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RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

FREE-SPINNING-TUNNEL TESTS OF A $\frac{1}{24}$-SCALE MODEL OF THE MCDONNELL XP-88 AIRPLANE WITH A CONVENTIONAL TAIL

By

Theodore Berman

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
WASHINGTON
SEP 4 1947

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FREE-SPINNING-TUNNEL TESTS OF A $\frac{1}{24}$-SCALE MODEL OF THE MCDONNELL XP-88 AIRPLANE WITH A CONVENTIONAL TAIL

By Theodore Berman

SUMMARY

An investigation of the spin and recovery characteristics of a $\frac{1}{24}$-scale model of the McDonnell XP-88 airplane has been conducted in the Langley 20-foot free-spinning tunnel. The effects of control settings and movements on the erect and inverted spin and recovery characteristics of the model in the normal loading were determined. Tests of the model in the long-range loading also were made. The investigation included tail-modification, spin-recovery parachute, pilot-escape, and rudder-pedal-force tests.

Recoveries were generally satisfactory for spins in the normal loading provided the ailerons were not held against the spin. Satisfactory recoveries were obtained regardless of aileron setting when the leading-edge flaps were deflected and normal recovery technique was used or when the horizontal tail was raised 70 inches, full scale. Recoveries were rapid from all inverted spins obtained. In the long-range loading with tanks on, it may be necessary to jettison the tanks in order to obtain recovery. A 12.0-foot spin-recovery parachute at the tail or a 4.0-foot parachute opened on the outer wing tip (drag coefficient of 0.66) was found to be effective for recoveries from demonstration spins. Test results showed that in an emergency the pilot should attempt to escape from the outboard side of the spinning airplane. The rudder-pedal forces in a spin were indicated to be within the capabilities of the pilot.

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INTRODUCTION

In accordance with the request of the Air Materiel Command, Army Air Forces, 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 McDonnell XP-88 airplane. This airplane is a midwing, jet-propelled fighter with sweptback wing and sweptback tail surfaces.

The erect and inverted spin and recovery characteristics of the model were determined for a normal-fighter loading and for long-range loading. Tests were also made to determine the minimum parachute size for emergency recovery, the rudder-pedal force necessary to effect recovery, and the proper procedure to follow if it became necessary for the pilot to leave the airplane during a spin. The effect of depressing the leading-edge flaps was also investigated.

The rudder length of the model was increased after the visit of Mr. D. B. Parke of the McDonnell Aircraft Corporation who stated that the tail design has been changed. The rudder was extended from water line 70 to water line 62.6. In conjunction with this change several other tail modifications were also tested.

SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing or elevator chord at any station along 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 water line (WL) 26.2 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 water line 26.2 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 McDonnell XP-88 airplane was built and prepared for testing by the Langley Laboratory. A three-view drawing of the model in the clean condition is shown in 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 normal (tanks-off) and long-range (tanks-on) loadings are shown in figure 2. Sketches of the tail modifications tested are shown in figure 3. A sketch of the wing leading-edge flaps in the normal and depressed positions is shown in figure 4.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho = 0.001496$ 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 model launching technique has been changed. With the controls set in the desired positions the model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, the recovery attempt is made by moving one or more controls by means of a remote-control electro-magnetic mechanism. After recovery the model dives into a safety net. A photograph of the model during a spin is shown in figure 5.

The spin data presented were determined and converted from model values to corresponding full-scale values by methods described in reference 2. Spin-tunnel tests are made to determine the spin and recovery characteristics of the model for 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 (against the spin for the XP-88 model), and the elevator is set at two-thirds of its full-up deflection. Recovery is attempted by either rapidly reversing the rudder from full with the spin to 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 by rudder reversal or a combination of rudder and elevator reversal. This value has been selected on the basis of spin-tunnel experience and on the basis of the comparable full-scale airplane spin-recovery data that are available.

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 feet per second. 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 as 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."

The testing technique for determining the minimum size of, and the towline length for, spin-recovery parachutes is described in detail in reference 3. For the tail parachute tests, the parachute pack and towline were attached to the model below the horizontal tail near the rear of the fuselage and on the inboard side. 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 clear 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, if practicable, 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 recovery was due entirely to the effect of opening the parachute. Silk parachutes having a drag coefficient of approximately 0.66 (based on the canopy area measured with the parachute spread out flat) were used for the spin-recovery parachute tests.

For the tests to determine from which side of the spinning airplane it would be best for the pilot to make an emergency escape, the pilot was released from the inboard and outboard side of the fuselage at the cockpit in both steep and flat spins and the path of egress 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 hinge moment about the rudder hinge line and recovery tests were run. The tension was reduced systematically until the turns for recovery began to increase. The model rudder hinge moment at this point was taken as the minimum tension which should be applied and 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, degree	± 1
ϕ, degree	± 1
V, percent	± 5
Ω, percent	± 2
Turns for recovery	$\pm\frac{1}{4}$ from motion-picture records $\pm\frac{1}{2}$ from visual observation

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 80 percent of the models predicted satisfactorily the number of turns required for recovery from the spin for the corresponding airplanes and that 10 percent overestimated and 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, 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-88 model varied from the true scaled-down values within the following limits:

Weight, percent		1 low to 1 high
Center-of-gravity location, percent $\bar{c}$		0 to 4 rearward of normal
Moments of inertia	I_X, percent	1 high to 8 high
	I_Y, percent	4 high to 19 high
	I_Z, percent	3 high to 16 high

The accuracy of measuring the weight and mass distribution is believed to be 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

Tests were performed for the model conditions listed in table II. The mass characteristics and inertia parameters for loadings possible on the airplane and for the loadings of the model during tests are shown in table III. The inertia parameters for the loadings possible on the XP-88 airplane and for the loadings tested on the model are also shown in figure 6. As discussed in reference 5, figure 6 can be used 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	20 right, 20 left
Elevator, degrees	25 up, 15 down
Ailerons, degrees	20 up, 20 down
Leading-edge flaps, degrees	30 down

Intermediate control deflections used were:

Rudder, two-thirds deflected, degrees	$13\frac{1}{3}$
Elevator, two-thirds up, degrees	$16\frac{2}{3}$
Elevator, one-third down, degrees	5
Ailerons, one-third deflected, degrees	$6\frac{2}{3}$

A few tests were also made with the ailerons deflected only 5°.

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented in charts 1 to 4 and in tables IV and V. 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, and landing gear retracted). Results for right and left spins were quite similar and in the charts, results for right spins are arbitrarily presented.

Normal Loading

Erect spins.- The results of erect spin tests of the model in the normal loading (loading point 1 in table III and fig. 6) are shown in chart 1. For the normal control configuration for spinning, the model spins were moderately steep and oscillatory and recoveries by rudder reversal were rapid. Elevator setting was found to have little effect. When the ailerons were set with the spin, the spins became very steep and recoveries were rapid. When the ailerons were set fully against the spin, the model spins were wandering and oscillatory in roll and yaw, and the model attitude became slightly flatter, but it became difficult or impossible to obtain recoveries. The criterion spin (ailerons $6\frac{2}{3}^{\circ}$ against the spin, elevator two-thirds up) was somewhat similar to the spins with ailerons full against the spin but not as oscillatory. Recoveries varied from satisfactory to unsatisfactory. When the ailerons were set at only 5° against the spin, however, all recoveries were satisfactory.

