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RESEARCH MEMORANDUM

for the

Army Air Forces, Air Materiel Command

SPIN AND RECOVERY CHARACTERISTICS OF THE CURTISS-WRIGHT XP-87 AIRPLANE

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SUMMARY

The spin and recovery characteristics of the Curtiss-Wright XP-87 airplane, as well as the spin-recovery parachute requirements, the control forces that would be encountered in the spin, and the best method for the crew to attempt an emergency escape, are presented in this report. The characteristics were estimated rather than determined by model tests because the XP-87 dimensional and mass characteristics were considered to be noncritical and because data were available from model tests of several similar airplanes.

The study indicated that the recovery characteristics of the airplane will be satisfactory for all loadings if the controls are reversed fully and rapidly. The control forces, however, will probably be beyond the capabilities of the pilot unless some additional balance or a booster is used. A 6-foot tail parachute or a 3.5-foot wing-tip parachute with a drag coefficient of 0.7 will be a satisfactory, emergency spin-recovery device for spin demonstrations. If it is necessary for the crew to abandon the spinning airplane, they should leave from the outboard side of the cockpit.

INTRODUCTION

The Army Air Forces, Air Materiel Command, requested that an investigation be conducted to determine the spin and recovery characteristics of the Curtiss-Wright XP-87 airplane. The XP-87 is a four-engine, two-place, midwing, jet-propelled fighter airplane equipped with wing slats, wing speed brakes, and landing flaps. The dimensional and mass characteristics of the airplane were examined by the spin-tunnel section, and it was decided that the spin and recovery characteristics of the airplane could be estimated and that tests of a model would, therefore, not be necessary. The characteristics were estimated rather than determined by model tests because XP-87 dimensional and mass characteristics were considered to be noncritical and because data were available from model tests of several similar airplanes. Accordingly, a prediction of the spin and recovery characteristics for various flight conditions of the XP-87 at an arbitrarily chosen altitude of 15,000 feet has been made. In making the prediction, the values of dimensional and mass parameters which have been found to have a major effect on the spin and recovery characteristics of an airplane have been considered. In addition, an estimate has been made of the spin-recovery parachute requirements, the control forces that would be encountered in a spin, and the best method for the crew to attempt an emergency escape from an uncontrolled spin.

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 thrust 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 $\left(\frac{m}{\rho Sb}\right)$

AIRPLANE CHARACTERISTICS

The dimensional and mass characteristics for the XP-87 airplane were furnished by the Curtiss-Wright Corporation. A three-view drawing of the airplane is shown in figure 1. Spoiler-type speed brakes are installed on the upper and lower surfaces of the wing but are not shown in figure 1. The dimensional and mass characteristics of the airplane are given on tables I and II, respectively. Mass-distribution parameters for the loadings presented in table II have been plotted on figure 2.

Airplane recovery characteristics were considered satisfactory if it was believed that the airplane would pass Army Air Forces spin demonstrations. Current Army Air Forces specifications require recovery to be accomplished in $1\frac{1}{2}$ turns or less for this type airplane.

METHOD OF ESTIMATION

As previously mentioned, the estimation of the spin and recovery characteristics of the airplane was deemed possible because of the noncritical values of the dimensional and mass parameters which have a major effect upon spin and recovery characteristics. The most important of these parameters, as indicated in reference 1, are tail-damping power factor, inertia yawing-moment parameter, and airplane relative density. The recovery characteristics of the airplane were estimated by consideration of these three factors in the manner indicated in reference 1. The angle of attack and the rate of descent were estimated by consideration of reference 2 and also by analysis of results of tests of several models which were considered similar either in dimensions or in loading. The value of the inertia yawing-moment parameter was used to establish the relative effect on recovery characteristics of the ailerons and elevator (reference 3) and the wing slats (reference 4).

Tail and wing-tip spin-recovery parachute sizes required for satisfactory recovery by parachute action alone were based on an analysis of spin-recovery parachute data obtained in the Langley spin tunnel. The estimation of the parachute sizes were based on a drag coefficient of 0.7 (based on the canopy area measured with the parachute spread flat).

The rudder hinge-moment coefficient was determined by use of unpublished data which takes into consideration the location of the horizontal tail with respect to the vertical tail and the estimated angles of attack and sideslip. The estimated angle of attack in conjunction with elevator nose shape and type of balance were used to determine the elevator hinge-moment coefficient by means of reference 5. The pedal and stick forces were computed by combining the hinge-moment coefficients with appropriate dimensional factors.

