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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

FREE-SPINNING-TUNNEL TESTS OF A $\frac{1}{24}$-SCALE MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

A spin investigation has been conducted in the Langley 20-foot free-spinning tunnel on a $\frac{1}{24}$-scale model of the North American XP-86 airplane. The effects of control settings and movements upon the erect and inverted spin and recovery characteristics of the model were determined for the design gross weight loading. The long-range loading was also investigated and the effects of extending slats and dive flaps were determined. In addition, the investigation included the determination of the size of spin-recovery parachute required for emergency recovery from demonstration spins, the rudder force required to move the rudder for recovery, and the best method for the pilot to escape if it should become necessary to do so during a spin.

The results of the investigation indicated that the XP-86 airplane will probably recover satisfactorily from erect and inverted spins for all possible loadings. It was found that fully extending both slats would be beneficial but that extending the dive brakes would cause unsatisfactory recoveries. It was determined that a 10.0-foot-diameter tail parachute with a drag coefficient of 0.7 and with a towline 30.0 feet long attached below the jet exit or a 6.0-foot-diameter wing-tip parachute opened on the outer wing tip with a towline 6.0 feet long would insure recoveries from any spins obtainable. The rudder-pedal force necessary to move the rudder for satisfactory recovery was found to be within the physical capabilities of the pilot.

INTRODUCTION

In accordance with the request of the Air Materiel Command, U. S. Air Force, tests were performed in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a $\frac{1}{24}$-scale model of the North American XP-86 airplane. The airplane is a single-place, jet fighter with sweptback wing and tail surfaces.

The erect and inverted spin and recovery characteristics of the model were determined for the design gross weight loading and also for a long-range loading. In addition, tests were made with slats extended and with dive flaps extended. Spin-recovery-parachute, pilot-escape, and rudder-force tests were also made.

SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing or elevator chord at any station along the span
$\bar{c}$	mean aerodynamic chord, feet
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and thrust line to mean aerodynamic chord (positive when center of gravity is below thrust line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slugs per cubic foot

μ	relative density of airplane $\left(\frac{m}{\rho Sb}\right)$
α	angle between thrust line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), degrees
ϕ	angle between span axis and horizontal, degrees
V	full-scale true rate of descent, feet per second
Ω	full-scale angular velocity about spin axis, revolutions per second
σ	helix angle, angle between flight path and vertical, degrees (For the tests of this model, the average absolute value of the helix angle was approximately 4°.)
β	approximate angle of sideslip at center of gravity, degrees (Sideslip is inward when inner wing is down by an amount greater than the helix angle.)

APPARATUS AND METHODS

Model

The $\frac{1}{24}$-scale model of the North American XP-86 airplane was built by North American and was checked for dimensional accuracy and prepared for testing by the Langley Laboratory. A three-view drawing of the model as tested is shown as figure 1. Dimensional characteristics of the airplane are presented in table I. Tail-damping power factor was computed by the method described in reference 1. Photographs of the model in the different configurations tested are shown as figures 2 to 5.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 15,000 feet (ρ = 0.001496 slug/cu ft). For the pilot-escape tests, use was made of a model of a 200-pound man also ballasted at 15,000 feet. A remote-control mechanism was installed in the model to actuate the controls for the recovery attempts, to release the pilot for the pilot-escape tests, and to open the parachutes for the tail and wing-tip-parachute tests. Sufficient moments were exerted on the controls for the recovery attempts to reverse them fully and rapidly.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is, in general, similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel, except that the models are launched by hand with spinning rotation into the vertically rising air stream rather than launched by spindle. The airspeed is adjusted until it balances the weight of the model and, after a number of turns in the established spin, recovery is attempted by moving one or more controls by means of the remote-control mechanism. After recovery the model dives into a safety net. The model is retrieved, the controls reset, and the model is then ready for the next spin. A photograph of the model during a spin is shown as figure 6.

The spin data presented were obtained and converted to corresponding full-scale values by methods described in reference 2. The turns for recovery are measured from the time the controls are moved, or the parachute is opened, to the time the spin rotation ceases and the model dives into the net. For the spins which had a rate of descent in excess of that which can readily be attained in the tunnel, the rate of descent was recorded as greater than the velocity at the time the model hit the safety net, for example, >300. For these tests, the recovery was attempted before the model reached its final steeper attitude and while the model was still descending in the tunnel. Such results are conservative; that is, recoveries will not be so fast as when the model is in the final steeper attitude. For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery does not necessarily indicate an improvement over a >7-turn recovery. For recovery attempts in which the model did not recover, the recovery was recorded as ∞. When the model recovered without control movement, with the controls with the spin, the result was recorded as "no spin."

Spin-tunnel tests are usually made to determine the spin and recovery characteristics of the model at the normal-spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations including zero and maximum deflections. Recovery is generally attempted by rapid full rudder reversal. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the ailerons are set at one-third of the full deflection in the direction conducive to slower recoveries and the elevator is set at two-thirds of its full-up deflection. Recovery is attempted by rapidly reversing the rudder from full with to only two-thirds against the spin or by movement of the rudder to two-thirds against the spin in conjunction with moving the elevator to one-third down. This control configuration and movement is referred to as the "criterion spin." Recovery characteristics of the model are considered satisfactory if recovery from this criterion spin requires $2\frac{1}{4}$ turns or less. This value has been selected on the basis of full-scale airplane spin-recovery data that are available for comparison with corresponding model test results.

The testing technique for determining the optimum size of and the towline length for spin-recovery parachutes is described in detail in reference 3. For the tail-parachute tests, the towline was attached to the model at the junction of the horizontal tail and the rear tip of the fuselage above and below the jet exit. The parachute was packed under the horizontal tail on the right side of the fuselage for right spins. Wing-tip parachutes were attached to the outer wing tip. When the parachute was attached to the wing tip, the towline length was so adjusted that the parachute would just miss the horizontal tail. In every case, the folded parachute was placed on the fuselage or wing in such a position that it did not seriously influence the steady spin before the parachute was opened. For a full-scale wing-parachute installation, it is advisable that the parachute be packed within the wing. Full-scale-parachute installations should be provided with positive means of ejection. For the current tests, the rudder was held with the spin during recovery so that the recovery was due entirely to the effect of opening the parachute. Silk parachutes having a drag coefficient of approximately 0.7 (based on the canopy area measured with the parachute spread out flat) were used for the spin-recovery-parachute tests.

For tests to determine from which side of the spinning airplane it would be best for the pilot to make an emergency escape, the pilot model was released from the inboard and outboard side of the fuselage at the cockpit for both steep and flat spinning attitudes, and the path it followed was noted.

The full-scale rudder-pedal force necessary to move the rudder for recovery in a spin was determined from model tests. For these tests, tension in the rubber band which pulls the model rudder against the spin was adjusted to represent a known value of rudder hinge moment, and recovery tests were made. The tension was reduced systematically until the turns for recovery began to increase. The model rudder hinge moment at this point was converted to corresponding full-scale rudder-pedal force at the equivalent altitude at which the tests were run.

Precision

The model test results presented are believed to be true values given by the model within the following limits:

α, degrees . . . . ± 1
ϕ, degrees . . . . ± 1
V, percent . . . . ± 5
Ω, percent . . . . ± 2

Turns for recovery . . $\begin{cases} \pm\frac{1}{4} \text{ turn when obtained from motion-picture records} \\ \pm\frac{1}{2} \text{ turn when obtained from visual observation} \end{cases}$

The preceding limits may have been exceeded for some of the spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and full-scale results (references 2 and 4) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. In general, the models spun at a somewhat smaller angle of attack, at a somewhat higher rate of descent, and at from 5° to 10° more outward sideslip than did the airplanes. The comparison made in reference 4 for 20 airplanes showed that approximately 80 percent of the models predicted satisfactorily the number of turns required for recovery from the spin for the corresponding airplanes and that approximately 10 percent overestimated and approximately 10 percent underestimated the number of turns required.

Little can be stated about the precision of the pilot-escape tests because no comparable airplane data are available. It is felt, however, that if the model pilot is observed to clear all parts of the model by a large margin after being released from both steep and flat spinning attitudes, then the tests indicate that the pilot will be able to escape during a spin.

Because it is impracticable to ballast the model exactly and because of the inadvertent damage to the model during tests, the measured weight and mass distribution of the XP-86 model varied from the true scaled-down values within the following limits:

Weight, percent		1 low to 2 low
Center-of-gravity location, percent $\bar{c}$		1 high to 0
Moments of inertia	I_X, percent	3 low to 6 low
	I_Y, percent	4 high to 9 low
	I_Z, percent	5 high to 3 low

The accuracy of measuring weights and mass distribution was within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls were set with an accuracy of ±1°.

Test Conditions

The mass characteristics and inertia parameters for loadings possible on the airplane and for the loading of the model during tests are shown in table II and plotted in figure 7. As discussed in reference 5, figure 7 can be used as an aid in predicting the relative effectiveness of the controls on the recovery characteristics of the model.

The maximum control deflections used in the tests were:

Rudder, degrees	27.5 right, 27.5 left
Elevator, degrees	35 up, 17.5 down
Ailerons, degrees	25 up, 18 down

Intermediate control deflections used were:

Rudder, two-thirds deflected, degrees	18.3
Elevator, two-thirds up, degrees	23.3
Elevator, one-third down, degrees	5.8
Ailerons, one-third deflected, degrees	8 up, 7.5 down
Ailerons, one-fifth deflected, degrees	5 up, 5 down

Tests were also performed with the dive flaps fully extended and the slats fully extended. The horizontal tail, which was normally at an incidence of 0°, was set at an incidence of -10° for a few tests.