These results showed that the model recovery characteristics were unsatisfactory for the criterion spin. In judging the overall spin-recovery characteristics of this airplane, however, it is believed to be permissible to deviate slightly from the normal criterion. For the XP-88 airplane without external wing tanks, the loading is always predominantly heavy along the fuselage. Spin-tunnel experience has indicated that for such a loading condition, small deviations in loading from normal such as might be encountered during flight with fuel being consumed will not alter the general nature of the recovery characteristics and with ailerons neutral or with the spin, consistently good recoveries will be obtained. The floating tendency of the ailerons as indicated in reference 6 will be such as to make them float with the spin. Therefore, unless the pilot forcibly moves the ailerons against the spin, the ailerons will probably be with the spin and recoveries will be satisfactory.

Tail modifications.- Several tail modifications were investigated in an attempt to determine the extent of modifications required to make the recovery characteristics meet the standard criterion. The configurations tested are shown in figure 3 and the test results are shown in table IV. It was found that with a large ventral fin (number 2) and rudder extension (number 4), satisfactory recoveries were obtained for all aileron settings. This modification is the equivalent of moving the horizontal tail upwards approximately 70 inches (full scale) while keeping the trailing edge in the same position relative to the rudder.

Inverted spins.- The results of the inverted spin tests of the model in the normal loading are presented in 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 turning 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 not spin with the stick laterally neutral and forward or when the controls were together and the stick forward. With the controls crossed, the model spun for all elevator settings and satisfactory recoveries were obtained by rudder reversal.

Leading-Edge Flaps

The results of tests with the leading-edge flaps deflected (fig. 4) are presented in chart 3. These results show a marked effect in that the poor condition previously obtained with the aileron against the spin now became "No spins" and recoveries from all spins were satisfactory. This effect is similar to trends indicated for airplanes with leading-edge slots (reference 7). These results show that the leading-edge flaps can be an effective emergency-recovery device. If difficulty is encountered in a recovery attempt from the normal loading, the control should be returned to the normal spinning configuration, the leading-edge flaps should be deflected, and recovery attempted again.

Long-Range Loading

Test results obtained with the model in the long-range loading (loading point 2 in table III and fig. 6) are presented in chart 4. This loading was obtained by installing external wing-tip fuel tanks. The results show two types of spin for all but two of the control configurations tested. The model, when launched into the tunnel, continued to spin in the flat attitude at which it was launched for an abnormally long time but in all cases, eventually, the model steepened and reached equilibrium in a steeper spin. It was felt that this result might be an indication that the airplane might have two possible conditions of spinning equilibrium and therefore the results are presented as two types of spin.

The data show satisfactory recoveries from the steep spins by rudder reversal alone but unsatisfactory recoveries from the flat spins by rudder reversal alone or by simultaneous rudder and elevator reversal. This latter condition may not be critical, however, inasmuch as the airplane ordinarily enters a spin from a stall and roll-off and thus is in a steep attitude at the start of the spin while the model is launched into the tunnel in a flat attitude. The model showed no tendency to return to the flat attitude once the steep attitude was attained. If the airplane appears to be entering the flat spin, however, recovery should be attempted immediately and if recovery is not imminent, the tanks should be jettisoned and the recovery attempt repeated.

Spin-Recovery Parachutes

The results of spin-recovery parachute tests are presented in table V. A tail parachute 12.0 feet in diameter with a towline 40 feet long effected satisfactory recovery of the airplane by parachute action alone. A 9.6-foot-diameter tail parachute was considered marginal. Satisfactory recoveries were also obtained by opening a 4-foot-diameter parachute attached to the outer wing tip with a 16-foot towline.

The model parachutes as tested had values of drag coefficient of approximately 0.66. 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 went under the leading edge of the outboard wing and cleared the tail of the airplane when released from the outboard side of either flat or steep spins. When released from the inboard side, the model pilot went over the fuselage and followed approximately the same path as when released from the outboard side. These results indicate that the pilot should jump from the outboard side if it is necessary to abandon the airplane in a spin, as he will travel over a shorter path and thus have less chance of striking any part of the airplane.

Landing Condition

The landing condition was not tested 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 flaps and landing gear indicates that although the XP-88 airplane 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 trailing-edge 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 all tests sufficient force was applied to the controls to move them fully and rapidly. Sufficient force must be applied to the airplane controls to 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 normal 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 160 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. These tests were made with the original rudder on the model. It is believed that with the rudder extension planned by the McDonnell Aircraft Corporation or the other modifications tested the forces will be higher but not beyond the capabilities of the pilot.

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 all loadings and conditions of the airplane.

For erect spins, the rudder should be reversed briskly from full with the spin to full against the spin followed one-half turn later by movement of the stick forward maintaining it laterally neutral (normal recovery technique); care should be exercised to avoid excessive rates of acceleration in the recovery dive. If an accidental spin is entered with the trailing-edge flaps extended, the flaps should be retracted and recovery attempted immediately. For the condition with tanks off, particular care should be exercised to avoid aileron-against settings either during the spin or recovery.

For recovery from inverted spins, the rudder should be reversed briskly and the stick moved to neutral (laterally and longitudinally).

CONCLUSIONS

Based on results of spin tests of a $\frac{1}{24}$-scale model of the McDonnell XP-88 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 normal 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 one-half turn later by movement of the stick forward of neutral, while maintaining it laterally neutral.

2. With the horizontal tail raised 70 inches or with a large ventral fin added, satisfactory recoveries will be obtained for all aileron settings.

3. Satisfactory recoveries can be obtained for all aileron settings with the leading-edge flaps deflected.

4. Recoveries from inverted spins will be satisfactory and should be attempted by rapid full rudder reversal and stick neutralization.

5. In the long-range loading both a flat and a steep spin may be encountered: from the steep spin rapid recoveries will be obtained but from the flat type recoveries may be poor. If the airplane appears to be entering the flat spin, recovery should be attempted immediately and if recovery is not imminent, the tanks should be jettisoned and the recovery attempt repeated.

6. A 12.0-foot-diameter tail parachute with a towline of 40 feet or a 4.0-foot-diameter parachute with a 16.0-foot towline opened on the outer wing tip will be satisfactory for emergency recoveries from spins. These sizes are based on a drag coefficient of 0.66 for the laid-out-flat surface area.

7. If necessary to abandon the airplane in a spin, the pilot should leave from the outboard side.

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

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

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

Theodore Berman
Theodore Berman
Aeronautical Engineer

Approved: Thomas A Harris
Thomas A. Harris
Chief of Stability Research Division

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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. Stone, Ralph W., Jr., and Schneiter, Leslie E.: Calculation of the Aileron and Elevator Stick Forces and Rudder Pedal Forces for the Bell XP-83 Airplane (Project MX-511)in Spins. NACA MR No. L5H29, 1945.

7. 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.

SUPPLEMENTARY REFERENCES

1. Brower, R. L.: Estimated Weight and Balance Model XP-88. Rep. No. 438, McDonnell Aircraft Corp., Aug. 1, 1946.

2. Brower, R. L.: Model XP-88 Calculated Moments of Inertia. Rep. No. 439, McDonnell Aircraft Corp., Aug. 27, 1946.

3. McDonnell Aircraft Corporation Drawing Nos.:
    14-00000 General Arrangement Army Fighter.
    14-03015 Front View - XP-88 1/24 Scale Free Spinning Model.
    14-03015 Plan View - XP-88 1/24 Scale Free Spinning Model.
    14-03015 Shear View - XP-88 Free Spinning Wind Tunnel Model.