Inverted spin estimations were made on the basis of reference 6.

Crew escape recommendations were made on the basis of a compilation and analysis of data obtained from numerous model tests.

ESTIMATION OF SPIN AND RECOVERY CHARACTERISTICS

Clean Condition

Normal loading.- The recovery characteristics of the airplane in the normal loading and clean condition (flaps, slats, and landing gear retracted) will be satisfactory. For the normal control configuration for spinning (elevator up, ailerons neutral, and rudder full with the spin) the spin will be steep (average angle of attack between 20° and 30°) and the rate of descent will be of the order of 400 feet per second. The spin will probably be oscillatory in roll and yaw. Recovery will be satisfactory by rapid full reversal of the rudder. Movement of the elevator down before the rudder has been completely reversed may retard recoveries. It is therefore recommended that the following recovery technique be used: the rudder should be fully and rapidly reversed and, approximately 1/2 turn later, the stick should be moved forward of neutral keeping it laterally neutral. Care should be exercised, in the ensuing recovery dive, to avoid excessive accelerations. Although with the elevators full up the ailerons will have only little effect, in general, ailerons against the spin (stick left in a right spin) will be detrimental to recovery while ailerons with the spin will be beneficial.

Wing-tip tanks installed.- When wing-tip fuel tanks are installed on the airplane, the recovery characteristics will remain satisfactory when the recommended recovery technique is applied, although rudder reversal alone will probably not result in satisfactory recoveries. It is probable that the spins will be somewhat oscillatory in pitch. The airplane will probably not spin when the ailerons are against the spin for all elevator settings or when the elevators are down and the ailerons neutral. Aileron-with settings will affect recoveries adversely.

Effect of mass variation.- Variations in loading of the airplane between the two loading conditions presented due to the exhausting of fuel from the tip tanks will show changes in aileron and elevator effect, but recoveries will be satisfactory by normal control manipulation. If, however, difficulty is encountered during recovery, the tanks should be jettisoned and normal recovery procedure repeated.

Effect of center-of-gravity movement.- Movement of the center of gravity of the airplane approximately ±5 percent of the mean aerodynamic chord will have little effect on the spin and recovery characteristics of the airplane.

Effect of slats.- Tests of models with either full span or wing-tip slats have shown that slats have a slightly beneficial effect on recoveries for models with values of the inertia yawing-moment parameter similar to that for the normal loading of the XP-87 but that the effect becomes adverse as values of the inertia yawing-moment parameter approach that of the XP-87 airplane with the tip tanks installed. The slats on the XP-87, however, are of short span and located at the inboard end of the wing (fig. 1) where their effect on spinning would be least. It is therefore felt that the slats will have no appreciable effect on the spin and recovery characteristics of this airplane.

Effect of speed brakes.- Spin-tunnel experience shows that the spoiler-type wing speed brakes, used on this airplane, will have little effect on the spin and recovery characteristics of the airplane.

Inverted spins.- Based on the results in reference 6 and spin-tunnel experience gained with other models, satisfactory recovery can be expected from all inverted spins obtained with this airplane by full rudder reversal followed by stick neutralization.

Landing Condition

The landing condition is not considered critical inasmuch as the current specifications usually require airplanes 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 of many airplanes to determine the effect of flaps and landing gear indicates that the XP-87 airplane will recover satisfactorily from a 1-turn spin in the landing condition but that recoveries from fully developed spins in the landing condition may be unsatisfactory. It is recommended therefore that the flaps be neutralized and recovery be attempted immediately upon inadvertently entering a spin in the landing condition.

Control Forces

The discussion of recovery characteristics so far has been based on control effectiveness alone without regard to the forces required to move the controls. Sufficient force must be applied to the airplane controls to move them rapidly in the manner indicated to obtain the estimated results.

Estimations of the forces required to fully reverse the controls for recovery indicate that the rudder pedal and elevator stick forces will be of the order of magnitude of 1100 and 500 pounds, respectively. Both of these forces are appreciably beyond the capabilities of a pilot (reference 7). It therefore appears that in order to fully reverse the controls in a spin, trim tabs or some other suitable balance or booster arrangement may be necessary.