RESULTS AND DISCUSSION

The results of the spin tests are presented in charts 1 to 6 and in table III. The model data are presented in terms of the full-scale values for the airplane at a test altitude of 15,000 feet. Unless otherwise stated, all tests were performed with the model in the clean condition (cockpit closed, flaps neutral, slats retracted, and landing gear retracted). Results for right and left spins were quite similar so that results for right spins only are arbitrarily presented in the charts.

Design Gross Weight Loading

Erect spins.- The results of erect spin tests of the model in the design gross weight loading (loading point 1 in table II and fig. 7) are shown in chart 1. For the normal control configuration for spinning, the model spins were steady at a moderate angle of attack and recoveries by rudder reversal were rapid. Elevator setting was found to have little effect. When the ailerons were set with the spin (right aileron up and left aileron down in a right spin), the spins became very steep and recoveries were rapid. When the ailerons were set full against the spin, the motion of the model became extremely oscillatory, mainly in roll and yaw. As a result of these oscillations, the model rolled completely over on its back. This was recorded as "no spin" because this terminated the original spinning rotation and it was felt that the pilot could regain control of the airplane after this type of maneuver.

When the controls were set for the criterion spin, the model spin was steady and at a moderately flat angle of attack. Recovery was not satisfactory when the rudder was reversed from full with to only two-thirds against the spin. It was found that full reversal of the rudder when ailerons were one-third against the spin or setting of the ailerons less (5° up and 5° down) than one-third against the spin when the rudder was moved to two-thirds against the spin would cause satisfactory recoveries. It has also been shown that in a spinning airplane the variation of angle of attack along the wing is generally such as to cause the ailerons to float with the spin. Thus for the condition without external tanks, if the pilot does not force the ailerons against the spin, there should be no difficulty in spin recovery. Although this model would ordinarily be classed as unsatisfactory in regard to spin recovery because it did not recover satisfactorily from the criterion spin, due to the over-all recovery characteristics exhibited by the model and the fact that the ailerons of the airplane will probably float with the spin, it is believed the XP-86 airplane will recover satisfactorily from any spins encountered.

Inverted spins.- The results of the inverted spin tests of the model in the design gross weight loading are presented on chart 2. The order used for presenting the data for inverted spins is different from that used for erect spins. For inverted spins "controls crossed" for the established spin (right rudder pedal forward and stick to the pilot's left for a spin to the pilot's right) is presented to the right of the chart and stick back is presented at the bottom. When the controls are crossed in the established spin, the ailerons aid the rolling motion; when the controls are together, the ailerons oppose the rolling motion. The angle of wing tilt ϕ on the chart is given as up or down relative to the ground.

The inverted spin-recovery characteristics of the model were satisfactory. The model would spin only with the controls together, and recoveries from the spins were rapidly effected by rudder reversal. The model sometimes showed a tendency to spin in the opposite direction after some recoveries. It is therefore recommended that the rudder and elevator be neutralized when recovery is attempted in the airplane.

Slats extended.- The results of tests with the slats extended are presented in chart 3. These results are similar to the results of tests with the slats retracted except that the recoveries from the criterion spin were satisfactory by rudder reversal to two-thirds against the spin when the slats were extended. Reference 6 indicates that, when the mass is distributed chiefly along the fuselage, which is the case for the design gross weight loading, a favorable effect of slat extension may be expected. It is indicated, however, that the effect may be seriously adverse if the mass is distributed chiefly along the wings; and it is therefore recommended that if the airplane enters a spin with external stores on the wings and the slats extended, the slats be retracted immediately.

Dive flaps.– The results of tests with the dive flaps extended are presented in chart 4. The model would not recover from either the normal control configuration or from the criterion spin with the dive flaps extended. It therefore appears imperative that the dive flaps be kept retracted in a spin.

-10° incidence in horizontal tail.– Test results obtained with -10° incidence in the horizontal tail are shown in chart 5. There was generally only a slight difference between these results and those for the normal tail incidence of 0°. It was noted, however, that, with the elevator neutral or down and ailerons against the spin, the model spun steadily for an appreciable time. Eventually, the spin became oscillatory, and the model then very quickly rolled out of the spin as it had done at normal tail incidence. It was concluded that two conditions were possible for these control configurations, one a flat spin and one a "no spin."

Long-Range Loading

The results of tests of the model in the long-range loading (loading point 2 in table II and fig. 7) are shown in chart 6. This loading was obtained by installing external fuel tanks on the wings. In general, recovery characteristics were considered unsatisfactory when the rudder alone was reversed. When, however, the rudder and elevator were simultaneously reversed, recoveries were satisfactory. When the ailerons were against the spin, two types of spin were encountered from one of which recovery was very poor. When the ailerons were with the spin, recoveries were slower than for aileron-neutral spins, but were satisfactory when the rudder and elevator were reversed. In the event that the stick forces became too heavy for the pilot to move the elevator for recovery, or for some other reason, recovery does not seem imminent, the tanks should be jettisoned immediately and the recovery attempt repeated.

Spin-Recovery Parachutes

The results of spin-recovery-parachute tests are presented in table III. A tail parachute 11.4 feet in diameter with a towline 30 feet long appeared to be necessary for satisfactory recovery of the airplane by parachute action alone if attached above the jet exit. If, however, the parachute was attached below the jet exit, a 10.0-foot parachute was indicated to be satisfactory. A 6.0-foot-diameter wing-tip parachute attached to the outer wing tip of the airplane with a 6.0-foot towline was also indicated to be satisfactory for emergency spin recovery.

The model parachutes as tested had values of drag coefficient of approximately 0.7. If a parachute with a different drag coefficient is used on the airplane, a corresponding adjustment will be required in parachute size.

Pilot-Escape Tests

During the tests performed to determine from which side of the spinning airplane the pilot should attempt an emergency escape, it was observed that the model pilot cleared the model by a wide margin when released from the inboard side in flat spins and cleared the tail by a narrow margin when released from the inboard side in steep spins. When released from the outboard side in a flat spin, the model pilot cleared the model by a large margin. When, however, the model pilot was released from the outboard side in a steep spin it sometimes struck the wing and sometimes struck the tail. Based on these results, it appears that, to insure safe escape from a spinning XP-86 airplane, it may be necessary that the pilot be ejected. If no ejection equipment is installed, the safest procedure for this airplane for the pilot to use appears to be to jump from the inboard side of the cockpit if necessary to abandon the airplane in a spin.

Landing Condition

The landing condition was not investigated on this model inasmuch as current Army specifications require this type of airplane to demonstrate satisfactory recoveries in the landing condition from only 1-turn spins. At the end of 1 turn, the airplane will probably still be in an incipient spin from which recoveries are more readily obtained than from fully developed spins.

An analysis of full-scale and model tests to determine the effect of landing flaps and landing gear indicates that, although the XP-86 will probably recover satisfactorily from an incipient spin in the landing condition, recoveries from fully developed spins may be unsatisfactory. Therefore, in order to avoid entering a fully developed spin, it is recommended that the landing flaps be neutralized and recovery attempted immediately upon inadvertently entering a spin in the landing condition.

Rudder Forces

The discussion of the results so far has been based on control effectiveness alone without regard to the forces required to move the controls. As previously mentioned, for the regular test program, sufficient force was applied to the controls to move them fully and rapidly. The force applied to the airplane controls should move them in a similar manner in order for the model and airplane results to be comparable.

A few tests were performed with the model in the design gross weight loading in which the forces applied to the rudder in order to effect a satisfactory recovery were measured. The results indicated that the full-scale pedal force would be within the capabilities of the pilot. The pedal force was found to be approximately 180 pounds from the model tests. Because of lack of detail in the rudder balance of the model, of inertia mass-balance effects, and of scale effect, these results are only qualitative indications of the actual forces that may be experienced.

Recommended Recovery Technique

Based on the results obtained with the model and upon general spin-tunnel experience, the following recommendations are made as to recovery technique: for erect spins, the rudder should be reversed briskly from full with the spin to full against the spin followed 1/2 turn later by movement of the stick forward while allowing it to float laterally with the spin. Care should be exercised to avoid excessive rates of acceleration in the recovery dive. If an accidental spin is entered with the dive flaps or the landing flaps extended, the flaps should be retracted immediately and recovery attempted. For recovery from inverted spins, the rudder and elevator should be neutralized.

CONCLUSIONS

Based on results of spin tests of a $\frac{1}{24}$-scale model of the North American XP-86 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane at a spin altitude of 15,000 feet have been drawn:

1. Recoveries of the airplane in the design gross weight loading will be generally satisfactory provided the ailerons are not forcibly moved against the spin. Recovery should be attempted by reversal of the rudder fully and rapidly, followed 1/2 turn later by movement of the stick forward of neutral, while allowing it to float laterally with the spin.

2. Recoveries from any inverted spins obtained will be satisfactory and should be attempted by rapid rudder and stick neutralization.

3. When both leading-edge slats are fully extended in the normal loading, recoveries will be satisfactory for all control settings. If external stores are carried on the wings, however, open slats may seriously retard recovery.