TABLE I.– DIMENSIONAL CHARACTERISTICS
OF THE MCDONNELL XP-88 AIRPLANE

Length over-all, ft	54.25
Normal center-of-gravity location, percent $\bar{c}$	19.6
Wing:	
Span, ft	39.67
Area, sq ft	350
Sweepback at c/4, deg	35
Incidence, deg	1
Dihedral, deg	0
Section	NACA 65-009
Aspect ratio	4.50
Mean aerodynamic chord, in.	117.2
Leading edge of $\bar{c}$ rearward of leading edge of root chord, in.	82.0
Ailerons:	
Area, sq ft	18.4
Span, percent b/2	37.8
Hinge-line location, percent wing chord	75
Horizontal tail surfaces:	
Total area, sq ft	66.8
Span, ft	15.3
Elevator area aft of hinge line, sq ft	15.6
Distance from normal center of gravity to elevator hinge line at fuselage center line, ft	26.6
Incidence, deg	0
Vertical tail surfaces:	
Total area, sq ft	46.6
Total rudder area aft of hinge line, sq ft	10.7
Distance from normal center of gravity to rudder hinge line at water line 70, ft	27.7
Tail-damping power factor	1079×10^{-6}

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TABLE II.– CONDITIONS TESTED ON THE $\frac{1}{24}$–SCALE MODEL OF THE MCDONNELL XP-88 AIRPLANE

[Flaps and landing gear retracted unless otherwise noted; right spins]

Type of spin	Condition	Loading	Modification	Parachutes	Data presented in		Figure
					Chart	Table	
Erect	[a]Clean	Normal	-----------	-----	1	---	1, 2
Inverted	Clean	Normal	-----------	-----	2	---	1, 2
Erect	Leading-edge flaps deflected	Normal	-----------	-----	3	---	4
Erect	Clean	Long range	-----------	-----	4	---	2
Erect	Clean	Normal	Rudder extension number 1	-----	---	IV	3
Erect	Clean	Normal	Rudder extension number 2	-----	---	IV	3
Erect	Clean	Normal	Ventral fin number 1 and rudder extension number 3	-----	---	IV	3
Erect	Clean	Normal	Ventral fin number 2 and rudder extension number 4	-----	---	IV	3
Erect	Clean	Normal	-----------	Tail	---	V	----
Erect	Clean	Normal	-----------	Wing	---	V	----

[a] Pilot-escape and rudder-force tests were performed with the model in this condition.

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TABLE III.– MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING CONDITIONS POSSIBLE ON THE MCDONNELL XP-88 AIRPLANE AND FOR THE LOADINGS TESTED ON THE $\frac{1}{24}$-SCALE MODEL

[Model values are presented in terms of full-scale values]

Number (same as fig. 6)	Loading	Weight (lb)	μ		Center-of-gravity location		Moments of inertia about center of gravity			Mass parameters		
			Sea level	15,000 ft	$x/\bar{c}$	$z/\bar{c}$	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values												
1	Normal	16,522	15.6	24.8	0.196	0.067	12,211	42,218	51,888	-370×10^{-4}	-119×10^{-4}	489×10^{-4}
2	Long range	21,154	19.9	31.6	.330	.046	75,376	48,591	121,080	259	-698	439
Model values												
1	Normal	16,571	15.6	24.8	0.212	0.064	12,724	45,328	55,067	-402×10^{-4}	-120×10^{-4}	522×10^{-4}
2	Long range	21,340	20.1	31.9	.349	.064	73,671	52,671	122,386	202	-668	466

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TABLE IV.– EFFECT OF TAIL MODIFICATIONS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$–SCALE MODEL OF THE MCDONNELL XP-88 AIRPLANE

[Normal loading; flaps neutral; cockpit closed; recovery attempted by rapid rudder reversal to full against the spin except as indicated (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]

	Rudder extension number 1			Rudder extension number 2			Ventral fin number 1 and rudder extension number 3		Ventral fin number 2 and rudder extension number 4		
Ailerons	Neutral	1/3 against	Full against	Neutral	1/3 against	Full against	1/3 against	Full against	Neutral	1/3 against	Full against
Elevator	Up	2/3 up	Up	Up	2/3 up	Up	2/3 up	Up	Up	2/3 up	[a]Up
α, deg	----	38	----	37	41	----	40	----	45	39	37 52
ϕ, deg	----	0	----	3D	1U	----	1D	----	3D	1U	13U 5D
Ω, rps	----	0.33	----	0.33	0.34	----	0.32	----	0.31	0.32	0.30
V, fps	Approximately 265	272	258	268	268	Approximately 244	279	251	279	275	251
Turns for recovery	$\frac{1}{2}$, $\frac{1}{2}$	[b]4, [b]7	>4, ∞	$\frac{3}{4}$, $\frac{1}{2}$	[b]3, [b]>11$\frac{1}{2}$	$\frac{1}{2}$, >7	[b]2, [b]>6$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$, $\frac{1}{2}$	[b]$\frac{1}{2}$, [b]1	$\frac{1}{4}$, $\frac{1}{2}$

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[a] Oscillatory and wandering spin.

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

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TABLE V.– SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH THE $\frac{1}{24}$–SCALE MODEL OF THE MCDONNELL XP-88 AIRPLANE

[Loading point 1 on table III and figure 6; rudder fixed full with spin; model values converted to corresponding full-scale values; C_D of parachutes 0.66; right erect spins]

Parachute diameter (ft)	Towline length (ft)	Ailerons	Elevator	Turns for recovery
Tail parachutes				
8.0	40	1/3 against	2/3 up	1, > 3, ∞
9.6	40	1/3 against	2/3 up	1, 1, $1\frac{1}{4}$
9.6	40	Neutral	Full up	$\frac{3}{4}$, 1, $2\frac{1}{2}$
12.0	40	1/3 against	2/3 up	$\frac{1}{2}$, $\frac{1}{2}$, 1
12.0	40	Neutral	Full up	1, $1\frac{1}{4}$, $1\frac{1}{2}$
Wing-tip parachutes				
2.0	19.6	Neutral	Full up	∞, ∞
4.0	16.0	Neutral	Full up	$\frac{3}{4}$, $\frac{3}{4}$, 1

[a] Visual observation.

