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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

INVESTIGATION OF THE SPIN AND RECOVERY CHARACTERISTICS
OF A 0.057-SCALE MODEL OF THE MODIFIED
CHANCE VOUGHT XF7U-1 AIRPLANE

TED NO. NACA DE 311

By Theodore Berman and Norman E. Pumphrey

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a 0.057-scale model of the modified Chance Vought XF7U-1 airplane. The primary change in the design from that previously tested was a revision of the twin vertical tails. Tests were also made to determine the effect of installation of external wing tanks.

The results indicated that the revision in the vertical tails did not greatly alter the spin and recovery characteristics of the model and recovery by normal use of controls (full rapid rudder reversal followed approximately one-half turn later by movement of the stick forward of neutral) was satisfactory.

Adding the external wing tanks tended to cause the recovery characteristics to become critical and border on an unsatisfactory condition; however, it was shown that satisfactory recovery could be obtained by jettisoning the tanks, followed by normal recovery technique.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, a spin investigation supplementary to that reported in references 1 and 2 has been made in the Langley 20-foot free-spinning tunnel of a 0.057-scale

model of the Chance Vought XF7U-1 airplane. The current investigation was undertaken primarily to determine the effects on the spin and recovery characteristics of revised vertical fins and rudders. The nose of the fuselage of the modified design was somewhat larger than that previously tested. The effect of installation of external fuel tanks was also investigated.

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 root chord line to mean aerodynamic chord (positive when center of gravity is below root chord 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, slug per cubic foot
μ	relative density of airplane $\frac{m}{\rho S b}$
α	angle between root chord line and vertical (approximately equal to the angle of attack at the 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

APPARATUS AND METHODS

Model

A 0.057-scale model of the XF7U-1 airplane previously tested at the Langley Laboratory was available and was therefore used for the present investigation. The model was revised to incorporate the revised vertical tails and a lengthened fuselage nose, and provision was made for addition of external wing fuel tanks. A three-view drawing of the modified model is shown in figure 1. A sketch comparing the original and revised fin and rudder arrangements is presented in figure 2. A drawing showing the relative position of the external fuel tanks is given in figure 3. A photograph of the model spinning in the tunnel is shown in figure 4. The dimensional characteristics of the airplane are given in table I.

As indicated in reference 1, lateral and longitudinal controls of the airplane are combined in one pair of surfaces called ailavators. In this report, ailavator deflections for longitudinal and lateral control will be referred to, for simplicity, as elevator and aileron deflections, respectively.

The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho = 0.001496$ slug/cu ft) and a remote-control mechanism was installed in the model to actuate the controls for recovery tests. Sufficient moments were exerted on the control surfaces during recovery tests to insure their full and rapid movement.

Wind-Tunnel and Testing Technique

The model tests were performed in the Langley 20-foot free-spinning tunnel in a manner similar to that described in reference 1. The testing procedure and technique for obtaining and converting the data to full-scale values were the same as those used in reference 1.

PRECISION

The model test results 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	
from film	$\pm \frac{1}{4}$
from visual observation	$\pm \frac{1}{2}$

The preceding limits may have been exceeded for certain 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 spin-recovery results of airplanes and corresponding models (reference 3) indicates that spin-tunnel results are in agreement with full-scale spin-recovery results about 90 percent of the time, and that for the other 10 percent some indication of full-scale spin and recovery characteristics can be obtained.

Because of the impracticability of exact ballasting of the model and because of small inadvertent changes during testing, the measured weight and mass distribution of the model varied from the true scaled-down values by the following amounts:

Weight, percent	1 low to 1 high
Center-of-gravity location, percent \bar{c}	1 rearward to 1 forward
Moments of inertia:	
I_x , percent	5 low to 5 high
I_y , percent	8 low to 5 high
I_z , percent	8 low to 5 high

The limits of accuracy of the measurements of the mass characteristics are believed to be:

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

The controls were set with an accuracy of $\pm 1^\circ$.

TEST CONDITIONS

The mass characteristics and inertia parameters of the airplane and of the model as tested are shown in table II. The inertia parameters of the airplane and model are plotted in figure 5, which for conventional designs has been used as an indication of the probable effects of controls on the spin and recovery characteristics (reference 4).

The maximum control deflections used for the current tests were:

Rudders, degrees	20 right, 20 left
Ailavators, degrees	
As elevators	30 up, 20 down
As ailerons	15 up, 15 down

Intermediate control deflections used were:

Ailavators, degrees	
Deflected as elevator, stick two-thirds back	20 up
Deflected as ailerons, stick one-third left or right	±5

The differential deflections of the ailavators resulting from lateral stick displacement are added algebraically to the ailavator deflections resulting from longitudinal stick displacement.