4. In the long-range loading, recoveries will be satisfactory if the rudder and elevator are both reversed but will not be satisfactory if the rudder alone is reversed. If recovery does not appear imminent, the external fuel tanks should be jettisoned and the recovery attempt repeated.

5. A 10.0-foot-diameter tail parachute with a towline 30 feet long attached below the jet exit and with a drag coefficient of 0.7 will be satisfactory for emergency recoveries from spins. A 6.0-foot-diameter wing-tip parachute attached to the outer wing tip of the airplane with a 6.0-foot towline should also be satisfactory.

6. If a spin is inadvertently entered in the landing condition or with the dive flaps extended, the flaps should be neutralized and recovery attempted immediately.

7. The pedal forces necessary to move the rudder to effect satisfactory recovery will be within the physical capability of the pilot.

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REFERENCES

1. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN No. 1045, 1946.

2. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. No. 557, 1936.

3. Seidman, Oscar, and Kamm, Robert W.: Antispin-Tail-Parachute Installations. NACA RB, Feb. 1943.

4. Seidman, Oscar, and Neihouse, A. I.: Comparison of Free-Spinning Wind-Tunnel Results with Corresponding Full-Scale Spin Results. NACA MR, Dec. 7, 1938.

5. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery from a Spin. NACA ARR, Aug. 1942.

6. Neihouse, Anshal I., and Pitkin, Marvin: Effect of Wing Leading-Edge Slots on the Spin and Recovery Characteristics of Airplanes. NACA ARR No. 3D29, 1943.

TABLE I.– DIMENSIONAL CHARACTERISTICS OF THE

NORTH AMERICAN XP-86 AIRPLANE

Length over all, ft	37.5
Wing:	
Span, ft	37.1
Area, sq ft	287.9
Sweepback at c/4, deg	35
Incidence:	
Root, deg	1
Tip, deg	–1
Dihedral, deg	3
Section:	
Root	NACA 0012–64 modified
Tip	NACA 0011–64 modified
Aspect ratio	4.8
Mean aerodynamic chord, in.	97.0
Leading edge of $\bar{c}$ rearward of leading edge of root chord, in.	46.0
Ailerons:	
Area, sq ft	39.2
Span, percent b/2	50.1
Hinge–line location, percent c	70
Horizontal tail:	
Total area, sq ft	35.0
Span, ft	12.8
Sweepback at c/4, deg	35
Elevator area rearward of hinge line, sq ft	10.1
Distance from normal center of gravity to elevator hinge line at root, ft	18.1
Dihedral, deg	10
Incidence, deg	1 to –10
Vertical tail:	
Total area, sq ft	33.7
Sweepback at c/4, deg	35
Rudder area aft of hinge line, sq ft	8.7
Distance from normal center of gravity to rudder hinge line at root, ft	17.4
Unshielded rudder volume coefficient	0.0143
Tail–damping ratio	0.0204
Tail–damping power factor	0.000290

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TABLE II.– MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING CONDITIONS POSSIBLE ON THE NORTH AMERICAN XP-86 AIRPLANE AND FOR THE LOADINGS TESTED ON THE $\frac{1}{24}$-SCALE MODEL

[Model values converted to corresponding full-scale values; moments of inertia given about center of gravity]

Number (same as fig. 8)	Loading	Weight (lb)	μ sea level	μ 15,000 ft	Center-of-gravity location		Moments of inertia (slug-ft)^2			Mass parameters		
					$x/\bar{c}$	$z/\bar{c}$	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	Design gross weight	13,311	16.3	25.8	0.213	0.126	7,090	17,480	22,932	-182×10^{-4}	-96×10^{-4}	278×10^{-4}
2	Long range	16,438	20.1	31.9	.215	.190	14,121	18,786	30,079	-66	-161	227
3	Light weight	10,288	12.5	19.9	.252	.094	6,080	16,320	21,000	-233	-106	339
4	Design gross and two 1000-pound bombs	15,371	18.8	29.9	.224	.167	11,280	17,955	26,914	-102	-136	238
Model values												
1	Design gross weight	13,238	16.2	25.7	0.218	0.117	6,954	17,620	23,937	-188×10^{-4}	-112×10^{-4}	300×10^{-4}
2	Long range	16,169	19.8	31.4	.201	.169	13,610	18,264	30,095	-67	-171	238

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TABLE III.– SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH THE $\frac{1}{24}$–SCALE

MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE

[Loading point 1 on table II and figure 7; rudder fixed full with the spin; model values converted to corresponding full-scale values; C_D of parachutes 0.7; right erect spins]

Parachute diameter (ft)	Towline length (ft)	Ailerons	Elevator	Turns for recovery
Tail parachute attached above jet exit				
10.0	30.0	Neutral	Up	>3, >3, >4
11.4	30.0	Neutral	Up	$\frac{3}{4}$, 1, 1, $1\frac{1}{2}$
11.4	30.0	$\frac{1}{3}$ against	$\frac{2}{3}$ up	$\frac{3}{4}$, $\frac{3}{4}$, $\frac{3}{4}$, 1
Tail parachute attached below jet exit				
10.0	30.0	Neutral	Up	[a]$\frac{1}{2}$, [a]$\frac{3}{4}$, [a]$1\frac{1}{2}$, [a]2
Parachute attached at outer wing tip				
4.0	-------	Neutral	Up	$1\frac{3}{4}$, 3, 3
6.0	6.0	Neutral	Up	$\frac{3}{4}$, $\frac{3}{4}$, [a]$\frac{3}{4}$, 1

[a]Visual estimate.

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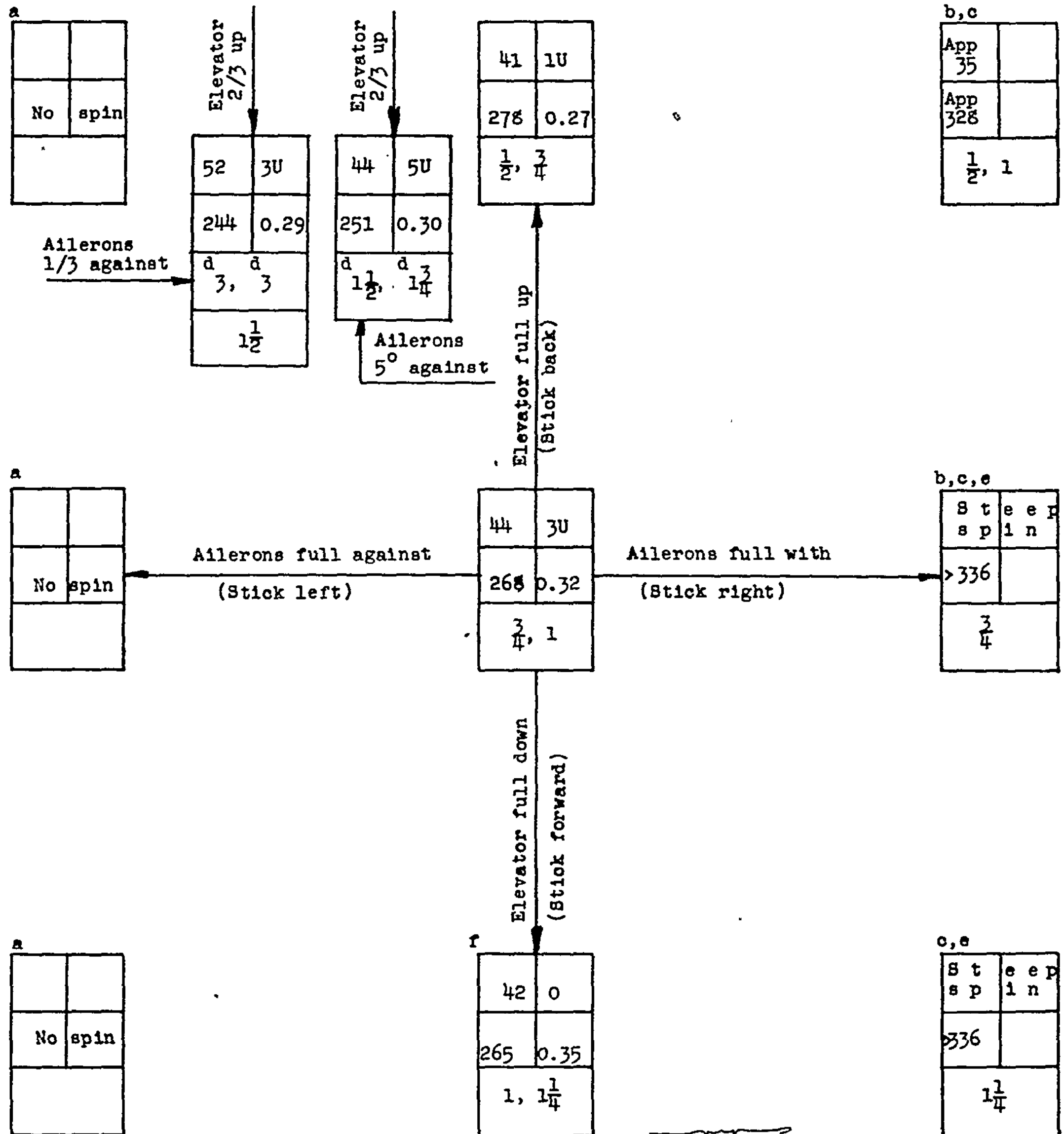
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE IN THE DESIGN GROSS WEIGHT LOADING

[Loading point 1 on table II and figure 7; flaps neutral; landing gear retracted; slats retracted; cockpit closed; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and developed spin data presented for, rudder-with spins); right erect spins]



[a]Extremely oscillatory motion until model rolls over and goes inverted.
[b]Spin oscillatory in yaw, whipping motion.
[c]Recovery attempted before model was in its final steeper attitude.
[d]Recovery attempted by reversal of rudder from full with to 2/3 against the spin.
[e]After recovery, model goes inverted.
[f]Model recovers in an inverted dive.