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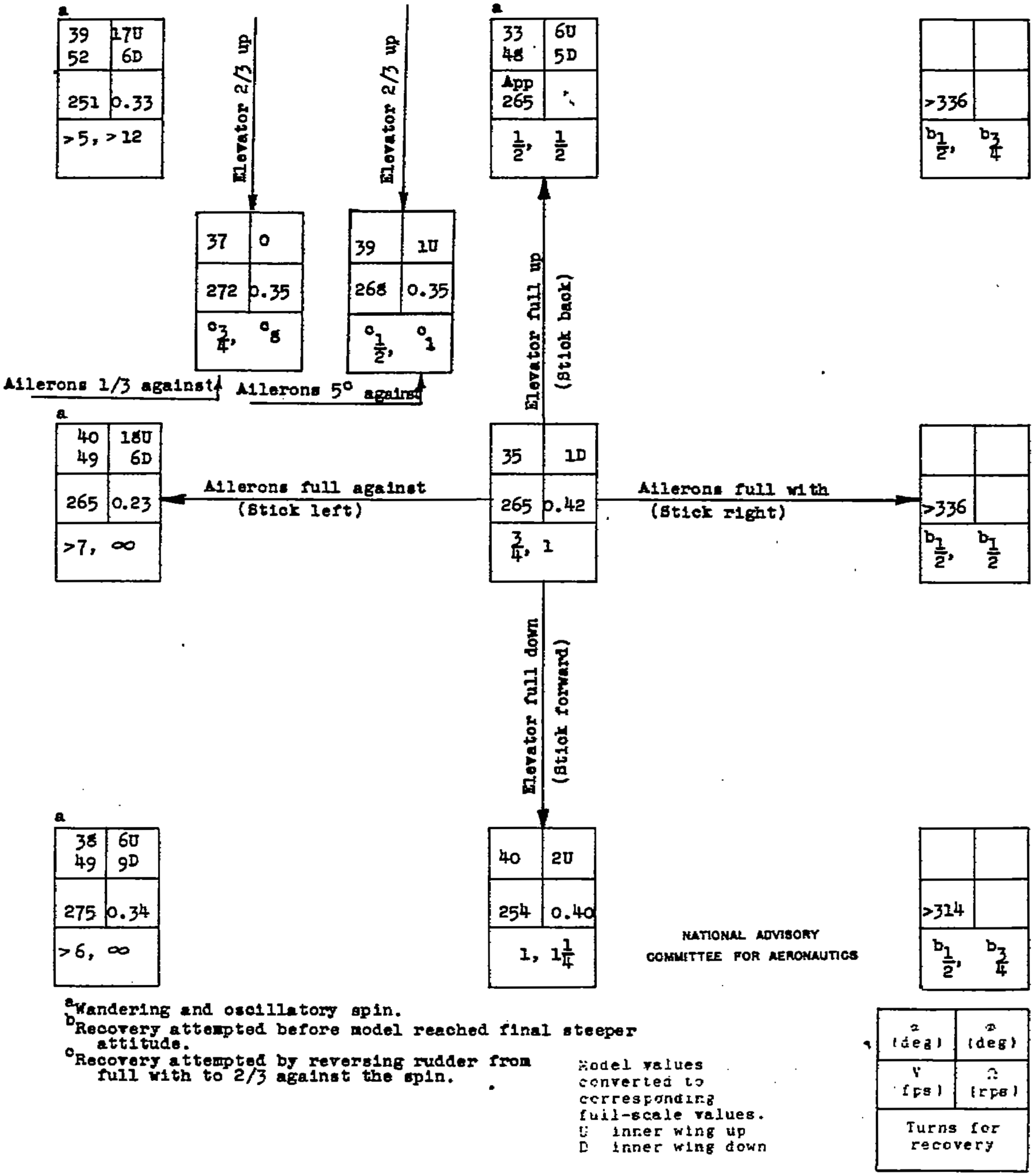
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{24}$-SCALE MODEL OF THE McDONNELL XP-85 AIRPLANE IN THE NORMAL LOADING

[Loading point 1 on table III and figure 6; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]



[a] Wandering and oscillatory spin.

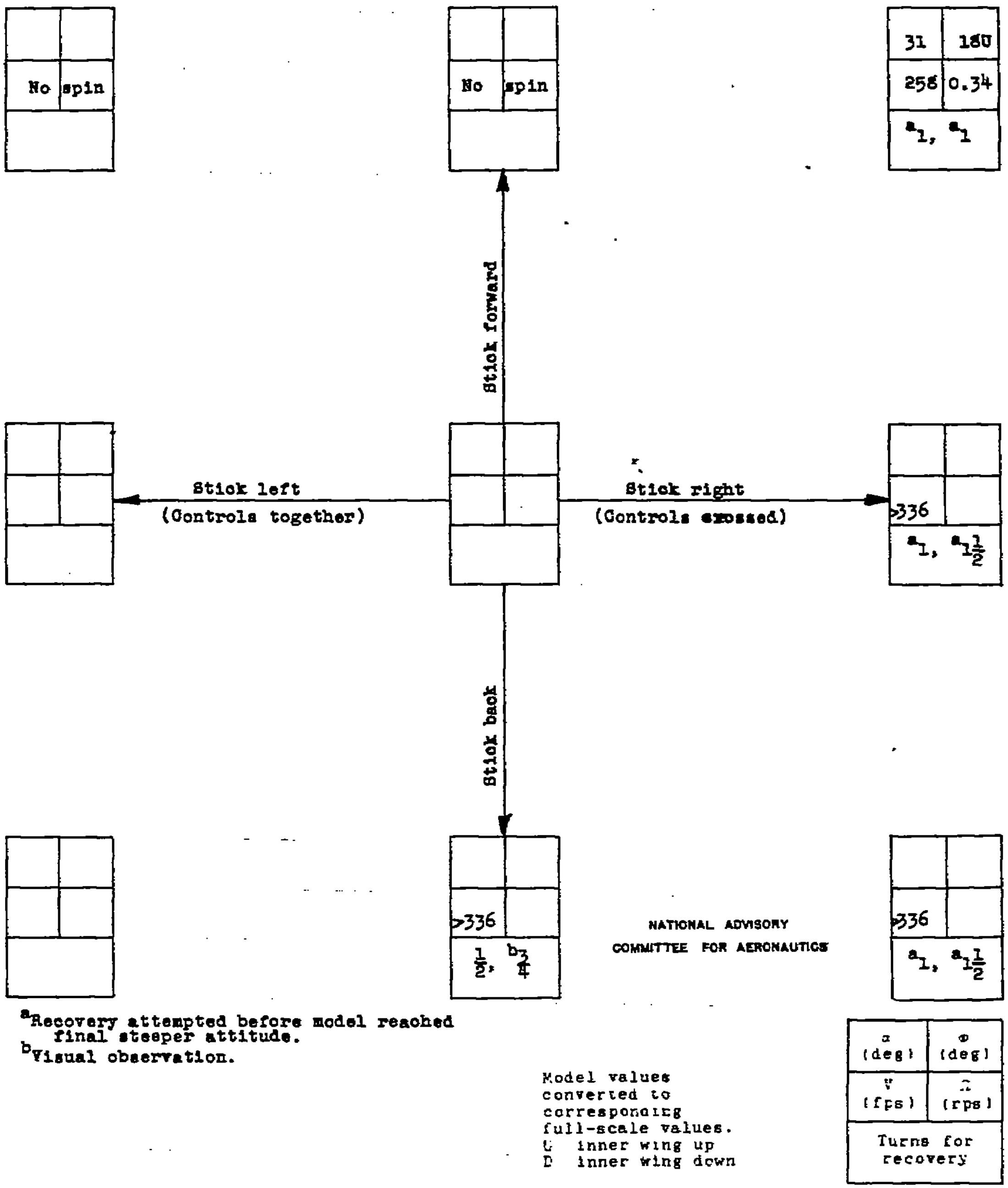
[b] Recovery attempted before model reached final steeper attitude.

