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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

INVESTIGATION TO DETERMINE THE EFFECTIVENESS OF A SPLIT-AILERON TYPE EMERGENCY SPIN-RECOVERY DEVICE FOR THE NORTHROP XF-89 AIRPLANE

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INVESTIGATION TO DETERMINE THE EFFECTIVENESS OF A SPLIT-AILERON TYPE EMERGENCY SPIN-RECOVERY DEVICE FOR THE NORTHROP XF-89 AIRPLANE

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SUMMARY

The present paper presents the results of a brief investigation made to determine the effectiveness of a proposed emergency spin-recovery device to be used during demonstration spins of the Northrop XF-89 airplane. The proposed device makes use of split-type ailerons deflected $\pm 60^{\circ}$ on the outboard wing (left wing in a right spin). Tests made on a model which represented the airplane to a scale of $\frac{1}{27}$ indicated that, if an uncontrollable spin is obtained in the design gross-weight loading, the device is not sufficiently effective to insure recovery.

INTRODUCTION

In accordance with a request of the Air Materiel Command, U. S. Air Force, received from Wright-Patterson Air Force Base, an investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the effectiveness of an emergency spin-recovery device proposed for use in lieu of parachutes for the spin demonstration of the Northrop XF-89 airplane. The proposed device makes use of split-type ailerons deflected $\pm 60^{\circ}$ on the outboard wing during a spin (left wing in a right spin). The emergency spin-recovery device was proposed because of anticipated structural difficulties associated with the use of spin-recovery parachutes. The present investigation included tests at the design gross-weight and minimum flying-weight loadings and at a loading simulating additional fuel in the wings. Results of an investigation to determine the spin and recovery characteristics of the XF-89 airplane were previously presented in reference 1.

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 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, slug per cubic foot
μ	relative density of airplane, $m/\rho Sb$
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

APPARATUS AND METHODS

Model

The model used for the present investigation was the same as used for the investigation of reference 1. A three-view drawing of the airplane with the spin-recovery device as simulated and installed by Langley Laboratory is shown in figure 1. The dimensional and mass characteristics of the airplane and of the model are given in tables I and II, respectively. The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet (ρ = 0.001496 slug per cu ft).

Wind-Tunnel and Testing Technique

The model tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 2 for the original Langley 15-foot free-spinning tunnel; the model is now launched by hand, however, with rotation into the vertically rising air stream, the velocity of which is adjusted to support the spinning model. After recovery from the spin, the model dives into a safety net.

The data presented were determined and converted to corresponding full-scale values by methods described in reference 2.

PRECISION

The precision of the results of the present investigation is believed to be generally similar to those of reference 1. When, however, visual estimates were made of the angle of attack of the spin, the accuracy is considered to be $\pm 5^{\circ}$.

RESULTS AND DISCUSSION

The results of the present investigation are presented in table III. Inasmuch as the behavior of the model in right and left spins was the same, the results are arbitrarily presented in terms of right spins.

Reference 1 indicated that poor recovery characteristics would be obtained for the design gross-weight loading when ailerons were full with the spin (stick right in a right spin) and the elevators were full-up. A check spin made for this control configuration indicated a fairly steep spin at an estimated angle of attack of 35°, which compared reasonably with the earlier tests of reference 1 for which the angle of attack had been measured at 40°. To simulate operation of the proposed spin-recovery device from a similar spin, the left down-going aileron was replaced by a split-type aileron deflected $\pm 60^{\circ}$. With right aileron full-up (13°) or at neutral, the model would not spin when launched with rotation into the vertically rising air stream, but lost its launching rotation quickly and went into a dive into the safety net of the tunnel. On the basis of these tests, the proposed spin-recovery device appeared effective, but it was felt that the attitude of the spin might be a critical factor in determining its effectiveness and, that on the corresponding airplane, the device might be ineffective for the design gross-weight loading if the airplane spin was somewhat flatter than that of the model. The ineffectiveness of the device, it was felt, would stem from the fact that, for a flatter spin attitude, the up-going split aileron would be shielded, with subsequent deterioration of the effectiveness of the device. Thus it appeared that, if the airplane spin and recovery characteristics were similar to those indicated by the model tests, use of an emergency device would not be necessary and normal use of controls (full rapid rudder reversal followed approximately one-half turn later by movement of the stick forward of neutral while maintaining it laterally neutral) would readily terminate the spin. On the other hand, if the airplane spin should be flatter than that indicated by the model, because of scale effect or any other reason, use of an emergency spin-recovery device might be necessary, but the proposed device might be ineffective.

In order to establish the importance of the spin attitude upon the effectiveness of the spin-recovery device at the basic loading, the rudder area with the spin was increased on the model, thus the spin was flattened to an angle of attack of 42°. As was feared, the effectiveness of the device deteriorated and the model continued to spin although the ensuing spin was steepened somewhat. Apparently in the steep spin, the split surfaces on the outboard wing (left wing in a right spin) produced an antispin areodynamic yawing moment, with little resulting rolling moment being obtained from the down-going and from the up-going surfaces. If, however, the spin was flattened even slightly, the up-going surface became shielded from the air stream and a net rolling moment with the spin, produced by the down-going surface, resulted. As indicated in reference 3, the effect of such a rolling moment is adverse for a loading such as the design gross-weight loading which has the mass distributed chiefly along the wings $\left(\frac{I_X - I_Y}{mb^2} \text{ is positive}\right)$.

