, aerodynamically correct, external fuel tanks.

TABLE III.- EFFECTS OF INCREASED ELEVATOR-UP AND INCREASED AILERON DEFLECTIONS

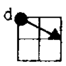
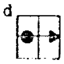
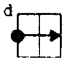
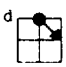
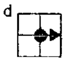
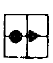
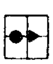
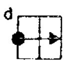
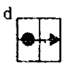
ON SPIN AND RECOVERY CHARACTERISTICS OF MODEL

[Left erect spins; Airplane, F-5E; Loading as indicated; Center of gravity as indicated; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	α, deg	ϕ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	Control deflection, deg (for spin / for recovery): δ_r	δ_e	δ_a	δ_f	Center-of-gravity location	Loading (see table II)	Turns for recovery
	86	5U 3D	77.7 (255)	0.51 (2.0)	30W	17U	R18W L14D	L.E., D T.E., D	0.165$\bar{c}$	1a	>5, $5\frac{1}{2}$, 4
	48 91	17U 7D	86.0 (282)	0.19 (5.3)	30A	0	R14D L18U	↓	↓	↓	$\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{4}$
	86	5U 3D	77.7 (255)	0.51 (2.0)	30W	17U	R18U L14D	↓	↓	↓	[a]∞
	48 91	17U 7D	86.0 (282)	0.19 (5.3)	30A	5.5D	R0 L0	↓	↓	↓	$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$
b 	84	4U 7D	78.9 (259)	0.44 (2.3)	30W	20U	R18U L14D	↓	↓	↓	>6, 7
					30A	0	R14D L18U	↓	↓	↓	
b 	84	4U 7D	78.9 (259)	0.44 (2.3)	30W	20U	R18U L14D	↓	↓	↓	>$4\frac{1}{2}$, 8
					30A	5.5D	R0 L0	↓	↓	↓	
c 	84	3U 4D	78.6 (258)	0.43 (2.3)	30W	24U	R18U L14D	↓	↓	↓	$6\frac{3}{4}$
	61 96	14U 11D	88.4 (290)	0.23 (4.3)	30A	0	R14D L18U	↓	↓	↓	$\frac{1}{4}$, $\frac{1}{4}$
c 	84	3U 4D	78.6 (258)	0.43 (2.3)	30W	24U	R18U L14D	↓	↓	↓	6, [a]∞
	61 96	14U 11D	88.4 (290)	0.23 (4.3)	30A	5.5D	R0 L0	↓	↓	↓	$\frac{1}{4}$
d 	86	9U 3D	75.0 (246)	0.53 (1.9)	30W	0	R35U L25D	↓	0.158$\bar{c}$	1b	6, [e]$3\frac{3}{4}$, [a]∞
	44 95	29U 25D	84.4 (277)	0.19 (5.3)	30A	0	R25D L35U	↓			

See footnotes at end of table, p. 21.

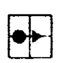
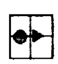
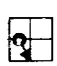
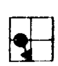
TABLE III.- Concluded

Spin block	Spin characteristics: α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	δ_f	Center-of-gravity location	Loading (see table II)	Turns for recovery
d 	39 94	25U 15D	85.3 (280)	0.19 (5.3)	30W / 30A	17U / 0	R35U L25D / R25D L35U	L.E., D T.E., D	0.115c̄	3	1/2, 1 1/2, 5 1/2, 1 1/4, 2 1/2
d 	85	9U 5D	75.9 (249)	0.53 (1.9)	30W / 30A	0 / 0	R18U L14D / R25D L35U				a∞, e3 1/4, e4, a∞
	49 82	16U 13D	80.2 (263)	0.21 (4.8)							
d 	84	8U 9D	79.2 (260)	0.53 (1.9)	30W / 30A	0 / 0	R35U L25D / R25D L35U				e2, e1, 6, 5
d 	83	6U 8D	77.1 (253)	0.45 (2.2)	30W / 30A	17U / 0	R0 L0 / R25D L35U				5 3/4, 4 3/4
d 	81	10U 7D	81.1 (266)	0.41 (2.4)	30W / 30A	0 / 0	R0 L0 / R25D L35U				a∞
	84	7U 4D	72.8 (239)	0.49 (2.0)	30W / 30A	0 / 0	R18U L14D / R14D L18U		0.199c̄	2a	8 1/2, c∞
	59 104	13U 13D	75.0 (246)	0.24 (4.2)							3/4, 4, 2 1/2, 3, 2 1/4
	86	9U 9D	72.8 (239)	0.53 (1.9)	30W / 30A	0 / 0	R18U L14D / R14D L18U		0.214c̄	2b	>4 3/4, >4 1/4
	67 100	27U 15D	79.2 (260)	0.30 (3.3)							1 3/4, 1 1/4, >3 3/4
d 	85	17U 15D	75.0 (246)	0.50 (2.0)	30W / 30A	0 / 0	R35U L25D / R25D L35U				>5 1/2, 6, 5
d 					30W / 30A	0 / 0	R18U L14D / R25D L35U				
	67 100	27U 15D	79.2 (260)	0.30 (3.3)							3, 2 3/4, 3 1/4

[a]Signifies 10 turns or greater.
[b]Elevator-up setting increased to 20°.
[c]Elevator-up setting increased to 24°.
[d]Aileron deflections increased; see spin block and δ_a values.
[e]Oscillating slightly when controls tripped.

TABLE IV.- EFFECTS OF LEADING-EDGE AND TRAILING-EDGE FLAP DEFLECTIONS ON SPIN AND RECOVERY CHARACTERISTICS OF MODEL

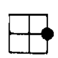
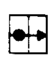
[Left erect spins; Airplane, F-5E; Loading 1a in table II; Center of gravity $0.165\bar{c}$; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics: α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	δ_f	Turns for recovery
	84	8U 7D	80.2 (263)	0.44 (2.3)	30W	0	R18U L14D	(a)	[b]∞
	58 92	17U 19D	84.1 (276)	0.25 (4.0)	30A	0	R14D L18U		$\frac{1}{2}$, 1
	81	9U 10D	78.9 (259)	0.37 (2.7)	30W	0	R18U L14D	(c)	6
	40 99	8U 19D	86.0 (282)	0.22 (4.5)	30A	0	R14D L18U		2, $1\frac{1}{4}$
	84	8U 7D	80.2 (263)	0.44 (2.3)	30W	0	R18U L14D	(a)	$5\frac{1}{2}$, $8\frac{1}{4}$
	58 92	17U 19D	84.1 (276)	0.25 (4.0)	30A	5.5D	R0 L0		1, $\frac{3}{4}$
	81	9U 10D	78.9 (259)	0.37 (2.7)	30W	0	R18U L14D	(c)	[d]8, [e]1, [e]$\frac{3}{4}$, [f]5
	40 99	8U 19D	86.0 (282)	0.22 (4.5)	30A	5.5D	R0 L0		

[a]L.E. flaps down 24° and T.E. flaps down 20°.
[b]Signifies 10 turns or greater.
[c]L.E. and T.E. flaps at 0°.
[d]From fast flat spin
[e]From slow oscillatory spin.
[f]Had started to oscillate when controls deflected.