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

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 McDONNELL XP-88 AIRPLANE IN THE NORMAL LOADING

[Loading point 1 on table III and figure 6; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); spins to pilot's right]



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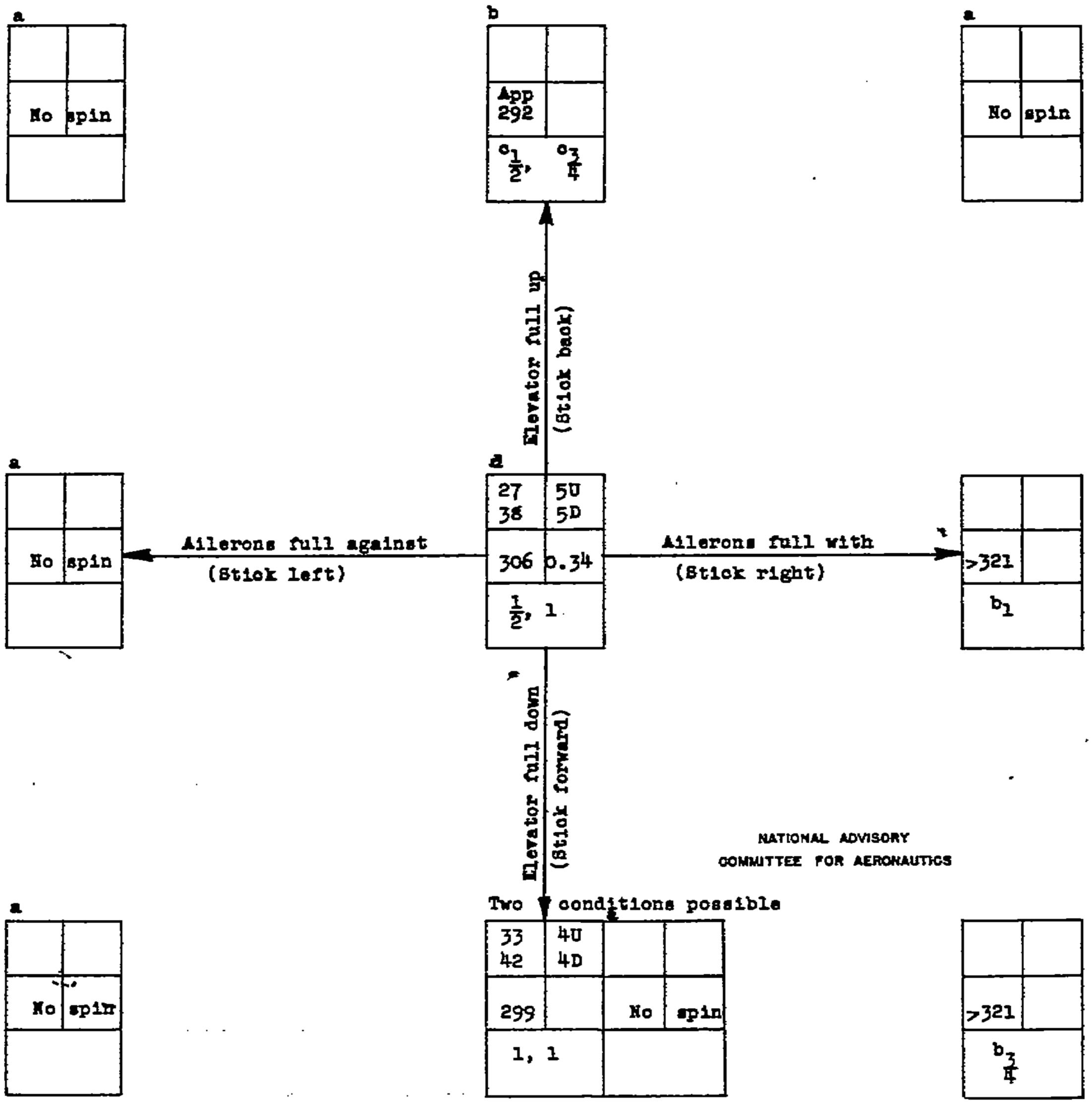
[a] Recovery attempted before model reached final steeper attitude.
[b] Visual observation.

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 McDONNELL XP-88 AIRPLANE WITH THE LEADING-EDGE FLAPS DEFLECTED 30°

[Normal loading (point 1 on table III and figure 6); trailing-edge flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]



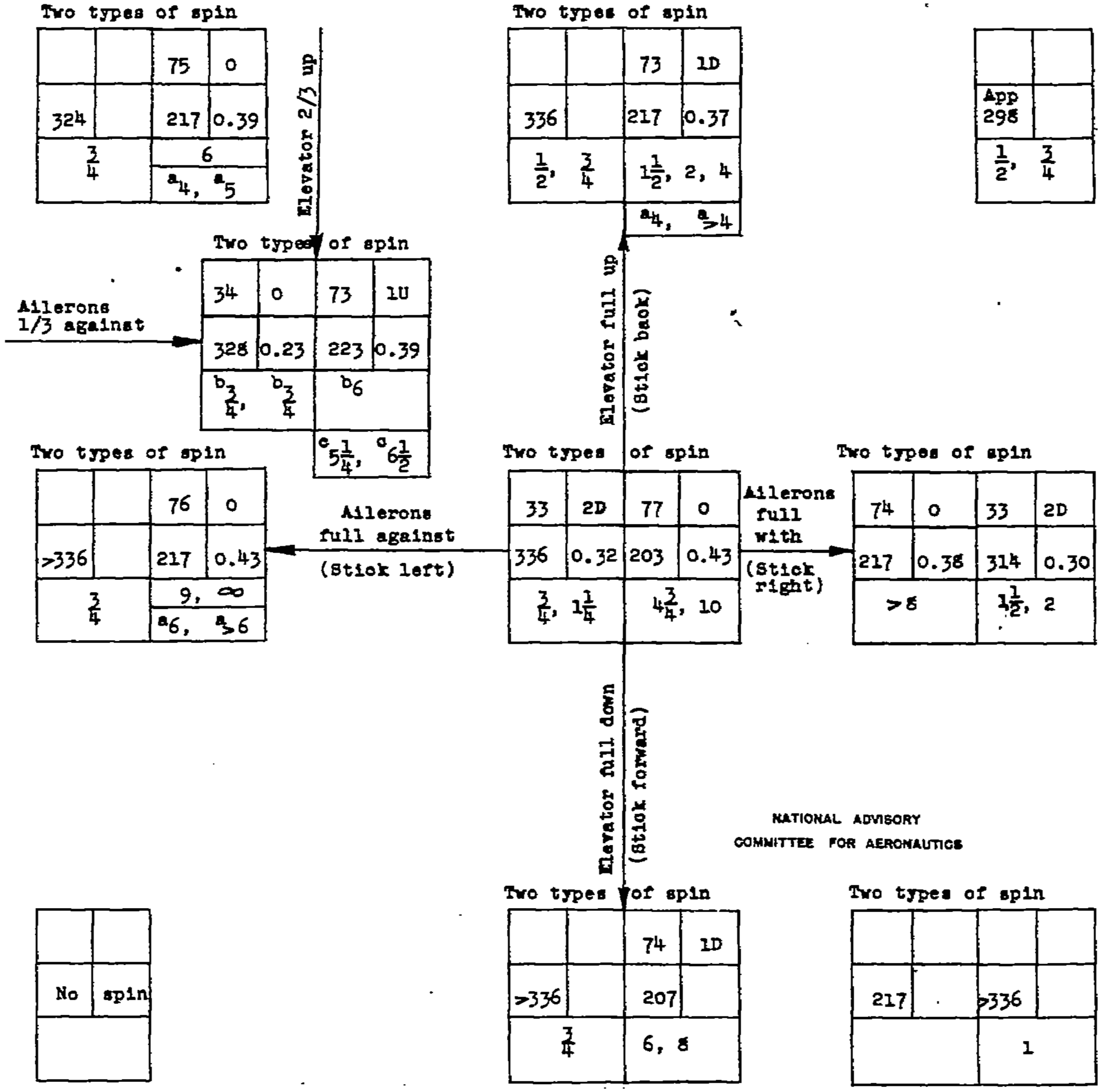
[a] Model goes into a dive.
[b] Wandering spin, oscillatory in yaw.
[c] Steep spin, recovery attempted before model reached final steeper attitude.
[d] Erratic, whipping motion.