When the mass distribution was increased along the wings to simulate added wing fuel, the device was ineffective even when only the normal-sized rudder was with the spin. A similar result was obtained when the up-going split aileron deflection was decreased to 40°. With the mass distribution along the wings decreased to simulate the minimum flying-weight loading, the results indicated that the device would be effective in preventing the spin, as would be expected from references 3 and 4. In essence, the effect of a lateral control in a spin depends upon the aerodynamic yawing and rolling moments contributed and the net effect of the rolling moment is critically dependent upon the mass distribution as indicated by the inertia yawing-moment parameter $\frac{I_X - I_Y}{mb^2}$.

CONCLUDING REMARKS

On the basis of brief supplementary tests of a model simulating the Northrop XF-89 airplane to a scale of $\frac{1}{27}$ to determine the effectiveness of a split-aileron type of spin-recovery device for the design gross-weight loading, it is felt that the proposed device is not reliable. At the design gross-weight loading the effectiveness of the device is critically dependent upon the attitude of the spinning airplane. Mass distribution of the airplane is an important factor in determining the effectiveness of such a device.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE NORTHROP XF-89

AIRPLANE AND THE $\frac{1}{27}$-SCALE MODEL TESTED

Characteristics	Model (full-scale values)	Airplane
Length, over-all, ft	50.4	50.5
Wing:		
Span, ft	55.0	52.0
Area, sq ft	523.0	606.2
L.E. wing at root to elevator hinge, ft	33.3	33.4
Incidence, deg	1.0	1.5
Aspect ratio	5.8	4.5
Leading edge of $\bar{c}$ rearward of L.E. of wing, in	11.3	12.0
Mean aerodynamic chord, in	104.9	145.6
Dihedral, deg	2.0	1.0
Ailerons:		
Span, ft	19.4	21.8
Area aft hinge line, sq ft	32.3	42.4
Chord, percent c	25.0	21.8
Full aileron deflection, deg	±13	±13
Horizontal tail:		
Span, ft	22.3	22.3
Total area, sq ft	114.6	114.6
Elevator area aft hinge line, sq ft	26.8	26.8
Incidence, deg	0	0
Full elevator-up deflection, deg	40	40
Full elevator-down deflection, deg	20	20
Vertical Tail:		
Total area, sq ft	44.4	44.4
Total rudder area aft hinge line, sq ft	7.4	7.4
Full rudder deflection, deg	±40	±40
Tail-damping ratio	0.05012	0.0476
Unshielded rudder-volume coefficient	0.01027	0.0093
Tail-damping power factor	0.000514	0.000443

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING POSSIBLE AND LOADINGS TESTED ON $\frac{1}{27}$-SCALE MODEL REPRESENTING THE NORTHROP XF-89 AIRPLANE

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

No.	Loading condition	Weight (lb)	Center-of-gravity location		Relative density, μ		Moments of inertia (slug-ft^2)			Mass parameters		
			$\frac{x}{c}$	$\frac{z}{c}$	Sea level	15,000 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	Design gross weight	31,000	0.301	-0.050	12.8	20.4	82,207	65,700	141,636	63×10^{-4}	-292×10^{-4}	229×10^{-4}
2	Minimum flying weight	23,010	0.287	-0.030	9.5	15.2	47,834	61,505	103,389	-71	-216	287
Model values												
1	Design gross weight	28,990	0.260	-0.050	12.6	20.0	87,888	78,335	158,588	35	-295	260
2	Minimum flying weight	26,042	0.236	-0.036	11.3	18.0	52,408	78,034	121,871	-105	-179	284
3	Fuel added to wing	31,011	0.273	-0.051	13.5	21.4	109,704	78,888	202,571	106	-425	319

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TABLE III.- EFFECT OF SPLIT-AILERON TYPE EMERGENCY SPIN-RECOVERY DEVICE ON THE SIMULATED $\frac{1}{27}$-SCALE MODEL OF THE NORTHROP XF-89

[Right erect spins]