Emergency Crew Escape

Results of spin-tunnel tests on approximately 20 models indicate that if necessary to escape from an uncontrollable spin of this airplane which has its cockpit ahead of the leading edge of the wing, the venture will be rather hazardous primarily because of the added danger of striking the wing after jumping. The results indicate, however, that if it is necessary to jump, leaving from the outboard side of the cockpit (left side in a right spin) will afford the better chance for getting out safely. In view of these results it appears that for this airplane, an ejection system might be desirable.

Emergency Spin-Recovery Parachute Requirements

Tail parachute.- For recovery from spins by tail parachute action alone, a 6-foot-diameter flat-type parachute with a drag coefficient of 0.7 and attached to the airplane with a 30-foot towline will be satisfactory. It is recommended that a positive ejection mechanism be used to throw the parachute clear of the tail and to assure rapid opening. The pack and attachment point must be so located that the equipment will not foul the tail surfaces. Reference 8 described various practical methods of tail-parachute installations.

Wing-tip parachute.- For recovery by wing-tip parachute action alone, a 3.5-foot-diameter flat-type parachute with a drag coefficient of 0.7 opened on the outer wing tip will be satisfactory. The length of the towline should be such that the parachute when fully extended just clears the horizontal tail. It is recommended that the parachute pack be installed inside the wing with a positive ejection device to throw the parachute clear.

The spin-recovery parachute sizes indicated are relatively small for this size airplane. This is a result of the relatively large amount of vertical area below the horizontal tail.

CONCLUSIONS

The study of the dimensional and mass characteristics of the Curtiss-Wright XP-87 airplane and the analysis of model test results of similar airplanes results in the following conclusions regarding the spin and recovery characteristics of the airplane at altitudes up to 15,000 feet:

1. For all loadings, recovery by proper control technique will be satisfactory; recovery should be attempted by rapid full rudder reversal followed, approximately 1/2 turn later, by movement of the stick forward of neutral while maintaining it laterally neutral. Care should be exercised to avoid excessive accelerations during the recovery. At the extreme fuselage-heavy and wing-heavy loadings, the spins will probably be oscillatory in roll and yaw and in pitch, respectively.

2. If a spin is inadvertently entered in the landing condition, the flaps should be neutralized and recovery attempted immediately.

3. The control forces will probably be appreciably beyond the capabilities of the pilot unless some type of balance or booster is used. The pedal and stick forces will be of the order of magnitude of 1100 and 500 pounds, respectively, to reverse fully the controls.

4. If it is necessary for the crew to abandon the spinning airplane, they should attempt escape from the outboard side of the airplane.

5. A 6-foot tail parachute or a 3.5-foot wing-tip parachute with a drag coefficient of 0.7 will be a satisfactory emergency spin-recovery device for spin demonstrations.

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TABLE I

DIMENSIONAL CHARACTERISTICS OF THE CURTISS-WRIGHT XP-87 AIRPLANE

Length, over all, ft	65.6
Normal weight, lb	37,500
Normal center-of-gravity location, percent $\bar{c}$	17.2
Wing:	
Span, ft	60.0
Area, sq ft	600.0
Section (modified T. E.)	NACA $65_{(112)}$-111
Incidence, deg	1.0
Aspect ratio	6.0
Sweepback, 25-percent-chord line, deg	0
Dihedral, deg	1.0
Mean aerodynamic chord, in.	128.5
Leading edge $\bar{c}$ aft leading root chord, in.	12.3
Flaps:	
Total area, sq ft	72.7
Span, percent b/2	33.4
Ailerons:	
Total area aft of hinge line, sq ft	16.8
Span, percent b/2	32.0
Horizontal tail surfaces:	
Total area, sq ft	135.0
Span, ft	24.5
Elevator area aft of hinge line, sq ft	39.1
Distance from normal center of gravity to elevator hinge line, ft	30.2
Vertical tail surfaces:	
Total area, sq ft	83.0
Total rudder area aft of hinge line, sq ft	21.5
Tail-damping power factor	1650×10^{-6}

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TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE

ON THE CURTISS-WRIGHT XP-87 AIRPLANE

No.	Loading	Weight (lb)	μ		Center-of-gravity location		Moments of inertia about center of gravity			Inertia parameters		
			Sea level	15,000 feet	$x/\bar{c}$	$z/\bar{c}$	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1	Design gross weight	37,500	13.6	21.6	0.172	0.021	64,927	138,043	194,125	-174×10^{-4}	-134×10^{-4}	308×10^{-4}
2	Design gross weight plus tip tanks	49,043	17.8	28.3	0.191	0.041	387,715	138,198	516,639	455	-690	235

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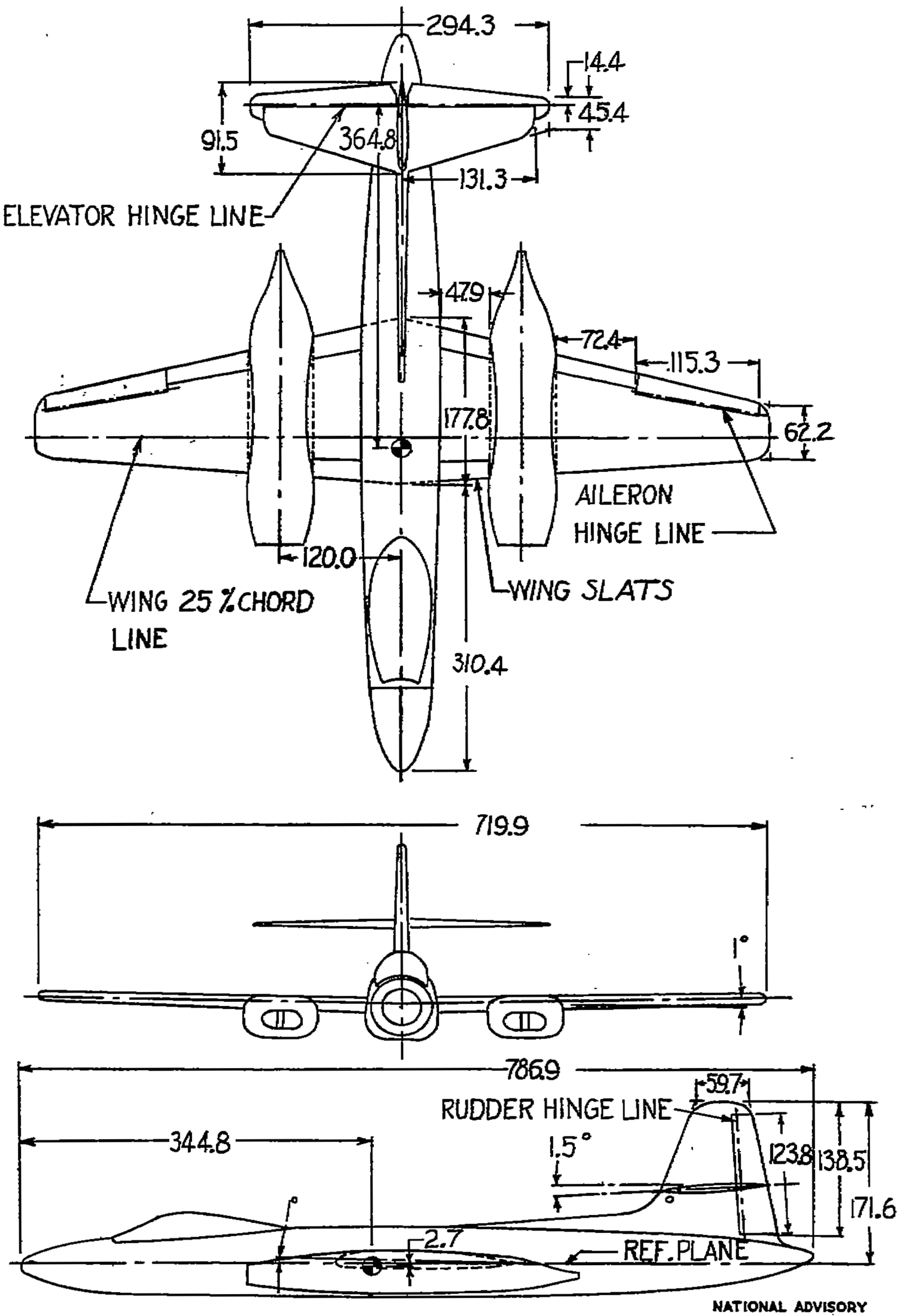

FIGURE 1. - DRAWING OF THE CURTISS-WRIGHT XP-87 AIRPLANE. CENTER OF GRAVITY INDICATED FOR NORMAL LOADING. DIMENSIONS ARE FULL SCALE INCHES.