TABLE V.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR THE WING-HEAVY LOADING

[Left erect spins; Airplane, F-5E; Loading as indicated; Center of gravity as indicated; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics				Control deflection, deg (For spin / For recovery)				Center-of-gravity location	Configuration	Loading (see table II)	Turns for recovery
	α, deg	ϕ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	δ_r	δ_e	δ_a	δ_f				
	83	8U 7D	90.5 (297)	0.45 (2.2)	30W / 30A	0 / 0	R18U L14D / R14D L18U	L.E., D T.E., D	0.164$\bar{c}$	Wing-heavy loading without external store shapes	4	a>$2\frac{1}{2}$, a>$2\frac{3}{4}$, a>$2\frac{3}{4}$
	83	8U 7D	90.5 (297)	0.45 (2.2)	30W / 30A	0 / 0	R18U L14D / R25D L35U	L.E., D T.E., D	0.164$\bar{c}$		4	$4\frac{1}{4}$, >$4\frac{3}{4}$, $4\frac{1}{4}$, 5
	No spin[b]				30W /	0 /	R25D L35U /	L.E., D T.E., D	0.164$\bar{c}$		4	
	82	10U 6D	87.2 (286)	0.40 (2.5)	30W / 30A	0 / 0	R18U L14U / R25D L35U	L.E., D T.E., D	0.172$\bar{c}$	Wing-heavy loading with external store shapes	5	$7\frac{1}{2}$, 5

[a]Deflecting controls had no effect on spin motion.
[b]Model lost applied rotation and dived.

TABLE VI.- EFFECTS OF EMPTY 1.04-m^3 (275-gal) EXTERNAL FUEL TANKS ON ERECT SPIN AND RECOVERY CHARACTERISTICS OF MODEL

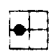
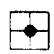
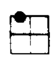
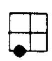
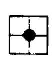
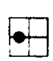
[Left erect spins; Airplane, F-5E; Loading as indicated; Center of gravity as indicated; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics				Control deflection, deg (For spin / For recovery)				Center-of-gravity location	Configuration	Loading (see table II)	Turns for recovery
	α, deg	ϕ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	δ_r	δ_e	δ_a	δ_f				
	86	9U 3D	75.0 (246)	0.53 (1.9)	30W / 30A	0 / 0	R35U L25D / R25D L35U	L.E., D T.E., D	0.158$\bar{c}$	Clean aircraft	1b	6, a$3\frac{3}{4}$, $13\frac{1}{2}$
	44 95	29U 25D	84.4 (277)	0.19 (5.3)	30W / 30A	0 / 0	R35U L25D / R25D L35U	↓	↓	Clean aircraft	1b	
	83	11U 11D	75.0 (246)	0.45 (2.2)	30W / 30A	0 / 0	R35U L25D / R25D L35U	↓	≈0.160$\bar{c}$	Three external tanks	6	$9\frac{1}{4}$, 9
	85	10U 2D	79.6 (261)	0.56 (1.8)	30W / 30A	0 / 0	R35U L25D / R25D L35U	↓	≈0.152$\bar{c}$	One external tank below fuselage center line	7	$6\frac{1}{2}$, 8
	84	13U 10D	81.7 (268)	0.52 (1.9)	30W / 30A	0 / 0	R35U L25D / R25D L35U	↓	0.168$\bar{c}$	Two external tanks below wings	8	7, 6
	42 98	12U 12D	88.1 (289)	0.20 (5.0)								$2\frac{1}{4}$, 2

[a]Had started to oscillate when controls deflected.

TABLE VII.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR ASYMMETRIC LOADING CONDITIONS

[Left erect spins, except as indicated; Airplane, F-5E; Loading as indicated; Center of gravity as indicated; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics: α, deg	Spin characteristics: φ, deg	Spin characteristics: V, m/sec (ft/sec)	Spin characteristics: Ω, rps (sec/turn)	Control deflection, deg (For spin / For recovery): δ_r	Control deflection, deg: δ_e	Control deflection, deg: δ_a	Control deflection, deg: δ_f	Center-of-gravity location	Asymmetric loading, N-m (ft-lb)	Turns for recovery
	(a)				30W	0	R12U L14D	L.E., D T.E., D	0.164c̄	4053 (2989), outboard wing heavy (loading 9 in table II)	
	(a)				30W	0	R0 L0				
	(a)				30W	17U	R18U L14D			11 869 (8754), outboard wing heavy (loading 10 in table II)	
	(a)				30W	0	R18U L14D				
	(a)				30W	5.5D	R18U L14D				
	(a)				30W	0	R0 L0				
	86	14U 9D	78.0 (256)	0.62 (1.6)	30W	0	R18U L14D		=0.199c̄	4053 (2989), outboard wing heavy (loading 11 in table II)	

See footnotes at end of table, p. 26.

TABLE VII.- Concluded

Spin block	Spin characteristics: α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	δ_f	Center-of-gravity location	Asymmetric loading, N-m (ft-lb)	Turns for recovery
	(a)				30W	0	R18U L14D	L.E., D T.E., D	≈0.199c̄	11 869 (8754), outboard wing heavy (loading 12 in table II)	
	(a)				30W	0	R18U L14D		≈0.115c̄	4053 (2989), outboard wing heavy (loading 13 in table II)	
	(b)				30W	0	R14D L14U				
	85	10U 2D	77.1 (253)	0.66 (1.5)	30W / 30A	0 / 0	R18U L14D / R14D L18U			11 869 (8754), outboard wing heavy (loading 14 in table II)	$^c\infty$, $^c\infty$
	84	9U 0	78.0 (256)	1.12 (0.9)	30W / 30A	0 / 0	R0 L0 / R14D L18U				7, $^d5$, $7\frac{1}{2}$
	85	10U	81.1 (266)	0.56 (1.8)							$>6\frac{1}{4}$, $3\frac{3}{4}$, $3\frac{1}{4}$, $2\frac{1}{2}$, $5\frac{1}{2}$
	77 91	14U 6D	80.2 (263)	0.62 (1.6)	30W / 30A	0 / 0	R18U L14D / R14D L18U			19 659 (14 500), outboard wing heavy (loading 15 in table II)	$^c\infty$, $7\frac{1}{4}$, $^d4$, $^c\infty$, $>3\frac{1}{2}$, >6
	No spin[e,f]				30W	0	R14D L18U		0.164c̄	4053 (2989), inboard wing heavy (loading 9 in table II)	
	No spin[e,f]				30W	0	R14D L18U		≈0.115c̄	4053 (2989), inboard wing heavy (loading 13 in table II)	

[a]Model dished and moved around in tunnel until hit side net or rolled over; poststall gyration indicated possible.
[b]Model dished and rolled out or hit side net.
[c]Signifies 10 turns or greater.
[d]Model had started to dish when controls deflected for recovery attempt.
[e]Model lost launch rotation, oscillated in pitch for one or two turns, then pulled out in erect glide.
[f]Direction of spin attempt: right.

TABLE VIII.- SUMMARY OF INFORMATION FROM TABLE VII

[Asymmetric loadings, outboard wing heavy]

Asymmetric moment, N-m (ft-lb) \ Center-of-gravity location	$0.115\bar{c}$	$0.164\bar{c}$	$0.199\bar{c}$
4 053 (2 989)	Poststall gyration indicated possible[a]	Poststall gyration indicated possible[a]	Fast flat spin
11 869 (8 754)	Fast flat spin; no recovery	Poststall gyration indicated possible[a]	Poststall gyration indicated possible[a]
19 659 (14 500)	Fast flat spin; no recovery		

[a]Model dished and moved around in tunnel until it hit side net or rolled over.