RESULTS AND DISCUSSION

The results of spin tests of the model are presented in charts 1 and 2. The model data are presented in terms of full-scale values for the airplane at a test altitude of 15,000 feet.

External Tanks Off and Outer-Wing-Panel Tanks Empty

Spin data obtained with the model loaded to simulate external tanks off and outer-wing-panel tanks empty (loading 1 in table II and fig. 5) are presented in chart 1. Because the right and left spins were generally similar, data for right spins only are arbitrarily presented. These results were compared to those results given in references 1 and 2 and were found to be generally similar. The model would not spin for most control configurations. Setting the ailerons full against the spin led to very poor recovery characteristics when the elevators were neutral or down. ||

Full External Tanks On and Full Internal Fuel

Spin data obtained with the model loaded to simulate full external tanks on and full internal fuel (loading 2 in table II and fig. 5) are presented in chart 2. For this loading condition the model was not symmetrical. Recovery characteristics were satisfactory from right spins but unsatisfactory from left spins when recovery was attempted by rudder reversal. Inasmuch as left spins were conservative, data for left spins only are presented. In an effort to find a method by which recovery characteristics for this loading could be improved the external tanks were removed whereupon the recovery characteristics became satisfactory. The results of these tests are also presented in chart 2. The results indicate that recoveries of the airplane in the tank-on loading condition may be marginal. To insure recovery from a spin in this condition, recovery should be attempted immediately by normal recovery technique (rudder reversal followed approximately one-half turn later by movement of the elevator down) and if recovery does not appear imminent after one turn, the external fuel tanks should be jettisoned and the normal recovery technique repeated. An analysis of the results indicates that the adverse effect obtained with external fuel tanks installed may be associated with aerodynamic effects rather than mass effects.

Control Forces

In reference 2 it was estimated that for the original rudders, relatively high rudder-pedal forces might be required for rapid full reversal or neutralization of the rudders while the airplane was in a spinning attitude. Calculations were made for the revised vertical tails, with their greatly decreased chords, based on reference 5, assuming an angle of attack of 25° at the plane of symmetry and a rate of rotation of 2.5 radians per second, full scale. The results indicated that the pedal force required for full rapid reversal of the modified rudders would be approximately 140 pounds. This rudder-pedal force is well within the capabilities of the pilot, as found in reference 6.

Recommended Recovery Technique

On the basis of the test results, the use of the following spin-recovery technique is recommended for all loadings: The stick should be held full back and laterally neutral; the rudders should be reversed fully and rapidly followed, approximately one-half turn later, by movement of the stick briskly forward of neutral while keeping it laterally neutral. Care should be exercised to avoid excessive rates of acceleration in the ensuing recovery dive.

CONCLUSIONS

Based on results of an investigation of the spin and recovery characteristics of a 0.057-scale model of the modified Chance Vought XF7U-1 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane spinning at an altitude of 15,000 feet are made:

1. For the loading condition with the external tanks off and the outer-wing-panel tanks empty, the spin and recovery characteristics of the airplane will be satisfactory.

2. For the loading condition with full external tanks on and full internal fuel, the recovery characteristics may be unsatisfactory. If recovery by normal recovery technique does not appear imminent, external tanks should be jettisoned whereupon recovery by normal technique will be satisfactory.

3. The pedal forces to move the rudders from full with to full against the spin will be well within the capabilities of the pilot.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE MODIFIED
CHANCE VOUGHT XF7U-1 AIRPLANE

Over-all length, ft	40.9
Wing:	
Span, ft	38.6
Area, sq ft	496
Aspect ratio	3.01
Root chord, in.	194.0
Tip chord, in.	116.0
Mean aerodynamic chord, in.	157.0
L.E. \bar{c} rearward L.E. root chord, in.	83.5
Taper ratio	0.60
Incidence (constant), deg	0
Dihedral, deg	0
Sweepback of quarter-chord line, deg	35
Airfoil section	CVA 4-(00)-(12)(40)-(1.1)(1.0)
Ailavator:	
Span, percent b/2	47.2
Total area, sq ft	54
Area rearward of hinge line, sq ft	53
Chord, percent c:	
Inboard station	22.4
Outboard station	29.2
Vertical tail:	
Height, ft	12.2
Total area, sq ft	137.2
Rudder area, sq ft	14.1
Sweepback quarter-chord line, deg	45
Airfoil section	Modified NACA 64-series