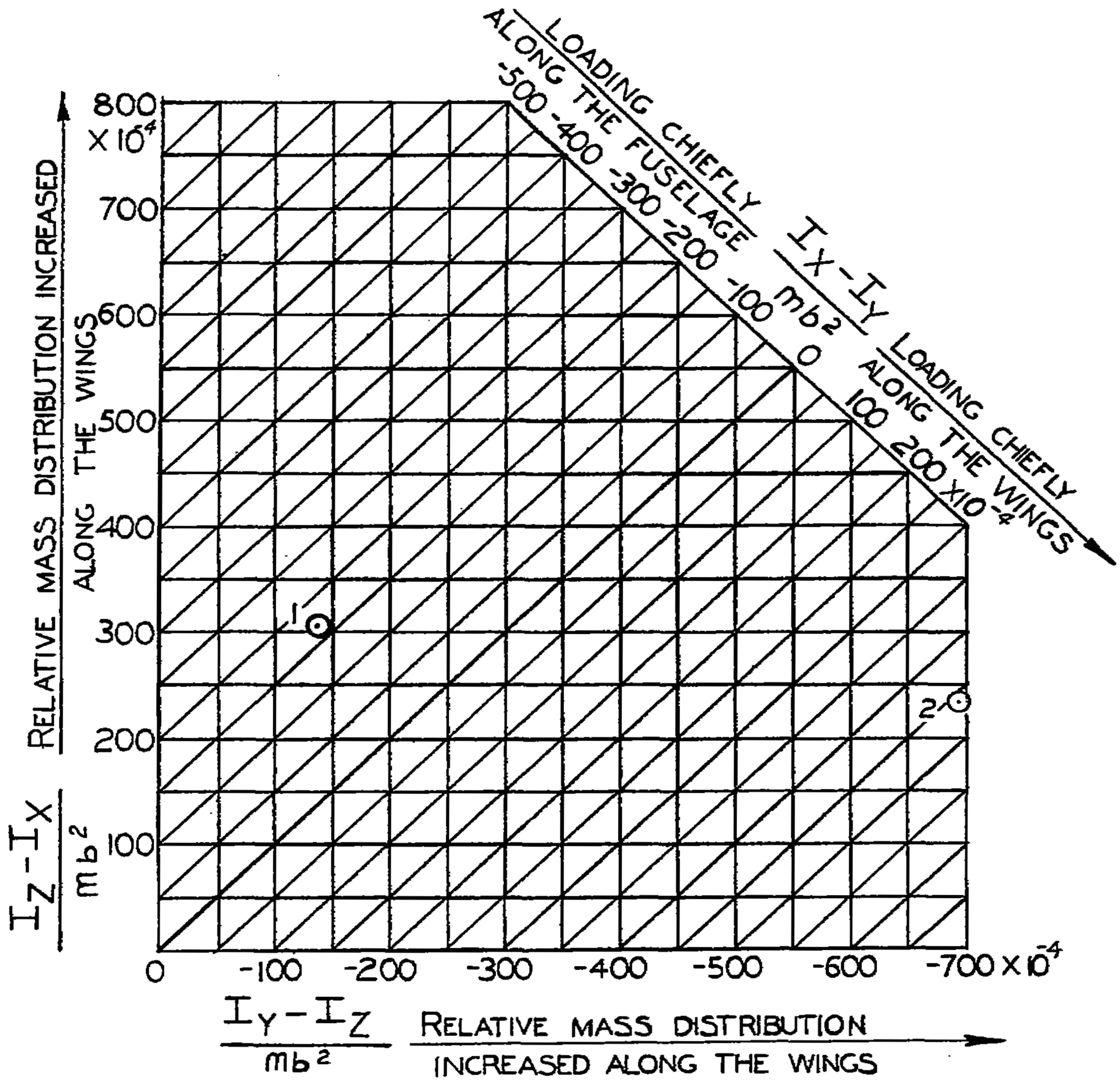

FIGURE 2.- MASS PARAMETERS FOR LOADINGS POSSIBLE ON THE CURTISS-WRIGHT XP-87 AIRPLANE. (POINTS ARE FOR LOADINGS LISTED ON TABLE II.)

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