TABLE IX.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR LOADING 2b IN TABLE II

[Inverted spin yawing to pilot's left; Airplane, F-5E; Loading 2b in table II; Center of gravity at 0.214c̄; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics: α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	Control deflection, deg (a), for spin / for recovery: δ_r	δ_e	δ_a	δ_f	Turns for recovery
	(b)				30W /	5.5D /	R0 L0 /	L.E., D T.E., D	
	(c)				30W /	5.5D /	R35U L25D /	L.E., D T.E., D	
	(d)				30W /	17U /	R35U L25D /	L.E., D T.E., D	
	(e)				30W /	17U /	R25D L35U /	L.E., D T.E., D	
f	-67	14U 14D	86.3 (283)	0.16 (6.3)	30W / 0	17U / 0	R18U L13D / R0 L0	L.E., D T.E., D	$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$
g	-65		83.8 (275)	0.14 (7.1)	30W / 0	17U / 0	R18U L13D / R0 L0	L.E., 0 T.E., 0	$\frac{1}{4}$

[a]Control settings for inverted (as well as erect) spins are given with respect to the pilot.

[b]No spin. Model lost launch rotation and recovered in inverted glide.

[c]Wandering spin, hard to get and test in tunnel, model makes short glide, then portion of a turn, then short glide, etc.; sometimes model lost applied rotation and went into aileron roll with nose down.

[d]Weak tendency to spin; sometimes model lost applied rotation and went into aileron roll.

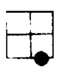
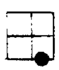
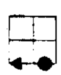
[e]No spin.

[f]Weak tendency to spin, hard to get, model wandered to side of tunnel a few turns after launch; sometimes model went into aileron roll, rather than spin.

[g]Same results as in footnote f, plus one time a smooth spin occurred for $3\frac{3}{4}$ turns, then model recovered without control movement.

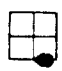
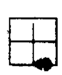
TABLE X.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR ASYMMETRIC LOADINGS WITH FLAPS DEFLECTED

[Inverted spin yawing to pilot's left; Airplane, F-5E; Loading as indicated; Center of gravity as indicated; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics: α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	Control deflection, deg (a), for spin / for recovery: δ_r	δ_e	δ_a	δ_f	Center-of-gravity location	Asymmetric loading, N-m (ft-lb)	Turns for recovery
	No spin				30W /	17U /	R18U L14D /	L.E., D T.E., D	0.215c̄	3390 (2500), outboard wing heavy (loading 16 in table II)	
	No spin				30W /	17U /	R18U L14D /	↓	0.216c̄	6780 (5000), outboard wing heavy (loading 17 in table II)	
	-61 -88	21U 55D	89.9 (295)	0.34 (2.9)	30W / 0	17U / 0	R18U L14D / RO LO	↓	0.215c̄	3390 (2500), inboard wing heavy (loading 16 in table II)	>$2\frac{1}{2}$, $3\frac{1}{2}$, 5
	-63 -97	1D 29D	86.0 (282)	0.28 (3.6)				↓	↓		$\frac{1}{2}$, $1\frac{3}{4}$, [b]∞
	-61 -88	21U 55D	89.9 (295)	0.34 (2.9)	30W / 30A	17U / 0	R18U L14D / RO LO	↓	↓		$1\frac{1}{2}$, 1, $1\frac{1}{2}$
	-63 -97	1D 29D	86.0 (282)	0.28 (3.6)				↓	↓		1, 2, 1
	-61 -88	21U 55D	89.9 (295)	0.34 (2.9)	30W / 30A	17U / 17U	R18U L14D / R25D L35U	↓	↓		$\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{2}$

See footnotes at end of table, p. 30.

TABLE X.- Concluded

Spin block	Spin characteristics: α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	Control deflection, deg (a), For spin / For recovery: δ_r	δ_e	δ_a	δ_f	Center-of-gravity location	Asymmetric loading, N-m (ft-lb)	Turns for recovery
	-61 -88	21U 55D	89.9 (295)	0.34 (2.9)	30W / 0	17U / 17U	R18U L14D / R0 L0	L.E., D T.E., D	0.215c̄	3390 (2500), inboard wing heavy (loading 16 in table II)	$1\frac{1}{2}$, 2, $5\frac{1}{2}$
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W / 30A	17U / 0	R18U L13D / R0 L0	↓	0.216c̄	6780 (5000), inboard wing heavy (loading 17 in table II)	>5, $4\frac{1}{2}$, >6
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W / 30A	17U / 0	R18U L13D / R25D L35U	↓	↓		>4, $>8\frac{1}{2}$, 11
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W / 0	17U / 17U	R18U L13D / R0 L0	↓	↓		>3, $>2\frac{3}{4}$, $3\frac{1}{2}$
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W / 30A	17U / 17U	R18U L13D / R25D L35U	↓	↓		2, $1\frac{1}{4}$, >3, 4, 2, 2

[a]Control settings for inverted (as well as erect) spins are given with respect to the pilot.
[b]Signifies 10 turns or greater.

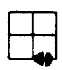
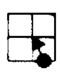
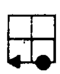
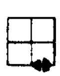
TABLE XI.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR ASYMMETRIC LOADINGS WITH FLAPS UNDEFLECTED

[Inverted spin yawing to pilot's left; Airplane, F-5E; Loading as indicated; Center of gravity as indicated; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics: α, deg	Spin characteristics: φ, deg	Spin characteristics: V, m/sec (ft/sec)	Spin characteristics: Ω, rps (sec/turn)	Control deflection, deg (a) (For spin / For recovery): δ_r	δ_e	δ_a	δ_f	Center-of-gravity location	Asymmetric loading, N-m (ft-lb)	Turns for recovery
	-57 -94	17U 47D	85.3 (280)	0.21 (4.8)	30W / 0	17U / 0	R18U L13D / R0 L0	L.E., 0 T.E., 0	0.215c̄	3390 (2500), inboard wing heavy (loading 16 in table II)	>6, >6
	-57 -94	17U 47D	85.3 (280)	0.21 (4.8)	30W / 30A	17U / 0	R18U L13D / R0 L0	↓	↓		[b]1, >3$\frac{1}{2}$, 2, 5$\frac{1}{2}$
	-57 -94	17U 47D	85.3 (280)	0.21 (4.8)	30W / 30A	17U / 0	R18U L13D / R25D L35U	↓	↓		$\frac{3}{4}$, 1$\frac{1}{2}$, >1$\frac{1}{4}$, $\frac{3}{4}$, >1, >1$\frac{1}{4}$, 1
	-57 -94	17U 47D	85.3 (280)	0.21 (4.8)	30W / 30A	17U / 17U	R18U L13D / R25D L35U	↓	↓		$\frac{3}{4}$, $\frac{3}{4}$, $\frac{1}{4}$, $\frac{3}{4}$, $\frac{1}{2}$

See footnotes at end of table, p. 32.

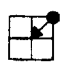
TABLE XI.- Concluded

Spin block	Spin characteristics: α, deg	Spin characteristics: φ, deg	Spin characteristics: V, m/sec (ft/sec)	Spin characteristics: Ω, rps (sec/turn)	Control deflection, deg (a), For spin / For recovery: δ_r	δ_e	δ_a	δ_f	Center-of-gravity location	**Asymmetric** loading, **N-m** (ft-lb)	Turns for recovery
	-57 -94	17U 47D	85.3 (280)	0.21 (4.8)	30W / 0	17U / 17U	R18U L13D / RO LO	L.E., 0 T.E., 0	0.215c̄	3390 (2500), inboard wing heavy (loading 16 in table II)	$5\frac{1}{2}$, 1, 1, $4\frac{1}{4}$
	-67 -86	40U 11D	87.2 (286)	0.28 (3.6)	30W / 30A	17U / 0	R18U L13D / RO LO	↓	0.216c̄	6780 (5000), inboard wing heavy (loading 17 in table II)	7, $6\frac{1}{4}$
	-67 -86	40U 11D	87.2 (286)	0.28 (3.6)	30W / 30A	17U / 0	R18U L13D / R25D L35U	↓	↓		$5\frac{1}{4}$, 7
	-67 -86	40U 11D	87.2 (286)	0.28 (3.6)	30W / 30A	17U / 17U	R18U L13D / R25D L35U	↓	↓		$1\frac{3}{4}$, $1\frac{1}{2}$, $>2\frac{1}{2}$, 1, 2, $2\frac{1}{2}$
	-67 -86	40U 11D	87.2 (286)	0.28 (3.6)	30W / 0	17U / 17U	R18U L13D / RO LO	↓	↓		$3\frac{3}{4}$, 6

[a]Control settings for inverted (as well as erect) spins are given with respect to the pilot.
[b]Flaps at 0° had adverse effect for this loading and this recovery control technique; see comparable results in table X for flaps deflected down.