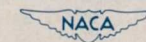




TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS OF THE MODIFIED CHANCE
VOUGHT XF7U-1 AIRPLANE AND FOR THE LOADINGS TESTED ON THE 0.057-SCALE MODEL

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

No.	Loading	Weight (lb)	Airplane relative density		Center-of-gravity location		Moments of inertia (slug-feet ²)			Mass parameters		
			Sea level	15,000 feet	x/c	z/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	External tanks off, outer panel tanks empty	20,545	14.00	22.26	-0.173	0	22,841	40,757	61,714	-188 × 10 ⁻⁴	-221 × 10 ⁻⁴	409 × 10 ⁻⁴
2	Full external tanks on, full internal fuel	25,105	17.12	27.21	-0.172	0.048	31,637	44,508	72,914	-110	-245	355
3	Loading 2 except external tanks jettisoned	21,805	14.89	24.66	-0.173	0	28,394	42,378	68,891	-138	-263	401
Model values												
1	External tanks off, outer panel tanks empty	20,558	14.00	22.26	-0.175	-0.009	22,785	40,225	62,077	-183 × 10 ⁻⁴	-230 × 10 ⁻⁴	413 × 10 ⁻⁴
2	Full external tanks on, full internal fuel	25,105	17.12	27.21	-0.174	0.032	31,733	44,397	72,965	-109	-246	355
3	Loading 2 except external tanks jettisoned	21,871	14.93	23.73	-0.175	-0.002	27,837	42,701	70,079	-147	-271	418