Test	Loading $\left(\frac{I_X - I_Y}{mb^2}\right)$	Control deflection, degrees (a)				ϕ (deg) (b)	α (deg)	V (fps)	Remarks
		Elevator	Rudder	Ailerons					
				Right	Left				
Normal rudder area									
1	35×10^{-4}	40U	40R	13U	13D	--	[c]35	294	--
2	35	40U	40R	13U	Split 60° U; 60° D	--	---	----	Did not spin. Went into steep spiral.
3	35	40U	40R	0	60° U; 60° D	--	---	----	Did not spin. Went into steep spiral.
Rudder area increased									
4	35	40U	40R	13U	13D	3D	42	272	--
5	35	40U	40R	13U	60U	1D	30	307	--
6	35	40U	40R	0	60U	1D	29	323	--
7	35	40U	40R	0	Split 60U; 60D	9D	27	>385	--
8	-105	40U	40R	0	Split 60U, 60D	--	---	----	Did not spin. Went into steep wide-radius gliding turn to right.
9	-105	40U	40R	0	60U	2D	37	296	--
10	-105	40U	40R	0	60D	--	---	----	Did not spin. Went into steep spiral.
Normal rudder area									
11	106	40U	40R	0	Split 60U; 60D	--	[c]30	323	--
12	35	40U	40R	0	50U; 60D	--	---	----	Did not spin. Went into steep wide-radius spiral.
13	35	40U	40R	0	40U; 60D	--	[c]25	423	--

NOTE: Model values converted to corresponding full-scale values.
[a]U - up; D - down; R - right.
[b]D - inner wing down.
[c]Visual estimate.

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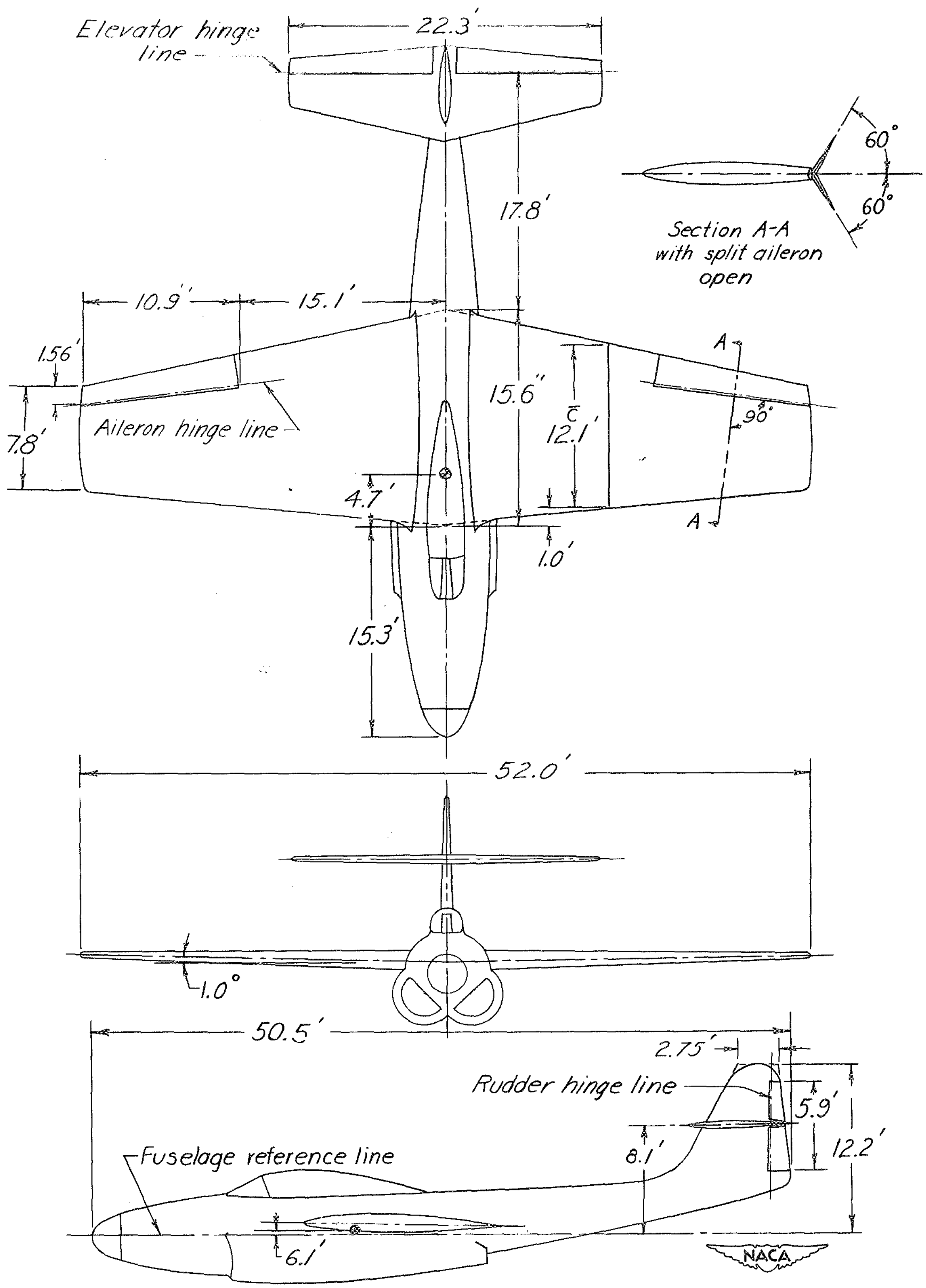

Figure 1.- Three-view drawing of the Northrop XF-89 airplane, also sectional view of split aileron shown deflected ±60°.