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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

ESTIMATION OF THE SPIN AND RECOVERY CHARACTERISTICS OF THE NORTH AMERICAN XSN2J-1 AIRPLANE

By

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ESTIMATION OF THE SPIN AND RECOVERY CHARACTERISTICS OF THE NORTH AMERICAN XSN2J-1 AIRPLANE

By Thomas L. Snyder

SUMMARY

The probable spin and recovery characteristics of the XSN2J-1 airplane have been estimated on the basis of the results of brief tests performed on a model of an airplane of somewhat similar design. The spin-recovery tail-parachute requirements for the airplane were also determined, and, in addition, an analysis was made to determine the best method of emergency pilot escape during a spin.

The results of the investigation indicate that the recovery characteristics of the airplane will be satisfactory for all probable loading conditions of the airplane. A 6-foot-diameter tail parachute attached to a 30-foot towline will be satisfactory as a spin-recovery device for emergency recovery from demonstration spins. If the occupants of the airplane decide to abandon the airplane in a spin, they should leave the airplane from the outboard side of the cockpit and as far rearward as possible.

INTRODUCTION

In accordance with a request of the Bureau of Aeronautics, Navy Department, an estimation of the probable spin and recovery characteristics of the North American XSN2J-1 airplane has been prepared by the Langley Laboratory. The XSN2J-1 is a single-engine, two-place, low-wing scout trainer. An examination of the mass and dimensional characteristics of the airplane indicated that a sufficiently precise estimation could be made by testing a model of similar design available at the Langley Laboratory, but modified in such a manner as to be generally representative of the XSN2J-1 airplane. Accordingly, the model was modified, primarily by altering the tail length, so that it represented a $\frac{1}{18}$-scale model of the XSN2J-1 design.

Based on reference 1, it appeared that the tail design and mass characteristics of the XSN2J-1 airplane were such that satisfactory recovery characteristics were probable. Brief tests were made on the model to verify this and to obtain specific results which it was felt would fairly accurately indicate in detail the probable spin and recovery characteristics of the XSN2J-1 airplane.

Tests were made on the modified model for the normal-trainer loading in the clean condition (flaps and landing gear retracted). The probable spin and recovery characteristics for the bomber-trainer and rocket-trainer loadings, also possible on the airplane, were estimated after consideration of the test results obtained with the normal-trainer loading. The spin-recovery tail-parachute requirements for the airplane for recovery from demonstration spins were also estimated, and, in addition, the best method of leaving the airplane from an uncontrollable spin was determined on the basis of results of tests of numerous other models.

SYMBOLS

b	wing span, feet
S	wing area, square feet
$\bar{c}$	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 fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X-, Y-, and Z-body axes, respectively, slug-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 fuselage reference 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 MODEL

Model

The dimensional characteristics of the XSN2J-1 airplane and the airplane represented by the model as tested are presented in table I, and a comparison three-view drawing is shown in figure 1.

The model used for the tests was ballasted with lead weights to obtain dynamic similarity to the XSN2J-1 airplane at an altitude of 10,000 feet ($\rho = 0.001756$ slug per cu ft). The weight, moments of inertia, and center-of-gravity location were obtained from data supplied by the North American Aviation Corporation. A remote-control mechanism was installed in the model to actuate the rudder for recovery tests.

The tail-damping power factor computed by methods described in reference 1 was 438×10^{-6} for the XSN2J-1 airplane. The horizontal tail surfaces of the model used for the tests, with the lengthened tail previously mentioned, was lowered slightly in order to obtain the same value of tail-damping power factor as that for the XSN2J-1.

Wind Tunnel and Testing Technique

The brief tests made were performed in the Langley 20-foot free-spinning tunnel. The testing technique applied for the methods of determining the spin data were generally the same as those indicated in reference 2.