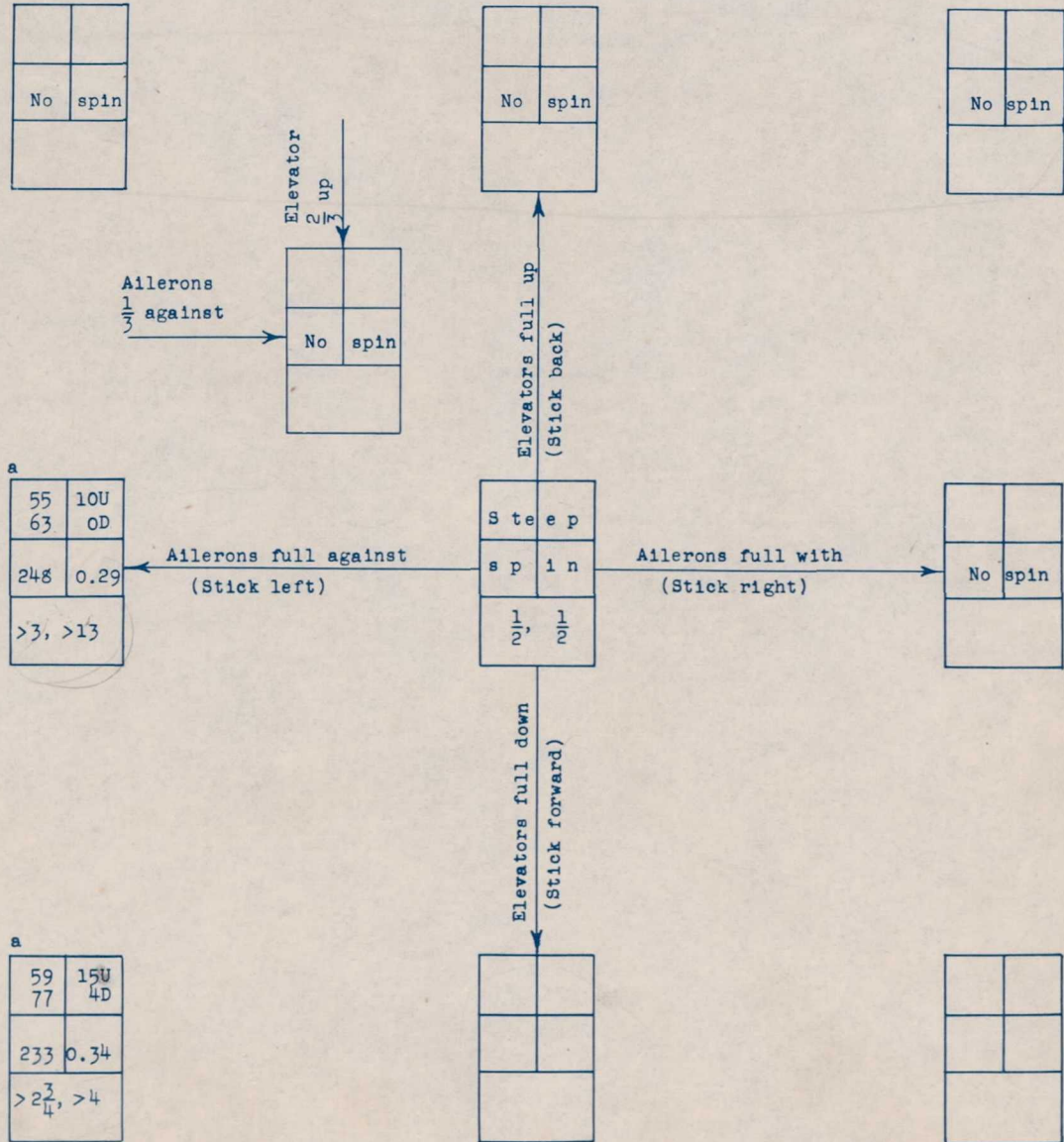


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CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE 0.057-SCALE MODEL OF THE MODIFIED CHANCE VOUGHT XF7U-1 AIRPLANE WITH THE EXTERNAL TANKS OFF AND OUTER WING PANEL TANKS EMPTY

Loading 1 in table II and figure 5; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); right spins



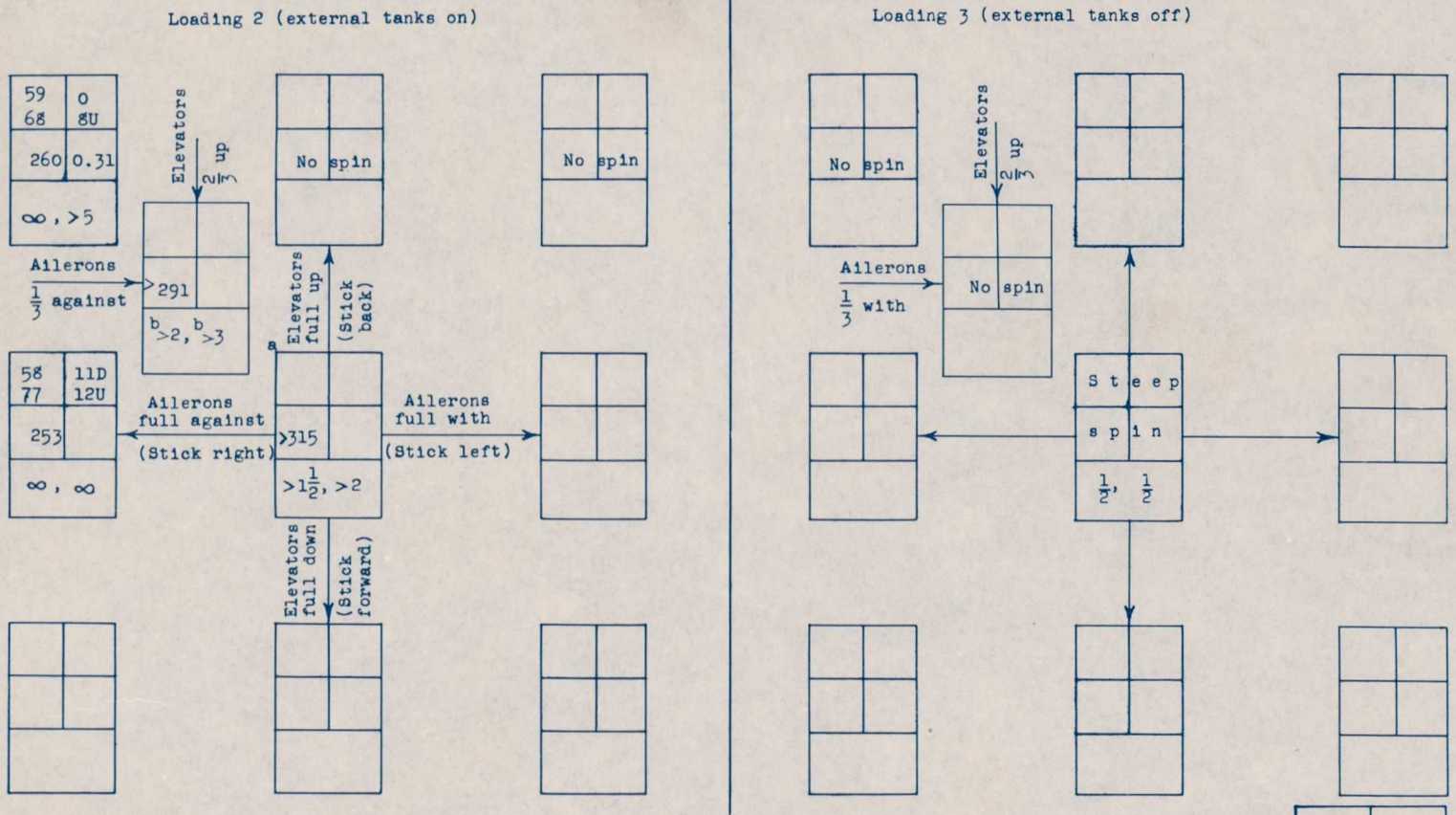
^aOscillatory spin. Range of values or average value given.