TABLE XII.- EFFECTS OF EMPTY 1.04-m^3 (275-gal) EXTERNAL FUEL TANKS ON INVERTED SPIN AND RECOVERY CHARACTERISTICS OF MODEL

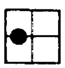
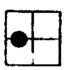
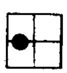
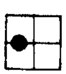
[Inverted spins yawing to pilot's left; Airplane, F-5E; Loading as indicated; Center of gravity as indicated; Altitude, 7620 m (25 000 ft); L, left; R, right; W, with; A, against; U, up; D, down]

Spin block	Spin characteristics				Control deflection, deg (a) — For spin / For recovery				Center-of-gravity location	Configuration	Loading (see table II)	Turns for recovery
	α, deg	ϕ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	δ_r	δ_e	δ_a	δ_f				
	-53 -77	4U 14D	88.4 (290)	0.19 (5.3)	30W / 0	5.5D / 0	L25D R35U / LO RO	L.E., D T.E., D	0.158$\bar{c}$	Clean aircraft	1b	$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$
	-58 -81	6U 14D	80.5 (264)	0.21 (4.8)	30W / 0	5.5D / 0	L25D R35U / LO RO		≈0.160$\bar{c}$	Three external tanks	6	$\frac{3}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$
	-57 -78	8U 36D	84.1 (276)	0.19 (5.3)	30W / 0	5.5D / 0	L25D R35U / LO RO		≈0.152$\bar{c}$	One external tank below fuselage center line	7	$\frac{1}{4}$, $\frac{1}{4}$
	-54 -81	5D 28D	83.2 (273)	0.19 (5.3)	30W / 0	5.5D / 0	L25D R35U / LO RO		0.168$\bar{c}$	Two external tanks below wings	8	$\frac{1}{2}$, $\frac{1}{4}$, $\frac{3}{4}$

[a]Control settings for inverted (as well as erect) spins are given with respect to the pilot.

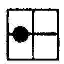
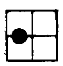
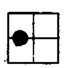
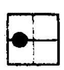
TABLE XIII.- ERECT SPIN-RECOVERY PARACHUTE TEST RESULTS FOR MODEL

[Left erect spins | Parachute riser-plus-shroud-line distance, 22.9 m (75 ft)
Airplane, F-5E | L, left
Loading as indicated | R, right
Center of gravity as indicated | W, with
Altitude, 7620 m (25 000 ft) | A, against
Parachute diameter, 6.9 m (22.8 ft) | U, up
Parachute C_D, 0.50 | D, down]

Spin block	Spin characteristics				Control deflection, deg				Center-of-gravity location	Loading (see table II)	Turns for recovery
	α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	For spin / For recovery						
					δ_r	δ_e	δ_a	δ_f			
	84	8U 7D	80.2 (263)	0.44 (2.2)	30W	0	R18U L14D	L.E., D T.E., D	0.165$\bar{c}$	1a	2, $2\frac{1}{4}$, $\frac{3}{4}$, $1\frac{1}{4}$
	58 92	17U 19D	84.1 (276)	0.25 (4.0)							$^{a}\frac{1}{2}$, $^{a}\frac{1}{2}$, 1, $^{a}\frac{1}{2}$, $\frac{1}{2}$
	84	7U 4D	72.8 (239)	0.49 (2.0)	30W	0	R18U L14D	↓	0.199$\bar{c}$	2a	2, 1, 2
	59 104	13U 13D	75.0 (246)	0.25 (4.0)							1, $\frac{1}{4}$, 1
	85	9U 5D	75.9 (249)	0.53 (1.9)	30W	0	R18U L14D	↓	0.115$\bar{c}$	3	2, 2
	49 92	16U 13D	80.2 (263)	0.21 (4.8)							$\frac{1}{2}$, 1
	L.E. flaps and T.E. flaps at 0°										
	81	9U 10D	78.9 (259)	0.37 (2.7)	30W	0	R18U L14D		0.165$\bar{c}$	1a	1, $1\frac{1}{2}$, 1, $1\frac{1}{2}$, $^{a}1\frac{1}{2}$, $^{a}1\frac{3}{4}$
	40 99	8U 19D	86.0 (282)	0.22 (4.5)							$\frac{3}{4}$, $^{a}1$, $\frac{3}{4}$

See footnotes at end of table, p. 35.

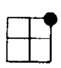
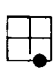
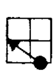
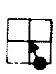
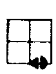
TABLE XIII.- Concluded

Spin block	Spin characteristics				Control deflection, deg				Center-of-gravity location	Loading (see table II)	Turns for recovery
	α, deg	φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	For spin / For recovery δ_r	δ_e	δ_a	δ_f			
Asymmetric loading of 11 869 N-m (8754 ft-lb), outboard wing heavy											
	(b)				30W	0	R18U L14D	L.E., D T.E., D	$0.199\bar{c}$	12	2, 1, $2\frac{1}{4}$, $2\frac{1}{4}$
	85	10U 2D	77.1 (253)	0.66 (1.5)	30W	0	R18U L14D	↓	$0.115\bar{c}$	14	a,$c_4\frac{1}{2}$, a,c_3, e_4, e_4, e_3, $d_2\frac{1}{2}$, a,$d_2\frac{1}{2}$, $d_2\frac{1}{2}$, d_2
Asymmetric loading of 19 659 N-m (14 500 ft-lb), outboard wing heavy											
	77 91	14U 6D	80.2 (263)	0.62 (1.6)	30W	0	R18U L14D	L.E., D T.E., D	$0.115\bar{c}$	15	c_3, c_4, c_4, c_4, $c_3\frac{1}{2}$, $d_3\frac{1}{2}$, d,e_2, d_5, a,d,$e_2\frac{1}{2}$, d_4, a,d,e_3, d_4
Wing-heavy loading											
	83	8U 7D	90.5 (297)	0.45 (2.2)	30W	0	R18U L14D	L.E., D T.E., D	$0.164\bar{c}$	4	2, $2\frac{1}{4}$, 2, 3, 2

[a]Visual observation.
[b]For these tests, parachute was opened before or just as dishing motion of model started; see footnote a in table VII.
[c]From apparent equilibrium spin ensuing after fast flat launch, prior to dishing motion.
[d]From an apparent spin condition while model was revving up and flattening its attitude following a slow steeper launch; attempt to open parachute just before or just as dishing motion started.
[e]Model had started to dish when parachute opened.