PRECISION

The spin data presented herein are believed to be the 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	±1/4 turn when obtained from motion-picture records ±1/2 turn when obtained by visual estimate

In some instances for which it was difficult to test the model due to the wandering nature of the spin, the foregoing limits may have been exceeded. Comparison between spin results of models and corresponding airplanes (references 3 and 4) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. In general, the model spun at a somewhat smaller angle of attack with a slightly higher rate of descent and with 5° to 10° more outward sideslip than did the corresponding airplane.

The comparison made in reference 4 for 20 models shows that 80 percent of the model recovery tests predicted satisfactorily the number of turns required for recovery from the spin of the corresponding airplane and that 10 percent were optimistic and 10 percent were pessimistic.

Because of the impracticability of ballasting the model exactly and because of the inadvertent damage to the model during the spin tests, the mass distribution of the model varied from the true scaled-down values within the following limits:

Weight, percent		1 low to 1 high
Center-of-gravity location, percent $\bar{c}$		1 forward to 1 rearward
Moments of inertia	I_X, percent	0 low to 0
	I_Y, percent	1 low to 5 high
	I_Z, percent	3 high to 7 high

The measurements of the mass characteristics were made within the following limits of accuracy:

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

The 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 condition tested on the model are listed in table II. The inertia parameters are also plotted in figure 2. As discussed in reference 5, figure 2 can be used in predicting the relative effectiveness of the controls on the recovery characteristics of the airplane.

The normal maximum control deflections of the XSN2J-1 used were

Rudder, degrees	30 right, 30 left
Elevator, degrees	30 up, 10 down
Ailerons, degrees	19 up, 19 down

The intermediate control deflections used were

Rudder, 2/3 deflected, degrees	20
Elevator, 2/3 up, degrees	20
Ailerons, 1/3 deflected, degrees	$6\frac{1}{3}$ up, $6\frac{1}{3}$ down

RESULTS AND DISCUSSION

Spin and Recovery Characteristics

The results of the model tests are presented in chart 1. The results for left and right spins were similar, and the results are arbitrarily presented in terms of equivalent right spins.

Normal-trainer loading.- For the normal-trainer loading at the normal control configuration for spinning (ailerons neutral, elevator full up, and rudder full with the spin) the model spin was fairly steep with a moderately high rate of descent, and recovery by rapid full rudder reversal was satisfactory. (See chart 1.) The deflection of the ailerons, either against the spin (stick left in a right spin) or with the spin, showed only a slight effect on the recovery characteristics of the model. Setting the ailerons against the spin did, however, tend to flatten the spin, whereas, setting the ailerons with the spin showed a tendency to steepen the spin. The results indicate that recovery by the normal control manipulation (rapid full rudder reversal followed approximately 1/2 turn later by movement of the stick forward of neutral) will be satisfactory.

The results indicate satisfactory recovery characteristics for the airplane and are in agreement with recovery characteristics estimated from a consideration of tail-damping power factor and mass characteristics by the method described in reference 1. Accordingly, it is felt that the results provide an accurate indication of the probable spin and recovery characteristics of the XSN2J-1 airplane.

Bomber-trainer and rocket-trainer loadings.- For the bomber-trainer and rocket-trainer loadings, the rudder will probably be somewhat less effective as a recovery device, and the elevator will be relatively more effective for recovery than when the airplane is in the normal-trainer loading because of the relative increase in mass distribution along the wings (references 1 and 5). Based on reference 1, however, it appears that recovery will be satisfactory by normal control manipulation (rapid full rudder reversal followed 1/2 turn later by movement of the elevator to down). If, however, recovery from a spin of the airplane in either of these loadings does not appear imminent, the bombs and rockets should be jettisoned and the recovery procedure repeated.

Mass variations.- An estimate was made to determine the effect of small variations in mass distribution on the spin-recovery characteristics of the airplane in order to allow for any error in estimating the moments of inertia of the airplane and also to allow for any rearrangement of the normal-trainer loading that may lead to a spinning condition from which recovery may be slower than for the normal-trainer loading. The possible variations in mass distribution due to possible error in estimating the moments of inertia of the airplane and possible rearrangement of the normal-trainer loading would be relatively small and it appears that the normal mass distribution of the airplane is such that small variations will not alter the spin and recovery characteristics of the airplane and recovery will be satisfactory by the normal control manipulation previously mentioned.