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 2.- THE EFFECT OF FULL EXTERNAL FUEL TANKS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE 0.057-SCALE MODEL OF THE MODIFIED CHANCE VOUGHT XF7U-1 AIRPLANE

Loading as indicated in table II and figure 5; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); left spins



^a Model wanders in spin.
^b Recovery attempted by reversal of rudders from full with to $\frac{2}{3}$ against 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	



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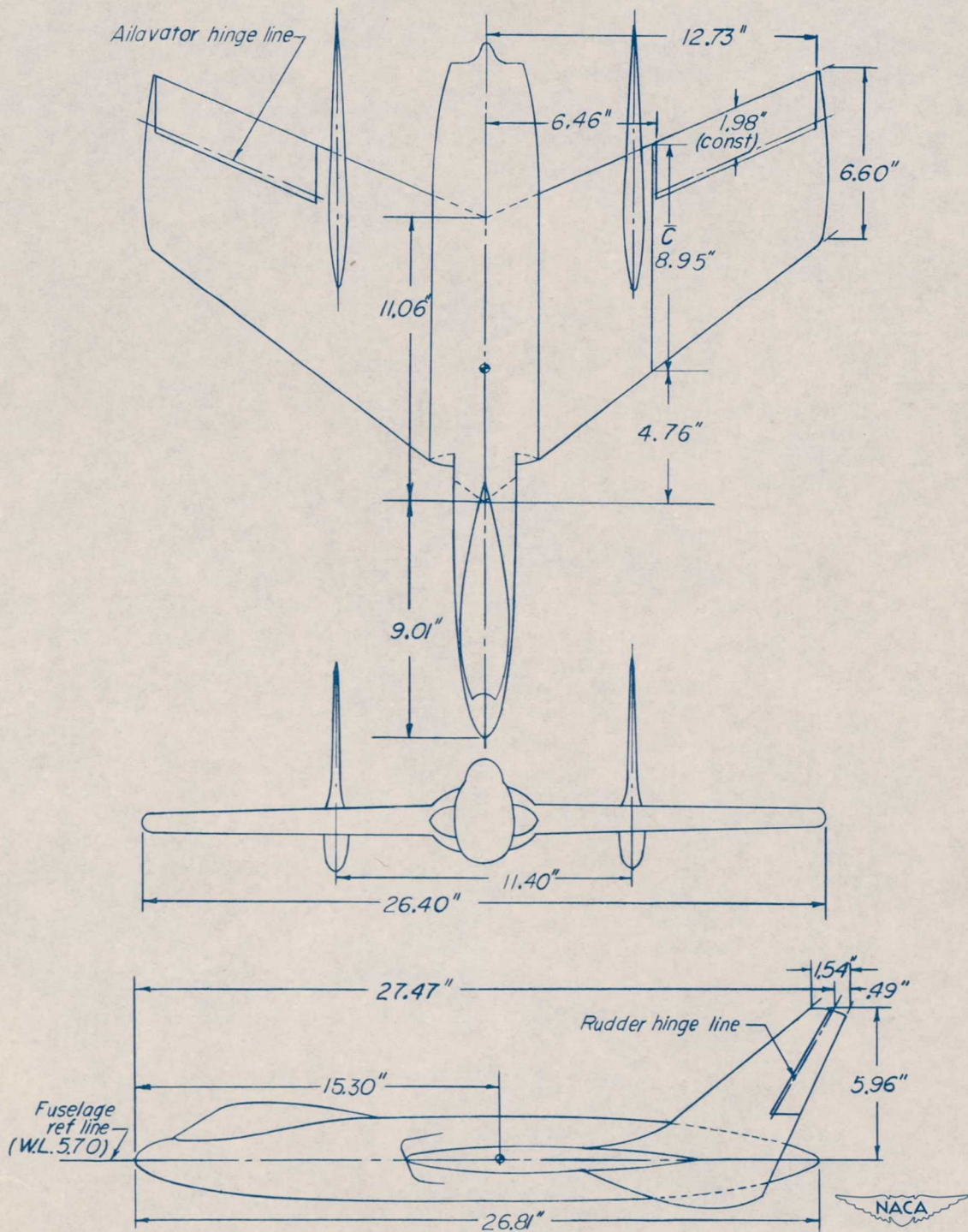


Figure 1.- Three-view drawing of the 0.057-scale model of the modified Chance Vought XF7U-1 airplane as tested in the Langley 20-foot free-spinning tunnel. Dimensions are model values. Center-of-gravity position shown is for loading 1, table II.