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 McDONNELL XP-88 AIRPLANE IN THE LONG-RANGE LOADING (WING-TIP FUEL TANKS INSTALLED)

[Loading point 2 on table III and figure 6; flaps neutral; cockpit closed; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder-with spins); right erect spins]



[a] Recovery attempted by simultaneous full reversal of the rudder and elevator.

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

[c] Recovery attempted by simultaneous reversal of the rudder to 2/3 against the spin and the elevator to 1/3 down.

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	

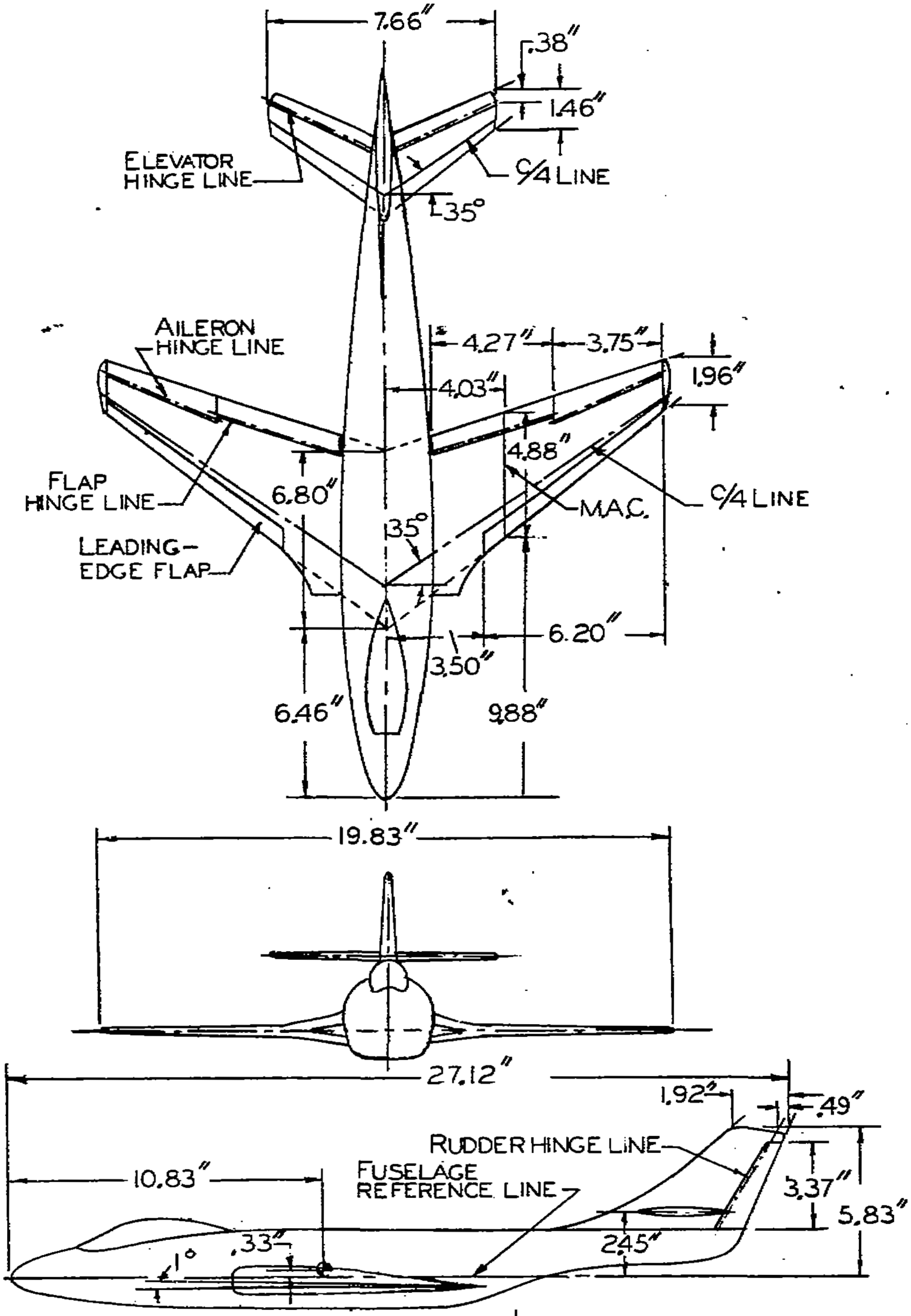


FIGURE 1.- THREE-VIEW DRAWING OF THE $\frac{1}{24}$-SCALE MODEL OF THE McDONNELL XP-88 AIRPLANE AS TESTED IN THE FREE-SPINNING TUNNEL. CENTER-OF-GRAVITY LOCATION IS SHOWN FOR NORMAL LOADING.

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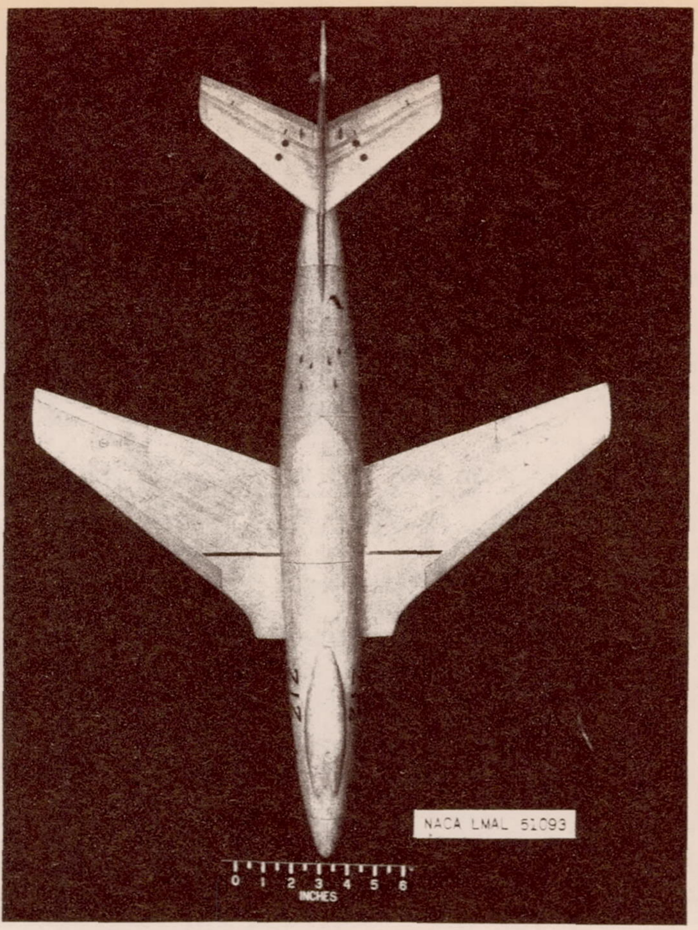

(a) Normal loading.