Landing condition.- Current Navy specifications require the 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 the results of full-scale and model tests of many airplanes indicates that the XSN2J-1 airplane will recover satisfactorily from a 1-turn spin in the landing condition. Nevertheless, if a spin in the landing condition is entered inadvertently, it is recommended that the flaps be neutralized and recovery attempted immediately by normal control manipulation.

Inverted spins.- Satisfactory recovery will be obtained from any inverted spins that the airplane may enter. For recovery, the rudder should be briskly and fully reversed to against the spin and the stick moved to neutral, laterally and longitudinally.

Control forces.- The estimate of the recovery characteristics so far has been based on control effectiveness alone without regard to the forces required to move the controls. The controls of the airplane will have to be moved rapidly in order for the airplane recoveries to be comparable to those estimated. Analysis of reference 6 indicated that for this airplane, the rudder-pedal forces required to fully and rapidly reverse the rudder will be approximately 275 pounds, which is within the capabilities of the pilot. An estimation of the stick forces is not presented herein inasmuch as rudder reversal alone effected satisfactory recovery. It is believed that the force required to move the stick forward of neutral, approximately 1/2 turn after rudder reversal, as recommended, will be within the capabilities of the pilot, inasmuch as after rudder reversal the airplane will nose down steeply and the elevator will therefore tend to float near neutral.

Estimation of Spin-Recovery Parachute Requirements

Tail parachutes.- Spin-tunnel tests have been conducted on numerous models to determine their spin-recovery parachute requirements over a wide range of mass distribution and airplane configurations. Analysis of the results of these tests indicated that a tail parachute 6 feet in diameter attached to a 30-foot towline would be adequate as an emergency spin-recovery device for the XSN2J-1 airplane for demonstration spins. The parachute diameter is based on a drag coefficient of 0.7 for the laid-out-flat area of the parachute. It is recommended that a positive ejection mechanism be used to throw the parachute clear of the tail and to assure quick opening of the parachute. Reference 7 describes practical methods of tail-parachute installations.

Emergency Pilot Escape

Based on pilot-escape tests conducted on approximately 20 models in the spin tunnel, it appears that the occupants of the XSN2J-1 airplane should leave from the outboard side of the cockpit and as far rearward as possible if the occupants decide to abandon the airplane in a spin.

CONCLUSIONS

Based on brief tests of a spin-tunnel model and upon general spin-tunnel experience, the following conclusions are made for the North American XSN2J-1 airplane:

1. The spins, in general, will be fairly steep with a fairly high rate of descent, and recovery by rapid full rudder reversal will be satisfactory.

2. For recovery from erect spins, the rudder should be reversed briskly and fully against the spin followed approximately 1/2 turn later by movement of the stick forward of neutral.

3. Upon inadvertently entering a spin in the landing condition, the flaps should be neutralized immediately and recovery attempted.

4. Recovery from inverted spins will be satisfactory by reversing the rudder and neutralizing the stick.

5. A 6-foot-diameter tail parachute having a drag coefficient of 0.7 and attached to a 30-foot towline will be effective for emergency recovery from demonstration spins.

6. If the occupants of the airplane decide to abandon the airplane during a spin, they should leave from the outboard side and as far rearward as possible.

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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. Berman, Theodore: Free-Spinning Tunnel Tests of a 1/25-Scale Model of the North American XFJ-1 Airplane - TED No. NACA 2400. NACA RM No. L6H29, Bur. Aero., 1946.

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

4. Seidman, Oscar, and Neihouse, A. I.: Comparison of Free-Spinning Wing-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. Stone, Ralph W., Jr., and Burk, Sanger M., Jr.: Hinge-Moment Characteristics of a Balanced Elevator and a Rudder for a Specific Tail Configuration on a Fuselage in Spinning Attitudes. NACA TN No. , 1947.