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

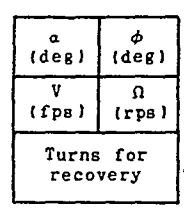
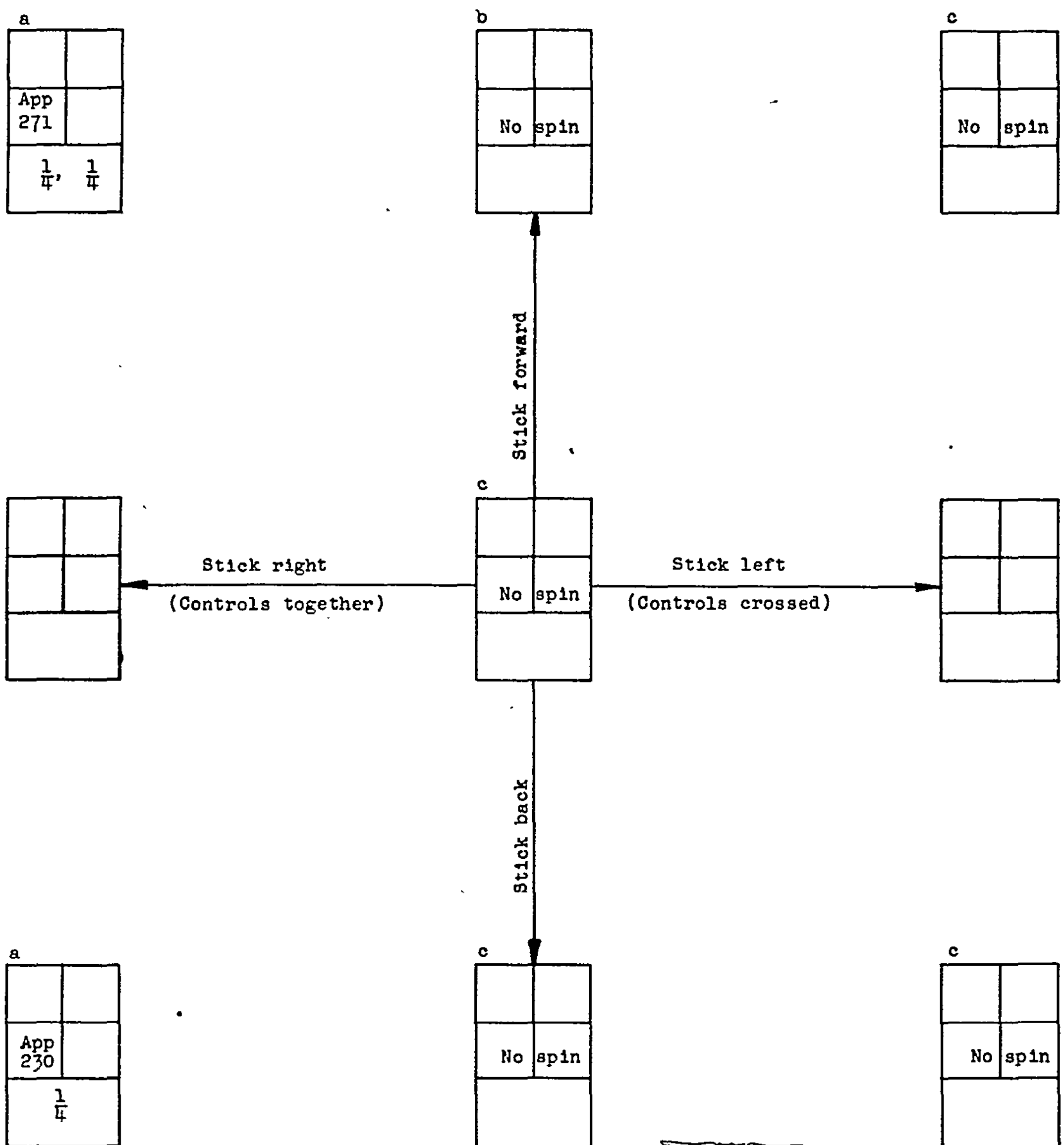


CHART 2.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE IN THE DESIGN GROSS WEIGHT LOADING

[Loading point 1 on table II and figure 7; flaps neutral; landing gear retracted; cockpit closed; slats retracted; recovery attempted by rapid full rudder reversal (recovery attempted from, and developed spin data presented for, rudder-with spins); spins to pilot's right]



[a]Very wandering spin, could not get steady-spin data.
[b]Recovers in a dive.
[c]Model assumes steep attitude and oscillates until the oscillations cause model to roll over and go erect.

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

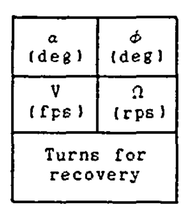
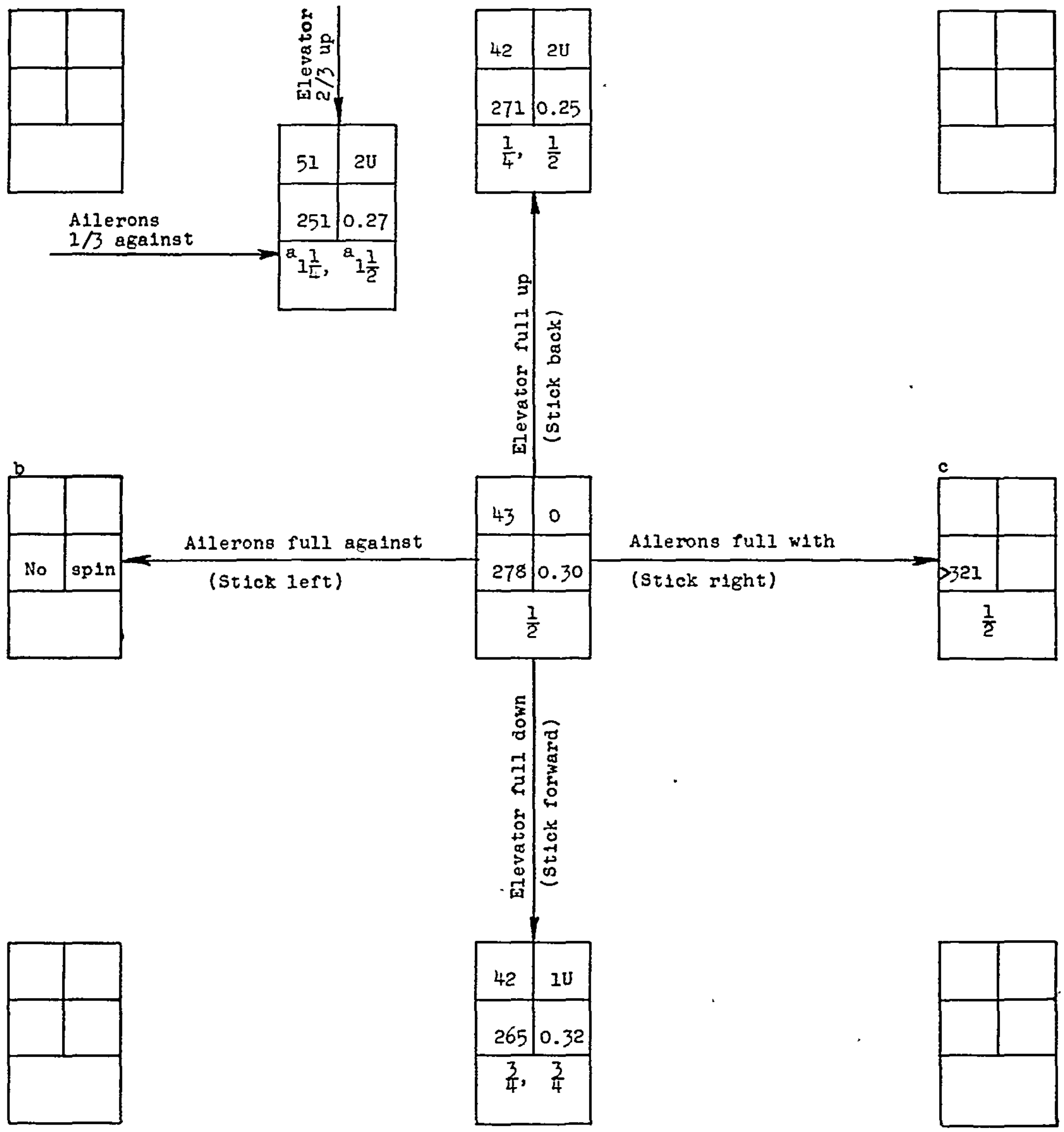


CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE WITH THE WING SLATS EXTENDED

[Loading point 1 on table II and figure 7; flaps neutral; landing gear retracted; cockpit closed; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and developed spin data presented for, rudder-with spins); right erect spins]



[a]Recovery attempted by reversal of the rudder from full with to 2/3 against the spin.
[b]Model oscillates until it rolls out of the spin in a left roll.
[c]Recovery attempted before model in final steeper attitude. Model went inverted.