(b) Long-range loading.

Figure 2.- The $\frac{1}{24}$-scale model of the McDonnell XP-88 airplane in the normal (tip tanks off) and long-range (tip tanks on) loadings.

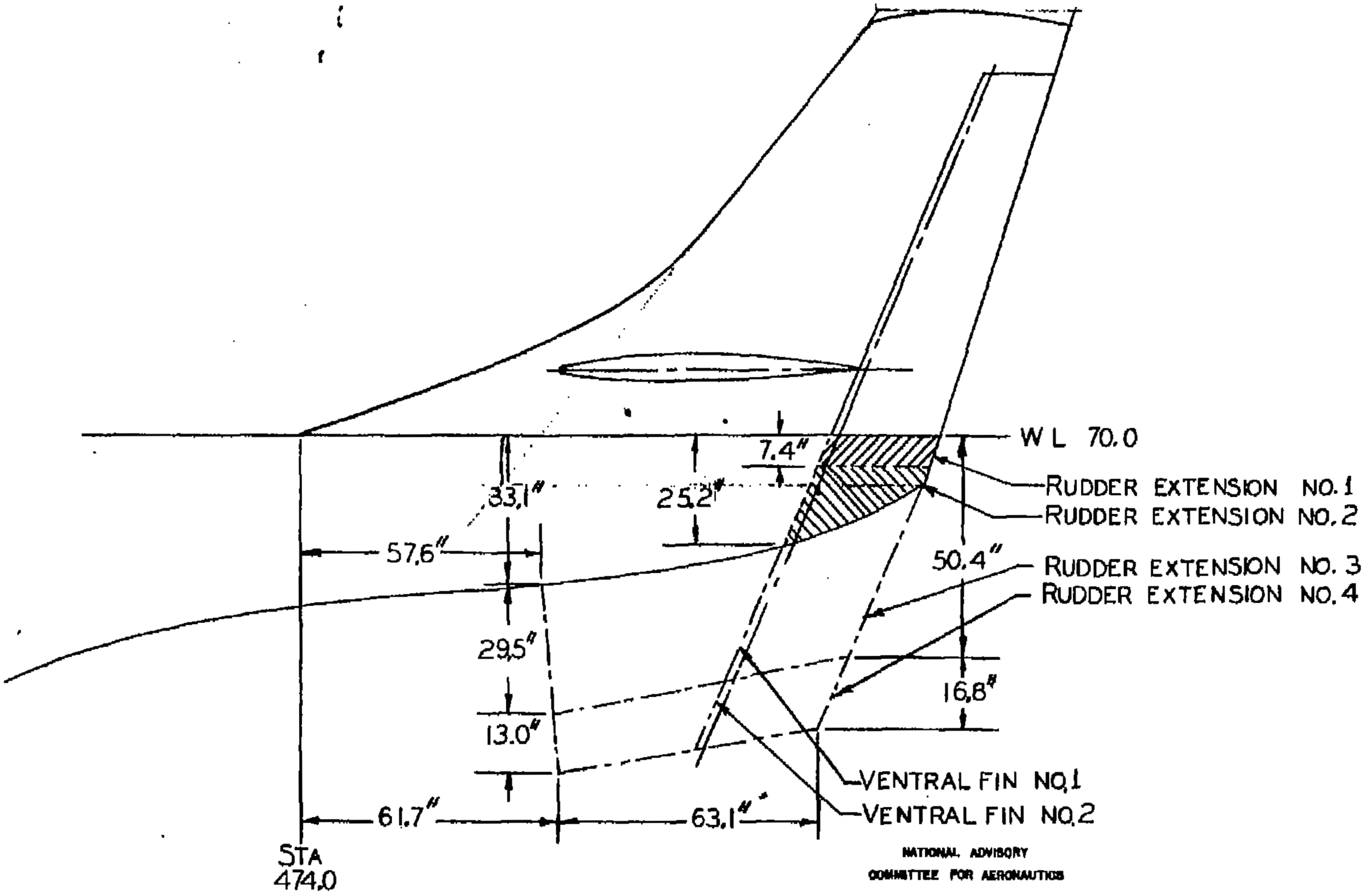

FIGURE 3.–RUDDER EXTENSIONS AND VENTRAL FINS TESTED ON THE $\frac{1}{24}$-SCALE MODEL OF THE McDONNELL XP-88 AIRPLANE. DIMENSIONS ARE FULL SCALE.

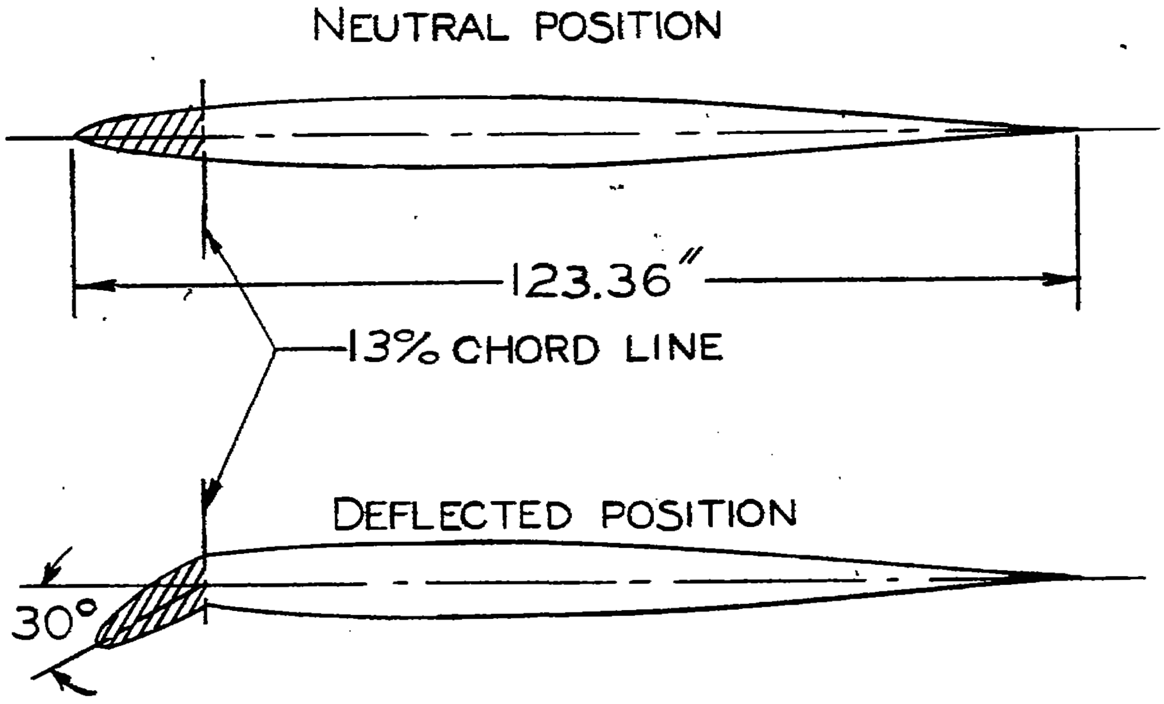

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FIGURE 4.- LEADING-EDGE FLAP POSITIONS TESTED ON THE $\frac{1}{24}$-SCALE MODEL OF THE McDONNELL XP-88 AIRPLANE. SECTION SHOWN IS INBOARD END OF FLAP. DIMENSIONS ARE FULL SCALE.