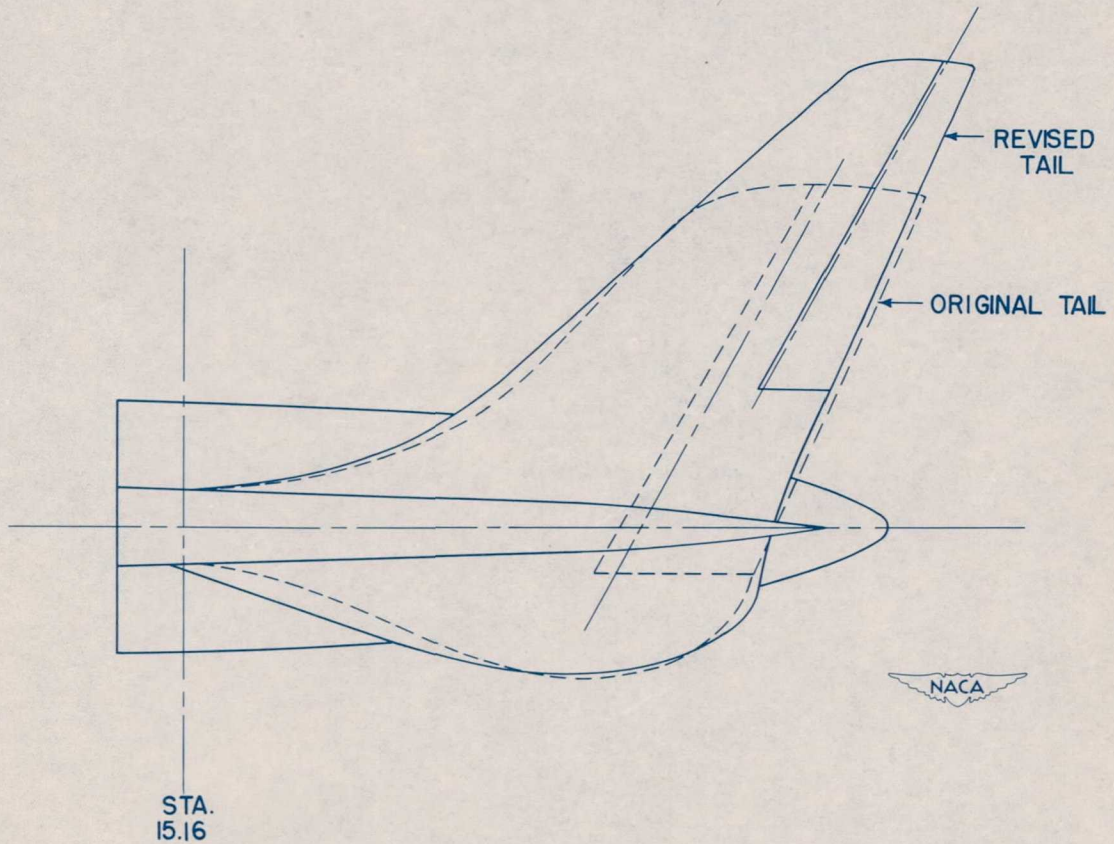


Figure 2.- Sketch comparing the original tail with the revised tail as tested on the 0.057-scale model of the modified Chance Vought XF7U-1 airplane.