TABLE XIV.- INVERTED SPIN-RECOVERY PARACHUTE TEST RESULTS FOR MODEL

[Inverted spin yawing to pilot's left
Airplane, F-5E
Loading as indicated
Center of gravity as indicated
Altitude, 7620 m (25 000 ft)
Parachute diameter, 6.9 m (22.8 ft)
Parachute C_D, 0.50
Parachute riser-plus-shroud-line distance, 22.9 m (75 ft)
L, left
R, right
W, with
A, against
U, up
D, down]

Spin block	Spin characteristics				Control deflection, deg (a) (For spin / For recovery)				Center-of-gravity location	Loading (see table II)	Turns for recovery
	α, deg	Φ, deg	V, m/sec (ft/sec)	Ω, rps (sec/turn)	δ_r	δ_e	δ_a	δ_f			
Symmetric loading											
	-53 -77	4U 14D	88.4 (290)	0.19 (5.3)	30W	5.5D	L25D R35U	L.E., D T.E., D	0.215c̄	16	1, 1
Asymmetric loading, 6780 N-m (5000 ft-lb), inboard wing heavy											
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W	17U	R18U L13D	L.E., D T.E., D	0.216c̄	17	3, $2\frac{1}{4}$, $4\frac{3}{4}$, >2, 2
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W / 30A	17U / 0	R18U L13D / R25D L35U	↓	↓	↓	2, $\frac{3}{4}$, 1, 1, 1
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W / 0	17U / 0	R18U L13D / R0 L0	↓	↓	↓	>$1\frac{1}{2}$, >$1\frac{1}{2}$, $2\frac{3}{4}$, $\frac{1}{2}$, 1
	-67 -86	40U 11D	87.2 (286)	0.28 (3.6)	30W / 0	17U / 17U	R18U L13D / R0 L0	L.E., 0 T.E., 0	↓	↓	$\frac{1}{2}$, $\frac{1}{2}$, 1, $\frac{1}{2}$
	-65 -91	7U 44D	91.4 (300)	0.32 (3.1)	30W / 0	17U / 17U	R18U L13D / R0 L0	L.E., D T.E., D	↓	↓	1, $\frac{1}{2}$, 1

[a]Control settings for inverted (as well as erect) spins are given with respect to the pilot.

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR LOADING 1a IN TABLE II

[Recovery attempted by moving elevators to neutral, ailerons to full with the spin, and rudder to full against the spin, unless otherwise noted (recovery attempted from and developed spin data presented for rudder full with spins)]

Airplane	Attitude	Direction	Loading 1a (see table II); 55 percent internal fuel; medium c.g. location
F-5E	Erect	Left	
Slots	L.E. and T.E. flaps down	Center-of-gravity position 0.165$\bar{c}$	Altitude 7620 m (25 000 ft)

Model values converted to full scale

U-inner wing up

D-inner wing down

Elevators full up (17°) (stick back), ailerons $\frac{1}{2}$ against (two conditions possible[a]; oscillatory spin[b])

86	5U 3D	48 91	17U 7D
77.7 (255)	0.51 (2.0)	86.0 (282)	0.19 (5.3)
$^{c}5\frac{1}{2}$, $^{c}5\frac{1}{2}$		$^{c}1\frac{1}{2}$, $^{c}\frac{1}{4}$	
>5, $^{c}5\frac{1}{2}$, $^{d}4$		$^{c}\frac{1}{2}$, $^{c}\frac{1}{2}$, $^{d}\frac{1}{4}$	
$^{d}10$		$^{d}\frac{1}{4}$, $^{d}\frac{1}{4}$	

Elevators full up (17°) (stick back), ailerons neutral[e]

No spin

Elevators full up (17°) (stick back), ailerons $\frac{1}{2}$ with[e]

No spin

Elevators neutral, [g]Ailerons $\frac{1}{2}$ against (stick right) (two conditions possible[a]; oscillatory spin[b])

84	8U 7D	58 92	17U 19D
80.2 (263)	0.44 (2.3)	84.1 (276)	0.25 (4.0)
$^{f}\infty$		$^{d}\frac{1}{2}$, $^{d}1$	
$^{d}5\frac{3}{4}$, $^{d}8\frac{1}{2}$		$^{d}1$, $^{d}\frac{3}{4}$	

Elevators neutral, ailerons neutral (two conditions possible[a]; oscillatory spin[b])

83	14U 19D	59 91	20U 25D
78.9 (259)	0.43 (2.3)	83.2 (273)	0.23 (4.3)
$^{c}10$, $^{d}8$		$^{d}1$, $^{c}\frac{1}{2}$	
>5, $^{f}\infty$		$^{d}\frac{1}{2}$, $^{d}1$	

Elevators neutral, [g]Ailerons $\frac{1}{2}$ with (stick left)[e]

No spin

Elevators full down (stick forward), ailerons $\frac{1}{2}$ against (two conditions possible[a]; oscillatory spin[b])

83	11U 12D	45 101	17U 20D
77.7 (255)	0.47 (2.1)	83.2 (273)	0.21 (4.8)
$^{d}6$, $^{f}\infty$		$^{h}2\frac{1}{2}$, $^{c}\frac{3}{4}$, $^{c,h}2\frac{1}{2}$	

Elevators full down (stick forward), ailerons neutral (two conditions possible[a]; oscillatory spin[b])

83	10U 9D	62 92	15U 15D
78.9 (259)	0.43 (2.3)	81.7 (268)	0.23 (4.3)
$^{d}3\frac{3}{4}$, $^{c}5\frac{1}{4}$		$^{d}1\frac{1}{4}$, $^{d}1\frac{3}{4}$	

Elevators full down (stick forward), ailerons $\frac{1}{2}$ with[i]

No spin

Key:

α, deg	φ, deg
V, m/sec (ft/sec)	Ω, rps (sec/turn)
Turns for recovery	

[a]Two conditions possible.
[b]Oscillatory spin; range of values given.
[c]Recovered in a glide.
[d]Recovered in a dive.
[e]Model lost applied rotation and entered a glide.
[f]Signifies 10 turns or greater.
[g]Aileron deflections for this chart: 18° up, 14° down.
[h]Visual observation.
[i]Model lost applied rotation and dived inverted, or rolled over.

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR LOADING 2 IN TABLE II

[Recovery attempted by moving elevators to neutral, ailerons to full with the spin, and rudder to full against the spin, unless otherwise noted (recovery attempted from and developed spin data presented for rudder full with spins)]

Airplane	Attitude	Direction	
F-5E	Erect	Left	Loading 2a (see table II); rearward c.g. location
Slats	L.E. and T.E. flaps down	Center-of-gravity position 0.199c̄	Altitude 7620 m (25 000 ft)

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

a, b

82	2U 8D	50 101	3U 12D
80.2 (263)	0.33 (3.0)	80.2 (263)	0.20 (5.0)
$^{c}4\frac{1}{2}$, $^{c}5\frac{1}{2}$		$^{d}\frac{1}{4}$, $^{e}1$	
f_{∞}, f,g_{∞}		g_1, g_2	

h

No spin	

Elevators full up (17°) (stick back)

a, b

84	7U 4D	59 104	13U 13D
72.8 (239)	0.49 (2.0)	75.0 (246)	0.25 (4.0)
$^{e}8\frac{1}{2}$, f_{∞}		$^{c}\frac{3}{4}$, $^{c,i}2\frac{1}{4}$	
$g_{7}\frac{1}{4}$, $g_{9}\frac{1}{4}$		$^{c}1\frac{1}{2}$, $^{c,i}1\frac{1}{2}$	

^{j}Ailerons $\frac{1}{2}$ against (stick right)

[a] Two conditions possible.
[b] Oscillatory spin; range of values given.
[c] Recovered in a glide.
[d] Recovered in an inverted glide.
[e] Recovered in a dive.
[f] Signifies 10 turns or greater.
[g] Recovered in an inverted dive.
[h] Model lost applied rotation and entered a glide.
[i] Visual observation.
[j] Aileron deflections for this chart: 18° up, 14° down.