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

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE XSN2J-1 AIRPLANE AND THE AIRPLANE REPRESENTED BY THE MODEL

	XSN2J-1	Model as tested (Dimensions are full scale)
Length over all, ft	33.85	33.52
Propeller diameter, ft	10.58	None
Propeller, number of blades	3	None
Wing:		
Span, ft	42.94	41.60
Area, sq ft	302.63	236.00
Aspect ratio	6.08	7.40
Chord, in.:		
Root	113.12	89.90
Mean aerodynamic chord	87.88	70.70
Tip (design)	57.88	47.00
Taper ratio	0.51	0.52
Location of mean aerodynamic chord, in.:		
Leading edge of $\bar{c}$ rearward of leading edge of root chord	6.28	4.80
Leading edge of $\bar{c}$ below fuselage reference line, perpendicular distance	4.08	10.90
Angle of incidence:		
Root	2°0'	3°0'
Mean aerodynamic chord	1°10'	1°13'
Tip	-1°0'	-1°0'
Dihedral of wing, deg	7	5
Angle of sweepback (at leading edge of wing)	3°10'	2°30'
Airfoil section:		
Root	NACA 2415R	NACA 2416
Tip	NACA 4412R	NACA 4409

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE XSN2J-1 AIRPLANE - Concluded

	XSN2J-1	Model as tested (Dimensions are full scale)
Ailerons:		
Area (both ailerons), sq ft		
Total	20.40	10.45
Span, in.	98.15	108.0
Chord, percent of wing chord	22	24.5
Horizontal tail surfaces:		
Area, sq ft		
Total	61.92	47.38
Elevator, rearward of hinge line	22.80	17.02
Span, ft	16.98	13.17
Distance from normal gross weight center of gravity to elevator hinge line, in.	237.8	252.05
Vertical tail surfaces:		
Area, sq ft		
Total	28.80	20.97
Rudder, rearward of hinge line	10.30	10.57
Span, ft	8.53	6.06
Distance from normal gross weight center of gravity to rudder hinge line, in.	265.8	265.8
Tail-damping power factor	438×10^{-6}	438×10^{-6}
Tail-damping ratio	0.0269	0.0281
Unshielded rudder volume coefficient	0.0163	0.0156

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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE XSN2J-1 AIRPLANE AND FOR LOADING TESTED ON THE MODEL USED TO REPRESENT THE AIRPLANE

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

No.	Loading	Weight (lb)	Airplane relative density		Center-of-gravity location		Moments of inertia (slug-ft^2)			Inertia parameters		
			μ sea level	μ 10,000 (ft)	$x/\bar{c}$	$z/\bar{c}$	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						
1	Normal trainer	8413	8.45	11.46	0.275	-0.001	4200	9378	12,651	-108×10^{-4}	-68×10^{-4}	176×10^{-4}
2	Bomber trainer	8737	8.80	11.90	.268	.024	6746	9324	14,925	-52	-112	164
3	Rocket trainer	8737	8.80	11.90	.258	.013	8319	9230	16,564	-18	-152	170
						Model						
1	Normal trainer	8441	11.20	15.20	0.278	0.016	4095	9303	12,870	-115	-79	194