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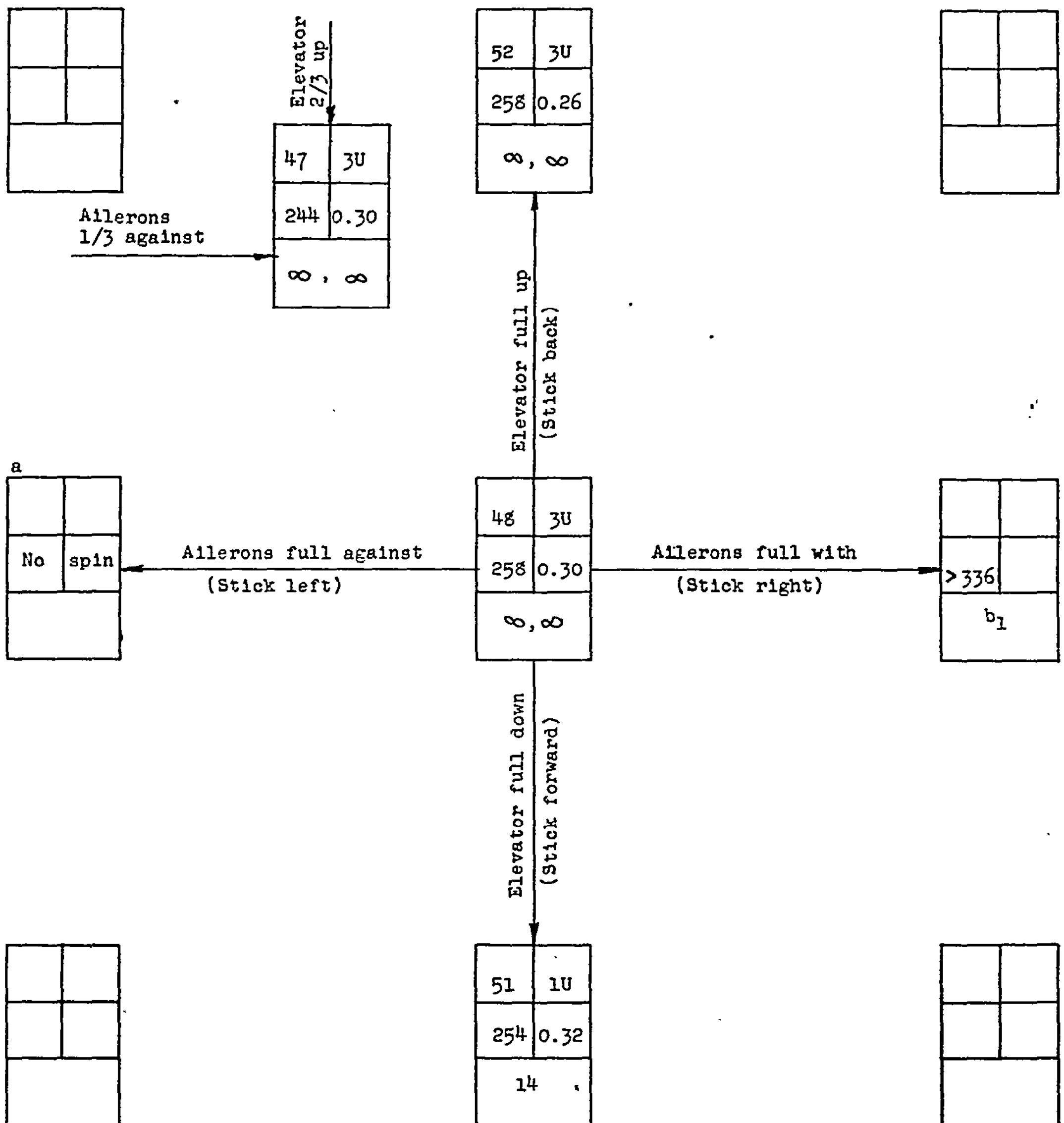
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

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

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE WITH THE DIVE FLAPS EXTENDED

[Loading point 1 on table II and figure 7; landing flaps neutral; landing gear retracted; slats retracted; cockpit closed; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and developed spin data presented for, rudder-with spins); right erect spins]



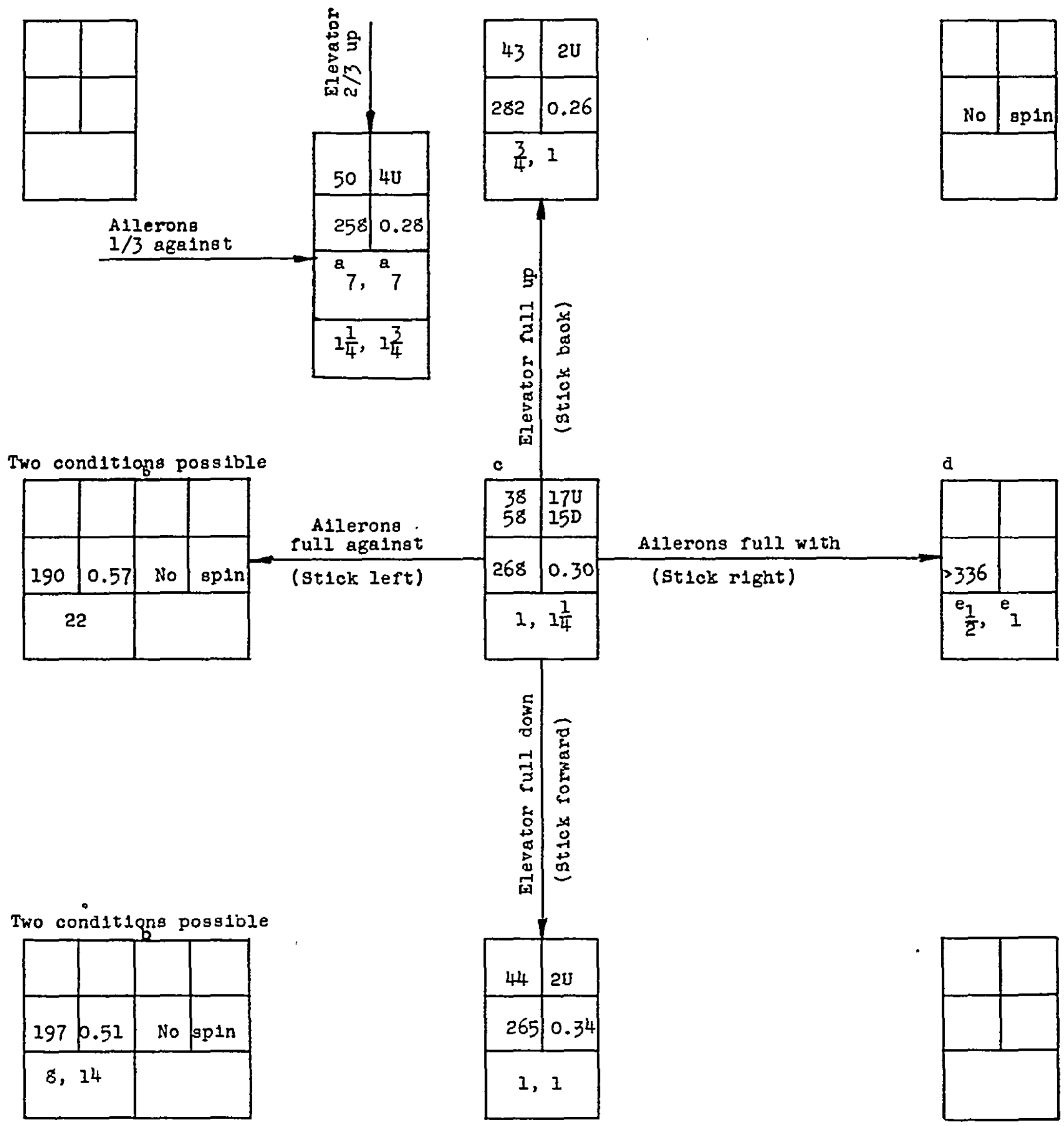
[a]Model motion became extremely oscillatory until model rolled out of the spin.
[b]Recovery attempted before model in final steeper attitude.

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

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

CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE WITH -10° INCIDENCE IN THE HORIZONTAL TAIL

[Loading point 1 on table II and figure 7; flaps neutral; landing gear retracted; slats retracted; cockpit closed; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and developed spin data presented for, rudder-with spins); right erect spins]



[a]Recovery attempted by reversing rudder from full with to 2/3 against the spin.
[b]Model oscillates with increasing amplitude until it rolls out of spin.
[c]Oscillatory spin, range of values or average value given.
[d]After recovery, model goes inverted.
[e]Recovery attempted before model reached its final steeper attitude.