α, deg	ϕ, deg
V, m/sec (ft/sec)	Ω, rps (sec/turn)
Turns for recovery	

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR LOADING 3 IN TABLE II

[Recovery attempted by moving elevators to neutral, ailerons to full with the spin, and rudder to full against the spin, unless otherwise noted (recovery attempted from and developed spin data presented for rudder full with spins)]

Airplane F-5E	Attitude Erect	Direction Left	Loading 3 (see table II); forward c.g. location	
Slats	L.E. and T.E. flaps down		Center-of-gravity position 0.115$\bar{c}$	Altitude 7620 m (25 000 ft)

Model values converted to full scale

U-inner wing up

D-inner wing down

a

b

84	5U 1D	50 101	21U 20D
77.1 (253)	0.56 (1.8)	83.2 (273)	0.25 (4.0)
$^{c}\infty$, $^{c}\infty$		$^{a}2\frac{1}{4}$, $^{d}4\frac{1}{2}$, $^{d}5$	
$^{c}\infty$, $^{c}\infty$		>$9\frac{1}{4}$	

a

b

83	6U 8D	49 99	18U 19D
77.1 (253)	0.45 (2.2)	78.0 (256)	0.22 (4.5)
$^{d}7\frac{1}{2}$, $^{c}\infty$		>7, $^{d}1\frac{3}{4}$, $^{e}5\frac{1}{2}$	
$^{f}6$, $^{c}\infty$		>8, $^{c}\infty$	

a

b

85	9U 5D	49 92	16U 13D
75.9 (249)	0.53 (1.9)	80.2 (263)	0.21 (4.8)
$^{c}\infty$, >6		$^{g}\frac{1}{2}$, $^{d}\frac{3}{4}$	
$^{f}8$, $^{c}\infty$		$^{c}\infty$, $^{g}1\frac{1}{4}$, >7	

^h Ailerons $\frac{1}{2}$ against (stick right)

^h Ailerons $\frac{1}{2}$ with (stick left)

80	6U 10D
73.8 (242)	0.36 (2.8)
$^{d}5\frac{1}{2}$, $^{d}4\frac{1}{4}$, $^{d}8\frac{1}{2}$	

^a Two conditions possible.
^b Oscillatory spin; range of values given.
^c Signifies 10 turns or greater.
^d Recovered in a dive.
^e Recovered in an aileron roll.
^f Recovered in an inverted dive.
^g Recovered in a glide.
^h Aileron deflections for this chart: 18° up, 14° down.

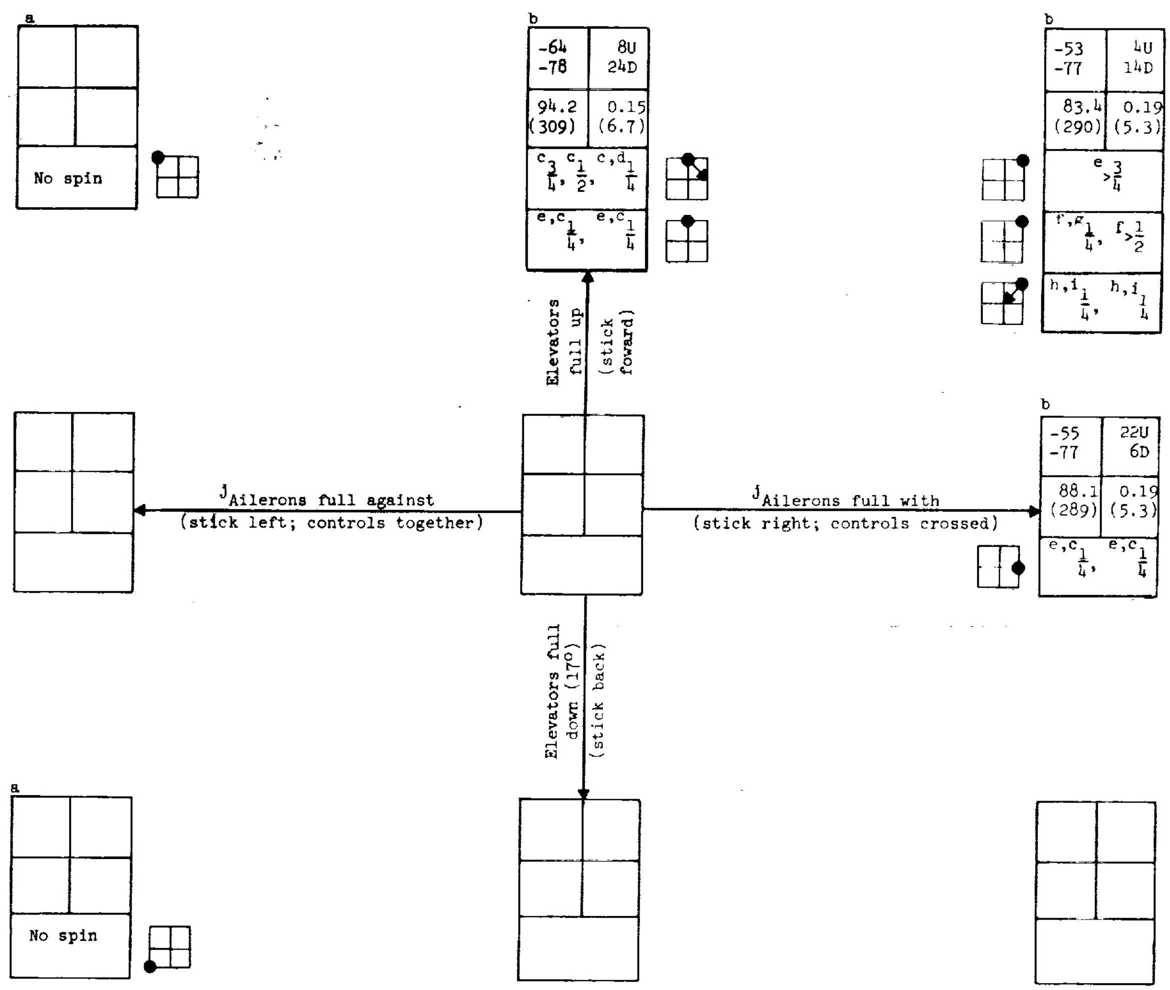
α, deg	ϕ, deg
V, m/sec (ft/sec)	Ω, rps (sec/turn)
Turns for recovery	

CHART 4.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR LOADING 1b IN TABLE II

[Recovery attempted by moving controls as indicated (recovery attempted from and developed spin data presented for rudder full with spins)]

Airplane F-5E	Attitude Inverted	Direction To pilot's left	Loading 1b (see table II)	
Slots	L.E. and T.E. flaps down		Center-of-gravity position 0.158c̄	Altitude 7620 m (25 000 ft)

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



a Model lost applied rotation and entered an inverted glide.
b Oscillatory spin; range of values given.
c Recovered in an inverted glide.
d Visual observation.
e Recovery attempted by rudder reversal only.
f Recovery attempted by rudder neutralization only.
g Recovered in an aileron roll.
h Recovery attempted by neutralization of ailerons, elevators, and rudder.
i Recovered in a dive.
j Aileron deflections for this chart: 35° up, 25° down.