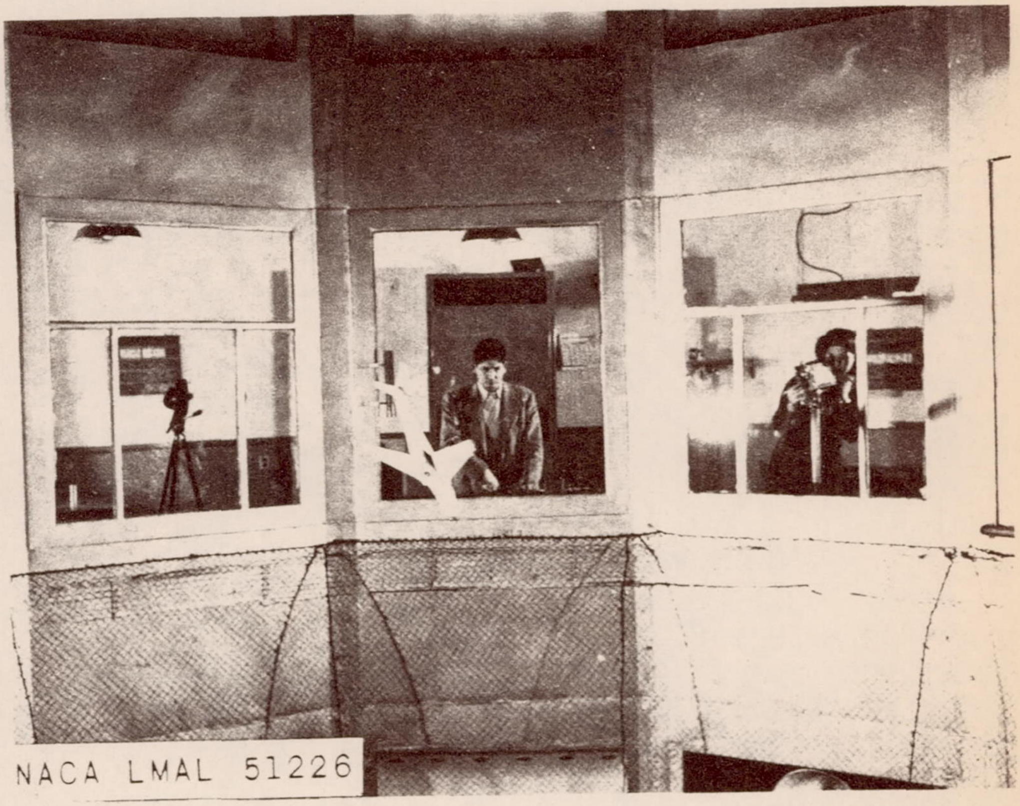

Figure 5.- Photograph of the $\frac{1}{24}$-scale model of the McDonnell XP-88 airplane spinning in the Langley 20-foot free-spinning tunnel.

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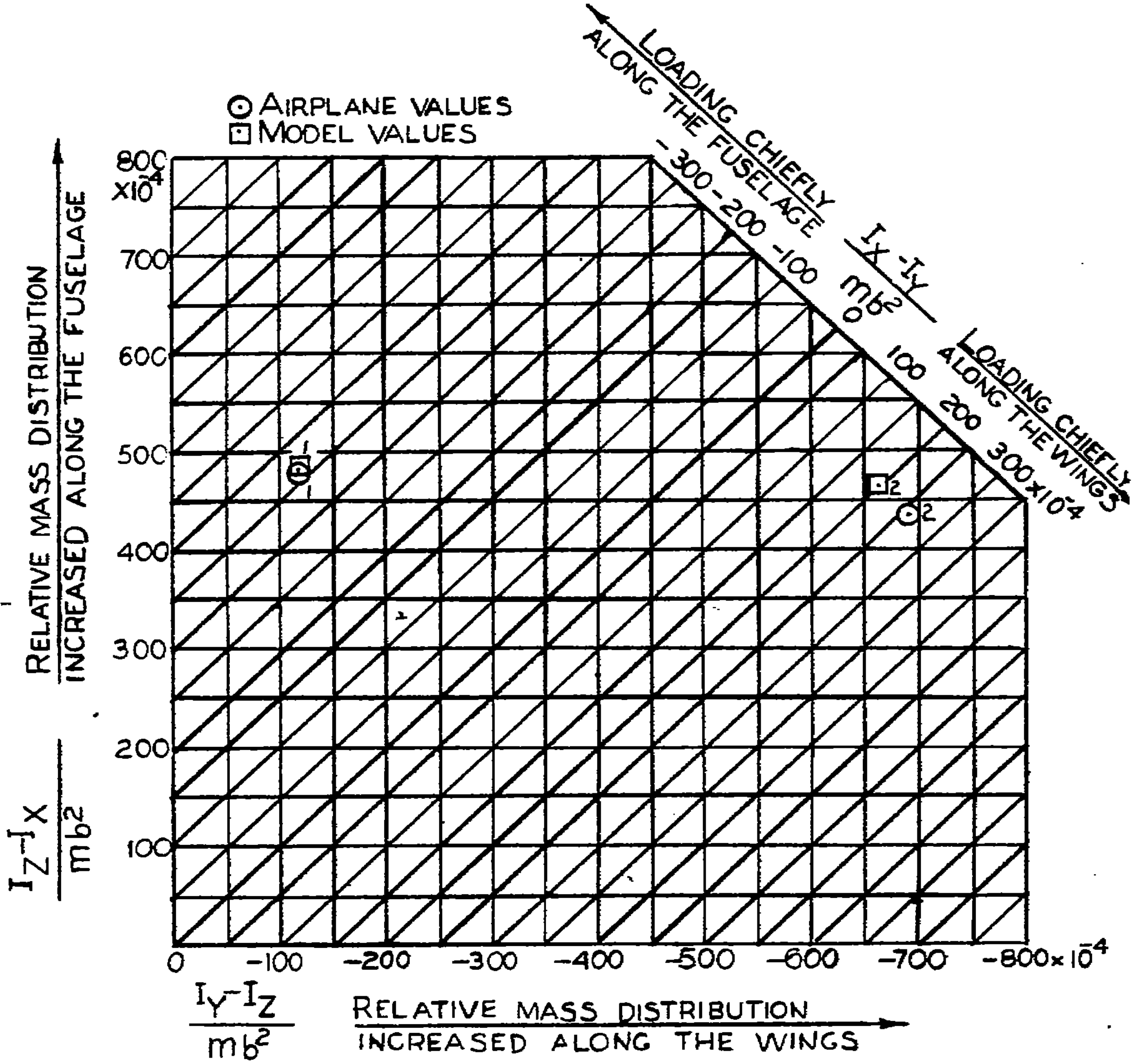

FIGURE 6.— INERTIA PARAMETERS FOR LOADINGS OF THE McDONNELL XP-88 AIRPLANE AND FOR THE LOADINGS TESTED ON THE $\frac{1}{24}$-SCALE MODEL. (POINTS ARE FOR LOADINGS LISTED IN TABLE III).

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