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

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

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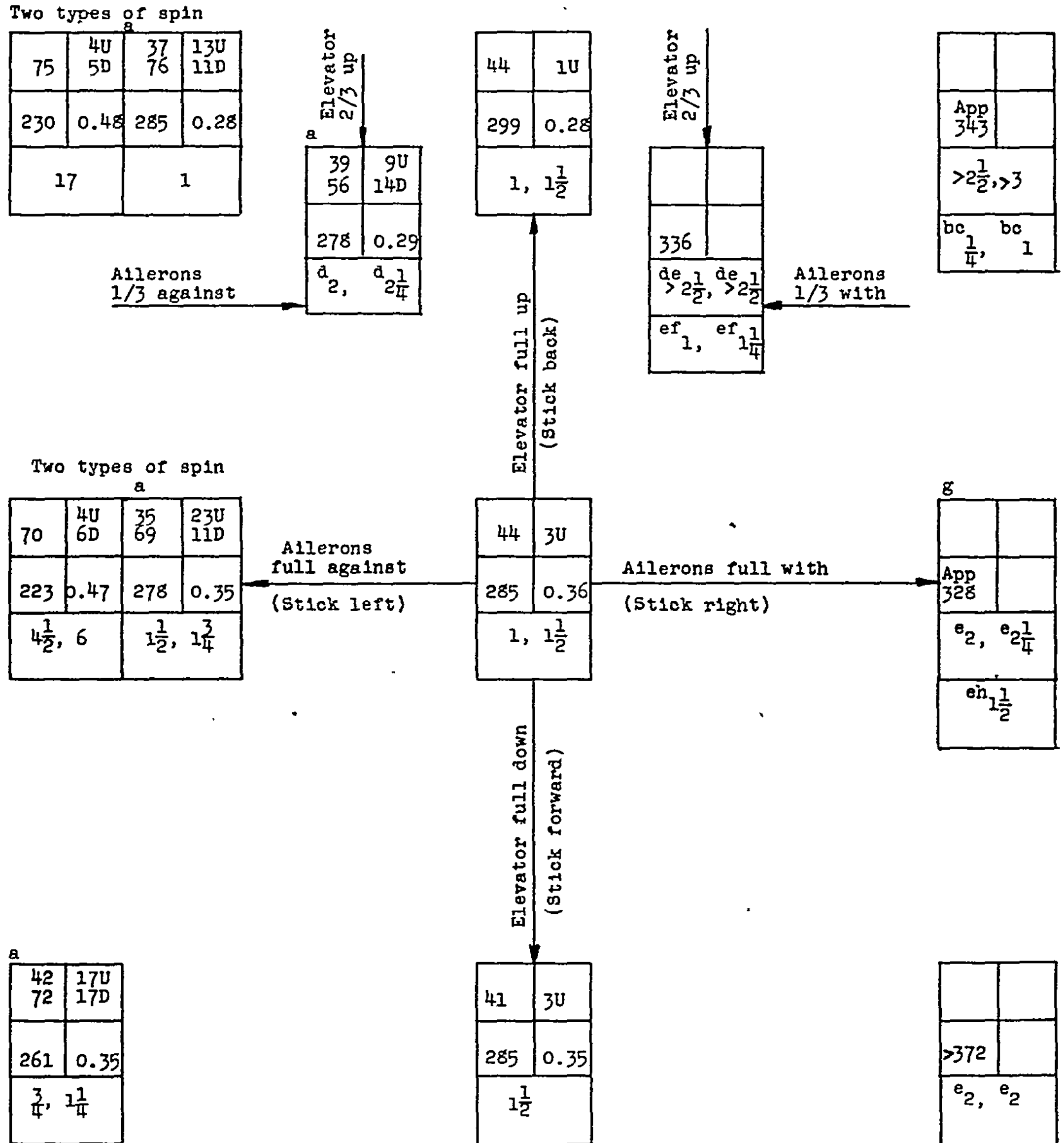
CHART 6.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE NORTH AMERICAN XP-86 AIRPLANE IN THE LONG-RANGE LOADING

[Loading point 2 on table II and figure 7; flaps neutral; landing gear retracted; slats retracted; cockpit closed; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and developed spin data presented for, rudder-with spins); right erect spins]



[a]Oscillatory spin. Range of values or average value given.
[b]Recovery attempted by simultaneous full reversal of rudder and elevator.
[c]After recovery, model goes inverted.
[d]Recovery attempted by reversing rudder from full with to 2/3 against the spin.
[e]Recovery attempted before model in final steeper attitude.
[f]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[g]Wandering, whipping spin.

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

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

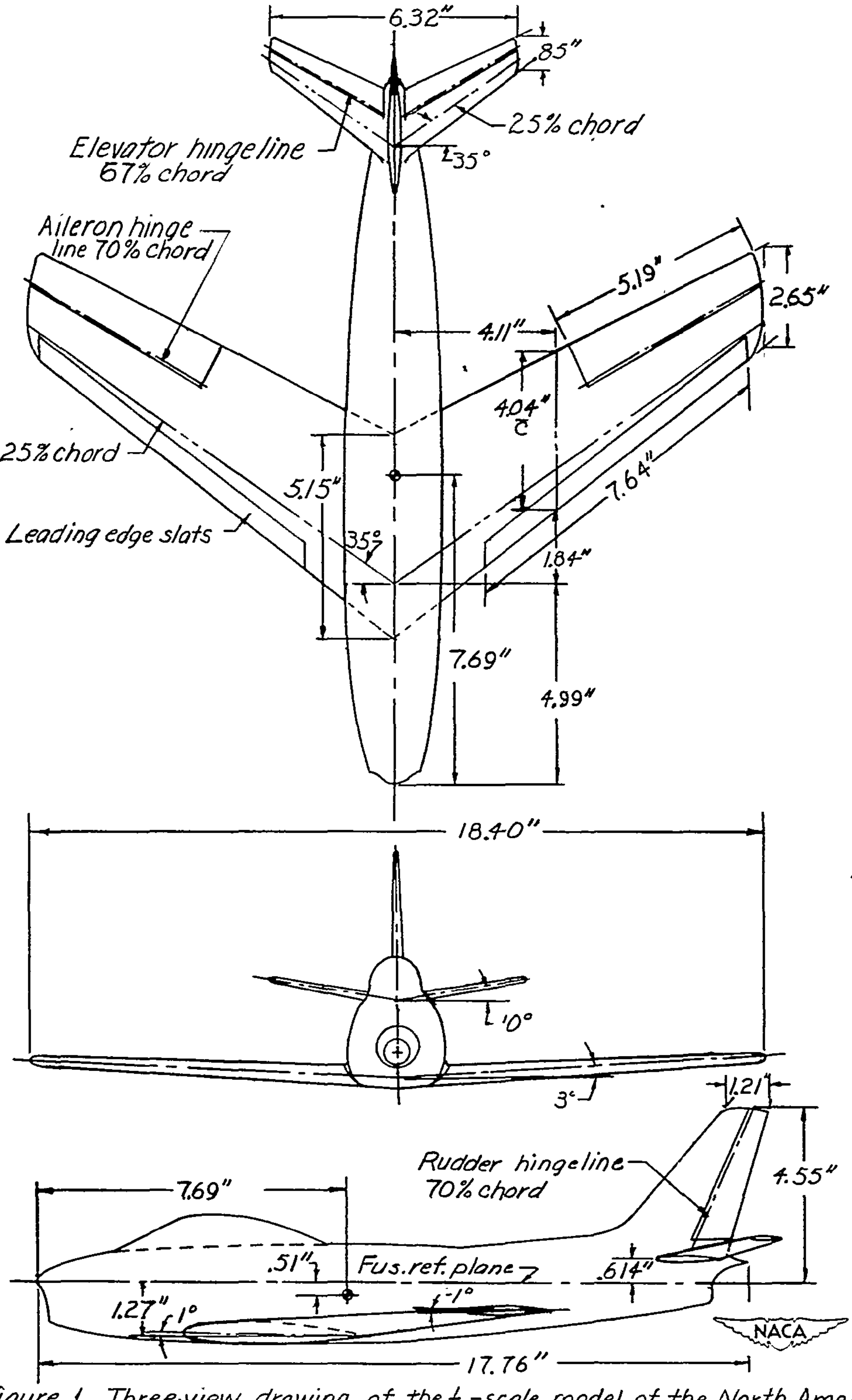


Figure 1. Three-view drawing of the $\frac{1}{24}$-scale model of the North American XP-86 airplane as tested in the free-spinning tunnel. Center-of-gravity location is shown for the design gross weight condition.