α, deg	ϕ, deg
V, m/sec (ft/sec)	Ω, rps (sec/turn)
Turns for recovery	

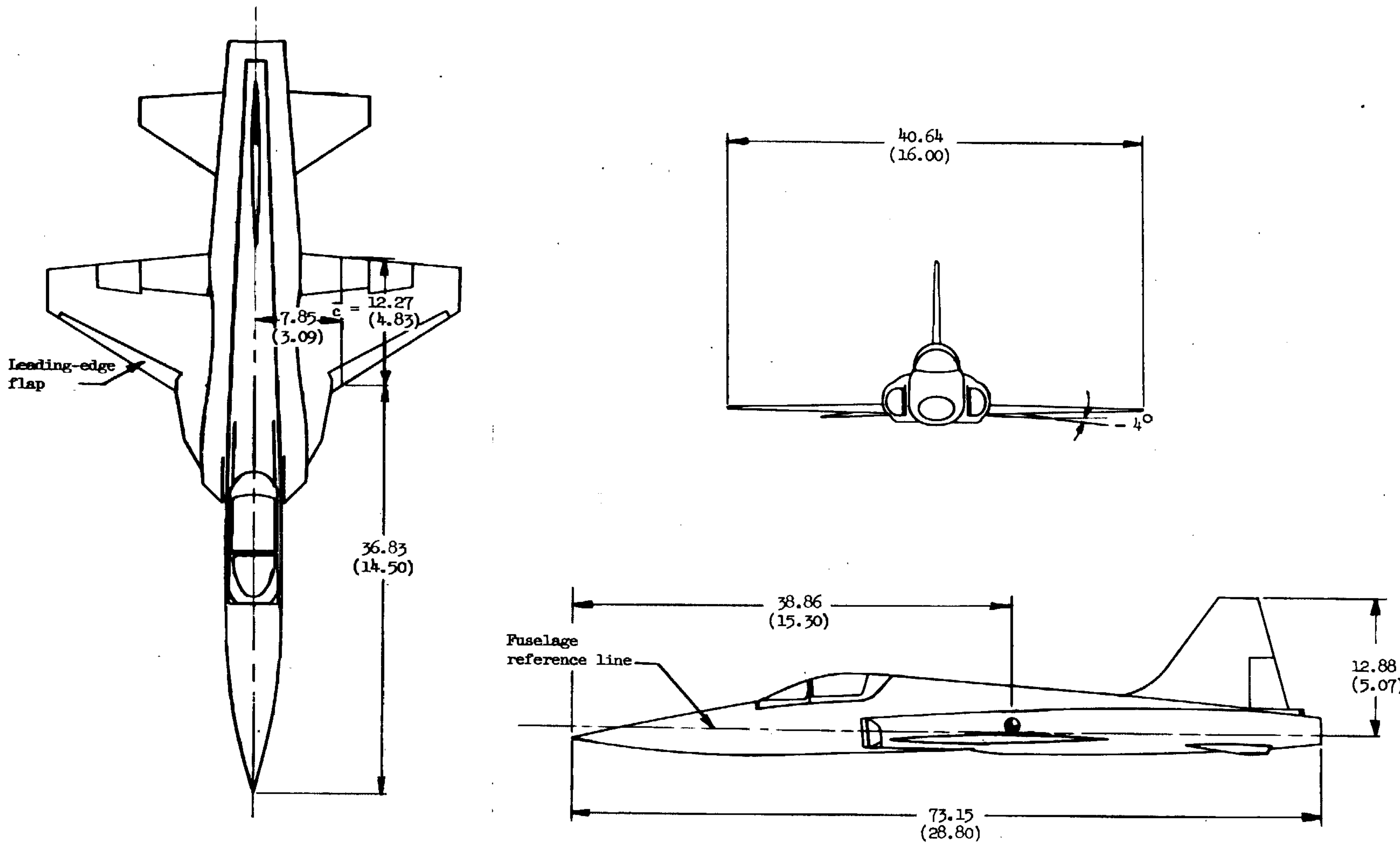
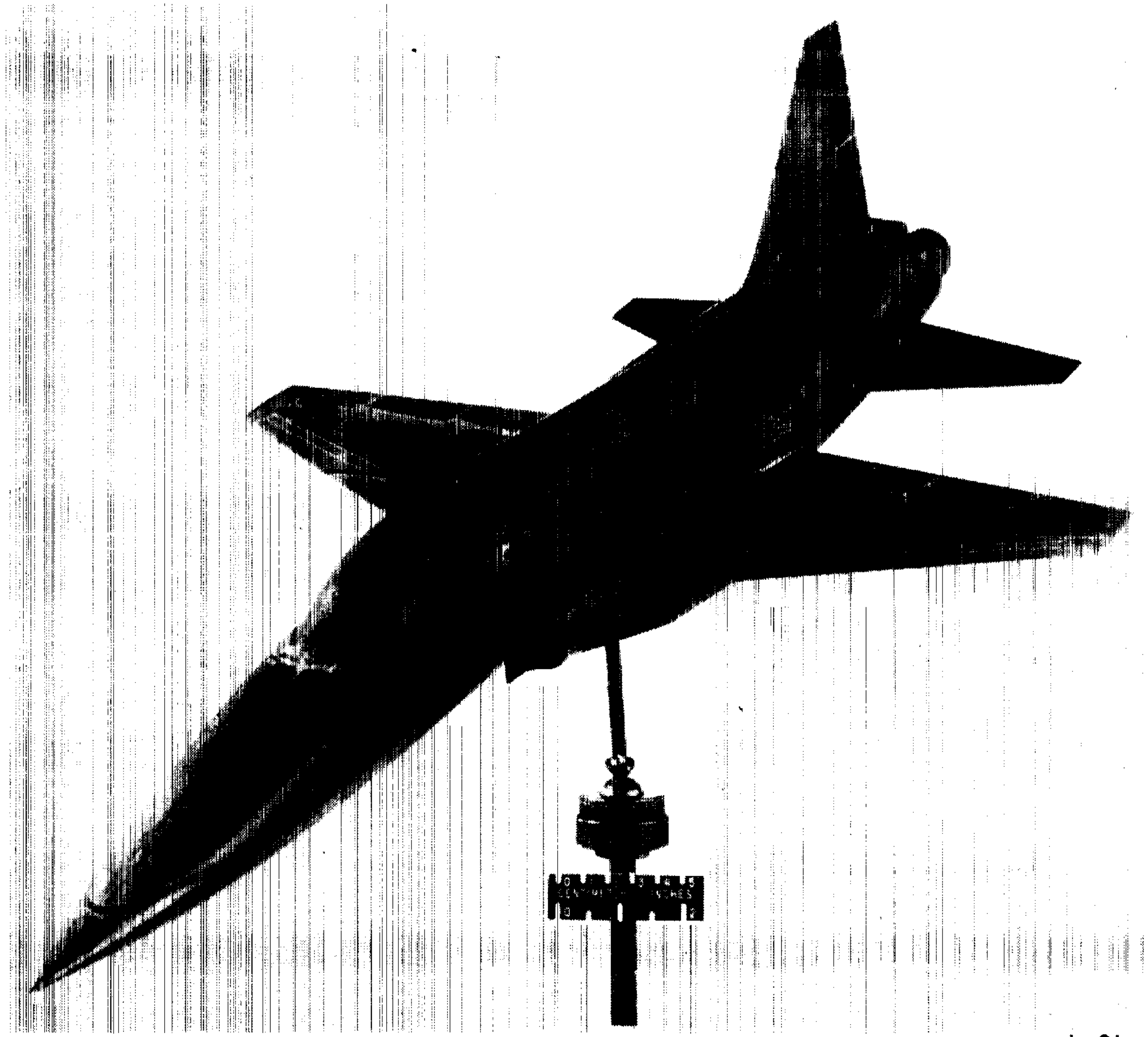
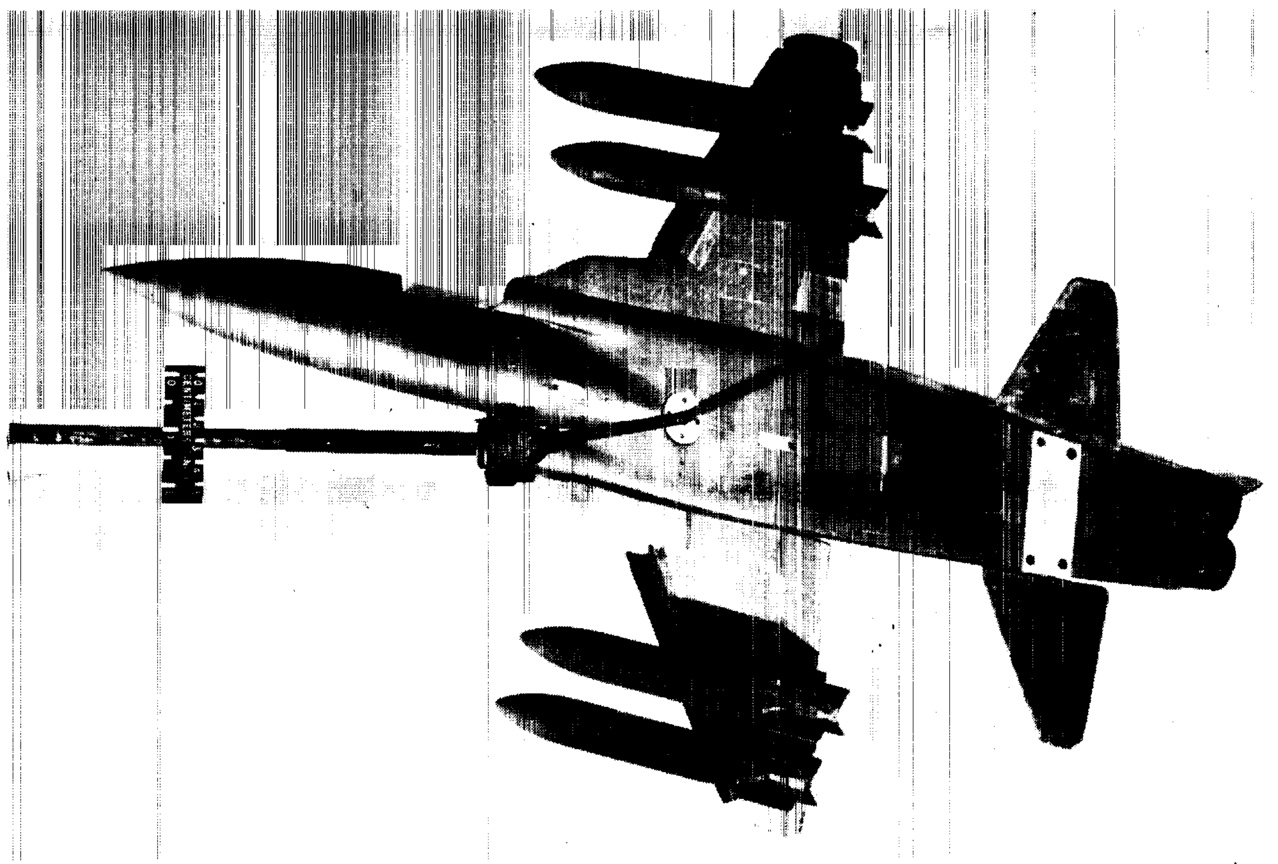