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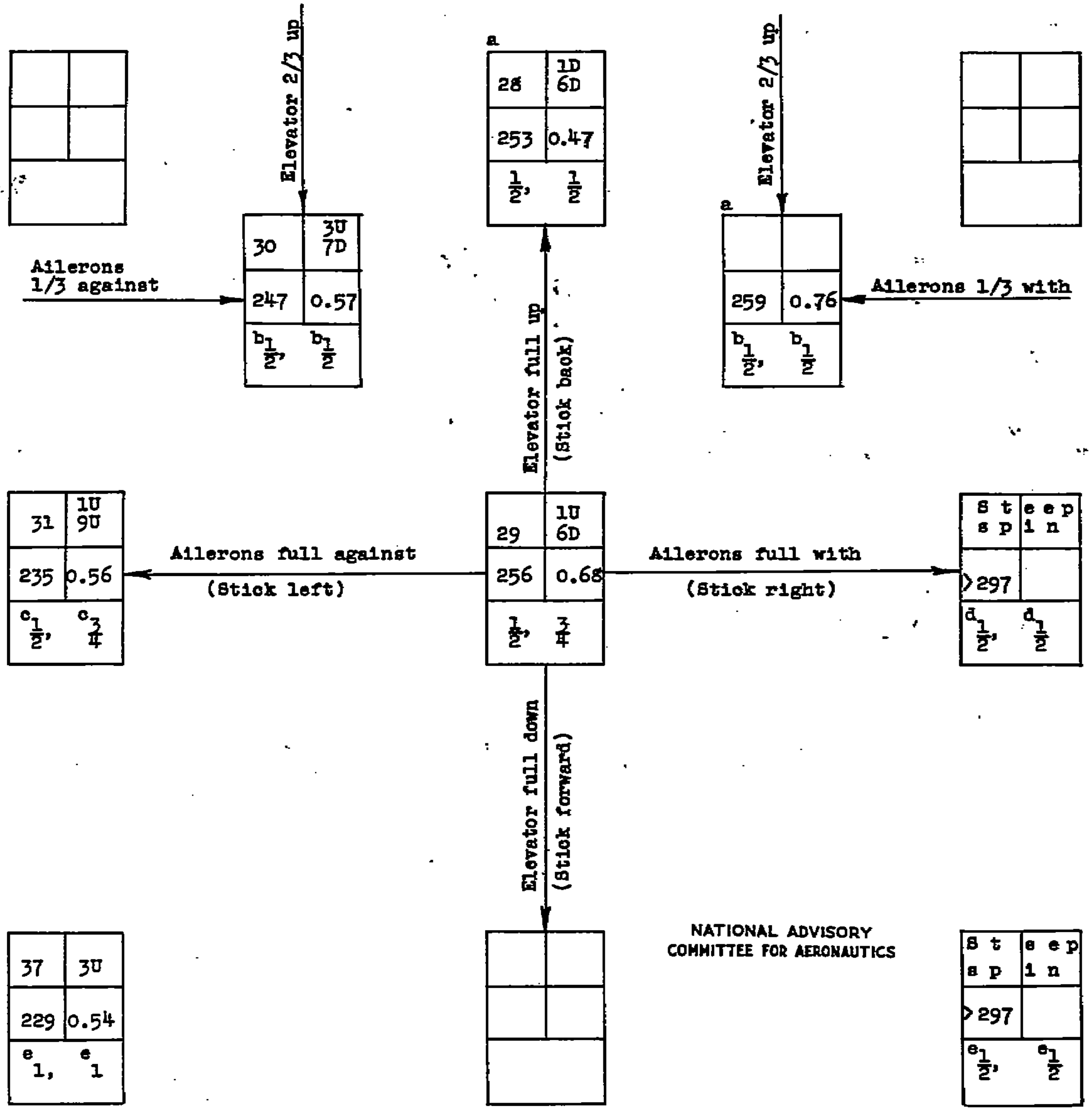
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL USED TO REPRESENT THE NORTH AMERICAN XSN2J-1 AIRPLANE

[Normal trainer loading; clean condition; recovery attempted by rapid full rudder reversal, except as indicated; recovery attempted from, and steady-spin data presented for, rudder-full-with spins; right erect spins]



[a] Model wanders.

[b] Recovery attempted by moving the rudder from full with the spin to 2/3 against the spin.

[c] Visual estimate.

[d] Model recovered in a vertical dive.