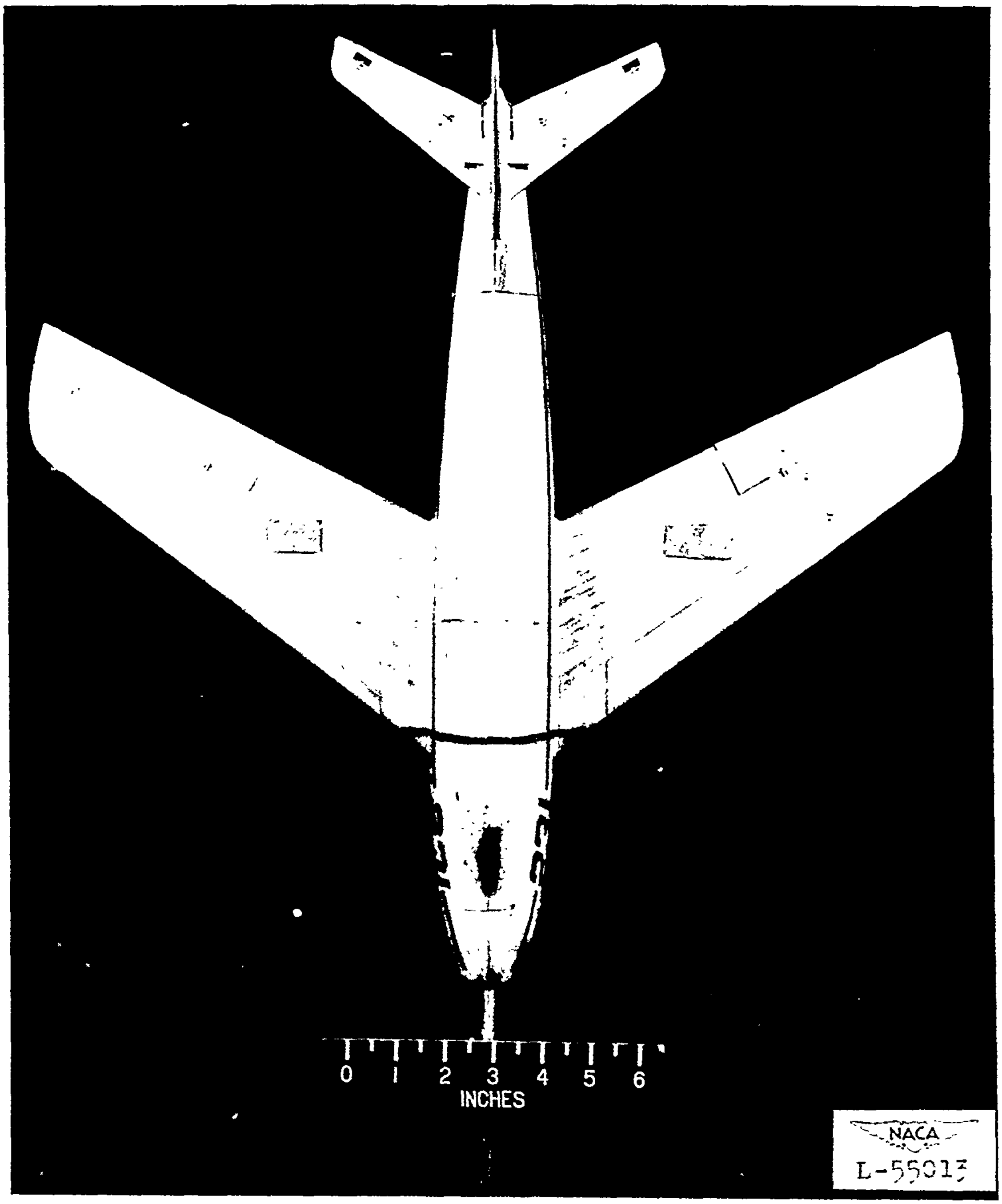


Figure 2.- The $\frac{1}{24}$-scale model of the North American XP-86 airplane in the design gross weight loading.

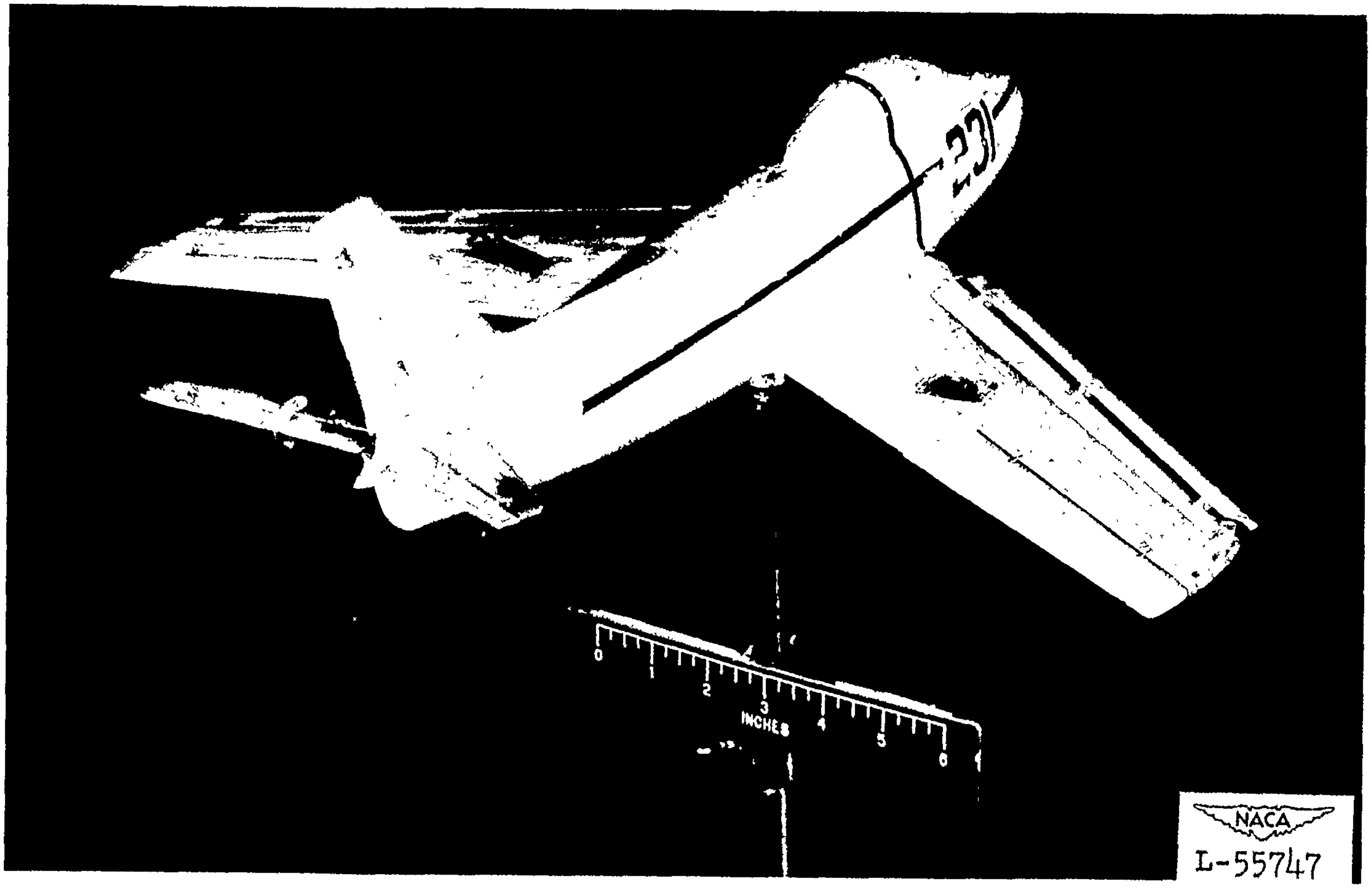


Figure 3.- The $\frac{1}{24}$-scale model of the North American XP-86 airplane with the leading-edge slats extended.

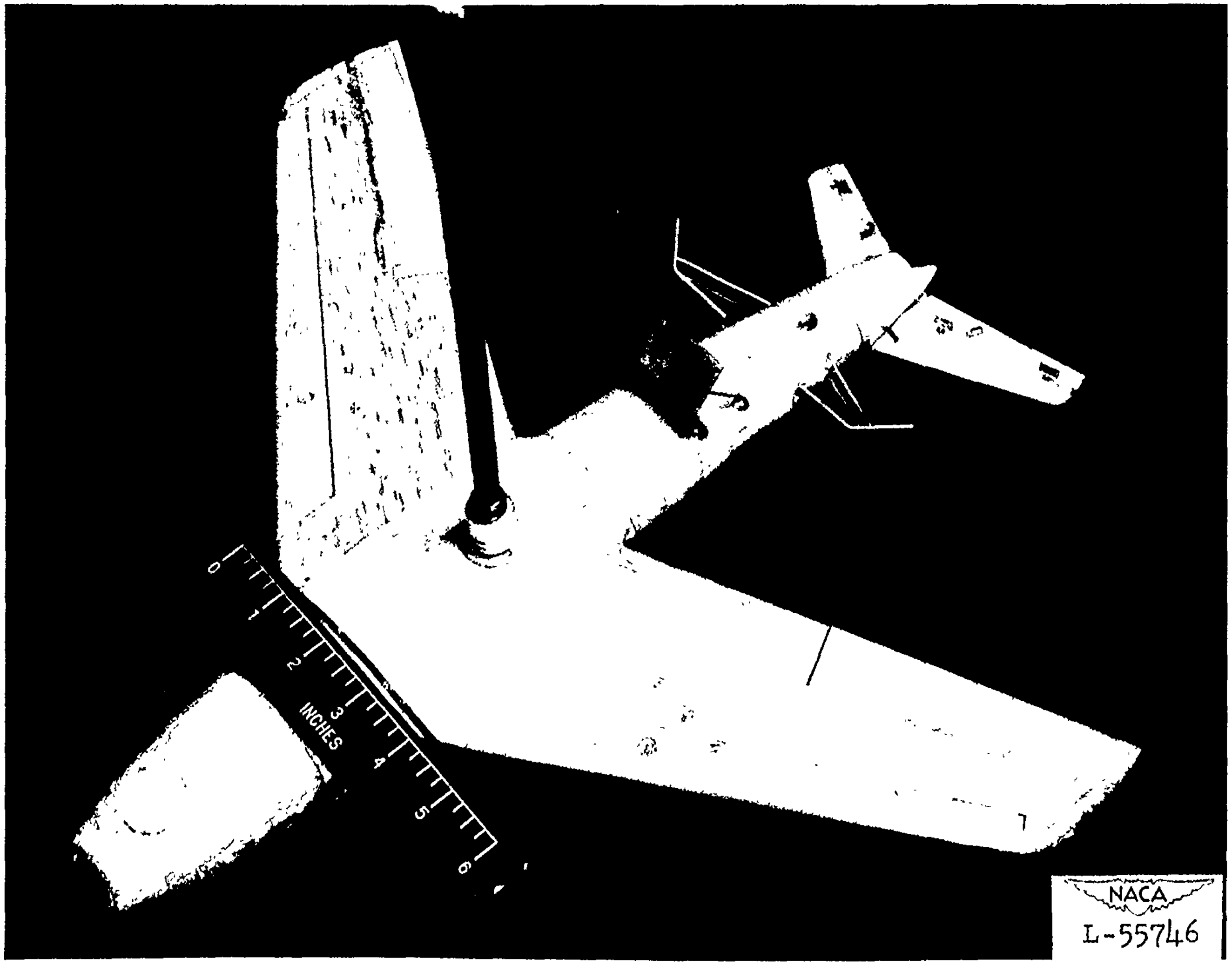


Figure 4.- The $\frac{1}{24}$-scale model of the North American XP-86 airplane with the dive flaps extended.