Figure 1.- Three-view drawing of 1/20-scale model of Northrop F-5E airplane. Center-of-gravity location indicated is at 0.165$\bar{c}$. Dimensions are given in centimeters (inches) unless otherwise noted.



L-74-8427

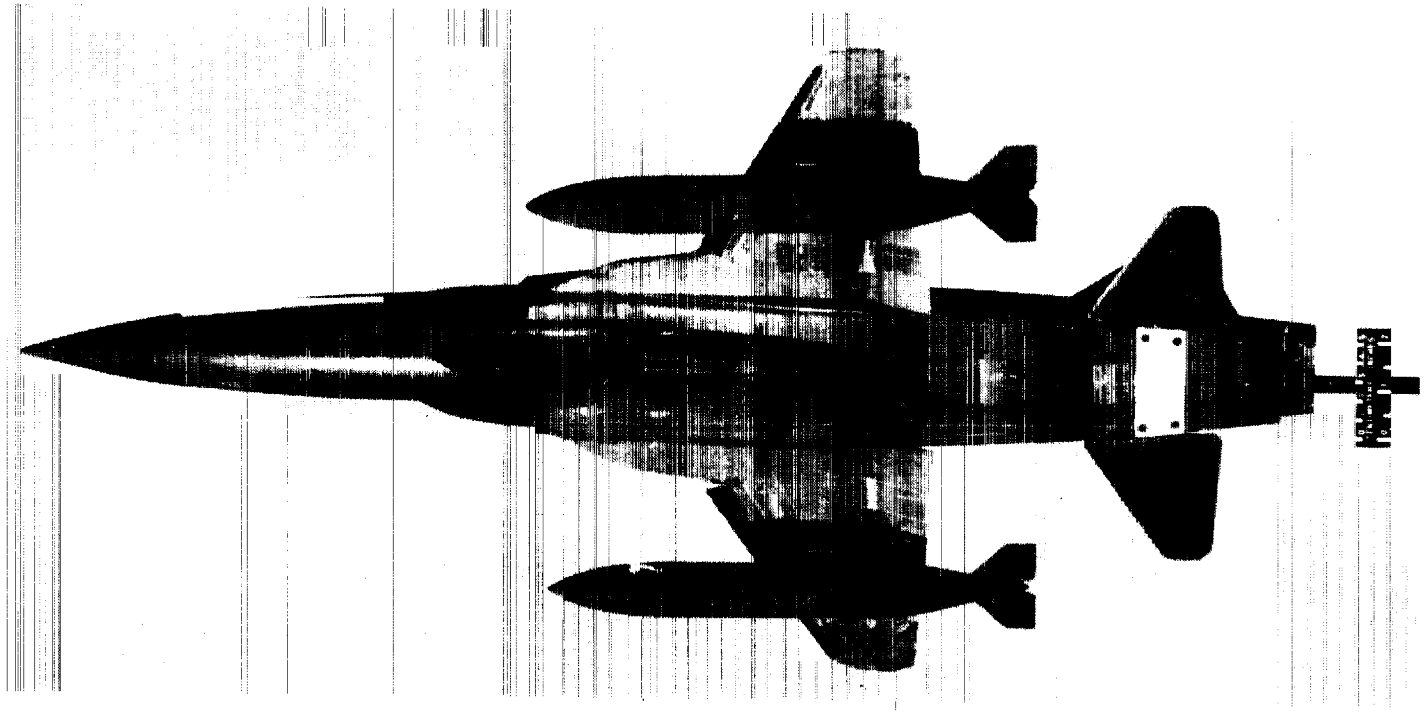
Figure 2.- Photograph of model in clean configuration with flaps undeflected.



L-75-4935

(a) External stores shapes.

Figure 3.- Photographs of model with strakes installed, leading-edge and trailing-edge flaps deflected, and external stores installed.



L-75-4938

(b) External fuel tank shapes.

Figure 3.- Concluded.