[e] After recovery from the erect spin, the model enters an inverted 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	

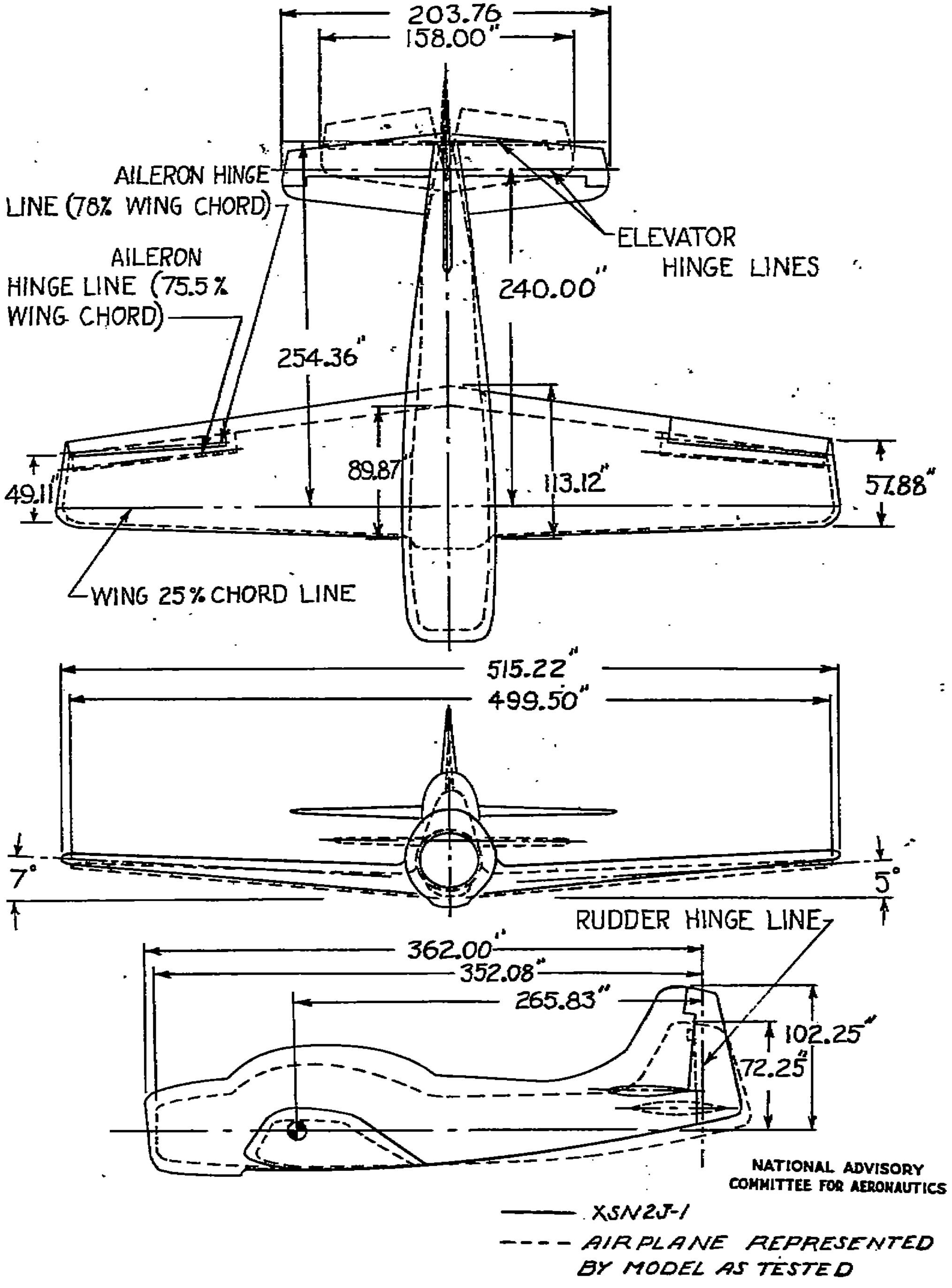


Figure 1.- Comparative drawing of the XSN2J-1 airplane and the airplane represented by the model as tested. The center-of-gravity position shown is for the normal trainer loading.