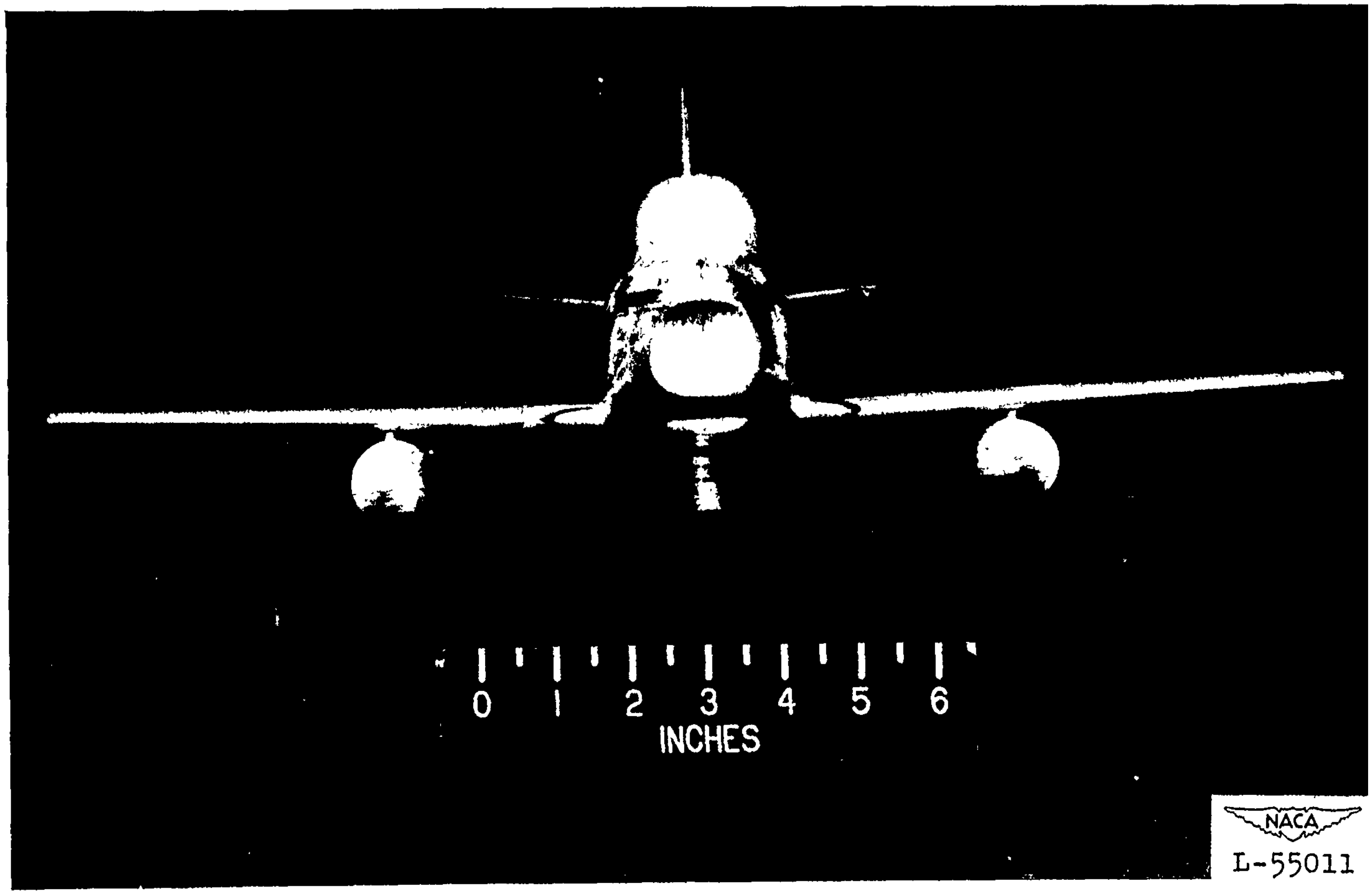


Figure 5.- The $\frac{1}{24}$-scale model of the North American XP-86 airplane in the long-range loading.

Figure 6.- The $\frac{1}{24}$-scale model of the North American XP-86 airplane spinning in the Langley 20-foot free-spinning tunnel.

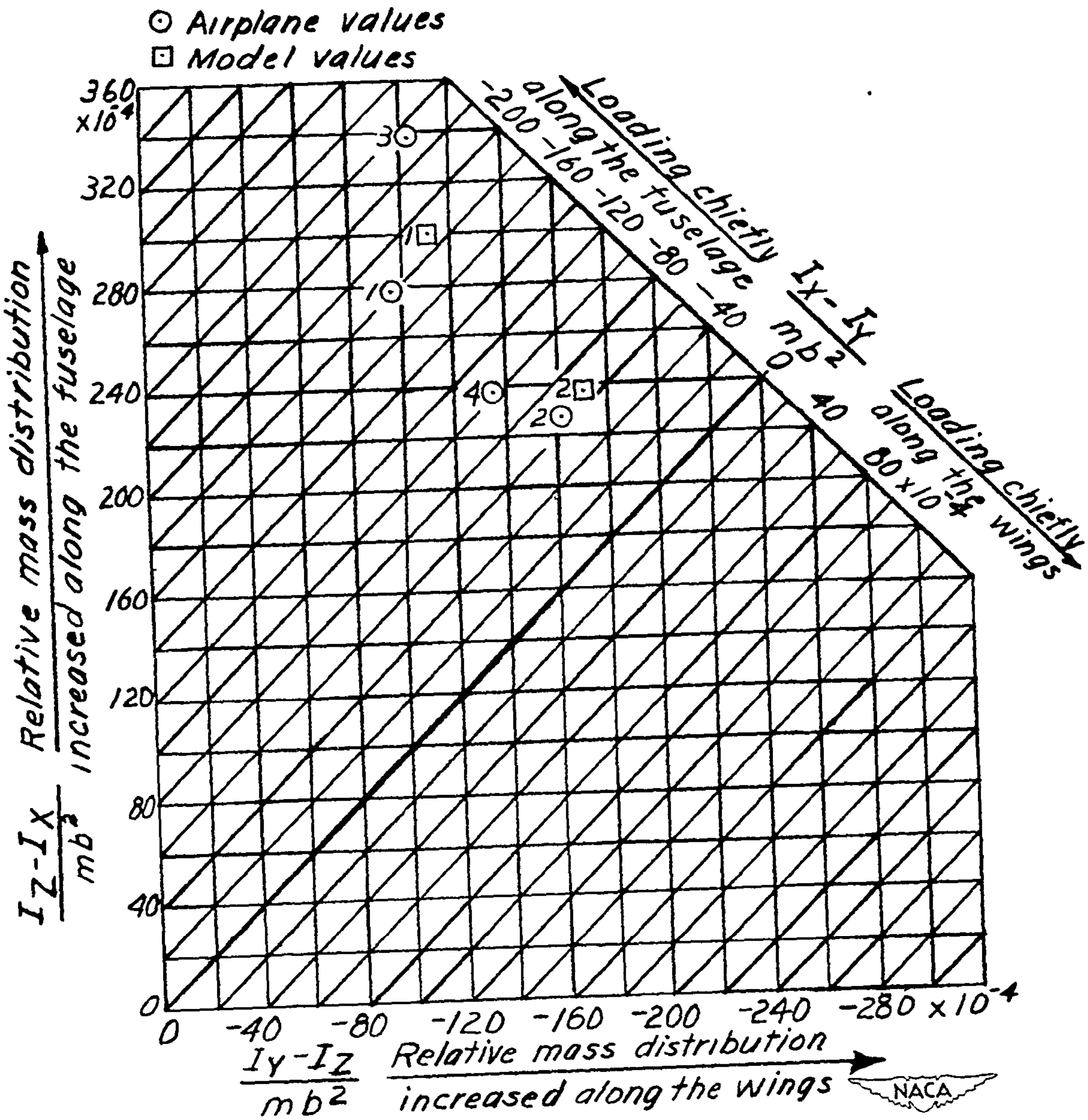


Figure 7.- Inertia parameters for loadings of the North American XP-86 airplane and for loadings tested on the $\frac{1}{24}$-scale model. (Points are for loadings listed in table II.)