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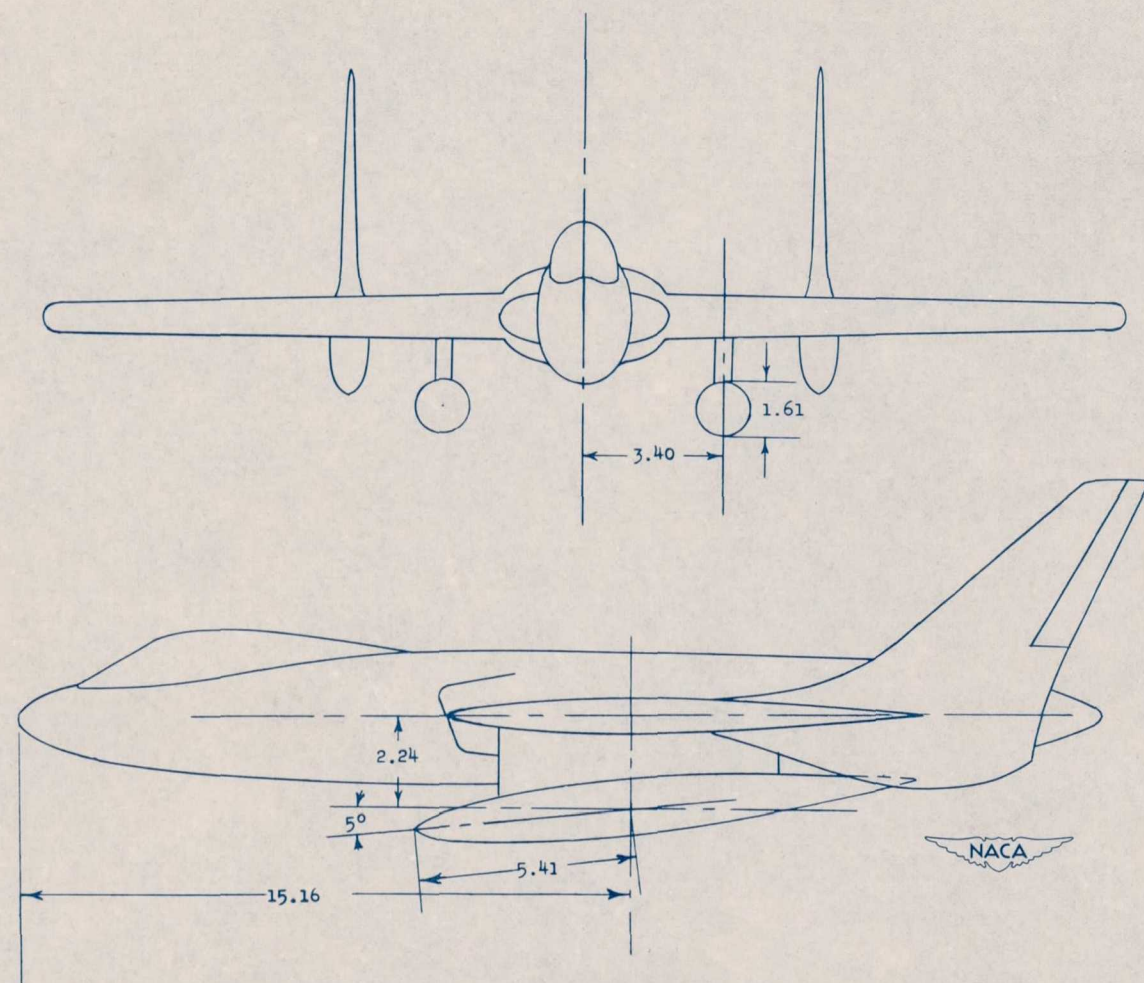
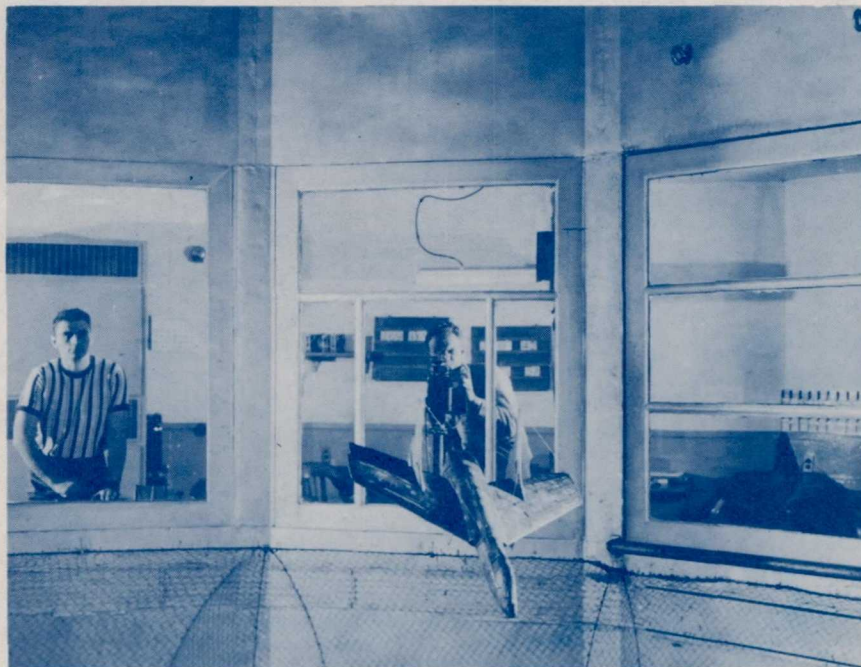


Figure 3.- Drawing showing the relative position of the external fuel tanks on 0.057-scale model of the modified Chance Vought XF7U-1 airplane as tested in the Langley 20-foot free-spinning tunnel. Dimensions shown are model values.