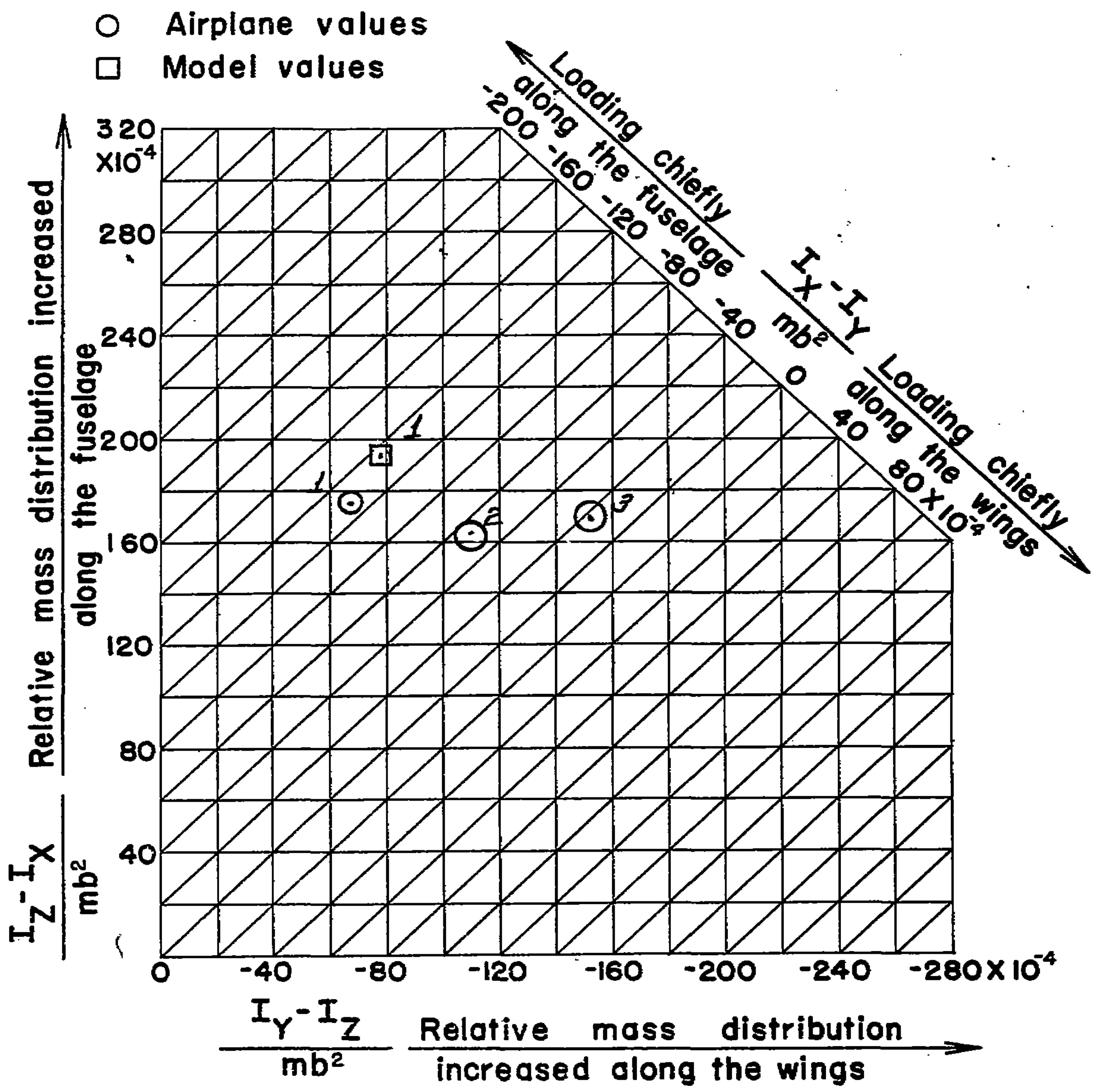


Figure 2.- Inertia parameters for loadings possible on the XSN2J-1 airplane and for the loading used on the model. (Points are for loadings listed in table II.)

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