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Figure 4.- Photograph of the 0.057-scale model of the modified Chance Vought XF7U-1 airplane spinning the Langley 20-foot free-spinning tunnel.

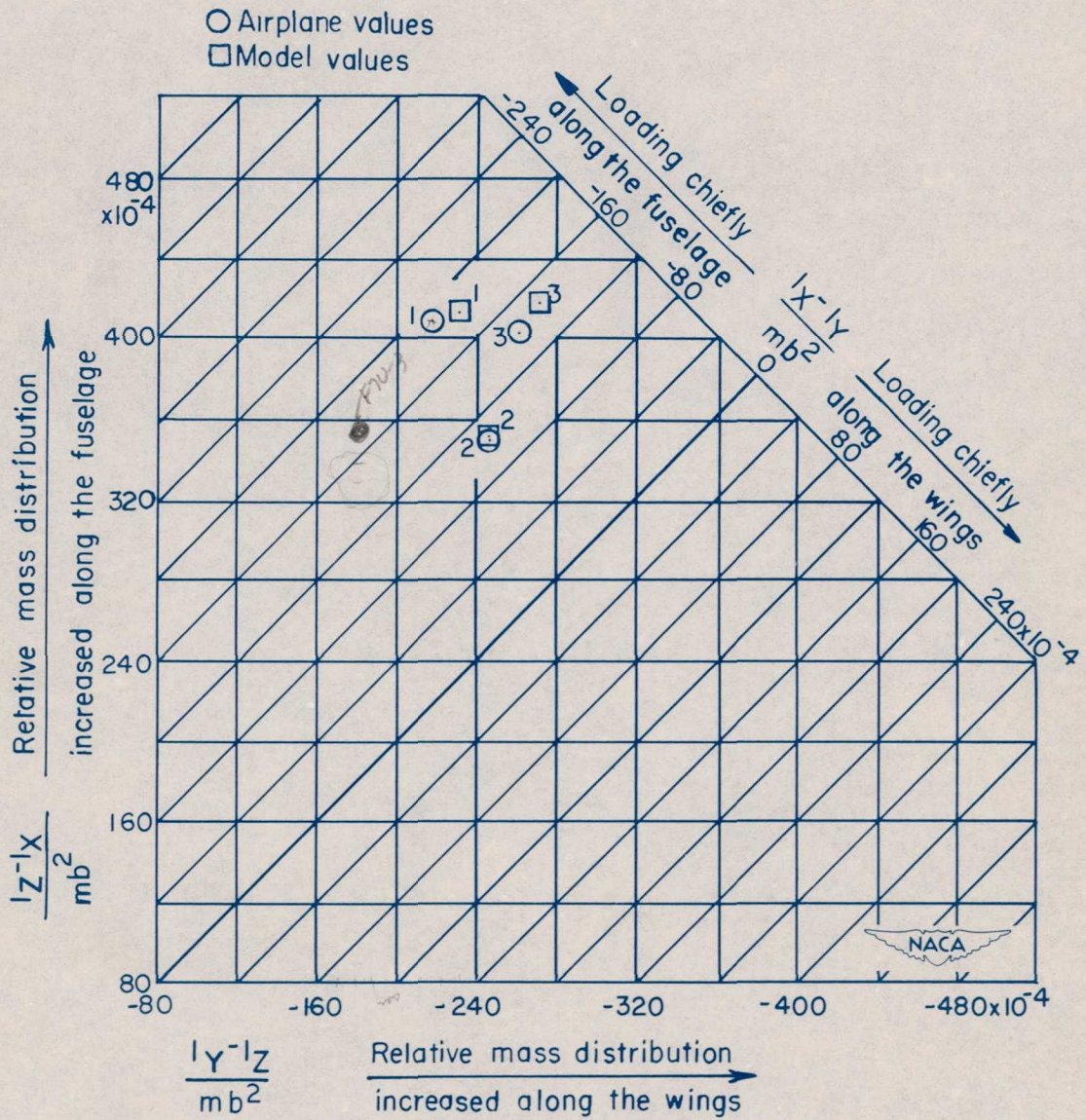


Figure 5.- Inertia parameters for loadings possible on the XF7U-1 airplane and for the loadings tested on the 0.057-scale model. (Points are for loadings listed in table III.)